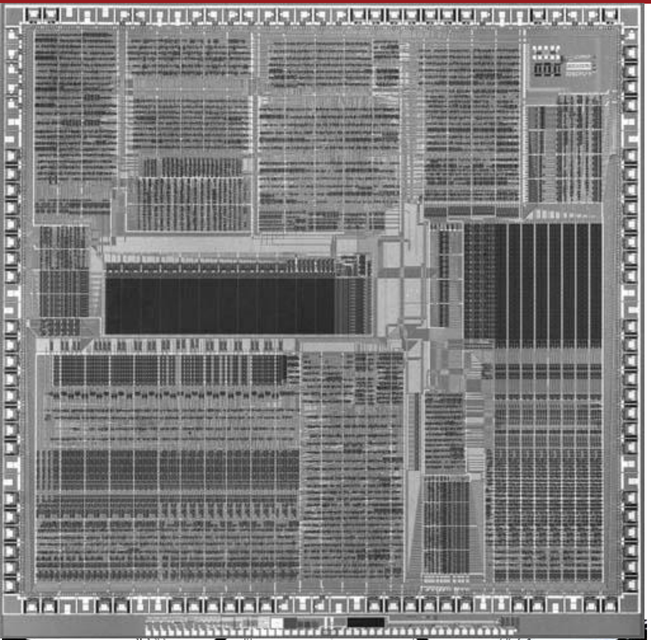
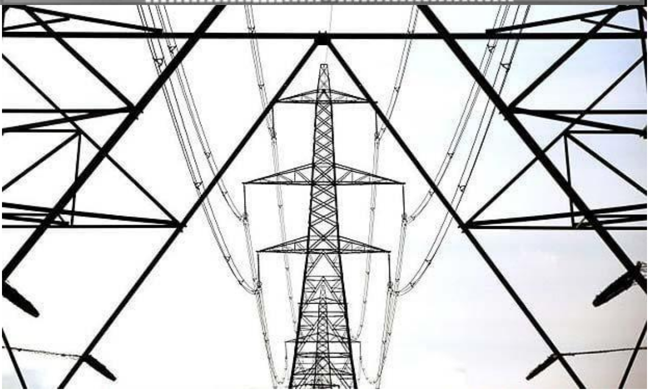
32nd Annual INCOSE international symposium

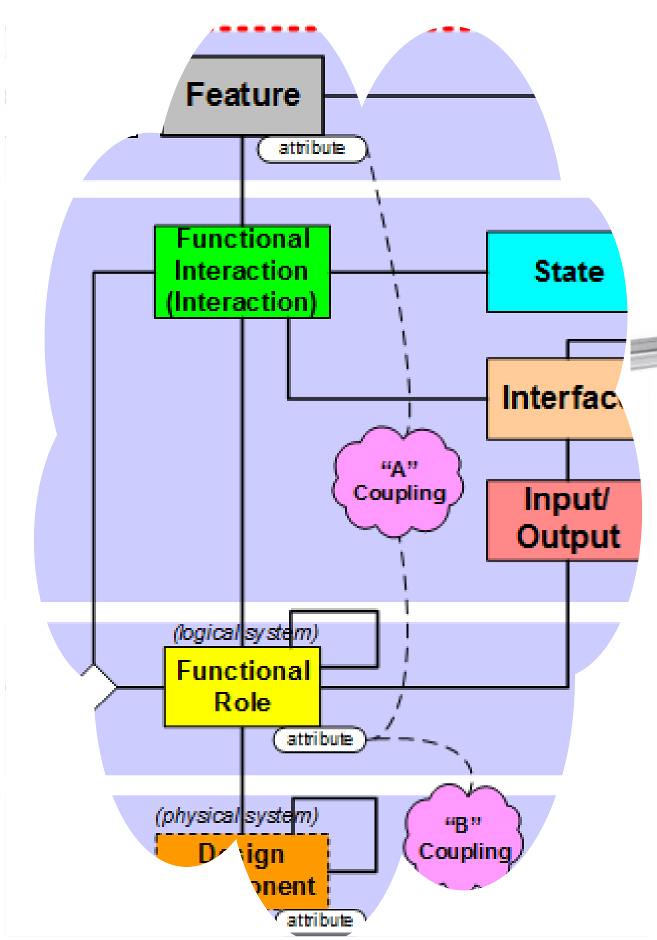
hybrid event

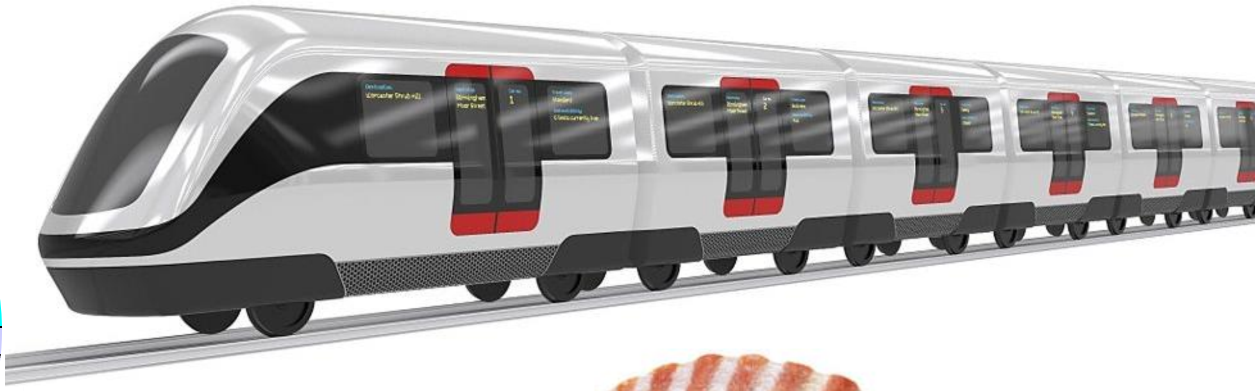
Detroit, MI, USA
June 25 - 30, 2022

MBSE Patterns Working Group







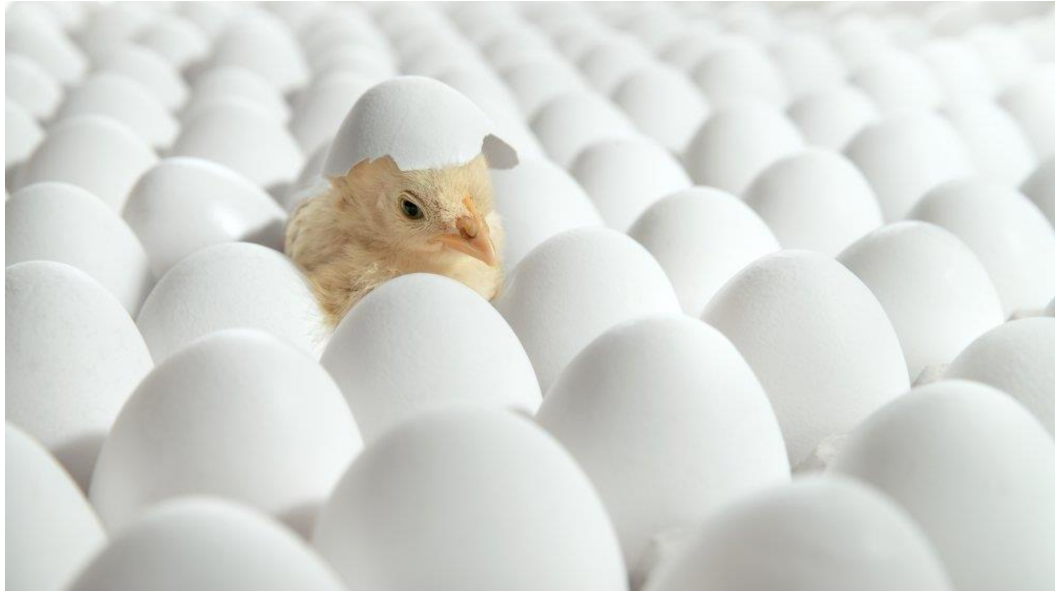


www.incose.org/symp2022

V1.3.5

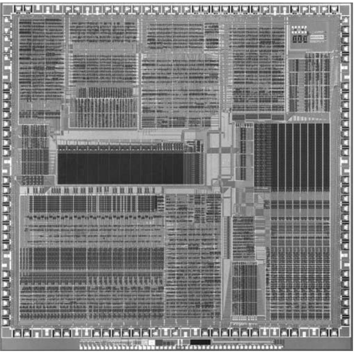
Agenda Summary

- 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

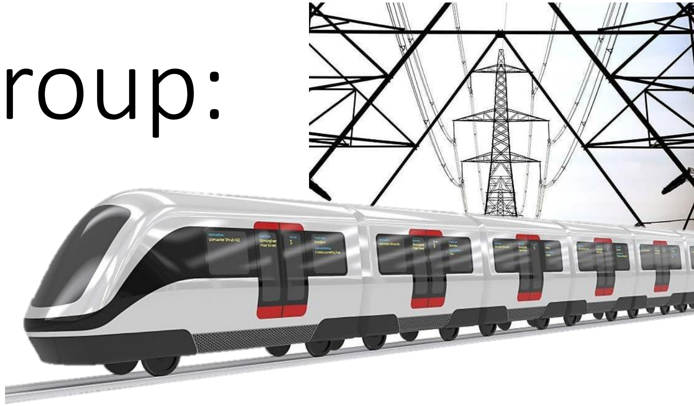


Began nine years ago, as MBSE Initiative Patterns Challenge Team:

- Part of the joint INCOSE/OMG MBSE Initiative, formed earlier.
- Six 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 the joint OMG-INCOSE MBSE wiki.

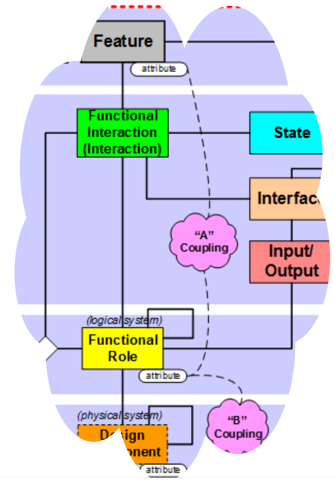


Focus of MBSE Patterns Working Group: S*Patterns



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

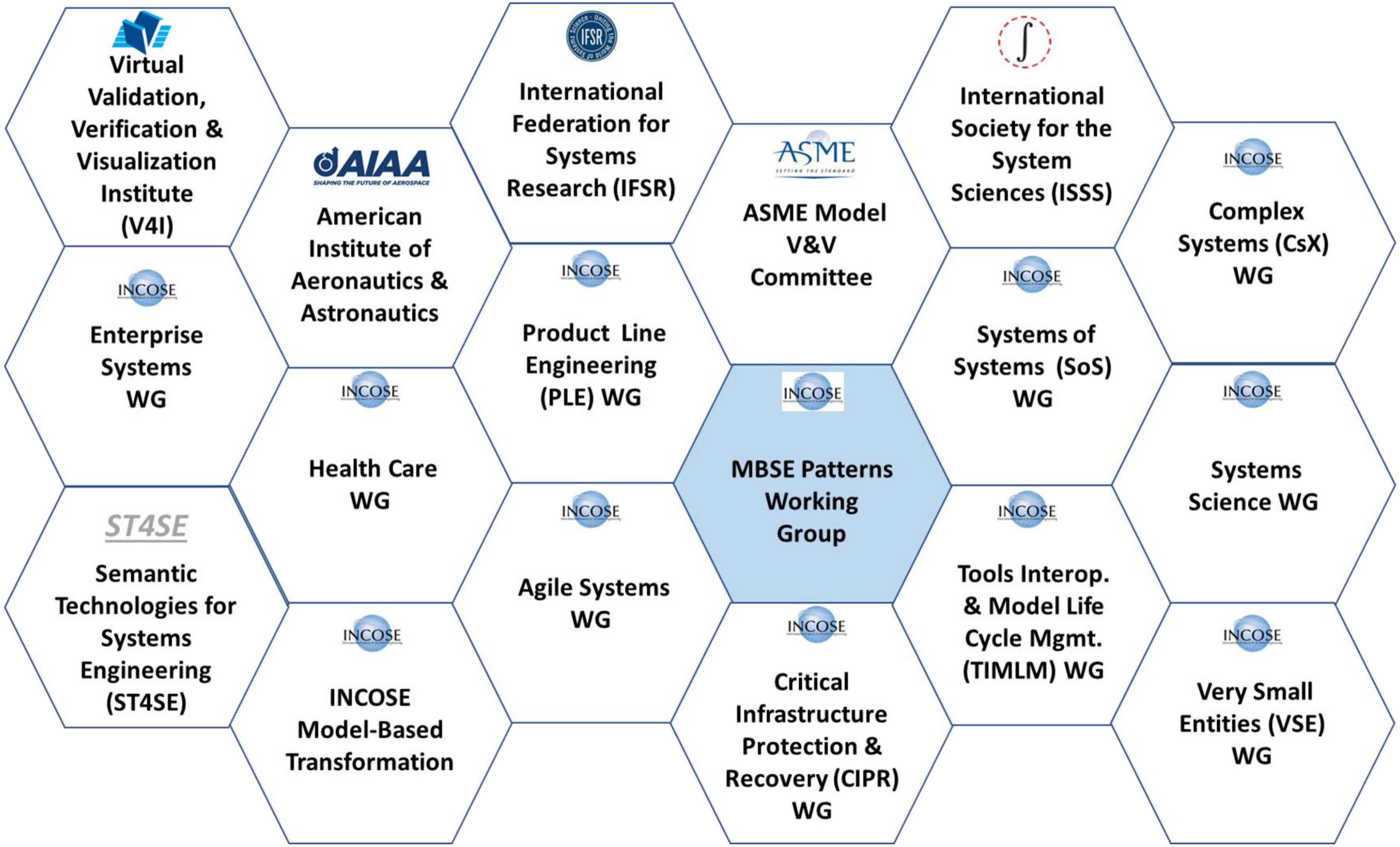
1. Models containing a certain minimal set of elements are called <u>S*Models</u> (S* is short for "Systematica")
2. Those underlying elements are called the S*Metamodel, which was inspired by the physical sciences
3. S*Models using those elements may be (have been) expressed in any modeling language (e.g., OMG SysML, or other languages)
4. S*Models can be (have been) created and managed in many different COTS modeling tools.
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
7. These are system-level patterns (models of whole managed platforms), not just smaller-scale component design patterns



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 nine 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.

Nearly all our work includes partner INCOSE WGs or others



Participate! Collaborate!

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 co-chair: Troy Peterson tpeterson@systemxi.com

Patterns WG web site:

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

IS2022 Patterns WG meeting web site:

https://www.omgwiki.org/MBSE/doku.php?id=mbse:patterns:mbse_patterns_wg_participation_in_incose_is2022

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
-
-
-
-

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 .

An “MBSE Patterns 101” Introduction

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

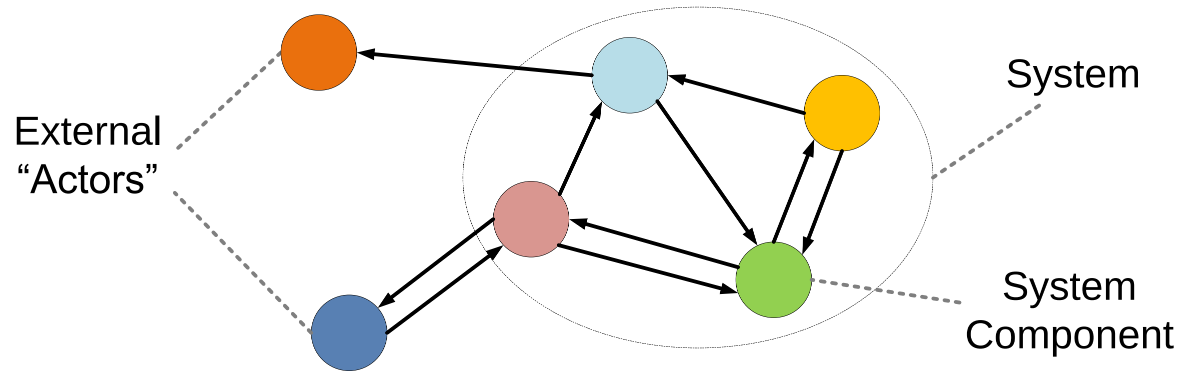
- A key point is realizing patterns suggest we *strengthen underlying MBSE representation*.

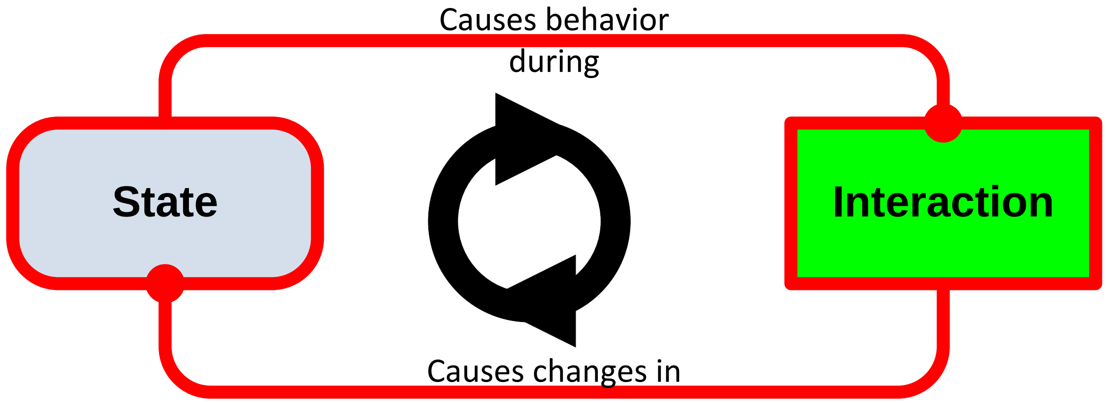
For a more complete look, see:

- PBSE Methods and Position in Related Subjects
  https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:pbse_extension_of_mbse--methodology_summary_v1.6.1.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

Formalizing System Terms and Representations

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



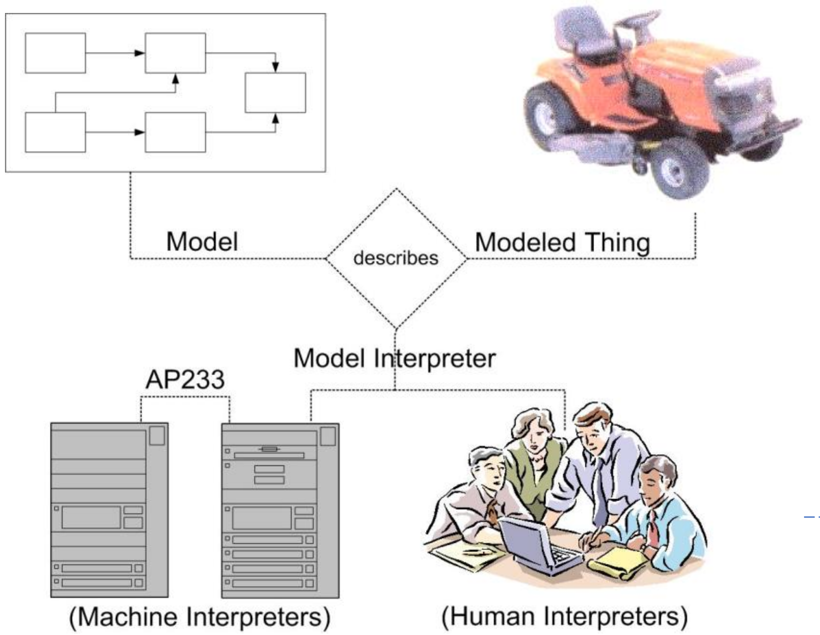


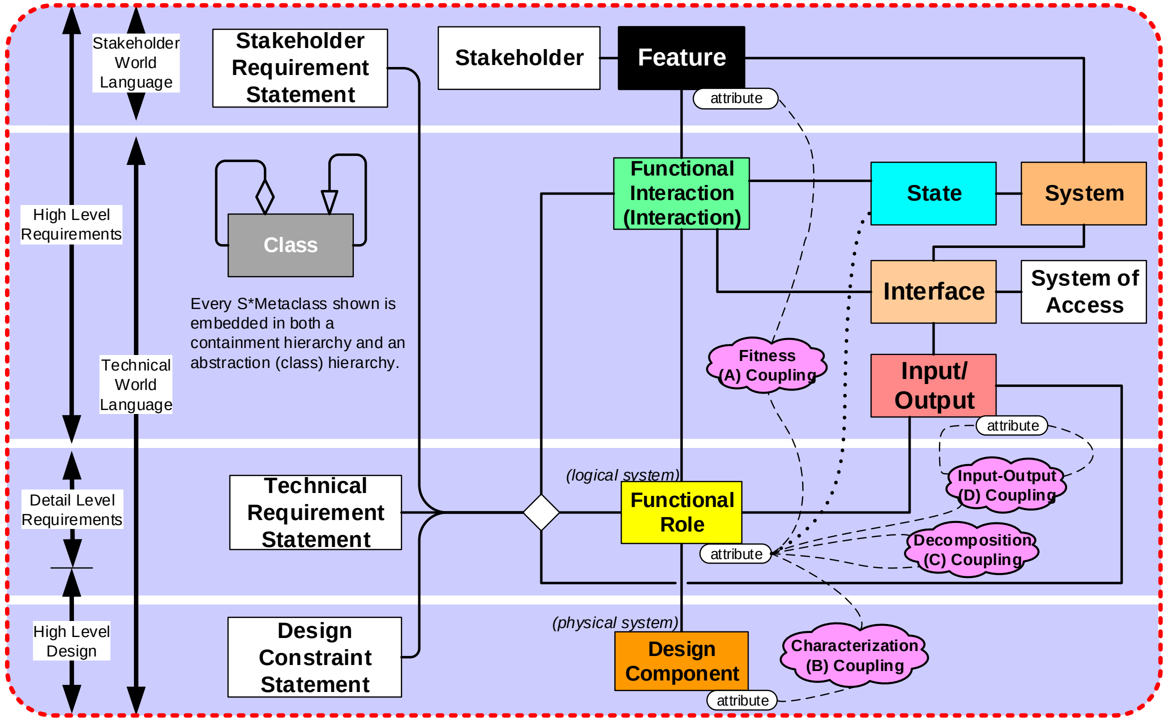
- By "interacting" we mean the exchange of energy, force, material, or information (all of these are "input-outputs") between system components, . . .
- . . . through which one component impacts the state of another component.
- By "state" we mean a property of a component that impacts its input-output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



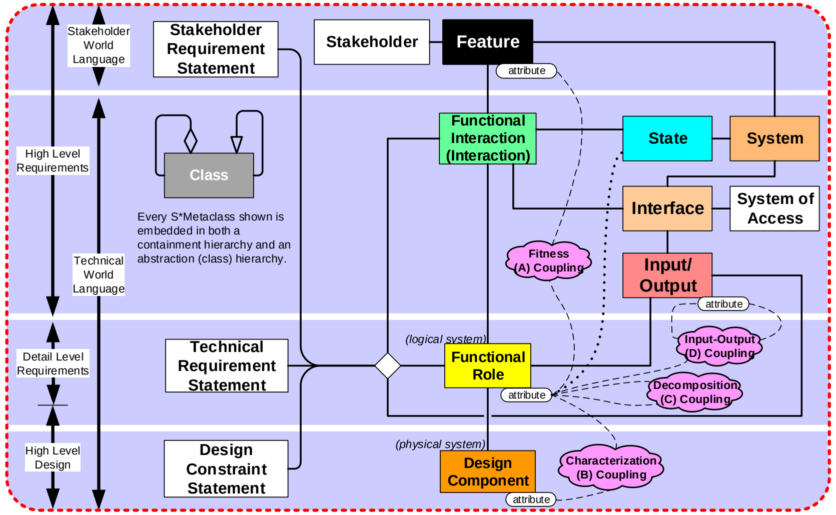


S*Metamodel informal summary pedagogical diagram
(formal S*Metamodel includes additional details.)

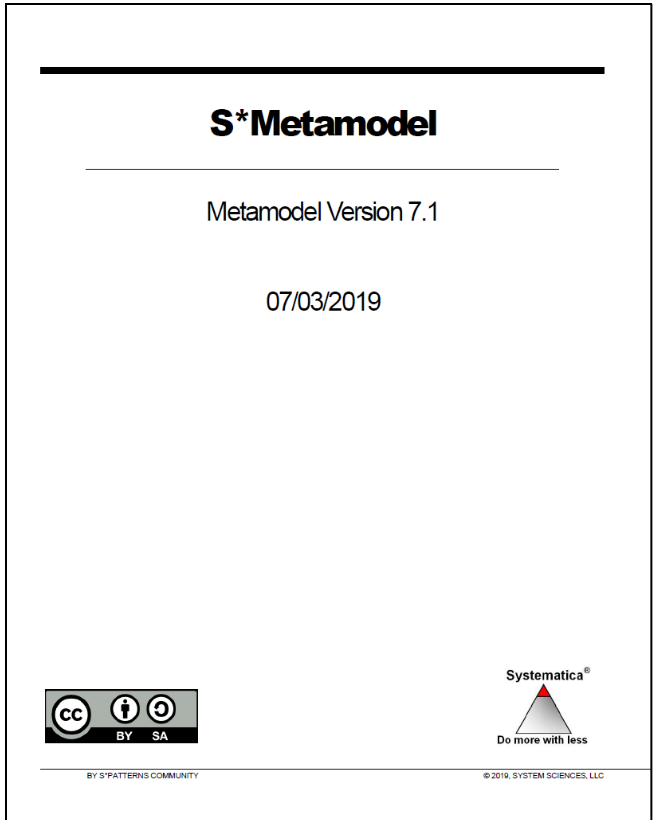
So what is the S*Metamodel, and more important why is it?

S*Metamodel: A reference model of models

- 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



S*Metamodel

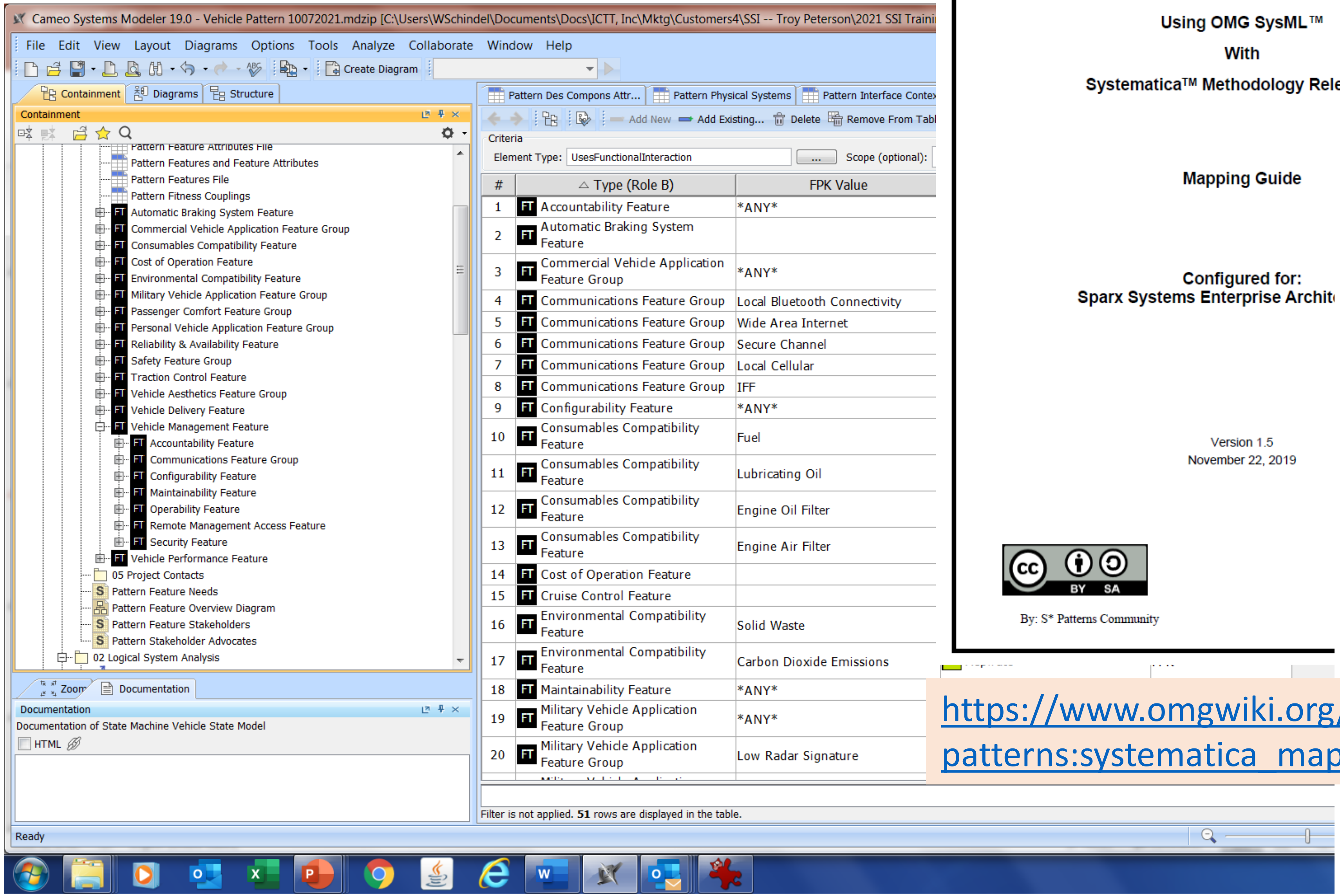
Metamodel Version 7.1

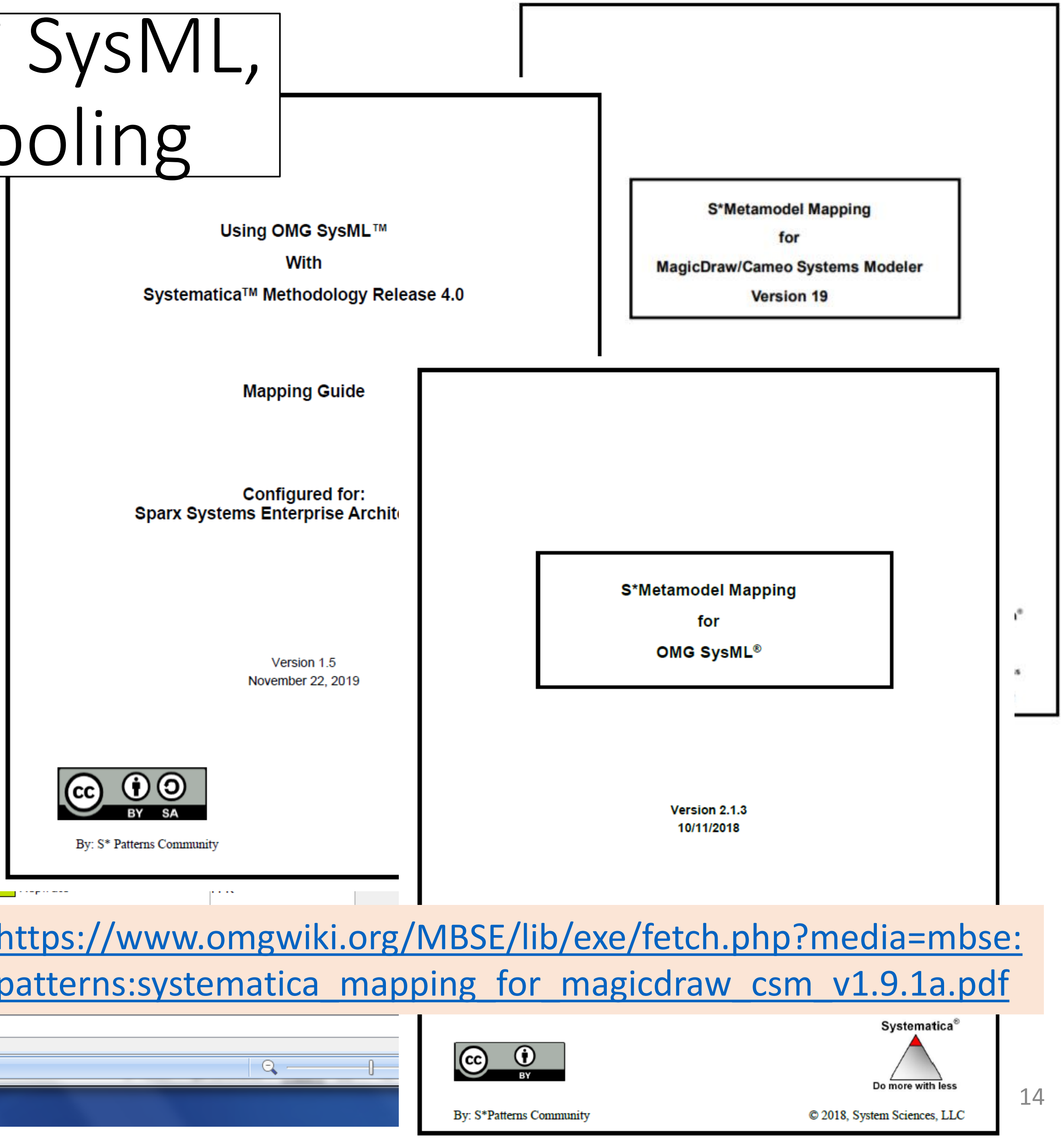
07/03/2019

Systematica®
Do more with less

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

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





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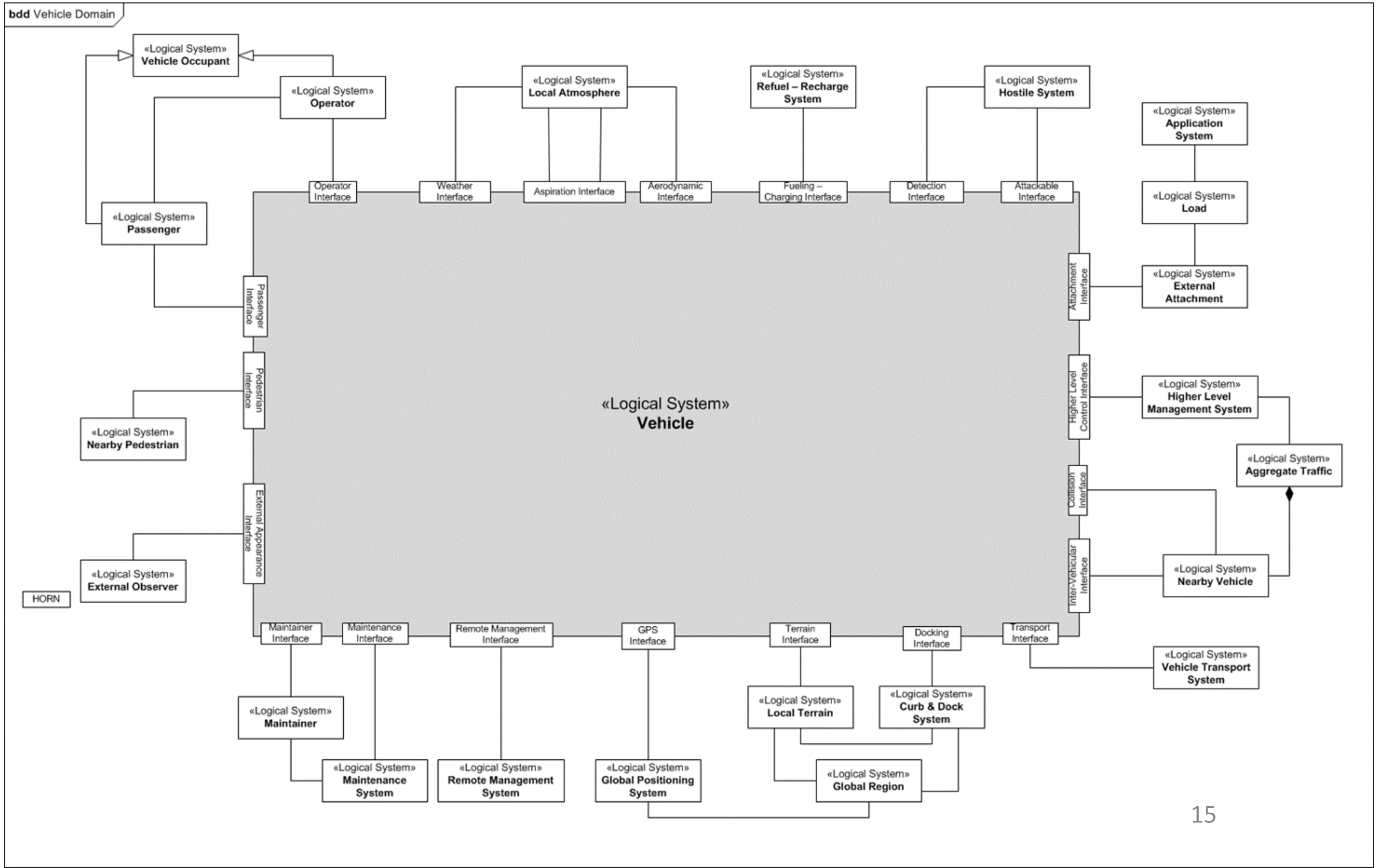
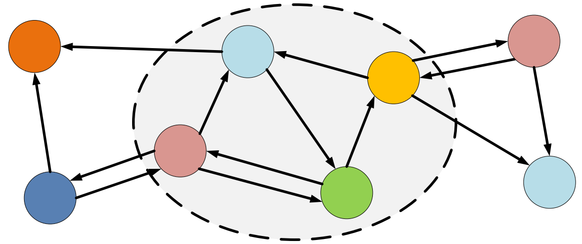
Domain Model: One important system model view

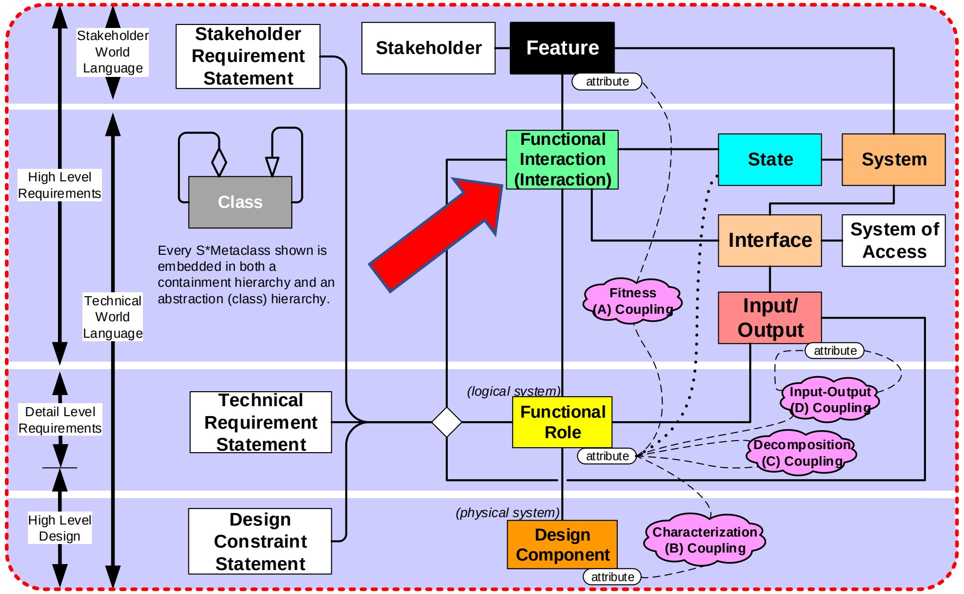
- All the external actors with which a system of interest interacts directly, forming a “Domain System”.
- The (larger) system that is the context of the System of Interest.
- Domain Patterns provide powerful introductions to the context of different system products, markets, and applications, such as:
    - 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



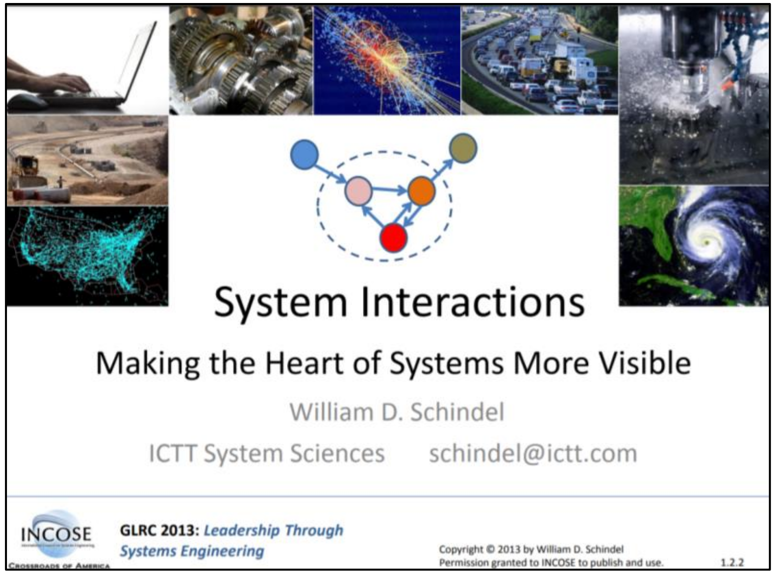
Functional Interactions: Phenomena; clarifying SE views of behavior



- 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.)



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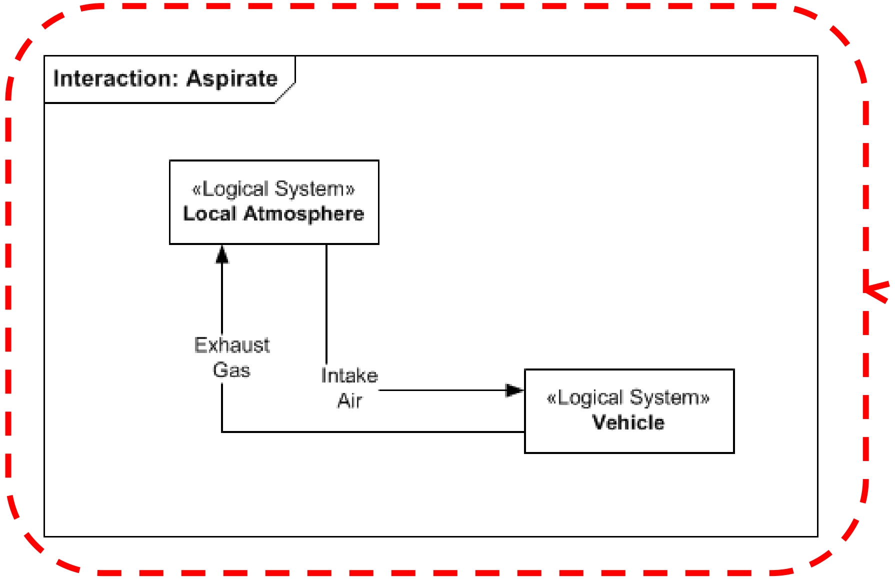
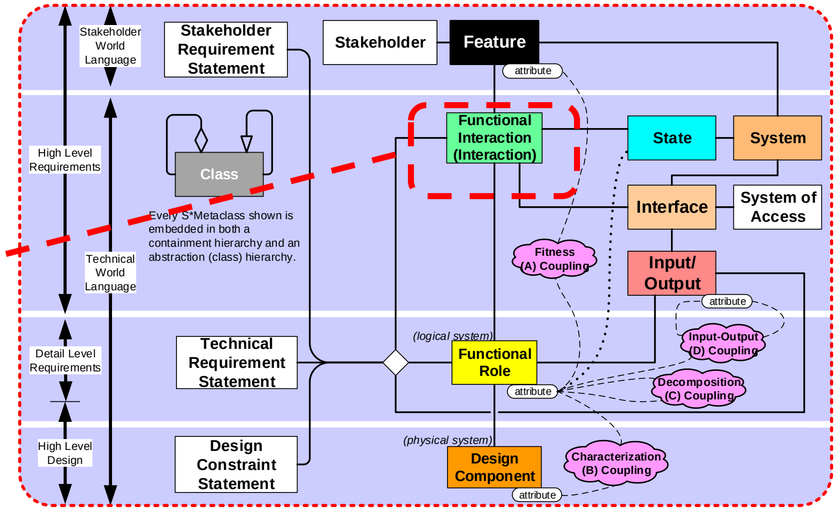
Interactions: Vehicle example





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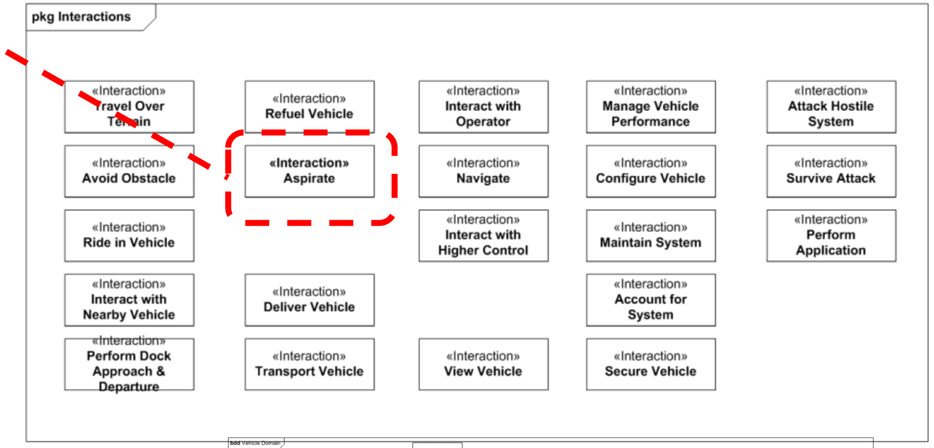
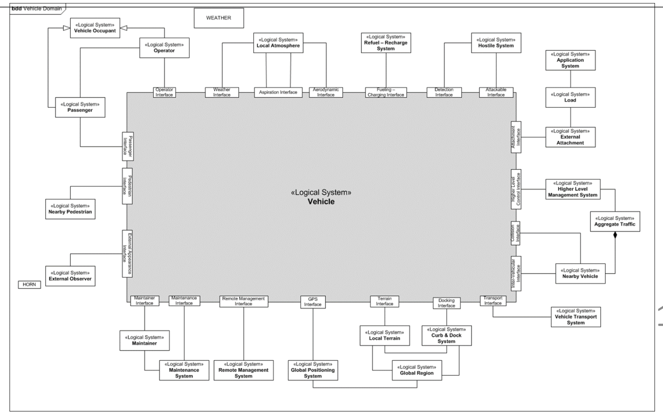
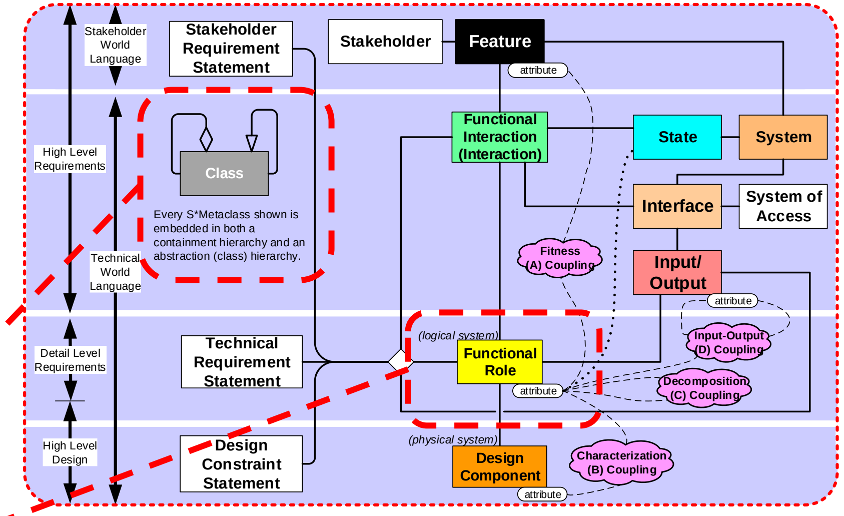




- A key point for systems engineers is not to over-emphasize "my system" as opposed to its interactions with external actors.
- Sometimes engineers object that "I am not responsible for and cannot control those other actors"; however, . . .
- The fact is, the only externally visible behaviors your product 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



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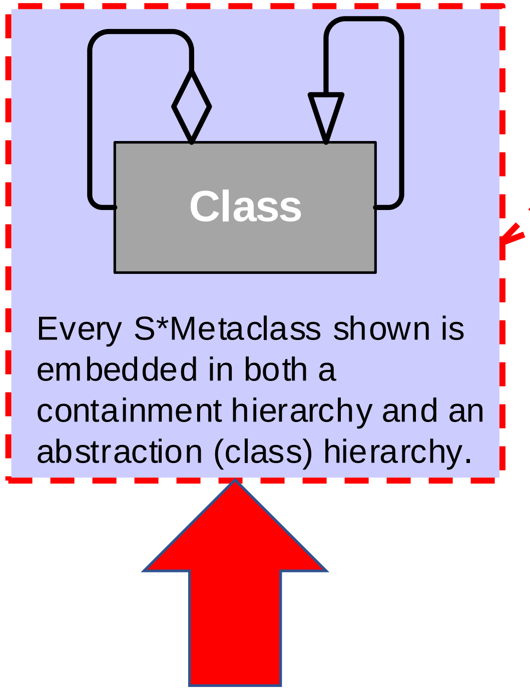


<u>Containment (Part-Whole) Hierarchy</u>:
- Vehicle System
- Vehicle Propulsion System
- Braking System
- Brake

Functional Roles (Logical Systems)

Important to traditional engineering decomposition and Bill-of-Materials

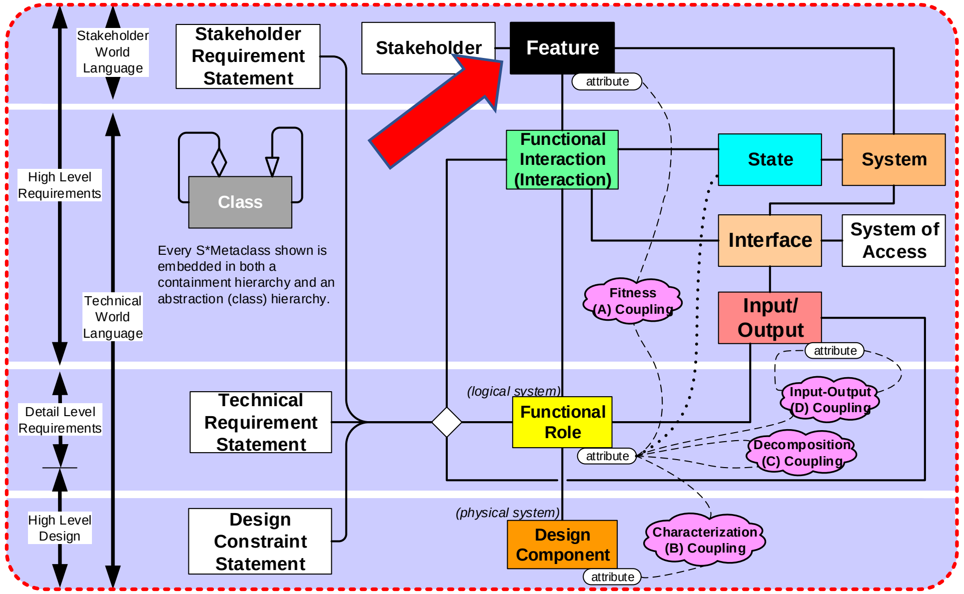
<u>Class (General-Special) Hierarchy</u>:
- Vehicle System
- Ambulance Vehicle System
- Military Ambulance Vehicle System
- Mil Ambulance Vehicle, configured for Desert.

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, 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!



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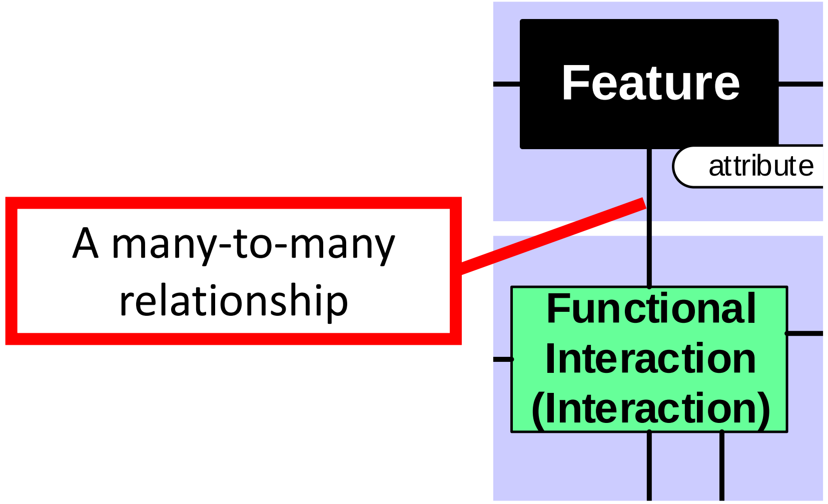
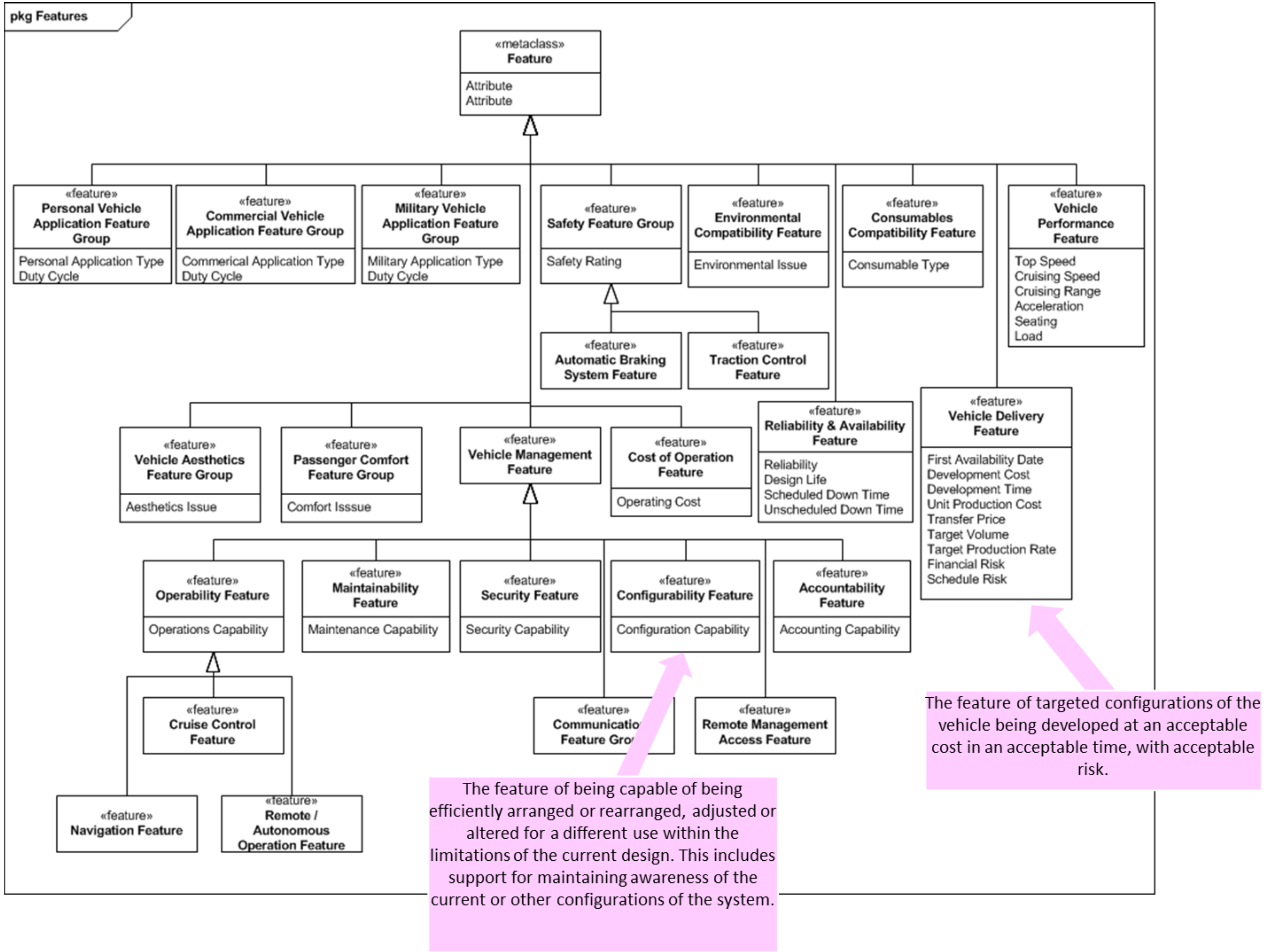


Stakeholder Features: Vehicle example



Feature configuration space: Bigger than expected

Like the Tardis: Bigger on the Inside!

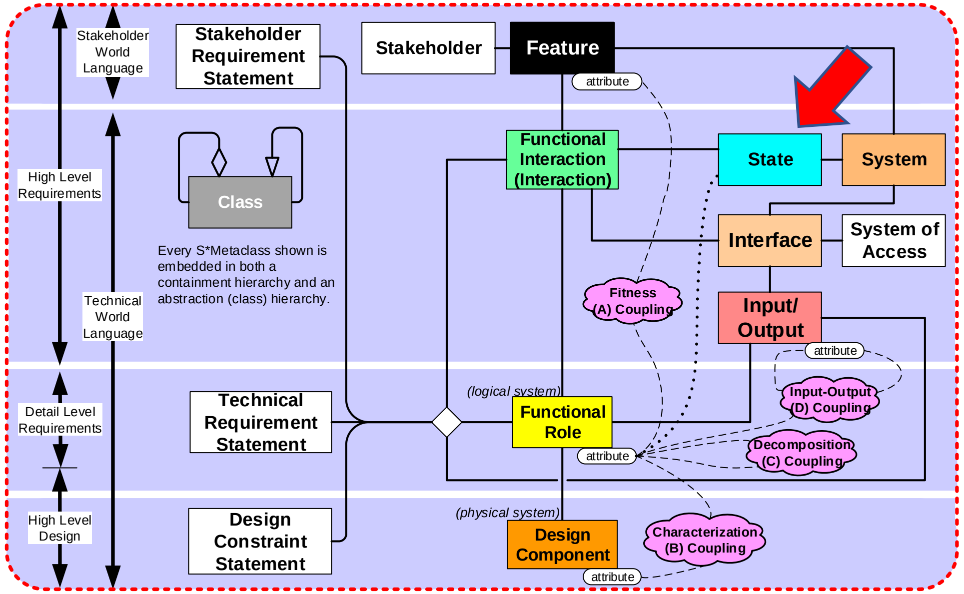
A perhaps surprising thing about Features is that they model a lot more than might be thought of at first when considering "value":

- Features discover examples of models that are both "too small" <u>and</u> "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 <u>*purpose*</u>, even when discovered by emergence and agile pivots, is in Feature Space.
3. <u>*All risk is risk to Stakeholder Features*</u>. So, the whole outcomes side of any Risk model should terminate in Feature space.
4. <u>*All Effects (the "E" part in FMEA analyses) are effects in Feature Space*</u>. 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. <u>*All product line segmentation / selection is described in Feature Space*</u>. (More on this as you learn about S*Patterns and pattern-based methods.)

States, State Variables

- In general, a <u>State</u> 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 <u>important special case</u> 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.



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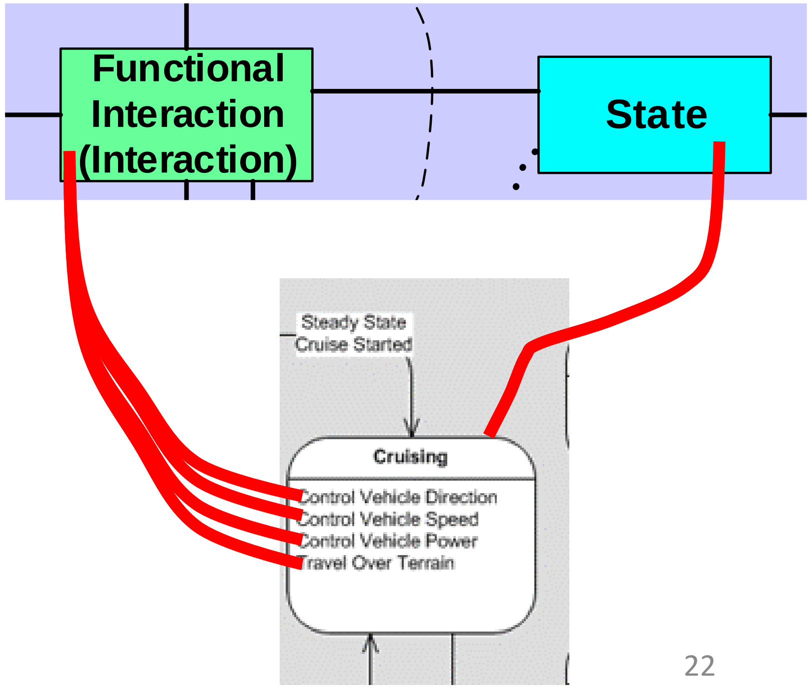
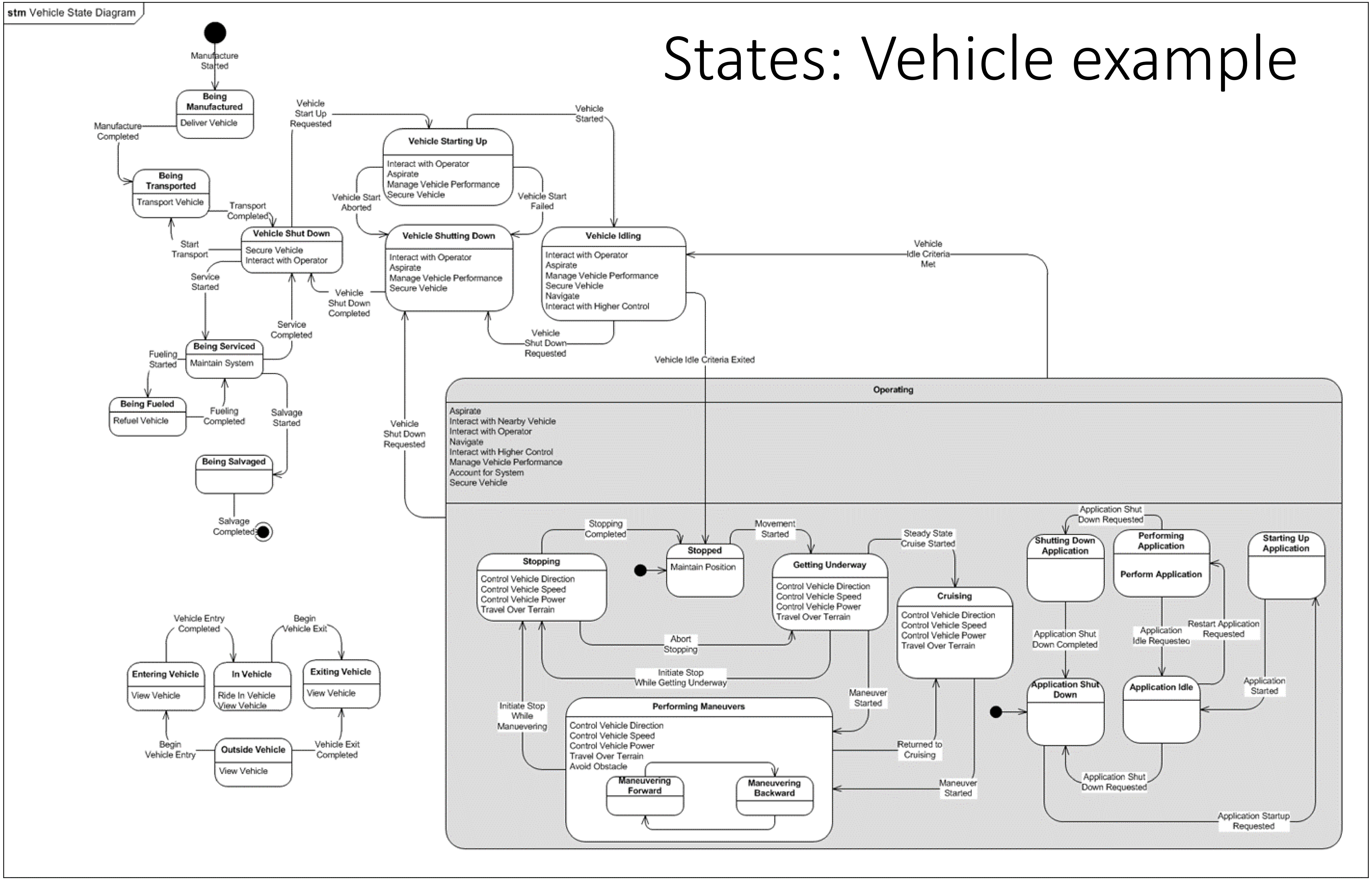
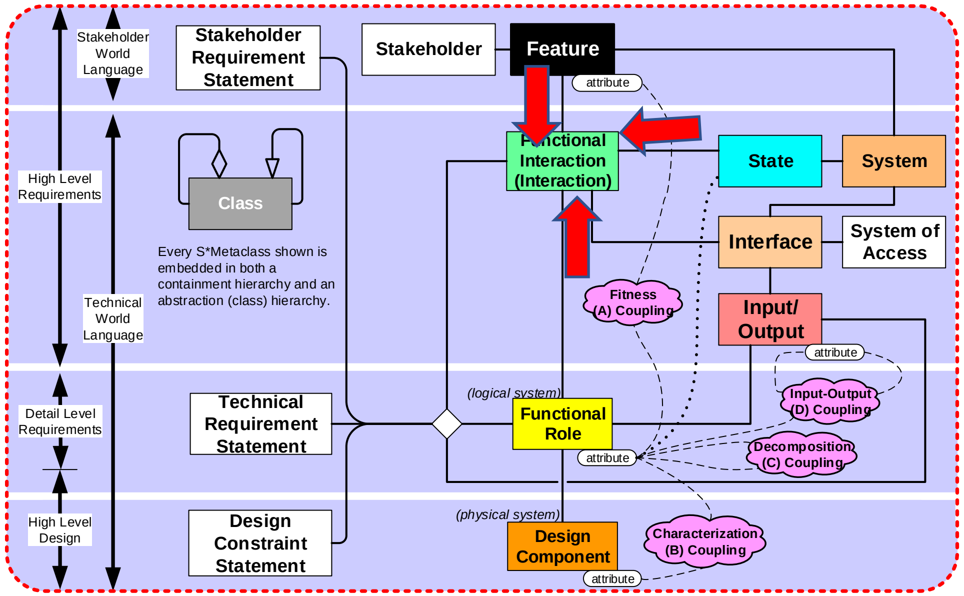


States: Vehicle example



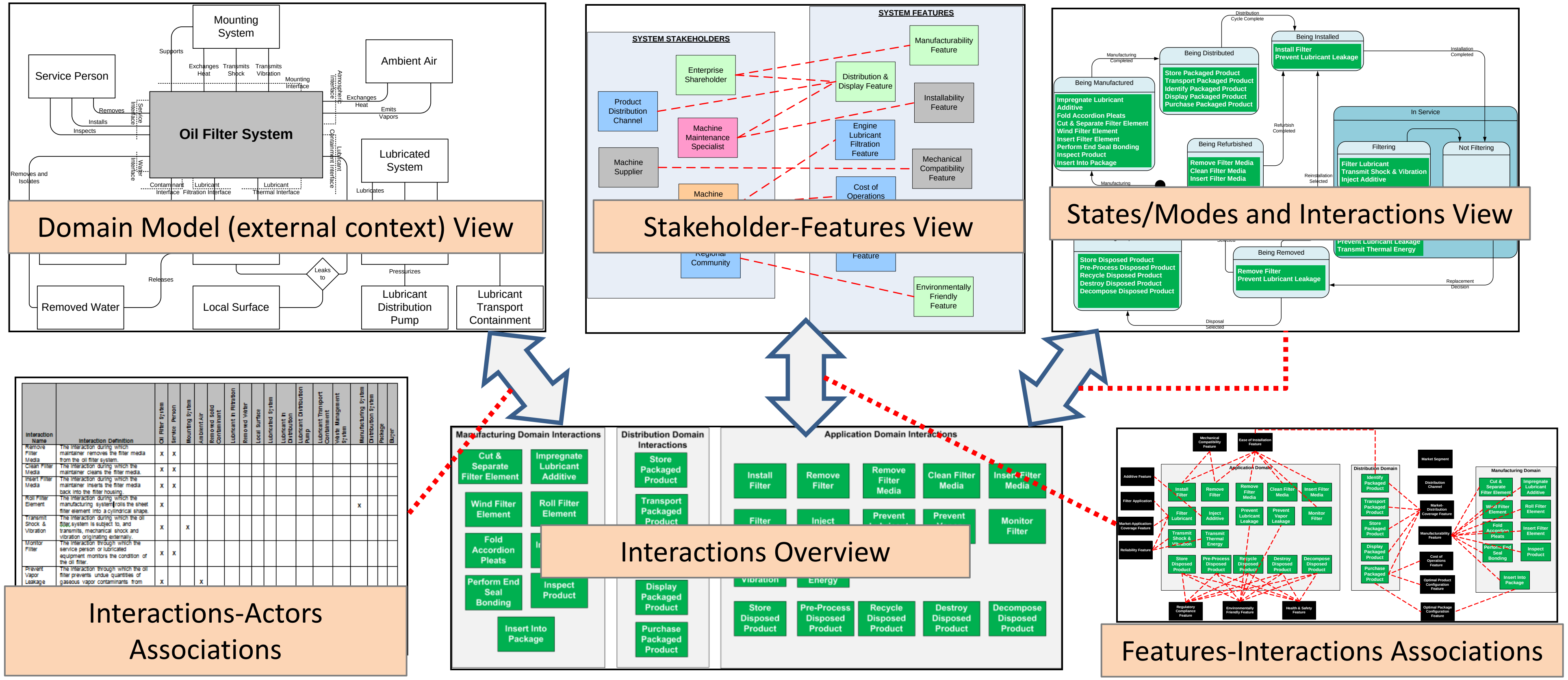
Three paths to finding all the Interactions

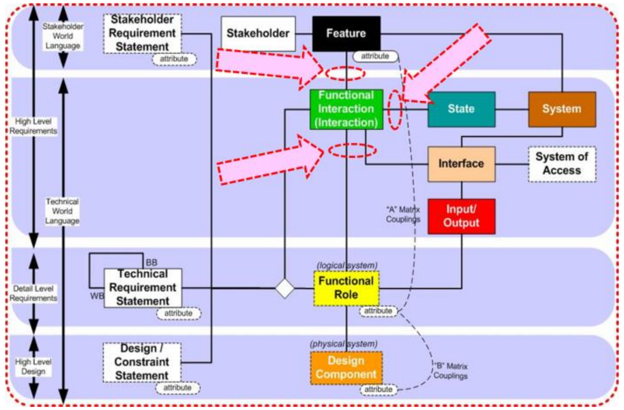
- It turns out that "discovering all the Interactions" that need to be modeled is very important:
  - You will eventually learn how this can greatly help us "find all the Requirements" for a system.
- So, the following is provided as a powerful way to "find all the Interactions":
  - There are three 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
(formal S*Metamodel includes additional details.)

- 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.





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

Three paths to the same Interactions

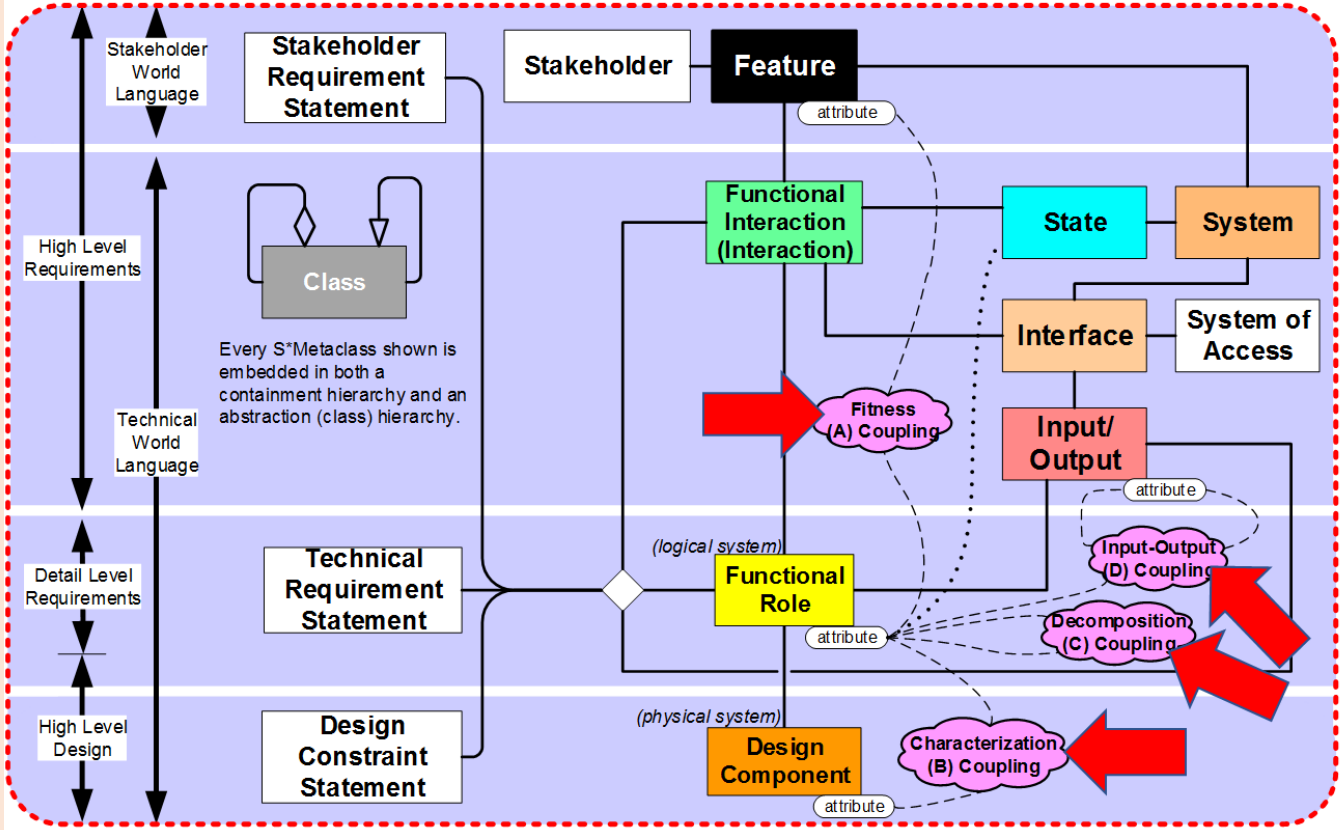
Patterns push us toward better model completeness and consistency

- 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.

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.

Classes of parametric couplings



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

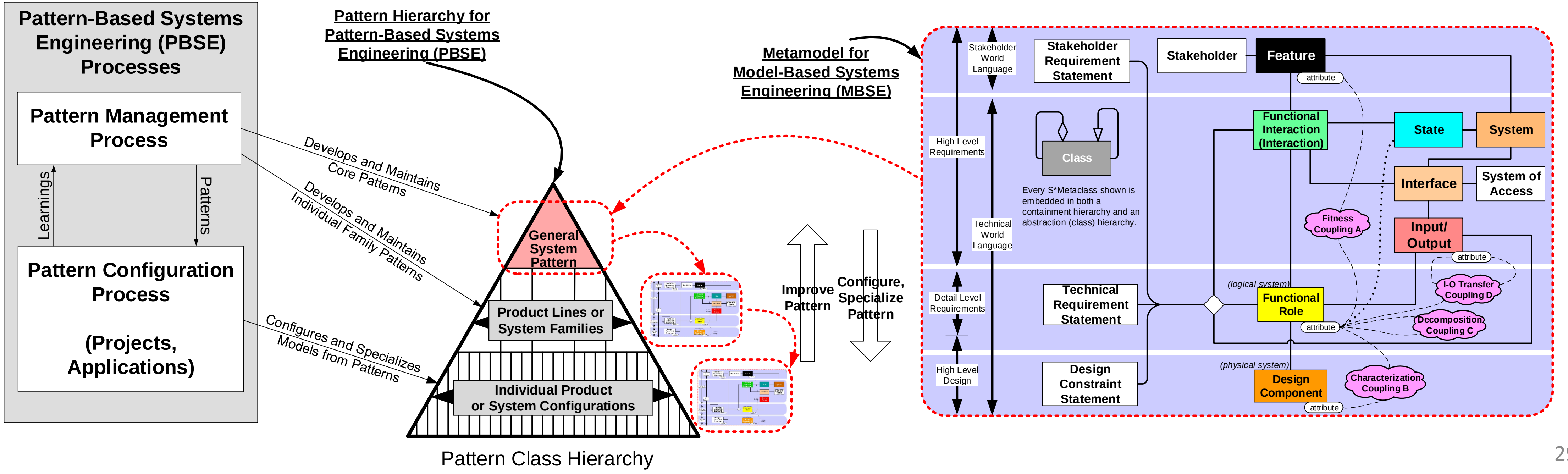
Integration of the Risk Model

- 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.

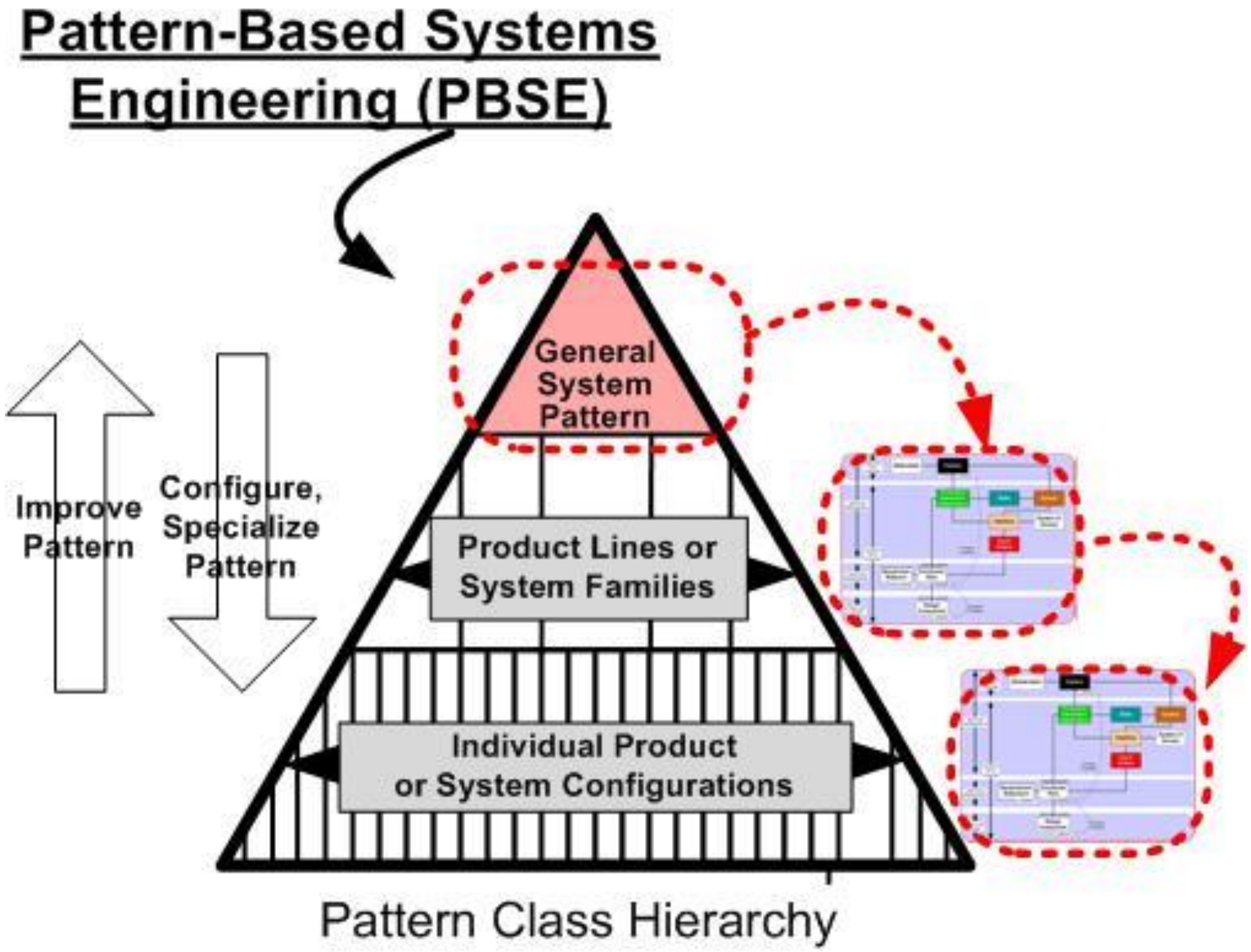
https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:improving_failure_analysis_using_mbse_v1.3.2.pdf

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!

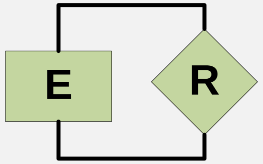
- Configurable patterns are the "sweet spot" targeted by S*Patterns.

Emergence of Patterns from Patterns: S*Pattern Class Hierarchy

More General

Definition of **Relational Modeling Paradigm**

Entity-Relationship Paradigm

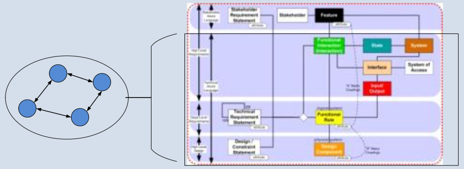


E=Entity
R= Relationship

Structured or unstructured semantic web

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

S*Metamodel Core



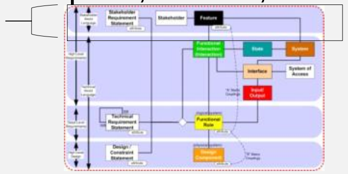
Core S*Metamodel

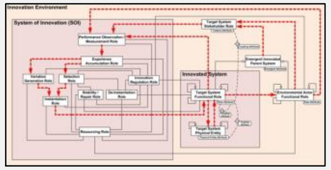
Smallest model of a system, for engineering or science

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

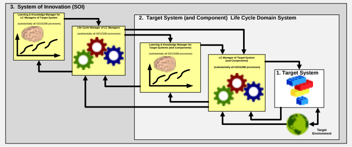
EI Pattern, SOI Pattern, Fitness, Value

S*Purpose, Fitness, Value

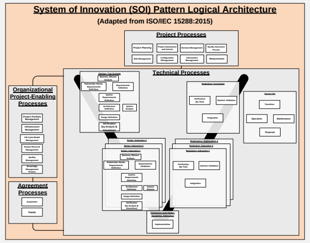




System of Innovation Pattern



Agile Sys Life Cycle Pattern



ISO 15288 System Life Cycle Mgmt Pattern

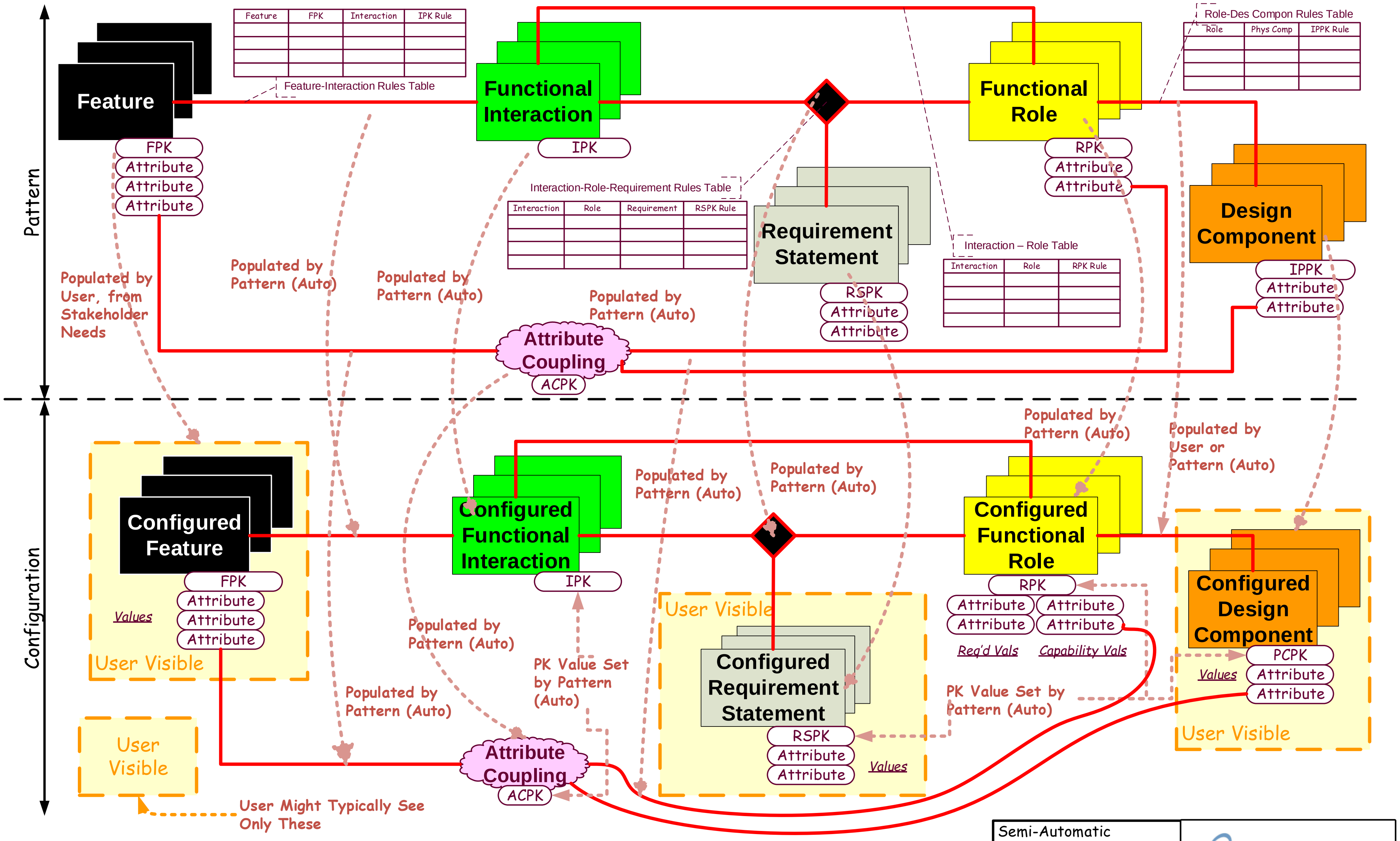
Emergence & Definition of **Domain Specific Systems**

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

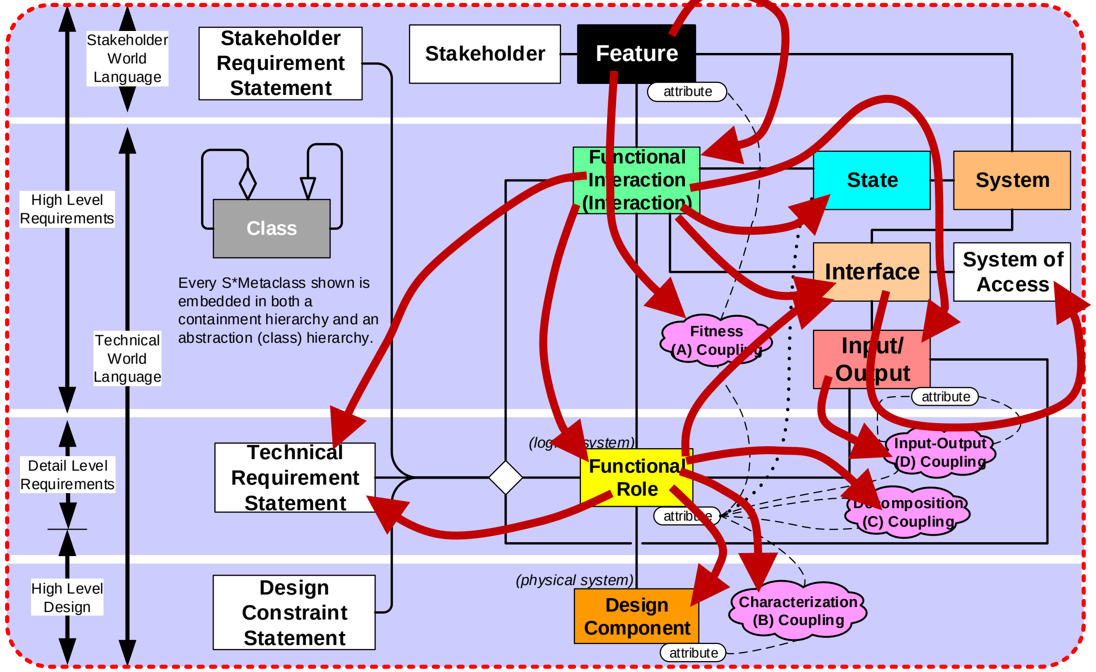
V1.3.10 03-15-16

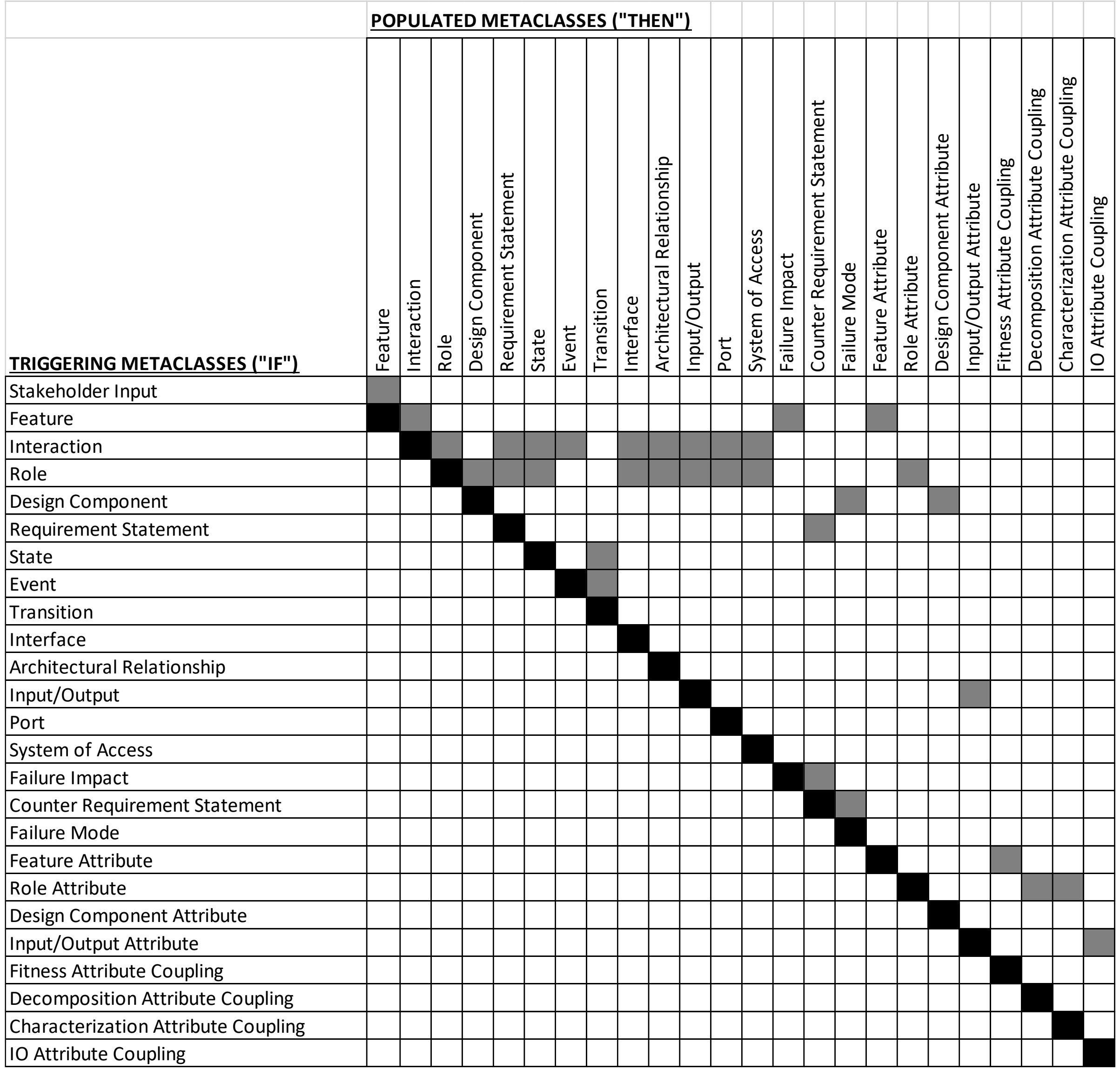
ICTT System Sciences Understand your systems.

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:



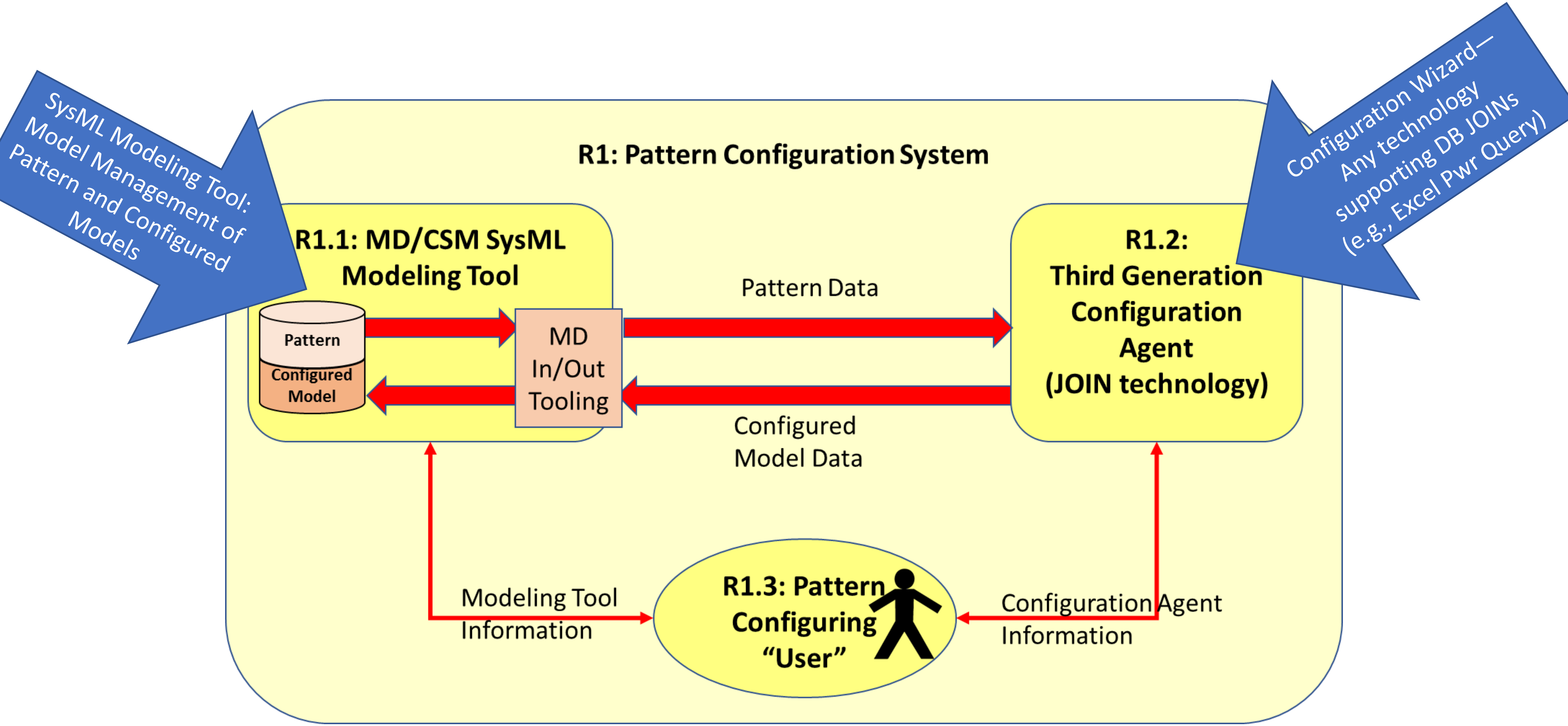


Relationship to Feature-Based PLE ala' ISO 26580

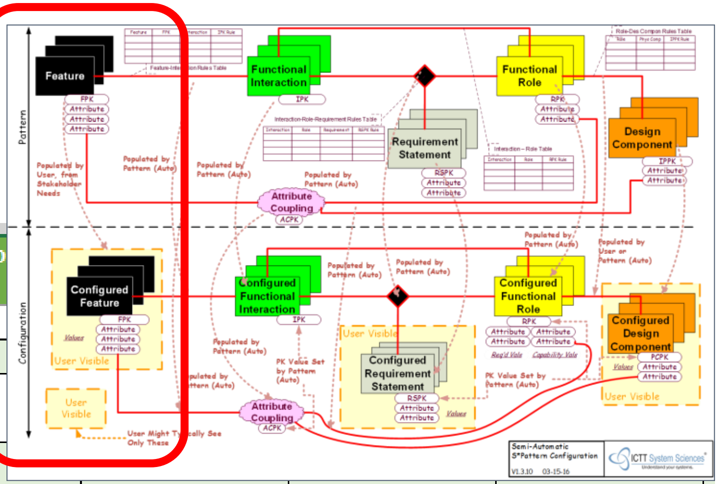
Very similar in the PLE aspects, with a few differences:

- 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)

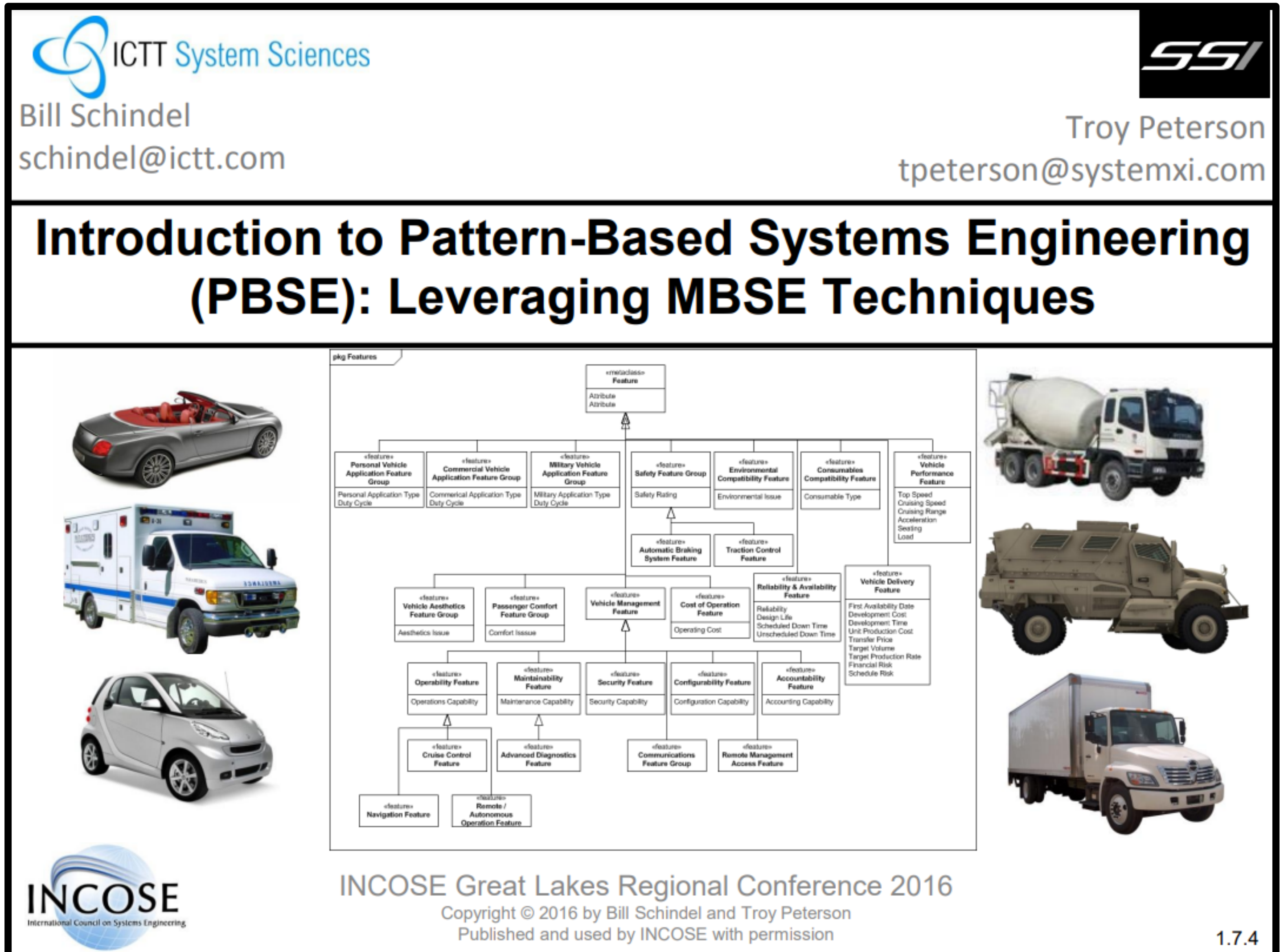


	Feature Configuration	Feature Name	Feature Attribute	Populate? Yes/No	Selection 1	Selection 2	Selectio			
1										
9	Mandatory	Cruise Control Feature								
10	Optional	Environmental Compatibility	Environmental Issue							
11	Mandatory	Maintainability Feature	Maintenance Capability							
12	Optional	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

How to find out more about configurable model-based patterns


ICTT System Sciences

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SSI

Troy Peterson
tpeterson@systemxi.com

Introduction to Pattern-Based Systems Engineering (PBSE): Leveraging MBSE Techniques

INCOSE

INCOSE Great Lakes Regional Conference 2016

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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: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

Patterns & Technologies | Related Publications

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

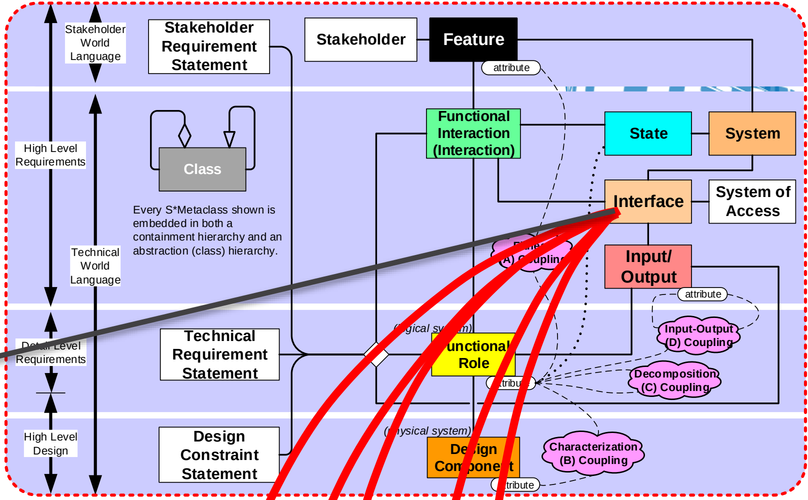
1. Interface Patterns Project
2. Semantic Technologies for Systems Engineering (ST4SE) Project (orig. suggested by S. Jenkins, H-P deKoning).
3. Adaptive Learning Ecosystem Pattern—the INCOSE ASELCM Reference Framework (orig. joint w/Agile SE WG).
4. Universal Model Metadata Wrapper: Model Characterization Pattern (MCP), w/ASME VV Stds Cmte & V4 Inst.
5. S*Pattern Configuration Wizard.
6. Minimal S*Models—A Primer (including S*Metamodel and its formal mappings to OMG SysML and tools)
7. S*Patterns Primer (second ed)
8. ASME Guideline for Managing Credibility of Models for Adv. Manufacturing, w/ASME VV50 Stds Working Grp.
9. AIAA Aerospace Digital Twins Case Studies Pub; Digital Twin Analysis and Planning Reference Pattern, w/AIAA.
10. AIAA Aerospace Digital Threads Position Pub; Digital Thread Analysis & Planning Reference Pattern, w/AIAA.
11. *Handbook of System Sciences*, for ISSS via Springer: Chapter: “Patterns in Science and Engineering”, w/ISSS.
12. *Handbook of Model-Based Systems Engineering*, Madni & Augustine, eds, Springer, Chapter: “MBSE Patterns”.
13. *INCOSE SE Handbook*, 5th Ed., for INCOSE, D. Walden et al, eds, material on S*Metamodel and ASELCM Pattern
14. *INCOSE Vision 2035*, SE Theoretical Foundations Project.
15. *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.

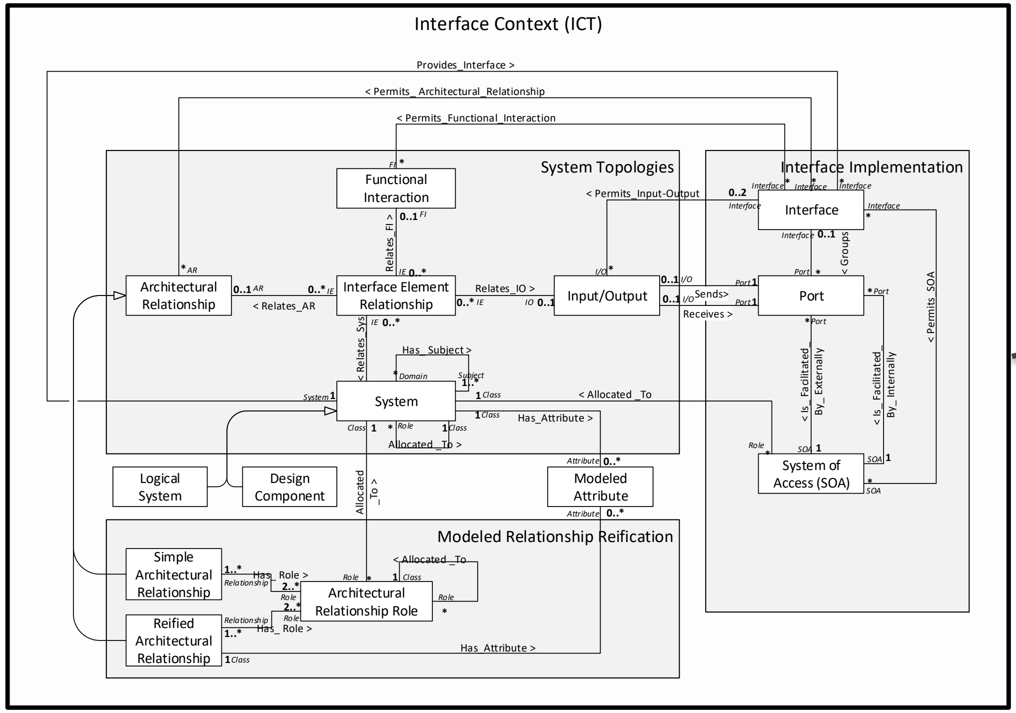
Interface Pattern Project

- 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 as part of Semantic Technologies for Systems Engineering (ST4SE) Project.

Interface Pattern Project

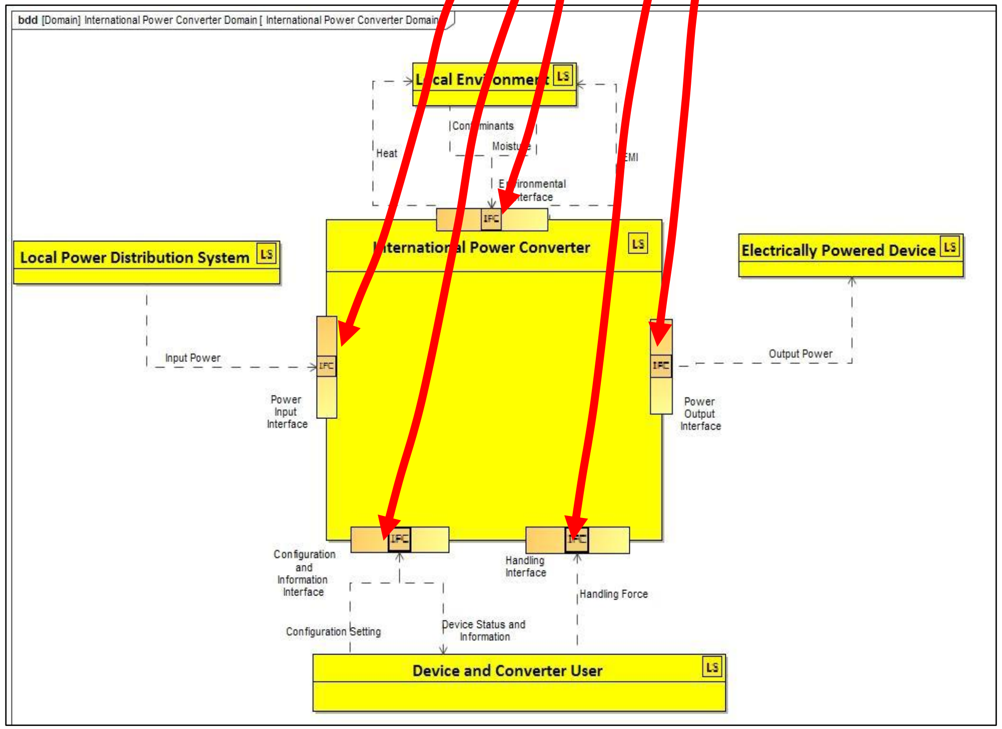
Generic S*Metamodel—Includes Interface Pattern

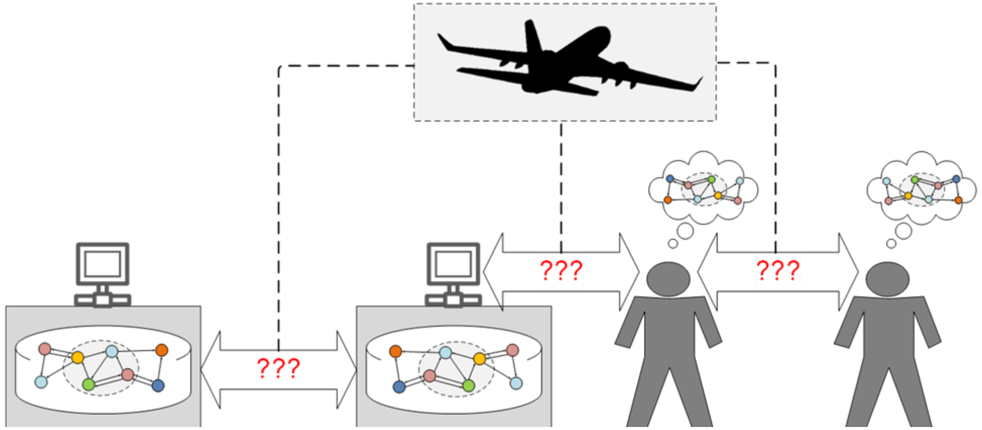




Improved Generic Interface Pattern (2021), a Subset of S*Metamodel

Configurable International Power Converter MBSE S*Pattern—Includes Family of Configurable Electrical, Mechanical, and Information Interfaces in ST4SE Project (2020-2022)



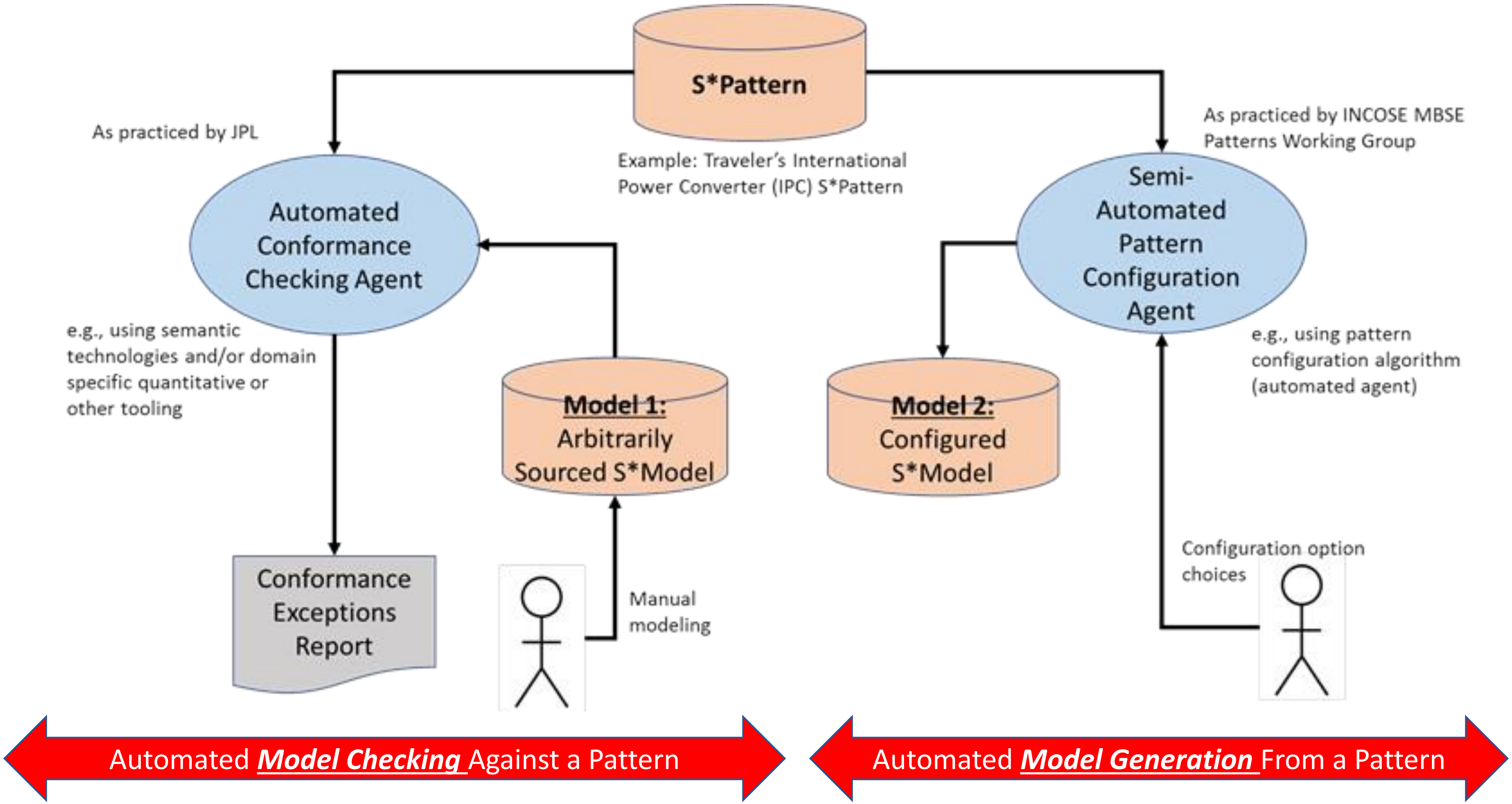


Semantic Technologies for Systems Engineering (ST4SE)

Suggested by S. Jenkins, H-P deKoning. INCOSE TPP: http://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:incose_patterns_wg_st4se_project_tpp_v2.0_signed.pdf

- This project combines demonstration of (1) [automated generation of consistent trustable models from trusted model-based patterns] with (2) [automated checking of human-generated models against trusted model-based patterns].
- Human beings may be the original interpreters of the meaning of models, but non-human semantic technologies have joined human interpreters of meaning.
- Information technologies that deal with model semantics (encoded meaning) include modeling languages, model authoring tools, simulation engines, web-based semantic data structures, and query and reasoning technologies.
- Semantic technologies strengthen impact of model-based semantics on engineering.
- Technical Product Plan: INCOSE distribution of data structures, not just documents.
- Interested participants can be part of evaluating utility and new distribution paradigms.

Semantic Technologies for Systems Engineering (ST4SE)



ST4SE Project Report: Red Team Review Draft

INCOSE Patterns Working Group Report:

Semantic Technologies for Systems Engineering (ST4SE) Project

Version 1.9.1

June 24, 2022

Pink Team Review Draft

INCOSE

International Council on Systems Engineering

INCOSE Patterns WG Report--ST4SE Project--PINK TEAM REVIEW DRAFT V1.9.1.docx 1

Pink Team Review Draft:
https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:incose_patterns_wg_report--st4se_project--pink_team_review_draft_v1.9.1.pdf

INCOSE Patterns WG Report--ST4SE Project

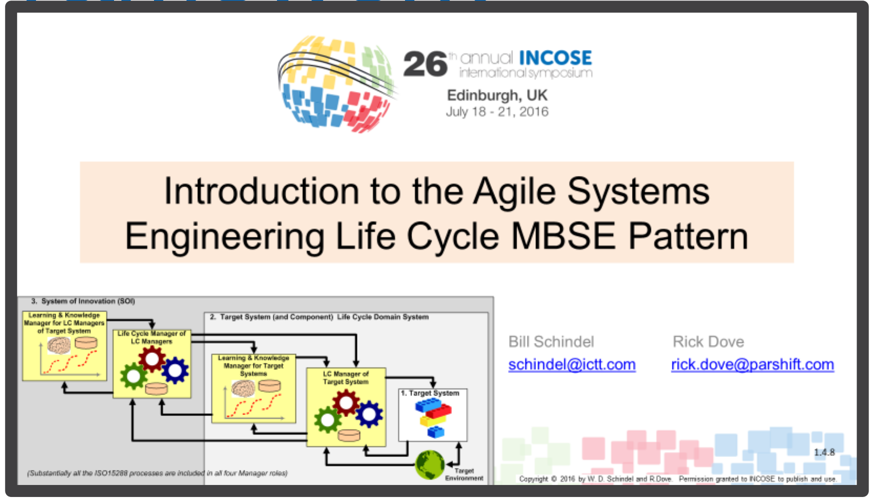
Decorated Cover | Copyright, Access, and Legends | Project Team

Contents

INCOSE Patterns WG Report--ST4SE Project--PINK TEAM REVIEW DRAFT V1.9.1.docx 2

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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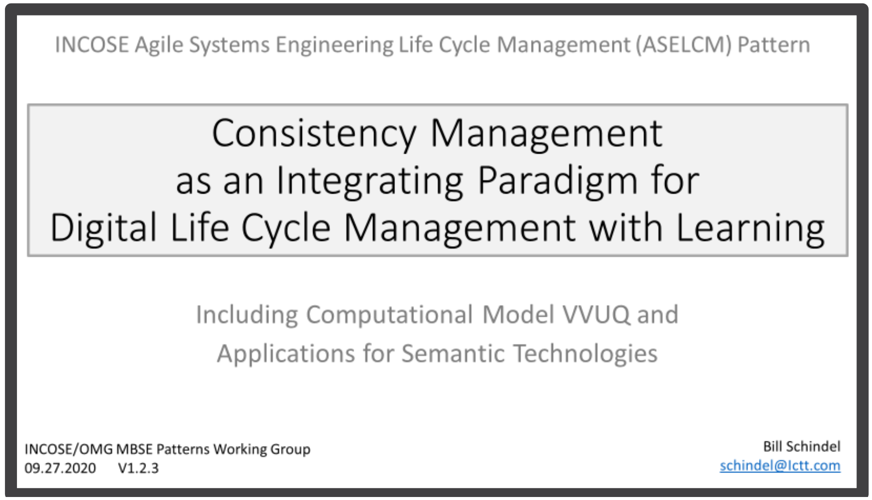
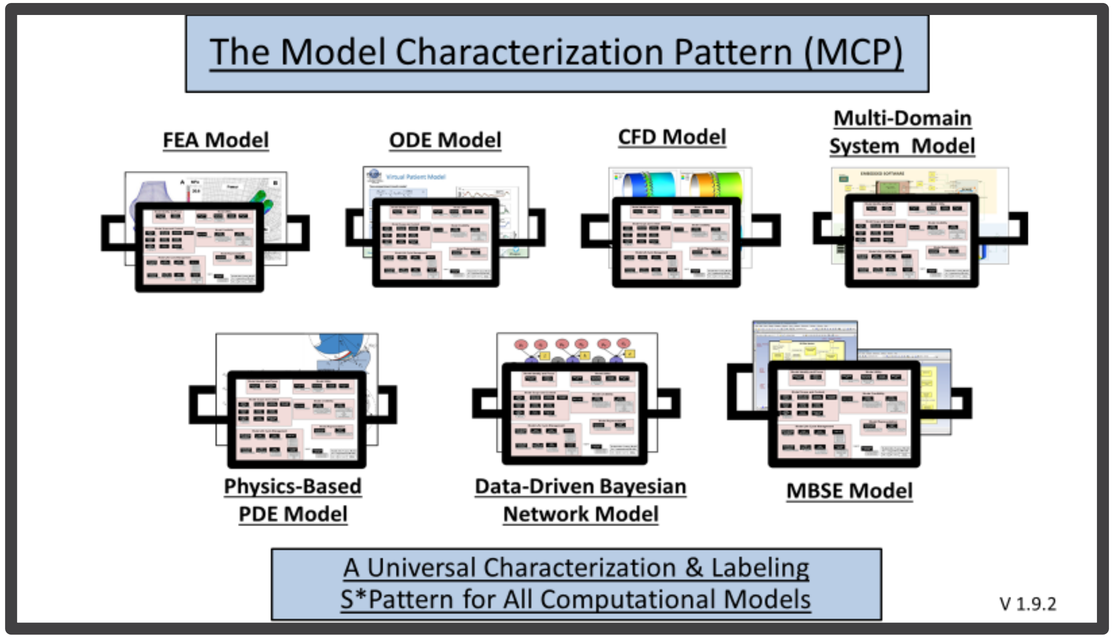


https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:aselcm_pattern_--_consistency_management_as_a_digital_life_cycle_management_paradigm_v1.3.1.pdf

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

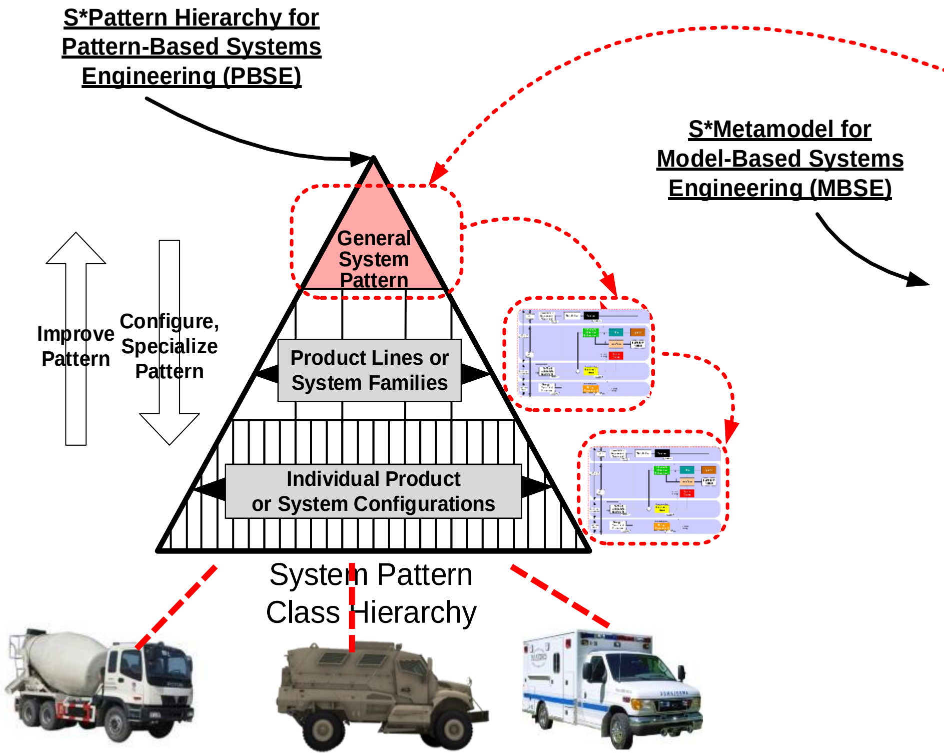
- Collaborating with ASME Standards Committee on Model Credibility, VV50 Subcommittee, Patterns WG created a configurable pattern for representing metadata on any virtual model, including Machine Learning, Simulation (FEA, CFD, SD, ODE), MBSE, otherwise. Auto generates Reqs for models. (ASME WG led by 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.

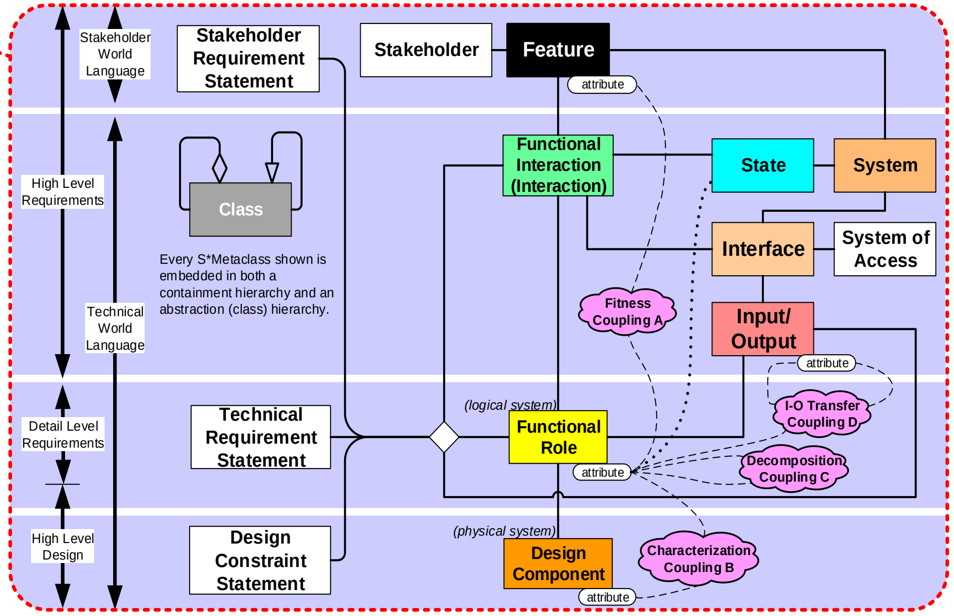


http://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:model_characterization_pattern_mcp_v1.9.3.pdf

S*Pattern Configuration Wizard

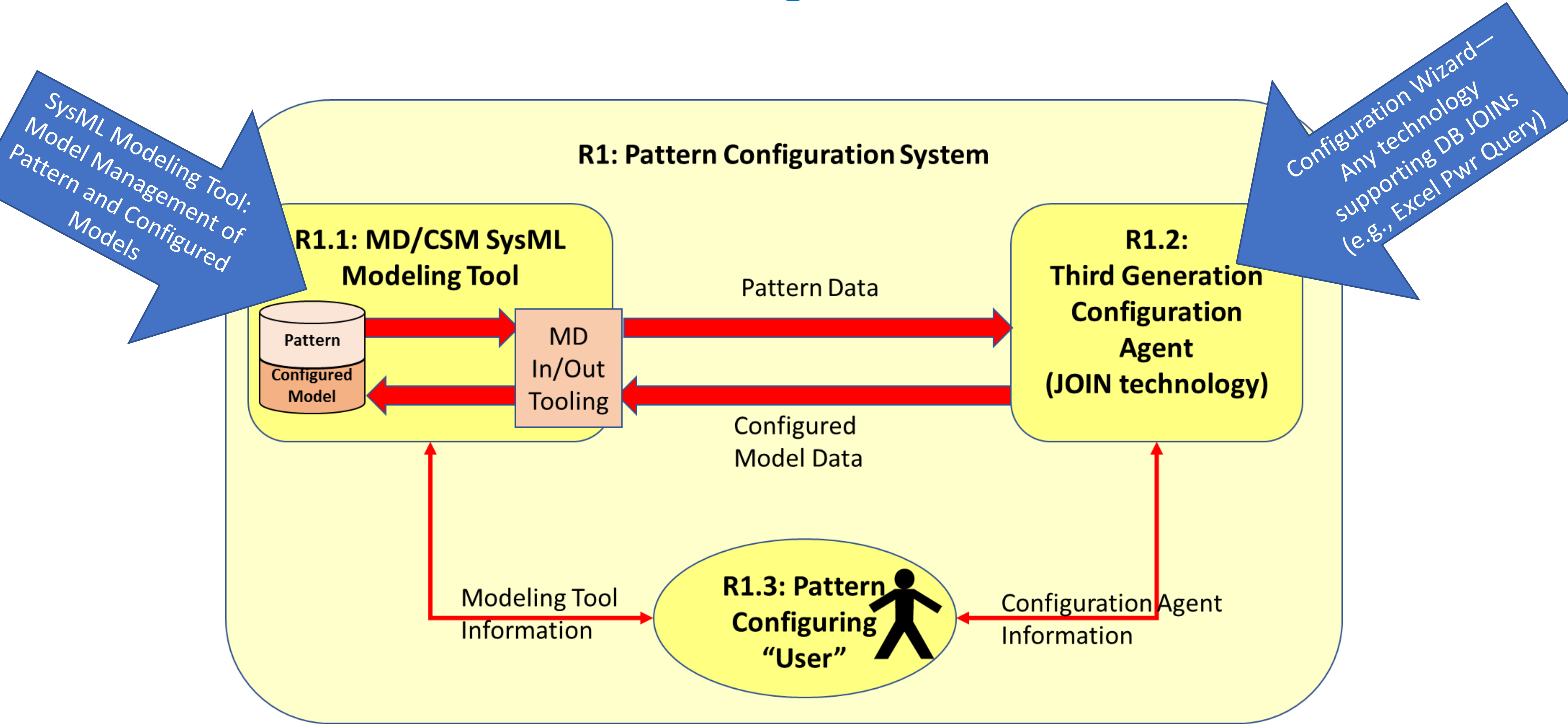
- Auto-generates MBSE model in SysML tool, as configuration of Pattern.
- Extendable to any modeling tool.
- Configuration algorithm encodable in any JOIN-supporting environment.
- Configurable patterns for products, enterprise ecosystems, other models.
- Currently in use in ST4SE Project, to be distributed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





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

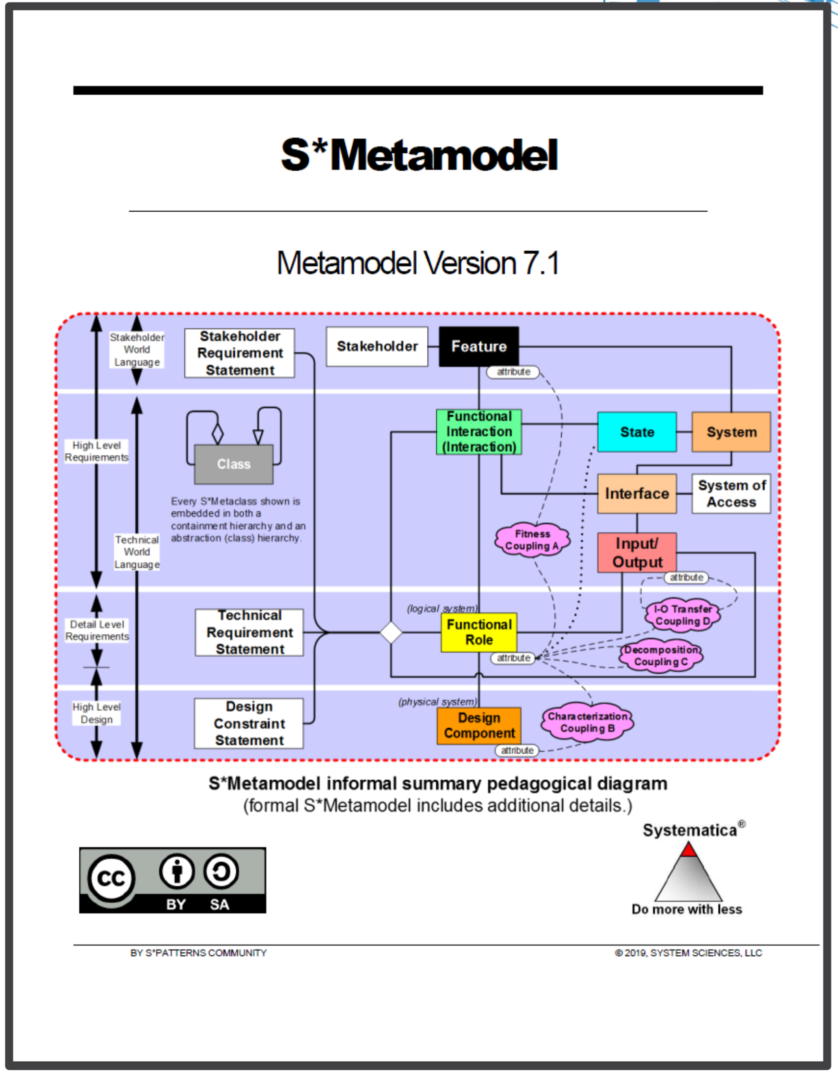
S*Pattern Configuration Wizard



Minimal S*Models—A Primer

Startup Project

- 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 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.



This formal Metamodel Ref is not the Primer.
https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:systematica_5_metamodel_v7.1.6a.pdf

Minimal S*Models—
A Primer

Startup Project

S*Models and the S*Metamodel: A Primer

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In a Nutshell: What Are S*Models? What Is the S*Metamodel? What Problem Do They Solve?

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- Strengthening SE Practice: Motivation from Current Practice
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- The INCOSE MBSE Patterns Working Group

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5 Tooling and Language Mapping

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- S*Profile for CSM

6 A Starter Kit for S*Modelers

7 More Example S*Model Content

- Oil Filter with FMEA etc.

8 References

- What is the smallest model of a System?
- S*Methodology V1.6.1
- Scientific foundations
- Handbook fifth edition
- See also S*Patterns Primer
- S*MTM Doc
- Downloadable profile
- S*Pattern Primer
- SE Handbook 5th edition
- WG web site

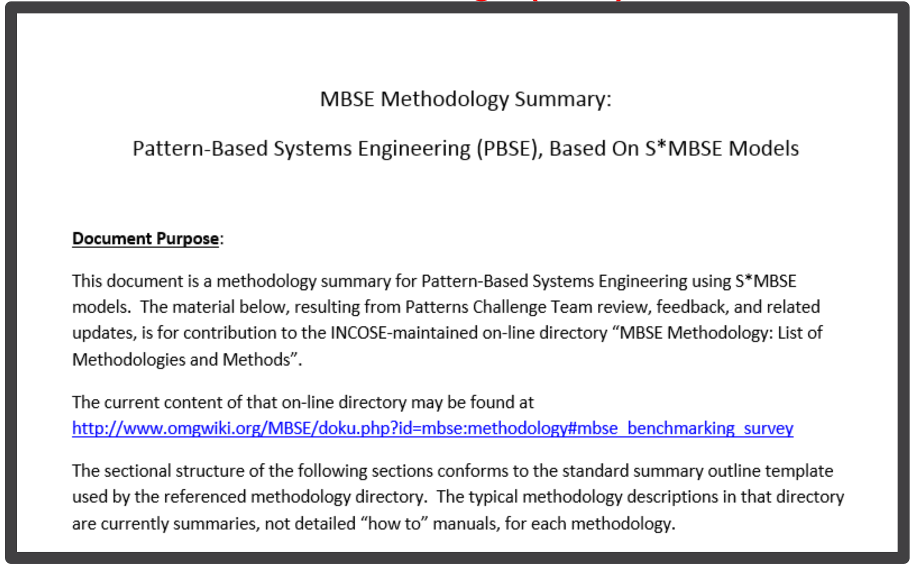
- Outline for Primer
- Join this project!
- Good way to learn about MBSE, S*Models, and the S*Metamodel.

S*Patterns Primer (second edition)

Startup Project

- 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.

Existing (first) edition



MBSE Methodology Summary:

Pattern-Based Systems Engineering (PBSE), Based On S*MBSE Models

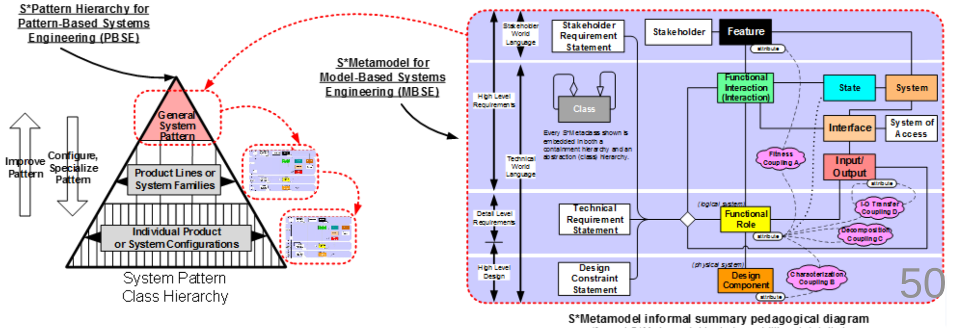
Document Purpose:

This document is a methodology summary for Pattern-Based Systems Engineering using S*MBSE models. The material below, resulting from Patterns Challenge Team review, feedback, and related updates, is for contribution to the INCOSE-maintained on-line directory “MBSE Methodology: List of Methodologies and Methods”.

The current content of that on-line directory may be found at http://www.omgwiki.org/MBSE/doku.php?id=mbse:methodology#mbse_benchmarking_survey

The sectional structure of the following sections conforms to the standard summary outline template used by the referenced methodology directory. The typical methodology descriptions in that directory are currently summaries, not detailed “how to” manuals, for each methodology.

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



S*Patterns Primer (second edition)

Startup Project

- Outline for Second Edition
- Join this project!
- Good way to learn about MBSE Patterns.
- Be a Reviewers or Writer.
- Second Edition—Restructures as a Primer

S*Patterns: A Primer

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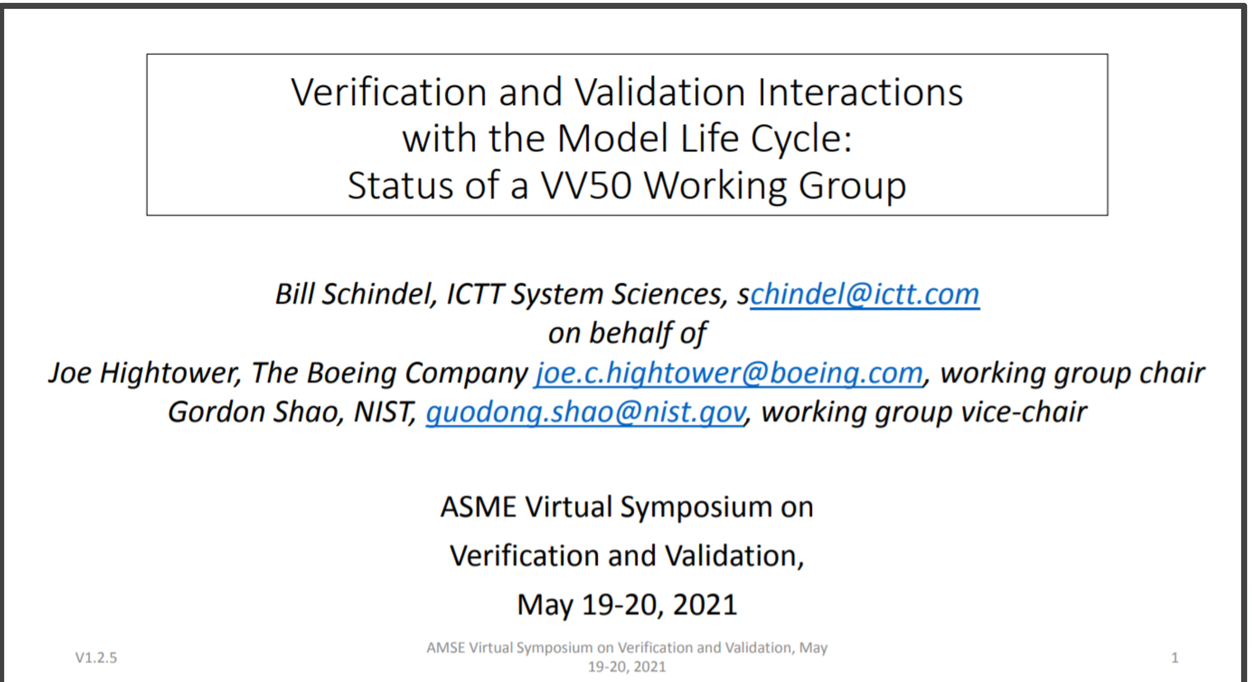
In a Nutshell: What Are S*Patterns? What Problems Do They Solve?

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

- ASME VV50 Standards-writing project supported by INCOSE began 2016.
- Combining lessons of computational model VVUQ with lessons of MBSE model learning and credibility, supported by model metadata pattern.
- Balloting in 2022.


Verification and Validation Interactions
with the Model Life Cycle:
Status of a VV50 Working Group

Bill Schindel, ICTT System Sciences, schindel@ictt.com
on behalf of
Joe Hightower, The Boeing Company joe.c.hightower@boeing.com, working group chair
Gordon Shao, NIST, guodong.shao@nist.gov, working group vice-chair

ASME Virtual Symposium on
Verification and Validation,
May 19-20, 2021

V1.2.5 AMSE Virtual Symposium on Verification and Validation, May 19-20, 2021 1

https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:model_life_cycle_working_group_status_v1.2.5.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 references, based on ASELCM Pattern

AIAA DEIC

DGE-02: Report on the Digital Twin Implementation Paper

Panel Chairs:
John Matlik (Rolls Royce Corporation) – john.f.matlik@rolls-royce.com
Olivia Pinon Fischer (Georgia Institute of Technology) – olivia.pinon@asdl.gatech.edu

AIAA SCITECH 2022
San Diego, CA
January 3rd, 2022

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Shaping the Future of Aerospace

OUTLINE & CONTENT

1. Purpose
   - Articulate the need for such paper
2. Descriptive Reference Model for Digital Twins
   - Provide a generic reference model and framework (INCOSE's Agile Systems Engineering Life Cycle Management (ASELCM) Pattern) for describing how Digital Twins integrate with the broader digital enterprise
3. Summary of Realization Case Studies
   - Provides context for demonstrating specific instance of the reference model
   - Industry prioritized case studies for Space, Air & Ground
4. Summary of ASELCM Applications
   - Synthesize how the generic reference model supports the various use case applications
5. Recommendations & Next Steps
   - Stay consistent with & integrate "recommendations/next steps" agreed as part of the AIA/AIAA Digital Twin Position Paper
6. Appendices
   - Full descriptions of the 7 use cases

AIAA
SHAPING THE FUTURE OF AEROSPACE
DIGITAL TWIN: REFERENCE MODEL, REALIZATIONS & RECOMMENDATIONS
An XXX and XXX Position Paper
Authored by the
AIAA Digital Engineering Integration Committee,
Approved by the
XXXX
DRAFT
RELEASE DATE
XXXX

4

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Shaping the Future of Aerospace

https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:aiaa_deic_dtw_implementation_paper_scitech2022panel_distribute.pdf

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

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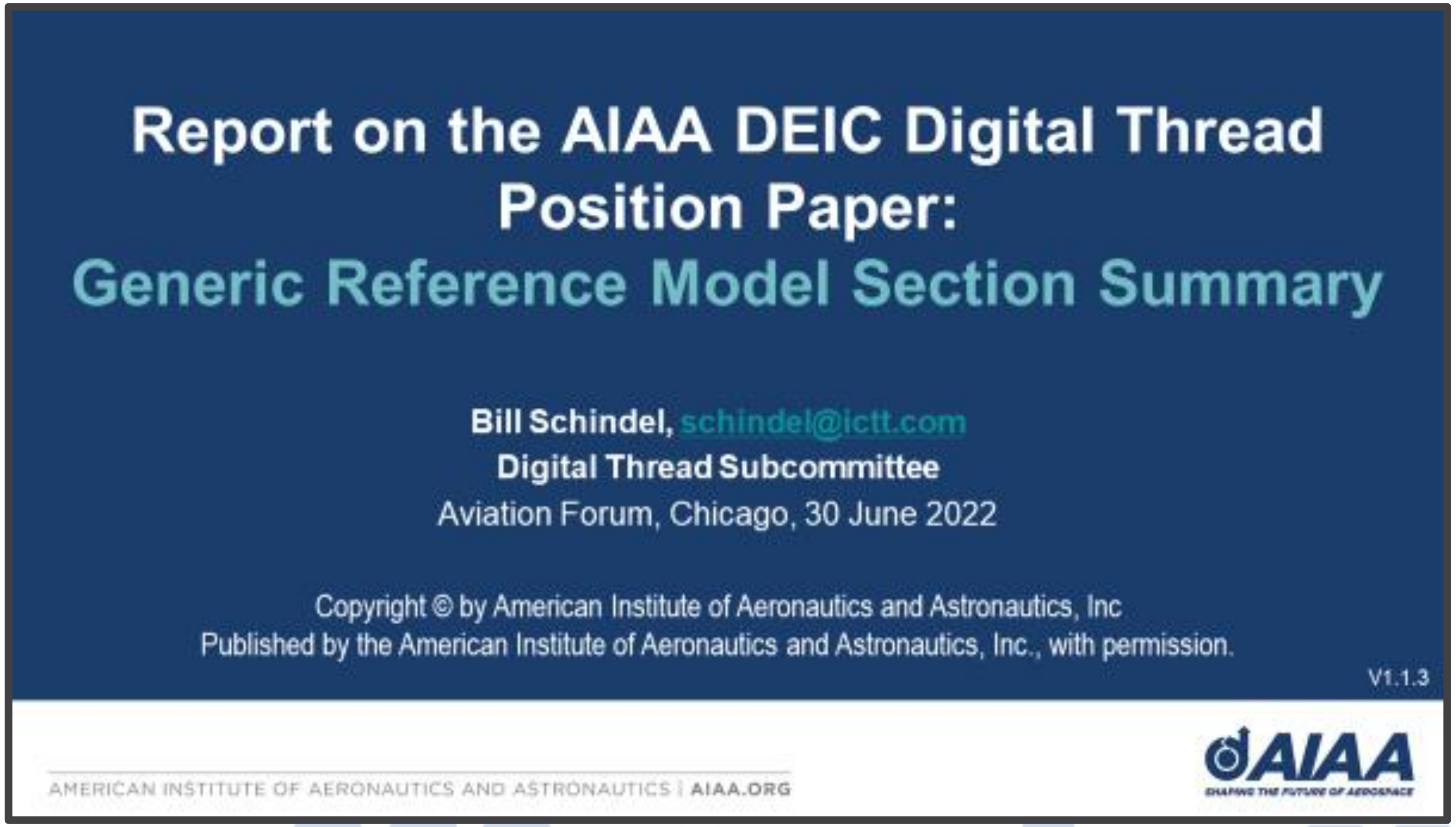
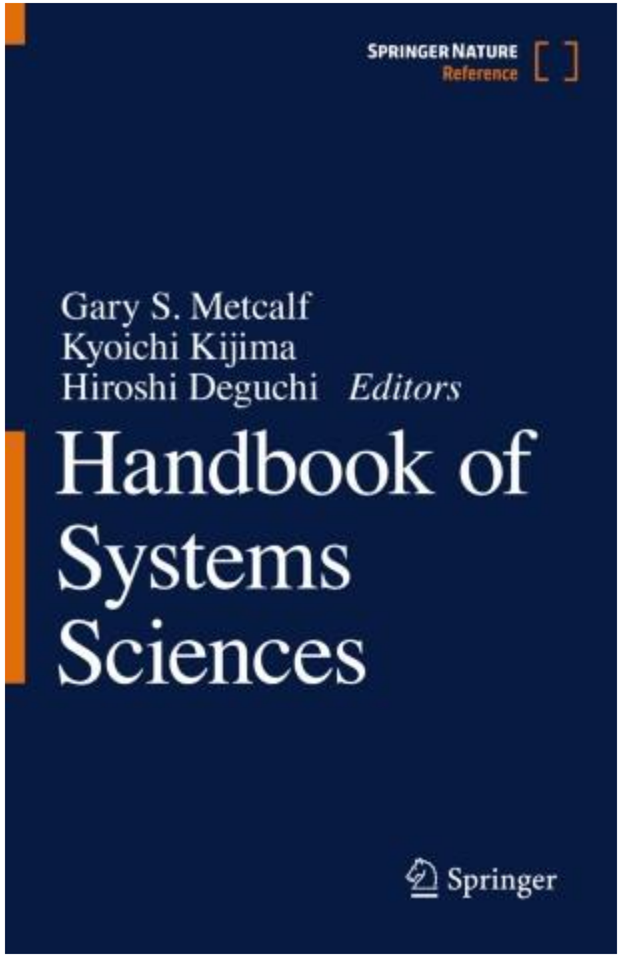


https://www.omgwiki.org/MBSE/doku.php?id=mbse:patterns:mbse_patterns_wg_participation_in_aiaa_aviation_2022

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




SpringerLink

Handbook of Systems Sciences pp 1-43 | Cite as

System Patterns in Engineering and Science

Authors | Authors and affiliations

William D. Schindel

Living reference work entry
First Online: 02 September 2020

2 Mentions
186 Downloads

Abstract

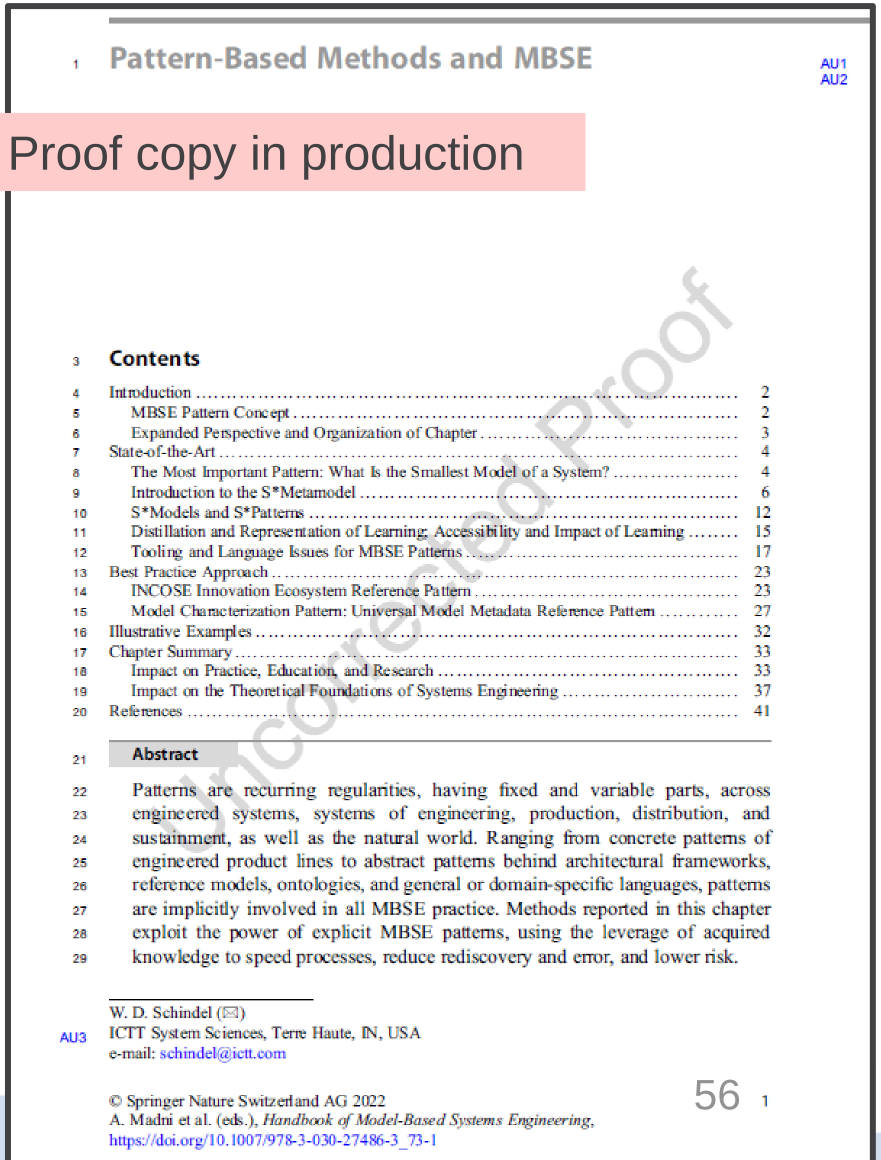
Human life is experienced as recurring system patterns – the informal events of everyday living, expression of creativity and aesthetic experiences of the arts, organized observation and discovery in the physical sciences, and technically engineering the systemic improvement of the human condition. Patterns 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.

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

Proof copy in production

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



Pattern-Based Methods and MBSE

AU1
AU2

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 (✉)
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e-mail: schindel@ictt.com

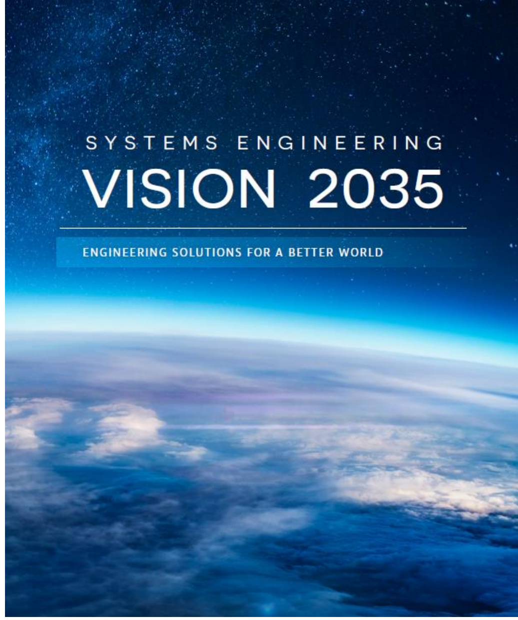
A. Madni et al. (eds.), *Handbook of Model-Based Systems Engineering*,
https://doi.org/10.1007/978-3-030-27486-3_73-1

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

- The Patterns Working Group is contributing invited content on pattern-based methods to the INCOSE SE Handbook, 5th edition project, now in generation.
- The structure of the 5th Edition of the SE Handbook is re-architected compared to past editions, based on progress and needs of the community.
- Those interested in participating also contributing to review of the related handbook material during defined project phases, as the overall SE Handbook 5th Edition progresses during 2021-2022.
- Reviews held during IW2021 and IW2022.
- Overall project is led by INCOSE Handbook Editorial Team, chaired by Dave Walden.

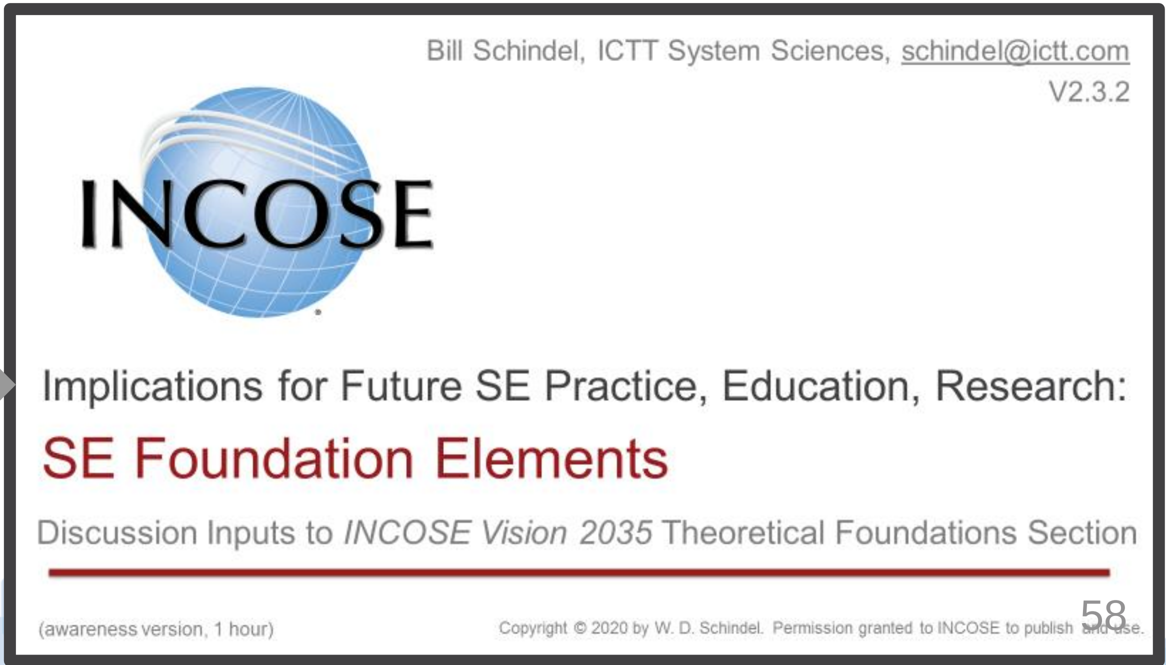
Current (4th) Edition

INCOSE Vision 2035 contributions, from SE Theoretical Foundations Project



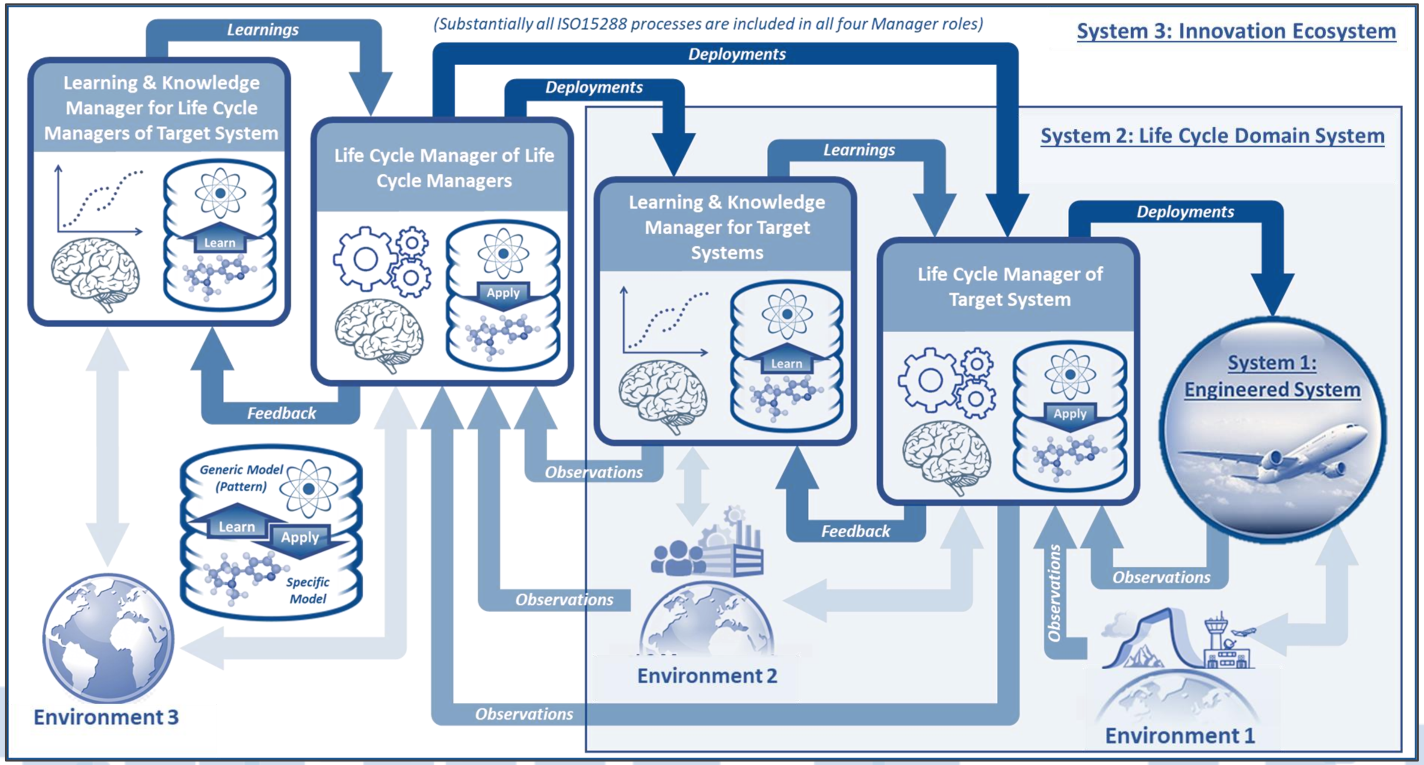
- The Patterns Working Group provided invited content on SE Theoretical Foundations for the *INCOSE Vision 2035* publication project, completed for IW2022.
- Publication project led by editorial team chaired by S. Friedenthal.
- Material drawn from the ongoing SE Theoretical Foundations Project of the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

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



INCOSE INSIGHT, Digital Engineering Issue, March, 2022

- Contributed invited article: “Realizing the Value Promise of Digital Engineering: Planning, Implementing, and Evolving the Ecosystem”
- Based on the INCOSE ASELCM Ecosystem Pattern:



F. Salvatore and T. Gilbert, special issue editors

INCOSE INSIGHT, Digital Engineering Issue, March, 2022

Related IS2022 paper will be presented Wed, June 29.

Realizing the Value Promise of Digital Engineering: Planning, Implementing, and Evolving the Ecosystem

William D. Schindel, schindel@ictt.com

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ABSTRACT

Gaining the benefits of Digital Engineering is not only about implementing digital technologies. The Innovation Ecosystem is a system of systems in its own right, at least partly engineered, subject to the risks and challenges of evolving socio-technical systems. This article summarizes an aid to analyzing and understanding, planning, implementation, and ongoing improvement of the Innovation Ecosystem or its components. It is based on a generic ecosystem analysis reference model with particular focal viewpoints. It is represented as a configurable model-based formal pattern and the INCOSE MBSE Patterns Working Group initially applied it in a related INCOSE collaboration project led by the Agile Systems Engineering Working Group. Users of the resulting framework subsequently elaborated and applied aspects in the context of a wide variety of commercial and defense ecosystems across different domains. While connecting to several current and historical contexts, it is particularly revealing of Digital Engineering's special promise. By explicating the recurrent theme of Consistency Management that underlies all historical innovation, it enhances our understanding of historical as well as future engineering and life cycle management. This includes the ecosystem preparation of internal and supply chain human and technical resources to effectively consume and exploit digital information assets, not just create them. The ecosystem model carries its own representation of enhanced capability implementation by generation of agile release train increments, along with evolutionary steering based on feedback and group learning.

KEYWORDS: digital ecosystem; digital engineering; digital thread; digital twin; model-based collaboration; mbse

INTRODUCTION

Many large-scale human endeavors have grown up and proliferated through the evolutionary forces of large-scale interactions and selection processes; however, as interacting systems of systems, they have not been consciously human engineered in the traditional sense. Human-performed systems of innovation include interacting elements such as competitive markets, scientific research, engineering, production, distribution, sustainment, and regulatory processes, and other life cycle management familiar to the systems engineering community (ISO 2015), (INCOSE 2015). In the natural world, systems of innovation provide a much longer history for discovery and study than the more recent human-performed cases.

The term "ecosystem," borrowed from the life sciences, has become more frequently applied to label the human-performed case, out of recognition of the vast extent, complexity, and dynamic evolution of the human-performed cases. The subject of this article is the formal INCOSE Innovation Ecosystem Reference Model, configurable across diverse specific cases. (Since this article is about a formal reference model, terms which are modeled class names from that reference model appear in title case as they appear in the named model components.)

The engineering community is certainly not without high value historical models of at least portions of the human-performed Innovation Ecosystem. The above-referenced ISO standard and INCOSE Handbook, the ubiquitous "Vee" model, DoD and enterprise-specific models, new model-based standard efforts to describe the Model-Based Enterprise, and others provide vital guidance. Out of respect for those historical assets and the importance of building upon them, we accommodate them within and mate them up with the larger-scale Innovation Ecosystem reference model's configurations referenced in this article.

Why is an ecosystem-level model needed? Smaller scale models inform teams about the work that they must perform, coordinate flows of information, plan information systems and other purposes. Is there really a need for an ecosystem level reference? Do our innovation ecosystems work well enough, and do we understand them well enough?

Ecosystem-level efforts and issues are arising that challenge our group-level abilities to effectively understand

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32nd Annual INCOSE international symposium
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Realizing the Promise of Digital Engineering: Planning, Implementing, and Evolving the Ecosystem

William D. Schindel, ICTT System Sciences
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Abstract. Gaining benefits of Digital Engineering is not only about implementing digital technologies. An ecosystem for innovation is a system of systems in its own right, only partly engineered, subject to risks and challenges of evolving socio-technical systems. This paper summarizes an aid to planning, analyzing, implementing, and improving innovation ecosystems. Represented as a configurable model-based reference pattern used by collaborating INCOSE working groups, it was initially applied in targeted INCOSE case studies, and subsequently elaborated and applied to diverse commercial and defense ecosystems. Explicating the recurrent theme of Consistency Management underlying all historical engineering, it is revealing of Digital Engineering's special promise, and enhances understanding of historical as well as future engineering and life cycle management. It includes preparation of human and technical resources to effectively consume and exploit digital information assets, not just create them, capability enhancements over incremental release trains, and evolutionary steering using feedback and group learning.

Keywords: digital ecosystem; digital engineering; digital thread; digital twin; collaboration; MBSE

Introduction

Many large-scale human endeavors have grown up and proliferated through the evolutionary forces of large-scale interactions and selection processes; however, as interacting systems of systems, they have not been consciously human-engineered in the traditional sense. Human-performed systems of innovation include interacting elements such as competitive markets, scientific research, engineering, production, distribution, sustainment, and regulatory processes, and other life cycle management familiar to the systems engineering community (ISO 2015), (INCOSE 2015). In the natural world, systems of innovation provide a much longer history for discovery and study than the more recent human-performed cases (Schindel 2013). For this paper's interest in human-performed cases for human use, we define "innovation" as delivery of significantly increased stakeholder value (Schindel, Peffers, et al 2011).

The term "ecosystem", borrowed from the life sciences, has become more frequently applied to label the human-performed case, out of recognition of the vast extent, complexity, and dynamic evolution of the human-performed cases. Systems engineers less familiar with MBSE details are encouraged to view this approach as a systems view of that ecosystem and systemic impacts of information, not the details of models. The descriptive backbone of this article is the formal INCOSE Innovation Ecosystem Reference Model, configurable across diverse specific cases. (Since this paper is about that formal reference model, terms which are modeled class names from that reference model are shown in title case as they appear in the named model components.)

Discussion of additional and future interests of attendees

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8. MBSE Patterns Working Group web sites:
   - Public-facing (main resources, INCOSE joint with OMG): http://www.omgwiki.org/MBSE/doku.php?id=mbse:patterns:patterns
   - Inward-facing (incose.org): https://www.incose.org/incose-member-resources/working-groups/transformational/mbse-patterns

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