MBSE Patterns Working Group Meeting, IW2026



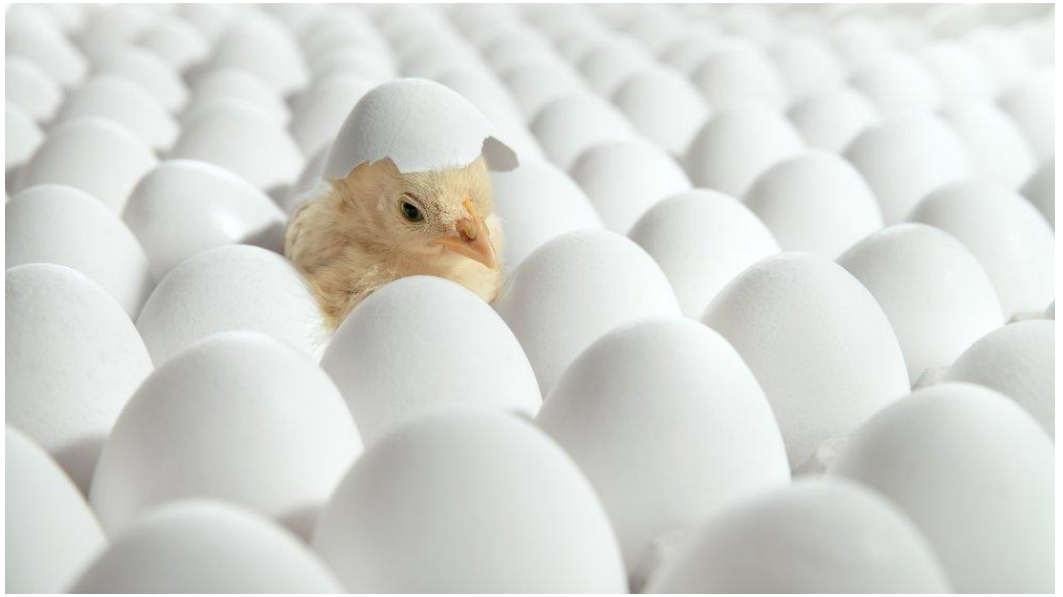
Monday, 02 Feb, 13:00-17:00 PT
On site meeting: Salon B
Remote access: <*Link to be published before mtg*>

INCOSE International Workshop 2026 | Torrance, California.
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V1.1.4

William.Schindel@INCOSE.net

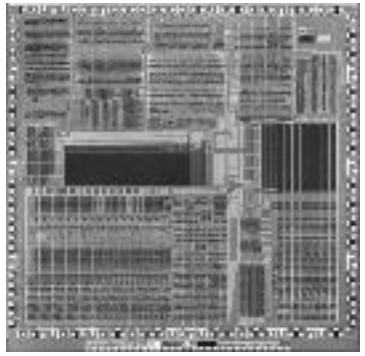
Meeting Agenda / Contents Summary: Monday, February 02, 2026

- Welcome and introduction to the MBSE Pattern Working Group's goals and focus
- Introductions and interests of meeting participants
- Overview of MBSE Patterns subject matter and relevance
- Status of current working group projects and activities; related Q&A and interests
- Discussion of additional and future interests of attendees
- Adjourn

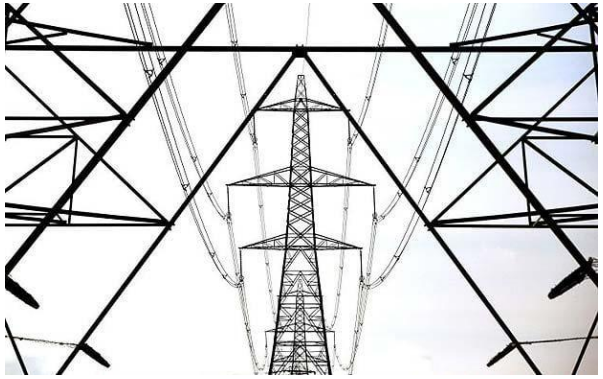


We began 13 years ago, as MBSE Initiative Patterns Challenge Team:

- Part of the joint INCOSE/OMG MBSE Initiative, formed earlier.
- Ten years ago (2016), our team formally became the INCOSE MBSE Patterns Working Group.
- Because of our MBSE focus, and in order to continue to support the MBSE Initiative, we continue to also be listed as part of that INCOSE/MBSE Initiative.
- ***Our working group web site remains part of joint OMG-INCOSE MBSE wiki.***

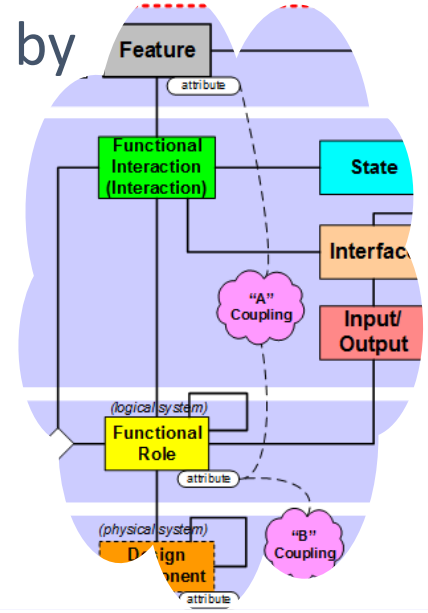


Focus of MBSE Patterns Working Group: ***S*Patterns***



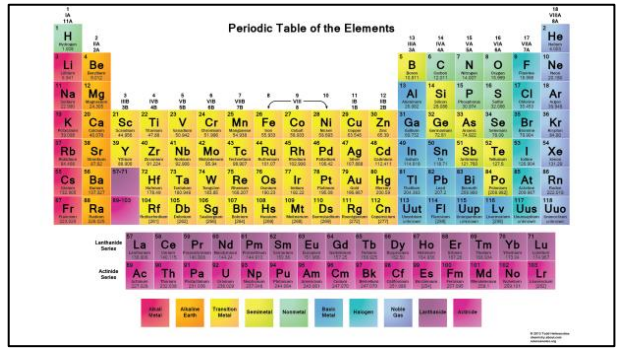
***Configurable, re-usable system models*:**

1. Models containing a certain minimal set of elements are called S*Models (S* is short for “Systematica”).
2. Those underlying elements are called the S*Metamodel; content was inspired by the unmatched success of the physical sciences and impact of STEM.
3. S*Models using those elements may be expressed in any modeling language via formal mapping (e.g., in OMG SysML, or in other languages).
4. S*Models can be (have been) created and managed in many different COTS modeling tools using such diverse languages.
5. Re-usable, configurable S*Models are called S*Patterns.
6. By “Pattern-Based Systems Engineering” (PBSE) we mean MBSE enhanced by these generalized assets to enable model configuration from trusted patterns.
7. These are typically system-level patterns (models of whole managed platforms), not just smaller-scale component design patterns.





Patterns in general are . . .

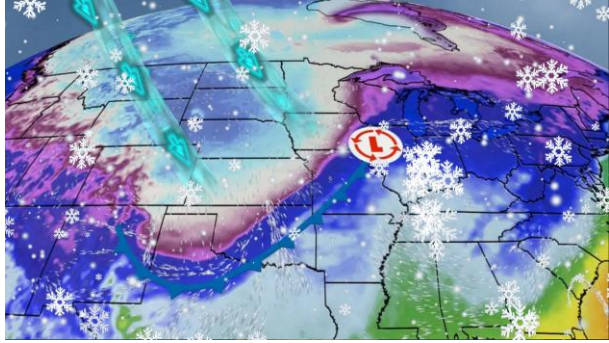


- Much, much more than just “templates for reusable models”; they are . . .
- recurrences (regularities, invariances), across time, locations, projects, products, customers, applications, people, companies, or otherwise;
- the basis of all known laws of physical sciences for the last 300 years;
- the basis of theoretical foundations of the engineering disciplines;
- the basis of learning--for individuals, groups, machines (what AI learns);
- the basis of human cognition and reasoning.

$$H(t)|\psi(t)\rangle = i\hbar\frac{\partial}{\partial t}|\psi(t)\rangle$$



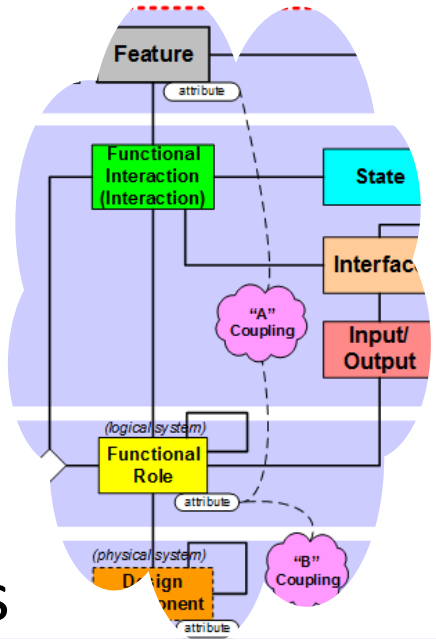
Patterns in general are . . .



- What we did not learn when we repeatedly miss the same opportunities or repeat same mistakes;
- why we wake up to a mostly recognizable world each day;
- described by both fixed and variable (parameterized, configurable) aspects;
- described informally by natural language;
- described formally by the models of science, engineering, and mathematics;
- not just about engineered products, but also methods of engineering, life cycle management, and socio-technical systems in general.

$$\nabla \cdot \mathbf{D} = \rho$$
$$\nabla \cdot \mathbf{B} = 0$$
$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$
$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$$

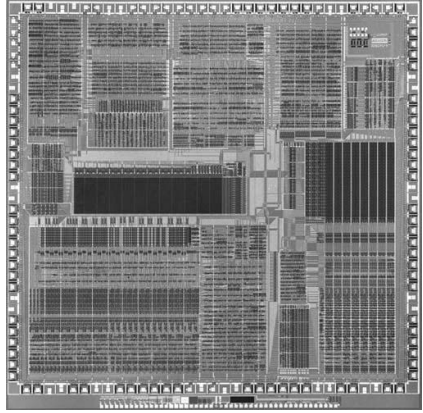
S*Models . . .



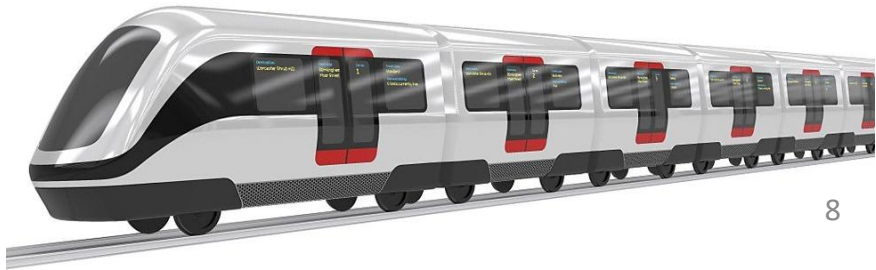
- Are models containing a certain minimal set of STEM-based elements are called S*Models (S* is short for "Systematica").
- Those underlying elements are called the S*Metamodel, which was inspired by the unmatched success of the physical sciences and impact of STEM.
- Asking STEM this question: "*What is the smallest model of a system over its life cycle, for purposes of engineering or science*?"
- S*Models using those elements may be expressed in any modeling language and tooling, via formal mapping (e.g., in OMG SysML, or in other languages).
- S*Models can be (have been) created and managed in many different COTS modeling tools using diverse languages.



S*Patterns in particular are . . .



- Re-usable, configurable S*Models are called S*Patterns.
- By “Pattern-Based Systems Engineering” (PBSE) we mean MBSE enhanced by these generalized assets to enable fast, semi-automatic MBSE model generation from trusted patterns.
- These are typically system-level patterns (models of whole managed platforms), not just smaller-scale component design patterns.
- The AIAA reference models for aerospace Digital Threads and Digital Twins are based on the INCOSE ASELCM Innovation Ecosystem Pattern . . . .



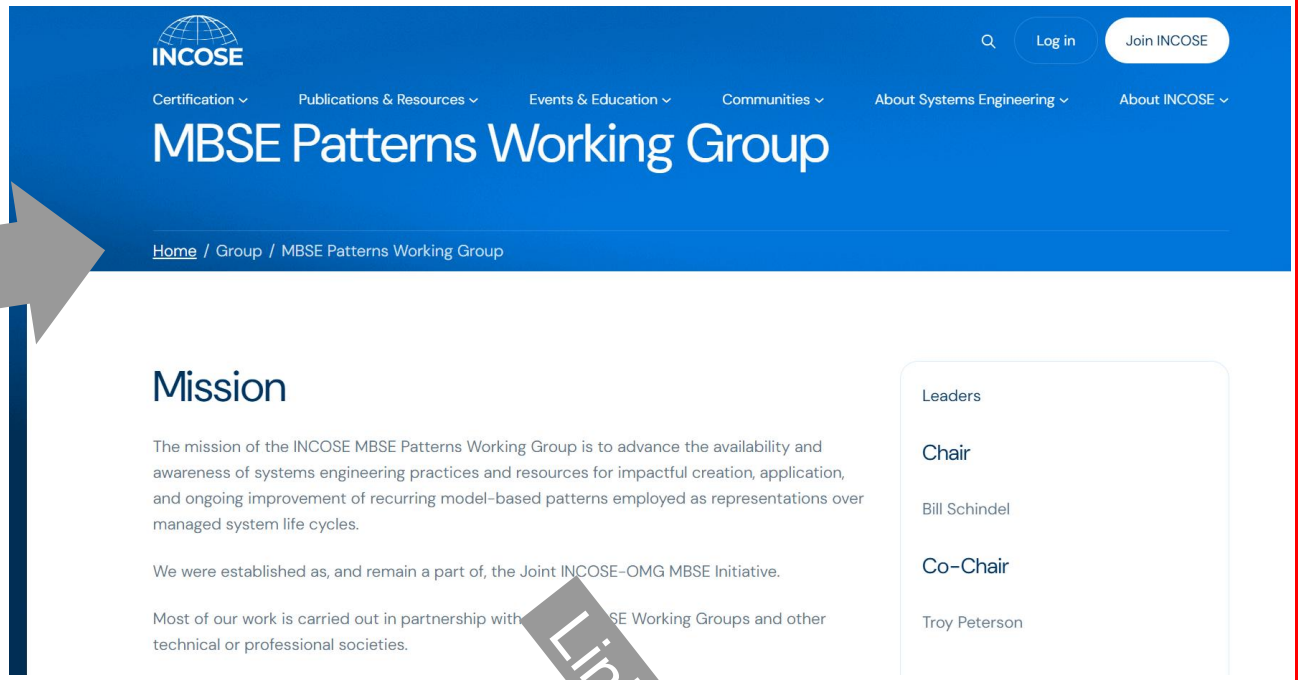
The INCOSE Patterns Working Group: *Who are we?*

- Our most active members came from across diverse domains:
  - Automotive
  - Advanced Manufacturing
  - Aerospace
  - Consumer Products
  - Defense
  - Health Care, Medical Devices, Pharmaceuticals
  - Others
- During the last ten years, over 200 colleagues have participated in Patterns Working Group activities:
  - Team meetings, work sessions, tutorials, meetings with other groups.
  - Construction of system patterns.
  - Writing related publications for INCOSE and other technical societies.
  - Invited presentations to INCOSE chapters.

INCOSE.org MBSE Patterns WG Launch Page:

In INCOSE.ORG site

https://www.incose.org/group/mbse-patterns-working-group/

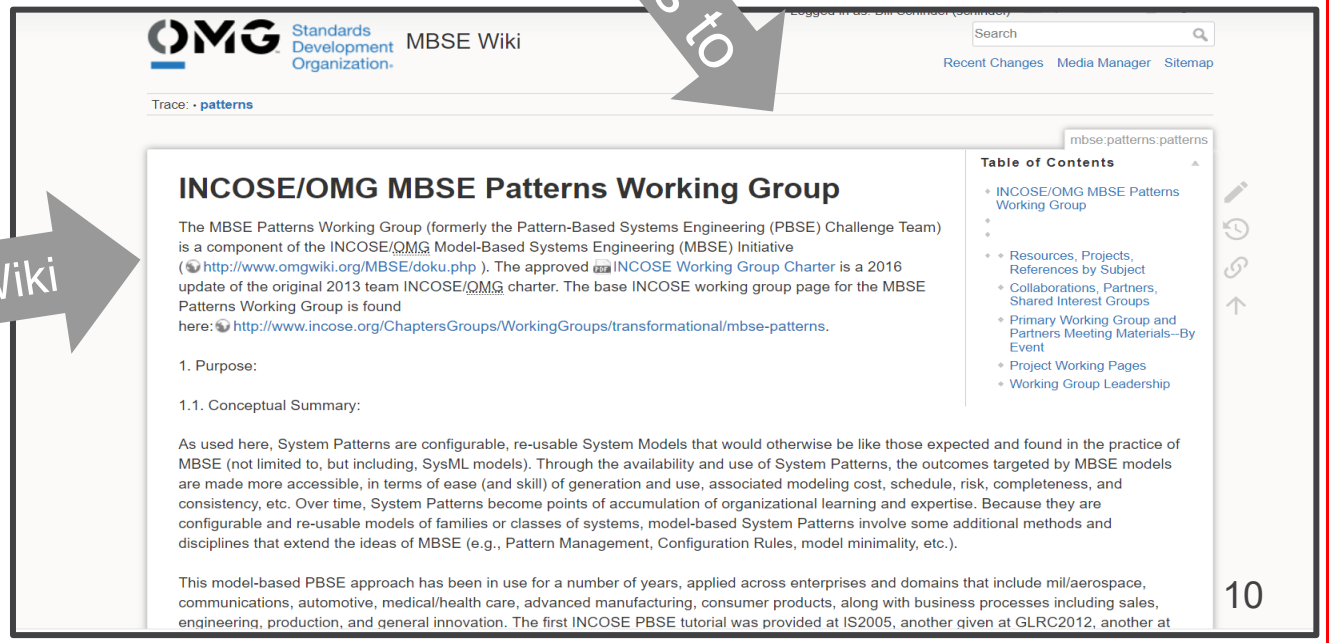


Links to

INCOSE-OMG MBSE Joint Initiative Web Site for MBSE Patterns WG:

Part of the OMG MBSE Wiki

https://www.omgwiki.org/MBSE/doku.php?id=mbse:patterns:patterns



Resources, Projects, References by Subject

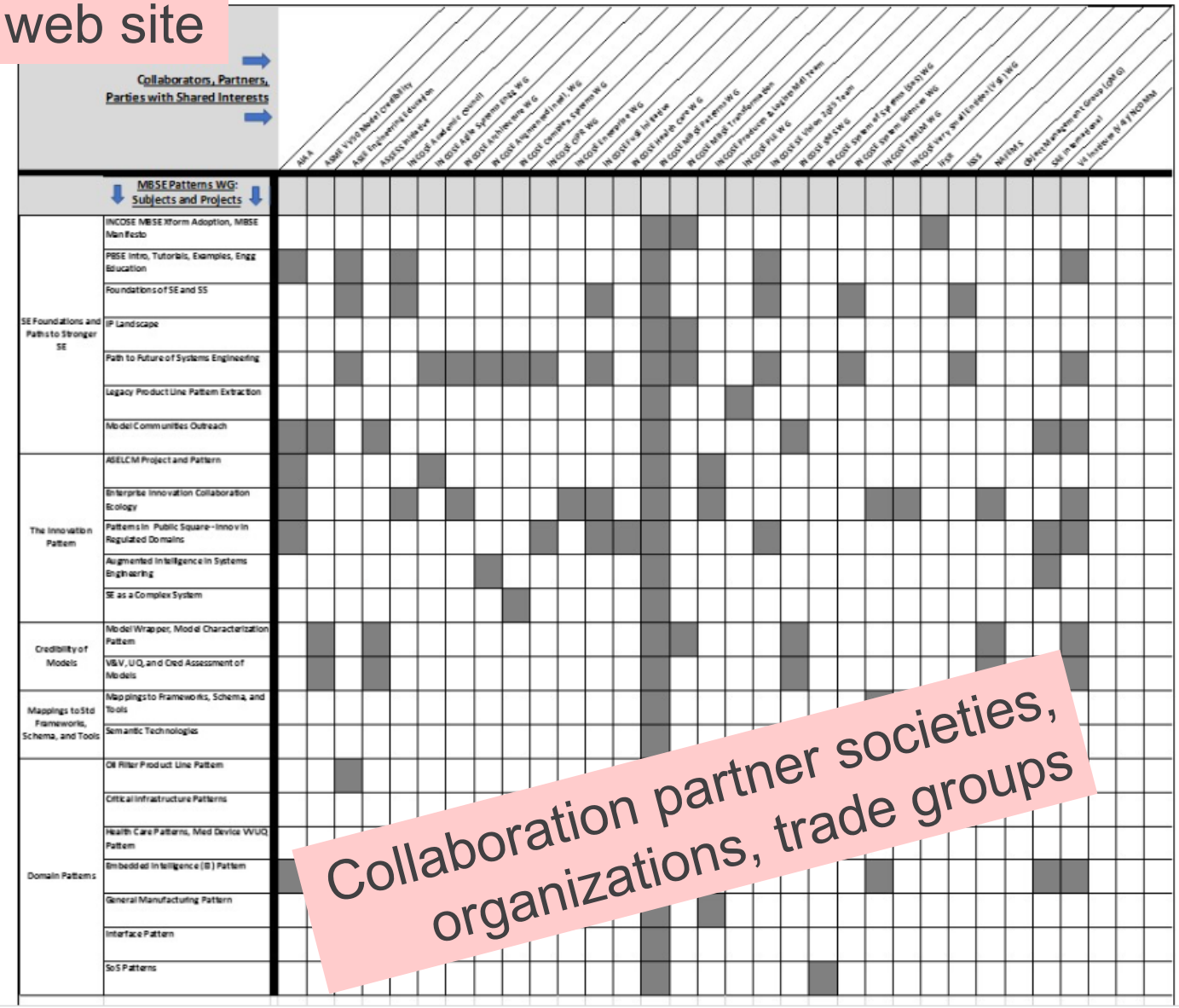
Foundations and Paths to Stronger SE	*How INCOSE and the systems community are visualizing and reaching out to the future. How the INCOSE MBSE Patterns Working Group is applying a stronger foundation based on the System Phenomenon and the history of patterns in the physical sciences and mathematics to enhance and transform the foundation capabilities of Systems Engineering.*
	MBSE_Transformation_Adoption_Pattern_Project
	PBSE Introduction, Basic Subjects, Tutorials, Education
	Strengthened Foundations of Systems Engineering and Systems Science
	S*Patterns--IP Landscape
	Paths to the Futures of Systems Engineering
	Legacy_Product_Line_Pattern_Extraction_Project_with_PLE_WG
	Model Communities Outreach
The Innovation Pattern	*The formal systems pattern reference framework that describes systems innovation in all its forms, configurable for planning and analyzing specific plans, situations, and roadmaps. A framework in which Systems Engineering (or any system life cycle management) of any method and organization referencing ISO15288 and the INCOSE SE Handbook; and the use of MBSE Patterns in particular, can be planned, organized, deployed, analyzed, and managed, and continuously advanced over time.*
	Agile_Systems_Engineering_Life_Cycle_Management_(ASELCM)_Discovery_Project_with_ASE_WG
	Innovation_Collaboration_Ecology_Project_with_TIMLM_WG_and_PLE_WG
	Patterns in the Public Square--Innovation in Regulated Domains
	Augmented Intelligence in Systems Engineering
	Systems Engineering as a Complex System
	Innovation Ecosystem Introduction Project
Credibility of Models--Trust in Patterns	*Models are increasingly used to support more critical and impactful decisions. Models are increasingly used by people or organizations other than those who authored them. Accordingly, trust in the credibility of models will only become more important to manage over time. What are the principles and practices for establishing, representing, communicating, and managing trust in models over their life cycles? How does the credibility of recurring patterns reduce the cost of establishing and maintaining that trust?*
	Model Wrapper, Model Characterization Pattern
	Trusted Model Repository Pattern
	Verification_&_Validation_of_Models_Project_with_ASME_Stds_Cmtee
Maps to Frameworks, Schema, Tools	*There are growing lists of architectural frameworks, reference architectures, ontologies, metamodels, and similar underlying semantic constructs, used as the basis for models of systems, automation tooling, product lines, and otherwise. Mapping the S*Metamodel to these provides an expanded means for understanding and using a given framework, schema, or tool. This includes making S*Models and S*Patterns tool agnostic, portable across modeling languages, and for supporting automated reasoning and more basic queries about models in different systems.*
	Mappings to Frameworks, Schema, and Tools
	Semantic Technologies
	S*Pattern Configuration Wizard
Domain Patterns	*S*Patterns are about recurring things within some general or narrow environment, referred to as a domain. The follow… illustrates S*Patterns across different application domains.*
	General Land Vehicle Pattern
	primary_flight_actuator_pattern_and_automated_verifcation
	Oil Filter Product Line Pattern
	Critical_Infrastructure_Protection
	Construction Fa…
	…ical Bracket Pattern
	SoS Patterns

On main web site

Generated resource materials, references, by subject

Collaborations, Partners, Shared Interest Groups

Most of the projects performed by the INCOSE MBSE Patterns WG are performed jointly with other INCOSE Working Groups or with organizations outside INCOSE, having mutual interests. The matrix below summarizes the different entities we work with, and refers to resulting items in the Resources, Activities, and Projects matrix above.



Collaboration partner societies, organizations, trade groups

Thirteen years of meeting materials by Patterns WG and collaborators, by event

On main PWG web site

Primary Working Group and Partners Meeting Materials--By Event

The following table lists chronological meetings, workshops, and other events participated in by the MBSE Patterns Working Group. The links on the right side of the following table link to event-specific minutes, resources, references, and materials:

Event_Date_	Event_Milestone_	Status	Point_of_Contact_	Link to References
June, 2013	Provide PBSE Tutorial at IS2013	Done	Bill Schindel, Troy Peterson	
Aug, 2013	Gain agreement of MBSE leadership	Done	Bill Schindel, Troy Peterson	
Jul-Aug 2013	Collect initial team members, refine charter	Done	Bill Schindel, Troy Peterson	
Oct, 2013	Provide PBSE Tutorial at GLRC2013	Done	Bill Schindel, Troy Peterson	
Dec, 2013	Challenge team wiki page created	Done	Bill Schindel	
Jan 27, 2014	Challenge team mtg IW2014	Done	Bill Schindel, Troy Peterson	
June 29-30, 2014	Challenge team mtg IS2014	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_0
Aug 12-14, 2014	Challenge team at NDIA GVSETS 2014	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_NDIA
Aug 18, 2014	Challenge team mtg	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_0
Sep 02, 2014	Challenge team mtg	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_0
Sep 15, 2014	Challenge team mtg	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_0
Sep 30, 2014	Challenge team mtg	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_0
Oct 14, 2014	Challenge team mtg	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_1
Oct 28, 2014	Challenge team mtg	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_1
Nov 10, 2014	Challenge team mtg	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_1
Dec 17, 2014	Challenge team mtg	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_1
Jan 12, 2015	Challenge team mtg	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_0
Jan 26-27, 2015	Challenge team mtg IW2015	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_0
Mar 17, 2015	Challenge team mtg	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_0
Apr 21, 2015	Challenge team mtg	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_0
May 19, 2015	Challenge team mtg	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_0
June 16, 2015	Challenge team mtg	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_0
June 14, 2015	ASEE System Competencies Workshop	Done	Mario Simoni	ASEE_2015_Systems_Competen
July 12-13, 2015	Challenge team mtg IS2015	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_0
Jan 12, 2016	Patterns WG mtg	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_0
Jan 30-31, 2016	Patterns WG mtg IW2016	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_0
May 24-25, 2016	MBSE Patterns WG Participation in INCOSE Agile Health Care Systems Conference	Done	Bill Schindel, Troy Peterson	MBSE Patterns_WG_Participation
July 5, 2016	MBSE Patterns WG mtg	Done	Bill Schindel, Troy Peterson	MBSE Patterns_WG_Mtg_07.05.1
July 17,2016	MBSE Patterns WG mtg IS2016	Done	Bill Schindel,Troy Peterson	MBSE Patterns_WG_Team_Mtg_(
July 28,2016	MBSE Patterns WG Participation in ISSS2016	Done	Bill Schindel	MBSE Patterns_WG_Participation
Sept 18-21, 2016	MBSE Patterns WG Participation in GLRC2016	Done	Bill Schindel	MBSE Patterns_WG_Participation
Nov 7-8, 2016	MBSE Patterns WG in ASME VV50 Cmtee on V&V of Models, Schenectady, NY	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
Nov 28-29, 2016	MBSE Patterns WG Partic in INCOSE/IEEE EnergyTech 2016, Cleveland	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
Jan 28-31, 2017	MBSE Patterns WG Mtgs at IW2017	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_0
April 12, 2017	MBSE Patterns WG Participation in INCOSE Enchantment Chapter Meeting (New Mexico)	Done	Bill Schindel	Patterns_WG_Partic_Enchantmer
May 2-5, 2017	MBSE Patterns WG Participation in ASME Model V&V Symposium, Las Vegas	Done	Bill Schindel	Patterns_WG_Partic_ASME_Mod
May 16-17, 2017	MBSE Patterns WG Participation in INCOSE Agile Health Care Systems Conf, Chicago	Done	Bill Schindel	Patterns_WG_Partic_INCOSE_Ag 17.17
May 21-24, 2017	MBSE Patterns WG Participation in No Magic MBSE Symposium, Allen, TX	Done	Bill Schindel	Patterns_WG_Partic_No_Magic_M
June 5-9, 2017	MBSE Patterns WG Partic. in AIAA Aviation 2017, Denver	Done	Bill Schindel, Troy Peterson	MBSE_Patterns_WG_Partic_In_A
July 15-17, 2017	MBSE Patterns WG Meetings at IS2017	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_0

	MBSE Symposium, Allen, TX			
June 5-9, 2017	MBSE Patterns WG Partic. in AIAA Aviation 2017, Denver	Done	Bill Schindel, Troy Peterson	MBSE_Patterns_WG_Partic_In_A
July 15-17, 2017	MBSE Patterns WG Meetings at IS2017	Done	Bill Schindel, Troy Peterson	Patterns_Challenge_Team_Mtg_0
	akes Conference GLRC11	Done	Bill Schindel	GLRC11_10.12.17
	VG Partic in ASA EnergyTech 2017,	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
	VG Partic in INCOSE ville, FL	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
	VG Partic in IFSR Conversation 2018, Linz, Austria	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
May, 2018	MBSE Patterns WG Partic in INCOSE 2018 Health Care Systems Conference, Minneapolis, MN	Done	Bill Schindel	MBSE_Patterns_WG_Participatio Conference 2018
May, 2018	MBSE Patterns WG Partic in Aerospace Corporation SE Forum, Chantilly, VA	Done	Bill Schindel	MBSE_Patterns_WG_Participatio 2018
July, 2018	MBSE Patterns WG Partic in INCOSE IS2018 Washington, DC	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
July, 2018	MBSE Patterns WG Partic in ISSS2018 Corvallis, OR	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
Oct, 2018	MBSE Patterns WG Partic in SAE 2018 Standards Summit, Tyson's Corner, VA	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
Oct, 2018	MBSE Patterns WG Partic in INCOSE GLRC 2018 Indianapolis, IN	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
Oct, 2018	MBSE Patterns WG Partic in FDA PBSE Seminar, Washington DC	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
Jan, 2019	MBSE Patterns WG Partic in INCOSE IW2019, Torrance, CA	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
May, 2019	MBSE Patterns WG Partic in ASME Model V&V 2019 Symposium, Las Vegas, NV	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
May, 2019	Model Characterization Pattern Workshop Prep, Indianapolis, IN	Done	Bill Schindel	Model_Characterization_Pattern_
July, 2019	MBSE Patterns WG Partic in INCOSE IS2019, Orlando, FL	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
Oct, 2019	MBSE Patterns WG Partic in ASSESS 2019, Atlanta, GA	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
January, 2020	MBSE Patterns WG Partic in INCOSE IW2020, Torrance, CA	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
January, 2021	MBSE Patterns WG Partic in INCOSE IW2021 Virtual Sessions	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
April, 2021	MBSE_Patterns_WG_Participation_In_ASME MBE Stds Cmtee Spring 2021 Mtgs	Done	Bill Schindel	MBSE_Patterns_WG_Participatio Mtgs
May, 2021	MBSE_Patterns_WG_Participation_In_ASME Model V&V 2021 Symposium	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
April, 2021	MBSE_Patterns_WG_Participation_In Big Lever Momentum 2021 Conference	Done	Bill Schindel	MBSE_Patterns_WG_Participatio
June, 2021	MBSE_Patterns_WG_Participation_In Indiana Digital Thread Technical Exchange Meeting	Done	Bill Schindel	MBSE_Patterns_WG_Participatio Exchange Meeting
December, 2021	INCOSE_North_Texas_Chapter_Program	Done	Bill Schindel	MBSE Patterns WG Participation I Program
January, 2022	AIAA_SCITECH2022	Done	John Matlik	MBSE Patterns WG Support for Al
January, 2022	INCOSE_IW2022	Done	Bill Schindel, Troy Peterson	MBSE Patterns WG Participation I
June, 2022	INCOSE North TX Chapter Pgm	Done	Bill Schindel	MBSE Patterns WG Participation I
June, 2022	INCOSE_IS2022	Done	Bill Schindel	MBSE Patterns WG Participation I
June, 2022	AIAA AVIATION 2022	Done	Bill Schindel	MBSE Patterns WG Participation I
Jan, 2023	INCOSE IW 2023	Pending	Bill Schindel, Troy Peterson	MBSE Patterns WG Participation I

On main PWG web site

Project Working Pages

Interface_Patterns_Team

Innovation_Collaboration_Ecology_Project_with_TIMLM_WG_and_PLE_WG

Legacy_Product_Line_Pattern_Extraction_Project_with_PLE_WG

Patterns_In_Systems_Of_Systems_Project_with_SoS_WG

MBSE_Transformation_Adoption_Pattern_Project

Critical_Infrastructure_Protection_and_Recovery_Patterns_Project_with_CIPR_WG

Health_Care_Domain_Patterns_Project_with_HC_WG

Verification_&_Validation_of_Models_Project_with_ASME_Stds_Cmtee

Agile_Systems_Engineering_Life_Cycle_Management_(ASELCM)_Discovery_Project_with_ASE_WG

Foundations_of_Systems_Science_and_Engineering_Project_with_SSWG

Semantic_Patterns_and_Technologies_for_Systems_Engineering_Project

Vision_2035_Support

S*Models Primer Project

S*Patterns Primer Project

How to get involved with Patterns WG

- If you'd like to participate in, or follow, a current WG project, . . .
- If you would like to suggest a new WG project, . . .

Contact:

WG chair: Bill Schindel schindel@ictt.com

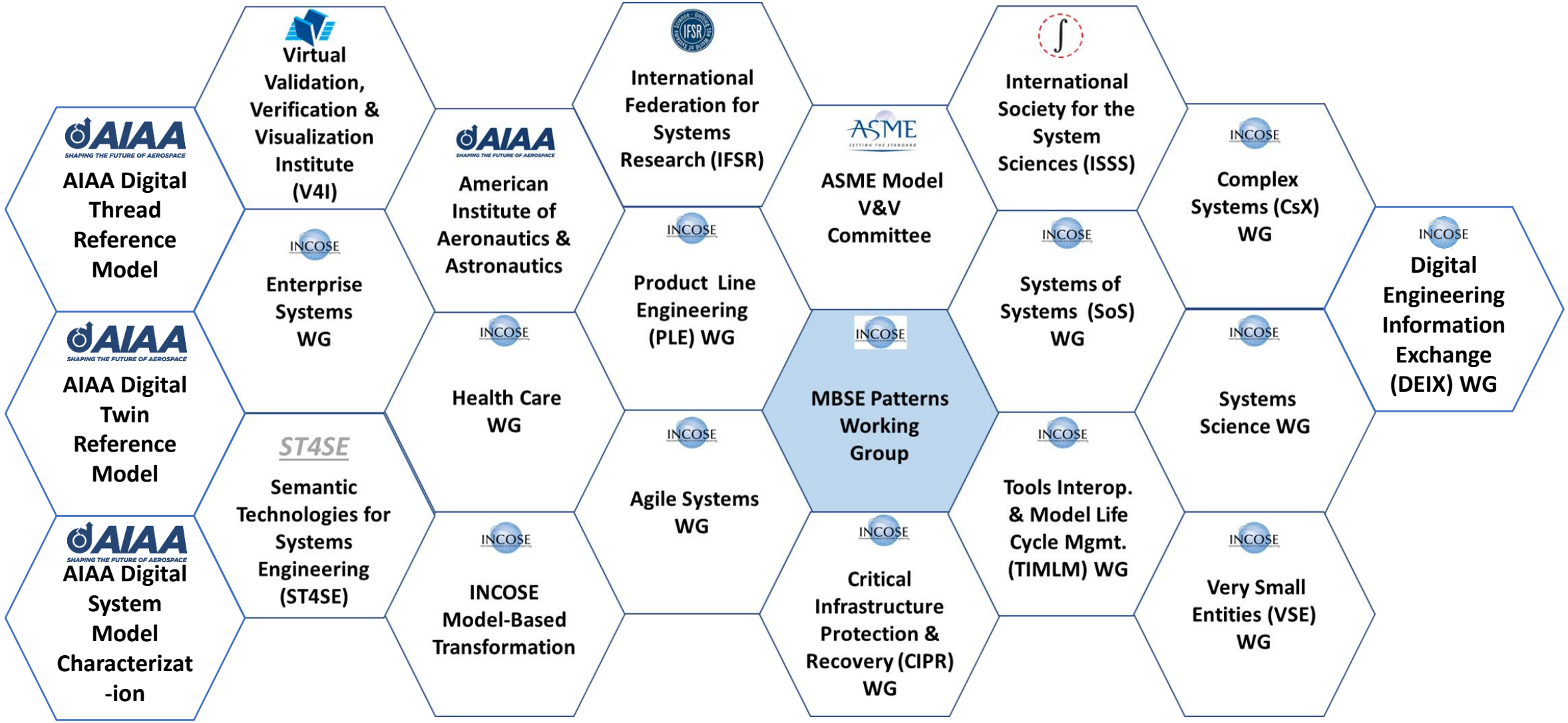
WG vice-chair: Troy Peterson tpeterson@systemxi.com

- Based on the newest INCOSE information systems, you should especially add to your INCOSE Member Profile (at incose.org) that you want to be affiliated with this WG.

Membership in the MBSE Patterns WG: Help us respond to your interest and engage!

- Anyone interested is welcome, but this WG is especially for INCOSE members.
- Over the years, how we track our WG's membership list and perform communications has been challenging, as INCOSE technical systems and even legal constraints have evolved.
- We are learning that the best way for you to get formally listed as a member of the WG and into our WG mail list is to indicate in your INCOSE Member Profile (www.incose.org) that you are affiliated with this WG.
- Sincere apologies to anyone we have missed in the past—please let us know and be sure to register your interest in this WG in your INCOSE Member Profile.

Nearly all our work includes collaboration with partner INCOSE WGs or other technical societies



Participate! Collaborate!

Participant introductions and interests

If today's meeting is not too large . . .

- Please introduce yourself
- Tell us about your interests in this meeting and its subjects
-
-
-
-

An “MBSE Patterns 101” Introduction

We’ll next look at a small sample of MBSE Patterns theory & practice for a few minutes:

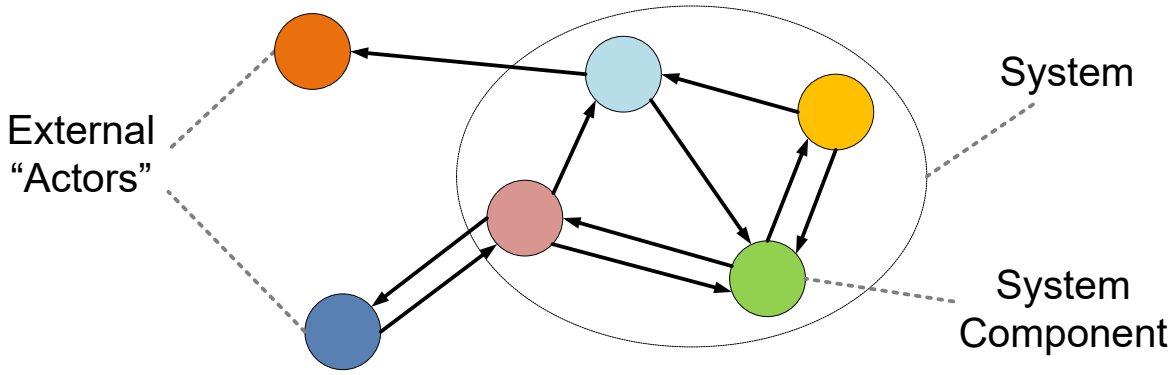
- A key point is that patterns work taught us to *first strengthen underlying MBSE representation*.

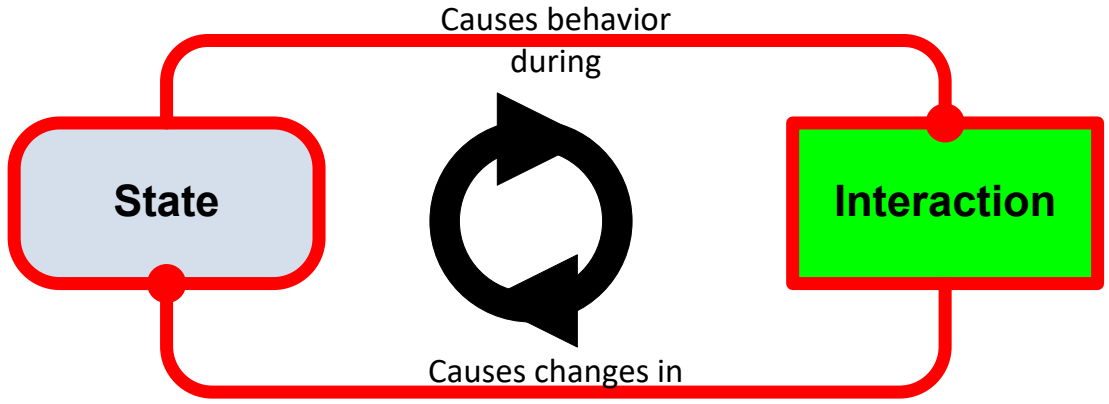
For a more complete look, see:

- S*Models and S*Metamodel Primer: https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:s-models_and_the_s-metamodel--a_primer_wg_review_draft_v1.2.2.pdf
- S*Patterns and PBSE Primer (Second Ed.): https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:s-patterns--a_primer_wg_review_draft--v1.2.1.pdf
- MBSE Patterns Tutorial: http://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:pbse_tutorial_glrc_2016_v1.7.4.pdf
- Simple Content Example: Oil Filter System: https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:oil_filter_example_v1.6.2.pdf
- Patterns WG web site: http://www.omgwiki.org/MBSE/doku.php?id=mbse:patterns:patterns
- Plus: The projects references and links in the later section of this meeting file.

Formalizing System Terms and Representations

- Definition*: In the perspective described here**, by "System" we mean a collection of interacting system components:



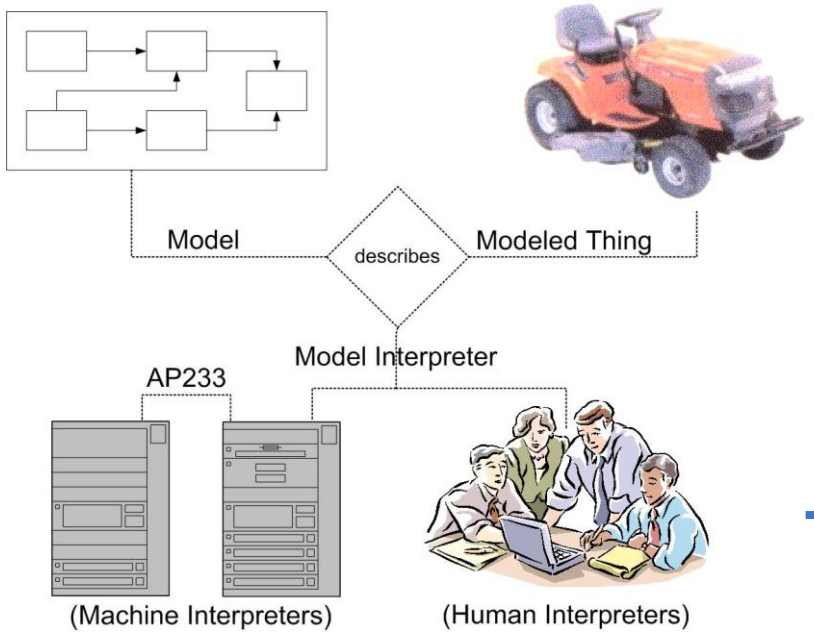


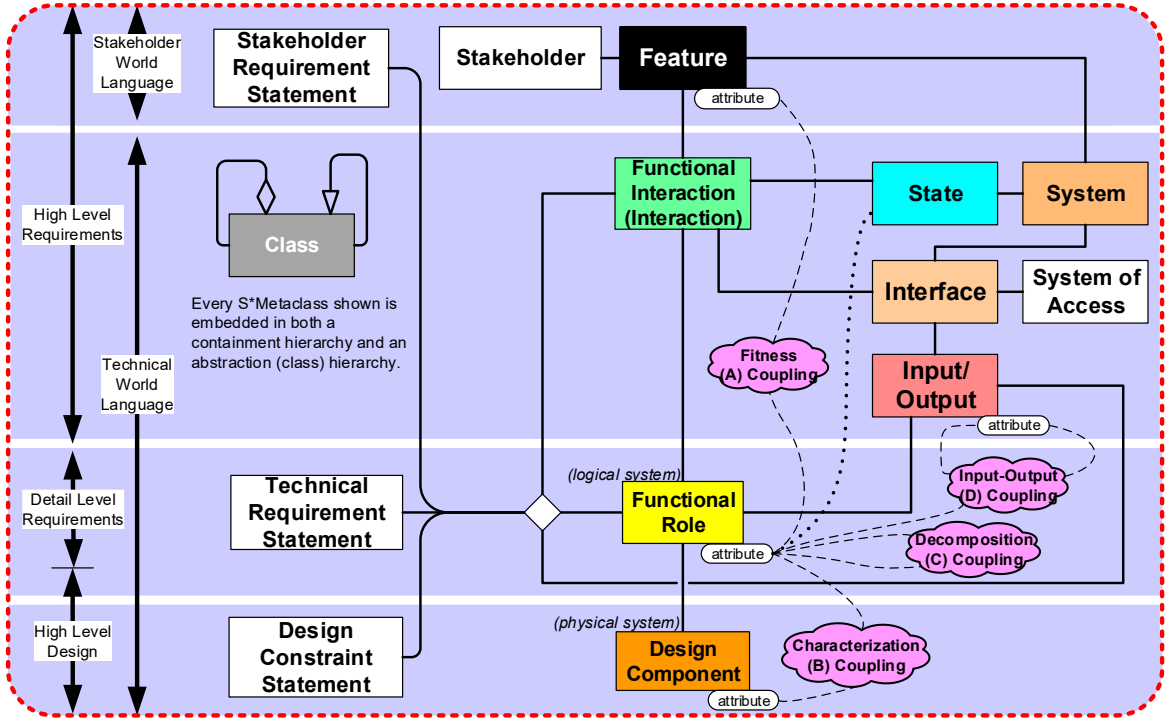
- By "interacting" we mean the exchange of energy, force, material, or information (all of these are "input-outputs") between system components, . . .
- . . . through which one component impacts the state of another component.
- By "state" we mean a property of a component that impacts its input-output behavior during interactions. (Note the circular cause-effect definition chain here.)
- So, a component's "behavior model" describes input-output-state relationships during interaction—*there is no "naked behavior" in the absence of interaction*.
- The behavior of a system involves emergent *states of the system as a whole*, exhibited in its behavior during its own external interactions, resulting in observable holistic aspects.

(* Other world view definitions of "System" are acknowledged; STEM is reason for our minimalist choice of definitions.)

S*Models

- An S*Model is any model (descriptive information construct) *of a system*, in any language, view, or tooling, which can be semantically mapped to the S*Metamodel (e.g., SysML, etc.):



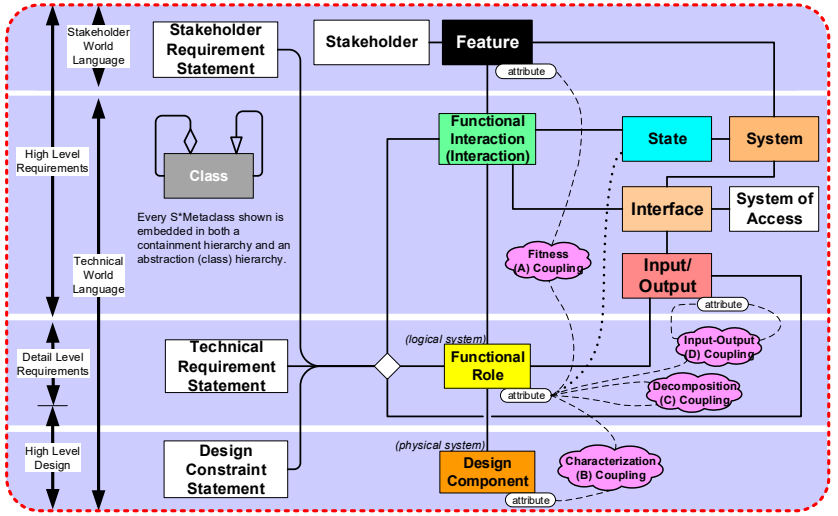


S*Metamodel informal summary pedagogical diagram
(formal S*Metamodel includes additional details.)

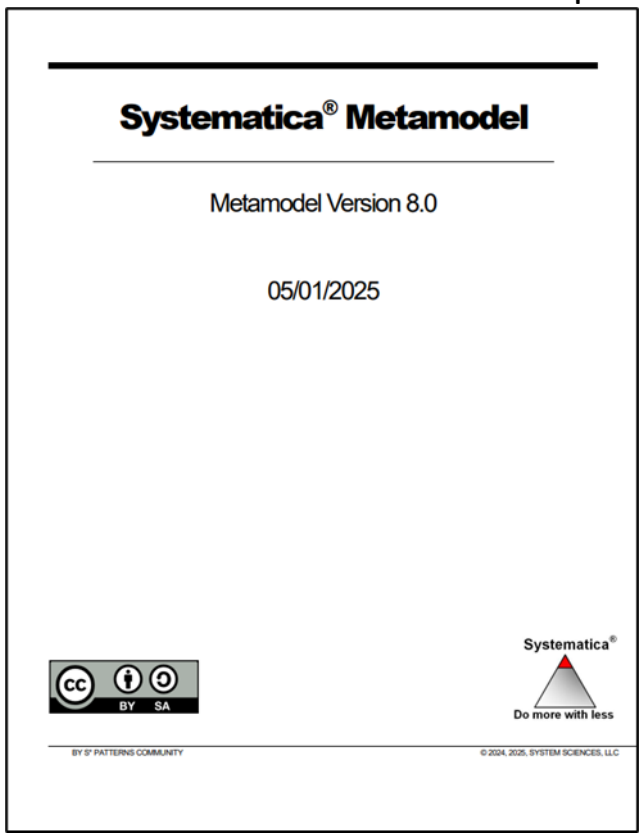
So what is the S*Metamodel, and more important why is it?

S*Metamodel: A reference model of models

- The S*Metamodel is intended to answer:
  - What is the smallest amount of information necessary to describe a system over its life cycle, for the purposes of science and engineering?
- Important because contemporary MBSE models often:
  - Are missing key aspects (are too small)
  - Contain redundant conflicting aspects (are too big)
  - At the same time!
  - We will be discussing prominent examples of both.
- This session will briefly refer to the "informal pedagogical" S*Metamodel diagram above, as a partial intuitive guide.
- Backed by the formal S*Metamodel (>100 pages of UML and prose), to understand its formal mapping to modeling languages like OMG SysML, third party modeling tools, etc.)
- Not an alternative modeling language or tool!



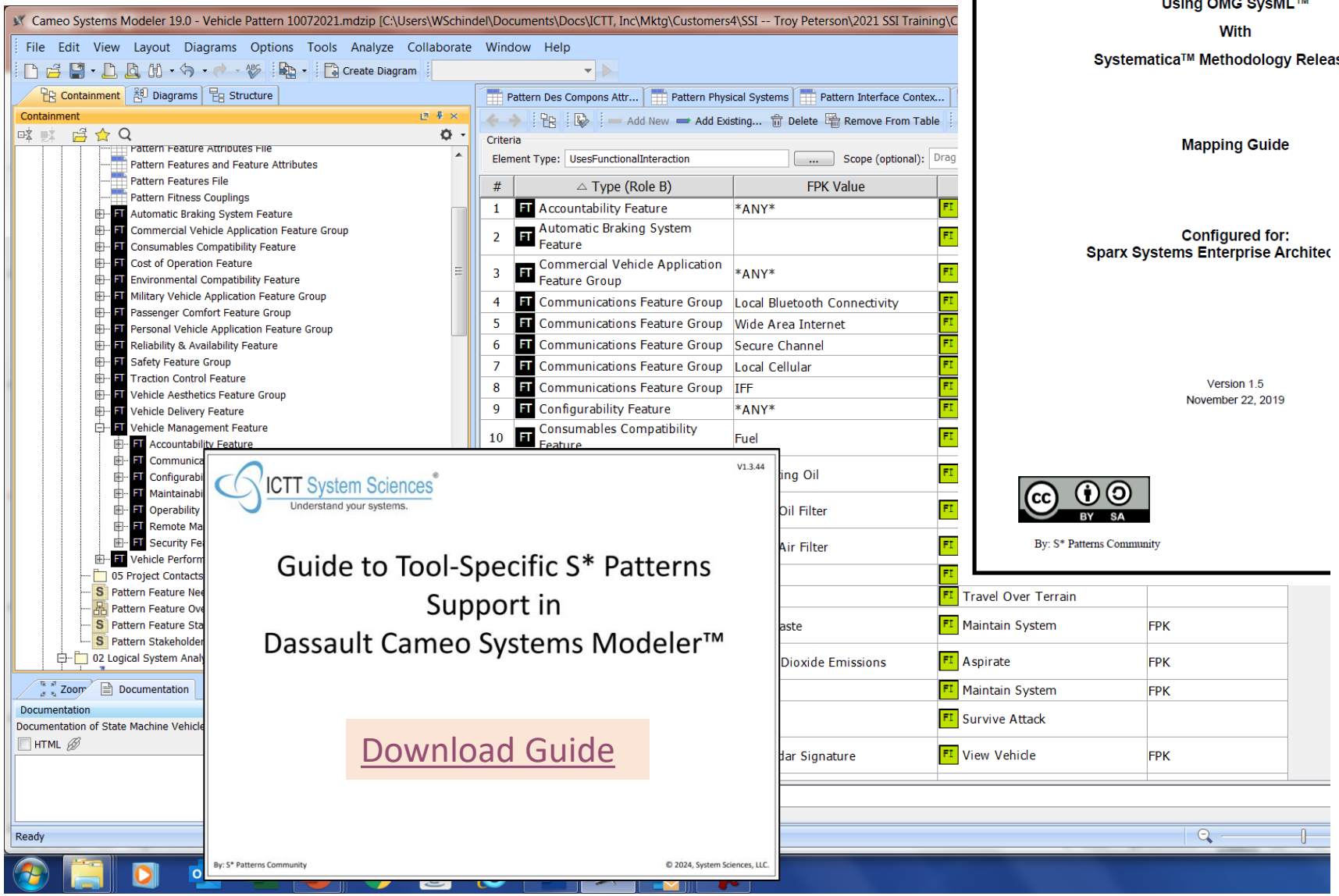
Informal pedagogical S*Metamodel subset diagram



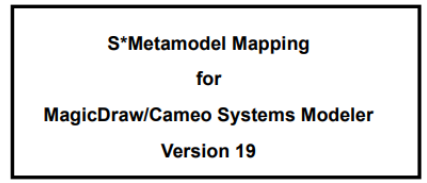
Download S*Metamodel

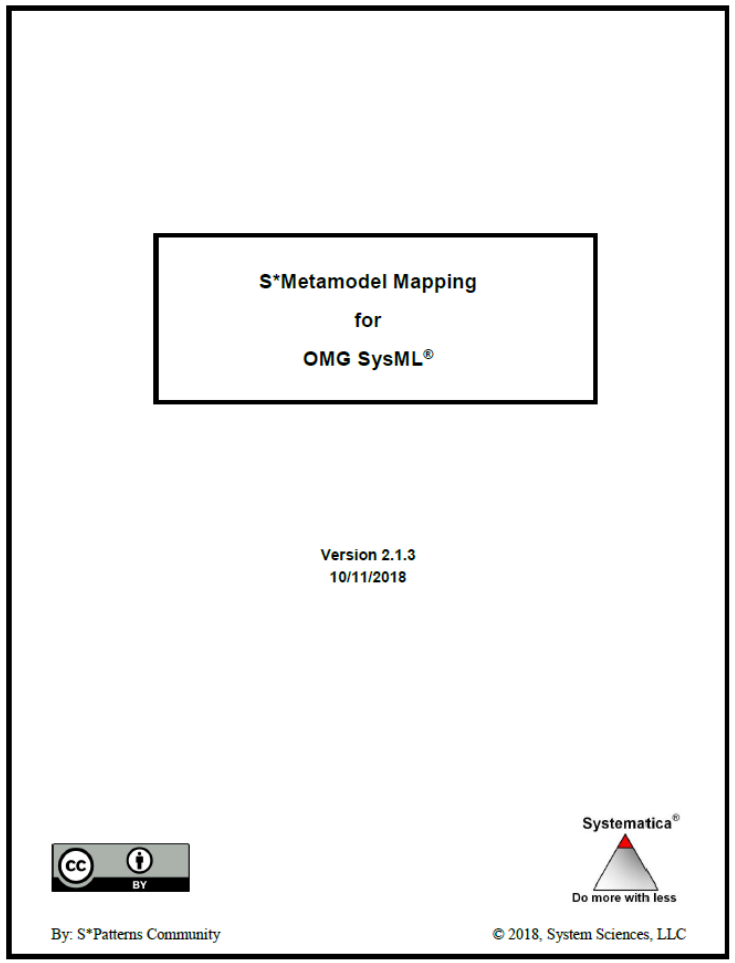
Formal S*Metamodel (>100 pages UML & prose)

Existing mappings into OMG SysML, other languages, and your tooling



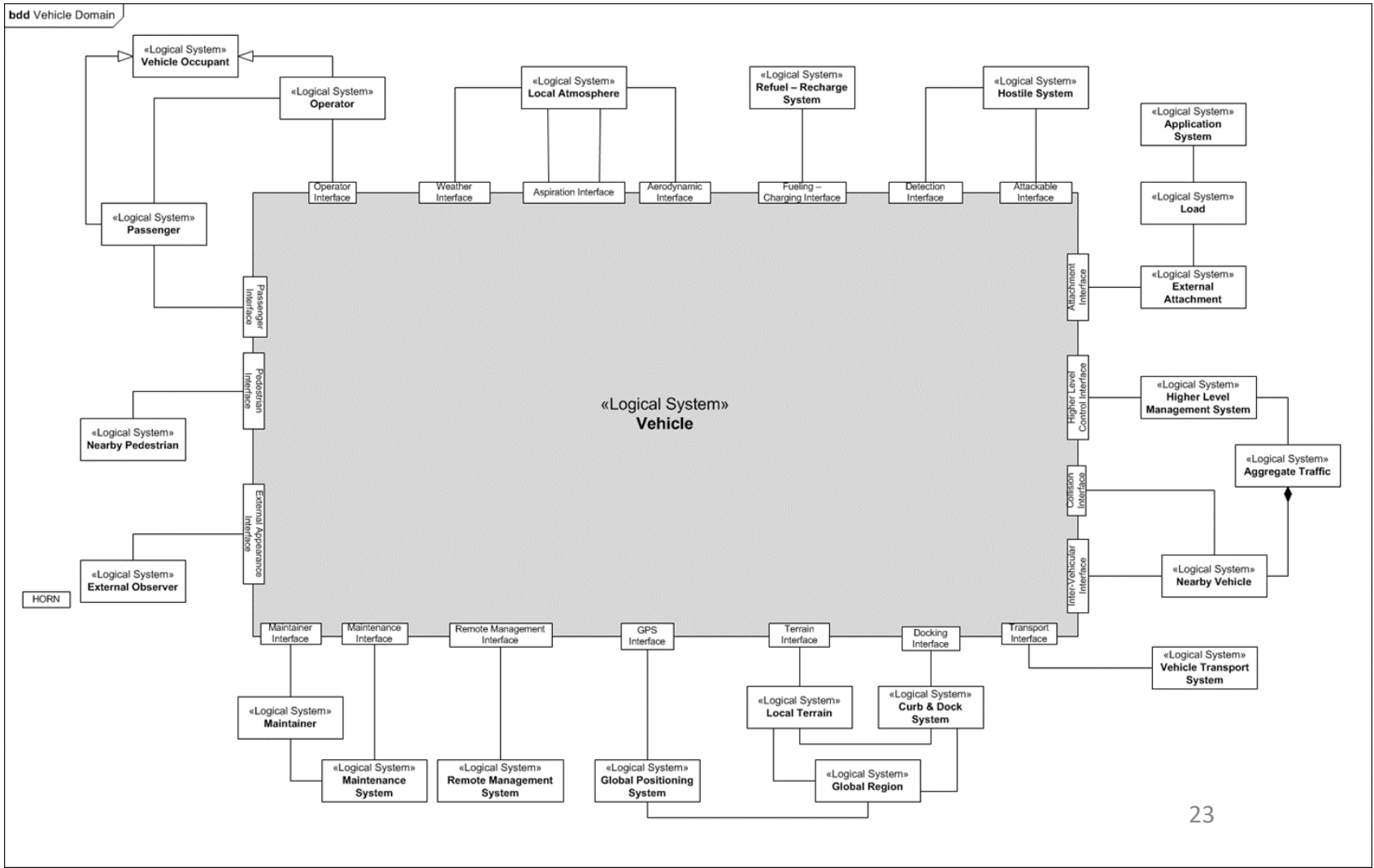
Download Mapping



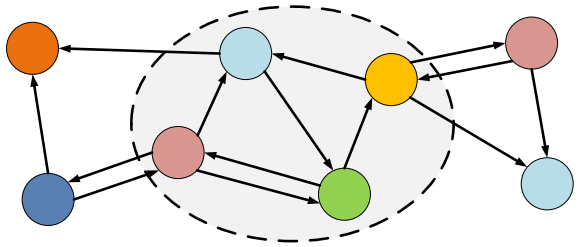


Domain Model: One important system model view

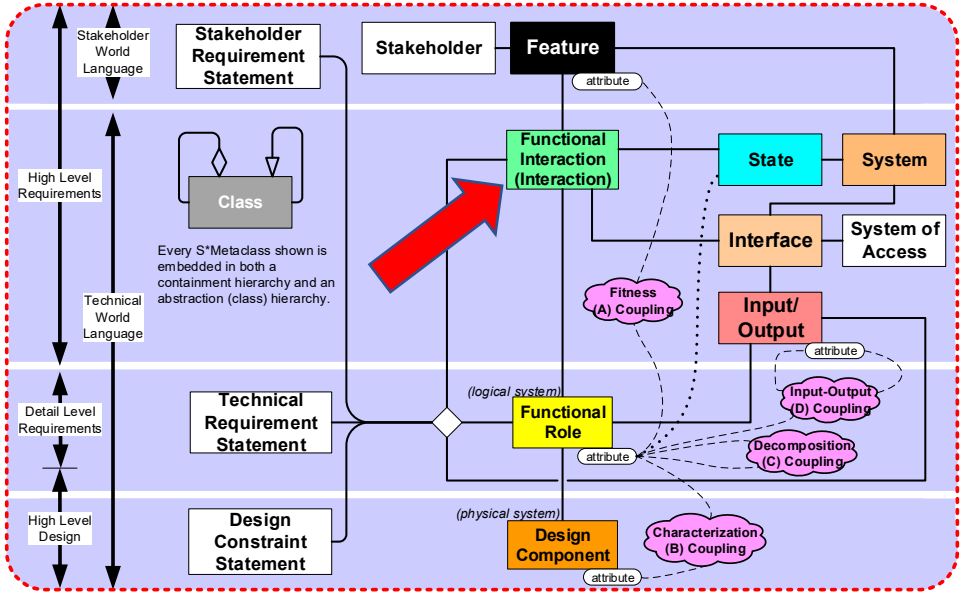
- All the external actors with which a system of interest interacts directly, forming a “Domain System”.
- The (larger) system that is the context of the System of Interest.
- Domain Patterns provide powerful introductions to the context of different system products, markets, and applications, such as:
  - Aerospace
  - Automotive
  - Medical Devices
  - Consumer Products
  - Telecommunications
  - Manufacturing
- Example Domain Systems:
  - Total life cycle domain
  - Operational or In-Service Domain
  - Maintenance or Sustainment Domain
  - Distribution Domain



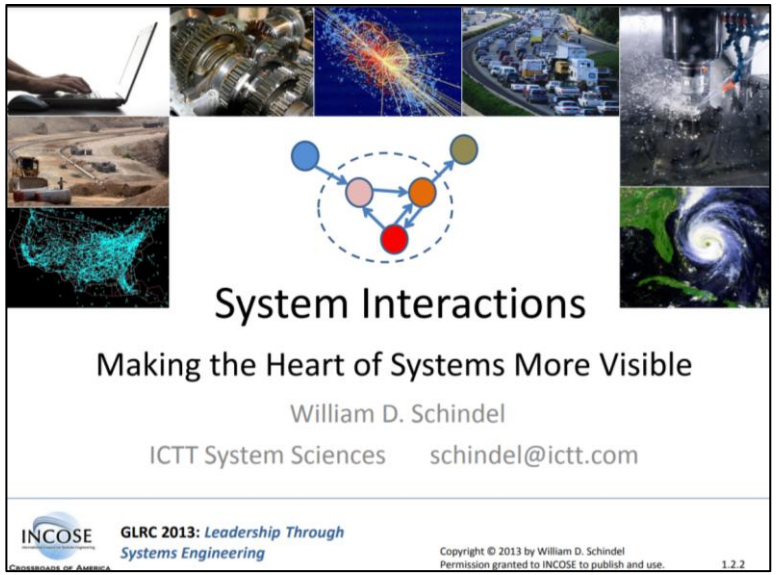
Functional Interactions: Phenomena; clarifying SE views of behavior



- A Functional Interaction (or simply, an Interaction) is an exchange of Input-Outputs (energy, force, material, information) between two or more system components, resulting in component changes of state.
- Two such components might be within a product you are designing—but they also might be that product (viewed as a "black box") and actors in its external environment, in which case the overall system is the Domain System.
- By "state" we mean a property of a component that impacts its input-output behavior during interactions. (Note the circular cause-effect definition chain here.)
- So, a component's "behavior model" describes input-output-state relationships during interaction—*there is no "naked behavior" in the absence of interaction*.
- Interactions are not an important "side issue"—they are at the heart of engineering and science:
  - All the known physical laws of the hard sciences are about or in the context of interactions.
- It will turn out to be very important to identify "all" the interactions—a subject to which we'll return.

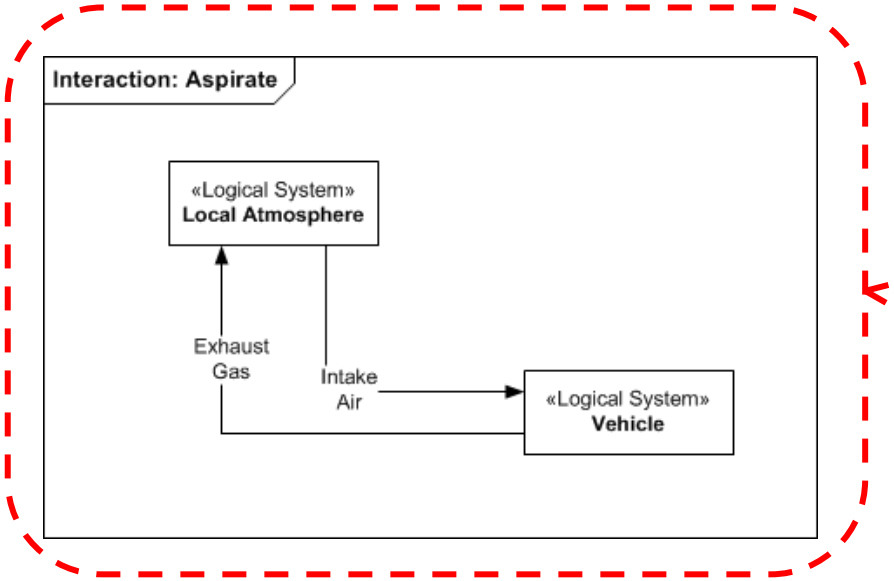


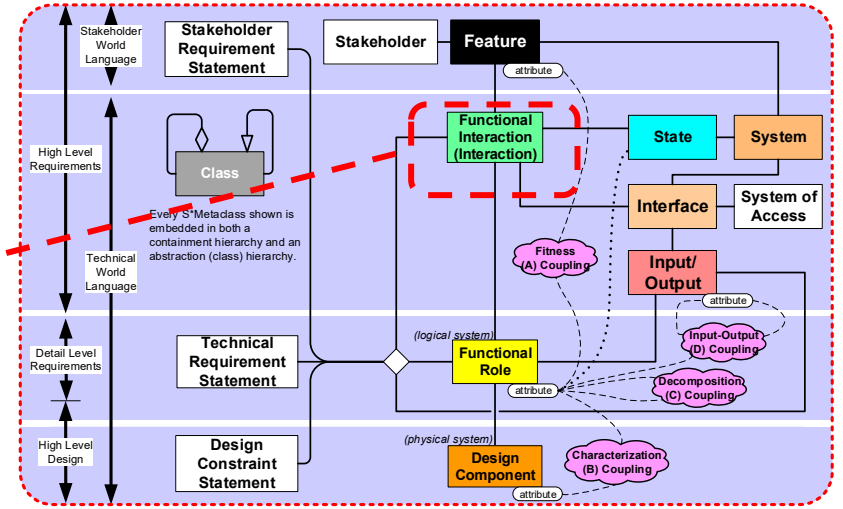
S*Metamodel informal summary pedagogical diagram
(formal S*Metamodel includes additional details.)



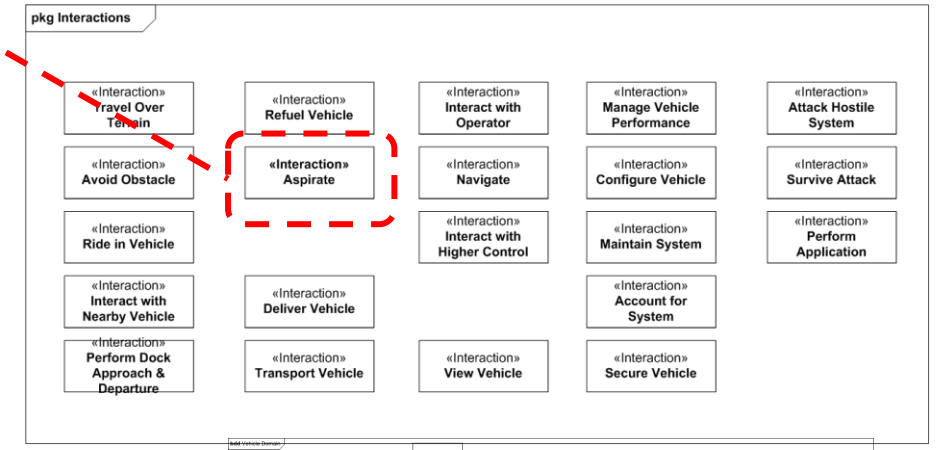
https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:system_interactions--making_the_heart_of_systems_more_visible_v1.2.2.pdf

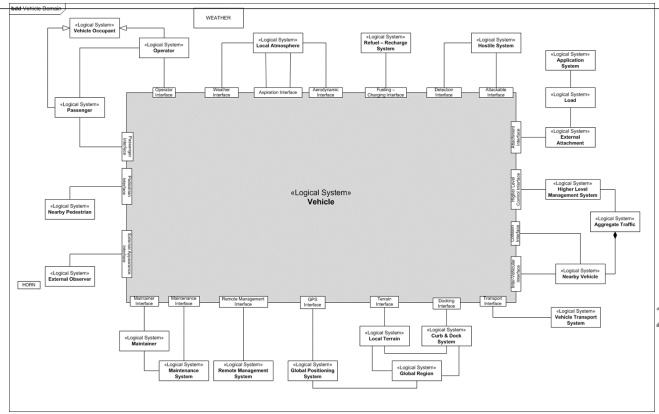
Interactions: Vehicle example





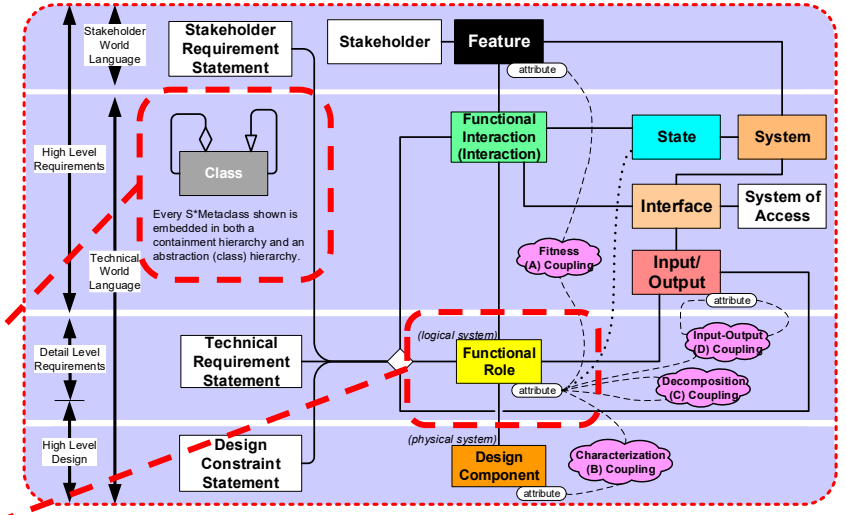
S*Metamodel informal summary pedagogical diagram
(formal S*Metamodel includes additional details.)



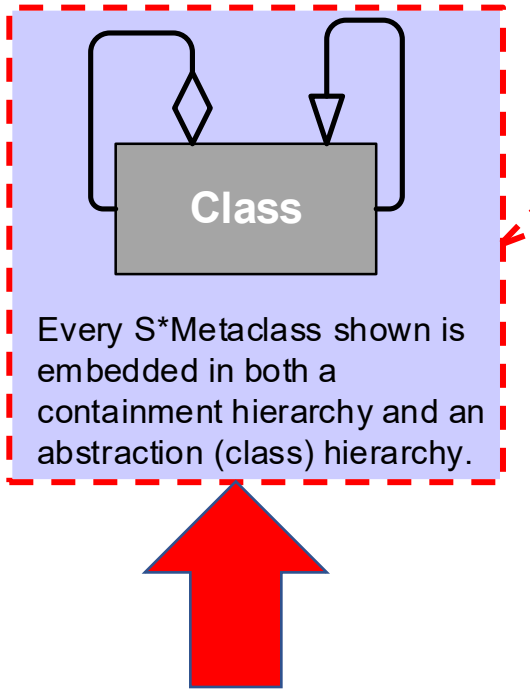


- A key point for systems engineers is not to over-emphasize “my system” as opposed to its interactions with external actors.
- Sometimes engineers object that “I am not responsible for and cannot control those other actors”; however, . . .
- The fact is, the only externally visible behaviors your product will exhibit are its interactions with those external actors.
- The technical requirement specifications for your product are all manifest in its interactions with external actors.
- You do not have to design or control those external actors, but *you do have to understand their behaviors in interaction with your product.*
- Interactions are shown as diverse types of model and tabular diagrams and views: Collaboration Diagrams, Sequence/Timing Diagrams, FFBDs, Free Body Diagrams, etc.

Dual Hierarchies: There are containment and class hierarchies of logical systems, as well as other classes



S*Metamodel informal summary pedagogical diagram
(formal S*Metamodel includes additional details.)



<u>Containment (Part-Whole) Hierarchy</u>:

- Vehicle System
- Vehicle Propulsion System
- Braking System
- Brake

Functional Roles (Logical Systems)

Important to traditional engineering decomposition and Bill-of-Materials

<u>Class (General-Special) Hierarchy</u>:

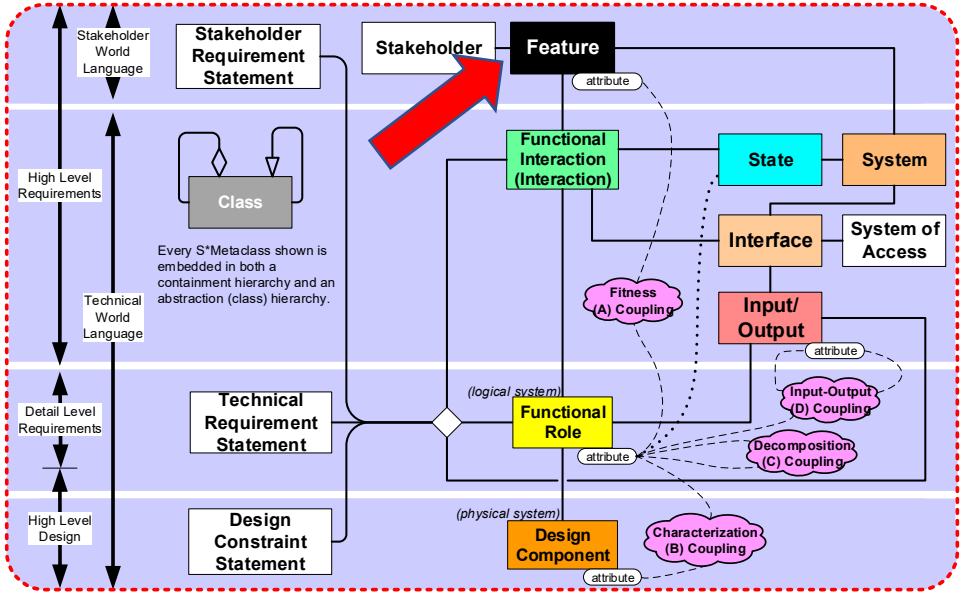
- Vehicle System
- Ambulance Vehicle System
- Military Ambulance Vehicle System
- Mil Ambulance Vehicle, configured for Desert.

Functional Roles (Logical Systems)

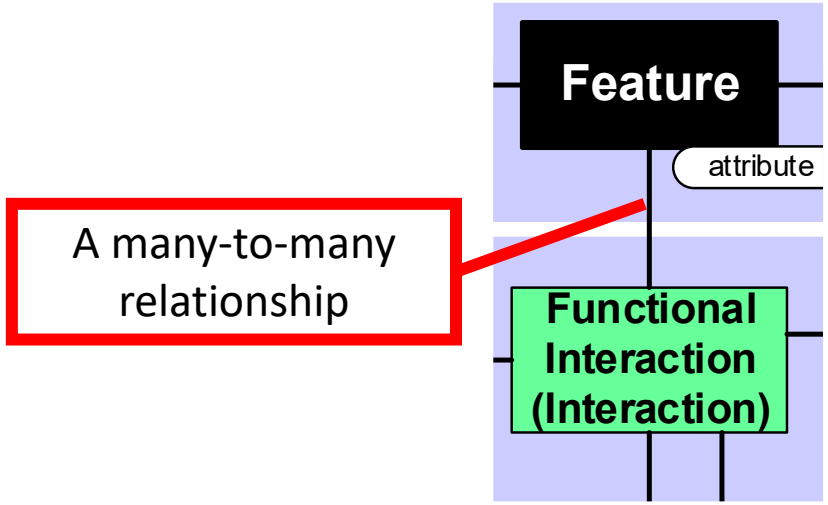
Important to pattern management, product line engineering, economics of re-use

Stakeholder Features; clarifying SE views of value, selection, risk, FMEA, configuration

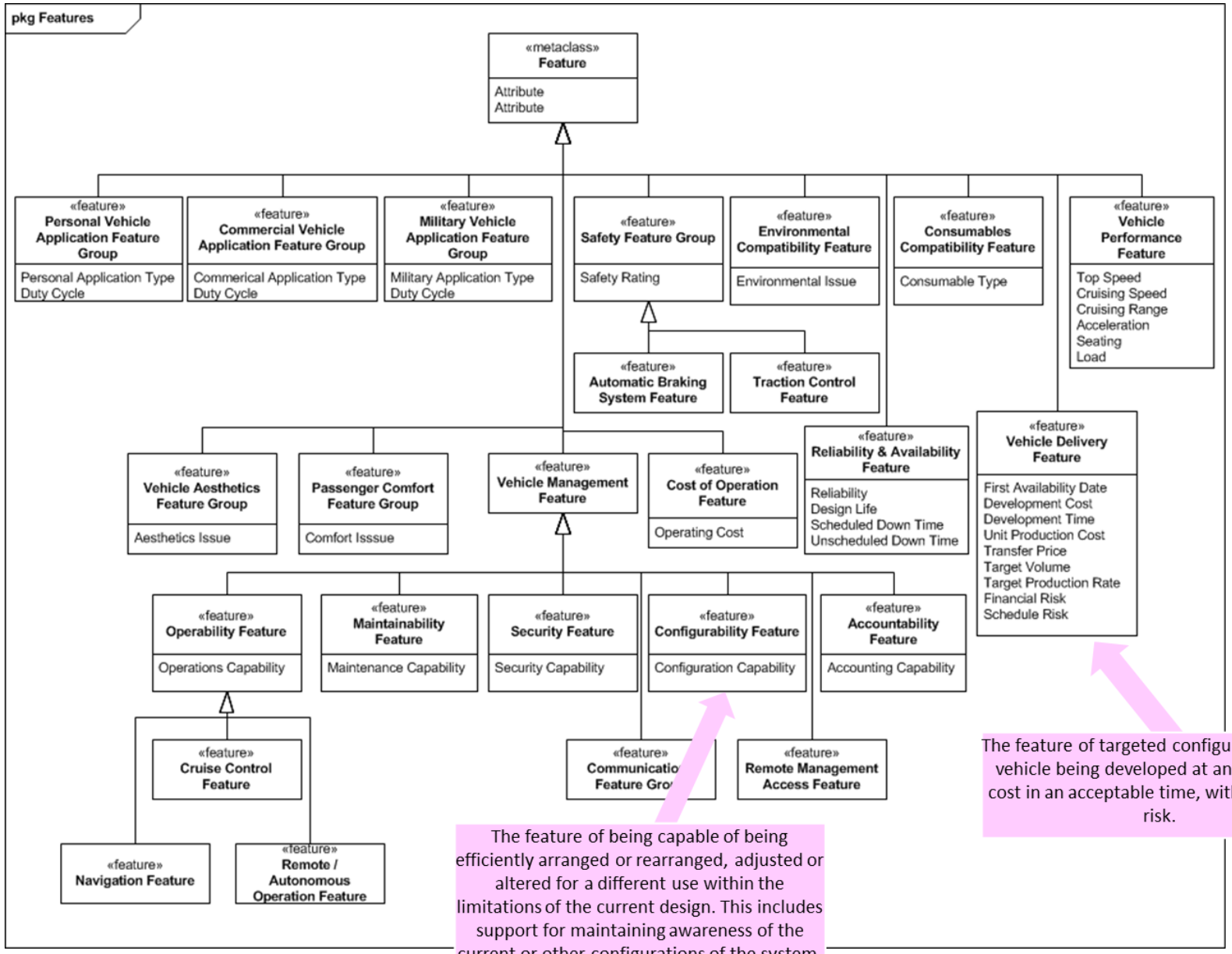
- Stakeholder Features model, in the language and conceptual values framework of the respective Stakeholders, chunks of value:
  - what is “at stake”
  - Often may be quite subjective
- Notice that we are describing twice the external behavior exhibited by the system of interest:
  - Interactions (and the Technical Requirements that will go with them) describe what is wanted in objective testable terms common to engineers.
  - Features describe the same system, but in terms of what is valued, capabilities, Measures of Effectiveness (MOEs), etc.
- Analogous to pre-model engineering practice of “Customer Requirements” and “Technical Requirements” (other terms also used included “Product Requirements”, “System Requirements”, etc.)
- Two different ontologies, in a many-to-many mesh!



S*Metamodel informal summary pedagogical diagram
(formal S*Metamodel includes additional details.)



Stakeholder Features: Vehicle example



Feature configuration space: Bigger than expected

Like the Tardis: Bigger on the Inside!



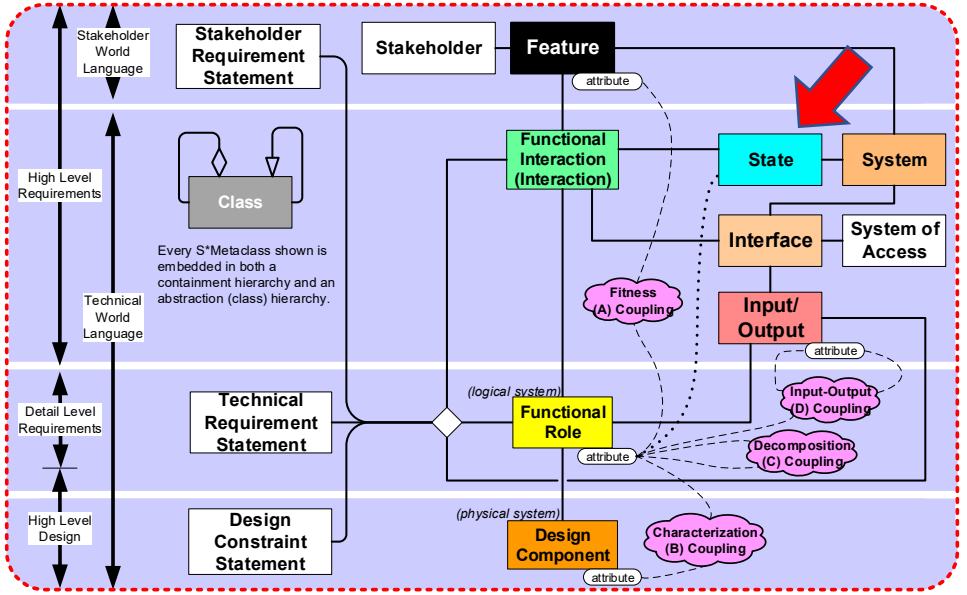
A perhaps surprising thing about Features is that they model a lot more than might be thought of at first when considering "value":

- Features discover examples of models that are both "too small" and "too large" (redundant and conflicting) at the same time.

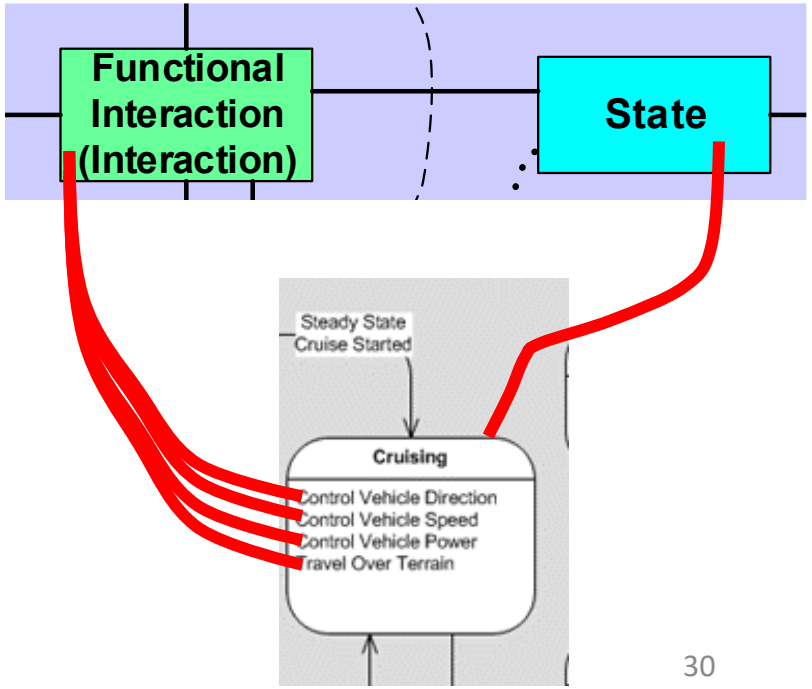
1. Features model the trade-space for optimization and trades—that one is not too surprising, but serves as a reminder to include the full range of stakeholder issues, not just end customer Features—who are all the stakeholders? The resulting Pareto Frontiers are in Feature Configuration Space.
2. All *purpose*, even when discovered by emergence and agile pivots, is in Feature Space.
3. *All risk is risk to Stakeholder Features*. So, the whole outcomes side of any Risk model should terminate in Feature space.
4. *All Effects (the "E" part in FMEA analyses) are effects in Feature Space*. Not realizing this, they are often described completely separately—a redundancy that costs a lot when not used to reinforce and improve both the positive and negative sides of models. (More on this when we cover model-based FMEAs.) This also applies to Consequences described in Safety and Cyber analyses.
5. *All product line segmentation / selection is described in Feature Space*. (More on this as you learn about S*Patterns and pattern-based methods.)

States, State Variables

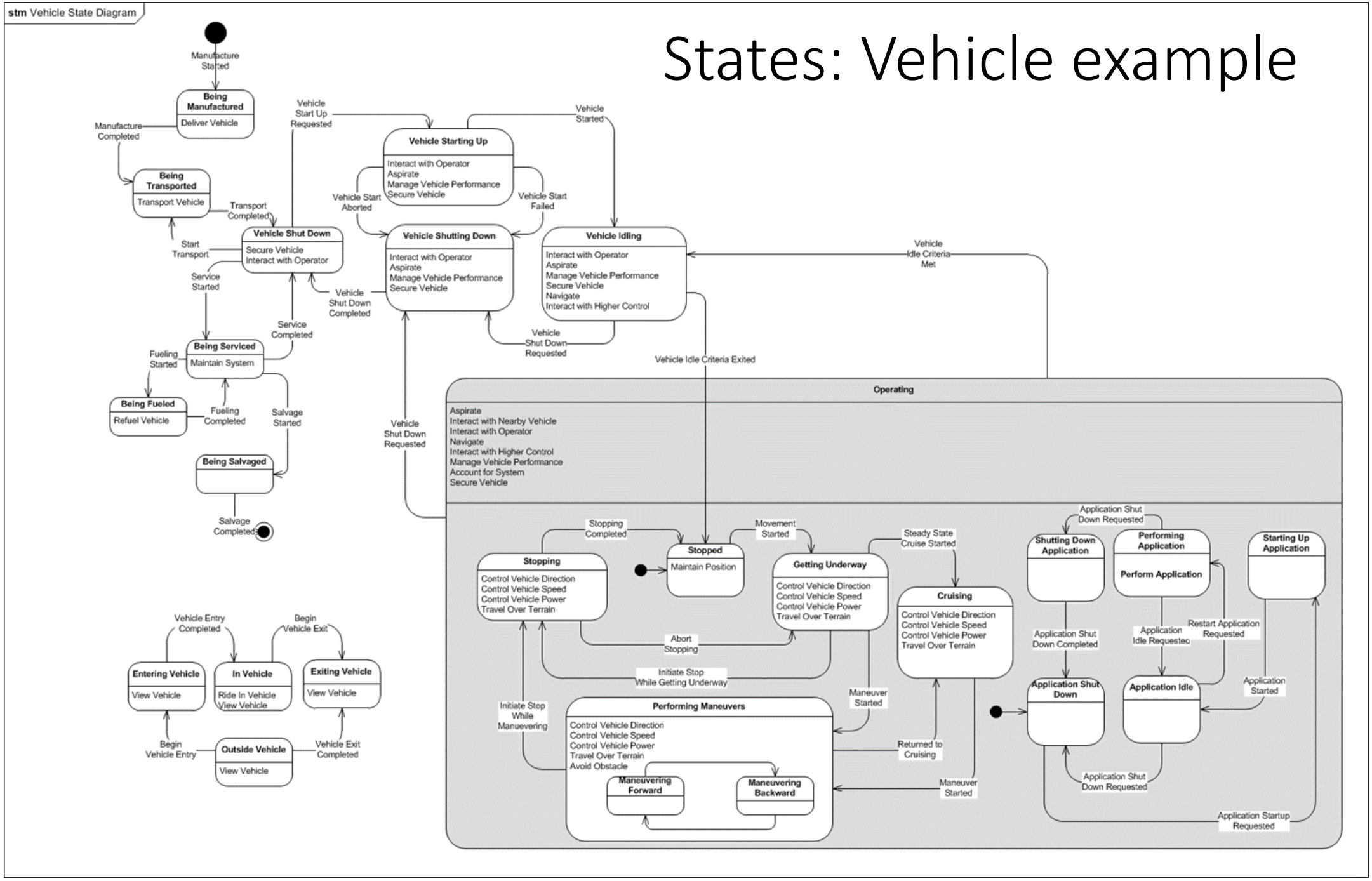
- In general, a State is a condition of a system, described by its State Variable(s) (e.g., position, velocity acceleration, temperature, pressure, etc.):
  - The state of a system component may determine its input-output behavior (even if statistical) during Interactions in which it participates.
- For the important special case of model-based Finite State Machines (FSMs; finite automata), a State is a single value of the related state variable, represented by one block of an FSM diagram, . . .
  - representing a condition, mode, or situation, persisting for a period of time,
  - during which the system exhibits behavior described by associated Interaction.
  - We may model "State Transitions" from one finite State to another (typically instantaneous).
  - Those transitions may be caused by modeled State Transition Trigger Events.



S*Metamodel informal summary pedagogical diagram
(formal S*Metamodel includes additional details.)

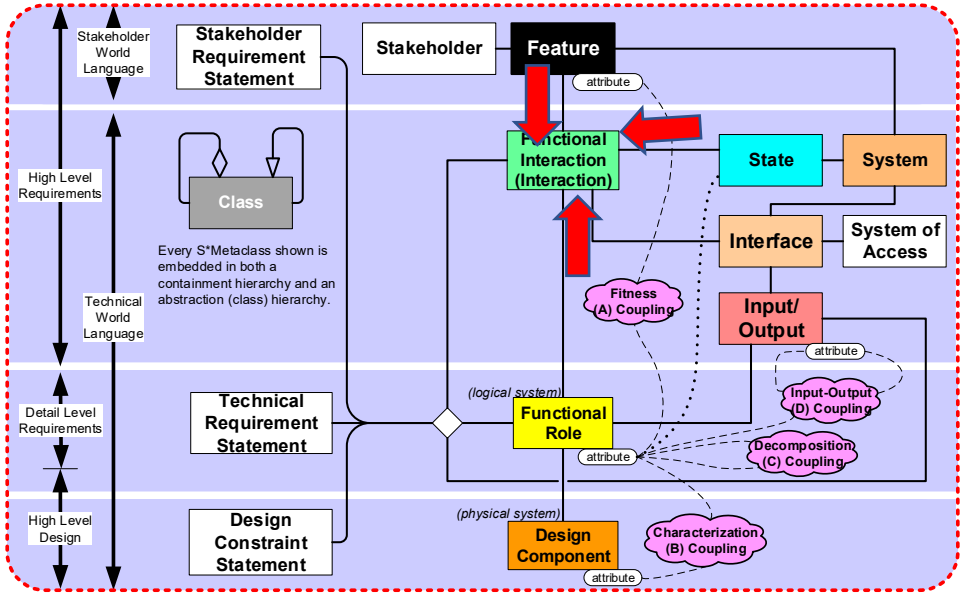


States: Vehicle example



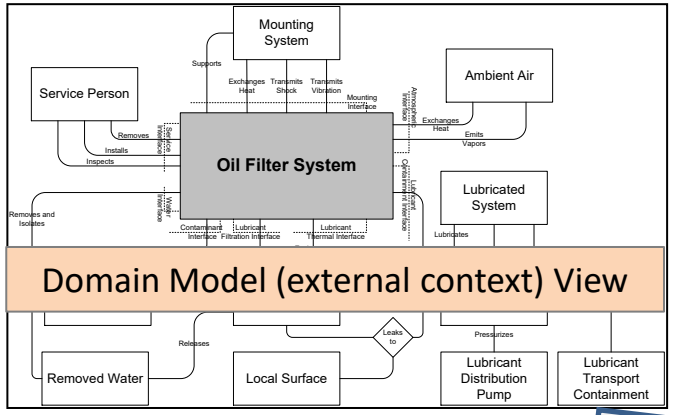
Three paths to finding all the Interactions

- It turns out that “discovering all the Interactions” that need to be modeled is very important:
  - You will eventually learn how this can greatly help us “find all the Requirements” for a system.
- So, the following is provided as a powerful way to “find all the Interactions”:
  - There are three orthogonal paths to Interactions in the S*Metamodel:
    1. Feature-Interaction pairs tell us “why” an Interaction occurs.
    2. State-Interaction pairs tell us “when” an interaction occurs.
    3. Actor/Interface – Interaction pairs tell us “who or what” engages in interaction.

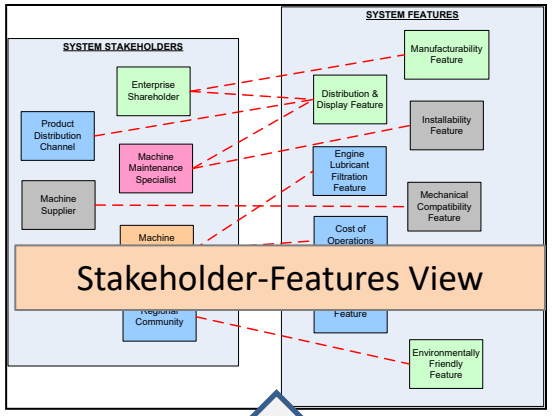


S*Metamodel informal summary pedagogical diagram
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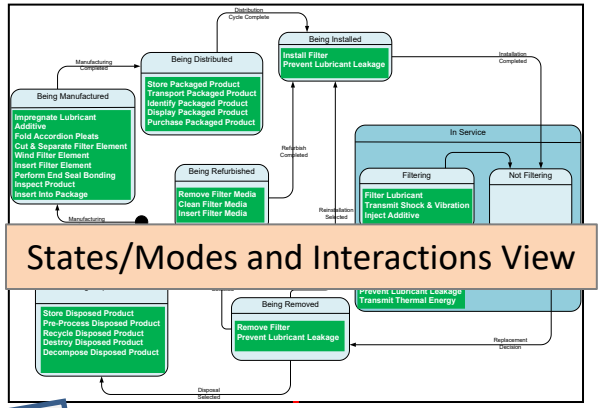
- The same interactions should appear in all three lists!
- However, it is very common to discover, for one of these three different perspectives, missing interactions that need to be added to all three.



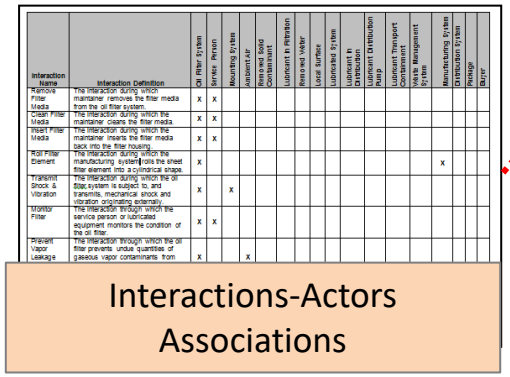
Domain Model (external context) View



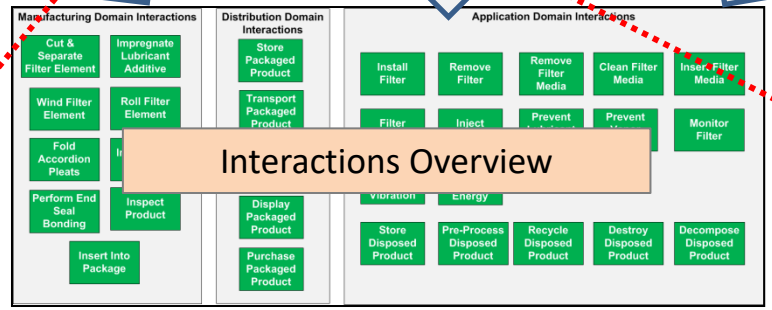
Stakeholder-Features View



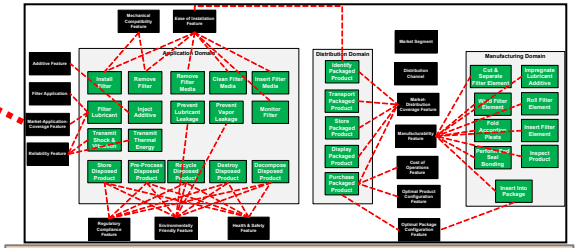
States/Modes and Interactions View



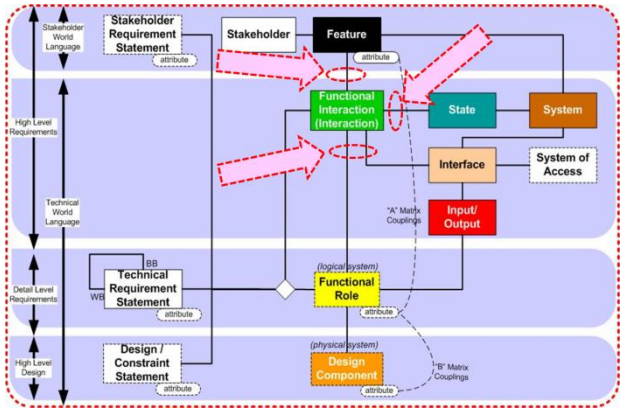
Interactions-Actors Associations



Interactions Overview



Features-Interactions Associations



Inherent Relational Checks of <u>High</u> Level Model Completeness / Consistency (Model Metrics)

Three paths to the same Interactions

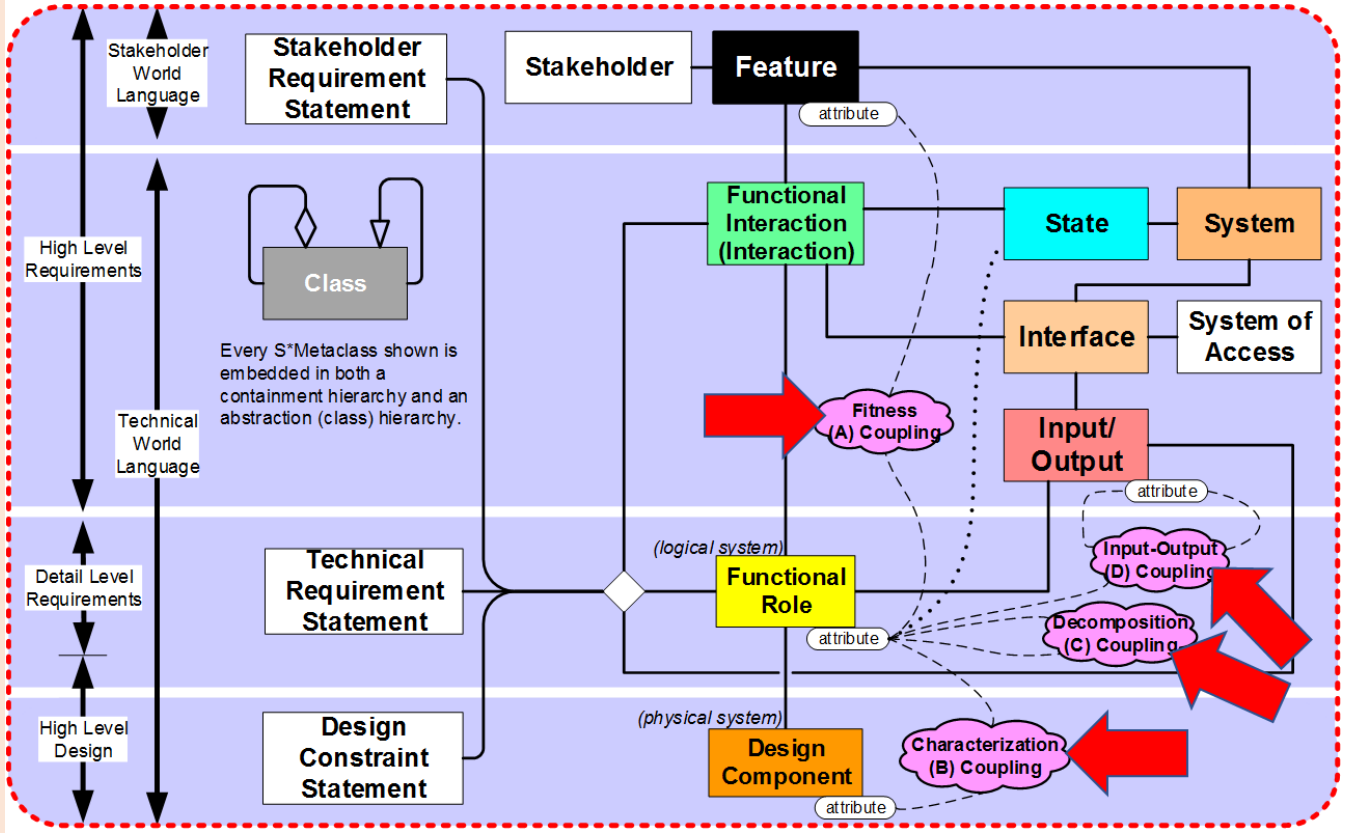
Patterns push us toward better model completeness and consistency

- The above means that a system model is not likely to be complete if it does not include:
  - Some form of domain model, showing all external actors/external interfaces.
  - Some form of state model, showing all possible system black box states.
  - Some form of stakeholder feature model, showing the stakeholders' value space.
- A listing of all the external interactions of the system of interest:
  - Mapped to its external actors/external interfaces
  - Mapped to its feature model
  - Mapped to its state model
- . . . that "covers" all the actors, features, and states.

Classes of parametric couplings

Examples of Each Attribute Coupling Type:

- **Fitness Couplings**: How is technical behavior valued by stakeholders? e.g., Surgical Installation Time.
- **Decomposition Couplings:** (AKA Emergence Couplings) How does component or subsystem performance impact system performance? e.g., Timing Stability Coupling.
- **Characterization Couplings**: How does the identity of material, chemical composition, or part number predict behavior of same item? e.g., Connection Lead Life as a function of Lead Material.
- **Input-Output Couplings**: How does a role input impact a role output? e.g., Waveform Detection time, as a function of Input Waveform.



S*Metamodel informal summary pedagogical diagram
(formal S*Metamodel includes additional details.)

Integration of the Risk Model

- Traditional systems engineering example risk analysis representations are well-established, and can be found in:
  - Failure Modes and Effects Analysis (FMEA) or Failure Modes, Effects, and Criticality Analysis (FEMCA).
  - Special cases for risks of designs, risks of production and other processes, risks introduced by human operators (D-FMEA, P-FMEA, A-FMEA).
  - Fault Tree Analysis (FTA).
  - Preliminary Hazard Analysis (PHA).
  - Reliability Centered Maintenance (RCM) analysis.
  - Hazards and Operability Analysis (HAZOP).
  - Safety and Cybersecurity Analysis cases of the above.
- S*Models and S*Patterns teach us that Feature Space becomes the key representation of Risk, generating the above analyses from an integrated model.

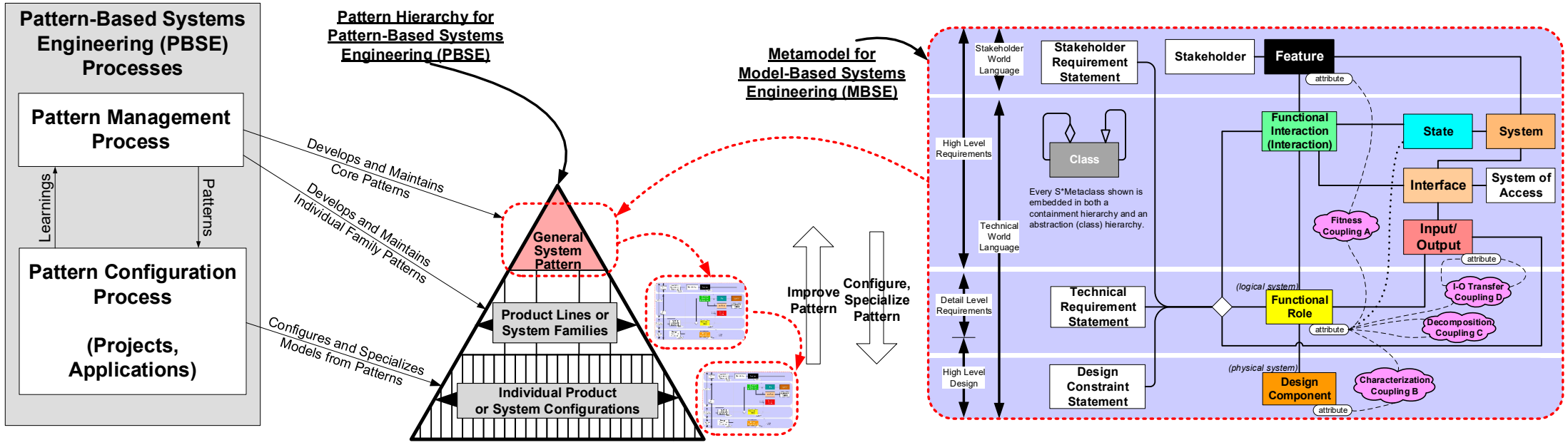


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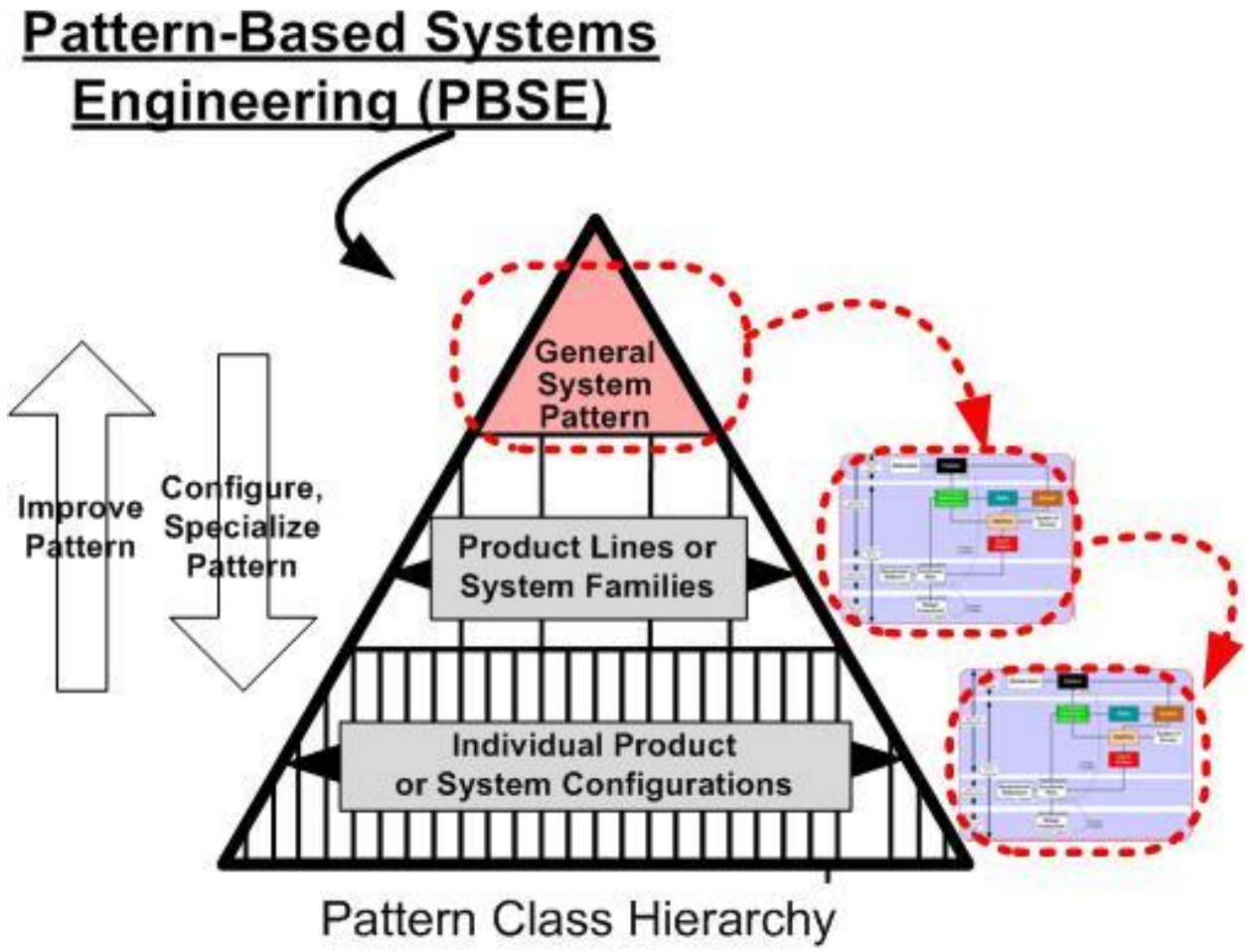
S*Patterns

- S*Patterns are S*Models of classes or families of systems.
- They are intended to be configurable, re-usable, and accumulate learning.
- They are often patterns of “whole systems”, as opposed to components.
- They are model-based patterns (there is a long history of other patterns).
- As S*Models, they are based on the S*Metamodel (in any tooling & language).



Pattern Class Hierarchy

S*Pattern Configuration, Specialization



- Specialization transforms from an upper pattern to a more specialized (lower) pattern / model.

- Configuration is a special case of specialization, requiring less modeling skill:
  - Populate (*including multiply*) or depopulated classes and relationships.
  - Set Attribute Values.

  That's all!

- Configurable patterns are the "sweet spot" targeted by S*Patterns.

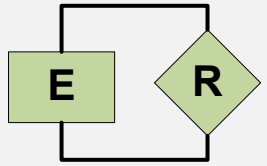
Emergence of Patterns from Patterns: S*Pattern Class Hierarchy

More General

More Specific

Definition of **Relational Modeling Paradigm**

Entity-Relationship Paradigm

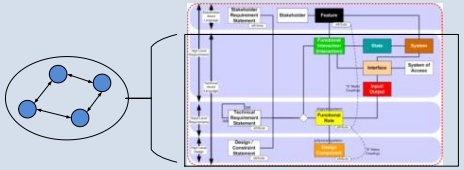


E=Entity
R= Relationship

Structured or unstructured semantic web

Minimal System S*Metamodel: Definition of (Elementary) System, Material Cause

S*Metamodel Core



Core S*Metamodel

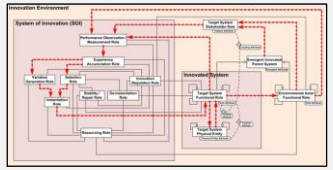
Smallest model of a system, for engineering or science

Emergence & Definition of **System of Innovation**, Fitness, Value, Purpose, Stakeholders, Agility, Final Cause, Formal Cause, Efficient Cause, Intelligence, Management, Science, Living Systems

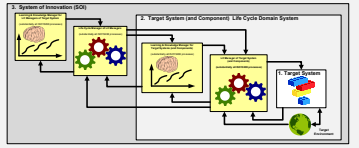
EI Pattern, SOI Pattern, Fitness, Value

S*Purpose, Fitness, Value

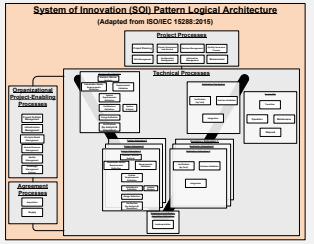




System of Innovation Pattern



Agile Sys Life Cycle Pattern



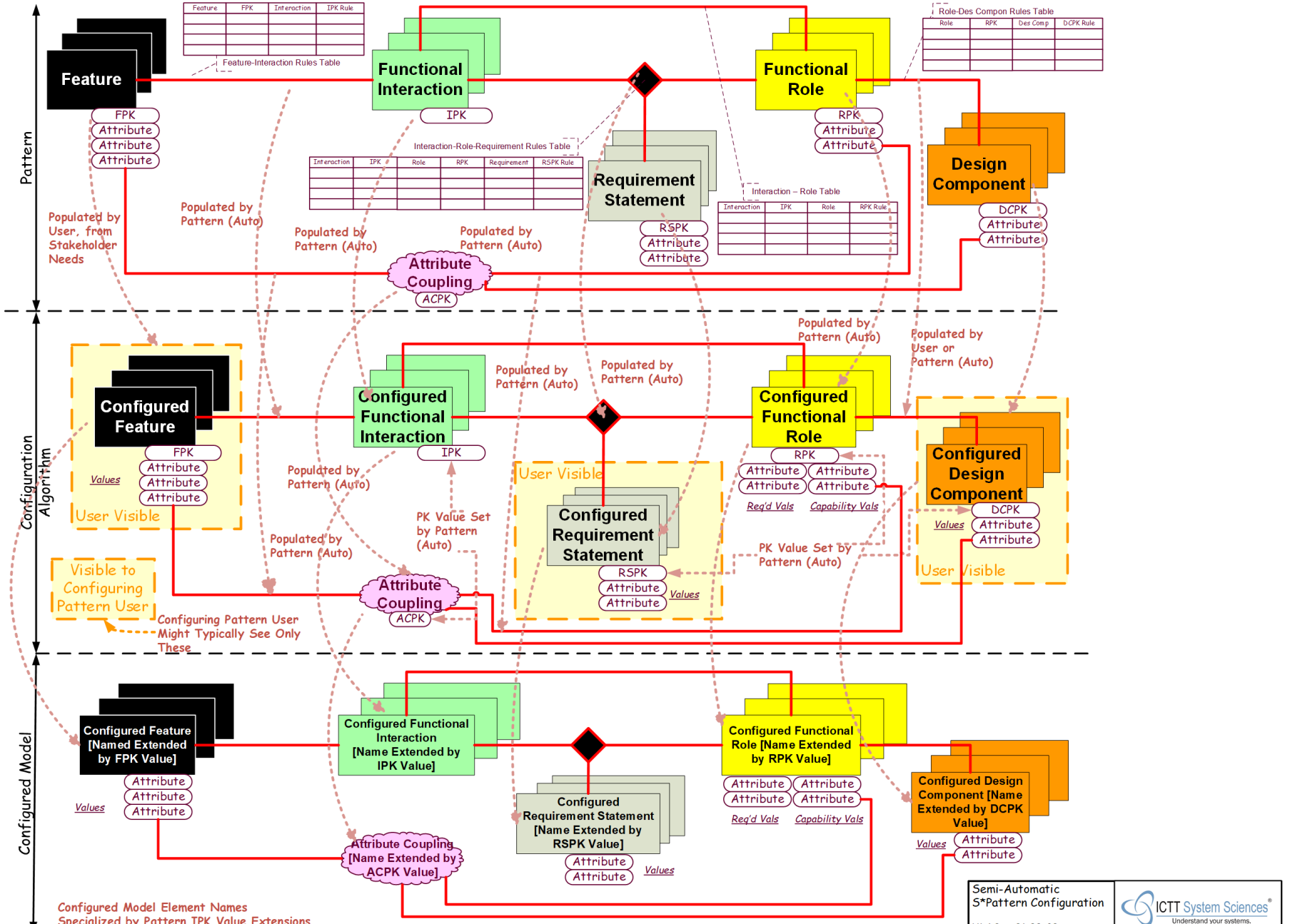
ISO 15288 System Life Cycle Mgmt Pattern

Emergence & Definition of **Domain Specific Systems**

Domain Specific Pattern

- Terrestrial Vehicle Domain Pattern
- Manufacturing System Pattern
- Product Service System Pattern
- Space Tourism Pattern
- Electrical Power Domain Pattern
- Aircraft Flight Control Pattern
- Medical Device Pattern
- Distribution System Pattern
- Socio-Technical Pattern
- Critical Infrastructure Domain Pattern

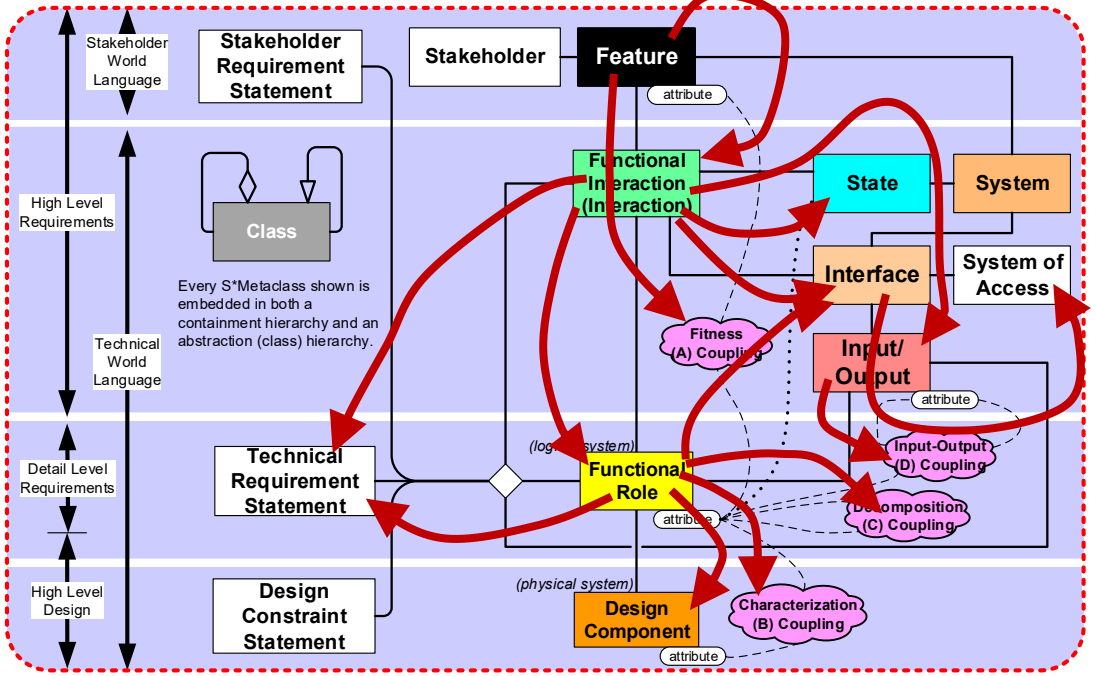
Models from Patterns: Overview of MBSE Pattern Configuration Algorithm



Propagation of configuration population is inherent to the nature of all engineered systems

- S*Feature Space drives configuration from a smaller set of (stakeholder based) degrees of freedom / points of variation.
- Simplifies Product Line Engineering (PLE) model configuration rule-making and integrates PLE.

Inherent PLE degrees of freedom configuration propagation:



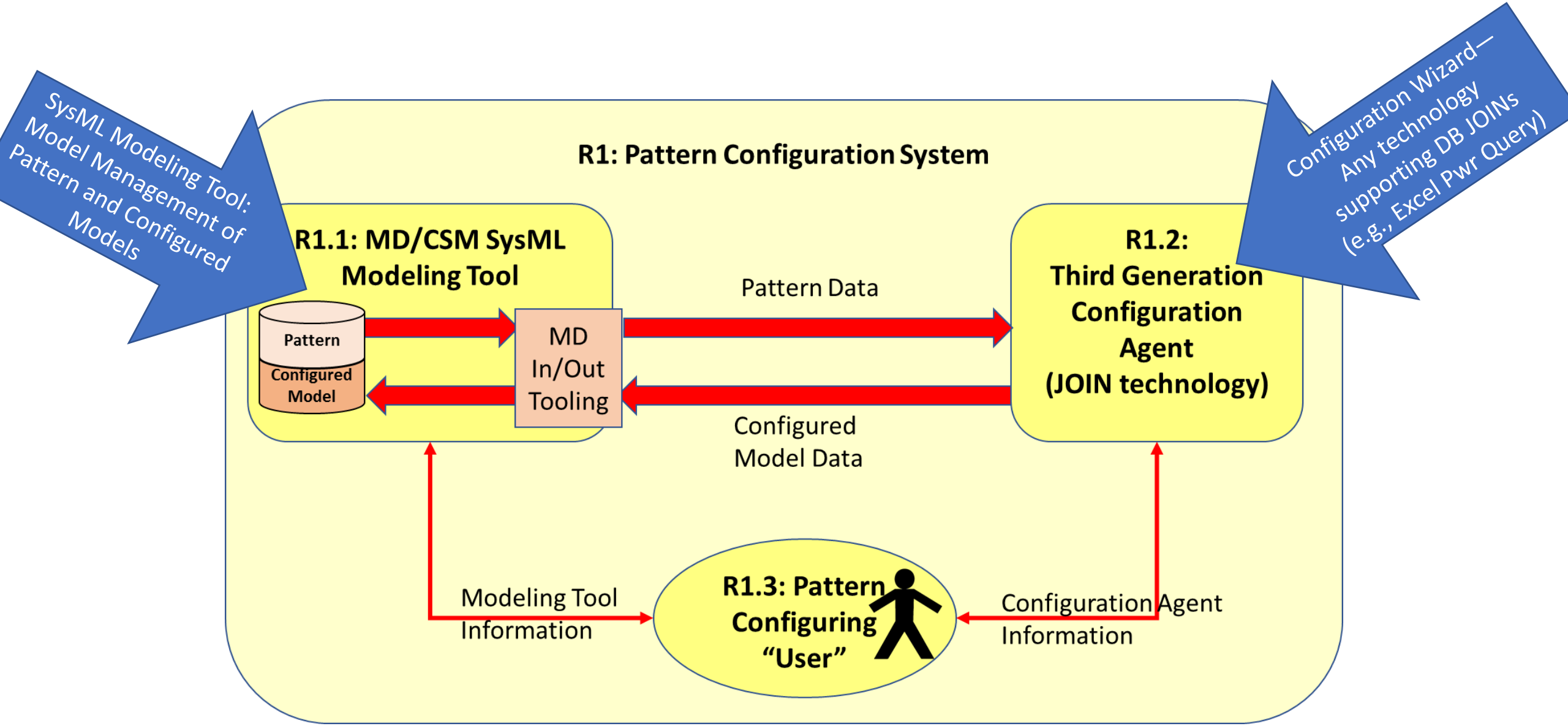
TRIGGERING METACLASSES ("IF") \ POPULATED METACLASSES ("THEN")	Feature	Interaction	Role	Design Component	Requirement Statement	State	Event	Transition	Interface	Architectural Relationship	Input/Output	Port	System of Access	Failure Impact	Counter Requirement Statement	Failure Mode	Feature Attribute	Role Attribute	Design Component Attribute	Input/Output Attribute	Fitness Attribute Coupling	Decomposition Attribute Coupling	Characterization Attribute Coupling	IO Attribute Coupling
Stakeholder Input	■																							
Feature	■	■												■			■							
Interaction		■	■		■	■	■		■	■	■	■	■	■										
Role			■	■	■	■			■	■	■	■	■					■						
Design Component				■												■			■					
Requirement Statement					■										■									
State						■	■																	
Event							■	■																
Transition								■	■															
Interface									■	■														
Architectural Relationship										■	■													
Input/Output											■	■								■				
Port												■	■											
System of Access													■	■										
Failure Impact														■	■									
Counter Requirement Statement					■									■	■	■								
Failure Mode				■											■	■								
Feature Attribute		■															■				■			
Role Attribute			■															■				■	■	
Design Component Attribute				■															■					
Input/Output Attribute											■									■				■
Fitness Attribute Coupling																					■			
Decomposition Attribute Coupling																						■		
Characterization Attribute Coupling																							■	
IO Attribute Coupling																								■

Relationship to Feature-Based PLE ala' ISO 26580

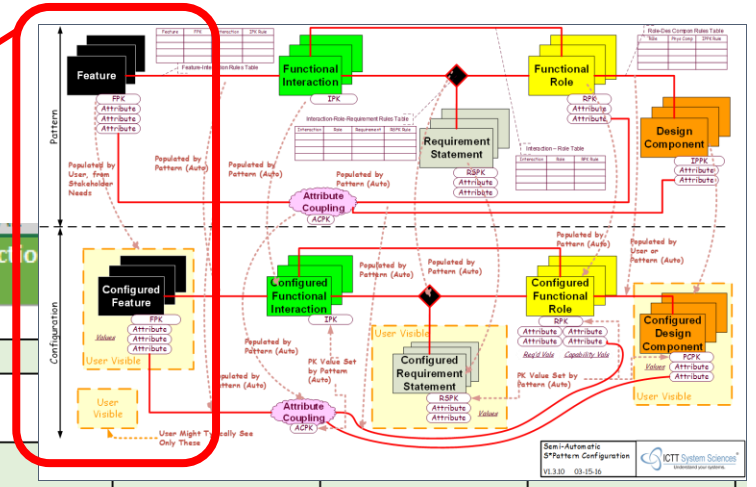
Very similar in the PLE aspects, with a few differences:

- ISO26580 PLE specifies modeling what changes, but specifies omitting what does not change; S*Feature models include baseline capabilities.
- ISO26580 refers to all the points of variation as "Features", with rules to be established between them; S*Patterns begins with a smaller set of "Stakeholder Features" degrees of freedom in stakeholder value space, then recognizes all the other points of variation throughout the model but connects them with each other up to the Stakeholder Features points of variation.
- This shows that the number of real degrees of freedom, after considering constraints, is smaller.
- Effectively complies with ISO26580 while making its use simpler and more integrated.

Automation aids for pattern configuration



Config. Wizard User's Feature Selection Interface (Including Feature Primary Key Value Population)

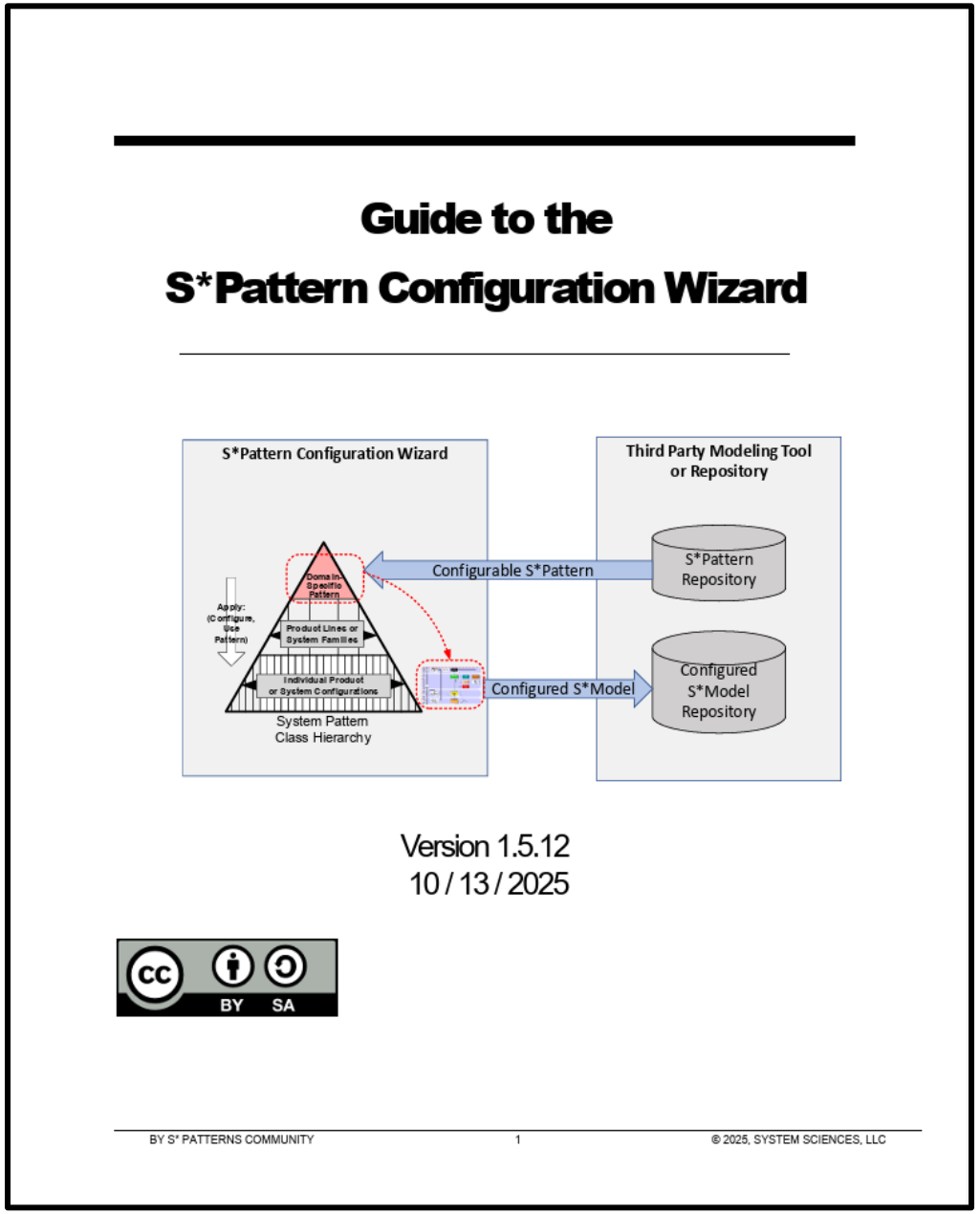


	Feature Configuratic	Feature Name	Feature Attribute	Populate? Yes/No	Selection 1	Selection 2	Selecto			
9	Mandatory	Cruise Control Feature								
10	Optional	Environmental Compatibility	Environmental Issue							
11	Mandatory	Maintainability Feature	Maintenance Capability							
12	Optional	Military Vehicle Application Feature Group	Military Application Type							
13	Optional	Navigation Feature	Navigation Capability							
14	Mandatory	Operability Feature	Operations Capability	Yes	Automatic Performance Data Measurement and Display	Automatic Performance Threshold Detection and Reporting	Maneuverability			
15	Optional	Passenger Comfort Feature Group	Comfort Issue							
16	Optional	Personal Vehicle Application Feature Group	Personal Application Type							
17	Mandatory	Reliability & Availability Feature								
18	Optional	Remote Management Access	Remote Access Capability							
19	Optional	Remote-Autonomous Operation		No						
20	Mandatory	Safety Feature Group								
21	Optional	Security Feature	Security Management Capability	No	Automatic Operational Privileges Authorization	Identification and Authentication	Physical Access Locks	Security Data Management		
22	Optional	Traction Control Feature		No						
23	Optional	Vehicle Aesthetics Feature Group	Aesthetics Issue	No	Exterior Body Style	Exterior Color Galeon Blue	Exterior Color Handon Green	Interior Color Rich Brown	Interior Color Sand Dune	Overall Passenger
24	Mandatory	Vehicle Delivery Feature		No						
25		Vehicle Management Feature		No						
26	Mandatory	Vehicle Performance Feature		No						

Automatic Performan
Automatic Performan
Maneuverability
Manual Performance
Manual Performance
Operations Procedure
Visibility

Selection of Feature Primary Key Values

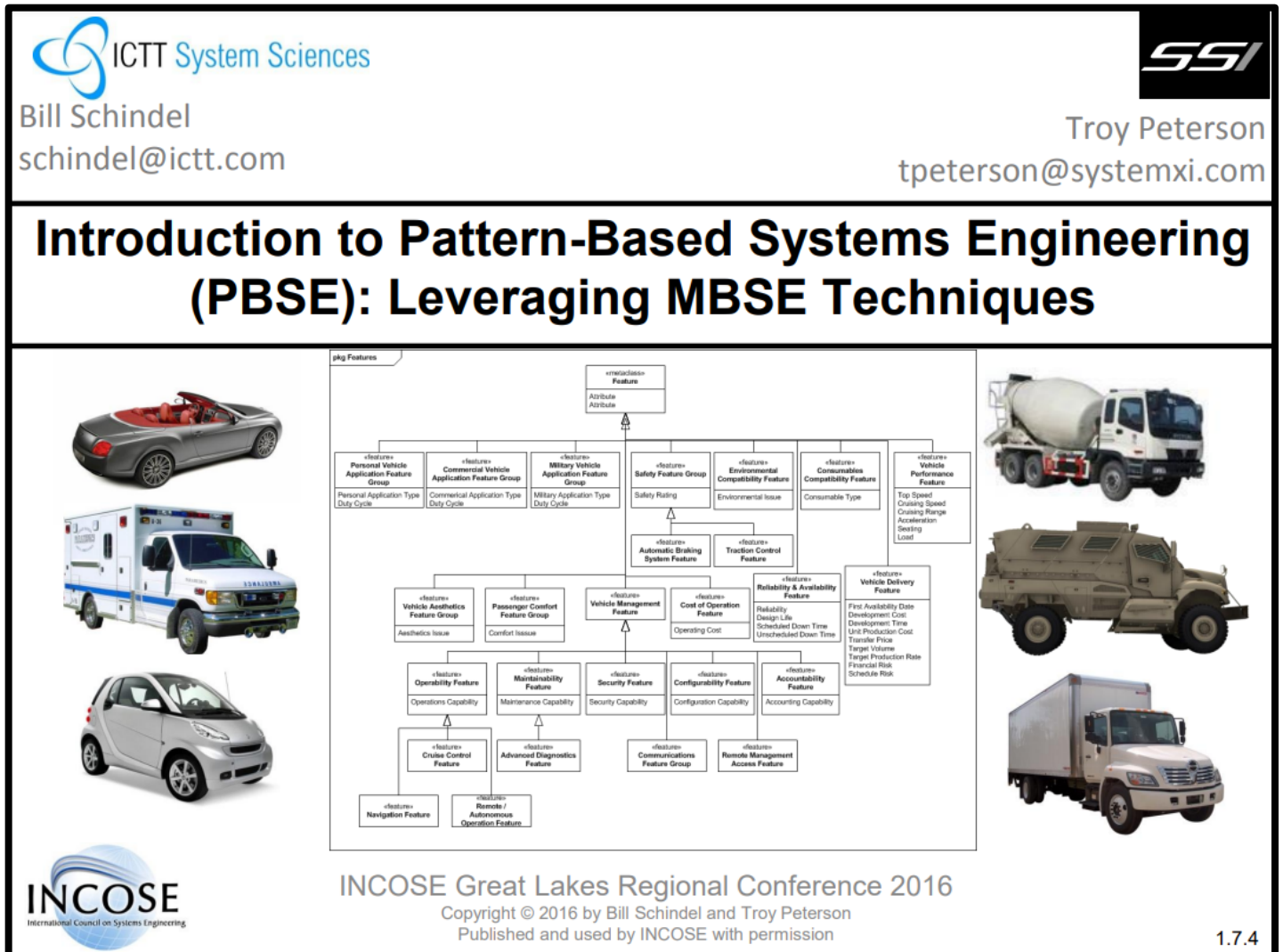
S*Pattern Configuration Wizard



Download Link for Pattern Configuration WIzard Guide

How to find out more about configurable model-based patterns

https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:pbse_tutorial_glrc_2016_v1.7.4.pdf



https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:s-patterns--a_primer_wg_review_draft--v1.2.1.pdf

https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:glrc_2018_tutorial--mbse_emerging_issues_v1.4.2.pdf

Recent / Current Patterns & Technologies Projects:

1. *Rosetta Stone: Consistency Management as Foundation for SE, enhanced by DE, ST, AI* — **ROSETTA STONE PUBLISHED IN 2025**
2. Adaptive Learning Ecosystem Pattern—the INCOSE ASELCM Reference Framework
3. *Vector Spaces, Projections, and Patterns: Support for MBSE, Learning, and Trust* — **NEW IN 2025**
4. Support for DEIX WG DE Standards Project – S*Metamodel and S*ASELCM Pattern
5. *S*Metamodel Library for SysML V2, supported by a formal mapping of S*MTM to SysML V2* — **NEW IN 2025-6**
6. *Support SysML V2 team with S*Stakeholder Features examples and feedback.* — **NEW IN 2026**
7. S*Pattern Configuration Wizard
8. *S*Patterns Starter Kit* — **CLASS MEDIA PUBLISHED IN 2025**
9. Universal Model Metadata Wrapper: Model Characterization Pattern (MCP), w/AIAA DEIC DSM WG
10. Support for Vision 2035 FuSE Implementation Streams: Innovation Applications, SE Foundations — **NEW IN 2026**
11. *S*Examples of System Dynamics Views emphasizing emergent, poorly understood, or unknown behaviors, with Resilience WG.*
12. *S*Interface Patterns examples supporting SysML V2 team.* — **NEW IN 2026**

Recent / Current Publications Projects:

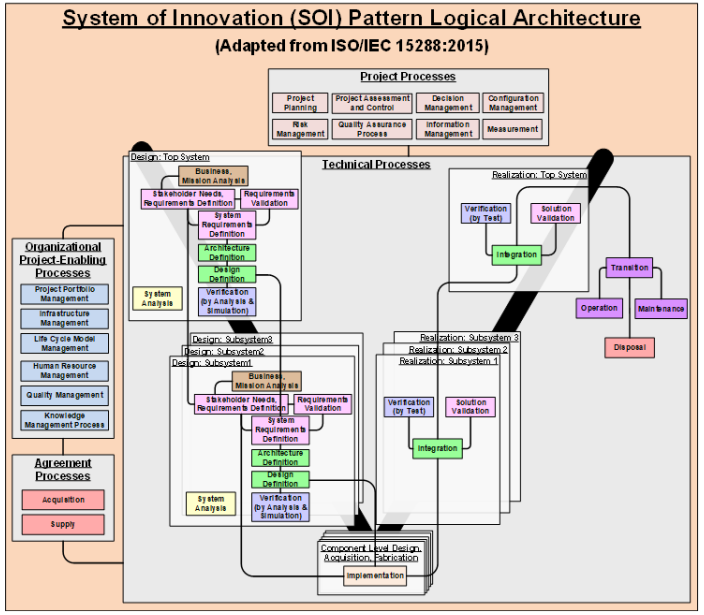
1. *INCOSE INSIGHT Digital Engineering Edition: "From Fragmentation to Federation"* — **INSIGHT PUBLISHED OCT 2025**
2. INCOSE *INSIGHT* Special Editions, Aug and Oct, 2024: S*Foundations--Impacts on SE Practice
3. Minimal S*Models—A Primer (including S*Metamodel and its formal mappings to OMG SysML and tools)
4. S*Patterns Primer (second edition)
5. *ASME VVUQ50.1 Guideline for Managing Life Cycle Credibility of Models, w/ASME* — **ASME RELEASED JAN 2026**
6. AIAA Aerospace Digital Twins Analysis and Planning Reference Pattern, w/AIAA DEIC
7. AIAA Aerospace Digital Threads Position Pub; Digital Thread Analysis & Planning Reference Pattern, w/AIAA
8. *Handbook of System Sciences*, for ISSS via Springer: Chapter: "Patterns in Science and Engineering", w/ISSS
9. *Handbook of Model-Based Systems Engineering*, Madni & Augustine, eds, Springer, Chapter: "MBSE Patterns"
10. *INCOSE SE Handbook*, 5th Ed., for INCOSE, D. Walden et al, eds., S*Metamodel and ASELCM Pattern

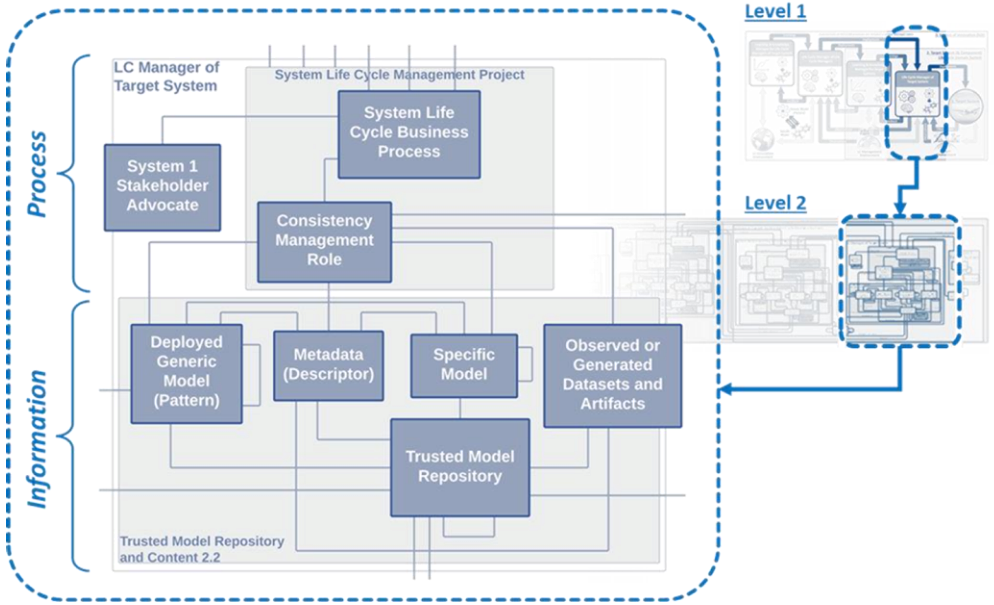
Consistency gap management paradigm

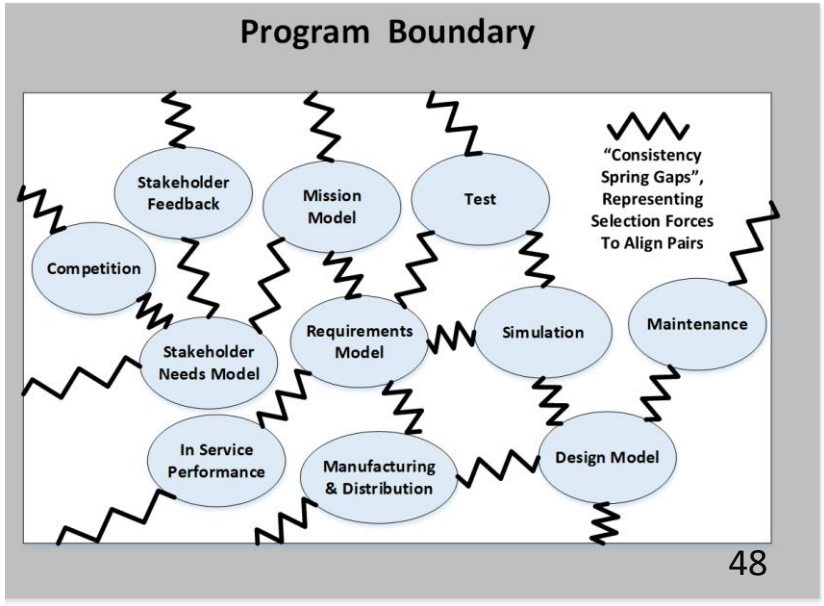
NEW IN 2025

Rosetta Stone Project, across four technical societies

- The consistency management paradigm is about the central information thread / web running through the ASELCM pattern's representation of any engineering/life cycle management / supply chain system's primary activities.
- Including the digital thread and its many precursors.



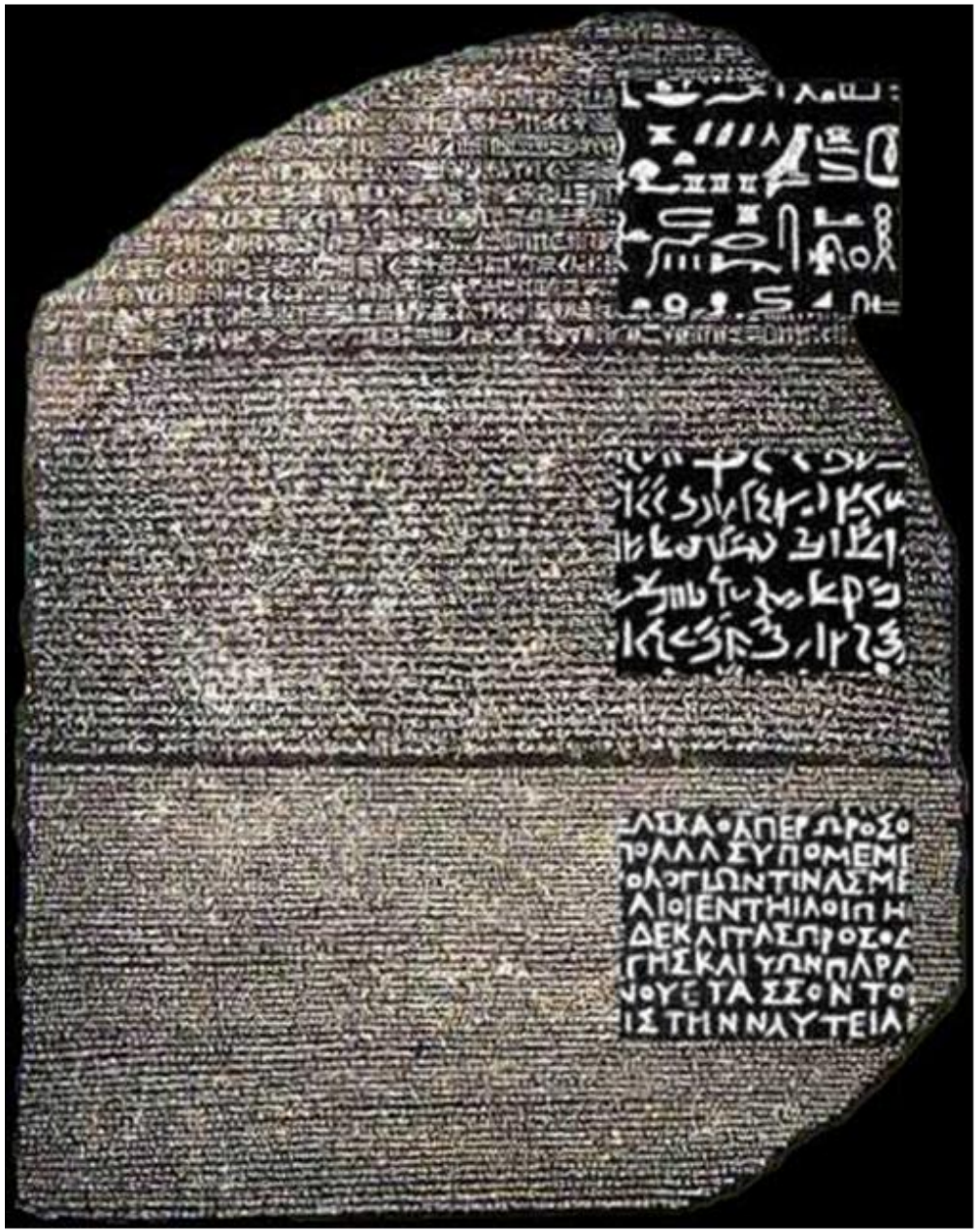




Related collaboration project across four societies:

- Different discipline communities have different consistency confirmation frameworks, nomenclatures, standards.
  - e.g., INCOSE ISO/IEC 15288 SE versus ASME VVUQ-1 computational modeling communities
- This can present challenges to engineering rigor, when performed “together” for trust-critical integrated systems.
  - e.g., When a computational model is “built into” a machine tool, or other cyber-physical system
- Working groups of INCOSE, ASME, AIAA, and NAFEMS are collaborating on a comparative “Rosetta Stone” mapping of different consistency confirmation frameworks of different communities.

Rosetta Stone



What have we learned from comparing four V&V frameworks for a computational model (CM)?

- ISO 15288 (general systems, including CM)
- ASME VVUQ-1 (CM)
- NAFEMS ESQMS (CM)
- AIAA-G077 (CM)

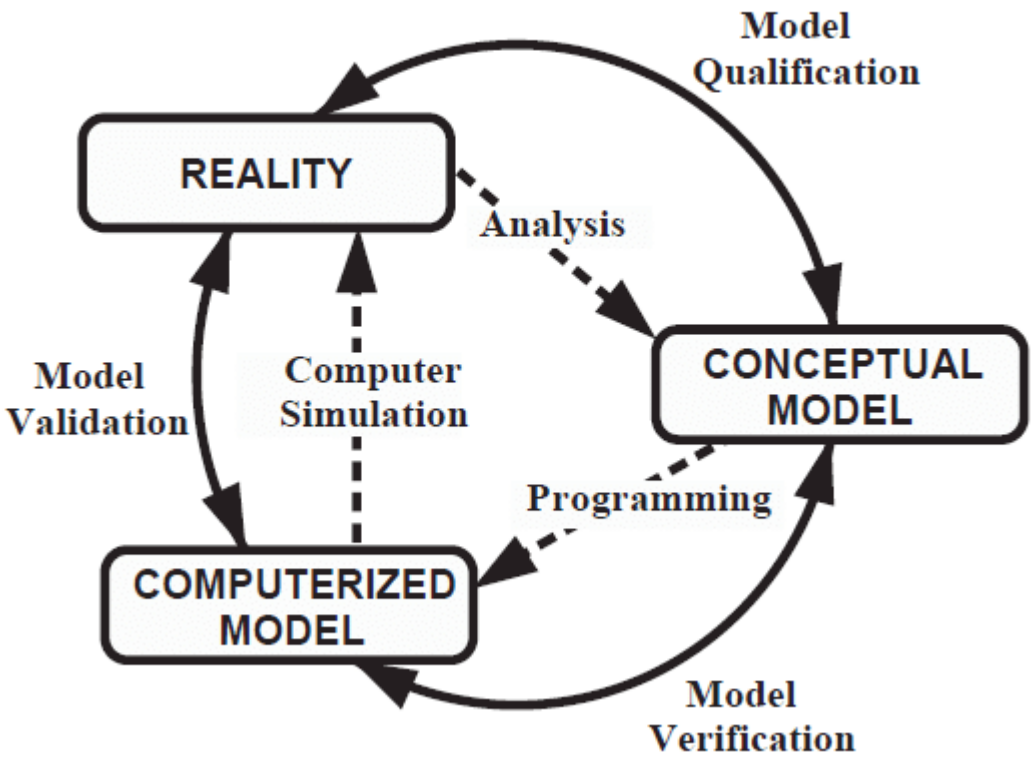
V&V grounded in characterizing accuracy for a computational model:

- ASME VVUQ-1
- AIAA-G077

V&V grounded in application requirements for a computational model:

- ISO 15288
- NAFEMS ESQMS

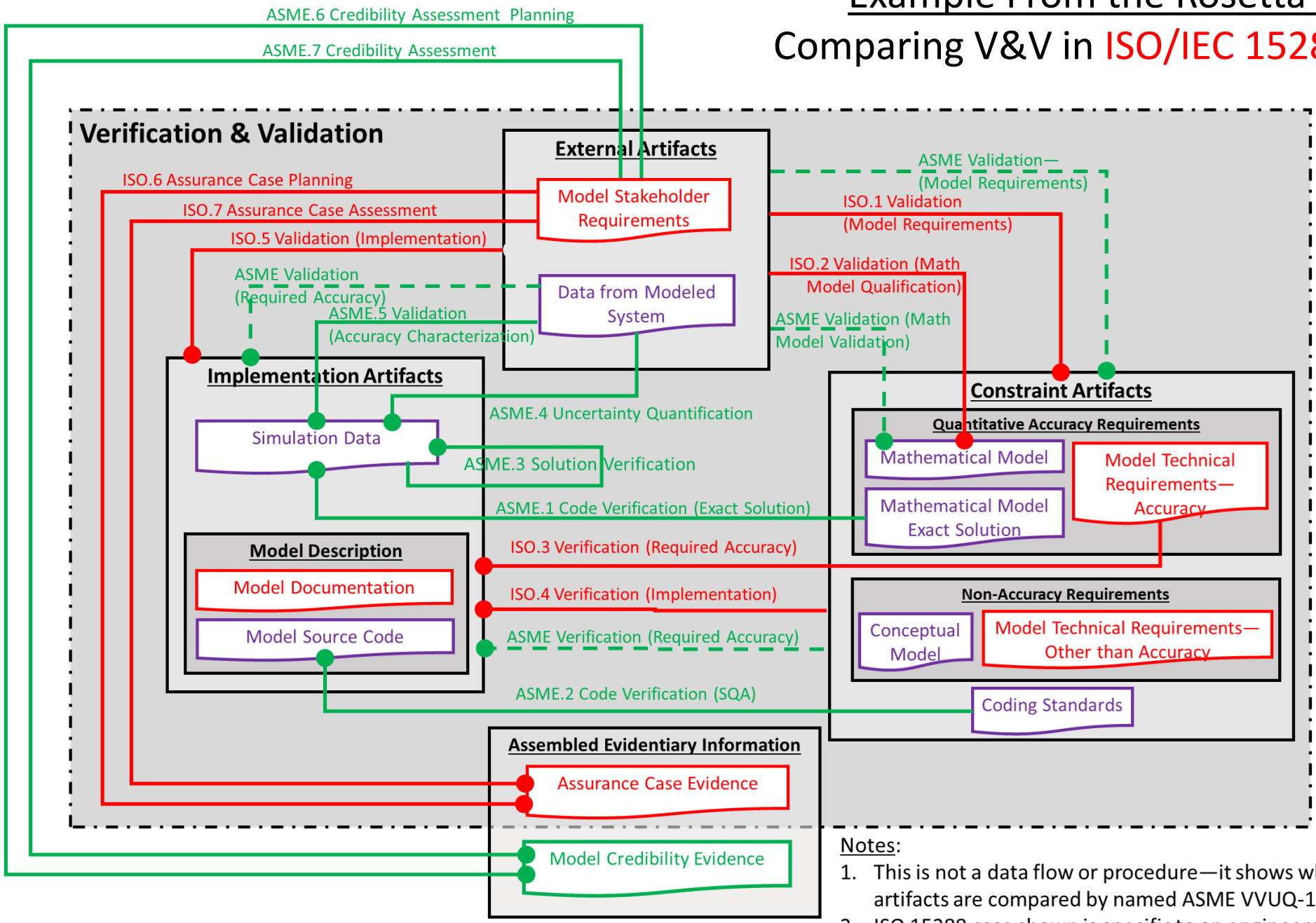
Rosetta Stone Project ***Consistency Management*** Inspiration: A 1979 Graph Diagram for Computational Model V&V



- This 1979 graph diagram is somewhat dated, but is a simple example with key ideas that continue to apply: Consistency of information artifacts.
- An informative discussion of this diagram and subsequent history is in Oberkampf and Roy (2010) [17], pp 22 and its following sections.

Diagram: The role of V&V in the development of simulation models (Schlesinger, 1979) [16].

Example From the Rosetta Stone Project Report:
Comparing V&V in ISO/IEC 15288 and ASME VVUQ-1



LEGEND:

Blocks: Information--

Artifact

Category of Artifacts

Lines: Consistency Checks Between Artifacts--

Subject — Referent

Color Codes:

Named ISO 15288 V&V Process

Named ASME VVUQ-1 Process

No ASME VVUQ-1 V&V Process

Artifact Used in V&V by Both ISO 15288 and ASME VVUQ-1

Artifact Used in V&V by ISO 15288

Notes:

1. This is not a data flow or procedure—it shows which subject and referent information artifacts are compared by named ASME VVUQ-1 and ISO 15288 V&V activities.
2. ISO 15288 case shown is specific to an engineered computational model.
3. Not all of ISO 15288 V&V applicabilities to that case are illustrated

For copy of ASME VVUQ2025 Symposium analysis of report:

NEW IN 2025

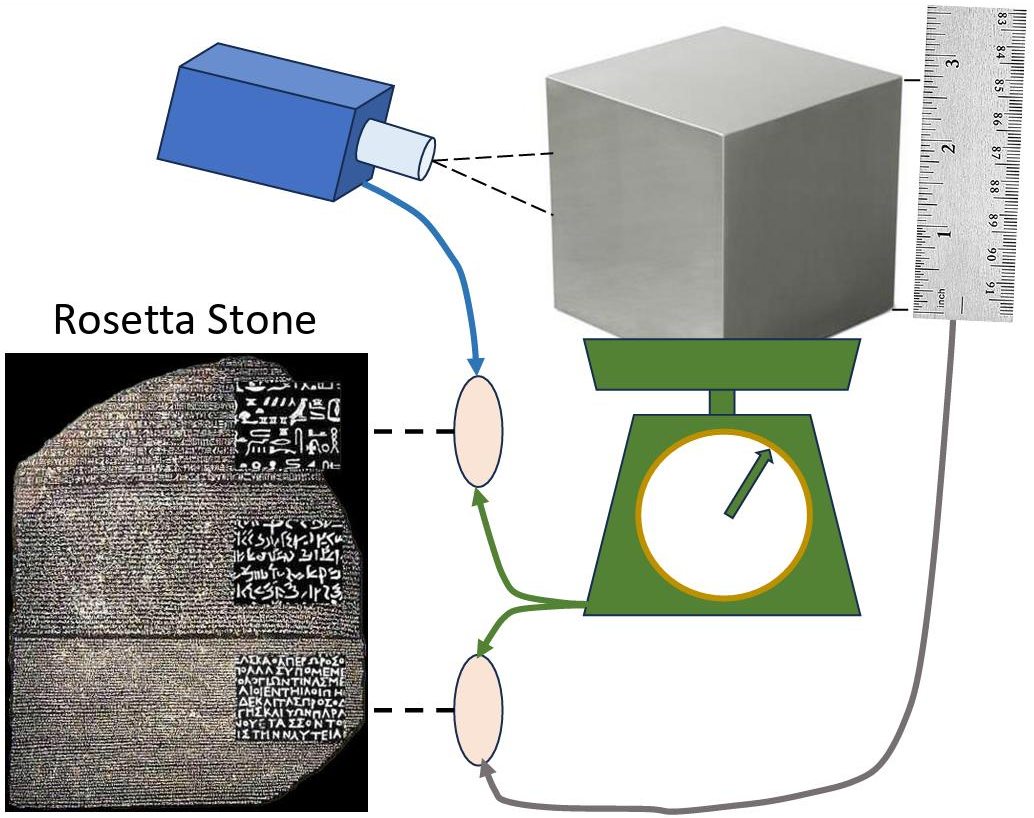
Rosetta Stone Project

NEW IN 2026

The Rosetta Stone Mapping was also incorporated into the ASME VVUQ 50.1 standard, published January, 2026.

For copy of 2024 project report:

A Cross-Society Collaboration Project: Mapping Consistency Confirmation Frameworks of Different Communities



Phase 1 Project Report

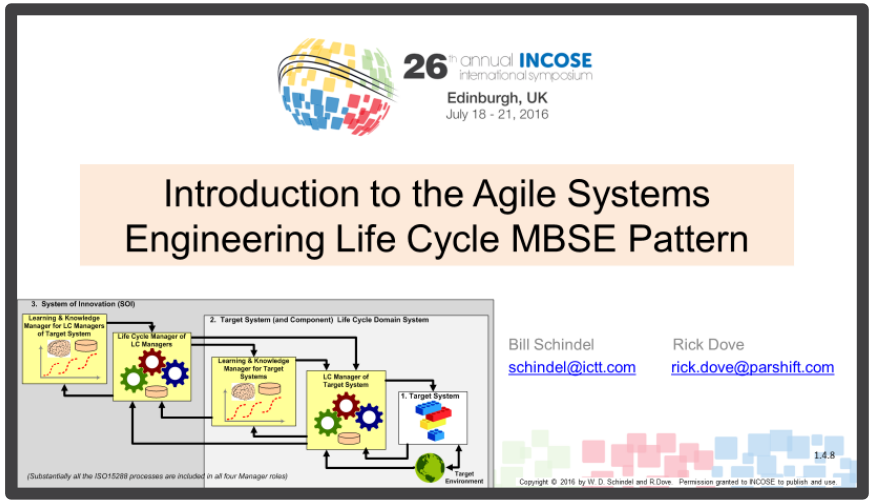
Olivia Fischer [1], Mat French [1,2]
Joe Hightower [3], Alex Karl [4]
John Matlik [1], Laura Pullum [3]
Bill Schindel [1,2,3], Guodong Shao [3]
Nigel Taylor [1,3]

1 – AIAA Digital Engineering Integration Committee
2 – INCOSE/OMG MBSE Patterns Working Group
3 – ASME VV50 Model Life Cycle Working Group
4 – NAFEMS Simulation Governance Working Group

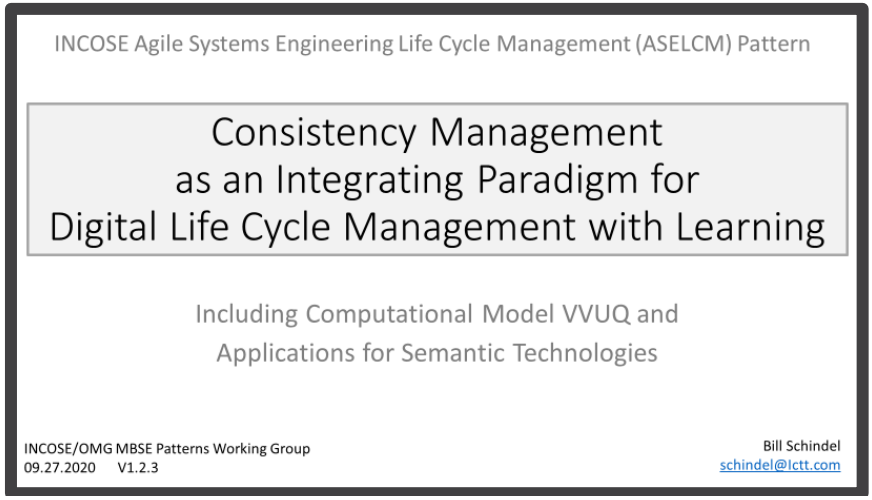
V2.1.5

Adaptive Learning Ecosystem Pattern—the Innovation Ecosystem (ASELCM) Pattern

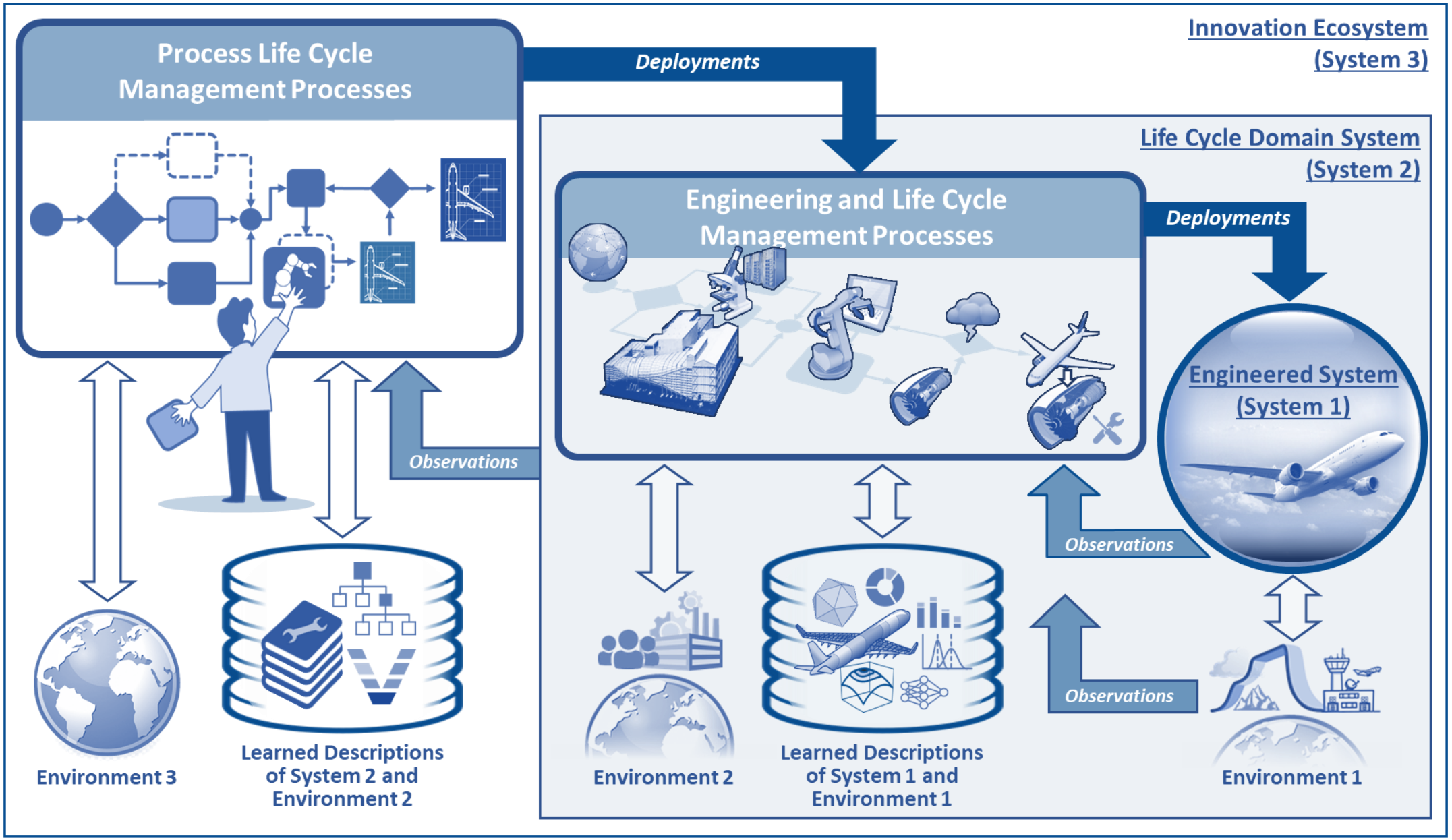
- Collaborating with INCOSE Agile SE WG, a reference pattern was contributed by Patterns WG during the two-year INCOSE study of agile SE practices of four major organizations during 2015-2017, leading to four published case studies. (Led by Rick Dove, Agile SE WG.)
- The original pattern (Agile SE Life Cycle Management (ASELCM) Operational Reference Pattern) was subsequently formalized by the Patterns WG as a configurable S*Pattern in SysML, for the planning, analysis, and management of advancement in learning ecosystems for projects, enterprises, and supply chains.
- The resulting multi-layer pattern focuses on leveraging Digital Engineering to advance performance through the paradigm of strengthened Consistency Management.
- Those interested in participating can be a part of extension and application of this pattern in case studies of their own projects, enterprises, or supply chains, plus related tooling.



http://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:is2016_intro_to_the_aselcm_pattern_v1.4.8.pdf



https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:aselcm_pattern_--_consistency_management_as_a_digital_life_cycle_management_paradigm_v1.3.1.pdf

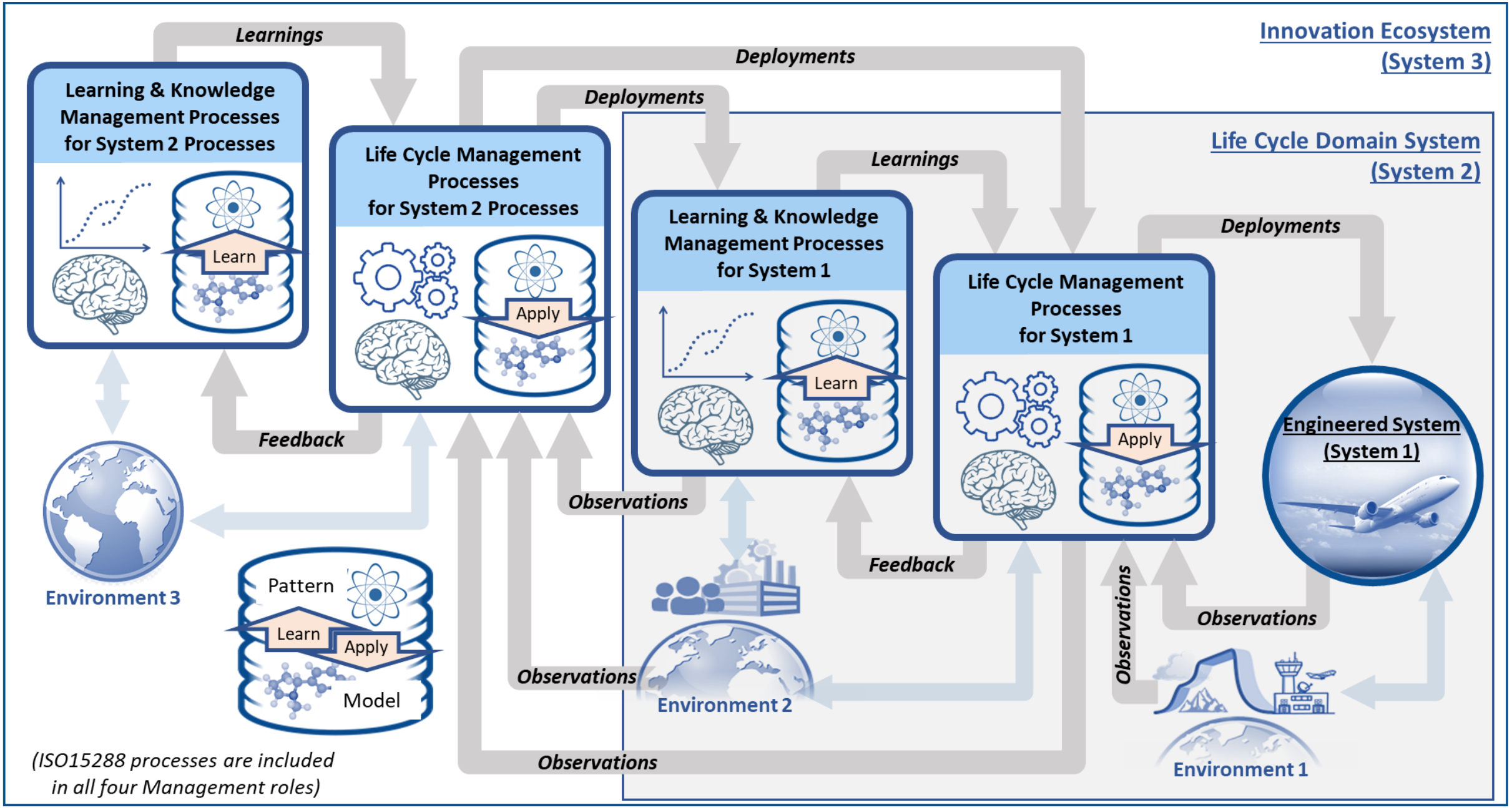


INCOSE ASELCM Level 0 Reference Model

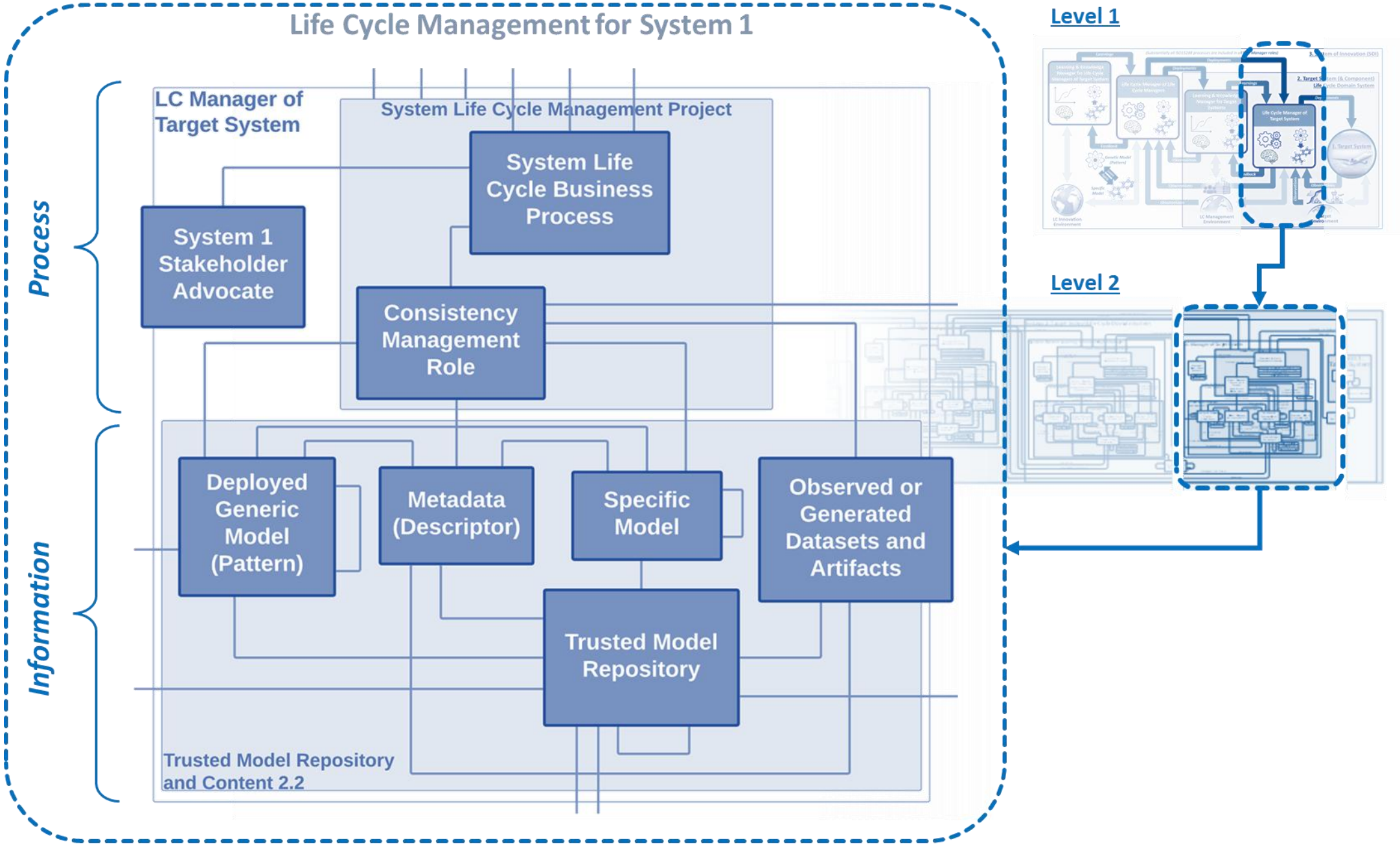
System 3: Process definition, advancement

System 2: Engineering, production, support, science

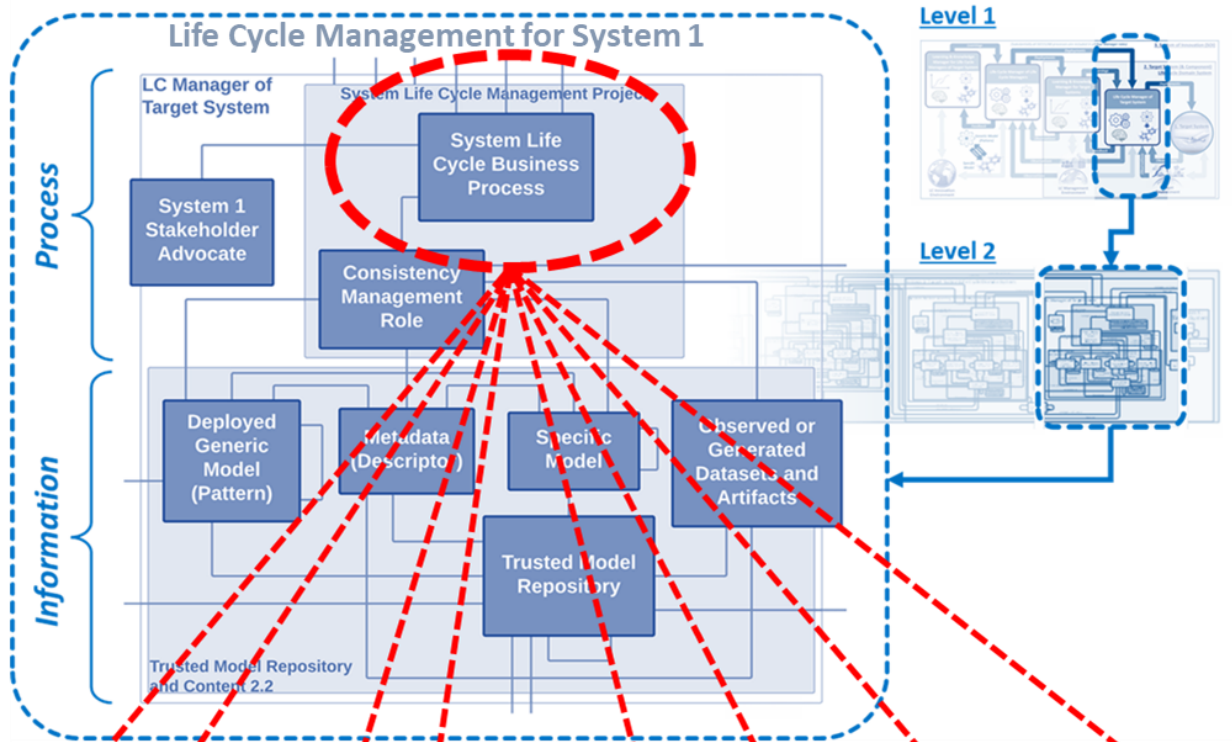
System 1: Products



INCOSE ASELCM Level 1 Reference Model

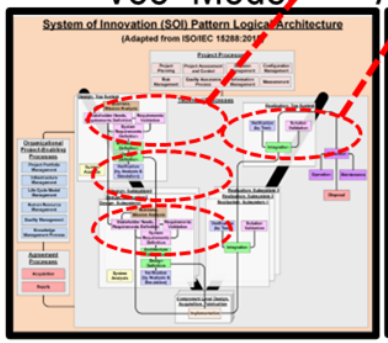


INCOSE ASELCM Level 2 Reference Model



Configurable to specific life cycle management models---

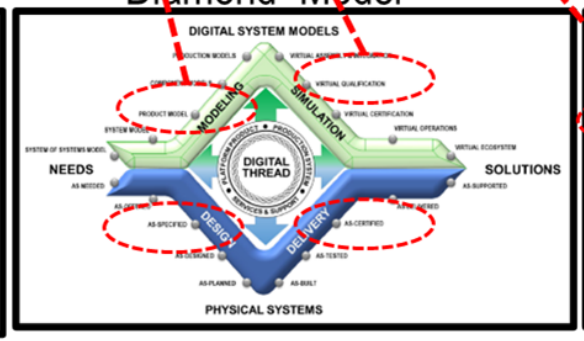
ISO15288 Life Cycle "Vee" Model[1]



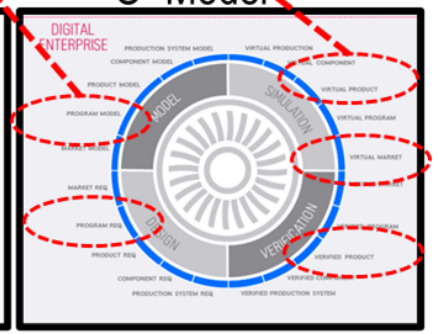
DoD 5000 Defense Acquisition Life Cycle Model[2]



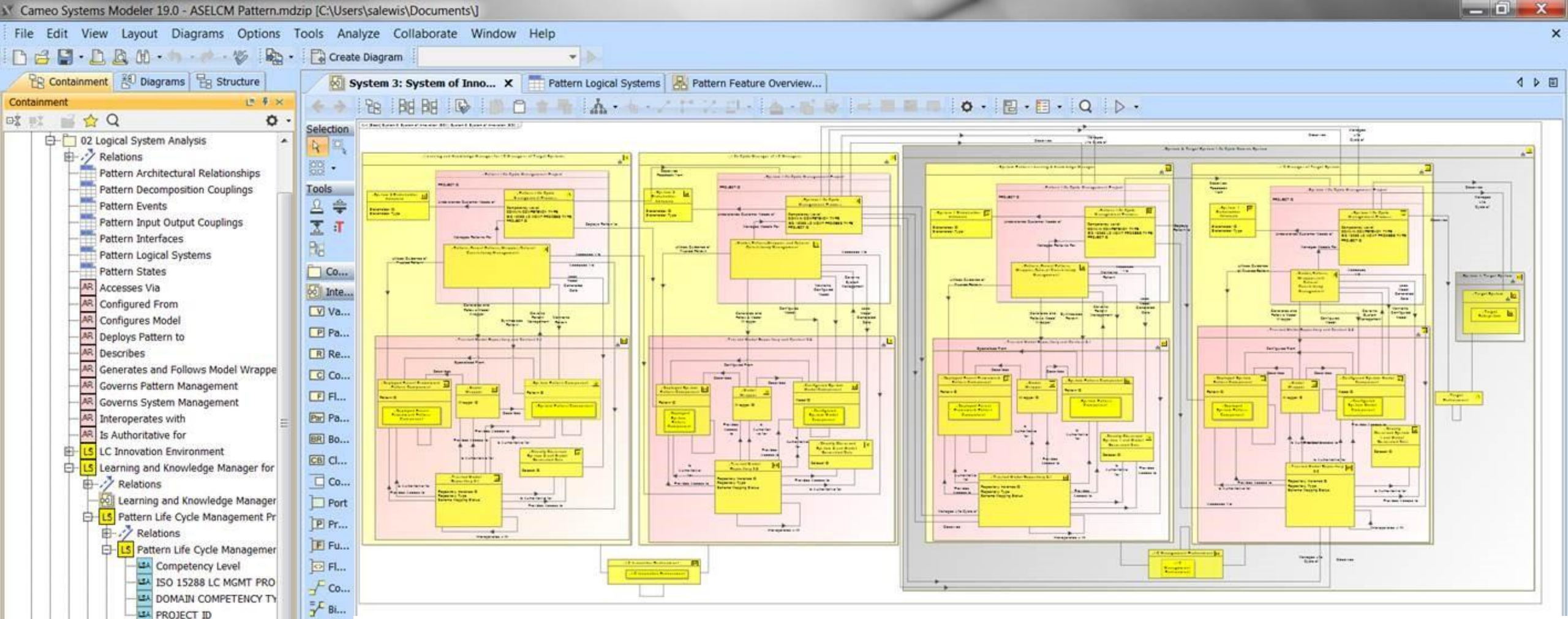
Boeing "Diamond" Model[3]



Rolls-Royce "O" Model[4]



Excerpted or adapted from: (1) ISO15288 and INCOSE SE Handbook; (2) DoD5000 Wall Chart; (3) AIAA Sci Tech, 01.2020, J. Hatakeyama; (4) AIAA DEIC Digital Twin Subcommittee, 04.08.19 Donaldson, Flay, French, Matlik, Myer, Pond, Randjelovic



In addition to its conceptual reference framework, ASELCM has also existed as a SysML configurable S*Pattern for several years:

Above: SysML view of S1, S2, S3 Logical Architecture Diagram, in Cameo Systems Modeler

Releasing the ASELCM Pattern SysML beta test implementation

Under consideration:

Beta Release to Test Sequence	Beta Test Package Content
1	S*Patterns SysML Environment Beta Package:
	S*Metamodel
	Mapping of S*Metamodel to Cameo Systems Modeler
	Profile and Templating for Cameo Systems Modeler
	Pattern Management Guide
	S*Pattern Configuration Wizard
	S*Pattern Configuration Wizard Guide
	Simple Test S*Pattern: International Power Converter
2	ASELCM S*Pattern Beta Package I:
	Configurable ASELCM Features, including Consistency Management Pairs, Digital Thread, Digital Twin, Package I Guidance.
3	ASELCM S*Pattern Beta Package II:
	ASELCM Interactions, Roles, Design Components, Package II Guidance.
4	ASELCM S*Pattern Beta Package III:
	ASELCM Parametric Couplings, Requirements, Package III Guidance.

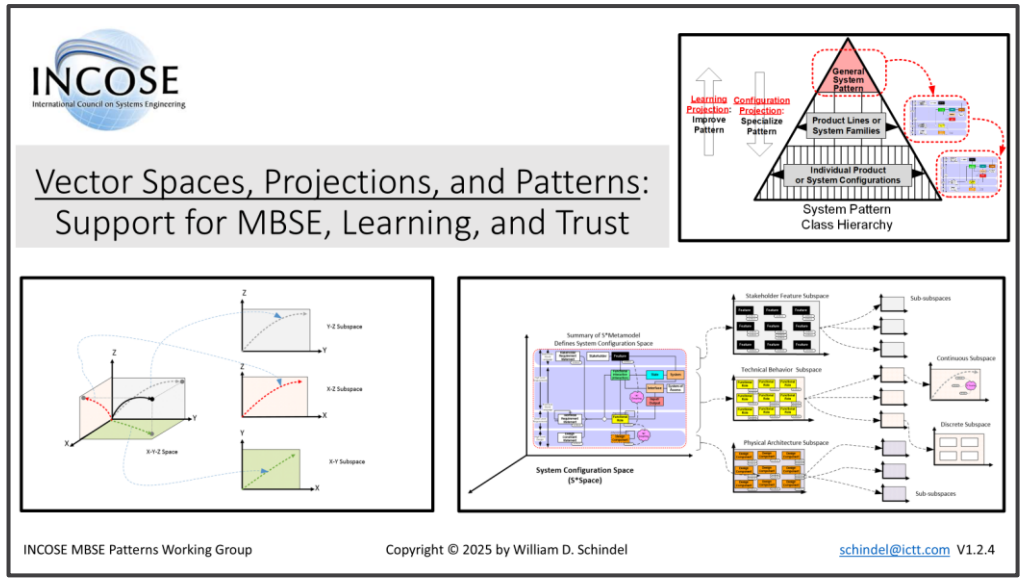
This sequence is also a learning curve for users

Working Group interest in beta testing?

Loading to the new INCOSE SE Lab.

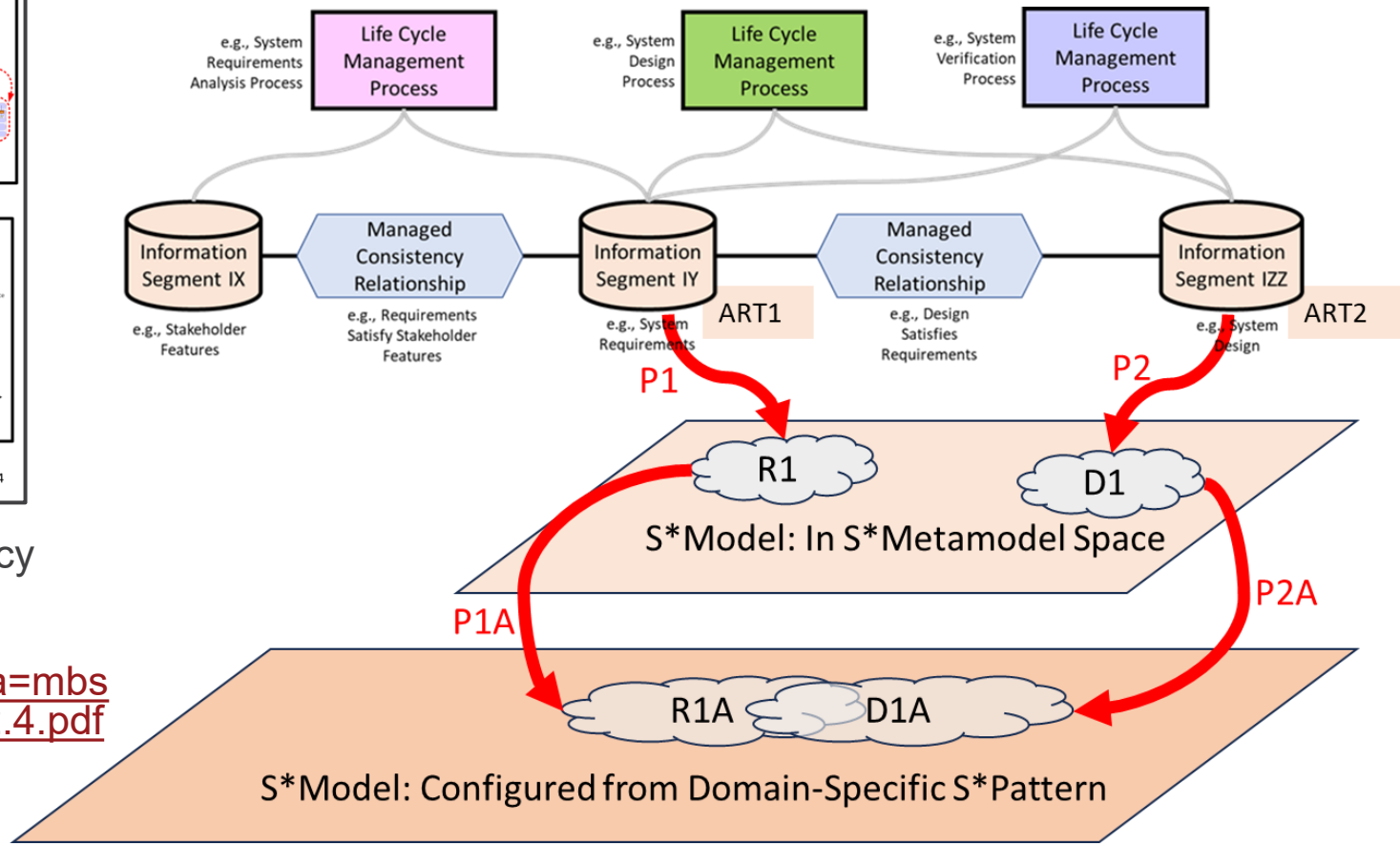
Vector Spaces, Projections, and Patterns: Support for MBSE, Learning, and Trust

NEW IN 2025



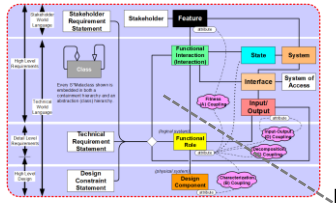
- How vector math projections enable model consistency checking and integrates human and AI based model generation and checking.

https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:expressing_patterns_in_vector_spaces_v1.2.4.pdf



Support for DEIX WG Digital Engineering Standards Project

(Led to INCOSE INSIGHT Oct 2025 Article)



STEM-based systems ontology

S*Metamodel

Upper Ontologies (BFO, CCO, etc.)

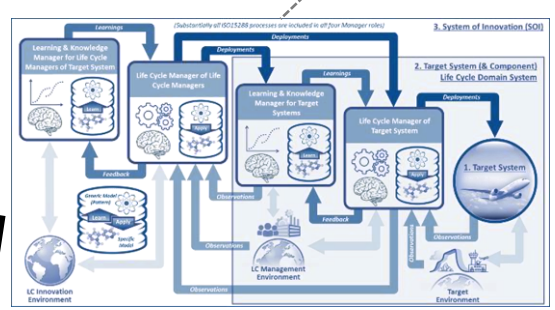
INCOSE DEIX WG Project

Digital Engineering Ontology

Offered Contribution

ASELCM S*Pattern

Domain-Specific Engineered Products S*Patterns





Engineering, Production, Sustainment, Life Cycle Mgmt. Ontology (S2, S3)

(S1)



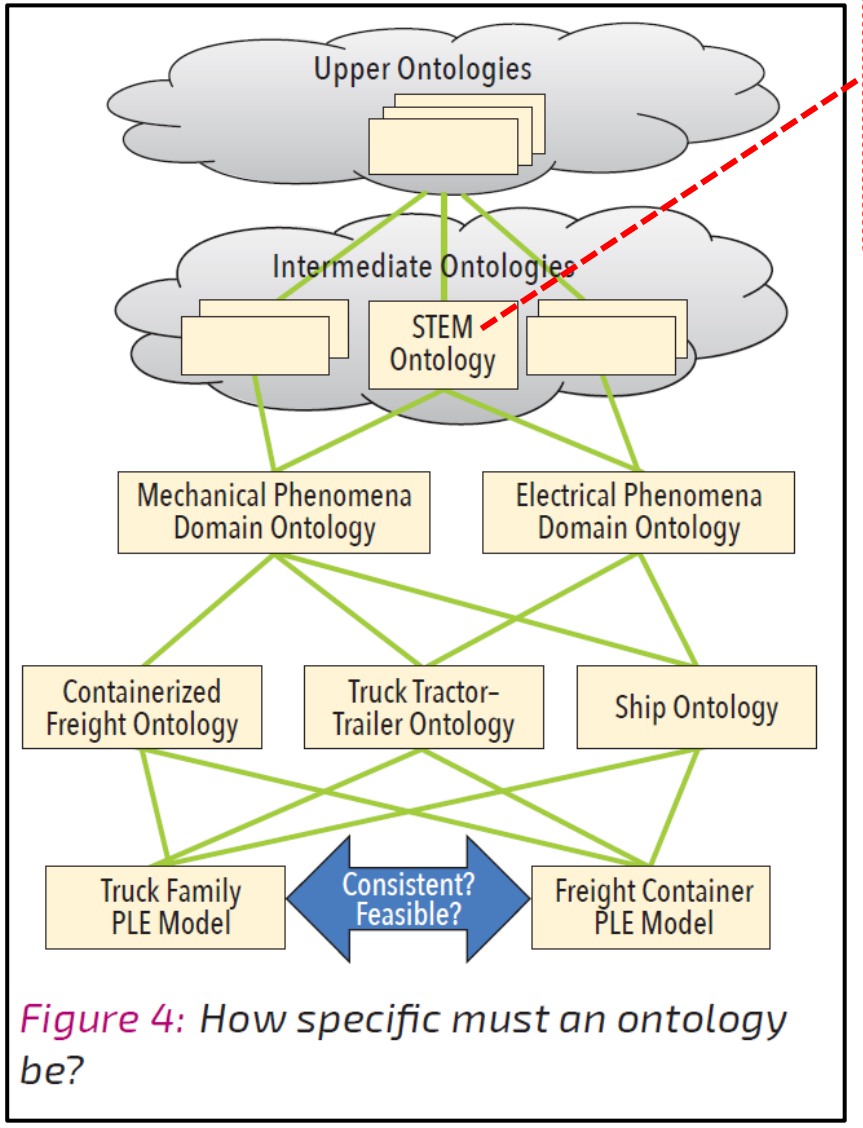
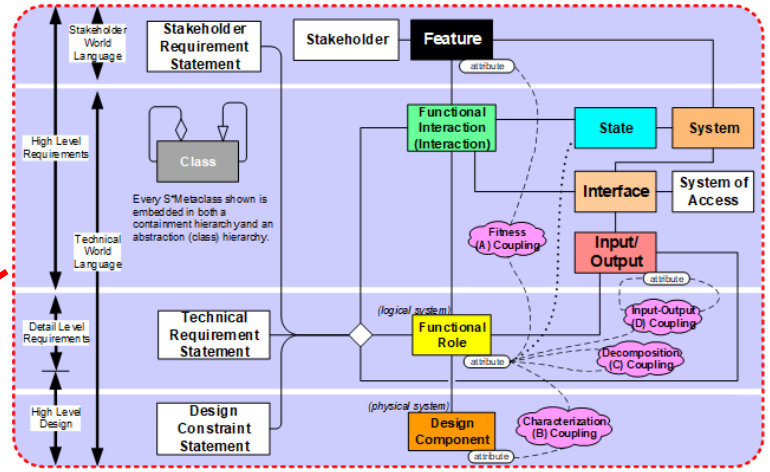


Figure 4: How specific must an ontology be?



S*Metamodel informal summary pedagogical diagram
(formal S*Metamodel includes additional details.)

[Download Link]

S*Metamodel Library for SysML V2, supported by formal mapping of S*MTM to SysML V2

Progress during 2025-6, thanks to Brian Larson's diligent efforts:

1. Draft of formal mapping document generated.
2. Draft of SysML V2 Library generated, in SysML V2 text language.
3. Ready to start 2026 testing by import into SysML V2 prototype tools.

S*Metamodel Mapping to SysML v2

Brian R Larson*

January 5, 2026

Version 0.1

*brl@multitude.net

SysML V2 Mapping

4 Detail Mapping

4.1 S*Metaclass Mapping Details

Table 3: Systematica Class mappings to SysML v2

Systematica Modeled Class Name	SysML v2 Element
Allowed Value	occurrence def AllowedValue
Architectural Relationship	connection def ArchitecturalRelationship
Architectural Relationship Role	occurrence def ArchitecturalRelationshipRole
Attribute Coupling	connection def AttributeCoupling
Attribute Coupling Map	occurrence def AttributeCouplingMap
Attribute Role	occurrence def AttributeRole
Characterization Attribute Coupling	connection def CharacterizationAttributeCoupling
Characterization Attribute Coupling Map	occurrence def CharacterizationAttributeCouplingMap
Class	occurrence def Class
Common Attributes	occurrence def CommonAttributes
Counter Requirement	requirement def CounterRequirementStatement
Decomposition Attribute	connection def

SysML V2 Library

```
1   //SMetamodel.sysml
2
3   package 'S*' {
4     doc /*
5     * This file defines metaclasses, and root classes for the Systematica Metamodel Version 8.0 05/01/2025
6     * Users specialize the classes corresponding to S*Metamodel classes which inherit their metadata markings.
7     */
8
9     private import ScalarValues::*;
10    private import Time::*;
11
12    occurrence def CommonAttributes {
13      doc /* Common Attributes are the subset of metaclass and metarelationship properties that apply
14        * to all Metaclasses and Metarelationships */
15      attribute author [0..1] : String {
16        doc /* An Author of a class is the person who last made changes to that class. */
17      }
18      attribute changeDate [0..1] : Date {
19        doc /* The Change Date of a class the time and date in which the latest changes were made to that
20  class. */
21      }
22      attribute changeDescription [0..1] : String {
23        doc /* The Change Description of a class is an explanation of the changes made to the previous
24          * version of that class */
25      }
26      attribute classLevel [0..1] : Integer {
27        doc /* The Class Level of a class is the depth of the class hierarchy in which that class is defined.
28          * This attribute indicates how abstract or specific a class with reference to the other classes
29          * defined. The smaller the level number, the more abstract a class is. The definitions and
30          * meanings of the class levels vary and are specific to an enterprise. */
31      }
32      attribute definition [0..1] : String {
33        doc /* The Definition of a class is a short summary of the concept that class models. */
34      }
```

Support SysML V2 team with S*Stakeholder Features examples and feedback

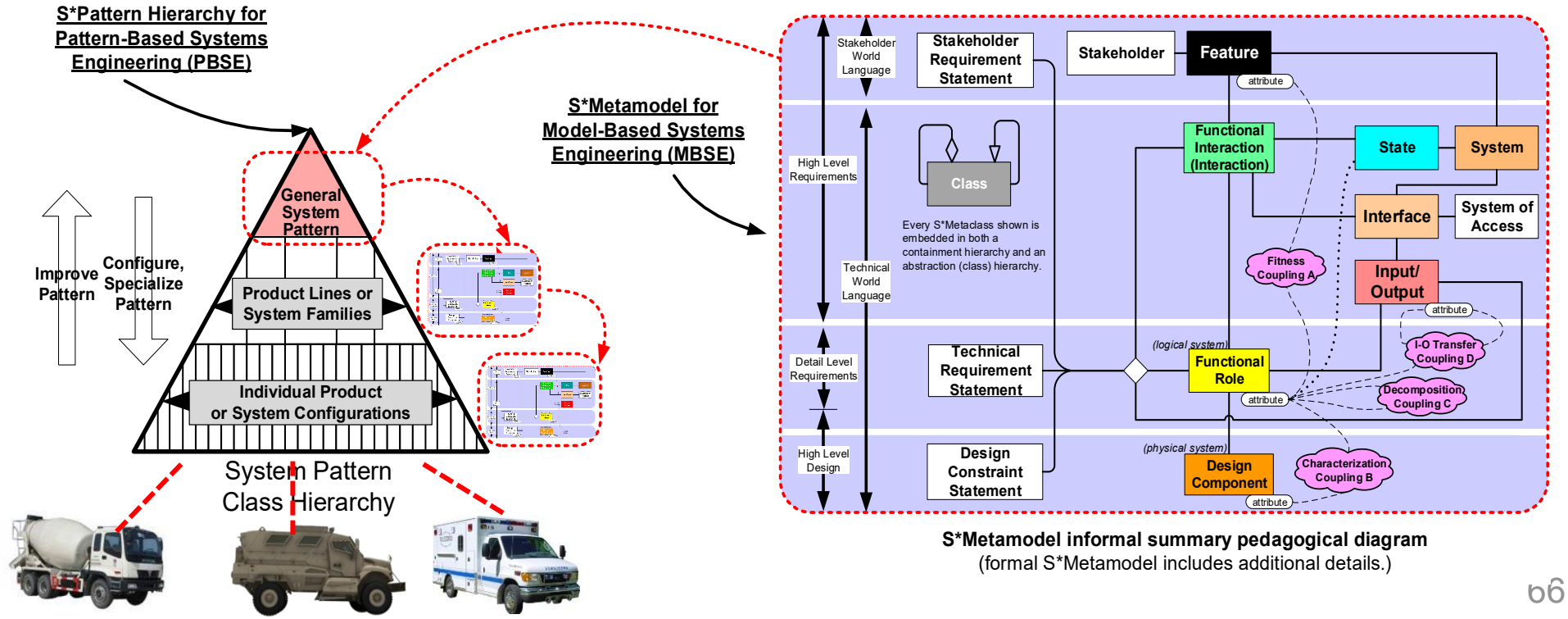
(Requested during IS2025 meeting of Patterns WG)



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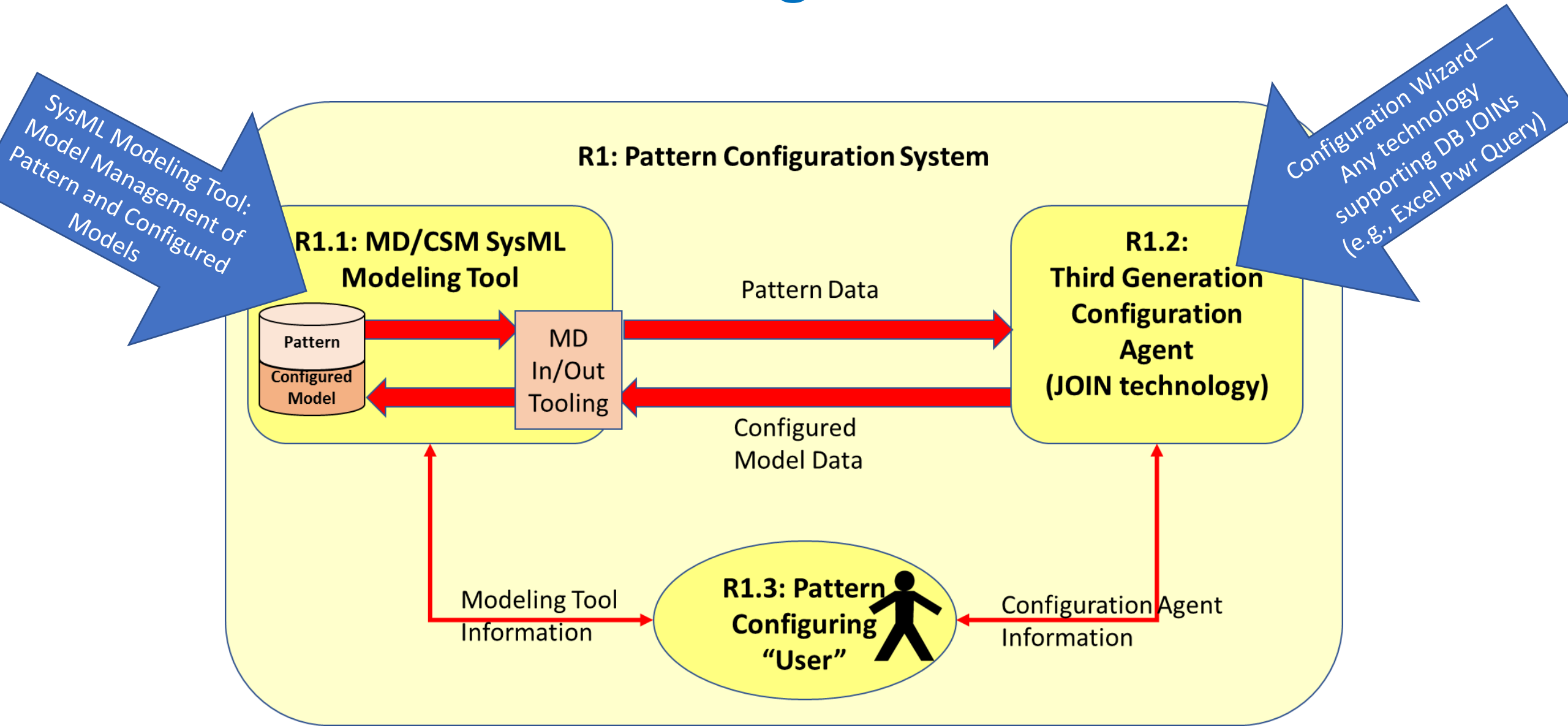
S*Pattern Configuration Wizard

- Auto-generates MBSE model in SysML tool, as configuration of Pattern.
- Extendable to any modeling tool.
- Configuration algorithm encodable in any JOIN-supporting environment.
- Configurable patterns for products, enterprise ecosystems, other models.
- Used in ST4SE Project.



S*Metamodel informal summary pedagogical diagram
(formal S*Metamodel includes additional details.)

S*Pattern Configuration Wizard



S*Pattern Configuration Wizard

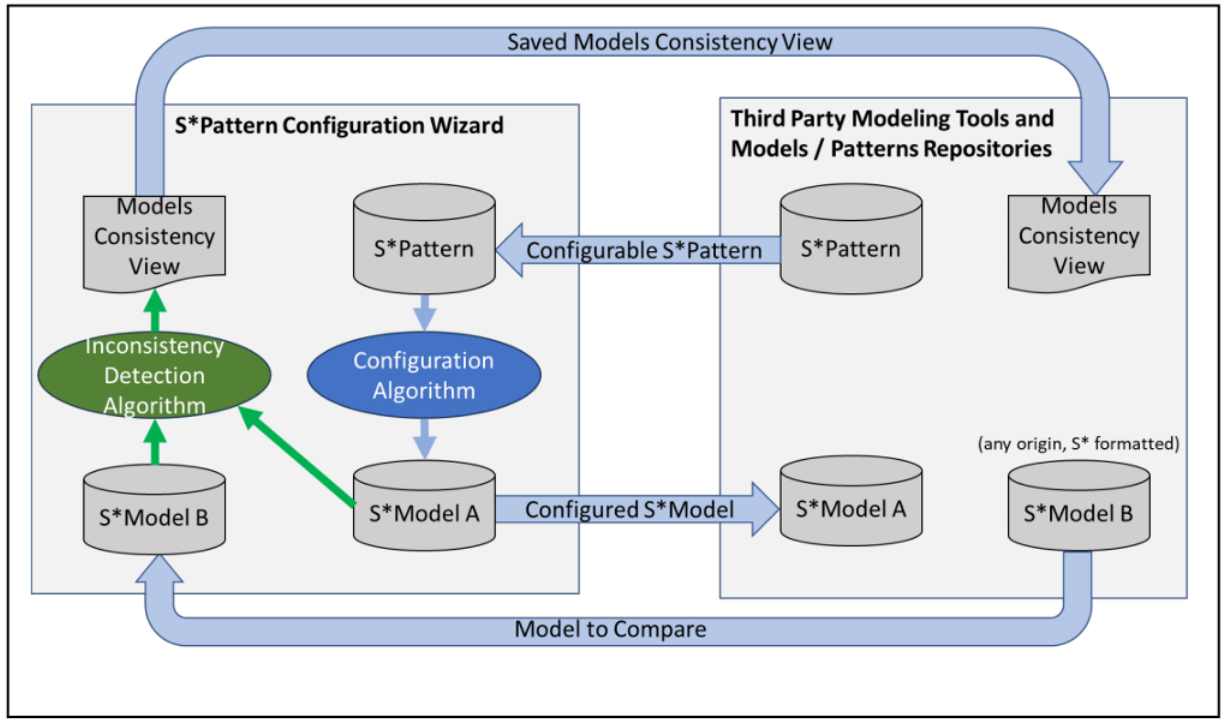
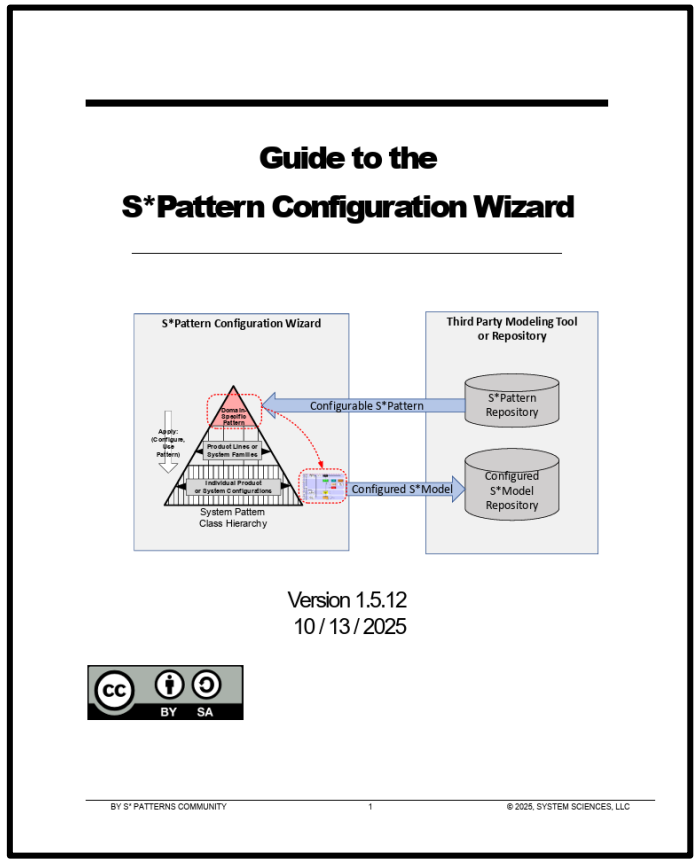


Figure 12 : Overview of Model AutoCompare

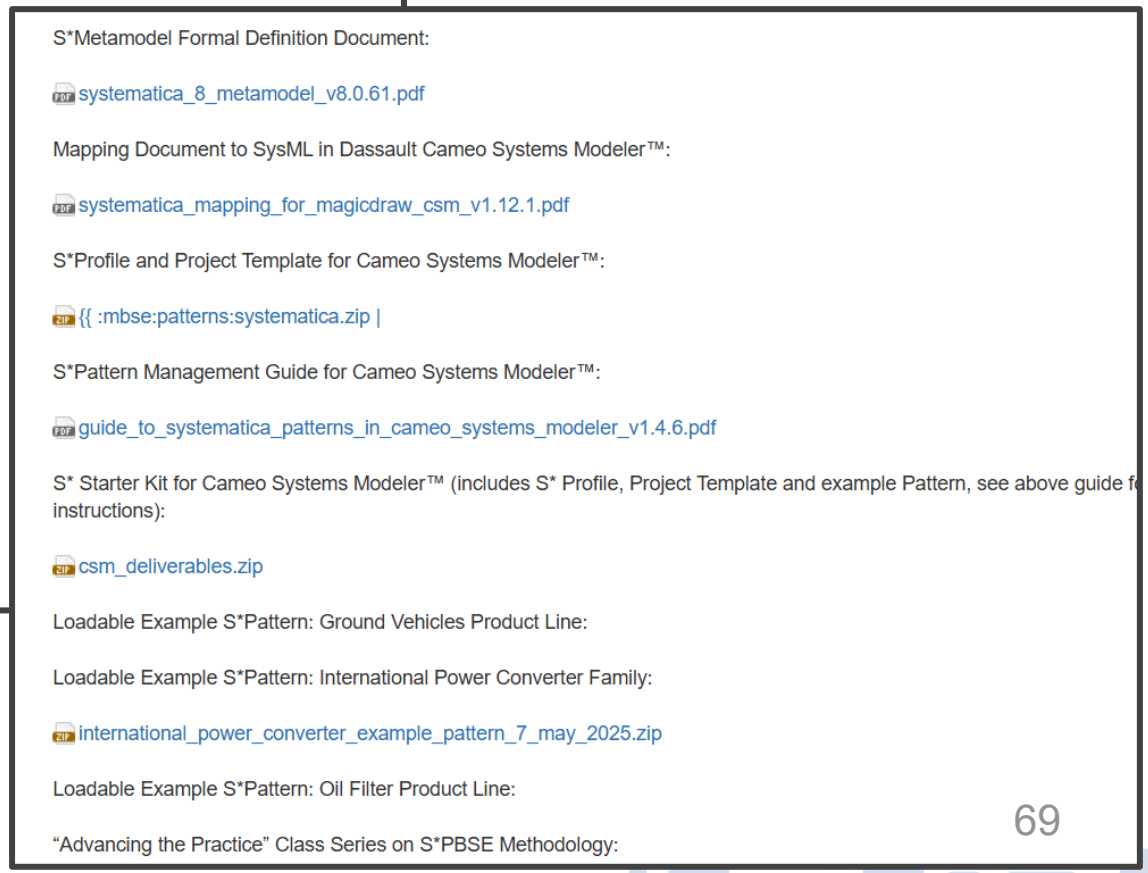


Download Link for Pattern Configuration WIzard Guide

- Added new capability to Pattern Wizard--
- Detection of inconsistencies between models.
- Includes “cosine distance” metric of distance between models.
- Support for ASELCM Consistency Management paradigm







S*Pattern Builder's Starter Kit

https://www.omgwiki.org/MBSE/doku.php?id=mbse:patterns:starter_kit_for_s_pattern_builders

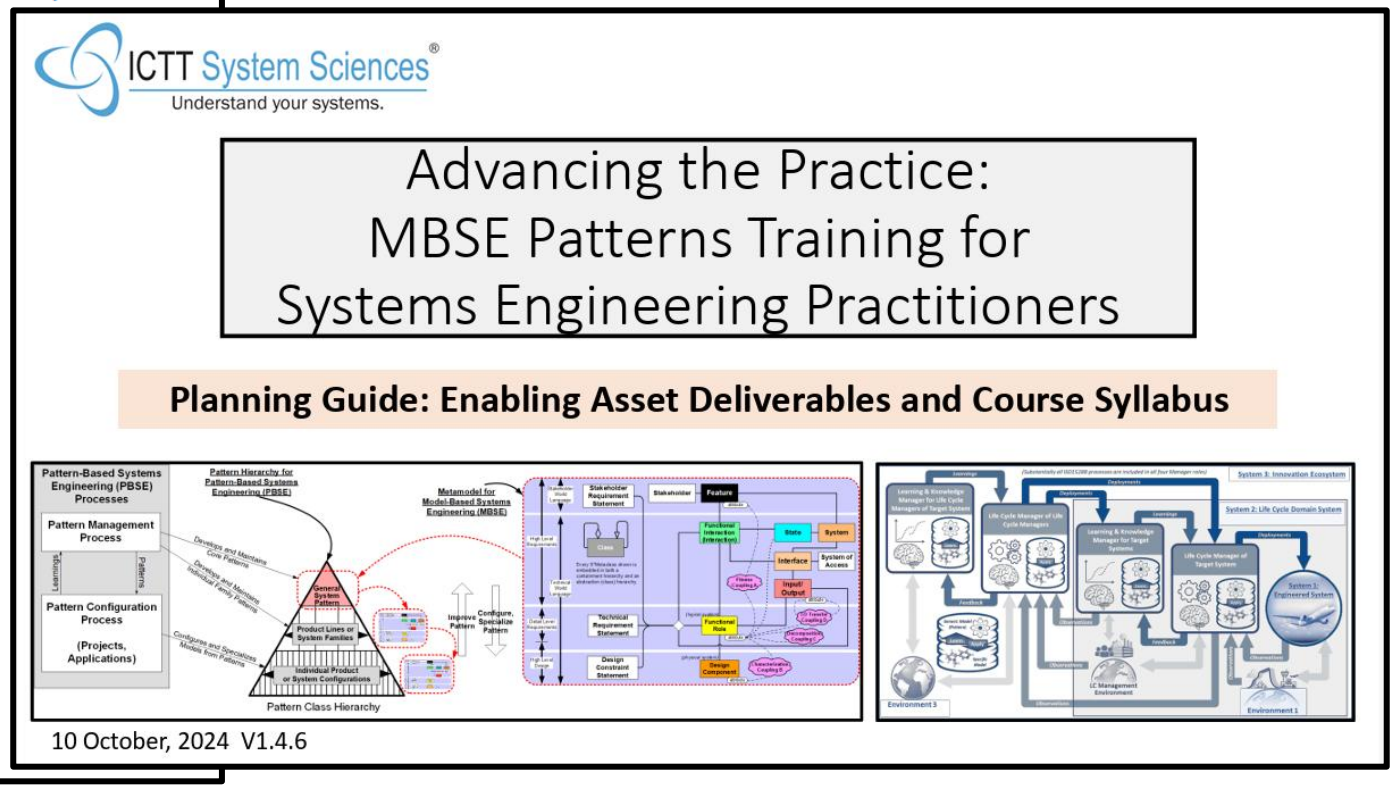
Class media added to the Starter Kit in 2025

- "Advancing the Practice" class media:
- 10 Class Modules, ~ 3 hours each
- Class Planning Guide and Course Syllabus

"Advancing the Practice" Class Series on S*PBSE Methodology:

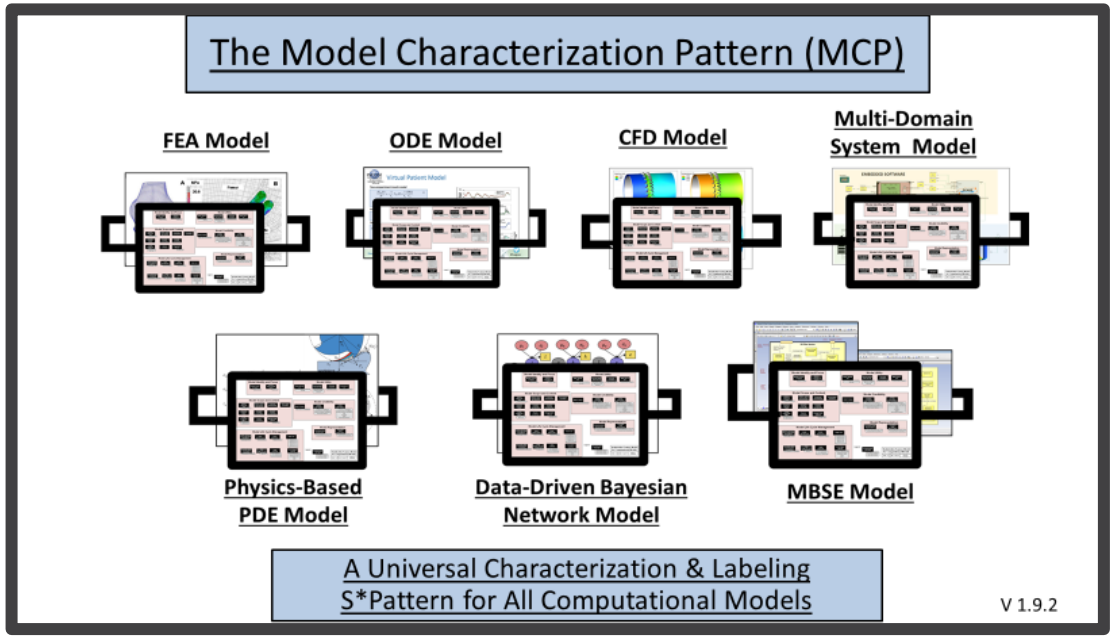
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- advancing_the_practice_phase_ii_session_3_v1.5.4.pdf
- advancing_the_practice_phase_ii_session_4_v1.4.9.pdf

https://www.omgwiki.org/MBSE/doku.php?id=mbse:patterns:starter_kit_for_s_pattern_builders



Universal Model Metadata Wrapper: The Model Characterization Pattern (MCP), w/ASME VV Standards Committee & V4 Institute

- Collaborating with ASME Standards Committee on Model Credibility, VV50 Subcommittee, Patterns WG created a configurable pattern for representing metadata on any virtual model, including Machine Learning, Simulation (FEA, CFD, SD, ODE), MBSE, otherwise. Auto generates Reqs for models. (ASME WG led by Joe Hightower.)
- AIAA Digital Systems Model WG using in describing digital information definition (DID).
- This universal metadata framework includes Model Identify and Focus, Model Utility, Model Scope and Content, Model Credibility, Model Representation, and Model Life Cycle Management.
- Those interested in participating can be a part of continued testing and feedback on the application of the MCP to model library organization and management, model exchanges and markets, and model life cycle credibility management.

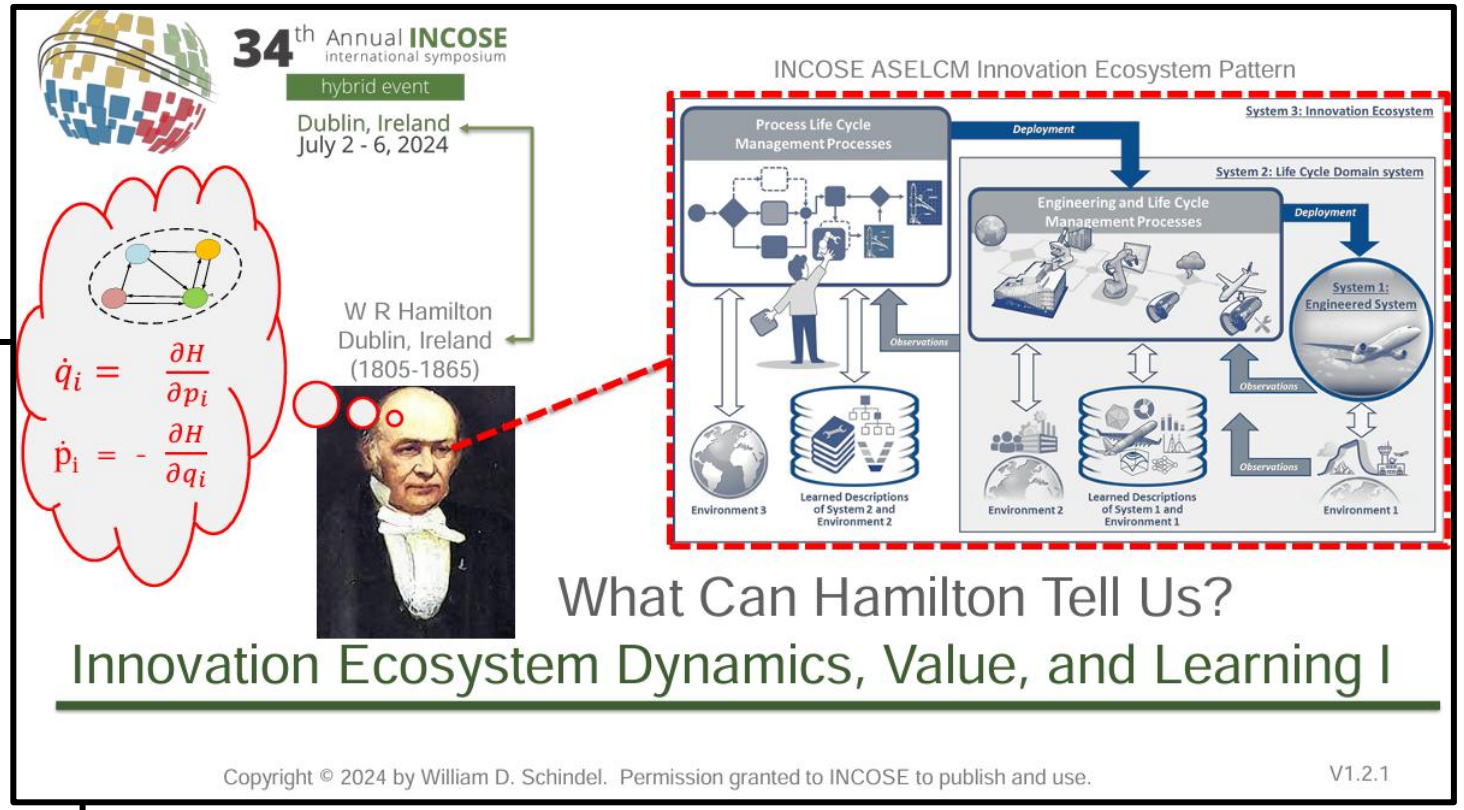


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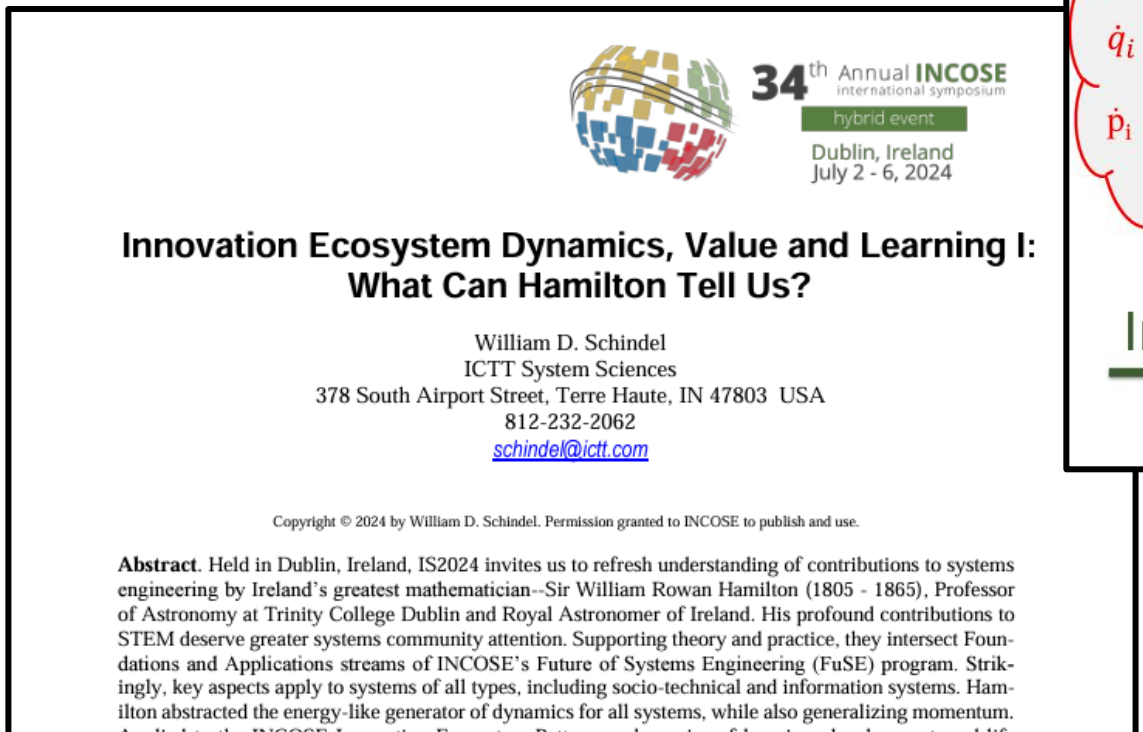
Support for INCOSE Vision 2035: Foundations, Applications

Connecting STEM theory and practice—both engineered products and innovation ecosystems

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34th Annual INCOSE international symposium
hybrid event
Dublin, Ireland
July 2 - 6, 2024

Innovation Ecosystem Dynamics, Value and Learning I: What Can Hamilton Tell Us?

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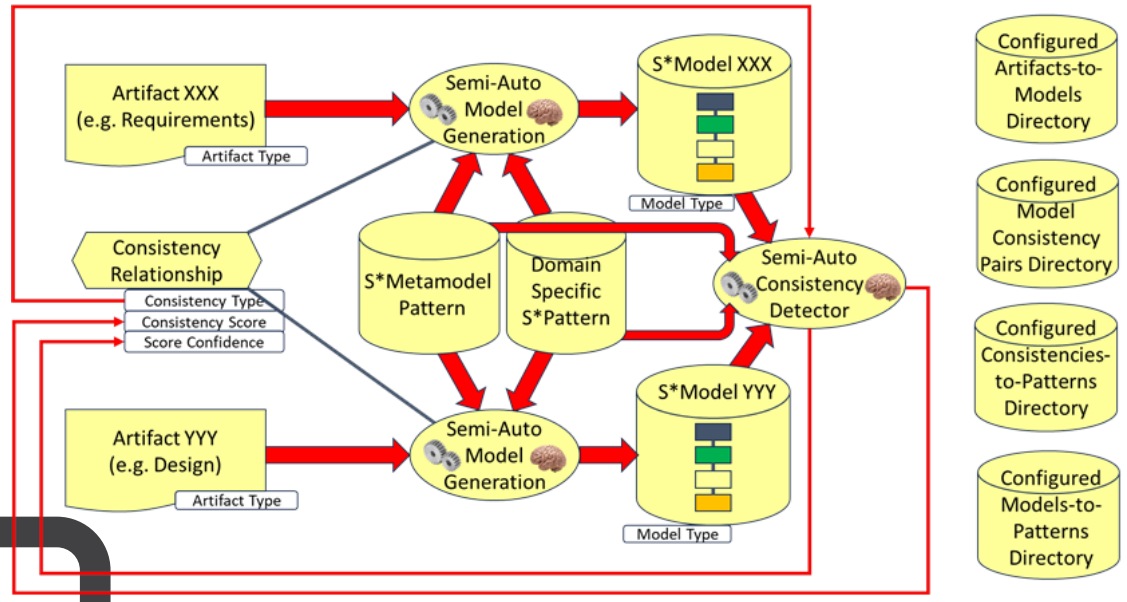
Abstract. Held in Dublin, Ireland, IS2024 invites us to refresh understanding of contributions to systems engineering by Ireland's greatest mathematician--Sir William Rowan Hamilton (1805 - 1865), Professor of Astronomy at Trinity College Dublin and Royal Astronomer of Ireland. His profound contributions to STEM deserve greater systems community attention. Supporting theory and practice, they intersect Foundations and Applications streams of INCOSE's Future of Systems Engineering (FuSE) program. Strikingly, key aspects apply to systems of all types, including socio-technical and information systems. Hamilton abstracted the energy-like generator of dynamics for all systems, while also generalizing momentum.

Related application of Hamiltonians for IT and socio-technical systems

- Adopting W R Hamilton's "characteristic function" perspective enriches interpretation of the nature of momentum and energy, in additional settings:
  - By reasoning in the right order, Hamiltonians can be defined for IT (i.e., digital) and socio-technical systems.
  - *Managed consistency gaps provide the potential energy part of the ASELCM System 2 Hamiltonian*.

Related application: Extending V&V foundations

NEW IN 2025



Innovation Ecosystem Dynamics, Value, Learning II: Can V&V Frameworks Tell Us More?

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Abstract. Can innovative system projects deliver faster, while also increasing earned confidence in the face of risk? This is not only a question of organizational paradigms, methods, and management—if we "push the envelope" far enough, it also begs the question of foundational limitations on underlying phenomena and capabilities of all systems of development, production, and other life cycle management, viewed as systems in their own right. Limitations on capabilities (including risks) of an engineered aircraft, bridge, or motor vehicle are ultimately constrained, through their designs, by underlying first principle phenomena. Is this perspective also applicable to phenomena of socio-technical innovation ecosystems?

This second paper in a series picks up where the first left off—with the underlying dynamics of systems of innovation, viewed through a Hamiltonian lens. That perspective showed how verification and validation (V&V) can be seen as more than the traditional "checks on the main work". Instead, they highlight *consistency gaps* which define the potential energy framework of the innovation ecosystem's Hamiltonian, driving the entire ecosystem.

But what happens when V&V frameworks, created in eras of pre-information technologies, are applied to engineering of cyber-physical systems? This paper summarizes results of a recent cross-disciplinary study of V&V frameworks of four technical societies, covering a range of engineered cyber-physical systems.

It may seem impractical to apply the mathematics of historical hard technologies to the human-intensive socio-technical systems of the supply chain ecosystem itself. But as a greater portion of such ecosystems are implemented in machine learning agents, the dynamics of such a hybrid human-IT socio-technical ecosystem, managing engineered cyber-physical systems, becomes a more attractive subject. Foundational limits don't just tell us what is impossible—they also tell us what is possible.

Keywords. Innovation Ecosystem, Verification and Validation, Cyber-Physical System, Hamiltonian, Machine Learning, Rapid Delivery, Risk Management

Introduction

Both commercial and defense domains have pressing interests in dramatically improving the performance of innovation ecosystems—the socio-technical supply chain systems of development, production, supply and distribution, and other life cycle management. Such ecosystems are often described in terms of human-

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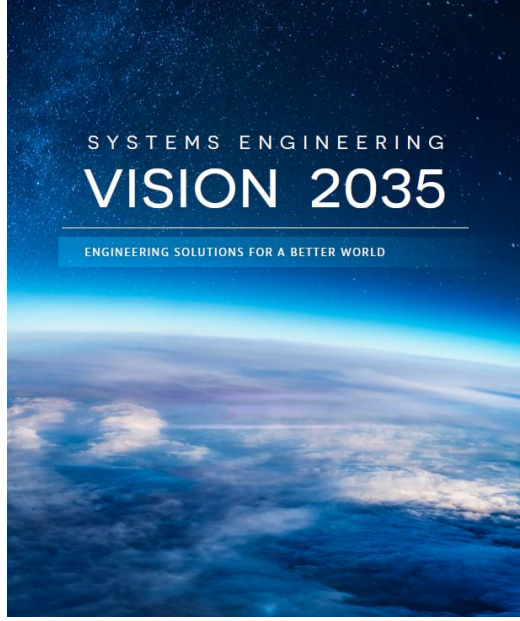
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Innovation Ecosystem Dynamics, Value and Learning I: What Can Hamilton Tell Us?

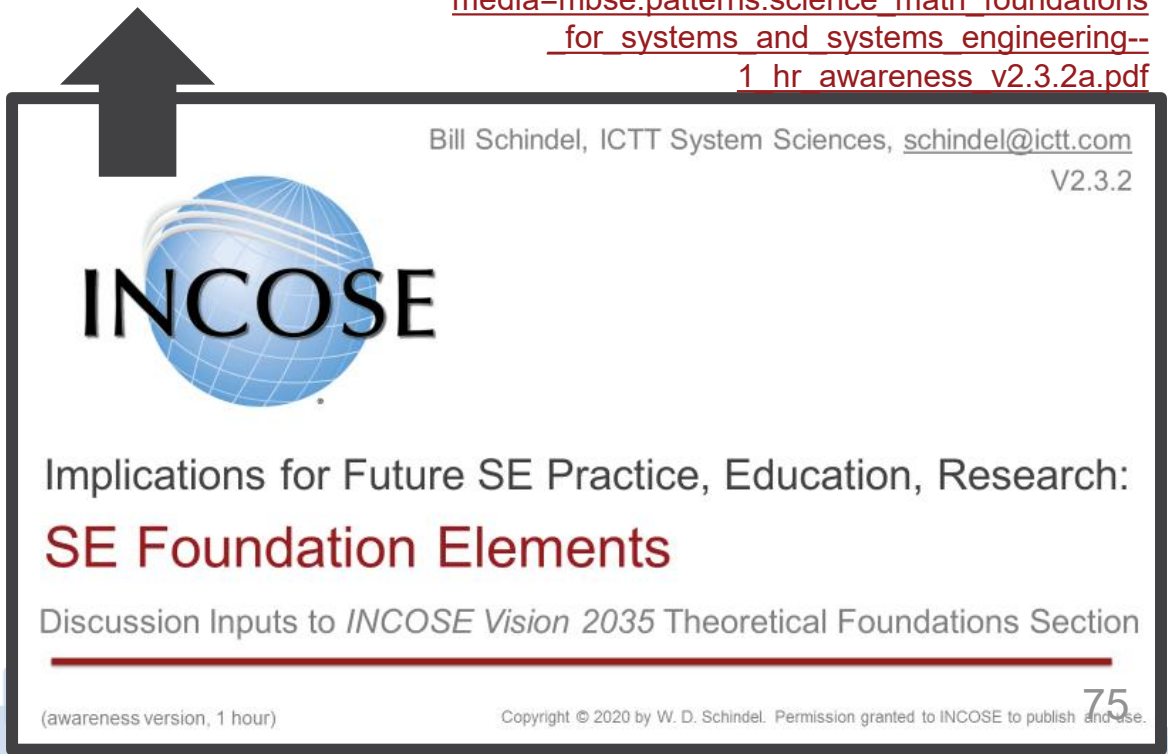
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INCOSE Vision 2035 contributions, from WG's SE Theoretical Foundations Project

- The Patterns Working Group provided invited content on SE Theoretical Foundations for the *INCOSE Vision 2035* publication project, completed for IW2022.
- Publication project led by editorial team chaired by S. Friedenthal.
- Material drawn from the ongoing SE Theoretical Foundations Project of the Patterns Working Group.
- Participating in related INCOSE FuSE streams



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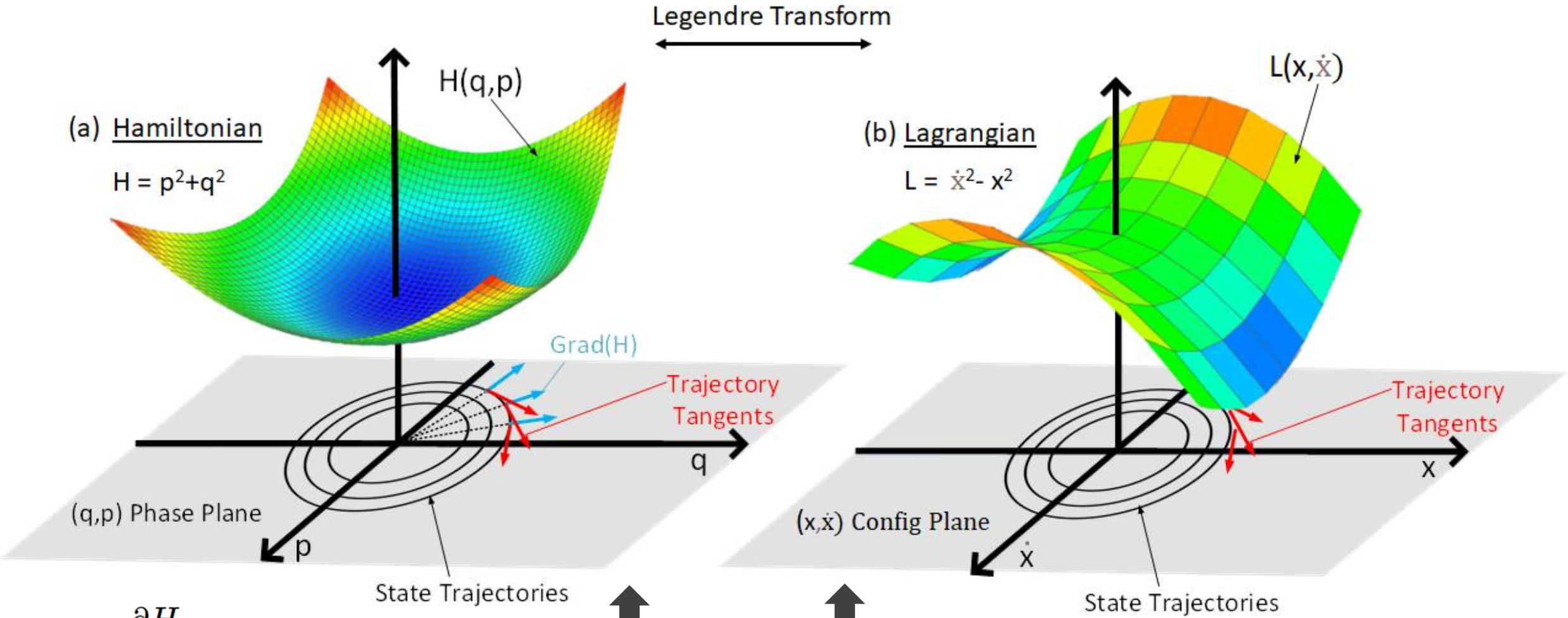


An alternate order for introducing and interpreting Hamiltonian and Hamilton's equations of motion

- Traditional Sequence (based on recognized energies of familiar types):
  - Start from an accepted Lagrangian for a familiar system class, energies (e.g., mechanical).
  - Perform Legendre transformation to obtain Hamiltonian (H).
  - H satisfies Hamilton's equations of motion, including generalized momentum, conservation of energy, etc., and is directly integrable via symplectic integrators.
- Alternate Sequence (based on observation of state trajectories):
  - Start with any deterministic[2] system and its state variables (state 'positions', velocities).
  - Observe the state trajectories of the system over time.
  - Generate a "characteristic function" H *from the observed state trajectories*[3].
  - This H likewise satisfies Hamilton's equations of motion, defines a generalized momentum, and is integrable via symplectic integrators.
  - Provides a broader interpretation of P.E. and K.E. beyond more familiar mechanical and other "traditional" systems—energy as a "characteristic function" in spirit of Hamilton.

(2) Also formulated for probabilistic and discrete systems. (3) One interesting method: Machine learning.

Example: Simple Harmonic Oscillator (SHO)



$$\dot{q}_i = \frac{\partial H}{\partial p_i}$$

$$-\dot{p}_i = \frac{\partial H}{\partial q_i}$$

$where\ \ p_i \equiv \frac{\partial H}{\partial \dot{x}_i}$

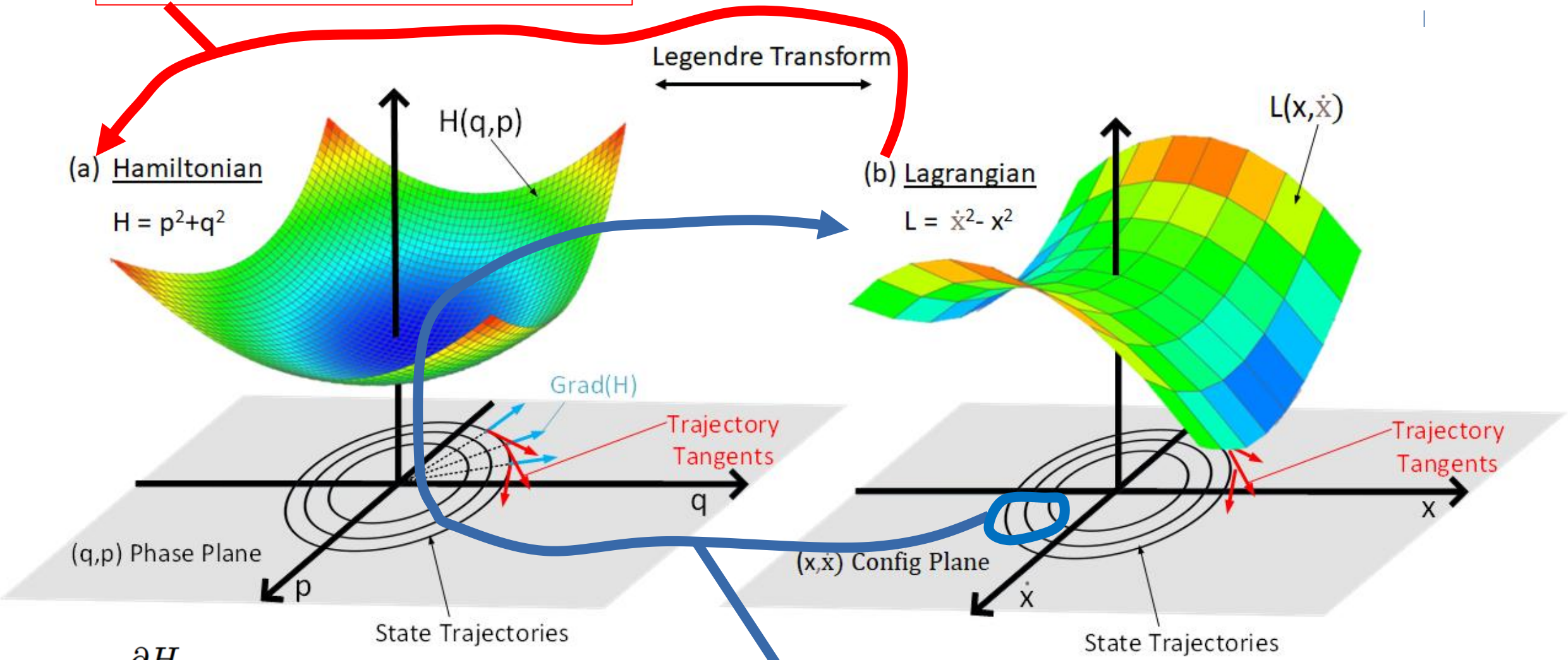
← Hamilton

Euler-Lagrange →

$$\frac{\partial L}{\partial x_i} - \frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{\partial L}{\partial \dot{x}_i}\right) = 0$$

Example: Simple Harmonic Oscillator (SHO)

Traditional Reasoning Sequence



Alternate Reasoning Sequence

$$\dot{q}_i = \frac{\partial H}{\partial p_i}$$

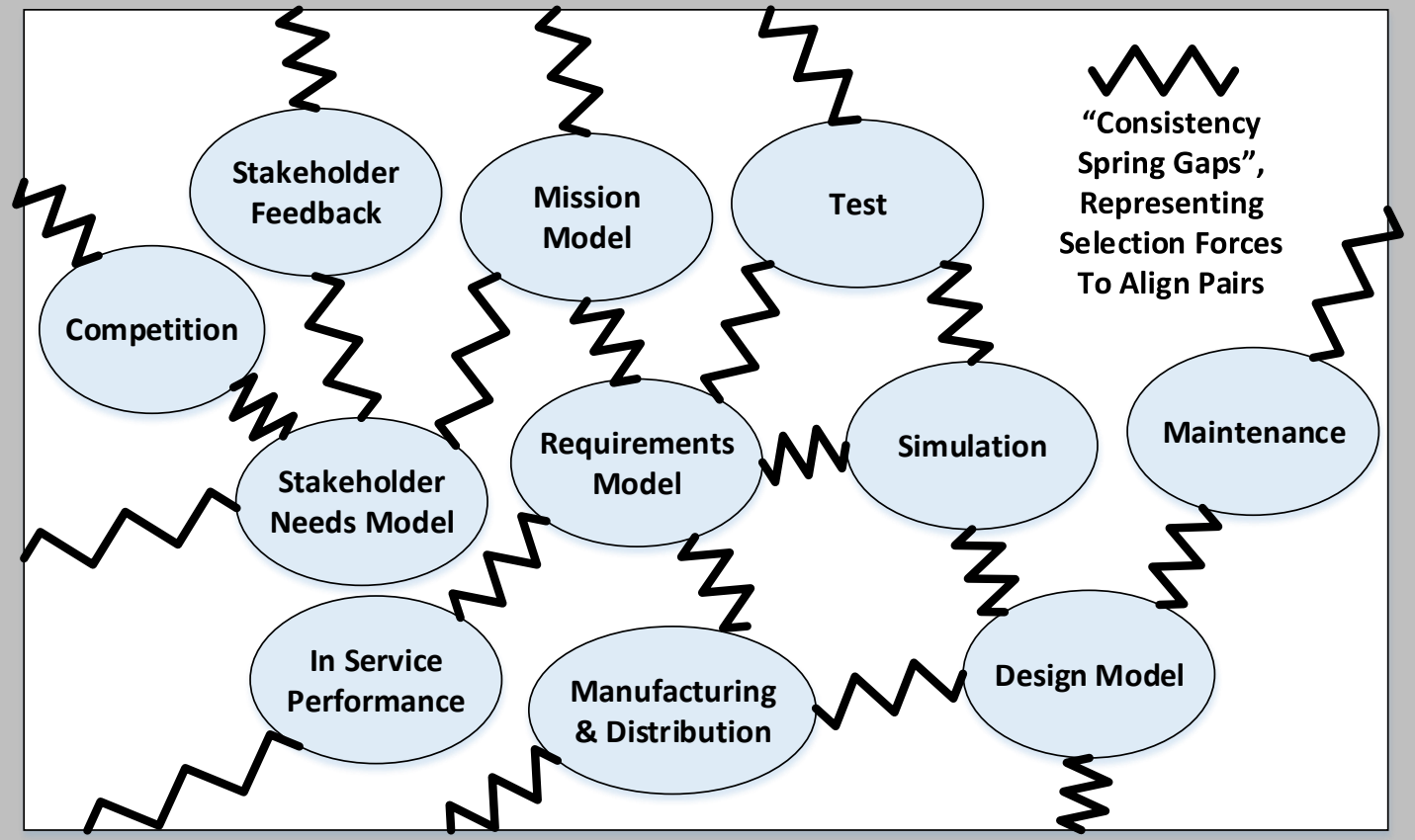
$$-\dot{p}_i = \frac{\partial H}{\partial q_i}$$

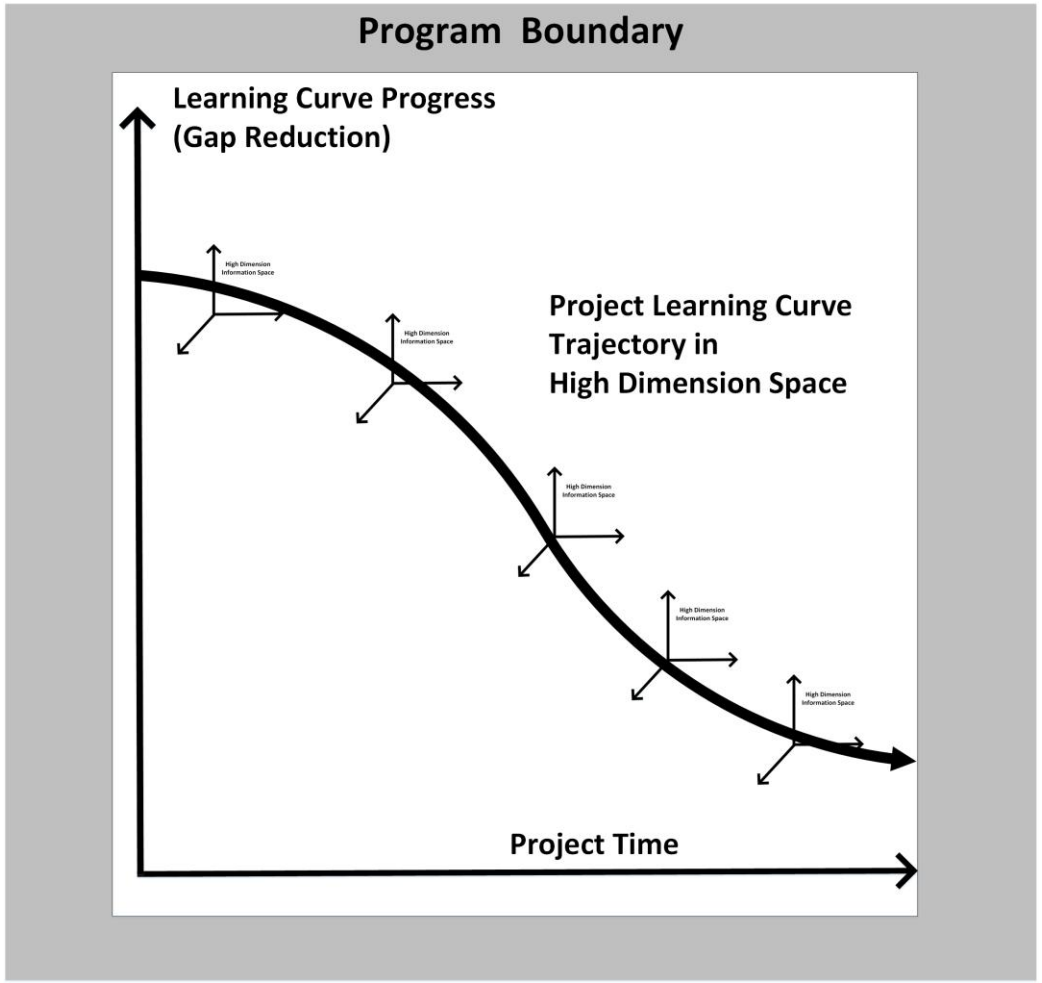
$$where \;\; p_i \equiv \frac{\partial H}{\partial \dot{x}_i}$$

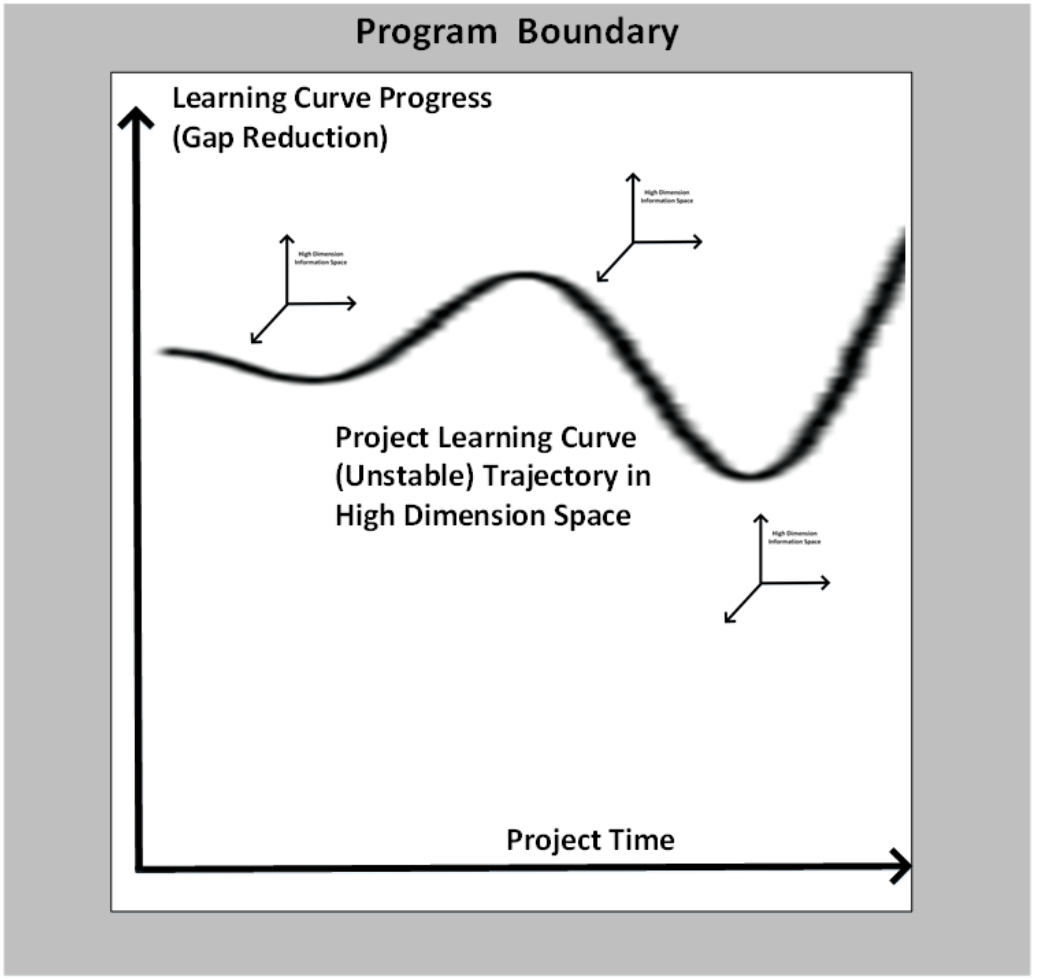
$$\frac{\partial L}{\partial x_i} - \frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{\partial L}{\partial \dot{x}_i}\right) = 0$$

Details: Related IS2024 Paper

Program Boundary



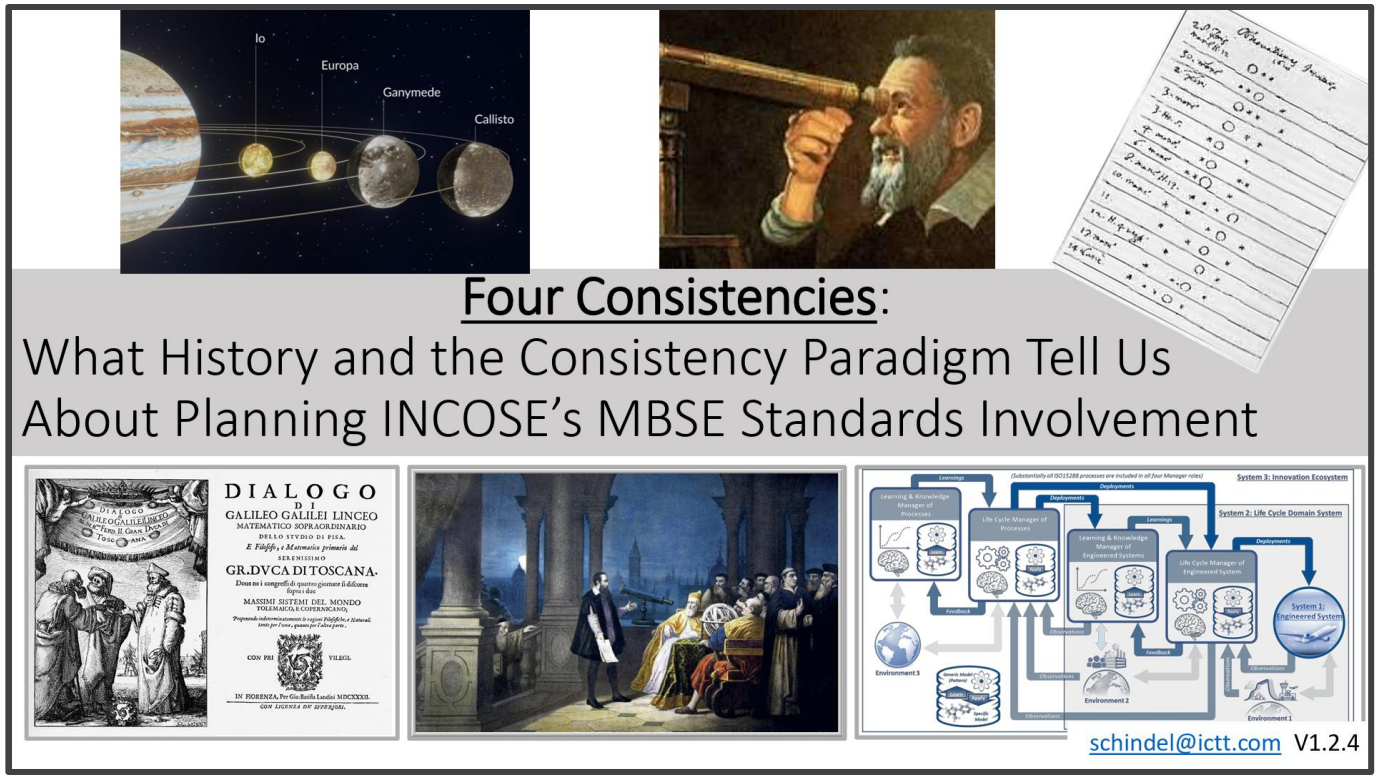

Program Boundary
Learning Curve Progress
(Gap Reduction)
High Dimension Information Space
Project Learning Curve
Trajectory in
High Dimension Space
Project Time


Program Boundary
Learning Curve Progress
(Gap Reduction)
High Dimension Information Space
Project Learning Curve
(Unstable) Trajectory in
High Dimension Space
Project Time

INCOSE INSIGHT Digital Engineering Edition: Standards Proposal Joint Article with DEIX Working Group

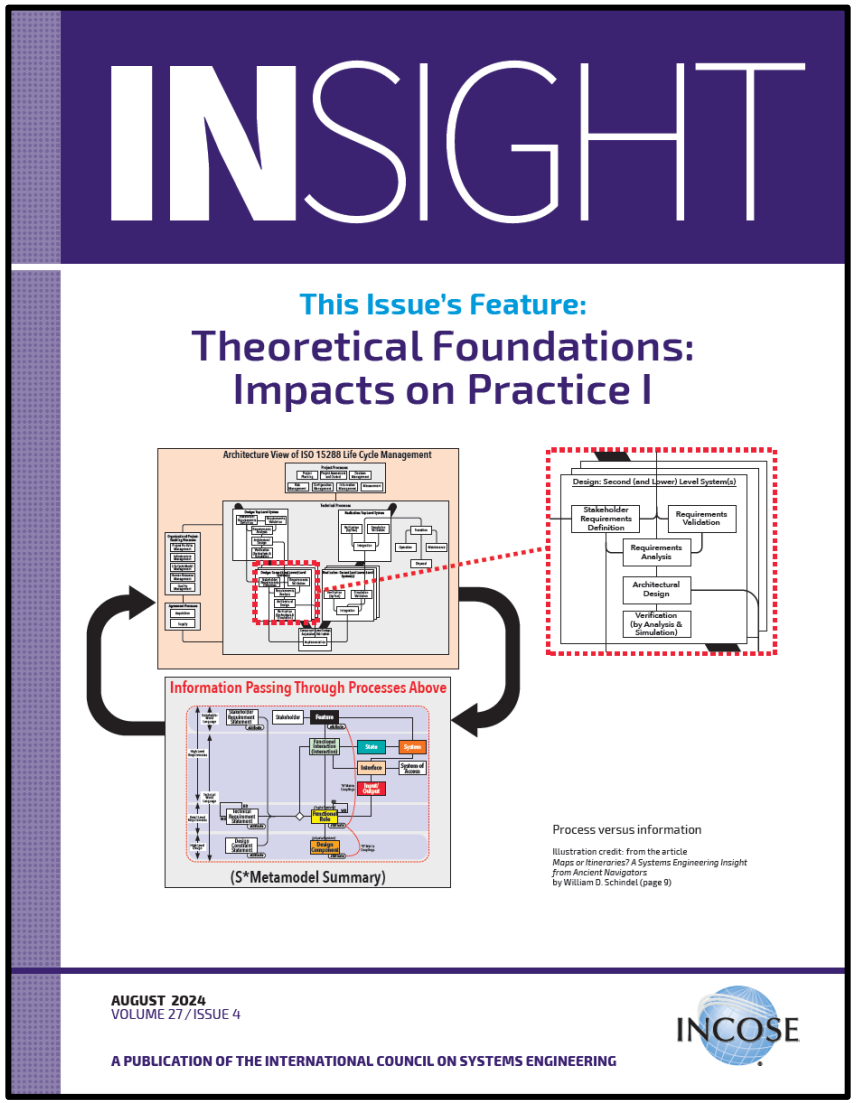


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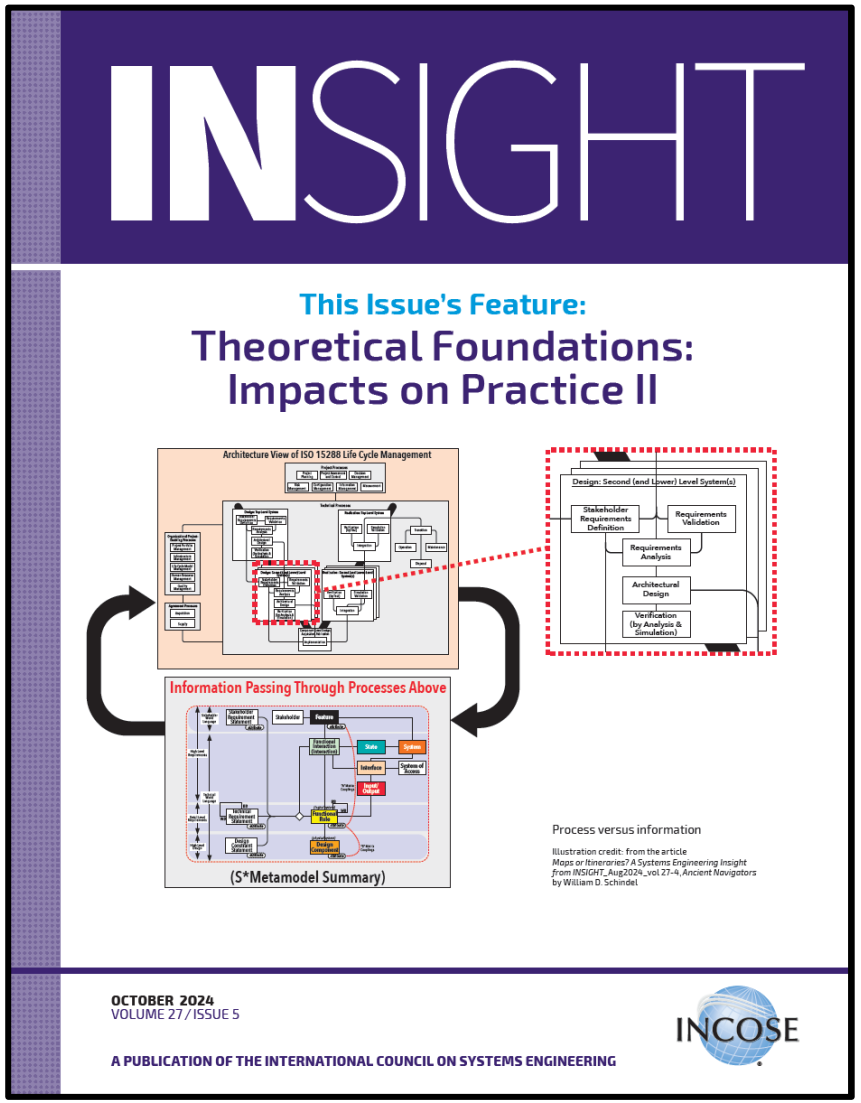


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INCOSE INSIGHT Special Issues on Practice Impacts of PWG



August 2024



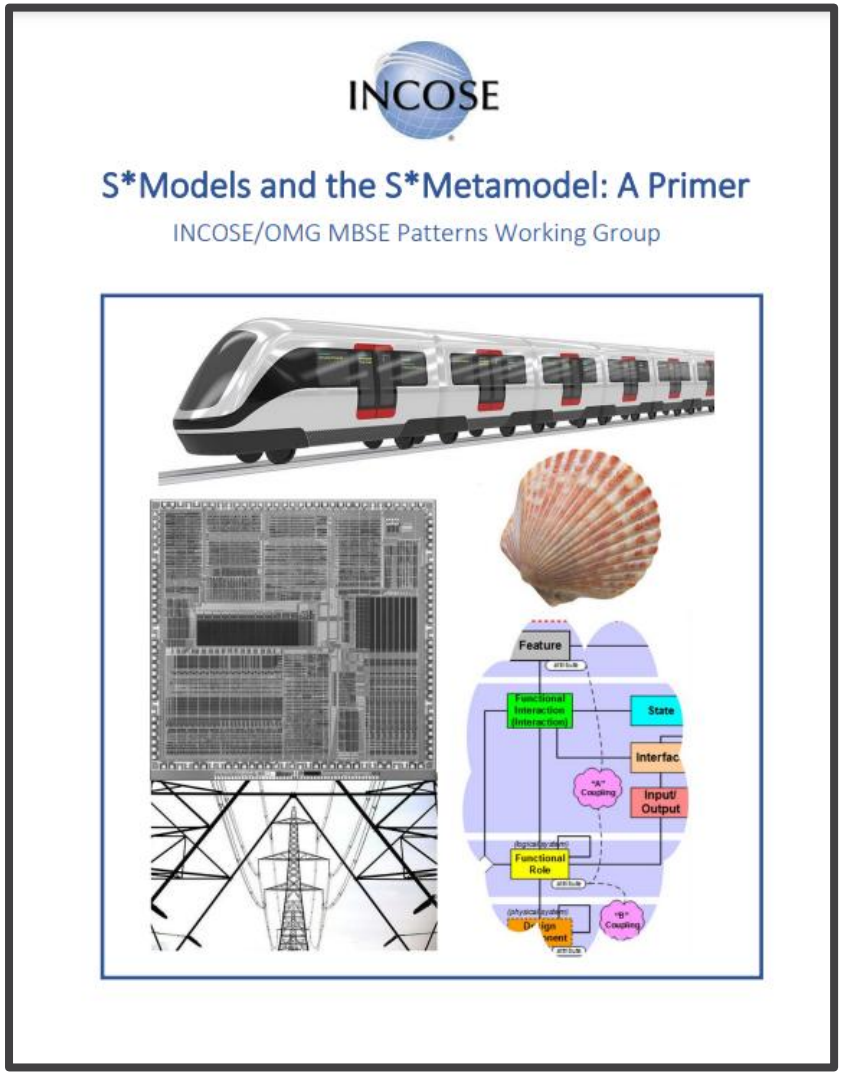
October 2024

Editor in Chief: William Miller, leader of INCOSE Future of Systems Engineering (FuSE) Initiative, proposed and guided this special issues pair.

Minimal S*Models—A Primer

Review Copy Available

- Introduction to S*Metamodel & its mapping to 3rd party COTS modeling tools.
- The laws of nature which are the basis of the natural sciences are all formal descriptions of recurring patterns associated with observable phenomena.
- Finding the smallest model-based representation of those patterns has important practical as well as theoretical importance.
- The practical importance is reduction of unnecessary proliferation of information that is redundant and often inconsistent or conflicting.
- The theoretical importance is that size of minimal models is one of formal measures of (Kolmogorov) complexity.
- Independent of choices of modeling languages, tools, and methods, we want to base our representation of system patterns on the simplest framework necessary for the purposes of engineering and science over the life cycle of systems.
- This Primer is to describe S*Models and the S*Metamodel—a long-tested pattern based on the history of physical sciences and engineering, focused on the minimal information set.
- Those interested in participating can be a part of writing and review of this S*Metamodel Primer—including examples.

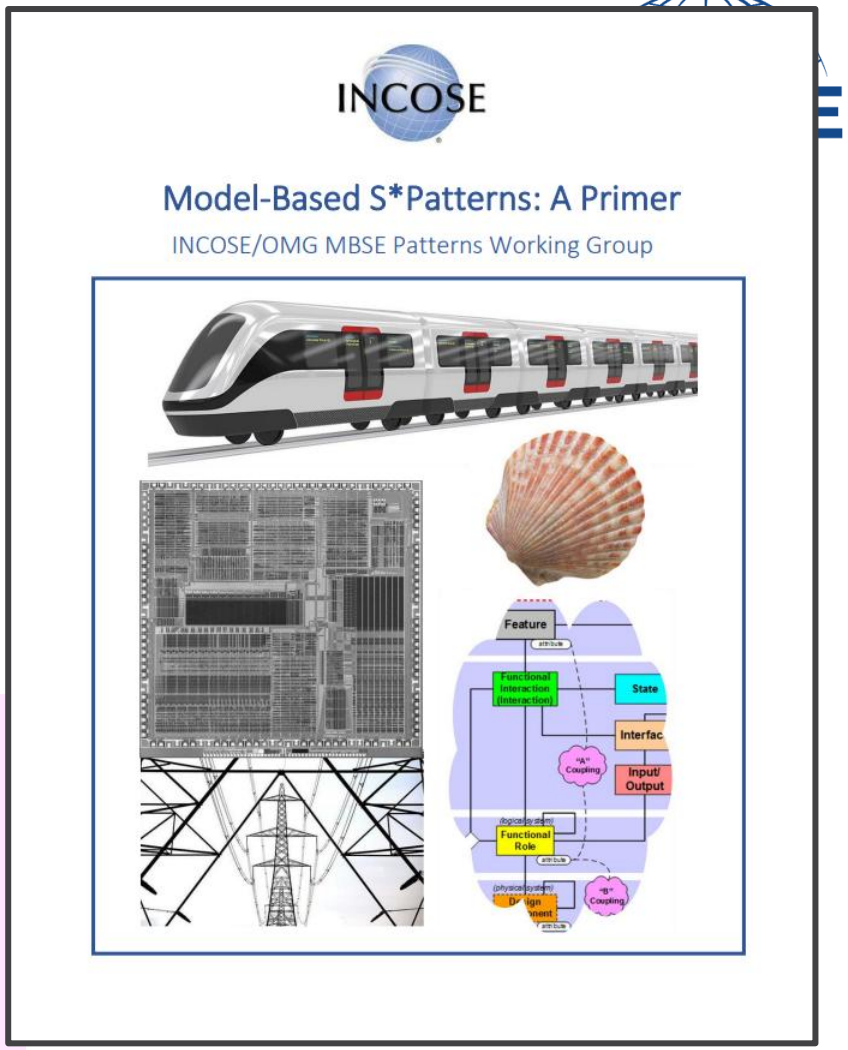


https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:s-models_and_the_s-metamodel--a_primer_wg_review_draft_v1.2.2.pdf

S*Patterns Primer (second edition)

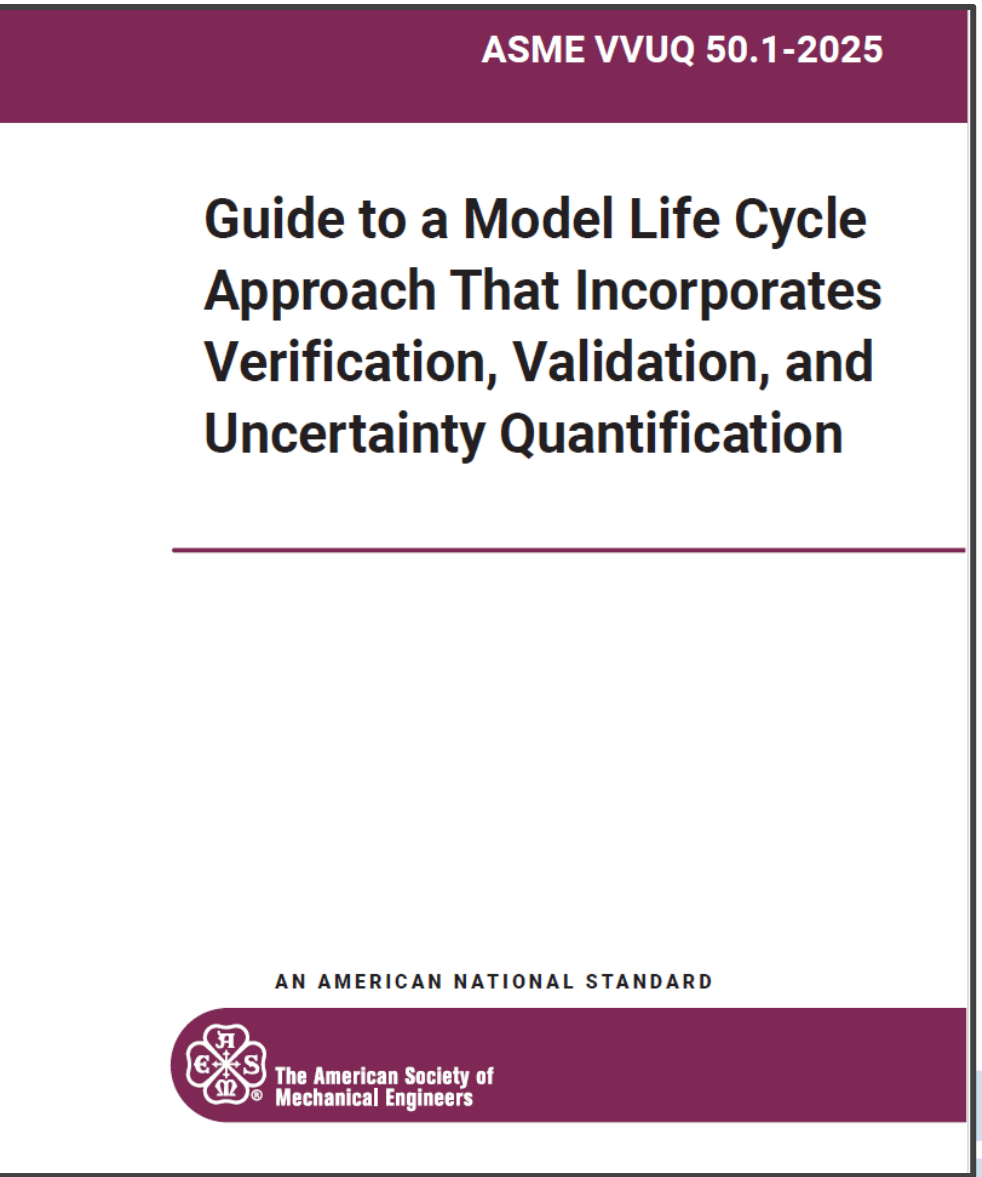
Review Copy Available

- The Patterns WG generated an introduction and overview of pattern-based methods and their relationships with other subjects—this was several years ago and before the emergence of newer INCOSE Tech Ops approaches to INCOSE Technical Product “primers” on various subjects supported by the working groups.
- This project is concerned with recasting the earlier publication in the form of an updated “Primer” on model-based patterns and related subjects.
- Those interested in participating can be a part of review of the earlier document and newer INCOSE primers, regeneration of an updated primer form asset, or review of the resulting document for submission as a Technical Product.



https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:s-patterns--a_primer_wg_review_draft--v1.2.1.pdf

ASME Guideline for Managing Credibility of Models for Adv. Manufacturing, w/ASME VV50 Standards Working Grp.



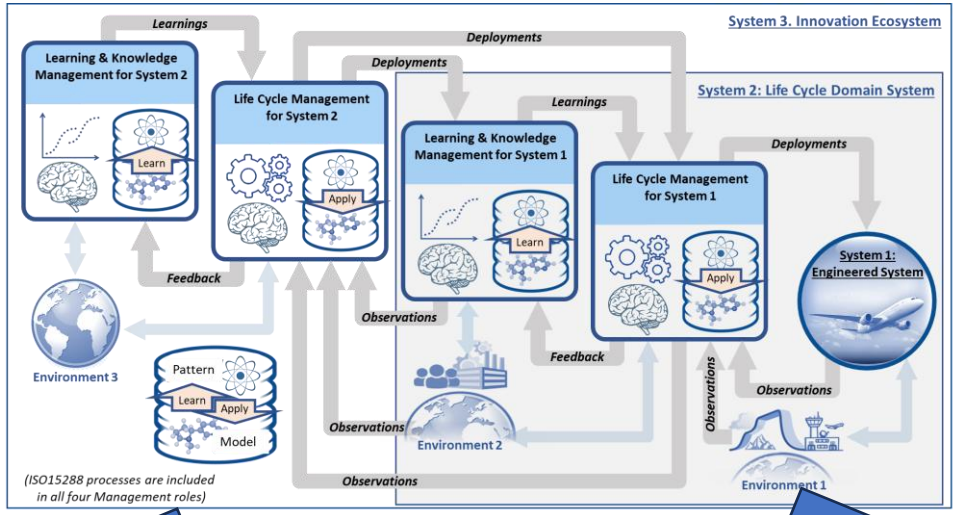
- ASME VV50 Standards-writing project supported by INCOSE PWG began 2016.
- Combining lessons of computational model VVUQ with lessons of MBSE model learning and credibility, supported by Model Characterization Pattern (MCP).
- Incorporated the Rosetta Stone Project mapping across multiple society VVUQ standards.
- ASME balloting passed in 2024, 2025; **standard published in Jan 2026**
- Download from ASME Standards Store

The INCOSE System of Innovation Ecosystem Pattern: Used by AIAA for its Aero Digital Thread & Digital Twin reference models

June, 2023



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ASELCM Level 1 Reference Model

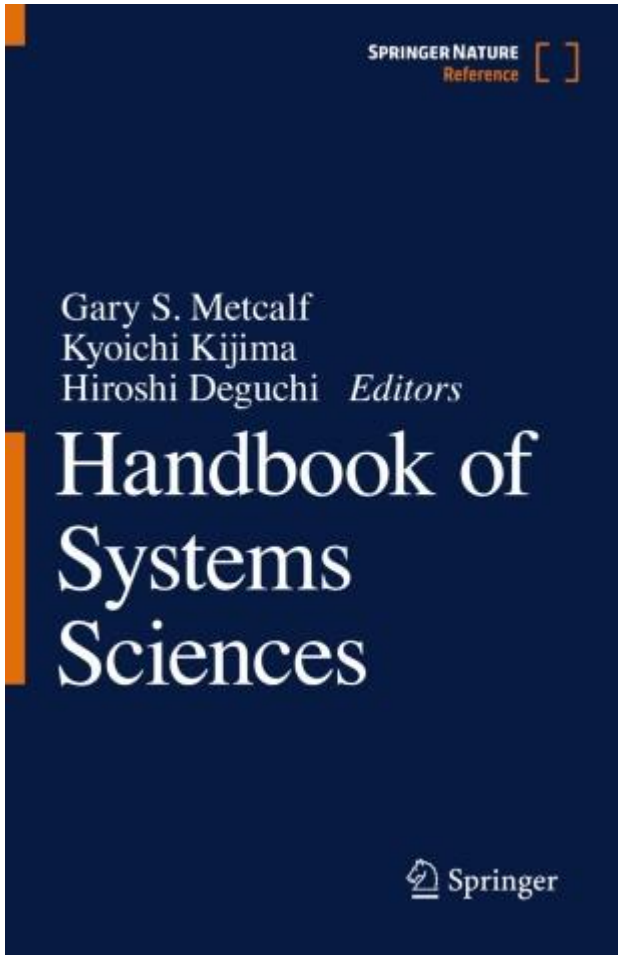
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Handbook of System Sciences, for ISSS via Springer--Chapter: “Patterns in Science and Engineering”, w/ISSS





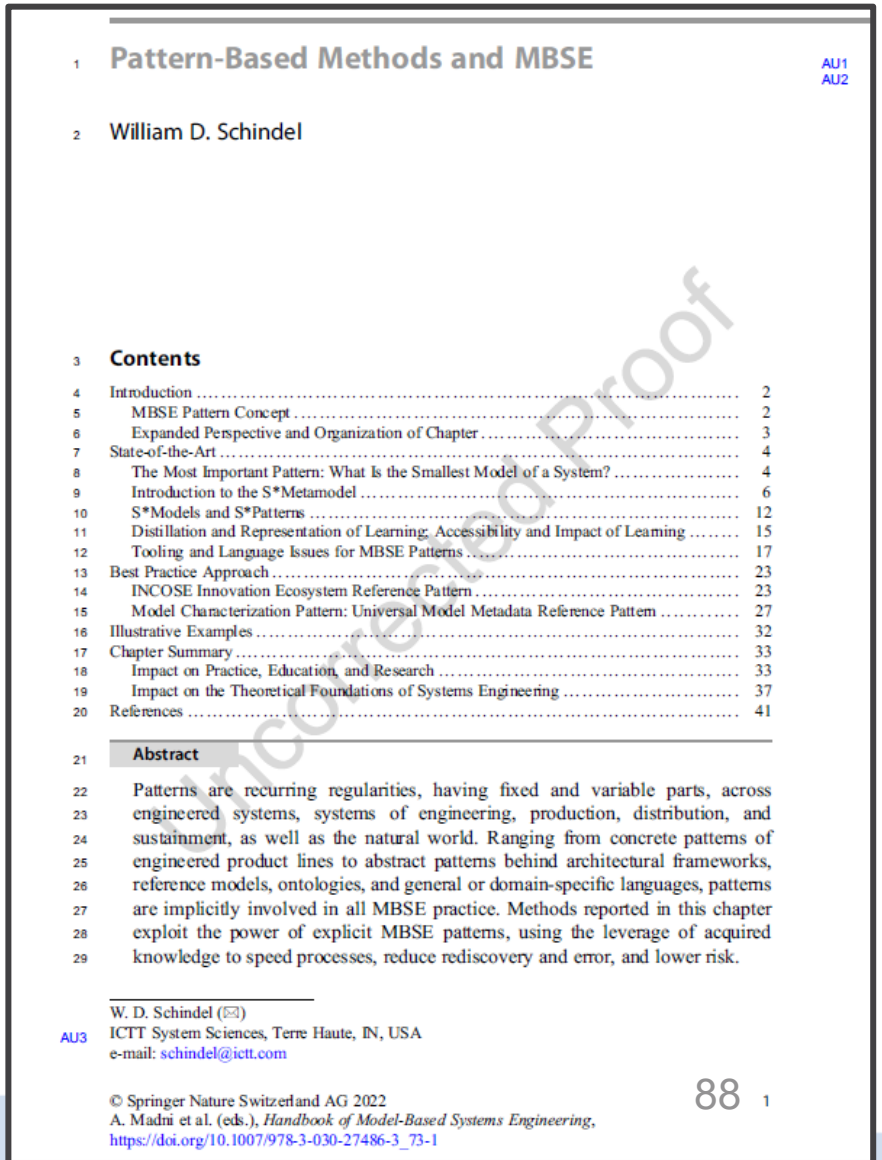
- ISSS Reference Textbook project supported by Patterns Working Group.
- Chapter on “System Patterns in Engineering and Science”
- An ISSS-INCOSE effort.

https://link.springer.com/referencework/10.1007/978-981-15-0720-5

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- Generation of “Pattern-Based Methods and MBSE” chapter for new *Handbook of Model-Based Systems Engineering.*
- Editors: A. Madni and N. Augustine.

https://link.springer.com/referencework/10.1007/978-3-030-93582-5



1 Pattern-Based Methods and MBSE AU1 AU2

2 William D. Schindel

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21 Abstract

22 Patterns are recurring regularities, having fixed and variable parts, across
23 engineered systems, systems of engineering, production, distribution, and
24 sustainment, as well as the natural world. Ranging from concrete patterns of
25 engineered product lines to abstract patterns behind architectural frameworks,
26 reference models, ontologies, and general or domain-specific languages, patterns
27 are implicitly involved in all MBSE practice. Methods reported in this chapter
28 exploit the power of explicit MBSE patterns, using the leverage of acquired
29 knowledge to speed processes, reduce rediscovery and error, and lower risk.

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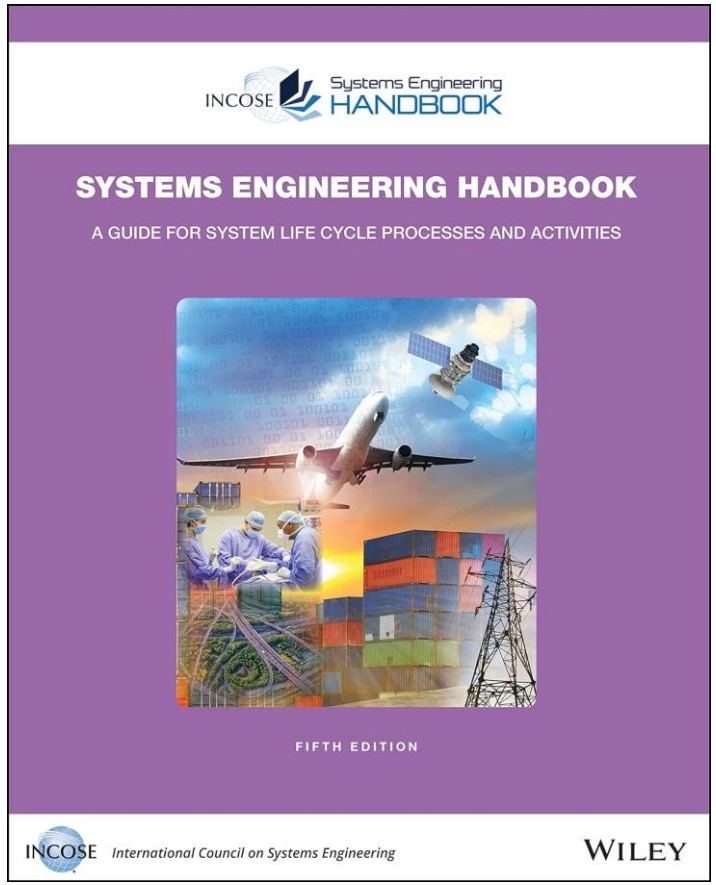
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A. Madni et al. (eds.), *Handbook of Model-Based Systems Engineering*,
https://doi.org/10.1007/978-3-030-27486-3_73-1

Uncorrected Proof

INCOSE SE Handbook, 5th Ed., for INCOSE, D. Contributed invited material on ASELCM Pattern, Pattern-Based Methods, and S*Metamodel

- The Patterns Working Group contributed invited content on pattern-based methods to the INCOSE SE Handbook, 5th edition project, now available.
- The structure of the 5th Edition of the SE Handbook was re-architected compared to past editions, based on progress and needs of the community.
- New content on S*Patterns and S*Metamodel.
- Overall project led by INCOSE Handbook Editorial Team, chaired by Dave Walden.



New (5th) Edition

Discussion of additional and future interests of attendees

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Thank you.



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