No Magic WORLD SYMPOSIUM
MODELING SIMULATION ANALYSIS

MBSE Maturity Assessment: Related INCOSE & ASME Efforts, and ISO 15288

INCOSE International Council on Systems Engineering

Bill Schindel
ICTT System Sciences
schindel@ictt.com

ASME SETTING THE STANDARD

Abstract

- Model-based methods have multiple connections to ISO15288 system life cycle management practices:
  - The INCOSE Model-Based Transformation project provides means for assessing and planning the migration of ISO15288 practices to model-based approaches.
  - The INCOSE Agile SE Life Cycle Management Discovery Project provides inputs to a future version of ISO15288 including agile SE, and includes the model-based ASELCM Pattern and its representation of the roles of models in innovation.
  - The INCOSE MBSE Patterns Working Group supports improving the leverage of model-based practices using formal S*Patterns, and is partnering with ASME toward standards for the verification and validation of computational models for ISO15288 purposes.
- This talk will summarize how these efforts are being fit together to provide usable practitioner value, and how to get involved.

In a nutshell . . .

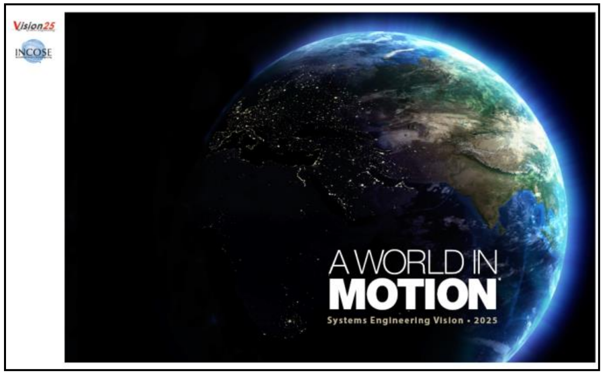
- Maturity in MBSE is not only about our models, methods, and tools--although it includes them:
  - What will we use models <u>for</u> (intended purpose)?   Who is "we"?
  - How do we go about <u>trusting</u> our model?
  - Is our <u>learning</u> effectively enhanced?
- State of art & practice in some of these areas still low:
  - So, expect significant continuing change.
  - Measuring against current base may not reflect "maturity".
- There are overall requirements we can use to measure our MBSE maturity:
  - Based on, but enlarging, the interpretation of ISO 15288, existing maturity models, and computational models.
  - Providing a foundation for future maturity assessment, planning.
- The emerging foundation opens up thinking about scope of impacts, and therefore scope of maturity assessment.

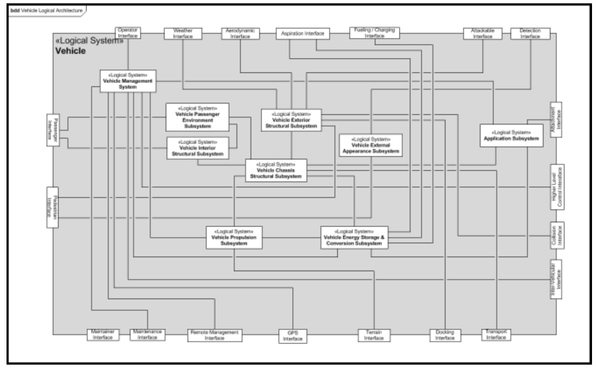
Contents

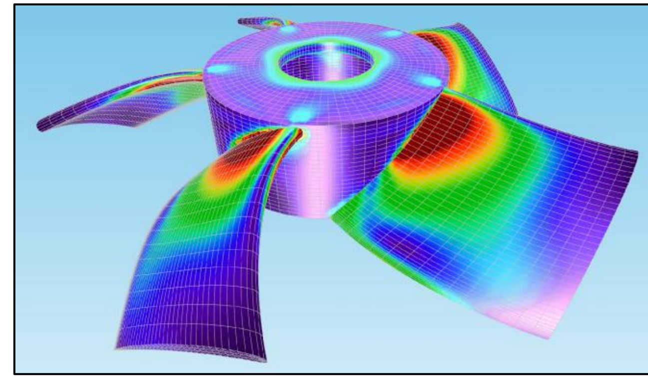
- Enthusiasm for models
- Models for what purposes?
- Sufficiency and minimality for purposes
- Models of more than our engineered systems
- Requirements for trustable, impactful models, as a basis for MBSE maturity
- Community activities
- What you can do

- References

Enthusiasm for Models



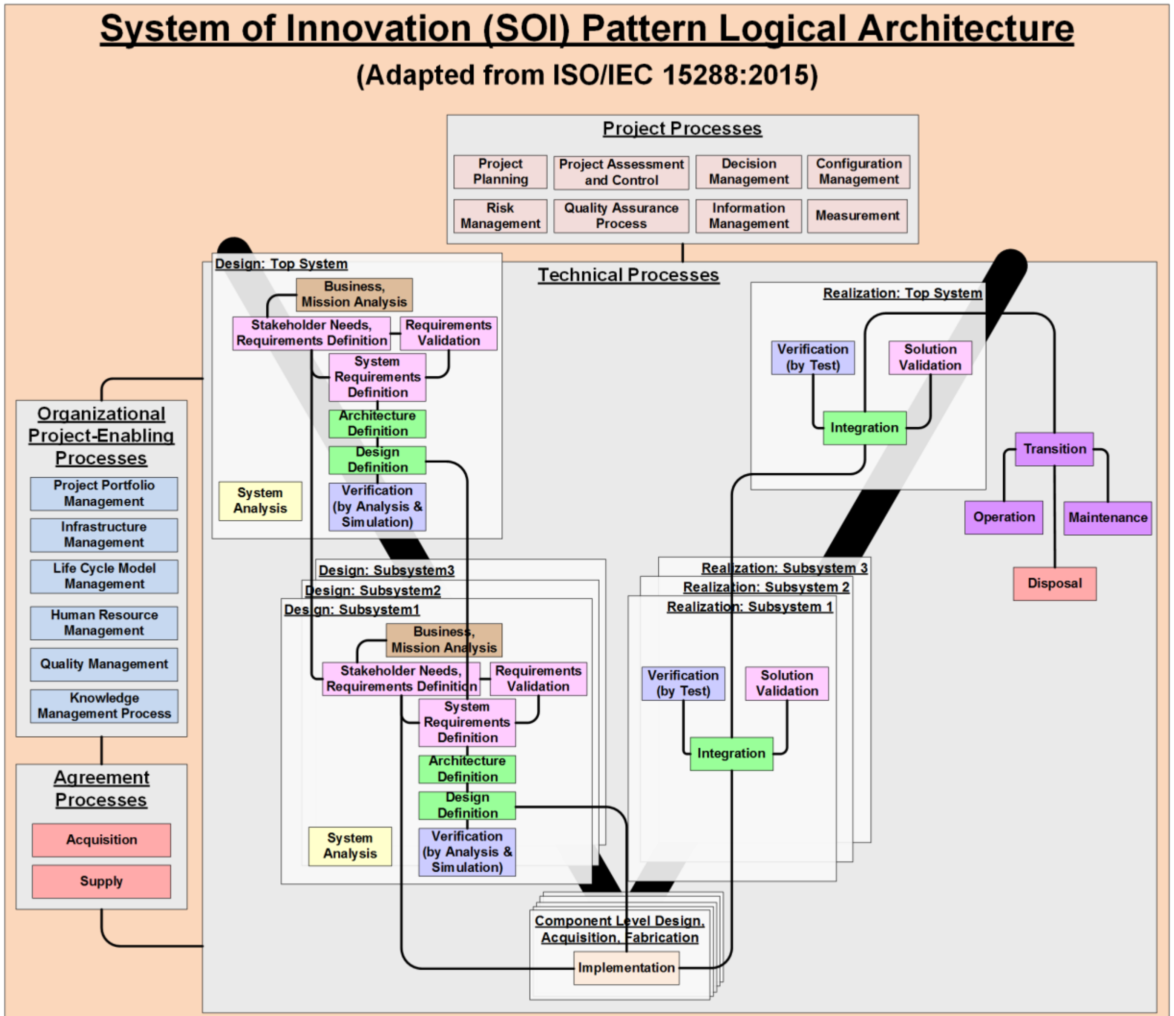




The INCOSE systems community has shown growing enthusiasm for "engineering with models" of all sorts:

- Historical tradition of math-physics engineering models
- A World in Motion: INCOSE Vision 2025
- Growth of the INCOSE IW MBSE Workshop
- Growth in systems engineers in modeling classes
- INCOSE Board of Directors' objective to accelerate transformation of SE to a model-based discipline
- Joint INCOSE activities with NAFEMS

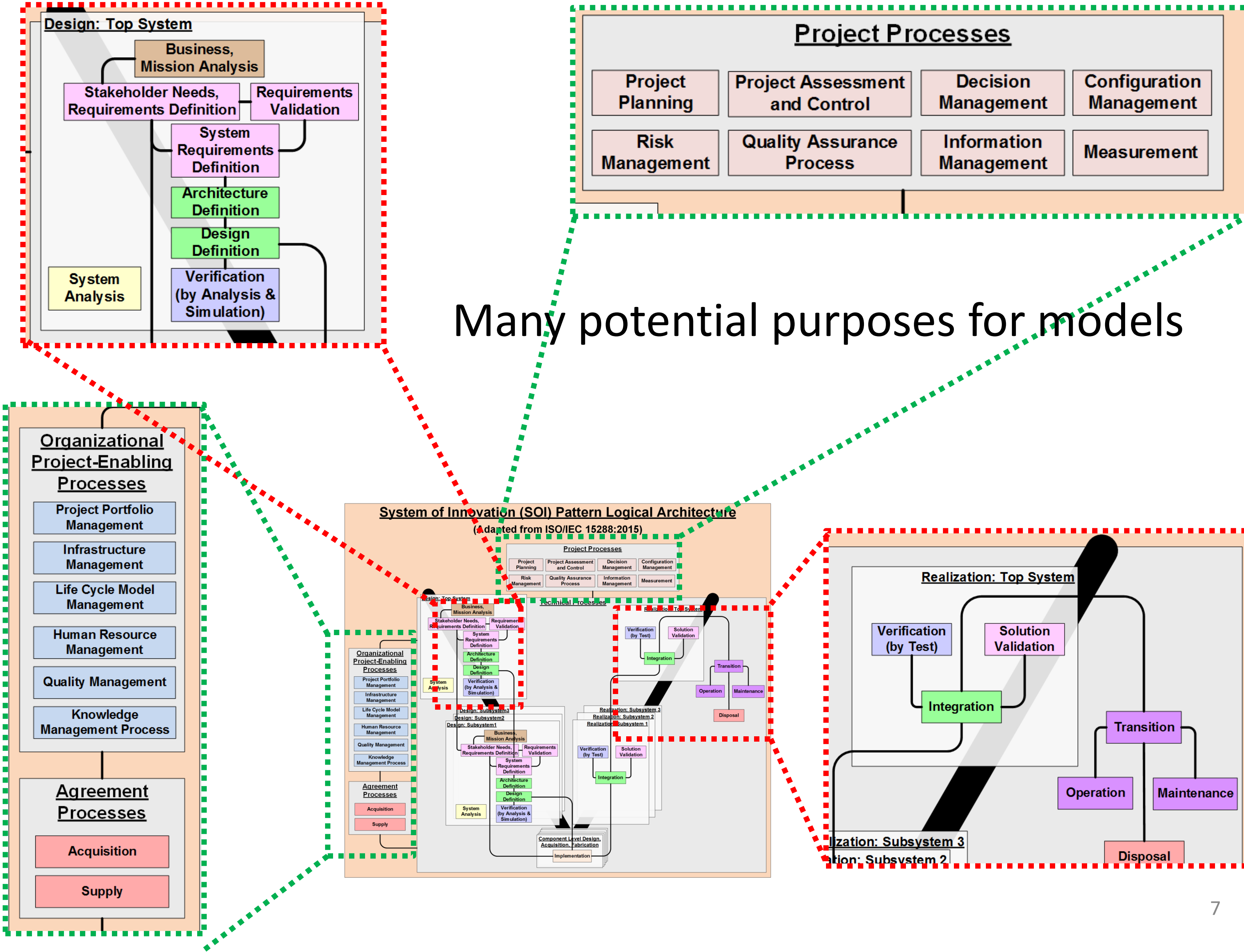
Models for what <u>purposes</u>?



Potentially for any ISO 15288 processes:

- If there is a net benefit . . .
- Some more obvious than others.
- The INCOSE MB Transformation is using ISO 15288 framework as an aid to migration planning and assessment.

Many potential purposes for models



INCOSE MB Transformation; planning and assessment

- One way to keep “maturity” focused pragmatically is to be very clear about explicit <u>purposes for models</u>.
- Because ISO 15288 offers a (relatively) well-known and accessible reference model for the life cycle management of systems, it provides a convenient “menu” listing of potential high level <u>purposes</u> of models in the life cycle of systems.
- The INCOSE Model-Based Transformation team is using this as the basis of an MBSE migration and maturation planning and assessment instrument . . .

INCOSE MB Transformation; Planning and Assessment Instrument

The INCOSE MBSE Transformation products are based on identification of --

Stakeholders in the MBSE Transformation:

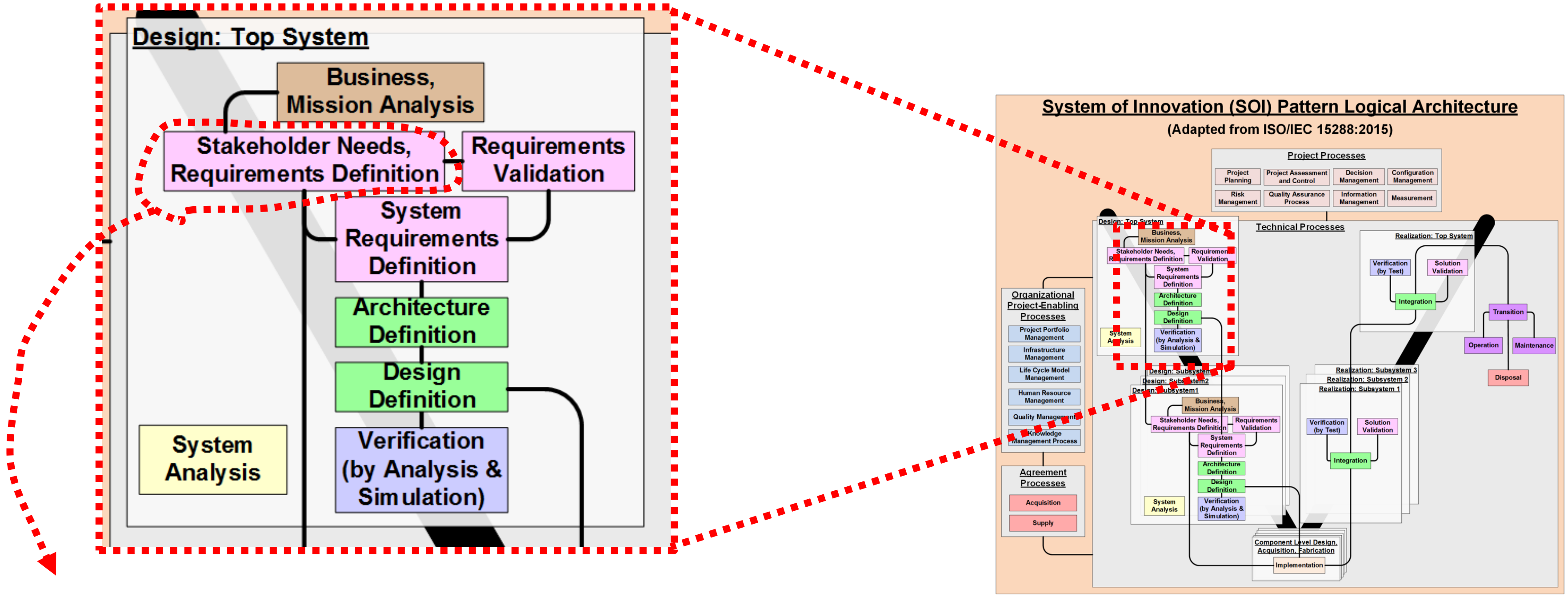
1. Model Consumers (Model Users);
2. Model Creators (including Model Improvers);
3. Complex Idea Communicators (Model "Distributors");
4. Model Infrastructure Providers, Including Tooling, Language and Other Standards, Methods;
5. INCOSE and other Engineering Professional Societies.

Notice that group (1) is by far the largest population of stakeholders, for future MBSE impact potential.

Further analysis of the Transformation Stakeholders
(also shows ET2016 Conference ratings of needs, opportunities)

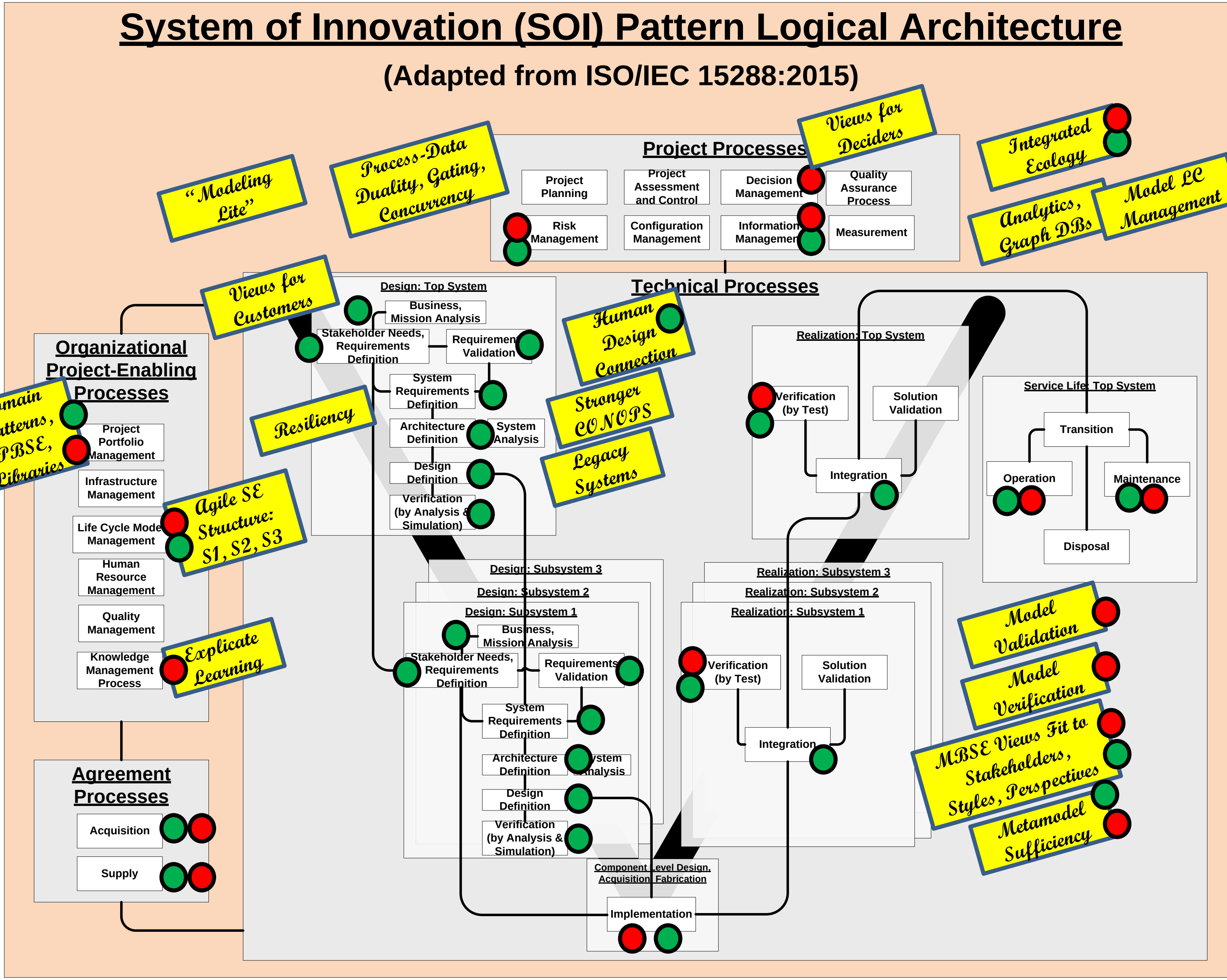
Population <-- Size (Log)	Stakeholders in A Successful MBSE Transformation (showing their related roles and parent organizations)	Industry & Gvmt. Initiatives	Organizations Internalizing MBSE, Including Gvmt Contractors & Commercial	Vendors of MBSE Tooling and Services	Academia and Researchers	Technical 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

Each 15288 process definition suggests potentially assessable model impacts



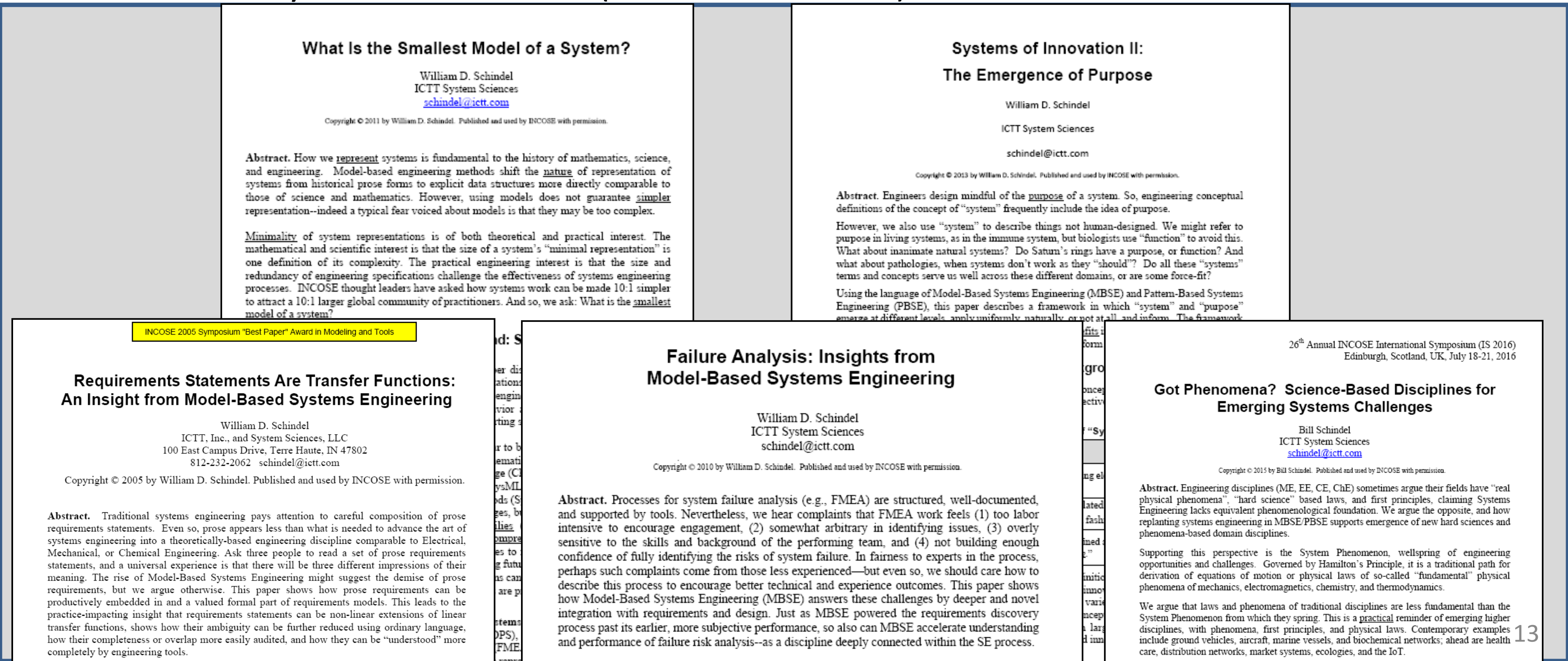
a) “Stakeholders of the system are identified.
b) Required characteristics and context of use of capabilities and concepts in the life cycle stages, including operational concepts, are defined.
c) Constraints on a system are identified.
d) Stakeholder needs are defined.
e) Stakeholder needs are prioritized and transformed into clearly defined stakeholder requirements.
f) Critical performance measures are defined.
g) Stakeholder agreement that their needs and expectations are reflected adequately in the requirements is achieved.
h) Any enabling systems or services needed for stakeholder needs and requirements are available.
i) Traceability of stakeholder requirements to stakeholders and their needs is established.”

Each ISO15288 process offers higher level targeting, assessment (Below: Energy Tech 2016 Feedback on MBSE in ISO15288)



Sufficiency for Purposes; Minimality

- Systems of Modeling, practiced, must be sufficient for their intended purposes, and preferably minimal / not overly complex, proliferated:
  - A lot of (continuing) effort by the modeling community being invested in sufficiency.
  - Understanding of what is needed improving, but lists of future capabilities are long.
- More is involved than modeling languages, tools, methods, alone; for example:
  - Fitness to non-technical users and uses
  - Strong enough conceptual foundation, based on STEM, not just information models.
  - Credibility of model content (trust in the model)



What Is the Smallest Model of a System?

William D. Schindel
ICTT System Sciences
schindel@ictt.com

Copyright © 2011 by William D. Schindel. Published and used by INCOSE with permission.

Abstract. How we represent systems is fundamental to the history of mathematics, science, and engineering. Model-based engineering methods shift the nature of representation of systems from historical prose forms to explicit data structures more directly comparable to those of science and mathematics. However, using models does not guarantee simpler representation--indeed a typical fear voiced about models is that they may be too complex.

Minimality of system representations is of both theoretical and practical interest. The mathematical and scientific interest is that the size of a system's "minimal representation" is one definition of its complexity. The practical engineering interest is that the size and redundancy of engineering specifications challenge the effectiveness of systems engineering processes. INCOSE thought leaders have asked how systems work can be made 10:1 simpler to attract a 10:1 larger global community of practitioners. And so, we ask: What is the smallest model of a system?

Systems of Innovation II: The Emergence of Purpose

William D. Schindel
ICTT System Sciences
schindel@ictt.com

Copyright © 2013 by William D. Schindel. Published and used by INCOSE with permission.

Abstract. Engineers design mindful of the purpose of a system. So, engineering conceptual definitions of the concept of "system" frequently include the idea of purpose.

However, we also use "system" to describe things not human-designed. We might refer to purpose in living systems, as in the immune system, but biologists use "function" to avoid this. What about inanimate natural systems? Do Saturn's rings have a purpose, or function? And what about pathologies, when systems don't work as they "should"? Do all these "systems" terms and concepts serve us well across these different domains, or are some force-fit?

Using the language of Model-Based Systems Engineering (MBSE) and Pattern-Based Systems Engineering (PBSE), this paper describes a framework in which "system" and "purpose" emerge at different levels, apply uniformly, naturally, or not at all, and inform. The framework

INCOSE 2005 Symposium "Best Paper" Award in Modeling and Tools

Requirements Statements Are Transfer Functions: An Insight from Model-Based Systems Engineering

William D. Schindel
ICTT, Inc., and System Sciences, LLC
100 East Campus Drive, Terre Haute, IN 47802
812-232-2062 schindel@ictt.com

Copyright © 2005 by William D. Schindel. Published and used by INCOSE with permission.

Abstract. Traditional systems engineering pays attention to careful composition of prose requirements statements. Even so, prose appears less than what is needed to advance the art of systems engineering into a theoretically-based engineering discipline comparable to Electrical, Mechanical, or Chemical Engineering. Ask three people to read a set of prose requirements statements, and a universal experience is that there will be three different impressions of their meaning. The rise of Model-Based Systems Engineering might suggest the demise of prose requirements, but we argue otherwise. This paper shows how prose requirements can be productively embedded in and a valued formal part of requirements models. This leads to the practice-impacting insight that requirements statements can be non-linear extensions of linear transfer functions, shows how their ambiguity can be further reduced using ordinary language, how their completeness or overlap more easily audited, and how they can be "understood" more completely by engineering tools.

Failure Analysis: Insights from Model-Based Systems Engineering

William D. Schindel
ICTT System Sciences
schindel@ictt.com

Copyright © 2010 by William D. Schindel. Published and used by INCOSE with permission.

Abstract. Processes for system failure analysis (e.g., FMEA) are structured, well-documented, and supported by tools. Nevertheless, we hear complaints that FMEA work feels (1) too labor intensive to encourage engagement, (2) somewhat arbitrary in identifying issues, (3) overly sensitive to the skills and background of the performing team, and (4) not building enough confidence of fully identifying the risks of system failure. In fairness to experts in the process, perhaps such complaints come from those less experienced—but even so, we should care how to describe this process to encourage better technical and experience outcomes. This paper shows how Model-Based Systems Engineering (MBSE) answers these challenges by deeper and novel integration with requirements and design. Just as MBSE powered the requirements discovery process past its earlier, more subjective performance, so also can MBSE accelerate understanding and performance of failure risk analysis--as a discipline deeply connected within the SE process.

26th Annual INCOSE International Symposium (IS 2016)
Edinburgh, Scotland, UK, July 18-21, 2016

Got Phenomena? Science-Based Disciplines for Emerging Systems Challenges

Bill Schindel
ICTT System Sciences
schindel@ictt.com

Copyright © 2015 by Bill Schindel. Published and used by INCOSE with permission.

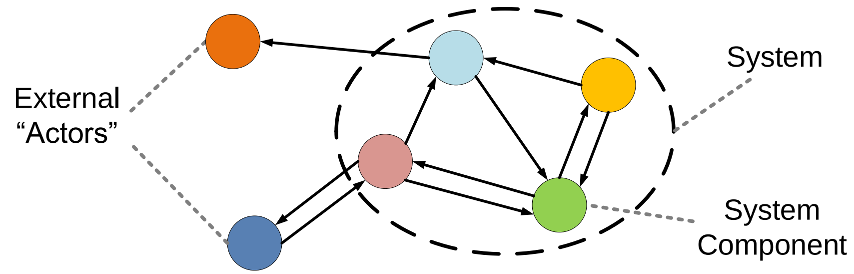
Abstract. Engineering disciplines (ME, EE, CE, ChE) sometimes argue their fields have "real physical phenomena", "hard science" based laws, and first principles, claiming Systems Engineering lacks equivalent phenomenological foundation. We argue the opposite, and how replanting systems engineering in MBSE/PBSE supports emergence of new hard sciences and phenomena-based domain disciplines.

Supporting this perspective is the System Phenomenon, wellspring of engineering opportunities and challenges. Governed by Hamilton's Principle, it is a traditional path for derivation of equations of motion or physical laws of so-called "fundamental" physical phenomena of mechanics, electromagnetics, chemistry, and thermodynamics.

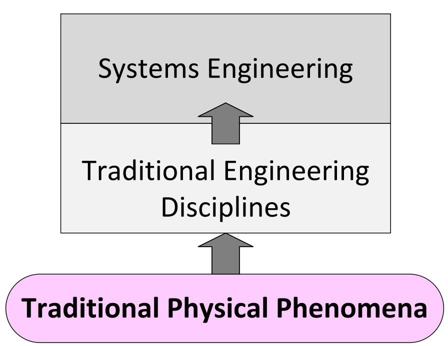
We argue that laws and phenomena of traditional disciplines are less fundamental than the System Phenomenon from which they spring. This is a practical reminder of emerging higher disciplines, with phenomena, first principles, and physical laws. Contemporary examples include ground vehicles, aircraft, marine vessels, and biochemical networks; ahead are health care, distribution networks, market systems, ecologies, and the IoT.

Scientific heritage (~300 years)

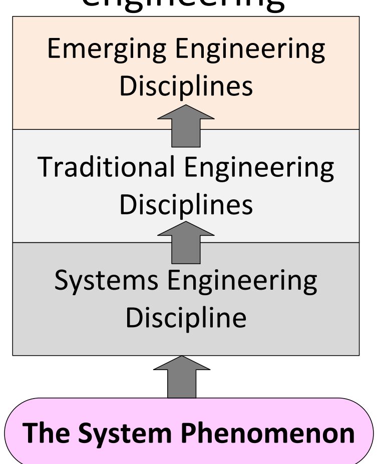
- The eventual flowering of the physical sciences depended upon the emergence of strong enough underlying model constructs (of math, physics) to better represent Nature.
- Specifically, the System Phenomenon (Newton, Lagrange, Hamilton):



A traditional view of systems engineering

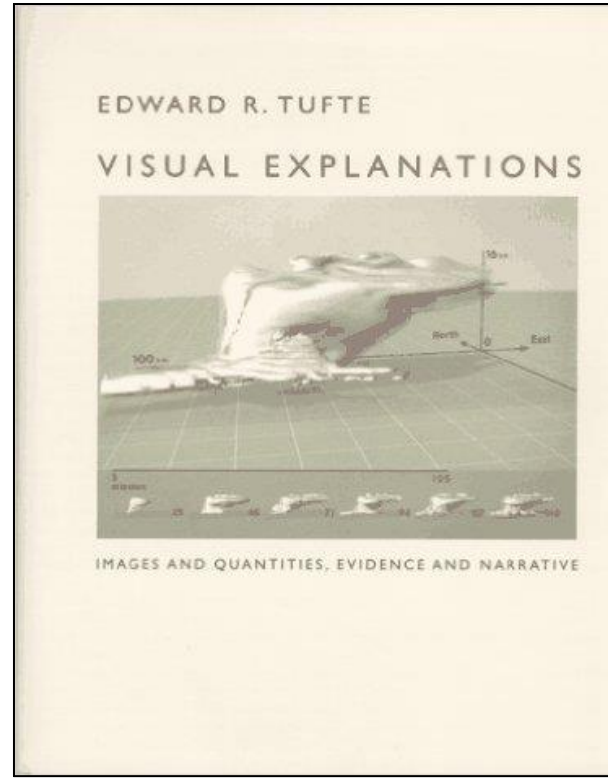


Our view of systems engineering



Sufficiency for Purposes; Minimality

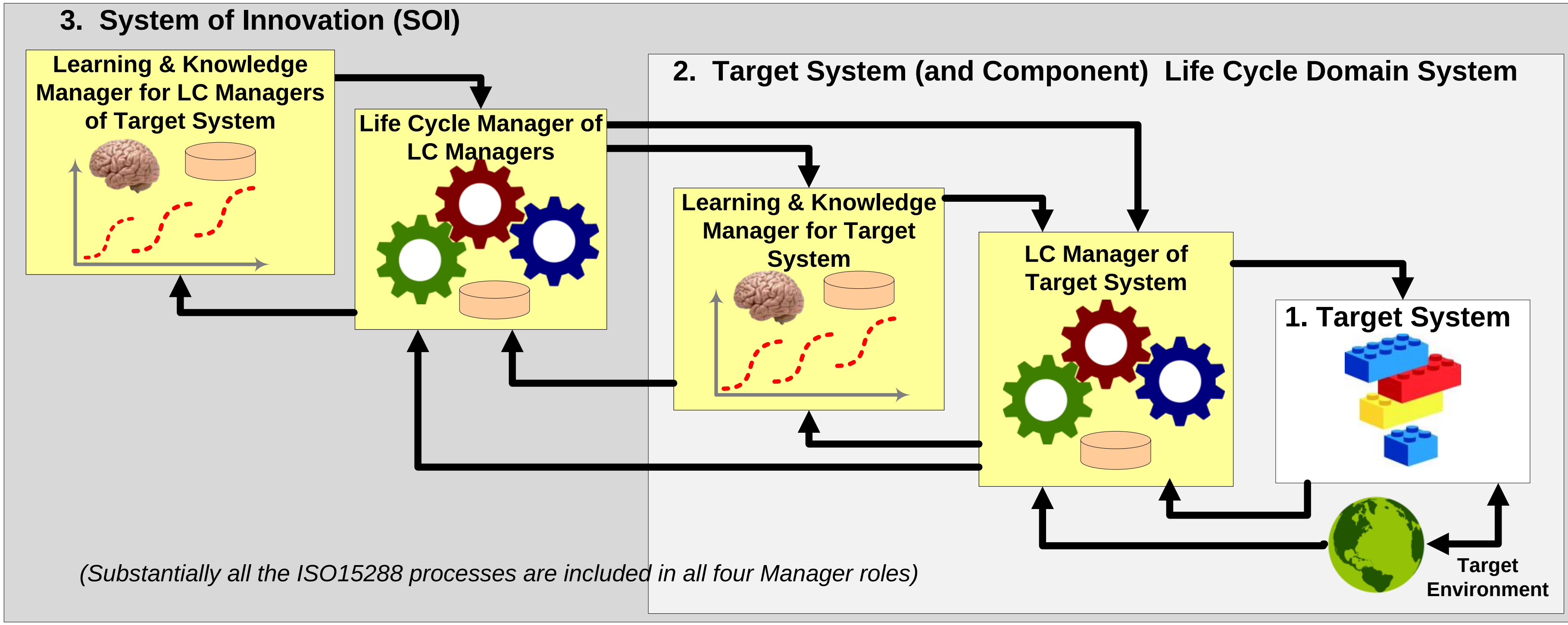
- Example: Fitness of model to use
  - Includes fitness of model views to intended uses, users.
- See discussions by E. Tufte, N Levinson, concerning NASA shuttle model views
- Culture plays a key part in this.
- So, measuring maturity of MBSE will take us across more subjects than technical practitioners might expect.



- Modeling more than just the “engineered” System 1
- Intended model uses and users, along with culture, are “System 2” issues . . . .

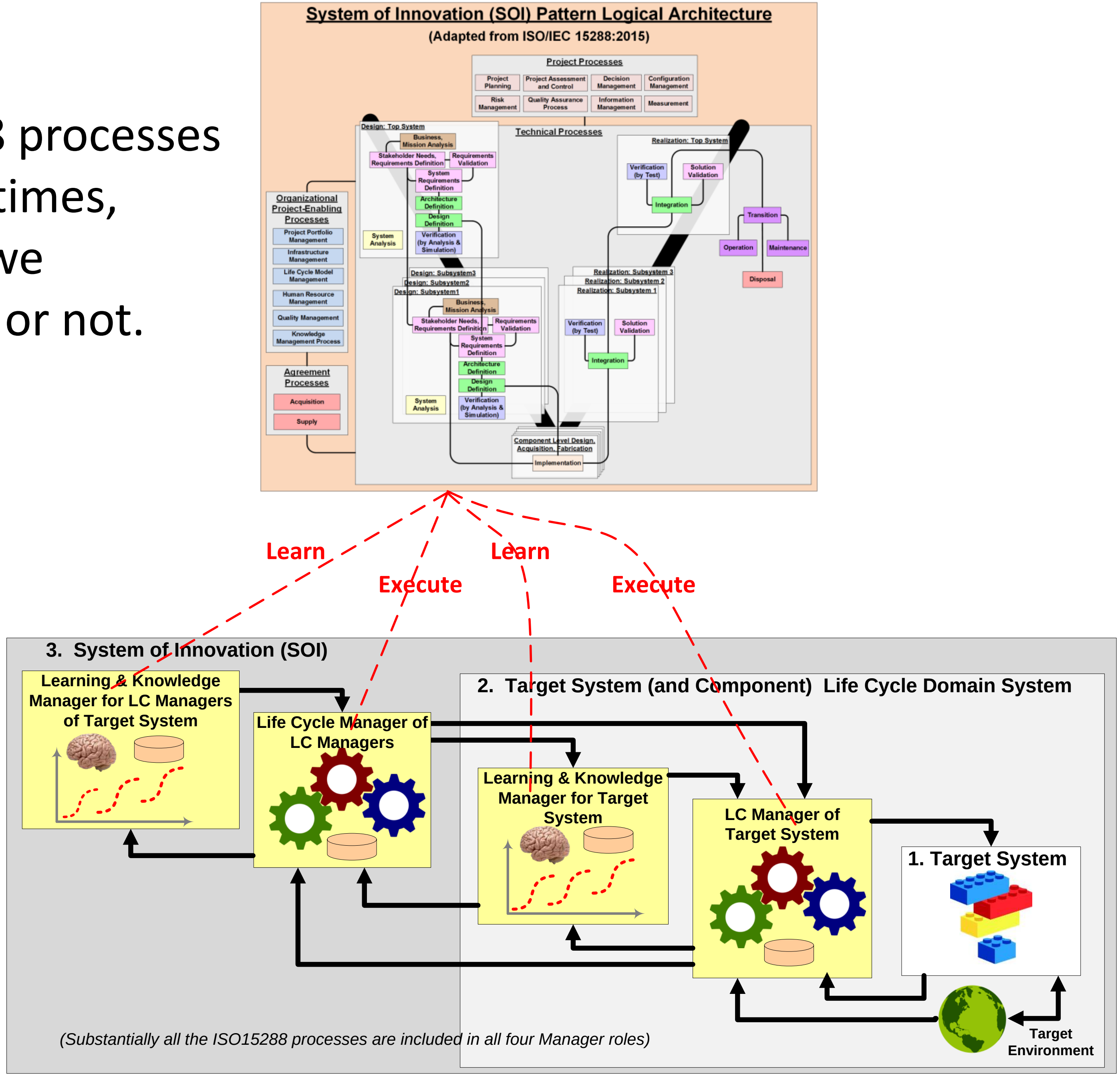
The System of Innovation (SOI) MBSE Pattern

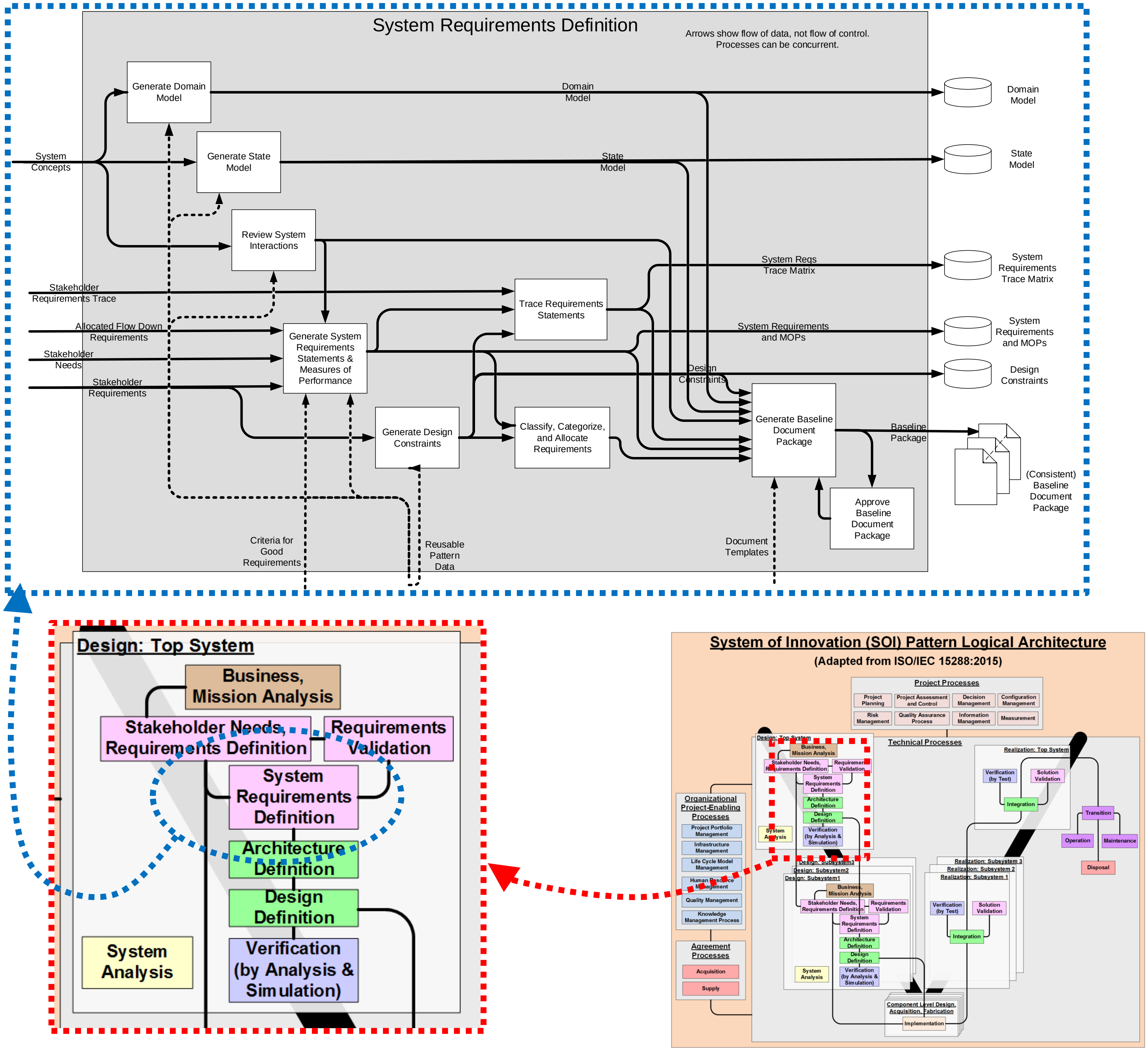
(Used for INCOSE Agile SE Project, INCOSE CIPR WG, etc.
Innovation reference model: Not prescriptive, but descriptive.)



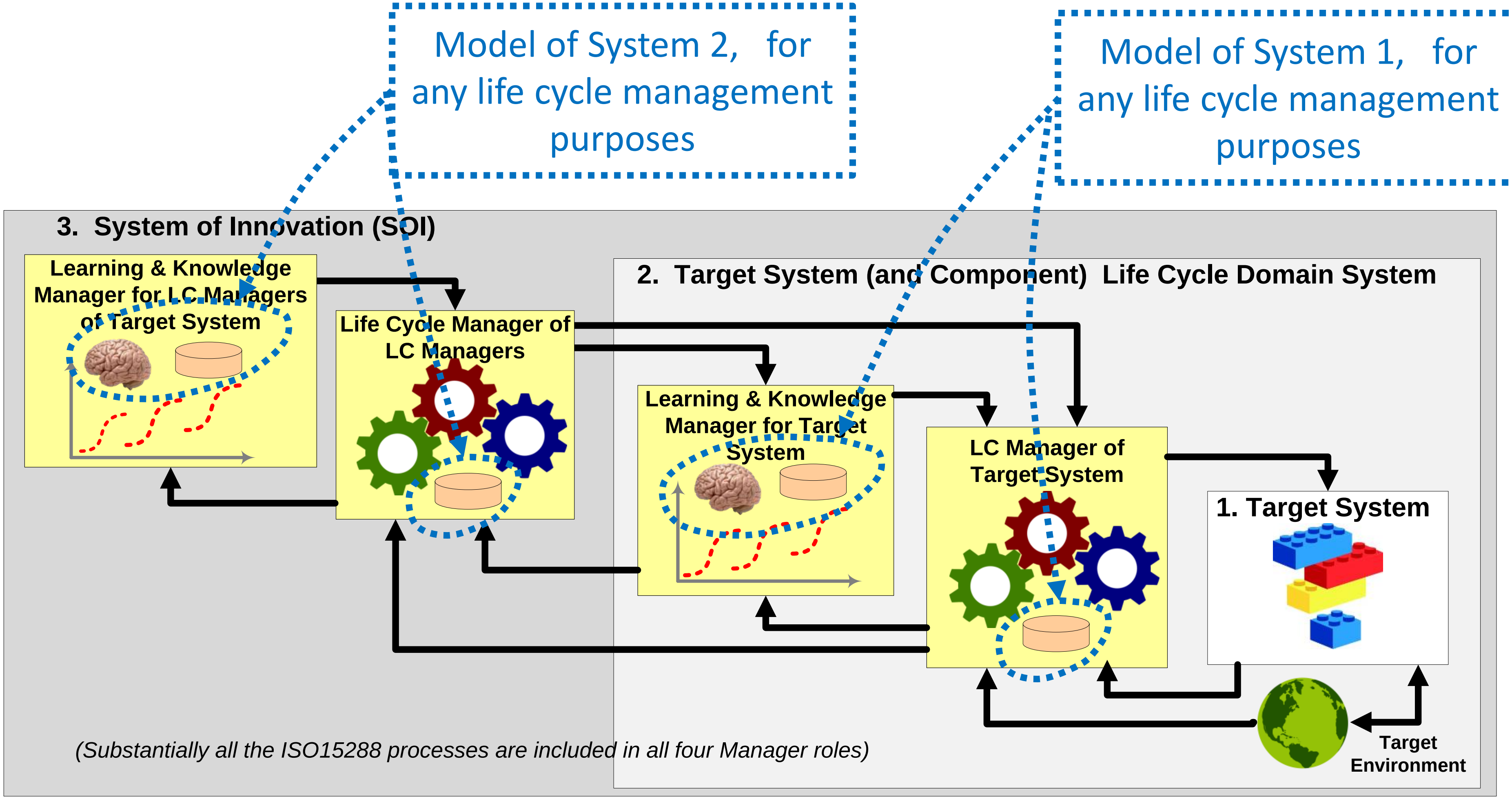
- System 1: Target system of interest, to be engineered or improved.
- System 2: The environment of (interacting with) S1, including all the life cycle management systems of S1, including learning about S1.
- System 3: The life cycle management systems for S2, including learning about S2.

ISO 15288 processes appear 4 times, whether we recognize or not.

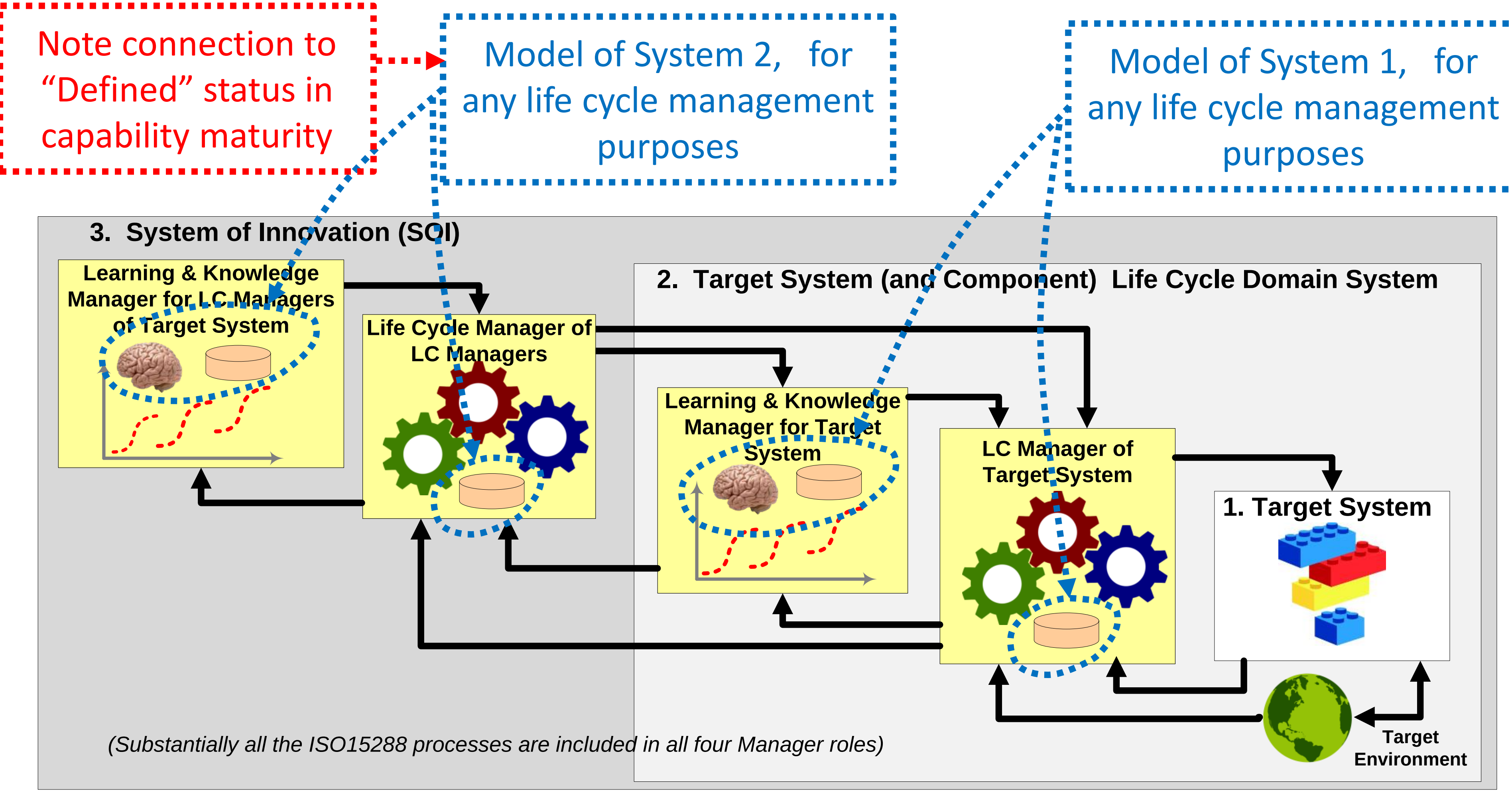




System Requirements Definition
Arrows show flow of data, not flow of control.
Processes can be concurrent.
Generate Domain Model
Generate State Model
Review System Interactions
Trace Requirements Statements
Generate System Requirements Statements & Measures of Performance
Generate Design Constraints
Classify, Categorize, and Allocate Requirements
Generate Baseline Document Package
Approve Baseline Document Package
System Concepts
Stakeholder Requirements Trace
Allocated Flow Down Requirements
Stakeholder Needs
Stakeholder Requirements
Domain Model
State Model
System Reqs Trace Matrix
System Requirements and MOPs
Design Constraints
Baseline Package
System Requirements Trace Matrix
(Consistent) Baseline Document Package
Criteria for Good Requirements
Reusable Pattern Data
Document Templates
Design: Top System
Business, Mission Analysis
Stakeholder Needs, Requirements Definition
Requirements Validation
System Requirements Definition
Architecture Definition
Design Definition
Verification (by Analysis & Simulation)
System Analysis
System of Innovation (SOI) Pattern Logical Architecture
(Adapted from ISO/IEC 15288:2015)
Project Processes
Technical Processes
Organizational Project-Enabling Processes
Agreement Processes
Realization: Top System



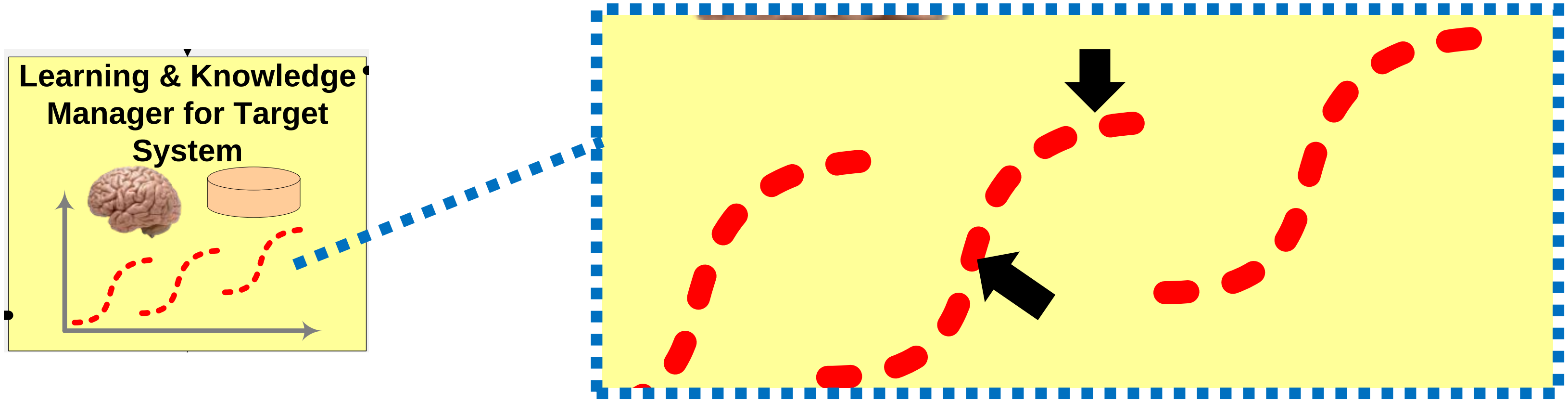
- System 1: Target system of interest, to be engineered or improved.
- System 2: The environment of (interacting with) S1, including all the life cycle management systems of S1, including learning about S1.
- System 3: The life cycle management systems for S2, including learning about S2.



- 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, including learning about S1.
- System 3: The life cycle management systems for S2, including learning about S2.

When is <u>im</u>maturity valued?

- The progressive "S Curves" of waves of new technologies, paradigms, product families, scientific, and other discoveries represent <u>learning</u>.
- In this context, "maturity" is the flat part at the top of each generation of learning.
- The earlier, "steep" part of the curve represents higher rates of change, as we learn more rapidly and exploit discovery.



- So, where do we want to be on this curve?
- Notice the challenging trade-off!
- Applies to learning about System 2 (e.g., methodology) as well as Learning about System 1 (engineered system).

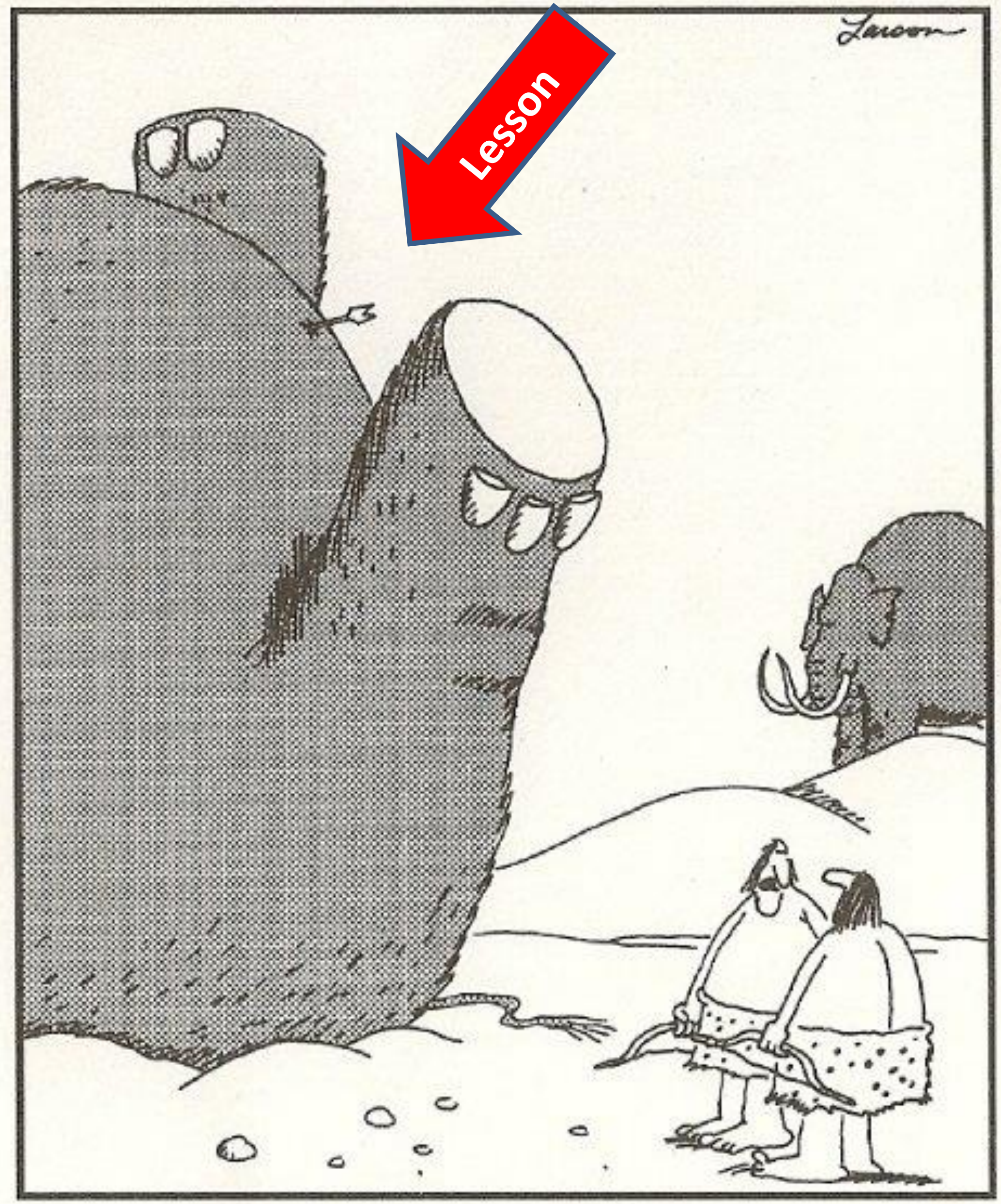
Lessons Learned: <u>Effective</u> Learning?

- In many enterprises, recording "lessons learned" is institutionalized as good practice:
  - At least, at the end of a project;
  - Often, in the form of a report or memorandum to file.
- Likewise, "Knowledge Management" efforts are noted, focusing on encoding what is deemed important for future work of others.
- Measuring effectiveness of such practices:
  - Instead of how often the data is referred to, how about . . .
  - how frequently related future work that <u>could</u> be impacted <u>is</u> effectively impacted, versus repeating similar work or problem consequences.

Lessons Learned?

Lessons Learned Report

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Sed aliquam odio eget massa feugiat, at tincidunt quam ullamcorper. Nullam ac purus tortor. Duis a ullamcorper augue. Pellentesque eu eros hendrerit, tempor tellus vitae, suscipit.

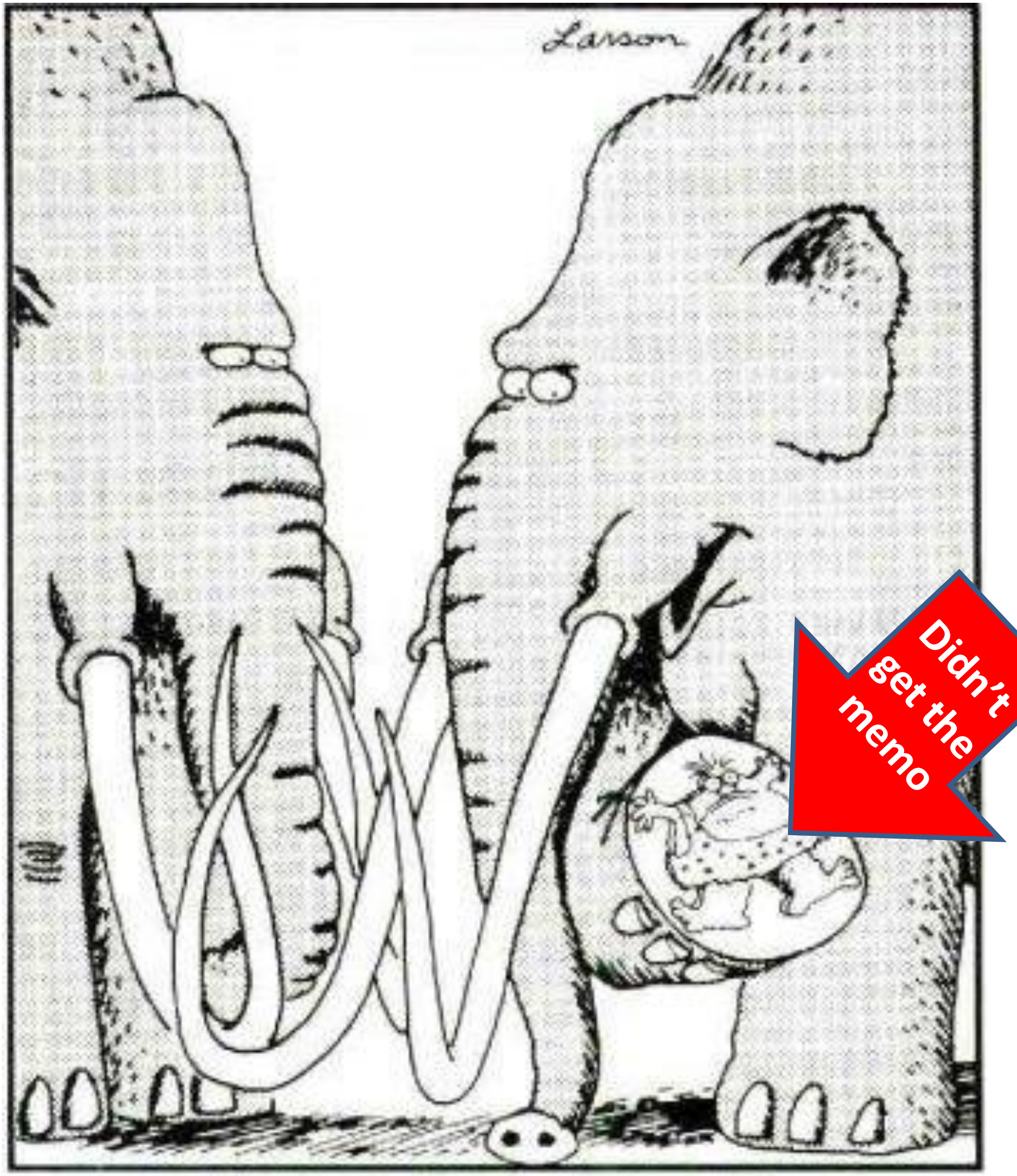


"We should write that spot down."

Lessons Effectively Learned?

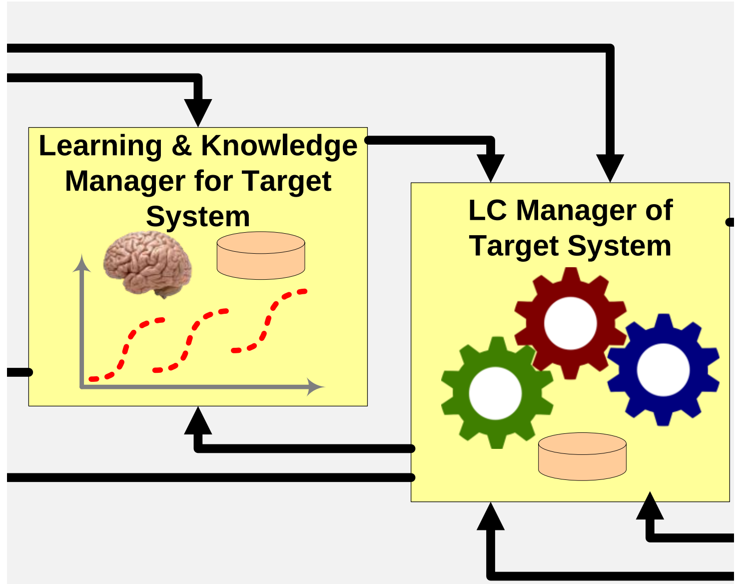
Lessons Learned Report

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Sed aliquam odio eget massa feugiat, at tincidunt quam ullamcorper. Nullam ac purus tortor. Duis a ullamcorper augue. Pellentesque eu eros hendrerit, tempor tellus vitae, suscipit.

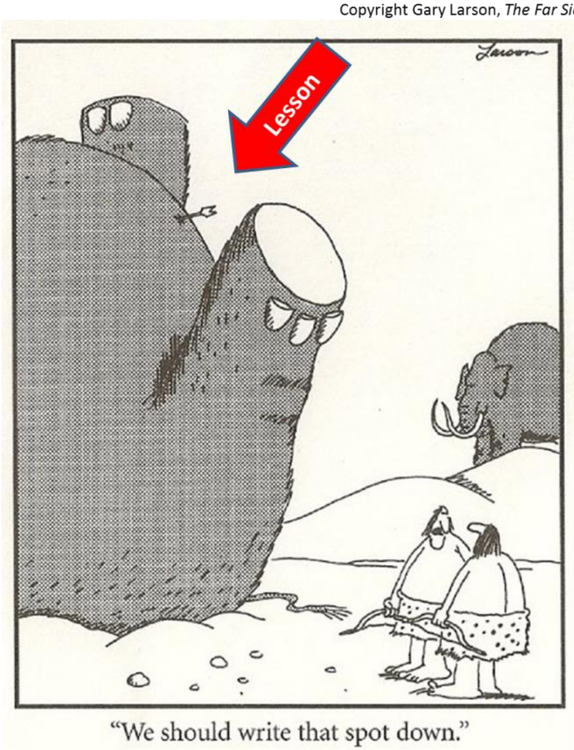


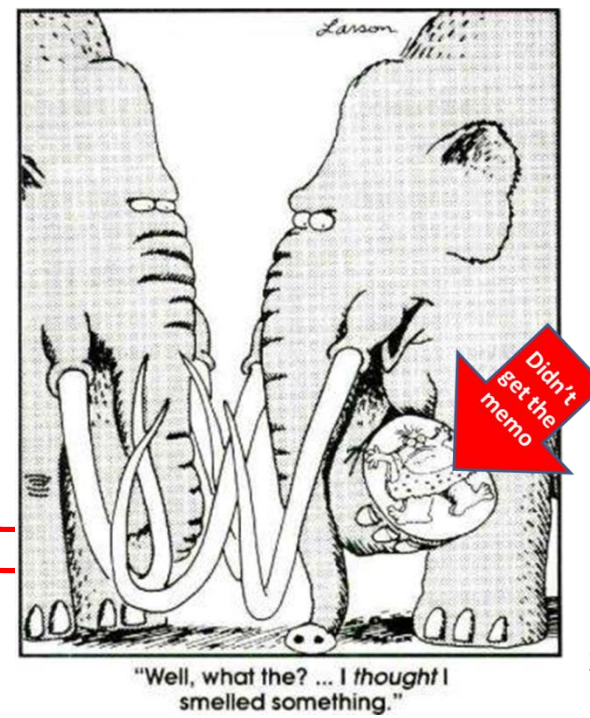
"Well, what the? ... I *thought* I smelled something."

Learning

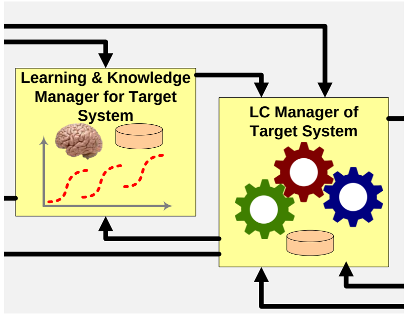


Executing





Lessons Learned: <u>Effective</u> Learning?



- <u>Where</u> are the "lessons learned" encoded? What would cause them to be <u>accessed</u>?
- Compare to biology:
  - "Muscle Memory" builds "motor" learning directly <u>*into a future situation*</u>, for future unconscious use, <u>*vs*</u>. syllogistic reasoning that may not be remembered fast enough, or at all
  - This is about "effective learning" for future agile use
  - Just having a growing file of "lessons learned", even if text searchable, is not the same as building what we learn directly in line with the path of future related work that will have to access it in order to be executed.
- Just because we label a report "lessons learned" does not mean that those who will need this information in the future will have access to it.

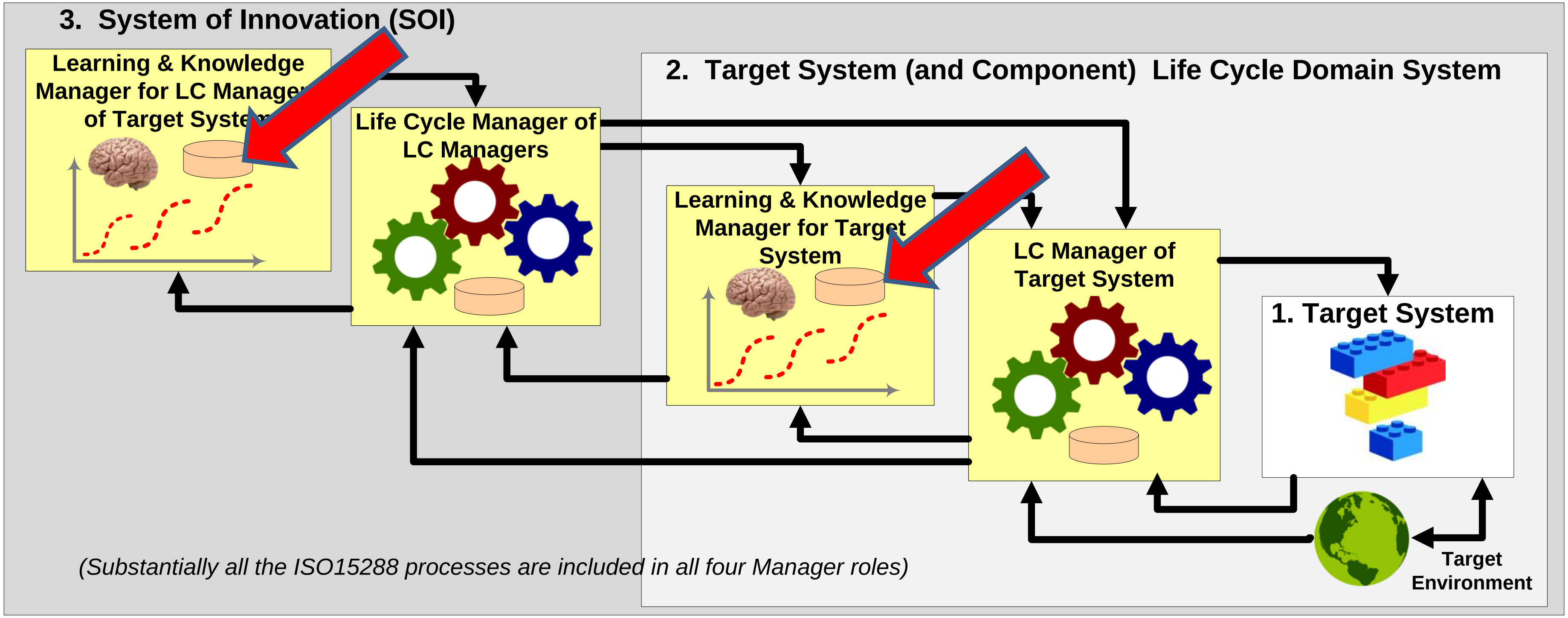
Learned models from STEM (~300 years) offer the most dramatic example of positive collaborative impact of effectively shared and validated models

- Effective Model Sharing:
  - We cannot view MBSE as mature if we perform modeling "from scratch", instead of building on what we (*including others*) already know.
  - This is the basis of MBSE Patterns, Pattern-Based Systems Engineering (PBSE), and the work of the INCOSE MBSE Patterns Working Group.
  - S1 Patterns are built directly into future S2 project work of other people—effective sharing only occurs to extent it impacts future tasks performed by others.
  - This sharing may occur across individuals, departments, enterprises, domains, markets, society.
  - It applies not only to models of S1 (by S2), but also models of S2 (by S3).
- Effective Model Validation:
  - Especially when shared, models demand that we trust them.
  - This is the motivation for Model Validation, Verification, and Uncertainty Quantification (Model VVUQ) being pursued with ASME standards committees.
  - Effectiveness of Model VVUQ is essential to MBSE Maturity.
  - Because Model VVUQ adds significantly to the cost of a trusted model, MBSE Patterns are all the more important—they IP of enterprises, industries.

An emerging special case: Regulated markets

- Increasing use of computational models in safety-critical, other regulated markets is driving development of methodology for Model VVUQ:
  - See, for example, ASME V&V 10, 20, 30, 40, 50, 60.
- Models have economic advantages, but the above can add new costs to development of models for regulatory submission of credible evidence:
  - Cost of evidentiary submissions to FDA, FAA, NRC, NTSB, EPA, OSHA, when supported by models—includes VVUQ of those models.
- This suggests a vision of collaborative roles for engineering professional societies, along with regulators, and enterprises:
  - Trusted shared MBSE Patterns for classes of systems
  - Configurable for vendor-specific products
  - With Model VVUQ frameworks lowering the cost of model trust for regulatory submissions
- Further emphasizes the issue of trust in models . . .

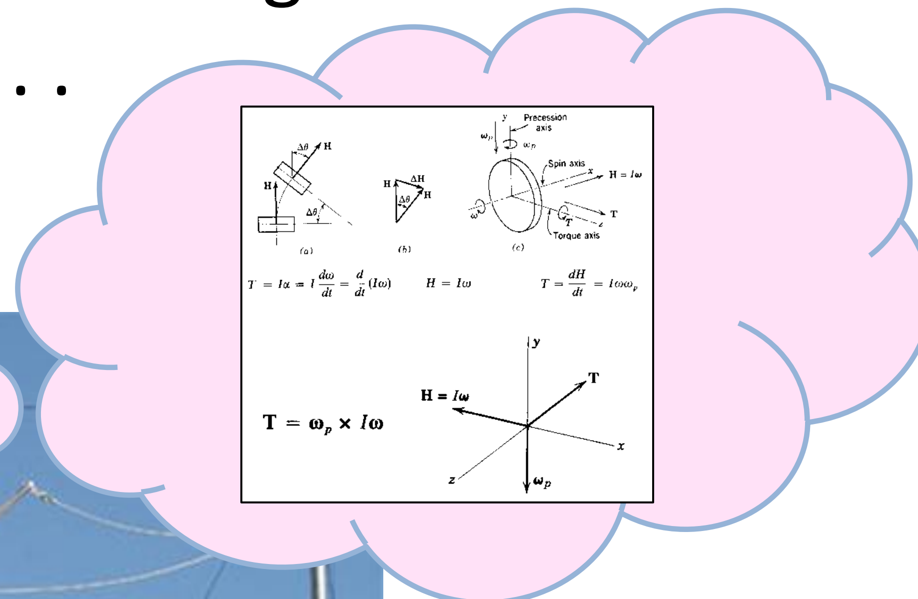
An emerging special case: Regulated markets



- Trusted shared MBSE Patterns for classes of systems
- Configurable for vendor-specific products
- With Model VVUQ frameworks lowering the cost of model trust for regulatory submissions

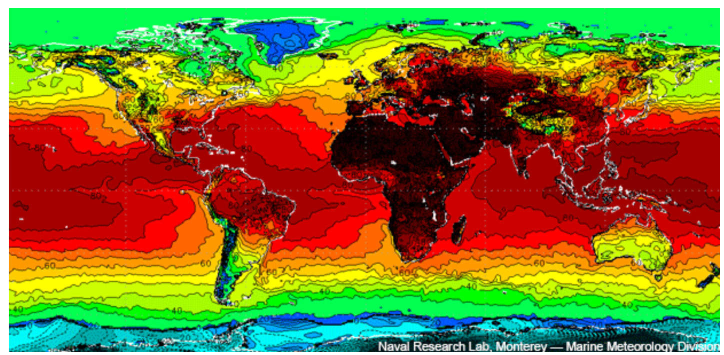
Requirements for trustable models

We cannot discuss maturity in development or use of models without discussing whether we can trust those models . . .



If we expect to use models to support critical decisions, then we are placing *increased trust in models*:

- Critical financial, other business decisions
- Human life safety
- Societal impacts
- Extending human capability



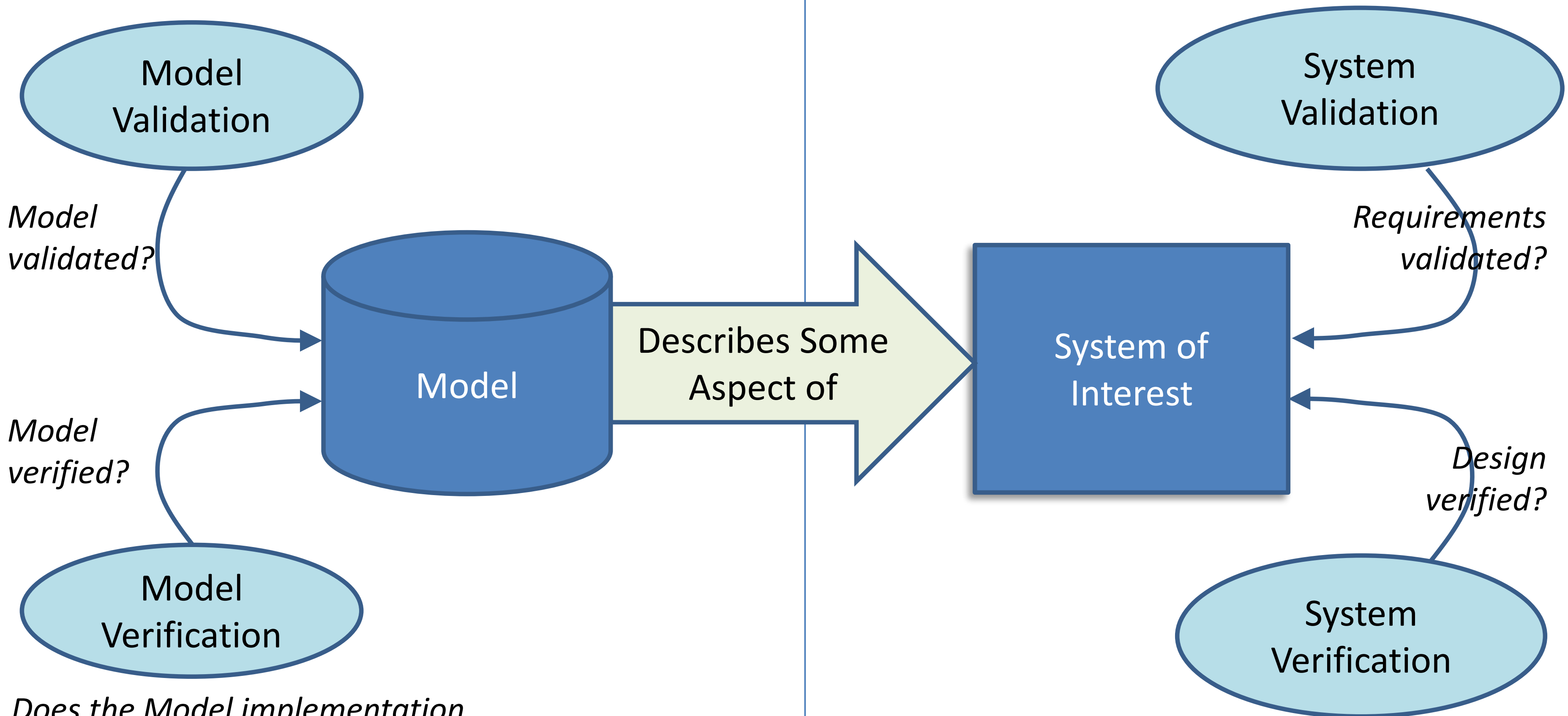
- MBSE Maturity requires that we characterize the structure of that trust and manage it:
  - The Validation, Verification, and Uncertainty Quantification (VVUQ) *of the models themselves*.

V&V of *Models*, Per Emerging ASME Model V&V Standards

V&V of *Systems*, Per ISO 15288 & INCOSE Handbook

Does the Model adequately describe what it is intended to describe?

Do the System Requirements describe what stakeholders need?

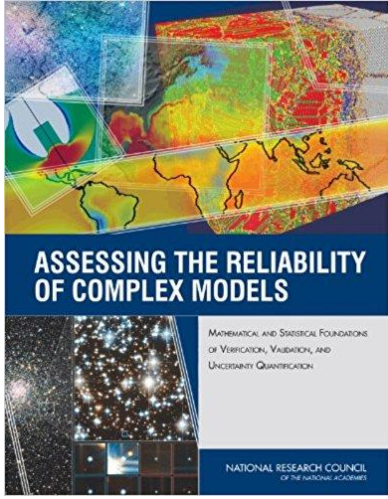


Does the Model implementation adequately represent what the Model says?

Does the System Design define a solution meeting the System Requirements?

Don't forget: A model (on the left) <u>may</u> be used for system verification or validation (on the right!)

Quantitative Fidelity, including Uncertainty Quantification (UQ)



- There is a large body of literature on a mathematical subset of the UQ problem, in ways viewed as the heart of this work.
- But, some additional systems work is needed, and in progress, as to the more general VVUQ framework, suitable for general standards or guidelines.

General structure of uncertainty / confidence tracing:

- Do the modeled external Interactions qualitatively cover the modeled Stakeholder Features over the range of intended S1 situations of interest?
- Quantify confidence / uncertainty that the modeled Stakeholder Feature Attributes quantitatively represent the real system concerns of the S1 Stakeholders with sufficient accuracy over the range of intended situation envelopes.
- Quantify confidence / uncertainty that the modeled Technical Performance Attributes quantitatively represent the real system external behavior of the S1 system with sufficient accuracy over the range of intended situation envelopes.

Related ASME activities and resources

- ASME, has an active set of teams writing guidelines and standards on the Verification and Validation of Computational Models.
  - Inspired by the proliferation of computational models (FEA, CFD, Thermal, Stress/Strain, etc.)
  - It could fairly be said that this historical background means that effort was not focused on what most systems engineers would call “system models”
- Also conducts annual Symposium on Validation and Verification of Computational Models, in May.
- To participate in this work, in 2016 the speaker joined the ASME VV50 Committee:
  - With the idea that the framework ASME set as foundation could apply well to systems level models; and . . .
  - with a pre-existing belief that system level models are not as different from discipline-specific physics models as believed by systems community.
- Also invited sub-team leader Joe Hightower (Boeing) to address the INCOSE IW2017 MBSE Workshop, on our related ASME activity.

ASME Verification & Validation Standards Committee

- V&V 10: Verification & Validation in Computational Solid Dynamics
- V&V20: Verification & Validation in Computational Fluid Dynamics and Heat Transfer
- V&V 30: Verification and Validation in Computational Simulation of Nuclear System Thermal Fluids Behavior
- V&V 40: Verification and Validation in Computational Modeling of Medical Devices
- V&V 50: Verification & Validation of Computational Modeling for Advanced Manufacturing
- V&V 60: Verification and Validation in Modeling and Simulation in Energy Systems and Applications

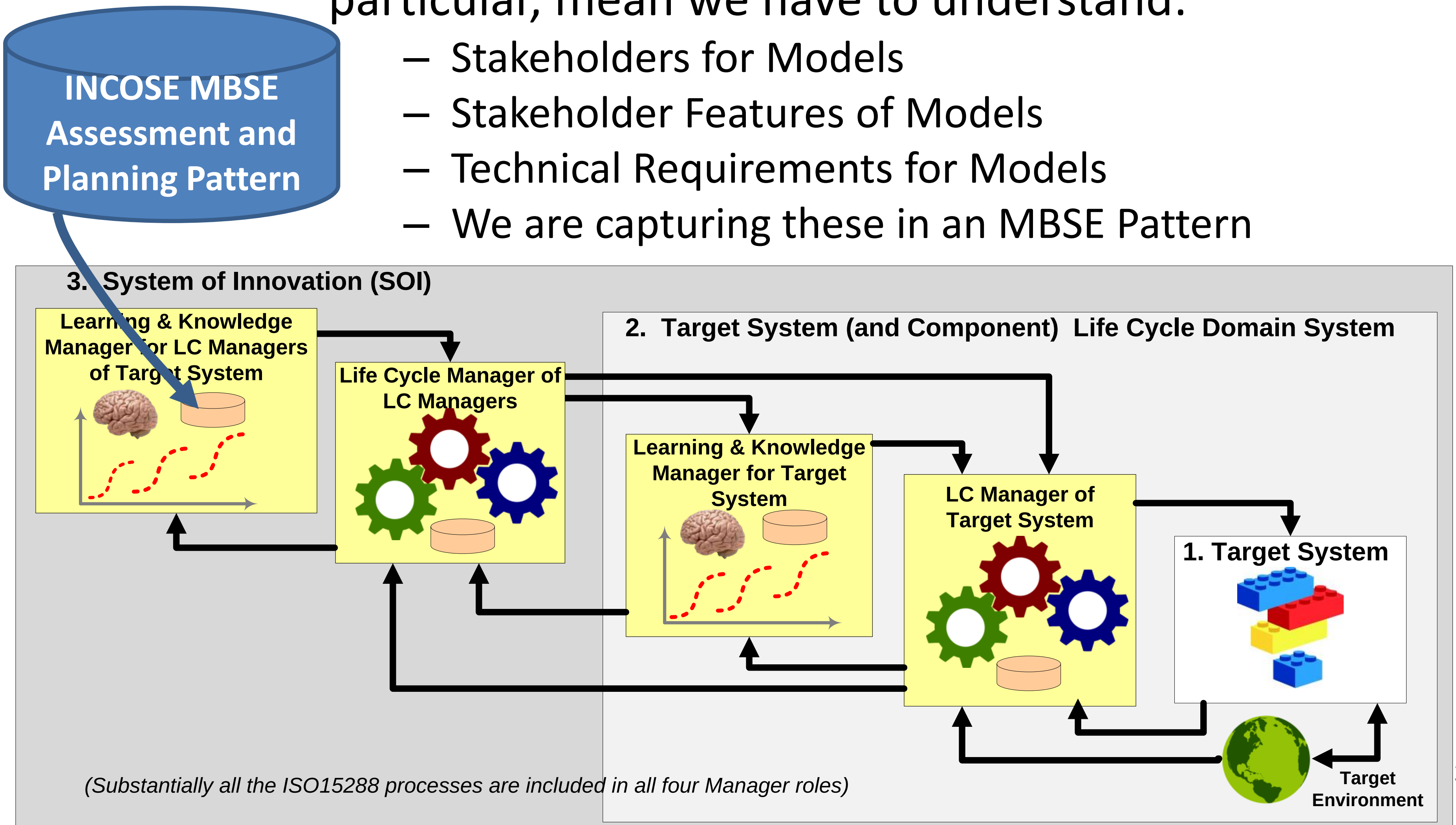
https://cstools.asme.org/csconnect/CommitteePages.cfm?Committee=100003367

ASME
SETTING THE STANDARD

Requirements for trustable, impactful models, as a basis for MBSE maturity

MBSE Maturity in general, and VVUQ for Models in particular, mean we have to understand:

- Stakeholders for Models
- Stakeholder Features of Models
- Technical Requirements for Models
- We are capturing these in an MBSE Pattern



Stakeholders for Models

Model Stakeholder Type	Definition
Model User	A person, group, or organization that directly uses a model for its agreed upon purpose. May include technical specialists, non-technical decision-makers, customers, supply chain members, regulatory authorities, or others.
Model Developer	A person who initially creates a model, from conceptualization through implementation, validation, and verification, including any related model documentation. Such a person may or may not be the same as one who subsequently maintains the model.
Model Maintainer	A person who maintains and updates a model after its initial development. In effect, the model maintainer is a model developer after the initial release of a model.
Model Deployer-Distributor	A person or organization that distributes and deploys a model into its intended usage environment, including transport and installation, through readiness for use.
Model Use Supporter	A person who supports or assists a Model User in applying a model for its intended use. This may include answering questions, providing advice, addressing problems, or other forms of support.
Regulatory Authority	An organization that is responsible for generating or enforcing regulations governing a domain.
Model Investor-Owner	A person or organization that invests in a model, whether through development, purchase, licenses, or otherwise, expecting a benefit from that investment.

INCOSE MBSE Assessment and Planning Pattern: Model Stakeholder Features Overview

Model Identity and Focus

- **Modeled System of Interest**
  - System of Interest
- **Modeled Environmental Domain**
  - Domain Type

Model Utility

- **Model Intended Use**
  - LIFE CYCLE PROCESS SUPPORTED (ISO15288)
- **Perceived Model Value and Use**
  - USER GROUP SEGMENT
  - Level of Annual Use
  - Value Level
- **Third Party Acceptance**
  - ACCEPTING AUTHORITY
- **Model Ease of Use**
  - Perceived Model Complexity

Model Scope and Content

- **Modeled Stakeholder Value**
  - STAKEHOLDER TYPE
- **Modeled System External (Black Box) Behavior**
- **Explanatory Decomposition**
- **Parametric Couplings--Fitness**
- **Parametric Couplings--Decomposition**
- **Parametric Couplings--Characterization**
- **Trusted Configurable Pattern**
  - CONFIGURATION ID
  - Pattern Type
- **Physical Architecture**
- **Managed Model Datasets**
  - DATASET TYPE

Model Fidelity

- **Model Envelope**
  - MODEL APPLICATION ENVELOPE
- **Validated Conceptual Model Fidelity**
  - Quantitative Accuracy Reference
  - Function Structure Accuracy Reference
  - Uncertainty Quantification (UQ) Reference
  - Model Validation Reference
- **Verified Executable Model Fidelity**
  - Quantitative Accuracy Reference
  - Function Structure Accuracy Reference
  - Uncertainty Quantification (UQ) Reference
  - Speed
  - Quantization
  - Stability
  - Model Validation Reference

Model Representation

- **Conceptual Model Representation**
  - Conceptual Model Representation Type
  - Conceptual Model Interoperability
- **Executable Model Representation**
  - Executable Model Representation Type
  - Executable Model Interoperability

Model Life Cycle Management

- **Model Versioning and Configuration Management**
  - CM CAPABILIY TYPE
- **Model Maintainability**
  - Maintenance Method
- **Model Deployability**
  - Deployment Method
- **Model Cost**
  - Development Cost
  - Operational Cost
  - Maintenance Cost
  - Deployment Cost
  - Retirement Cost
  - Life Cycle Financial Risk
- **Executable Model Environmental Compatibility**
  - IT ENVIRONMENTAL COMPONENT
- **Model Design Life Cycle and Retirement**
  - Design Life
- **Model Availability**
  - First Availability Date
  - First Availability Risk
  - Life Cycle Availability Risk

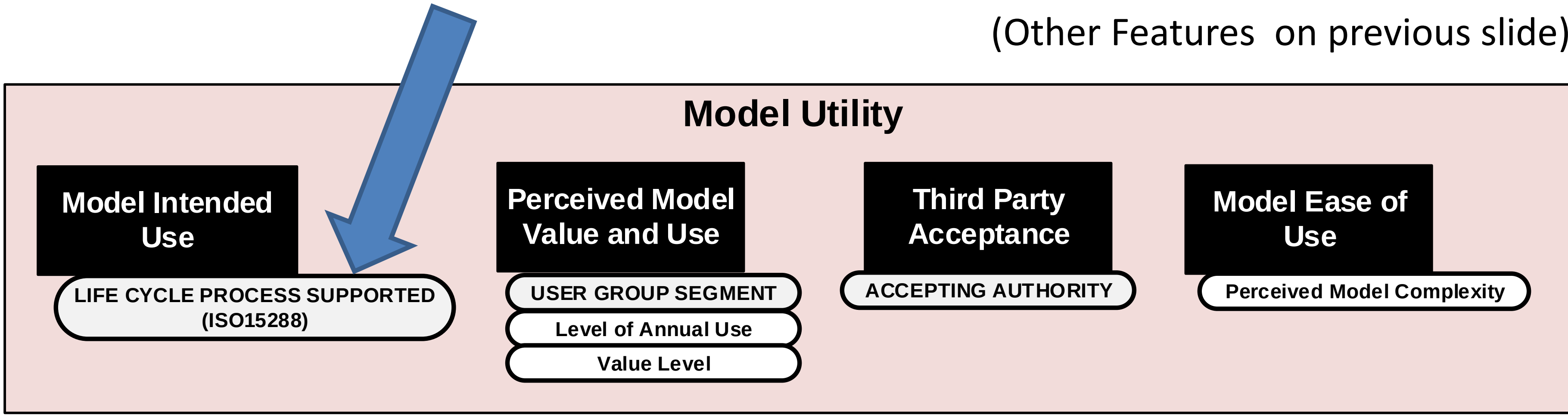
Legend:

- **STAKEHOLDER FEATURE**
  - FEATURE PK ATTRIBUTE
  - Other Feature Attribute
  - Other Feature Attribute

Stakeholder Feature Model for Computational Models		
Version: 1.4.15	Date: 30 Apr 2017	Drawn By: B Schindel

The ISO 15288 Processes provide the Model Stakeholder Feature Set for Planning & Assessment

(Other Features on previous slide)



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
	Third Party Acceptance	The degree to which the model is accepted as authoritative, by third party regulators, customers, supply chains, and other entities, for its stated purpose.	Accepting Authority	The identity (may be multiple) of regulators, agencies, customers, supply chains, accepting the model	**X**					**X**	**X**	X	X
	Model Ease of Use	The perceived ease with which the model can be used, as experienced by its intended users	Perceived Model Complexity	High, Medium Low	**X**					**X**		X	X

Related INCOSE, ASME communities

- **INCOSE:**
  - Model-Based Engineering Transformation Initiative
  - INCOSE-NAFEMS Joint Working Group on Simulation
  - MBSE Patterns Working Group
  - Agile Systems & Systems Engineering Working Group
  - Tools Interoperability and Model Life Cycle Management Group
  - INCOSE-OMG MBSE Initiative: Challenge Teams, Activity Teams

- **ASME Computational Model V&V Committee / Working Groups:**
  - V&V 10: Verification & Validation in Computational Solid Dynamics
  - V&V20: Verification & Validation in Computational Fluid Dynamics and Heat Transfer
  - V&V 30: Verification and Validation in Computational Simulation of Nuclear System Thermal Fluids Behavior
  - V&V 40: Verification and Validation in Computational Modeling of Medical Devices
  - V&V 50: Verification & Validation of Computational Modeling for Advanced Manufacturing
  - V&V 60: Verification and Validation in Modeling and Simulation in Energy Systems and Applications

Opportunities--what you can do

- Think larger about intended uses and users of MBSE, and judge its maturity in that light.
- Include how well MBSE enables group learning.
- Include the full breadth of model types in your thinking.
- Consider why you think a model should be trusted.
- Join the INCOSE MBSE Patterns Working Group, to advance practice.
- Join the ASME Computational VVUQ effort, to advance model trust.
- Exercise the emerging MBSE Planning and Assessment Framework, in your own company and work, and provide feedback.

References

1. "INCOSE MBSE Transformation Planning & Assessment Framework: Beta Test": http://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:planning_assessment_requirements_for_mbse_model_applications_v1.4.2.pdf
2. *Assessing the Reliability of Complex Models: Mathematical and Statistical Foundations of Verification, Validation, and Uncertainty Quantification* ISBN 978-0-309-25634-6 THE NATIONAL ACADEMIES PRESS, http://nap.edu/13395
3. Web site of ASME VV50 https://cstools.asme.org/csconnect/CommitteePages.cfm?Committee=100003367
4. "ASME V&V 10-2006: Guide for Verification and Validation in Computational Solid Mechanics", ASME, 2006.
5. "ASME V&V 20-2009: Standard for Verification and Validation in Computational Fluid Dynamics and Heat Transfer", ASME, 2009.
6. "ASME V&V 10.1-2012: An Illustration of the Concepts of Verification and Validation in Computational Solid Mechanics", ASME, 2012.
7. *Journal of Verification, Validation, and Uncertainty Quantification*, ASME. https://verification.asmedigitalcollection.asme.org/journal.aspx
8. AIAA (American Institute for Aeronautics and Astronautics). 1998. *Guide for the Verification and Validation of Computational Fluid Dynamics Simulations.* Reston, Va.
9. Box, G., and N. Draper. *Empirical Model Building and Response Surfaces*. New York: Wiley, 1987.

10. "CMMI for Development", CMMI-DEV, v1.3, 2010: http://www.sei.cmu.edu/library/abstracts/reports/10tr033.cfm
11. Hightower, Joseph, "Establishing Model Credibility Using Verification and Validation", INCOSE MBSE Workshop, IW2017, Los Angeles, January, 2017. http://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:incose_mbse_iw_2017:models_and_uncertainty_in_decision_making_rev_a.pptx
12. Beihoff, B., et al, "A World in Motion: INCOSE Vision 2025", INCOSE.
13. Schindel, W., "What Is the Smallest Model of a System?", Proc. of the INCOSE 2011 International Symposium, International Council on Systems Engineering (2011).
14. Schindel, W., and Dove, R., "Introduction to the Agile Systems Engineering Life Cycle MBSE Pattern", in Proc. of INCOSE 2016 International Symposium, 2016.
15. Schindel, W., "Got Phenomena? Science-Based Disciplines for Emerging Systems Challenges PBSE methodology summary", Proc. of INCOSE IS2017 Symposium, Adelaide, UK, 2017.
16. Schindel, W., "Requirements Statements Are Transfer Functions: An Insight from MBSE", Proc. of INCOSE IS2005 Symposium, Rochester, NY, 2005.
17. INCOSE MBSE Initiative Patterns Working Group web site, at http://www.omgwiki.org/MBSE/doku.php?id=mbse:patterns:patterns
18. 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

Speaker

Bill Schindel chairs the MBSE Patterns Working Group of the INCOSE/OMG MBSE Initiative. He is president of ICTT System Sciences, and has practiced systems engineering for over thirty years, across multiple industry domains. Bill serves as president of the INCOSE Crossroads of America Chapter, and is an INCOSE Fellow and Certified Systems Engineering Professional. An ASME member, he is part of the ASME VV50 standards team's effort to describe the verification, validation, and uncertainty quantification of models.