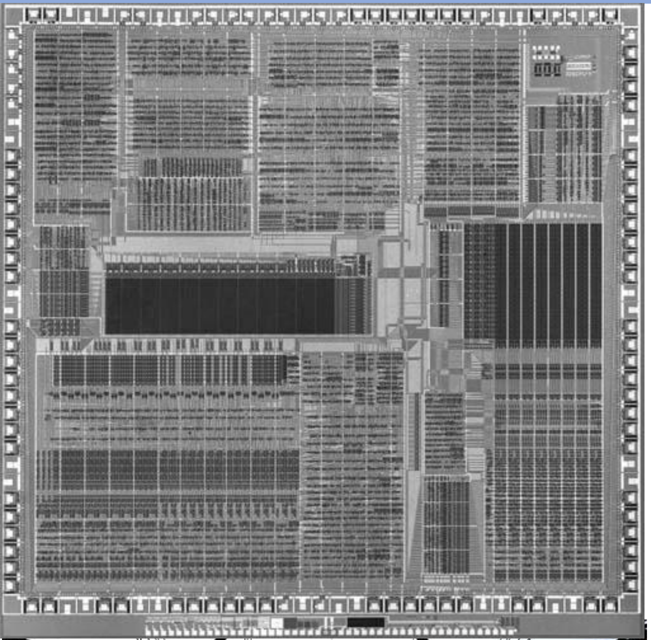
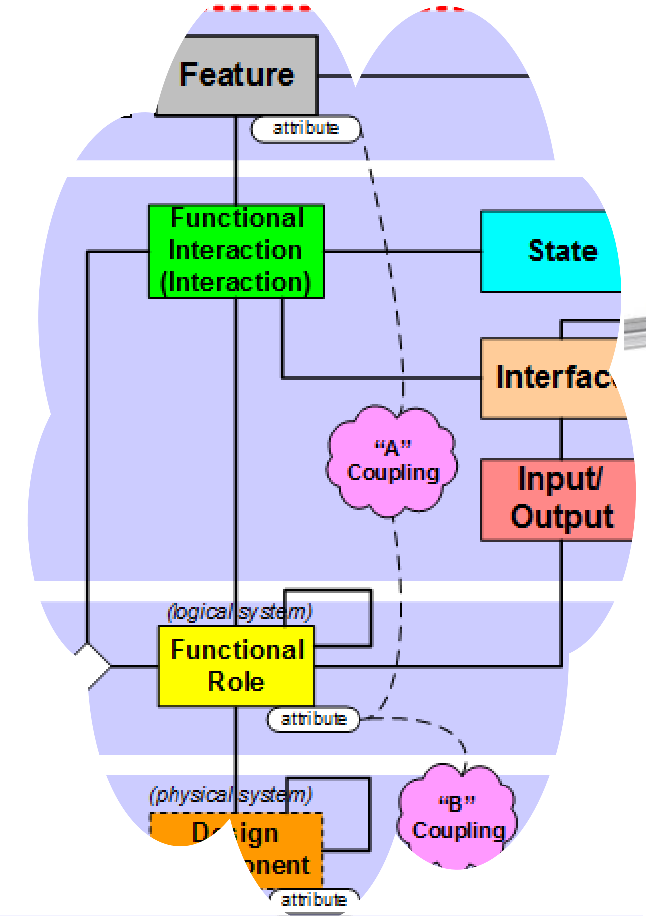
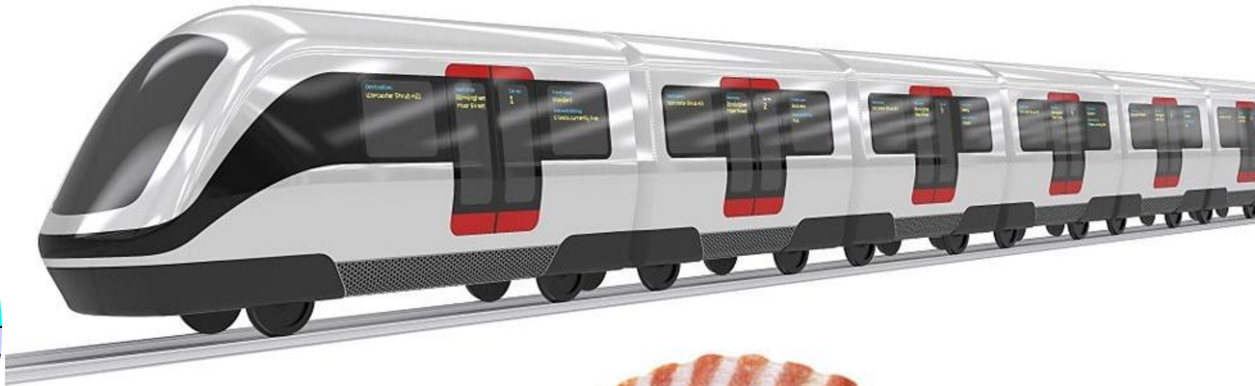
2024
Annual INCOSE
international workshop
HYBRID EVENT
Torrance, CA, USA
January 27 - 30, 2024

MBSE Patterns Working Group

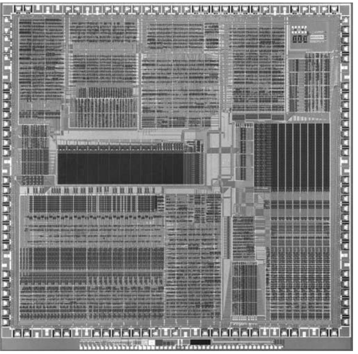




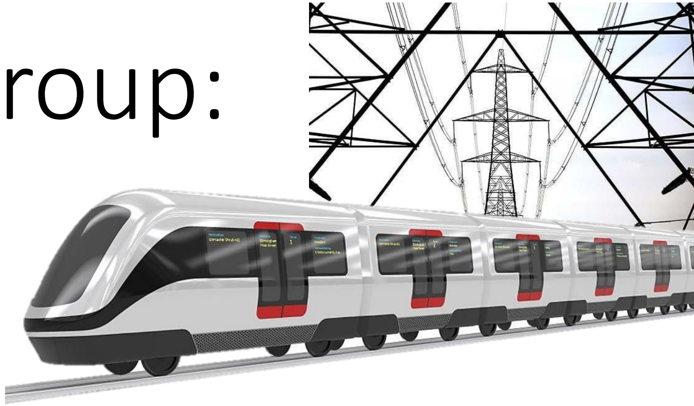


V1.1.5

www.incose.org/IW2024

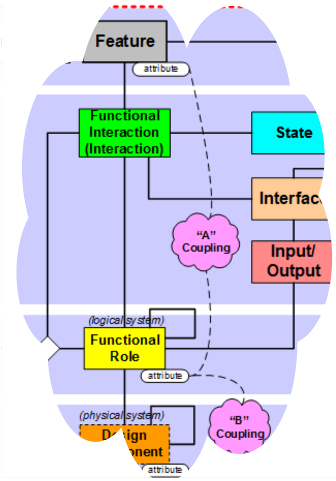


Focus of MBSE Patterns Working Group: S*Patterns



<u>Configurable, re-usable system models</u>:

1. Models containing a certain minimal set of elements are called <u>S*Models</u> (S* is short for “Systematica”).
2. Those underlying elements are called the S*Metamodel, which 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 <u>S*Patterns</u>.
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--subject matter and relevance

Patterns are . . .

- Recurrences (regularities), across time, locations, projects, products, customers, applications, people, companies, or otherwise;
- the basis of all known laws of the physical sciences for the last 300 years;
- the basis of theoretical foundations of the engineering disciplines;
- the basis of learning, for individuals, groups, and machines;
- the basis of human cognition and reasoning;
- what we did not learn when we repeatedly miss the same opportunities or make the same mistakes again and again;
- why we wake up to a mostly recognizable world each day;
- described by both fixed and variable (parameterized, configured) aspects;
- described informally by natural language;
- described formally by the models of science, engineering, and mathematics;
- not just about engineered products, but also about the methods of engineering, life cycle management, and socio-technical systems in general.

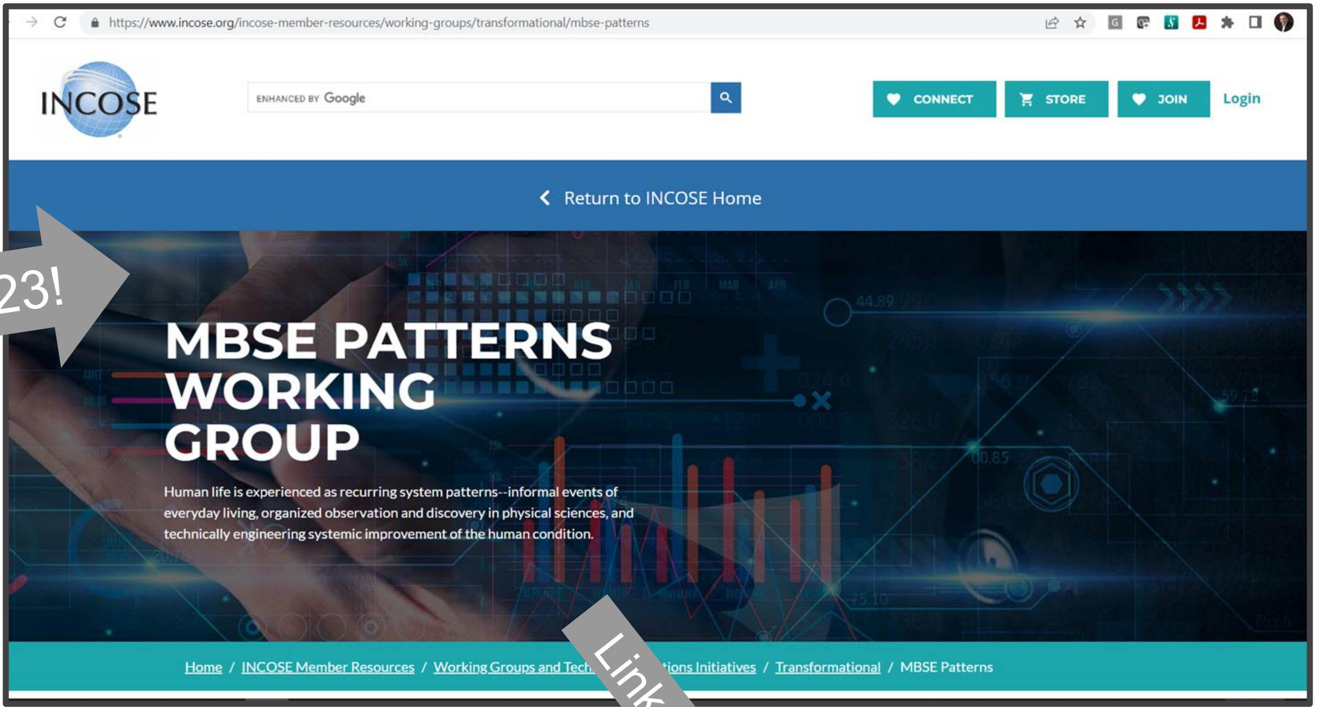
The INCOSE Patterns Working Group: ***Who are we*?**

- Our most active members come 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:

New (replacement) in 2023!

https://www.incose.org/incose-member-resources/working-groups/transformational/mbse-patterns

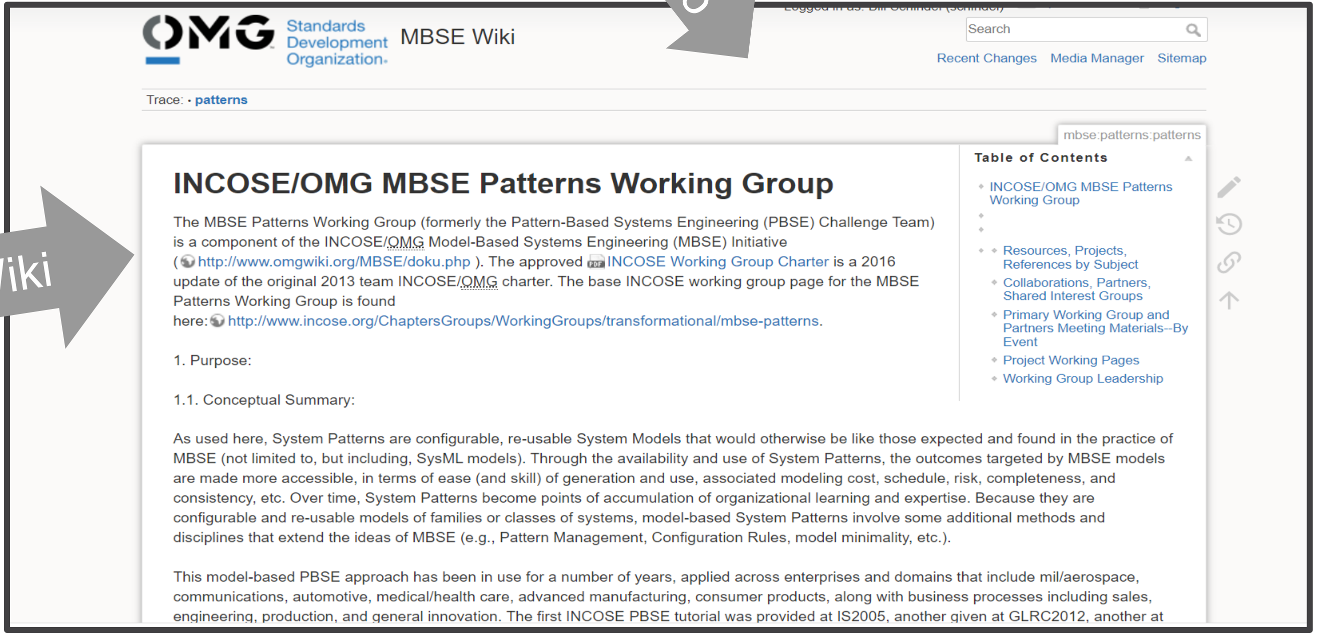


Links to

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



On main web site

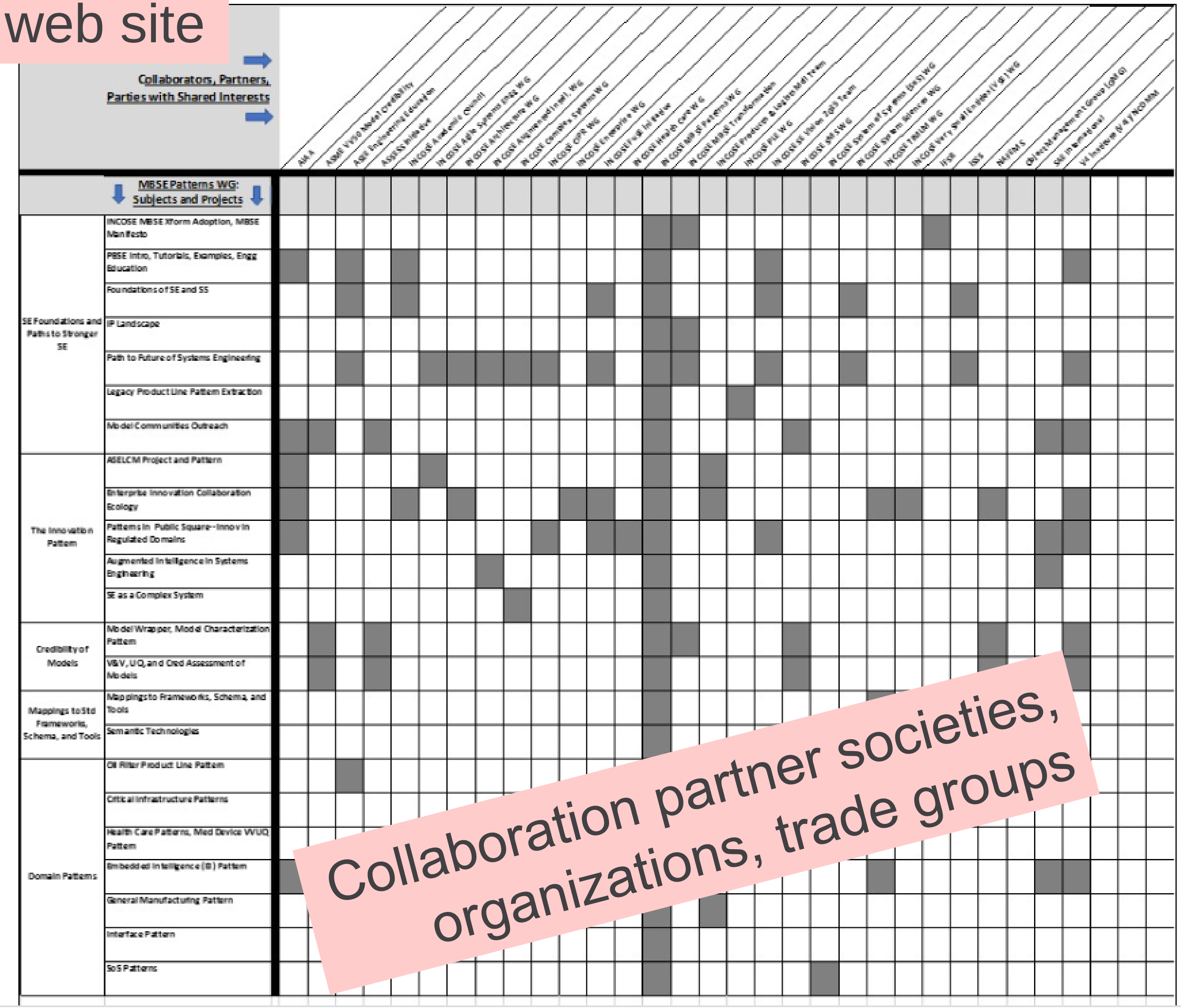
Resources, Projects, References by Subject

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 followi[...] 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 E[...]
	[...]nical Bracket Pattern
	SoS Patterns

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

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

On main 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	Patterns_Challenge_Team_Mtg_0
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_Participatior
Nov 28-29, 2016	MBSE Patterns WG Partic in INCOSE/IEEE EnergyTech 2016, Cleveland	Done	Bill Schindel	MBSE_Patterns_WG_Participatior
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_I
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_Participatior
Jan 20-23, 2018	MBSE Patterns WG Partic in INCOSE IW2108 Jacksonville, FL	Done	Bill Schindel	MBSE_Patterns_WG_Participatior
April, 2018	MBSE Patterns WG Partic in IFSR Conversation 2018, Linz, Austria	Done	Bill Schindel	MBSE_Patterns_WG_Participatior
May, 2018	MBSE Patterns WG Partic in INCOSE 2018 Health Care Systems Conference, Minneapolis, MN	Done	Bill Schindel	MBSE_Patterns_WG_Participatior Conference 2018
May, 2018	MBSE Patterns WG Partic in Aerospace Corporation SE Forum, Chantilly, VA	Done	Bill Schindel	MBSE_Patterns_WG_Participatior 2018
July, 2018	MBSE Patterns WG Partic in INCOSE IS2018 Washington, DC	Done	Bill Schindel	MBSE_Patterns_WG_Participatior
July, 2018	MBSE Patterns WG Partic in ISSS2018 Corvallis, OR	Done	Bill Schindel	MBSE_Patterns_WG_Participatior
Oct, 2018	MBSE Patterns WG Partic in SAE 2018 Standards Summit, Tyson's Corner, VA	Done	Bill Schindel	MBSE_Patterns_WG_Participatior
Oct, 2018	MBSE Patterns WG Partic in INCOSE GLRC 2018 Indianapolis, IN	Done	Bill Schindel	MBSE_Patterns_WG_Participatior
Oct, 2018	MBSE Patterns WG Partic in FDA PBSE Seminar, Washington DC	Done	Bill Schindel	MBSE_Patterns_WG_Participatior
Jan, 2019	MBSE Patterns WG Partic in INCOSE IW2019, Torrance, CA	Done	Bill Schindel	MBSE_Patterns_WG_Participatior
May, 2019	MBSE Patterns WG Partic in ASME Model V&V 2019 Symposium, Las Vegas, NV	Done	Bill Schindel	MBSE_Patterns_WG_Participatior
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_Participatior
Oct, 2019	MBSE Patterns WG Partic in ASSESS 2019, Atlanta, GA	Done	Bill Schindel	MBSE_Patterns_WG_Participatior
January, 2020	MBSE Patterns WG Partic in INCOSE IW2020, Torrance, CA	Done	Bill Schindel	MBSE_Patterns_WG_Participatior
January, 2021	MBSE Patterns WG Partic in INCOSE IW2021 Virtual Sessions	Done	Bill Schindel	MBSE_Patterns_WG_Participatior
April, 2021	MBSE_Patterns_WG_Participation_In_ASME MBE Stds Cmtee Spring 2021 Mtgs	Done	Bill Schindel	MBSE_Patterns_WG_Participatior Mtgs
May, 2021	MBSE_Patterns_WG_Participation_In_ASME Model V&V 2021 Symposium	Done	Bill Schindel	MBSE_Patterns_WG_Participatior
April, 2021	MBSE_Patterns_WG_Participation_In Big Lever Momentum 2021 Conference	Done	Bill Schindel	MBSE_Patterns_WG_Participatior
June, 2021	MBSE_Patterns_WG_Participation_In Indiana Digital Thread Technical Exchange Meeting	Done	Bill Schindel	MBSE_Patterns_WG_Participatior 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 AI
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 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

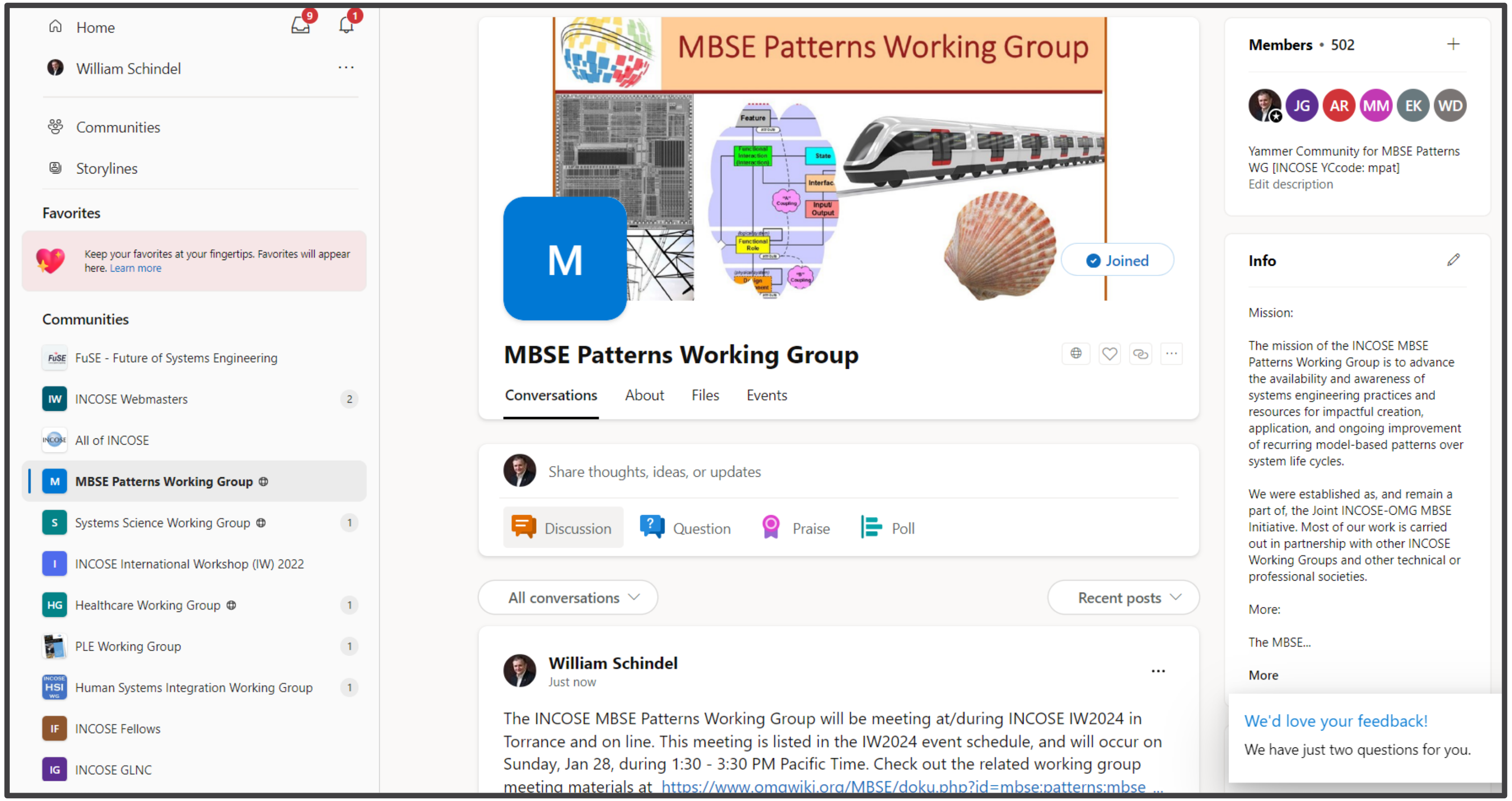
Vision_2035_Support

S*Models Primer Project

S*Patterns Primer Project

- INCOSE is also *just starting* to make use of “Viva Engage” (formerly “Yammer”), another form of social media in the new INCOSE IT ecosystem.
- The MBSE Patterns WG has a Yammer Community getting started, but not nearly as far along with this as the other (10 years’) Patterns WG web resources above.
- You are welcome to join this community, but please contribute and be patient as we learn to make good use of it!

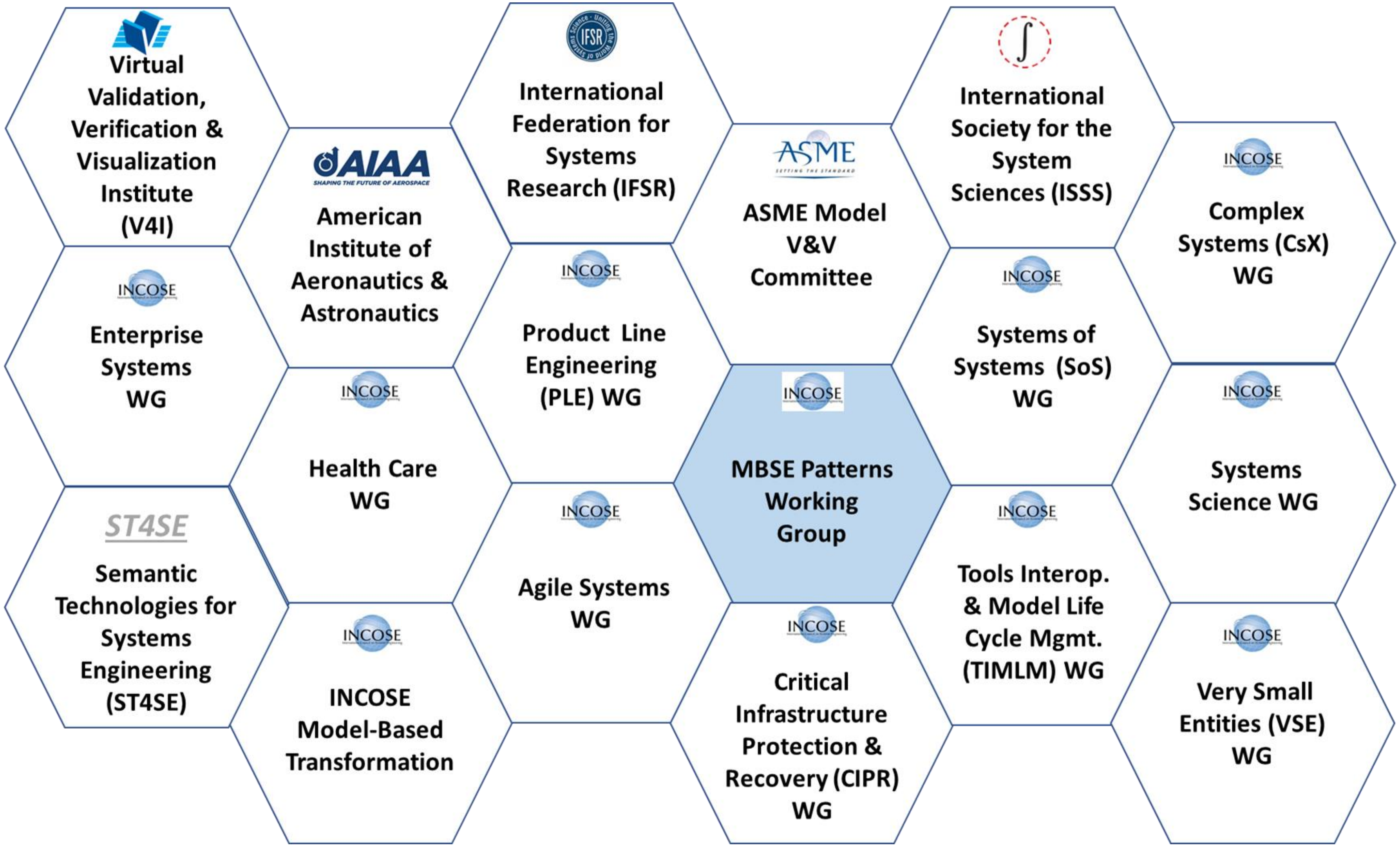
Viva Engage (Formerly Yammer)



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.

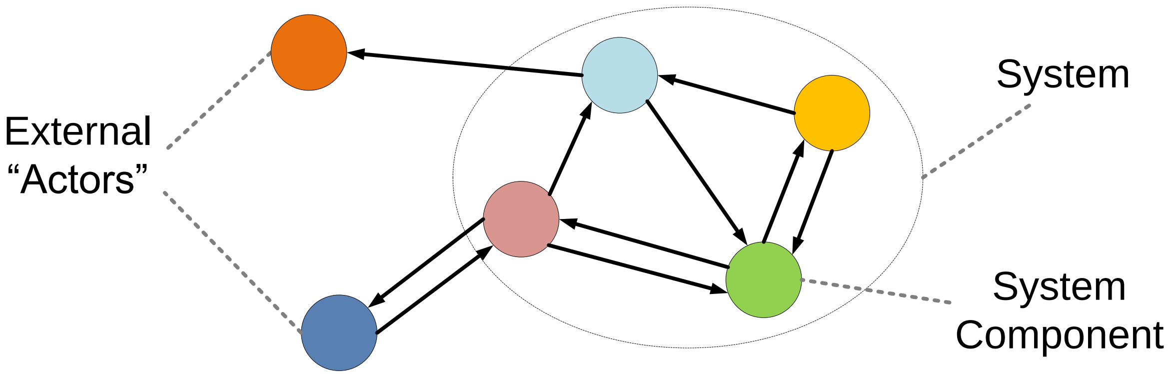
Nearly all our work includes partner INCOSE WGs or others

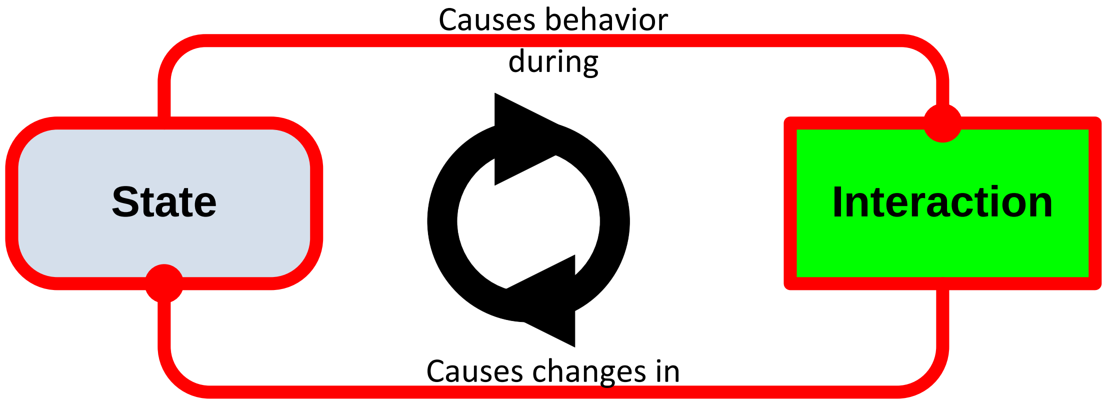


Participate! Collaborate!

Formalizing System Terms and Representations

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



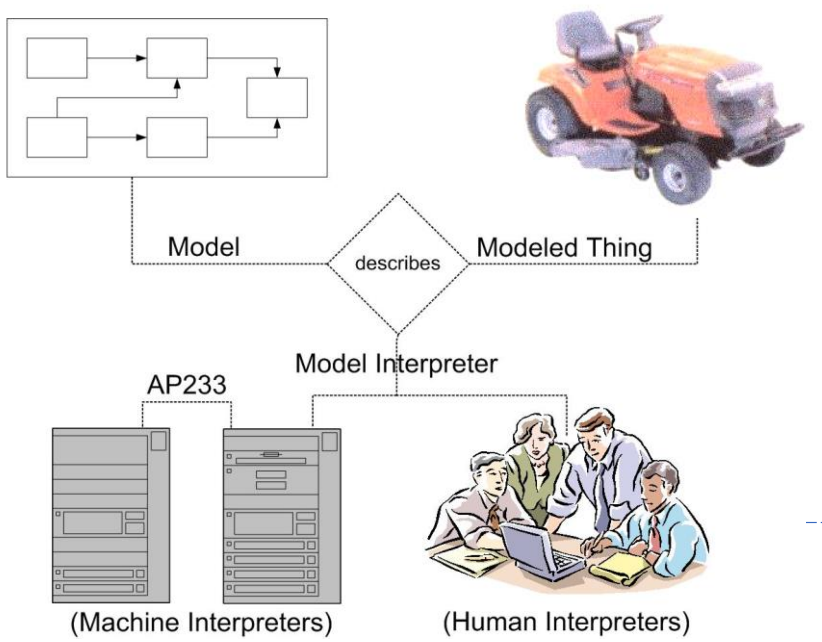


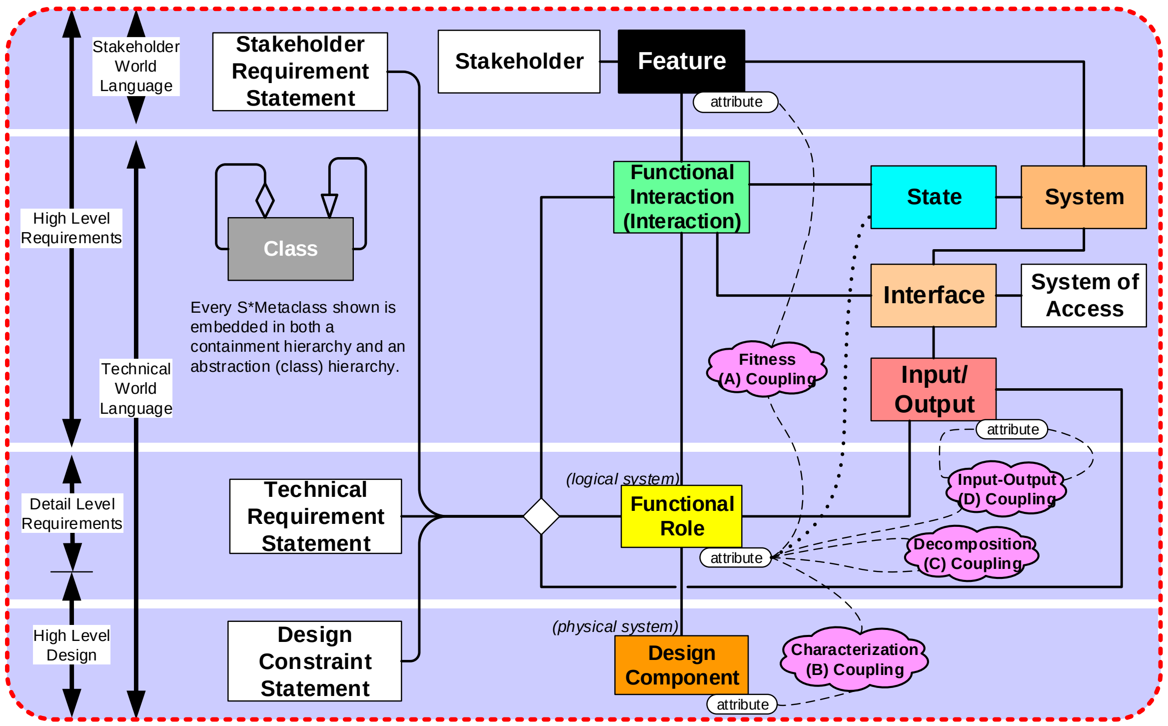
- By "interacting" we mean the exchange of energy, force, material, or information (all of these are "input-outputs") between system components, . . .
- . . . through which one component impacts the <u>state</u> of another component.
- By "state" we mean a property of a component that impacts its input-output 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; there are reasons 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.):

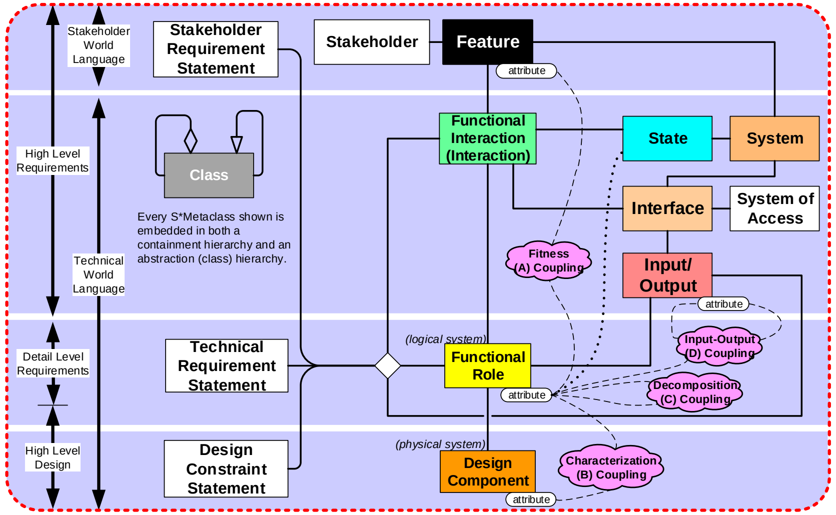




S*Metamodel informal summary pedagogical diagram
(formal S*Metamodel includes additional details.)

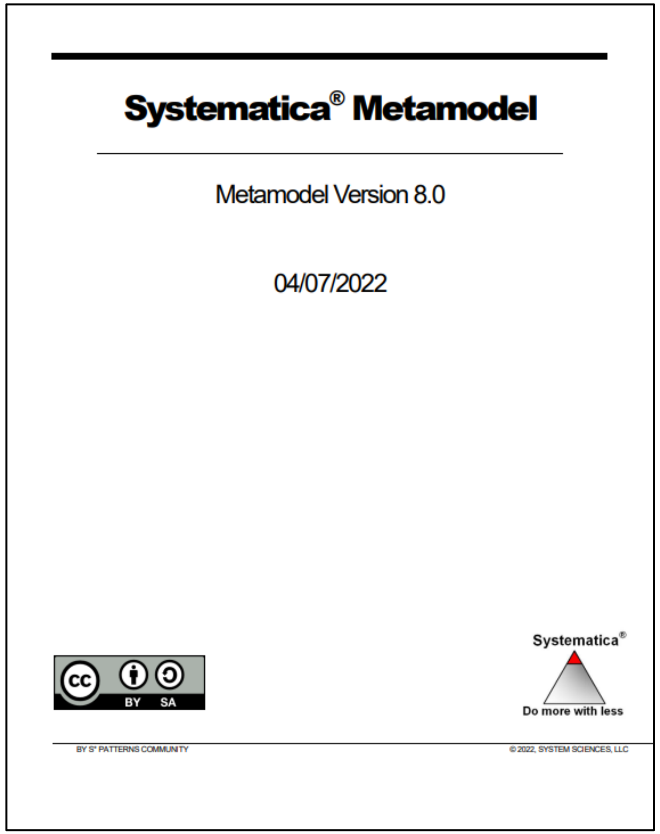
So what is the S*Metamodel, and more important why is it?

S*Metamodel: A reference model of models



Informal pedagogical S*Metamodel subset diagram

- 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 (1>00 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!


Systematica® Metamodel

Metamodel Version 8.0

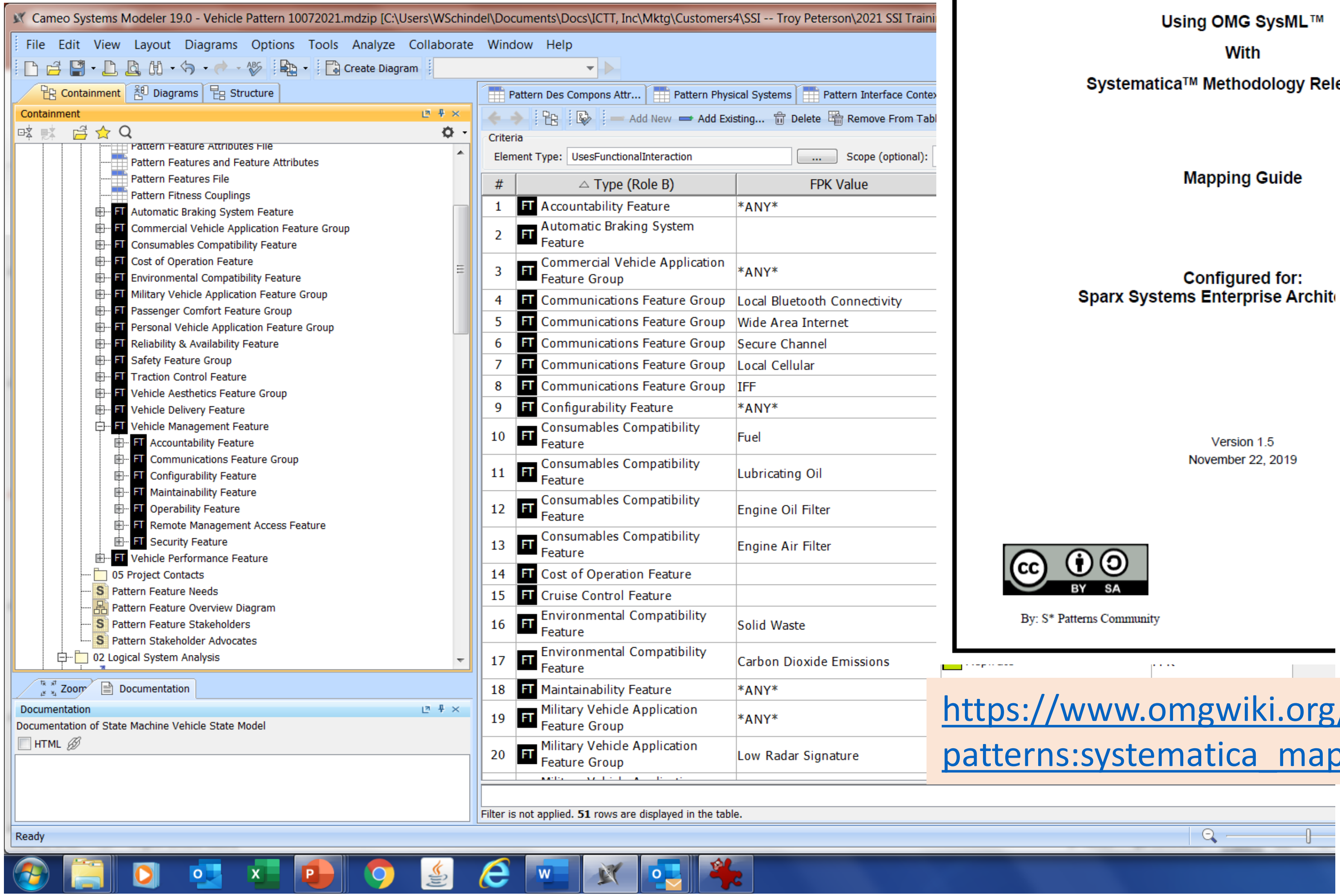
04/07/2022

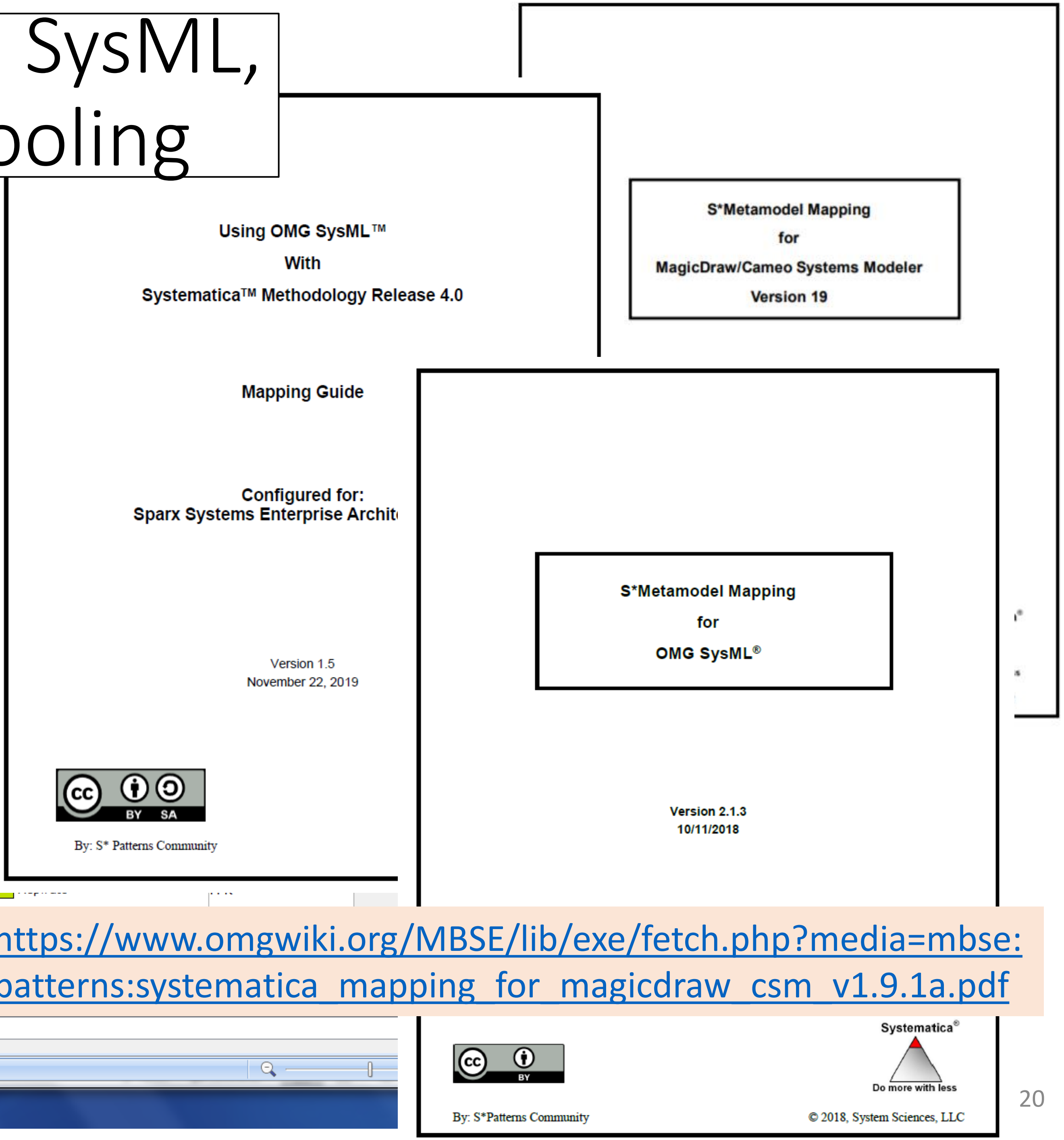
Systematica®
Do more with less

BY S* PATTERNS COMMUNITY
©2022, SYSTEM SCIENCES, LLC

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

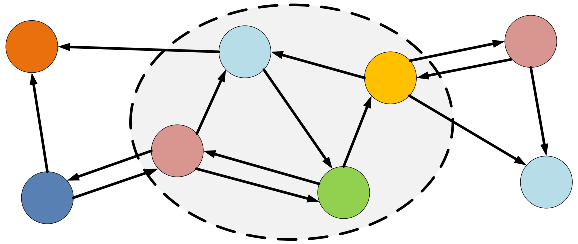
Existing mappings into OMG SysML, other languages, and your tooling



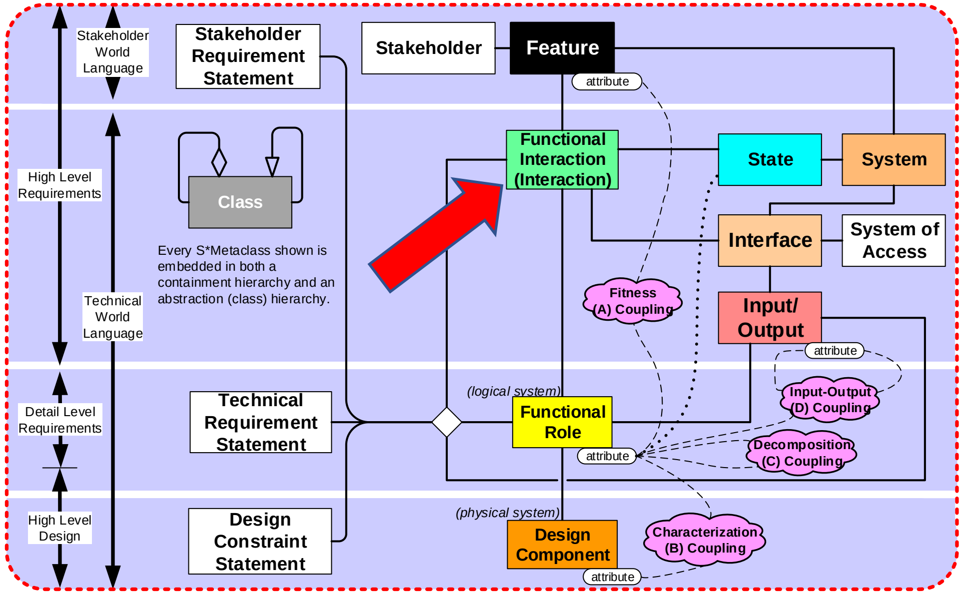


https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:systematica_mapping_for_magicdraw_csm_v1.9.1a.pdf

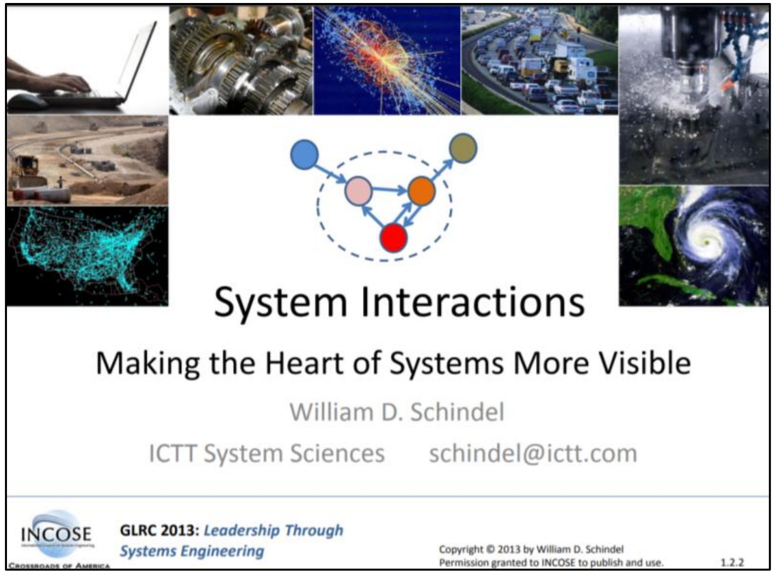
Functional Interactions: Phenomena; clarifying SE views of behavior



- A <u>Functional Interaction</u> (or simply, an <u>Interaction</u>) 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 <u>heart</u> 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.



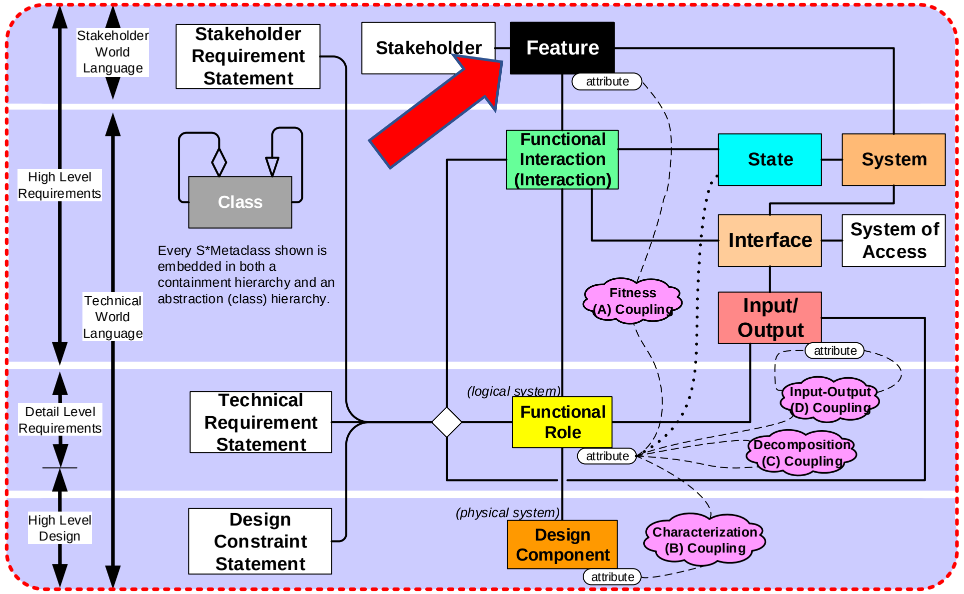
S*Metamodel informal summary pedagogical diagram
(formal S*Metamodel includes additional details.)



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

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, 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
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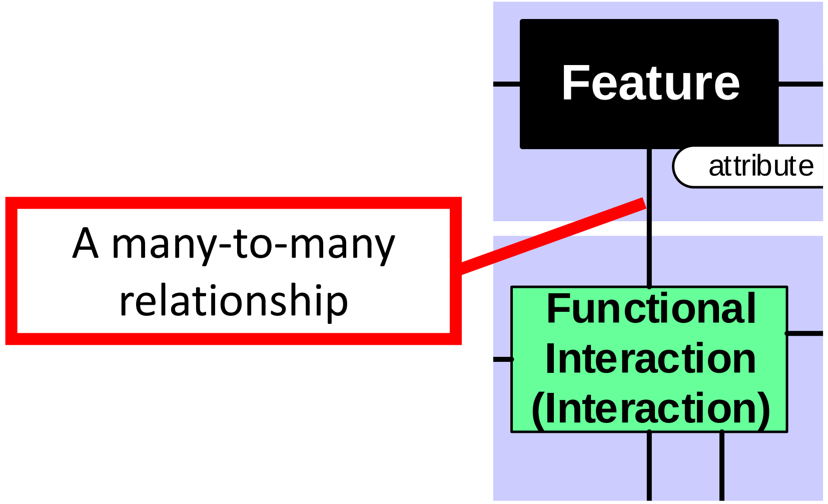
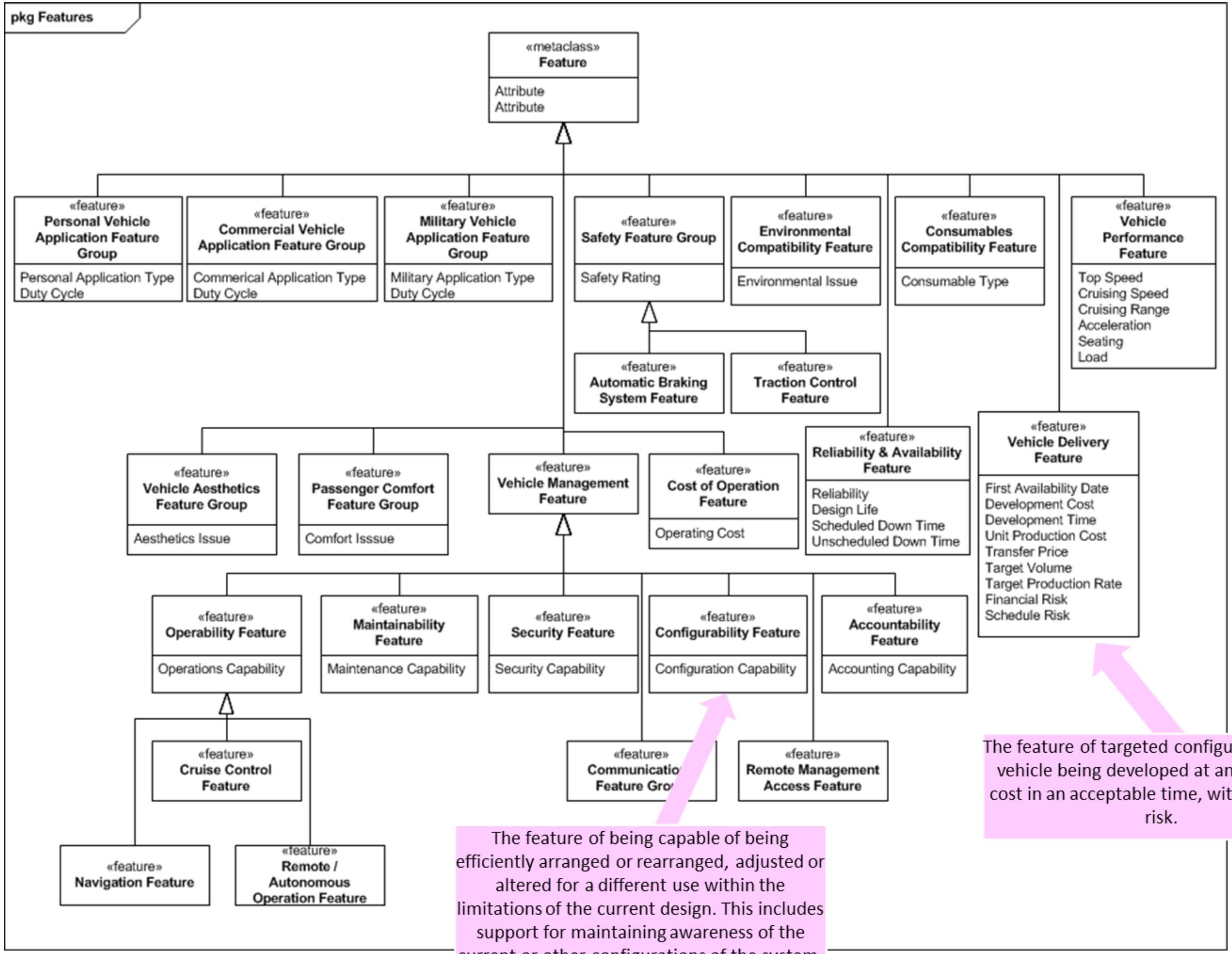


Stakeholder Features: Vehicle example



The feature of being capable of being efficiently arranged or rearranged, adjusted or altered for a different use within the limitations of the current design. This includes support for maintaining awareness of the current or other configurations of the system.

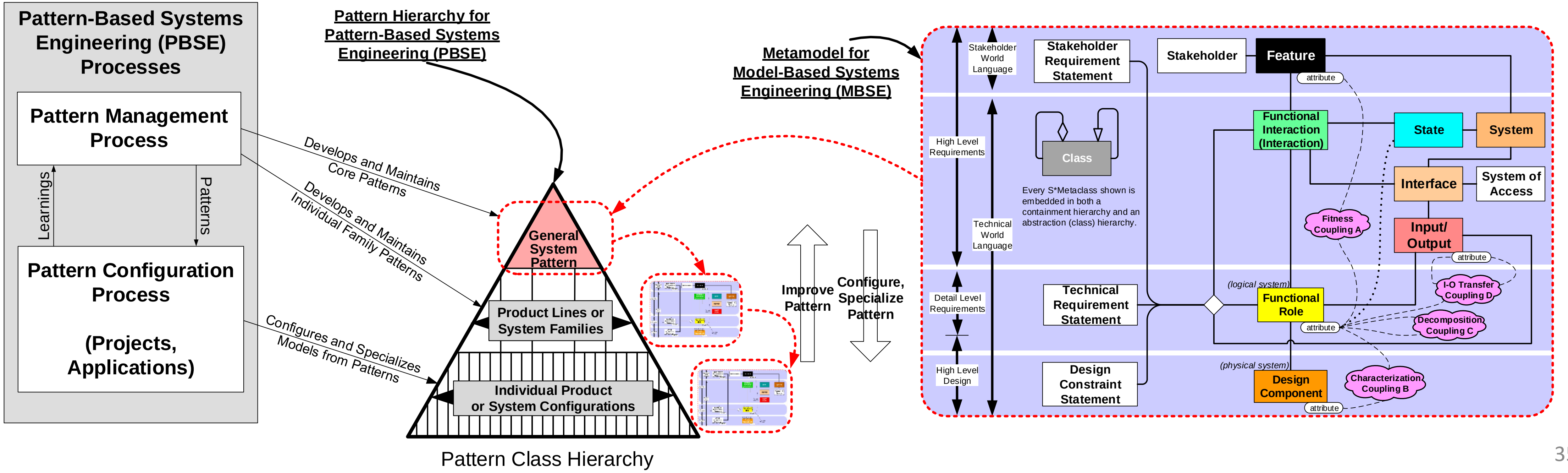
The feature of targeted configurations of the vehicle being developed at an acceptable cost in an acceptable time, with acceptable risk.

Patterns push us toward better model completeness and consistency

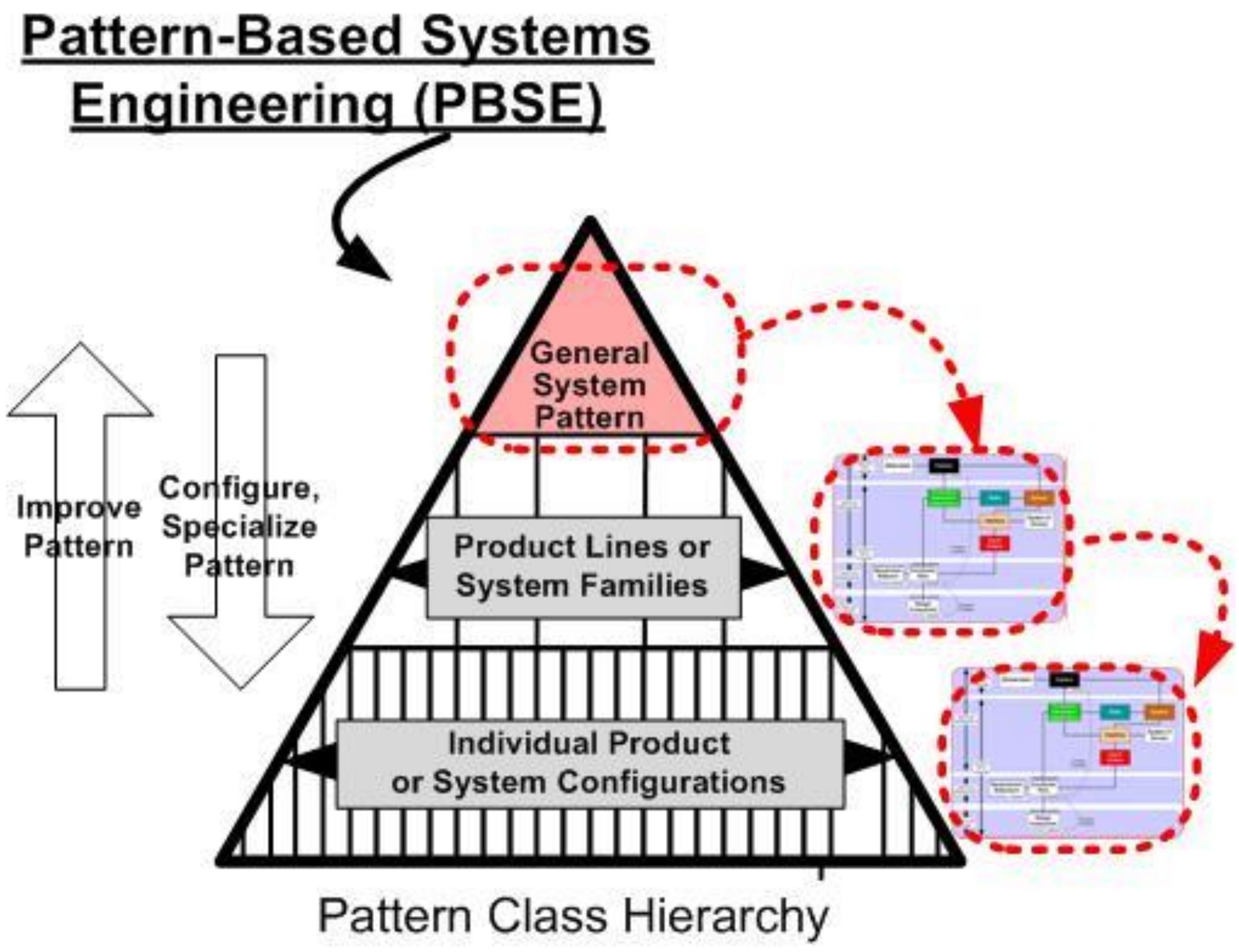
- The above means that a system model is not likely to be complete if it does not include:
  - Some form of domain model, showing all external actors/external interfaces.
  - Some form of state model, showing all possible system black box states.
  - Some form of stakeholder feature model, showing the 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.

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).



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!

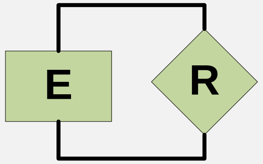
- Configurable patterns are the "sweet spot" targeted by S*Patterns.

Emergence of Patterns from Patterns: S*Pattern Class Hierarchy

More General

Definition of **Relational Modeling Paradigm**

Entity-Relationship Paradigm

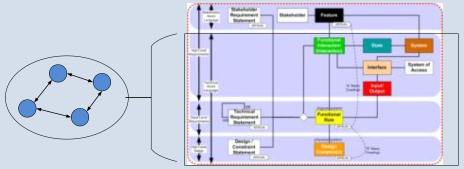


E=Entity
R= Relationship

Structured or unstructured semantic web

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

S*Metamodel Core



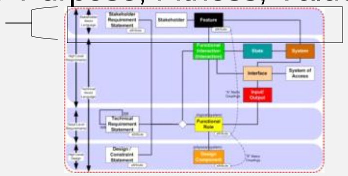
Core S*Metamodel

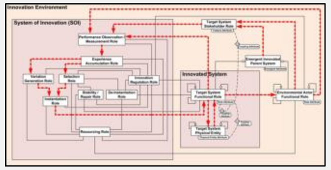
Smallest model of a system, for engineering or science

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

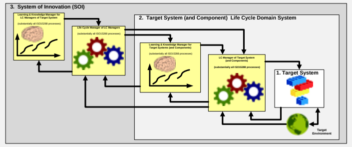
EI Pattern, SOI Pattern, Fitness, Value

S*Purpose, Fitness, Value

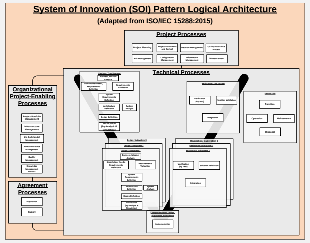




System of Innovation Pattern



Agile Sys Life Cycle Pattern



ISO 15288 System Life Cycle Mgmt Pattern

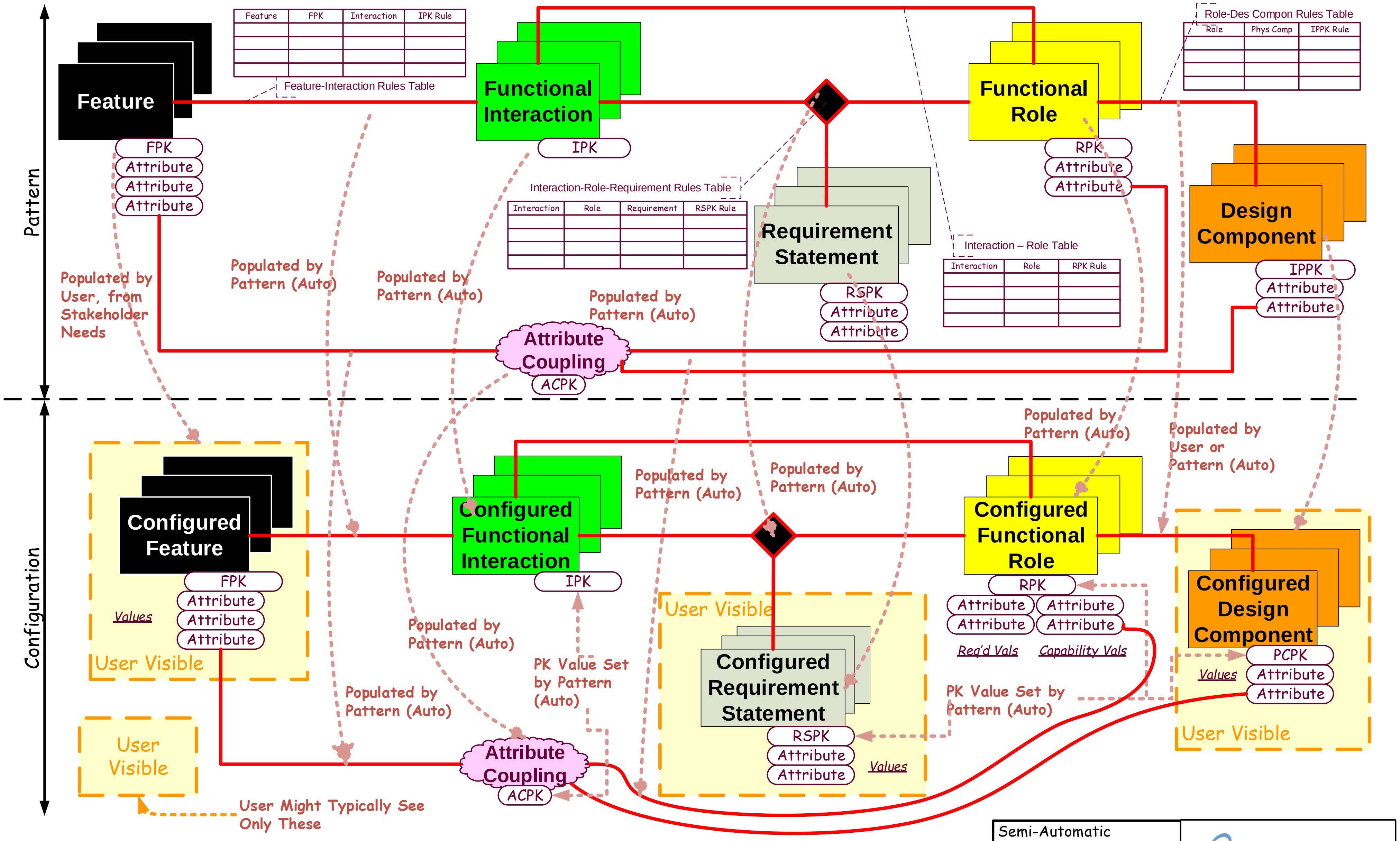
Emergence & Definition of **Domain Specific Systems**

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

More Specific

Models from Patterns: Overview of MBSE Pattern Configuration Algorithm



Semi-Automatic S*Pattern Configuration

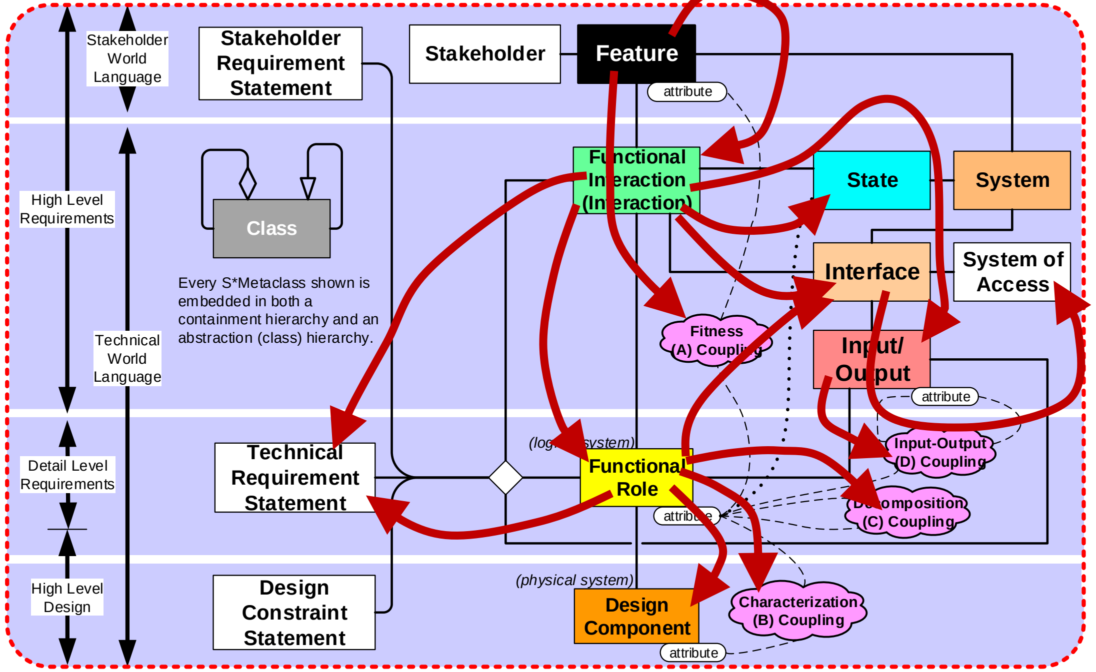
V1.3.10 03-15-16

ICTT System Sciences
Understand your systems.

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.

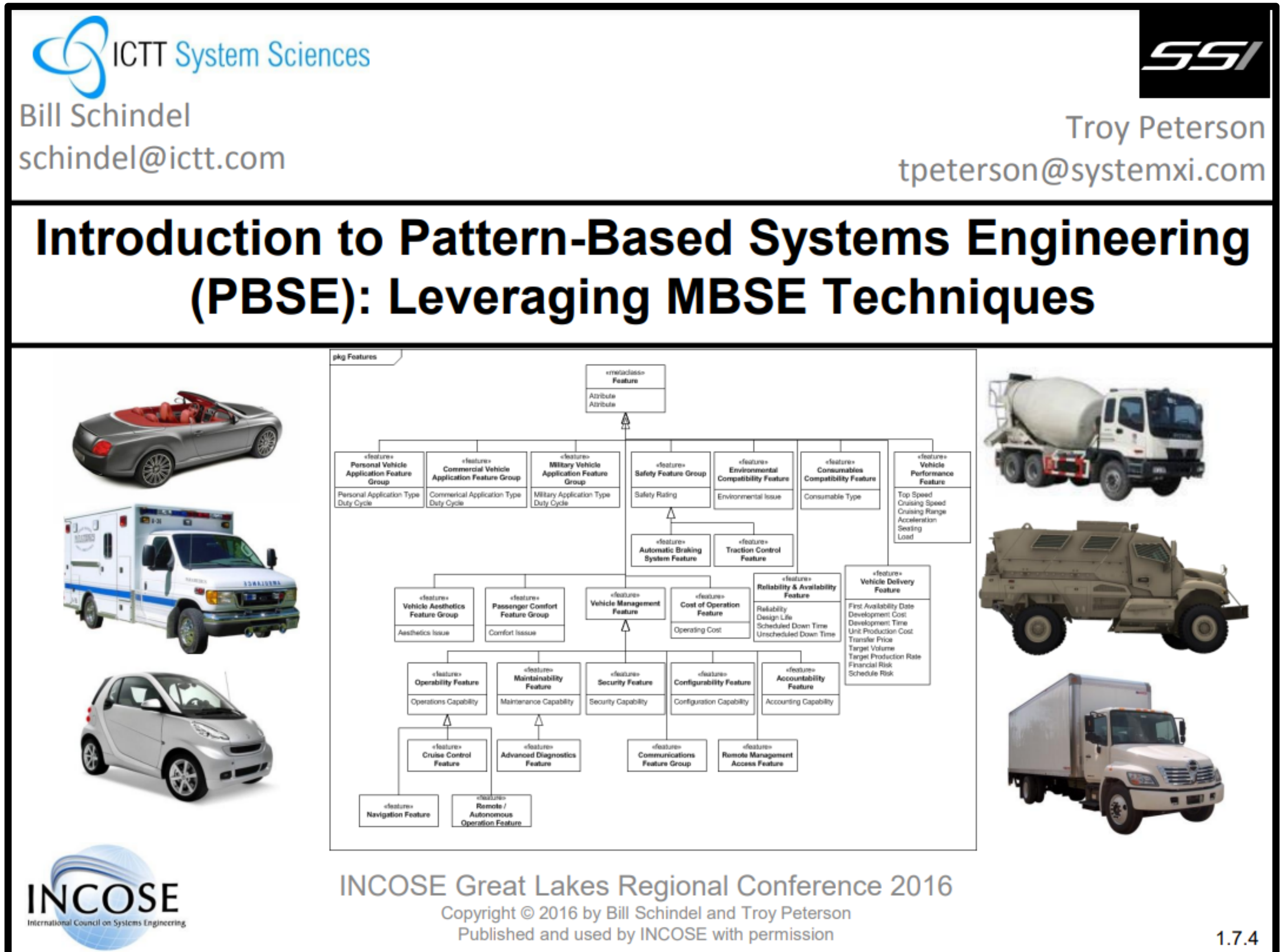
Inherent PLE degrees of freedom configuration propagation:



POPULATED METACLASSES ("THEN")

TRIGGERING METACLASSES ("IF")	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																								■

How to find out more about configurable model-based patterns



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https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:pbse_extension_of_mbse--methodology_summary_v1.6.1.pdf

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

Current working group projects, activities—status, Q&A

Patterns & Technologies:

1. Semantic Technologies for Systems Engineering (ST4SE) Project.
2. Adaptive Learning Ecosystem Pattern—the INCOSE ASELCM Reference Framework.
3. Universal Model Metadata Wrapper: Model Characterization Pattern (MCP), w/ASME VV Stds Cmte & V4 Inst.
4. S*Pattern Configuration Wizard.

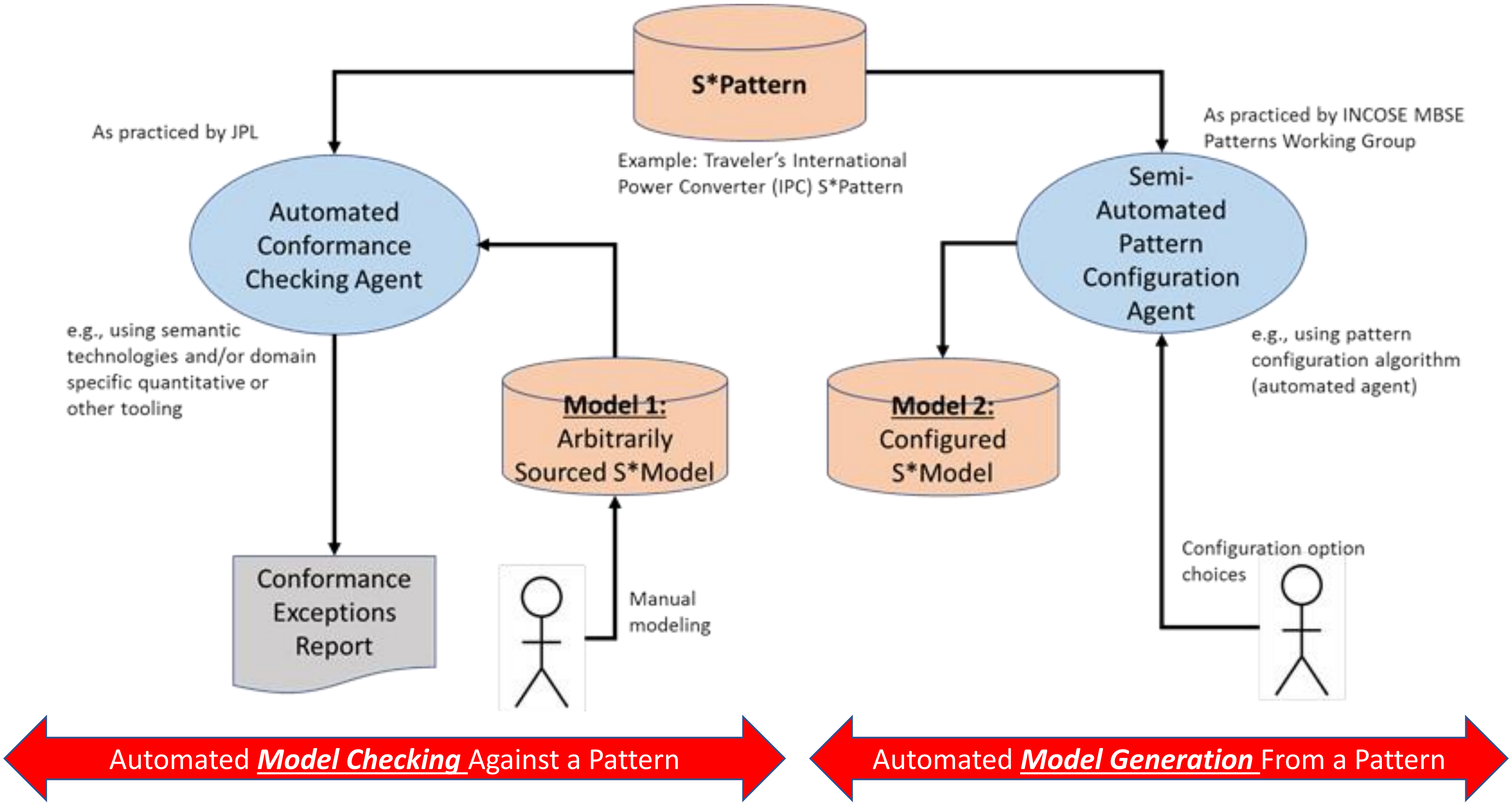
Publications:

1. Minimal S*Models—A Primer (including S*Metamodel and its formal mappings to OMG SysML and tools)
2. S*Patterns Primer (second ed)
3. ASME Guideline for Managing Credibility of Models for Adv. Manufacturing, w/ASME VV50 Stds Working Grp.
4. AIAA Aerospace Digital Twins Case Studies Pub; Digital Twin Analysis and Planning Reference Pattern, w/AIAA.
5. AIAA Aerospace Digital Threads Position Pub; Digital Thread Analysis & Planning Reference Pattern, w/AIAA.
6. *Handbook of System Sciences*, for ISSS via Springer: Chapter: "Patterns in Science and Engineering", w/ISSS.
7. *Handbook of Model-Based Systems Engineering*, Madni & Augustine, eds, Springer, Chapter: "MBSE Patterns".
8. *INCOSE SE Handbook*, 5th Ed., for INCOSE, D. Walden et al, eds, material on S*Metamodel and ASELCM Pattern
9. Support for Vision 2035 Implementation Streams: Innovation Applications, SE Foundations.
10. *INCOSE INSIGHT,* Dig. Engg. Issue, 2022, F. Salvatore, ed, Realizing the Promise of Digital Engineering: The Innovation Ecosystem Reference Pattern for Analysis, Planning, and Implementation.

Interface Pattern Project (became part of ST4SE Project)

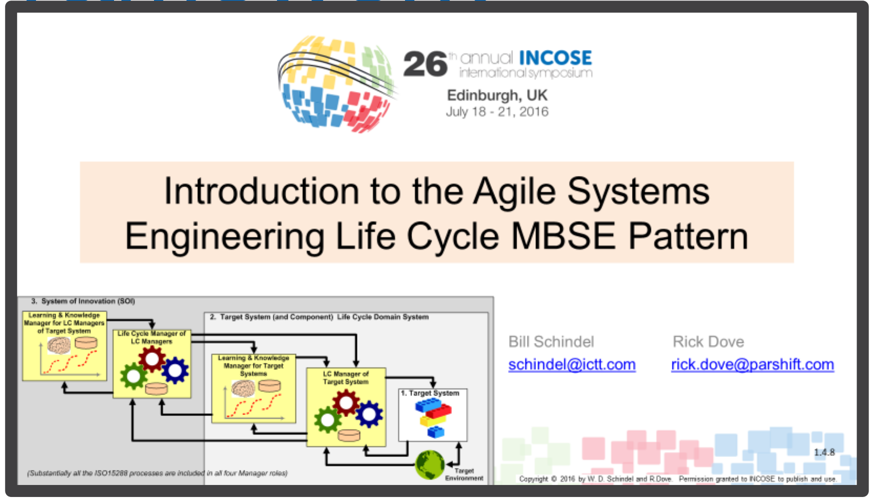
- Configurable patterns for Interfaces of all types
- Originally suggested by Frank Salvatore
- Initial work during 2017-2019
- Became part of ST4SE Project in 2020
- Additional progress on configurable Interface Pattern achieved in 2021-2022 as part of Semantic Technologies for Systems Engineering (ST4SE) Project.

Semantic Technologies for Systems Engineering (ST4SE)



Adaptive Learning Ecosystem Pattern—the Learning Ecosystem (ASELCM) Reference Framework

- 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.



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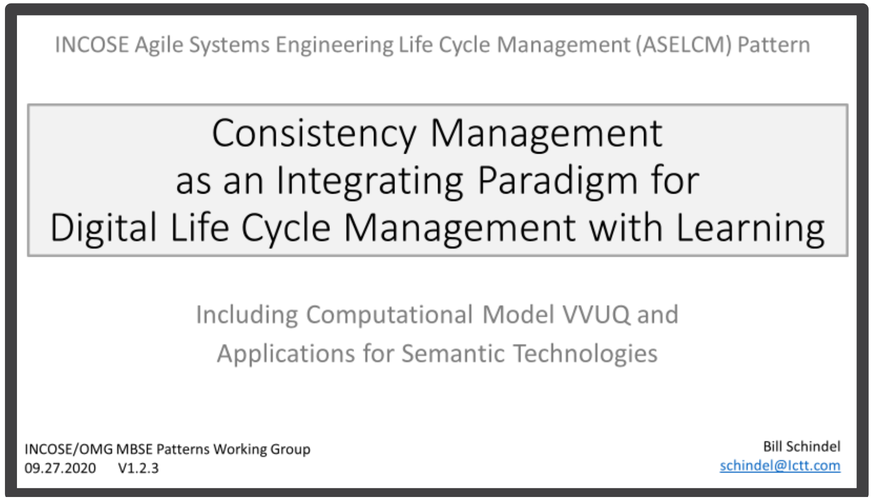

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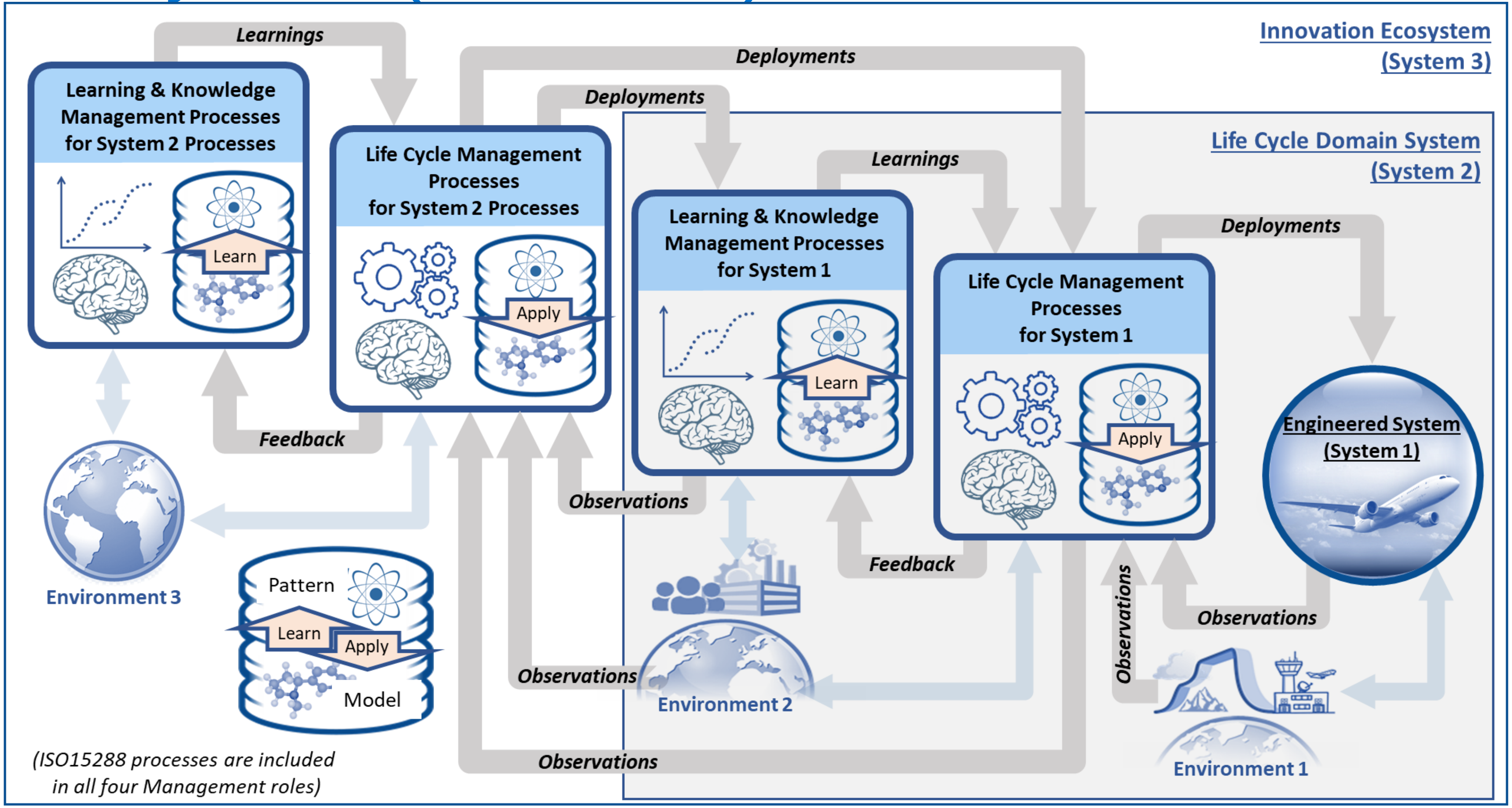
Adaptive Learning Ecosystem Pattern—the Learning Ecosystem (ASELCM) Reference Framework

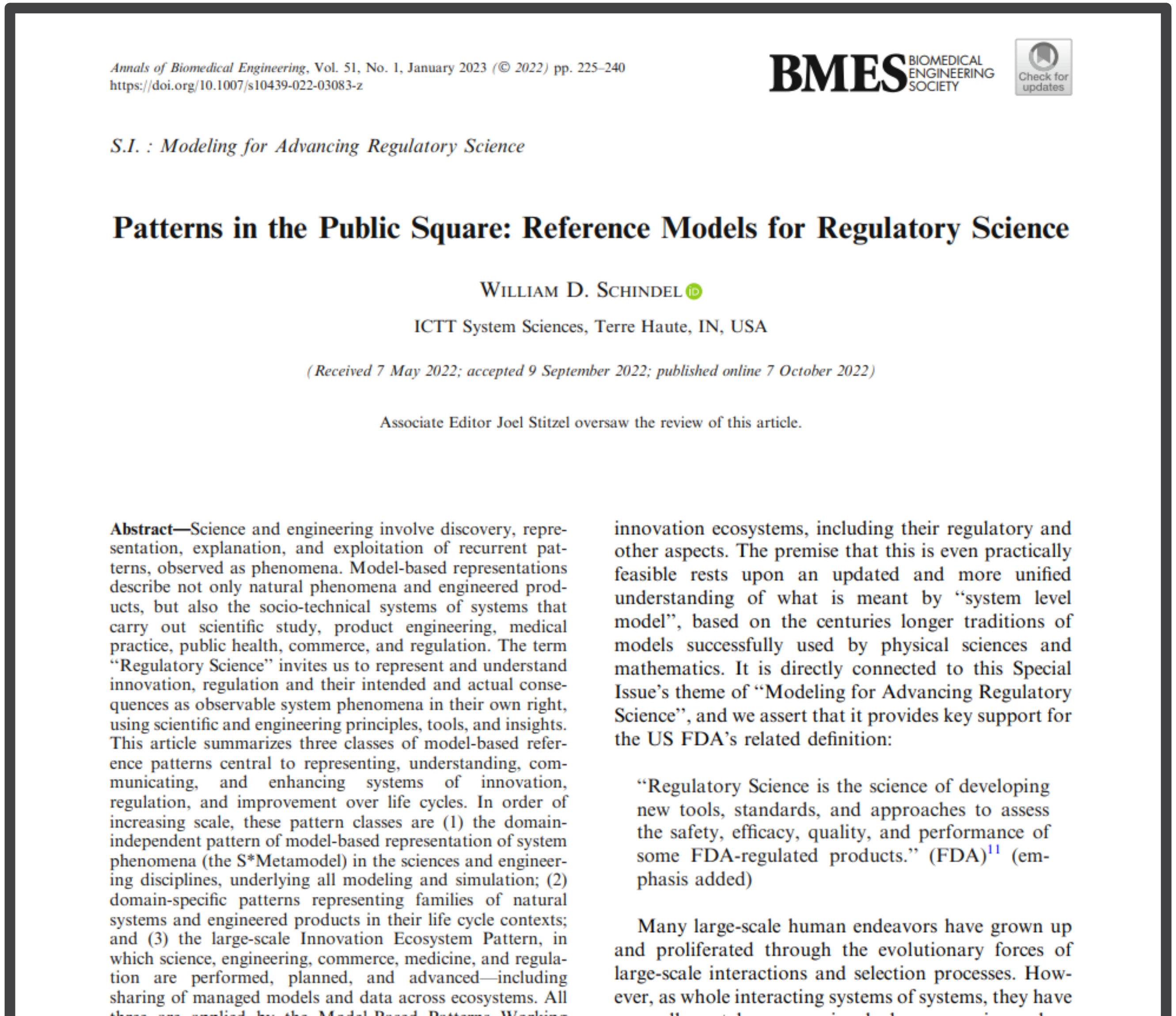


Pattern Description

AIAA Pattern Application

Being used at IW2023 for FuSE Vision 2035 Implementation: Innovation Application Workstream

Adaptive Learning Ecosystem Pattern—the Learning Ecosystem (ASELCM) Reference Framework



Annals of Biomedical Engineering, Vol. 51, No. 1, January 2023 (© 2022) pp. 225–240
https://doi.org/10.1007/s10439-022-03083-z

BMES BIOMEDICAL ENGINEERING SOCIETY

Check for updates

S.I. : Modeling for Advancing Regulatory Science

Patterns in the Public Square: Reference Models for Regulatory Science

William D. Schindel
ICTT System Sciences, Terre Haute, IN, USA

(*Received 7 May 2022; accepted 9 September 2022; published online 7 October 2022*)

Associate Editor Joel Stitzel oversaw the review of this article.

Abstract—Science and engineering involve discovery, representation, explanation, and exploitation of recurrent patterns, observed as phenomena. Model-based representations describe not only natural phenomena and engineered products, but also the socio-technical systems of systems that carry out scientific study, product engineering, medical practice, public health, commerce, and regulation. The term "Regulatory Science" invites us to represent and understand innovation, regulation and their intended and actual consequences as observable system phenomena in their own right, using scientific and engineering principles, tools, and insights. This article summarizes three classes of model-based reference patterns central to representing, understanding, communicating, and enhancing systems of innovation, regulation, and improvement over life cycles. In order of increasing scale, these pattern classes are (1) the domain-independent pattern of model-based representation of system phenomena (the S*Metamodel) in the sciences and engineering disciplines, underlying all modeling and simulation; (2) domain-specific patterns representing families of natural systems and engineered products in their life cycle contexts; and (3) the large-scale Innovation Ecosystem Pattern, in which science, engineering, commerce, medicine, and regulation are performed, planned, and advanced—including sharing of managed models and data across ecosystems. All

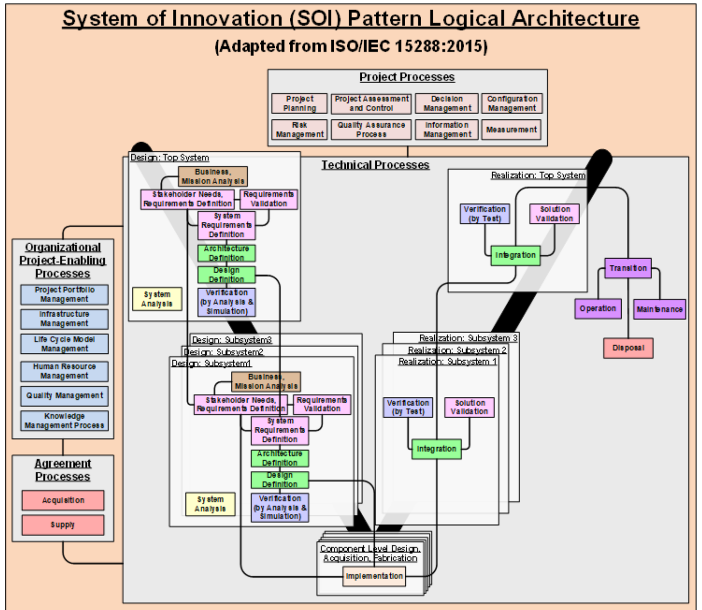
innovation ecosystems, including their regulatory and other aspects. The premise that this is even practically feasible rests upon an updated and more unified understanding of what is meant by "system level model", based on the centuries longer traditions of models successfully used by physical sciences and mathematics. It is directly connected to this Special Issue's theme of "Modeling for Advancing Regulatory Science", and we assert that it provides key support for the US FDA's related definition:

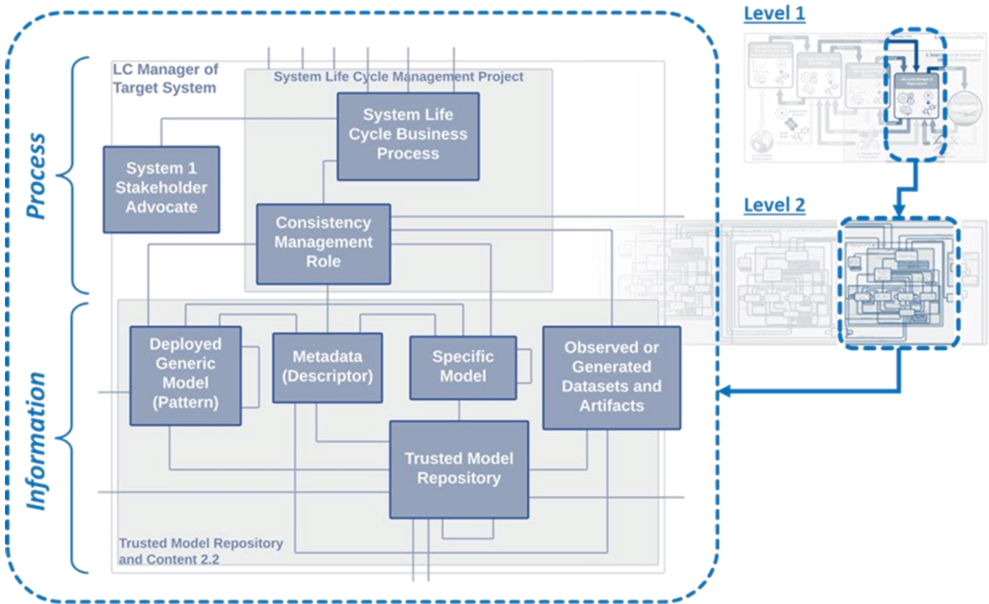
> "Regulatory Science is the science of developing new tools, standards, and approaches to assess the safety, efficacy, quality, and performance of some FDA-regulated products." (FDA)[11] (emphasis added)

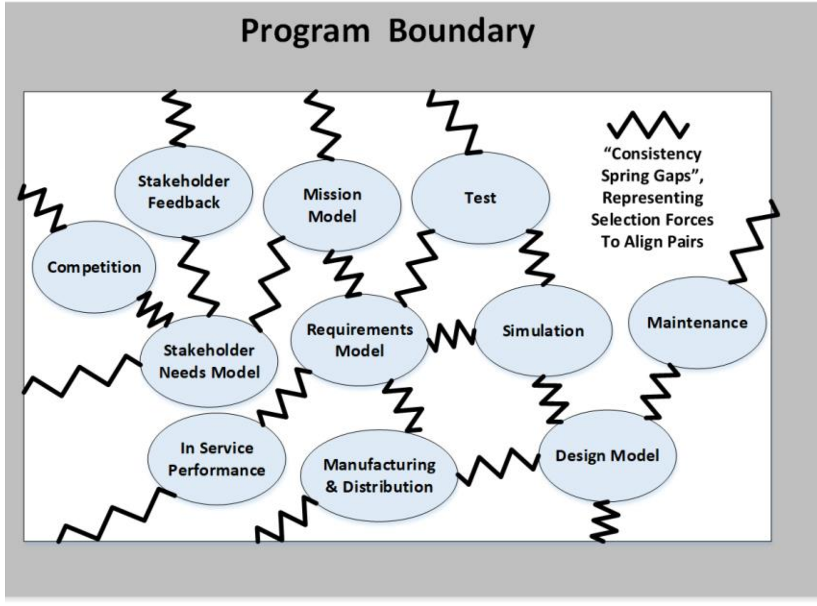
Many large-scale human endeavors have grown up and proliferated through the evolutionary forces of large-scale interactions and selection processes. However, as whole interacting systems of systems, they have

Consistency gap management paradigm for innovation ecosystems

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





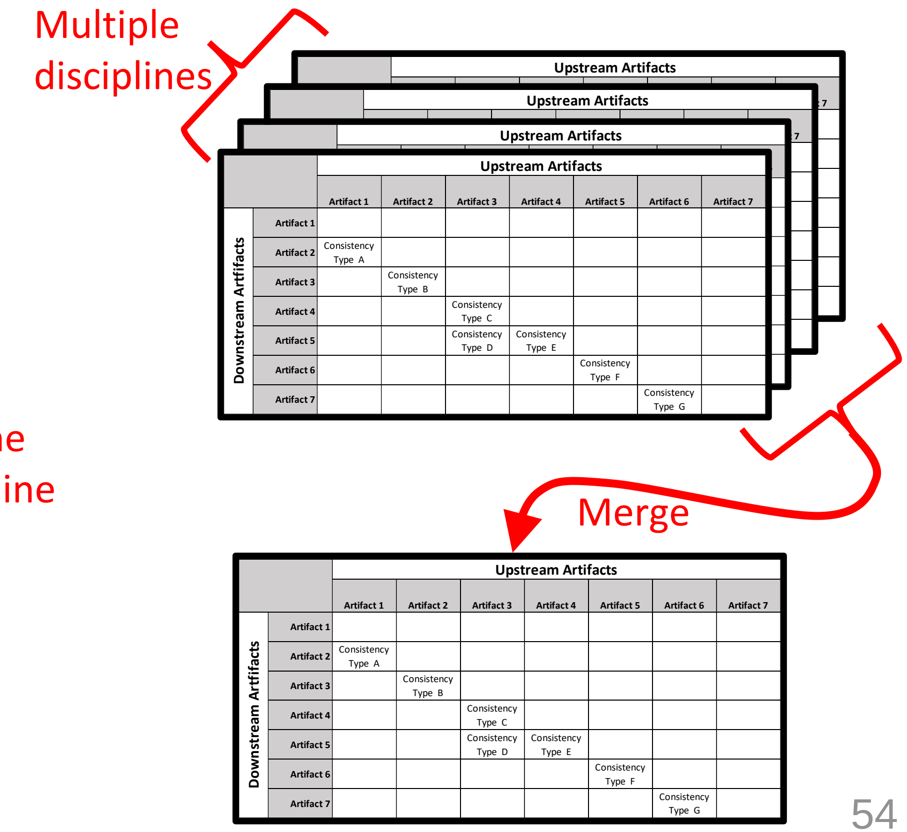


Related collaboration project across four technical societies

- Different discipline communities (e.g., ISO 15288 SE *versus* ASME VVUQ-1 computational modeling communities) have different consistency confirmation frameworks, nomenclatures, standards.
- This can be a challenge when performed "together" for trust-critical integrated systems.
- Working groups of INCOSE, ASME, AIAA, and NAFEMS are collaborating on a comparative "Rosetta Stone" mapping of different consistency confirmation frameworks of different communities:

		Upstream Artifacts						
		Artifact 1	Artifact 2	Artifact 3	Artifact 4	Artifact 5	Artifact 6	Artifact 7
Downstream Artfifacts	Artifact 1							
	Artifact 2	Consistency Type A						
	Artifact 3		Consistency Type B					
	Artifact 4			Consistency Type C				
	Artifact 5			Consistency Type D	Consistency Type E			
	Artifact 6					Consistency Type F		
	Artifact 7						Consistency Type G	

For one discipline



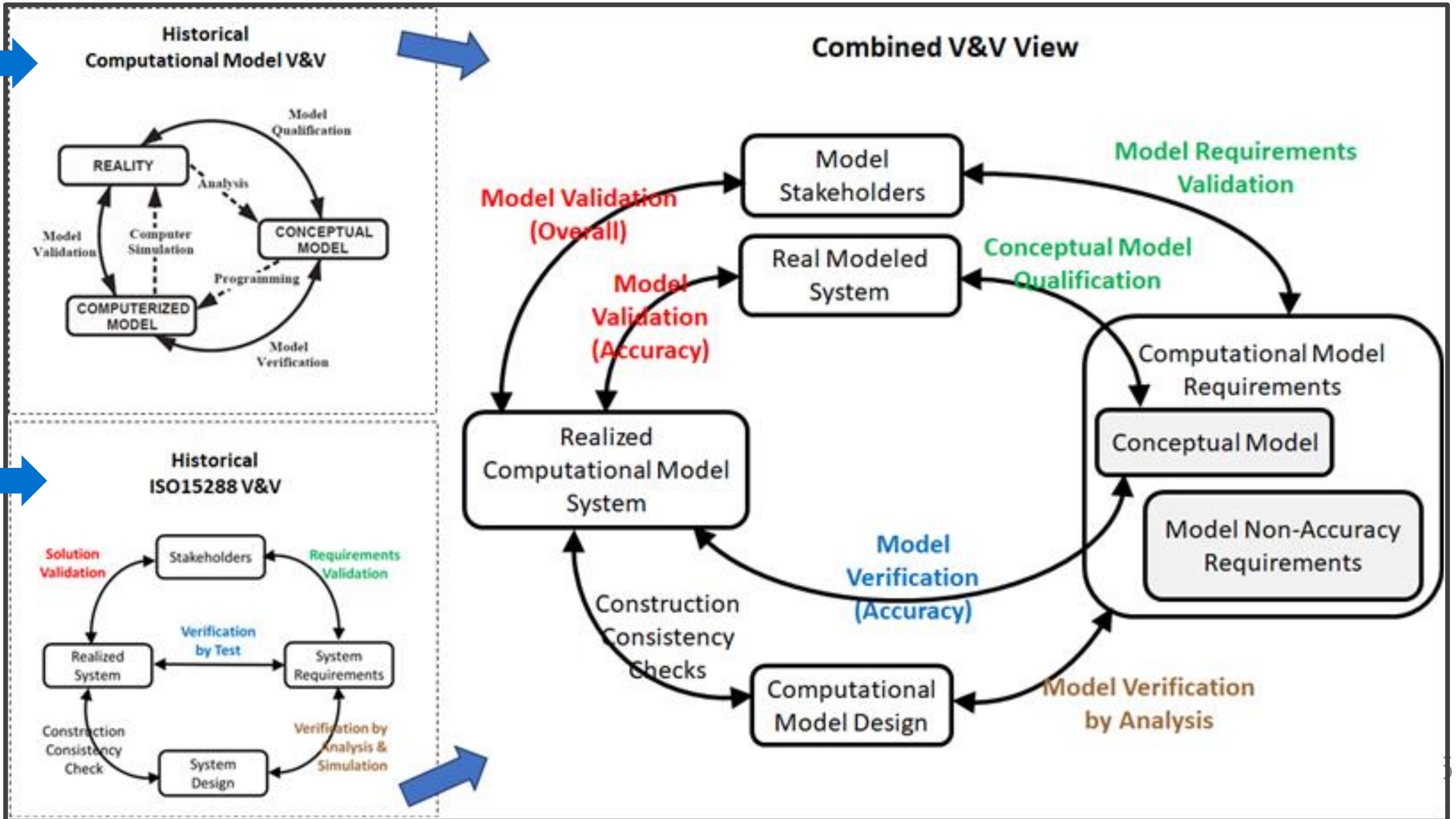
Merged multiple discipline mapping

Related collaboration project across four technical societies

Simple example: Computational model community VVUQ-1 consistency confirmation nomenclature versus ISO 15288 systems engineering consistency confirmation nomenclature:

ASME VVUQ-1 (2022)

ISO - 15288 (2023)



Related application of Hamiltonians for IT and socio-technical systems

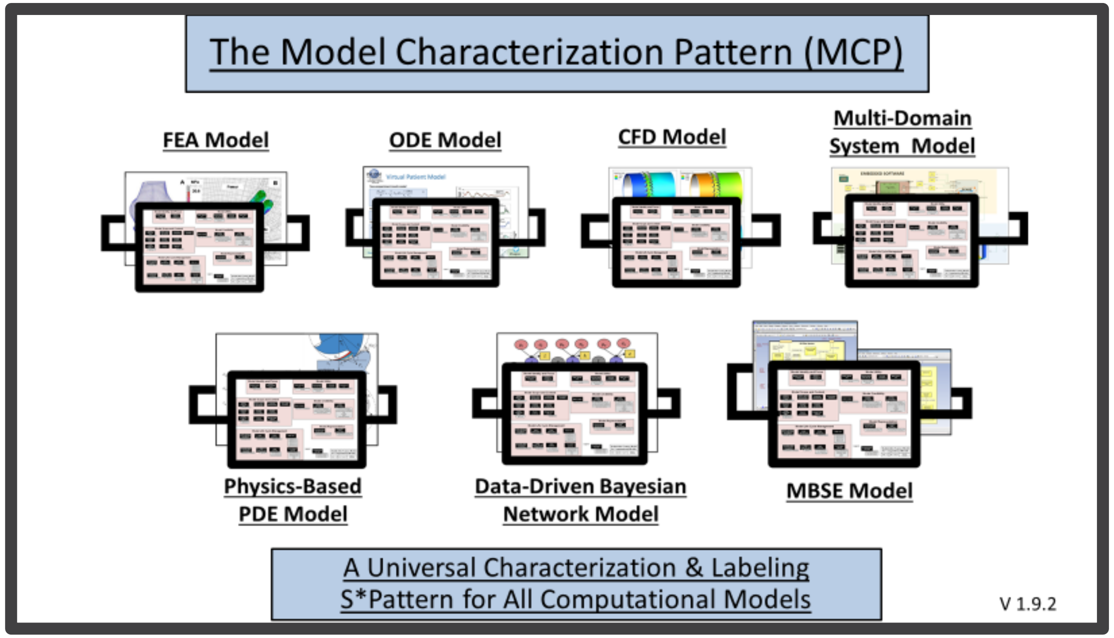
- Adopting W R Hamilton's "characteristic function" perspective enriches interpretation of the nature of momentum and energy, in additional settings:
  - By reasoning in the right order, Hamiltonians can be defined for IT (i.e., digital) and socio-technical systems.
  - *Managed consistency gaps provide the potential energy part of the ASELCM System 2 Hamiltonian*.
- Dublin was Hamilton's home, where we'll expand on the following this summer during IS2024.

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.)

- 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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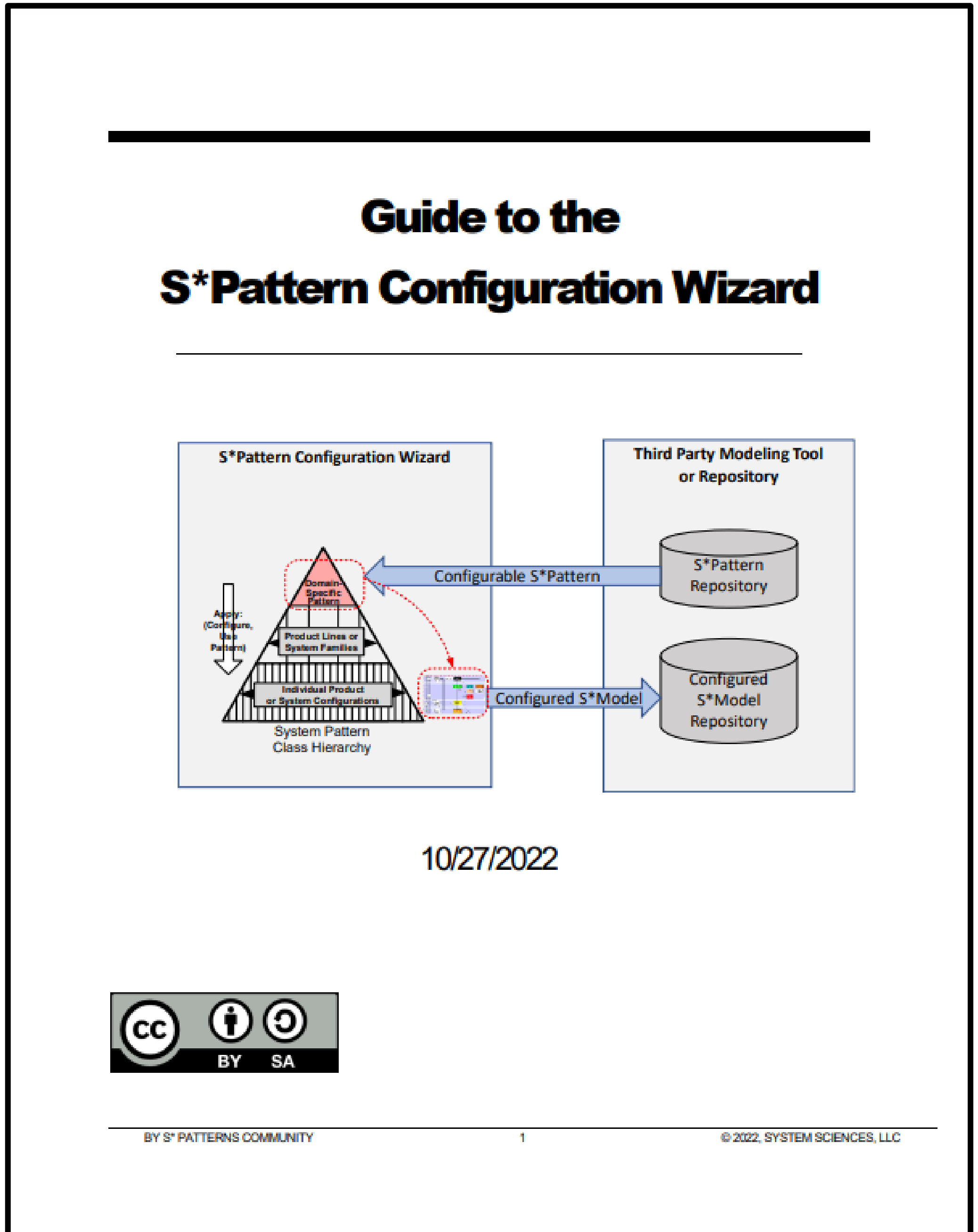
S*Pattern Configuration Wizard


Guide to the

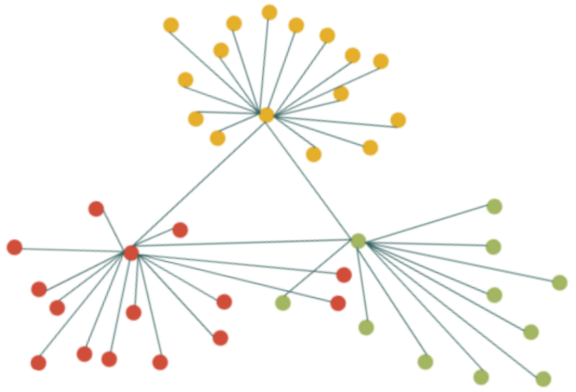
S*Pattern Configuration Wizard

10/27/2022

https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:guide_to_the_pattern_configuration_wizard_v1.2.8.pdf

Related collaboration project by ASME-INCOSE-AIAA-NAFEMS

Managing Engineered Consistencies:
Reconciling Semantics of Confirmation Frameworks



Encouraging A Conversation Across Technical Societies

schindel@ictt.com
Discussion Draft
V1.2.4

Startup Project

https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:cross_discipline_consistency_dialogue_v1.2.4.pdf

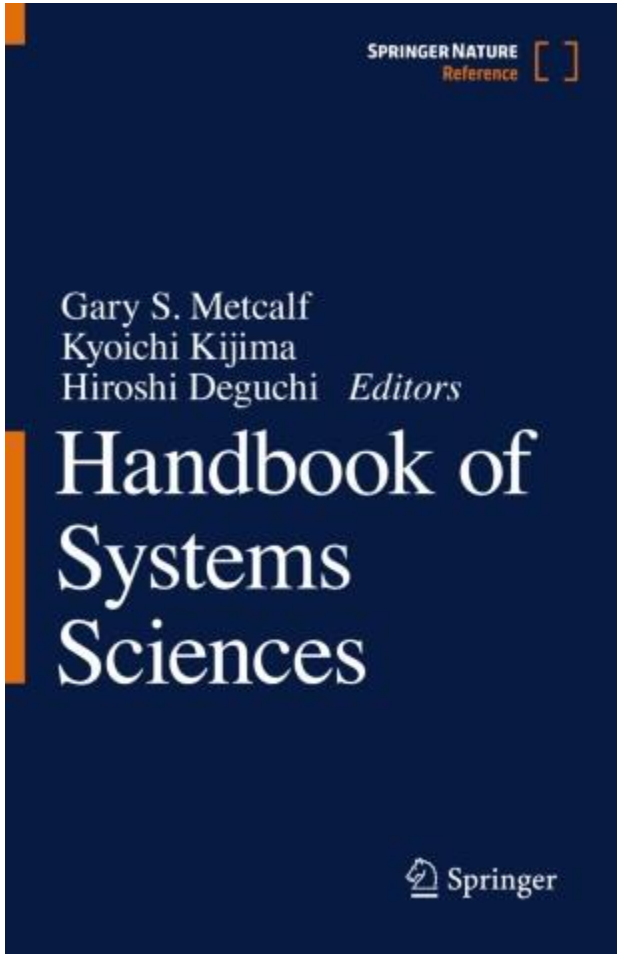
AIAA Aerospace Digital Twins Case Studies Publication and AIAA Aerospace Digital Thread Position Publication—Supported by INCOSE ASELCM Reference Pattern

AIAA-INCOSE Collaboration producing Aerospace Digital Twin and Aerospace Digital Thread reference models, *based on ASELCM Pattern*

https://www.aiaa.org/resources/digital-twin-implementation-white-paper

https://www.aiaa.org/resources/digital-thread-white-paper

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



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Handbook of Systems Sciences pp 1-43 | Cite as

System Patterns in Engineering and Science

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2 Mentions 186 Downloads

Abstract

Human life is experienced as recurring system patterns – the informal events of everyday living, expression of creativity and aesthetic experiences of the arts, organized observation and discovery in the physical sciences, and technically engineering the systemic improvement of the human condition. Patterns have been expressed and analyzed across these diverse domains in the languages native to each. In the case of science and engineering, the subject of this chapter, explicit formal methods for discovering, synthesizing, representing, analyzing, and applying patterns, have reached great heights, transforming human life over three centuries. In spite of successes, diversity of language and perspective across individual physical science and engineering disciplines has masked the common thread of system patterns running through these scientific and engineering works. The more recent attention to the science and engineering of systems in general, including explicit models of general systems, illuminates the nature of general system patterns and their fundamental contribution to representation and progress in science and engineering of systems. In addition to providing a unifying perspective to historical accomplishments of specialized disciplines, system patterns also simplify the complexity of existing engineering environments while advancing ability to develop new scientific and engineering disciplines for more complex domains, including markets, networks, distribution systems, the Internet of Things, communities, and the innovation process itself. This chapter and references provide an actionable perspective for readers interested in this revolution. A key lesson of this chapter is that system patterns reduce the challenge of accomplishing nearly any goal in the life of systems.

- 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

Handbook of Model-Based Systems Engineering, Madni & Augustine, eds, Springer, Chapter: “MBSE Patterns”.

- 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

Pattern-Based Methods and MBSE

AU1
AU2

William D. Schindel

Contents

Abstract

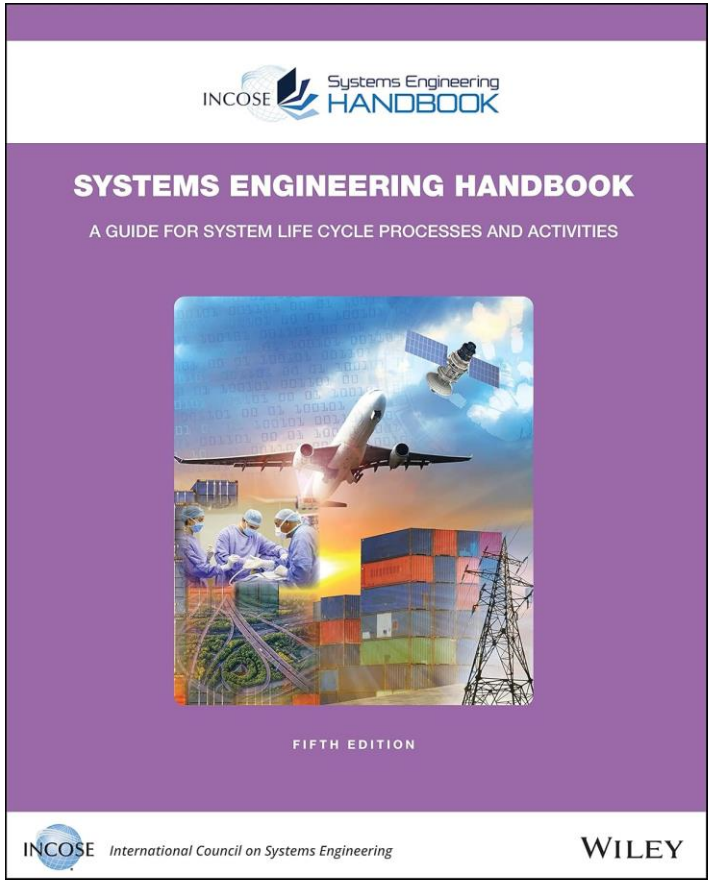
Patterns are recurring regularities, having fixed and variable parts, across engineered systems, systems of engineering, production, distribution, and sustainment, as well as the natural world. Ranging from concrete patterns of engineered product lines to abstract patterns behind architectural frameworks,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

W. D. Schindel (✉)
AU3 ICTT System Sciences, Terre Haute, IN, USA
e-mail: schindel@ictt.com

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

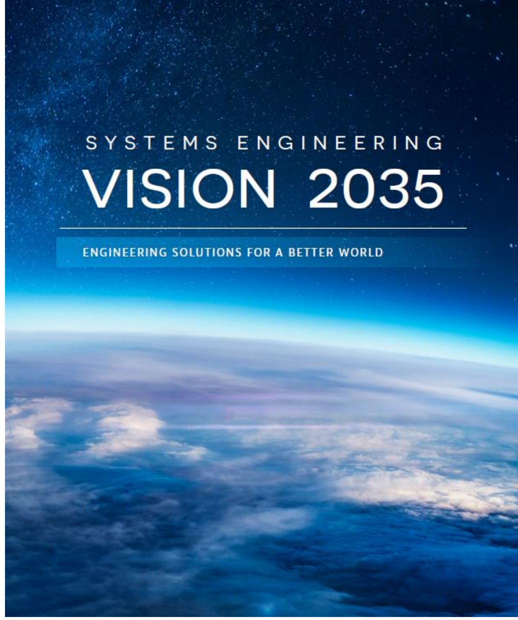
INCOSE SE Handbook, 5th Ed., for INCOSE, D. Contributed invited material on ASELCM Pattern, Pattern-Based Methods, and S*Metamodel

- 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.



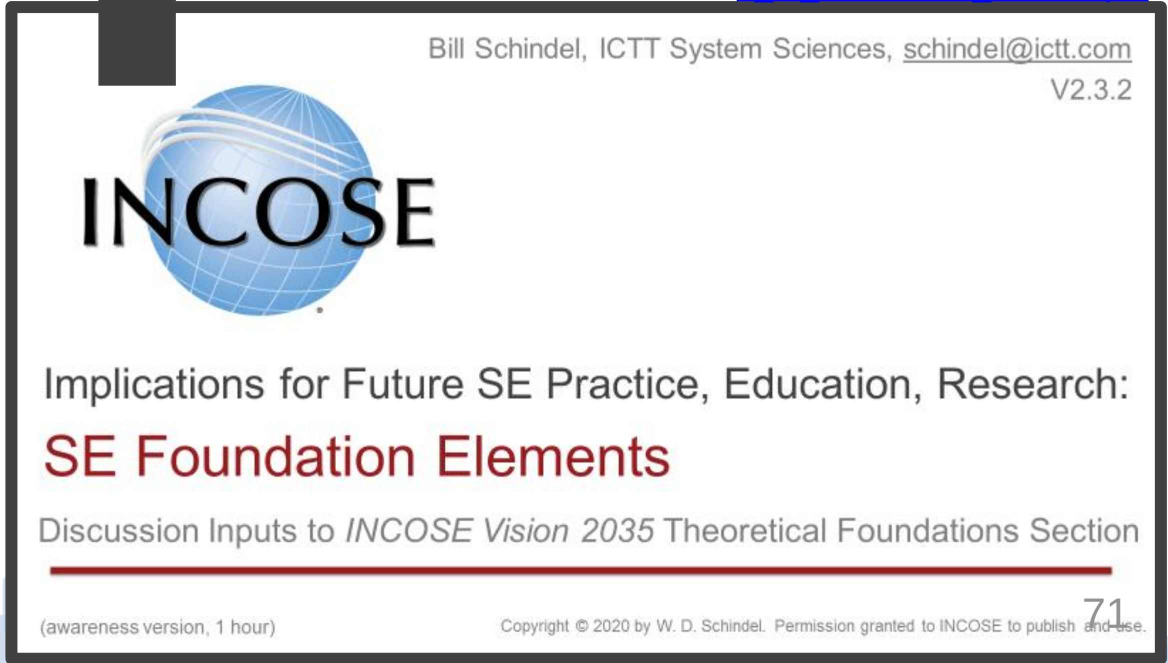
New (5th) Edition

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

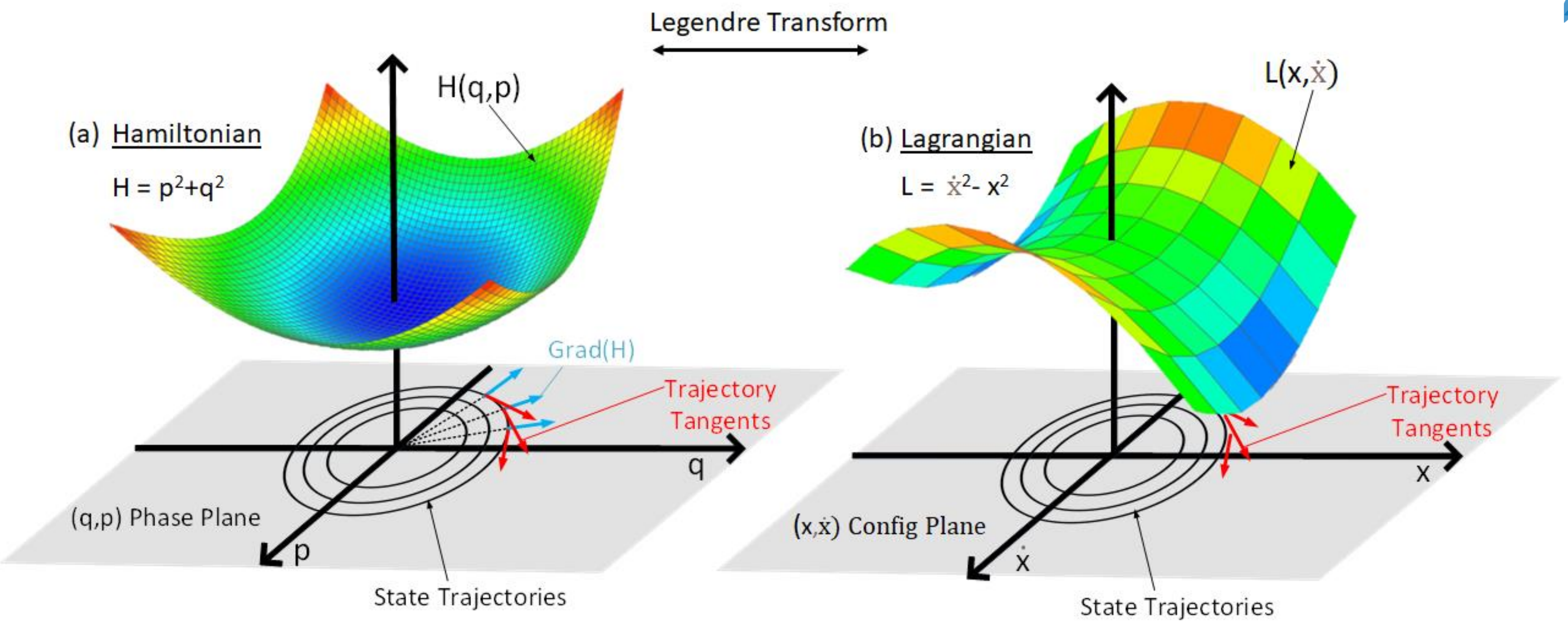
http://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:science_math_foundations_for_systems_and_systems_engineering--1_hr_awareness_v2.3.2a.pdf



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

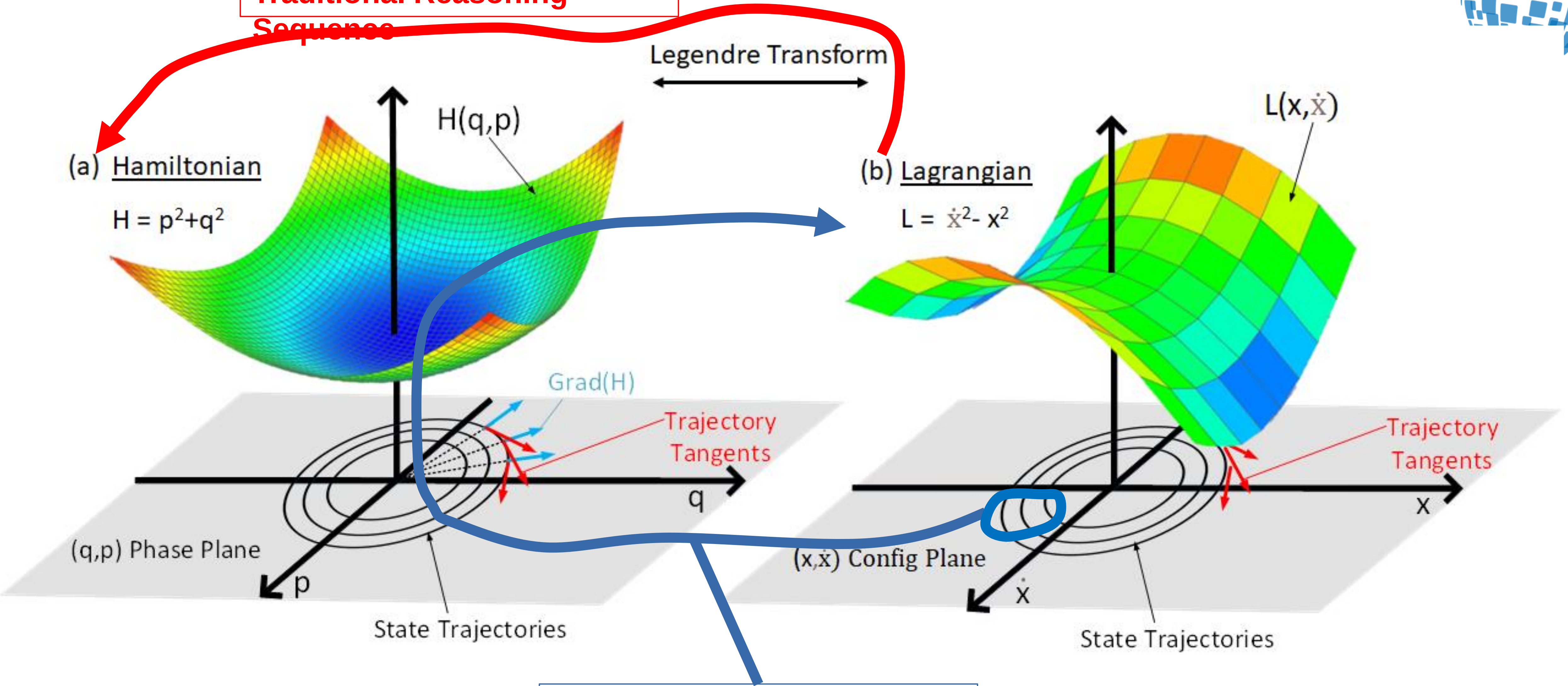
- Traditional Sequence (based on recognized energies of familiar types):
  - Start from an accepted Lagrangian for a familiar system class, energies (e.g., mechanical).
  - Perform Legendre transformation to obtain Hamiltonian (H). [Ref 11]
  - H satisfies Hamilton's equations of motion, including generalized 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 [Refs 12-13].



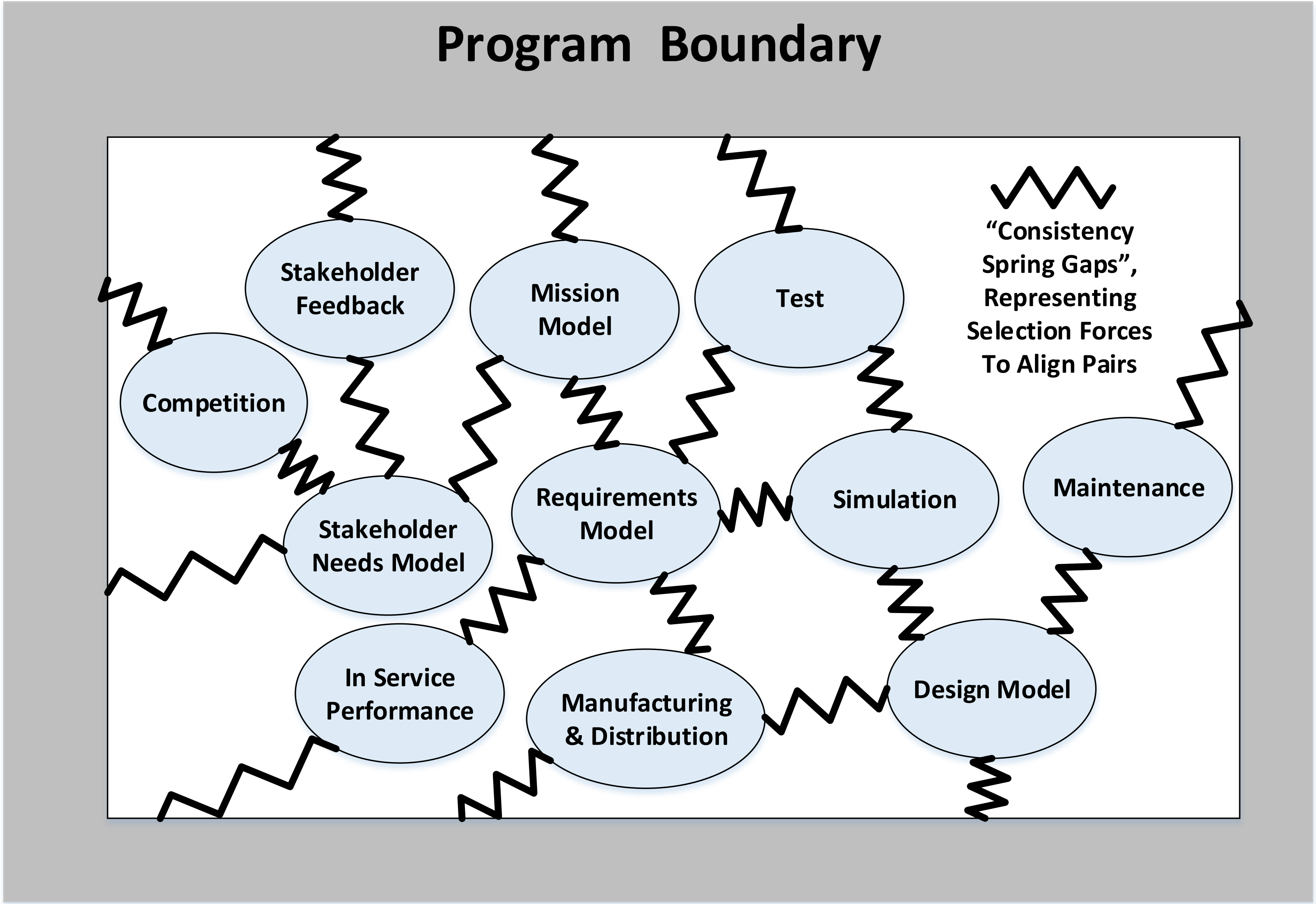
Example: Simple Harmonic Oscillator (SHO)

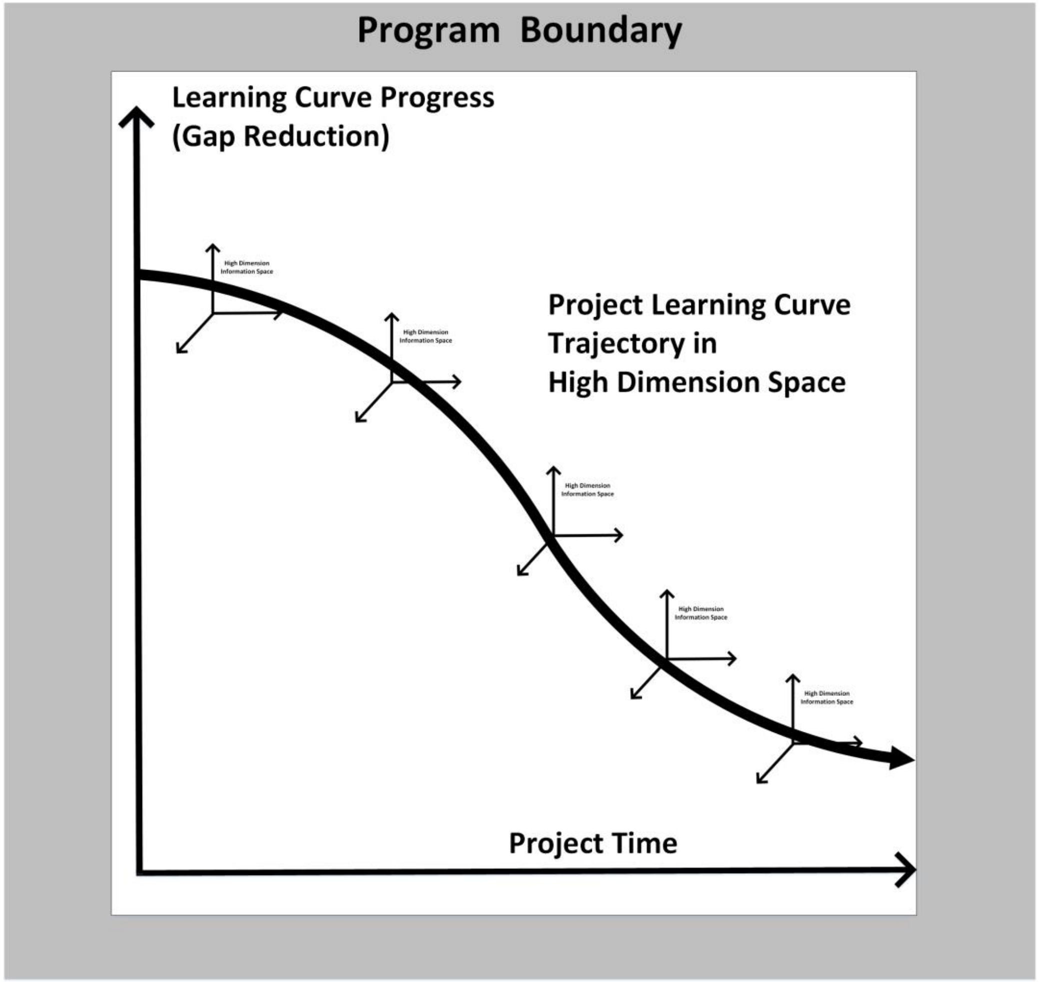
Traditional Reasoning Sequence

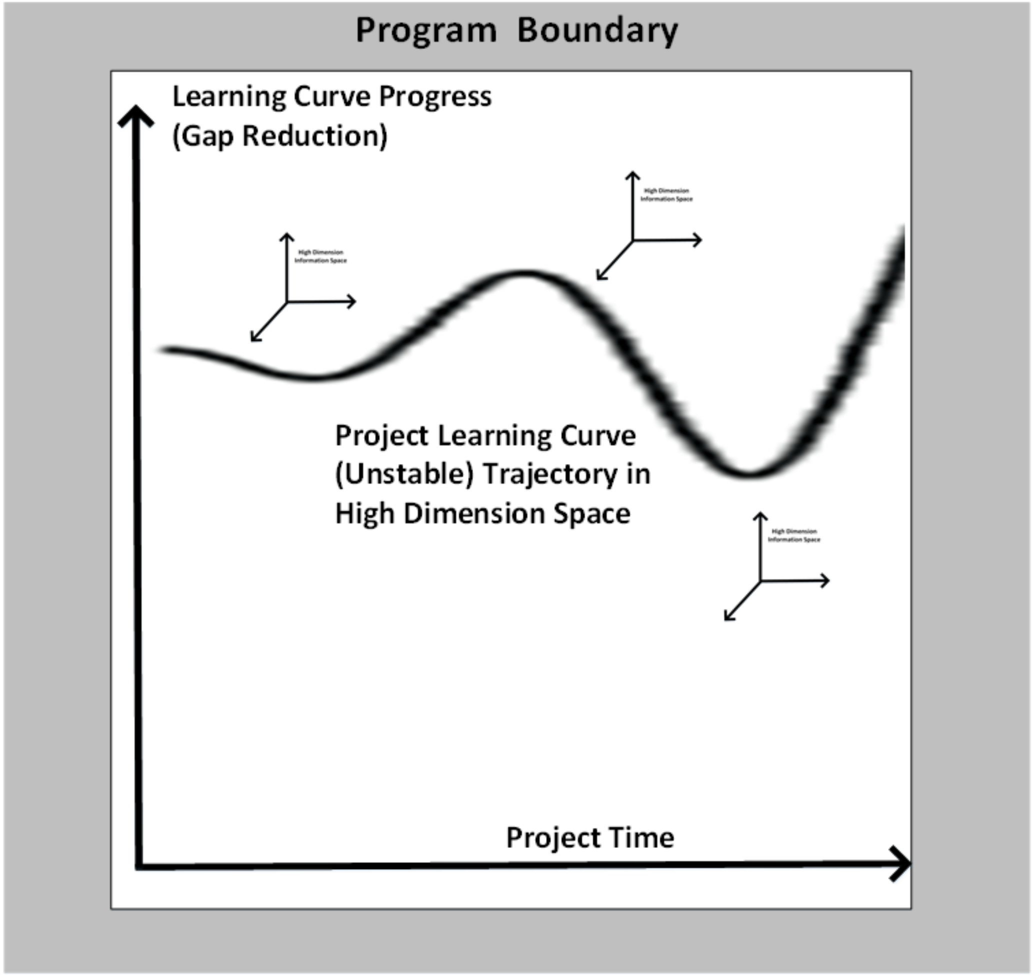


Alternate Reasoning Sequence

Example: Simple Harmonic Oscillator (SHO)


Program Boundary
Stakeholder Feedback
Mission Model
Test
"Consistency Spring Gaps", Representing Selection Forces To Align Pairs
Competition
Requirements Model
Simulation
Maintenance
Stakeholder Needs Model
In Service Performance
Manufacturing & Distribution
Design Model


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

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   - Inward-facing (incose.org): https://www.incose.org/incose-member-resources/working-groups/transformational/mbse-patterns

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