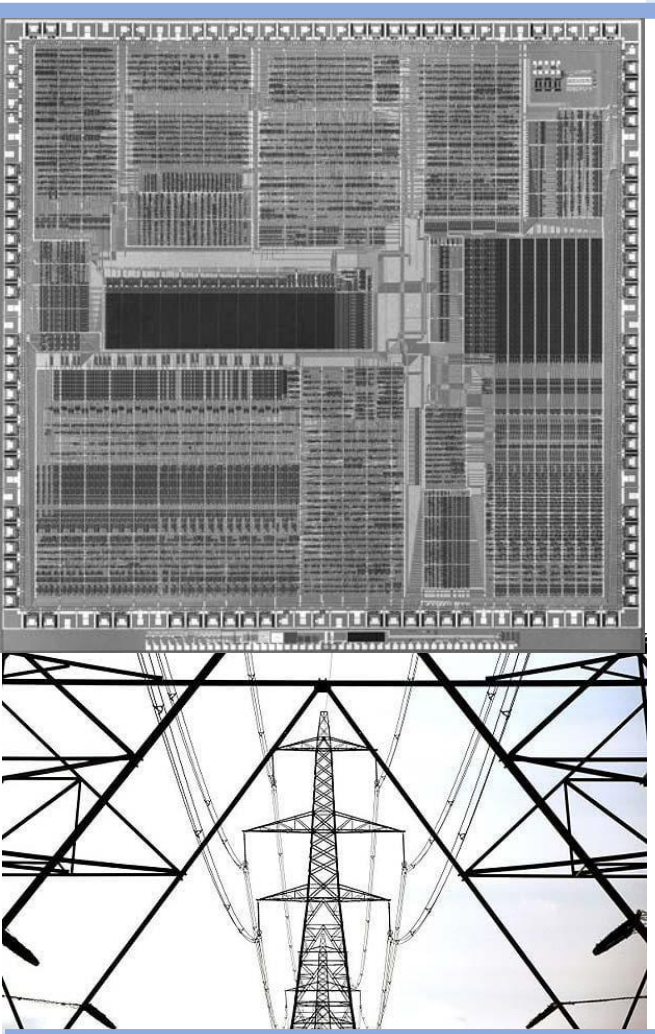
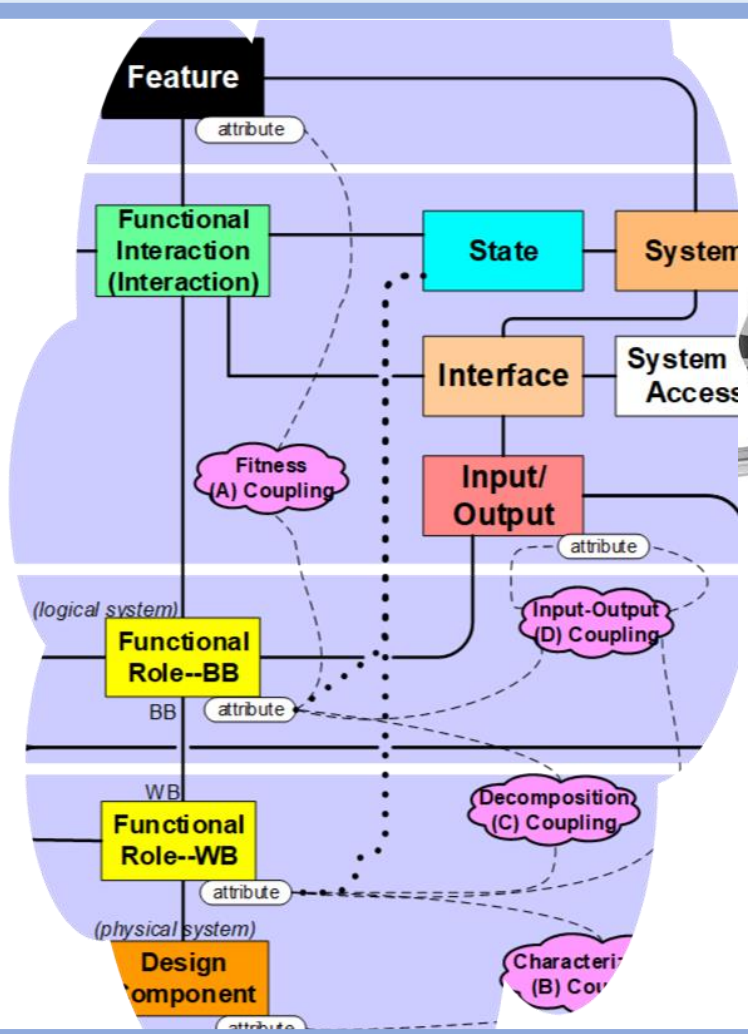
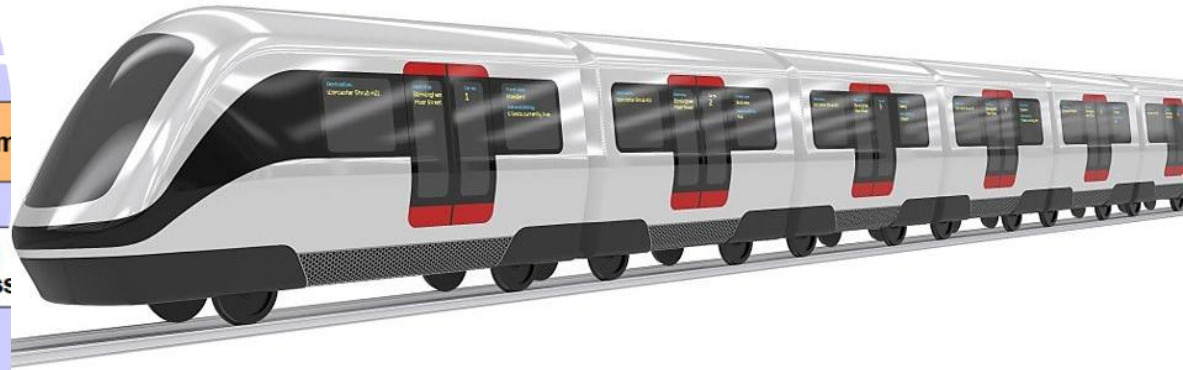
INCOSE MBSE Patterns Working Group:
Meeting with INCOSE Leadership







Meeting of
27 August 2024



V1.3.3

Meeting Agenda / Contents Summary

- Introductions, meeting objectives, agenda plan
- MBSE Patterns WG mission, identity, focus
- Alignment with INCOSE Strategic Plan
- Packaging INCOSE products
- Recent and current projects
- Informal discussion, questions
- Adjourn

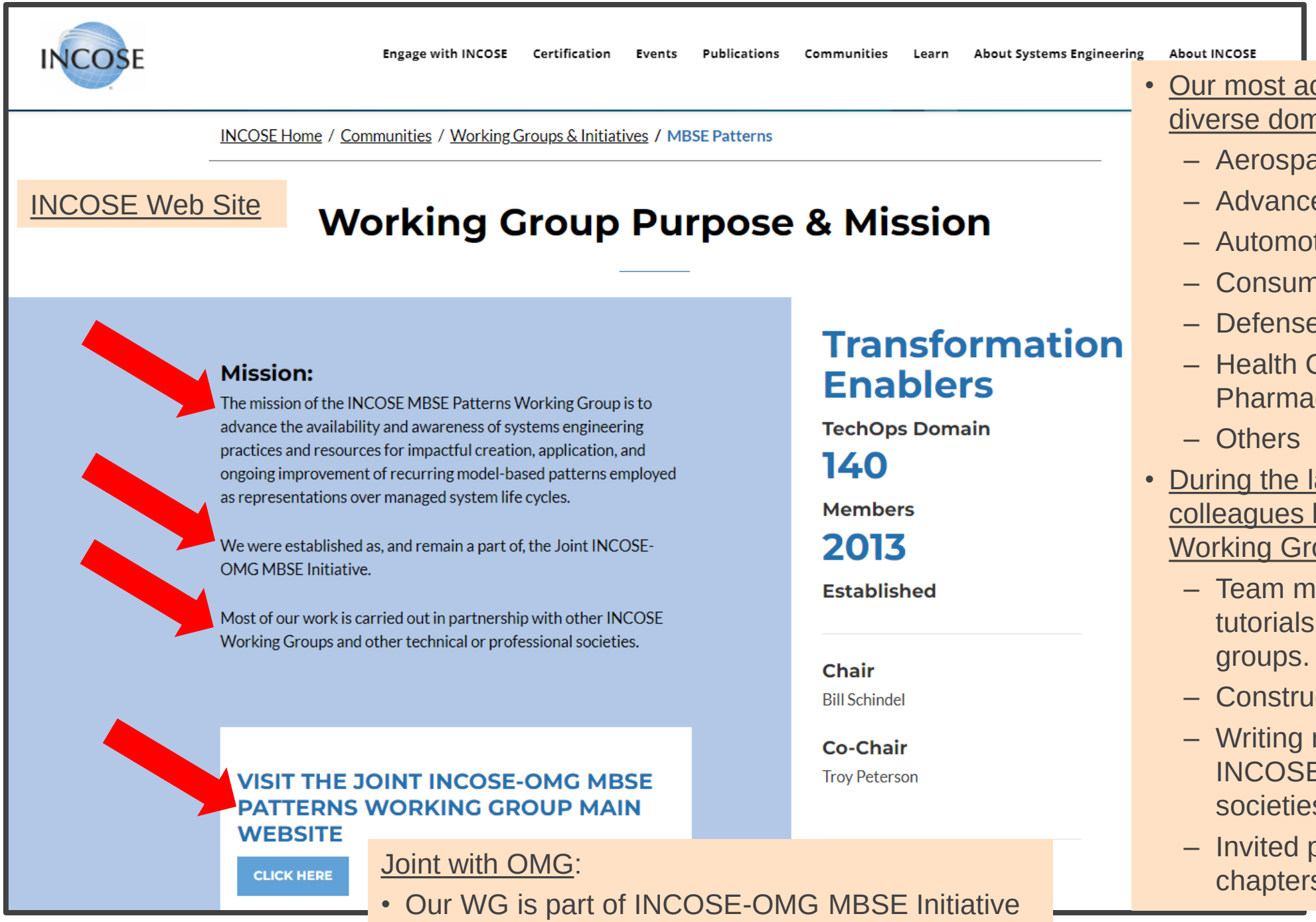
10 slides

- Attachment: Additional information on WG projects

Who are we?

- Our most active members come from diverse domains:
  - Aerospace
  - Advanced Manufacturing
  - Automotive
  - 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, projects, collab with other groups.
  - Construction of system patterns.
  - Writing related publications for INCOSE and other technical societies and textbooks.
  - Invited presentations to INCOSE chapters.

INCOSE Web Site



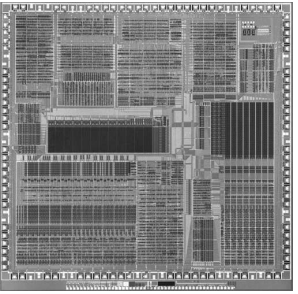
Joint with OMG:

- Our WG is part of INCOSE-OMG MBSE Initiative

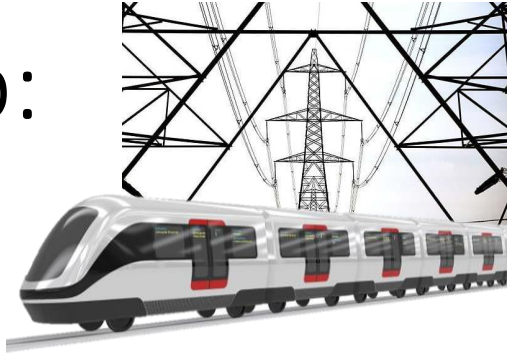
Relevance—much more than "model templates"

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 human cognition and reasoning;
- the basis of learning--by individuals, groups, and machines--to go faster;
- what we did not learn when we repeatedly miss the same opportunities or make the same mistakes again and again;
- the foundations of competencies, technical education, and formalized standards;
- the basis for resistance to change, whether as discipline or inertia;
- how we wake up to a mostly recognizable world each day;
- described by fixed (invariant) and variable (parameterized, configurable) aspects;
- described informally by natural language;
- described formally by models of science, engineering, and mathematics (STEM);
- describe engineered products, but also the ecosystems of engineering, life cycle management, information systems, and socio-technical systems in general.

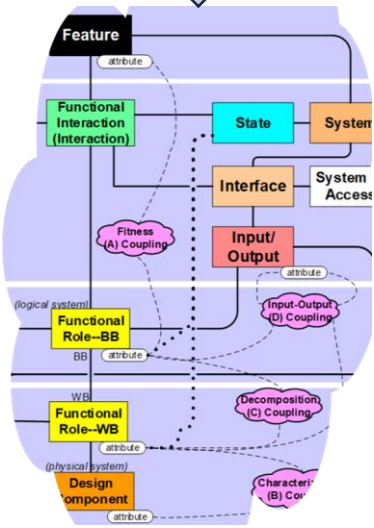


Focus of MBSE Patterns Working Group: *S*Patterns in Particular*

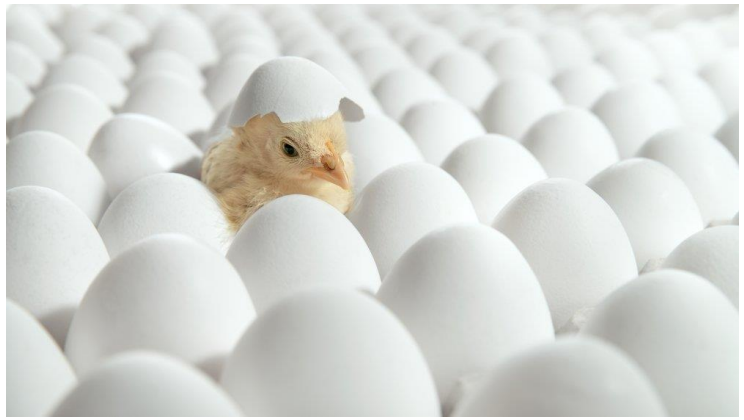


***Configurable, re-usable system models*:**

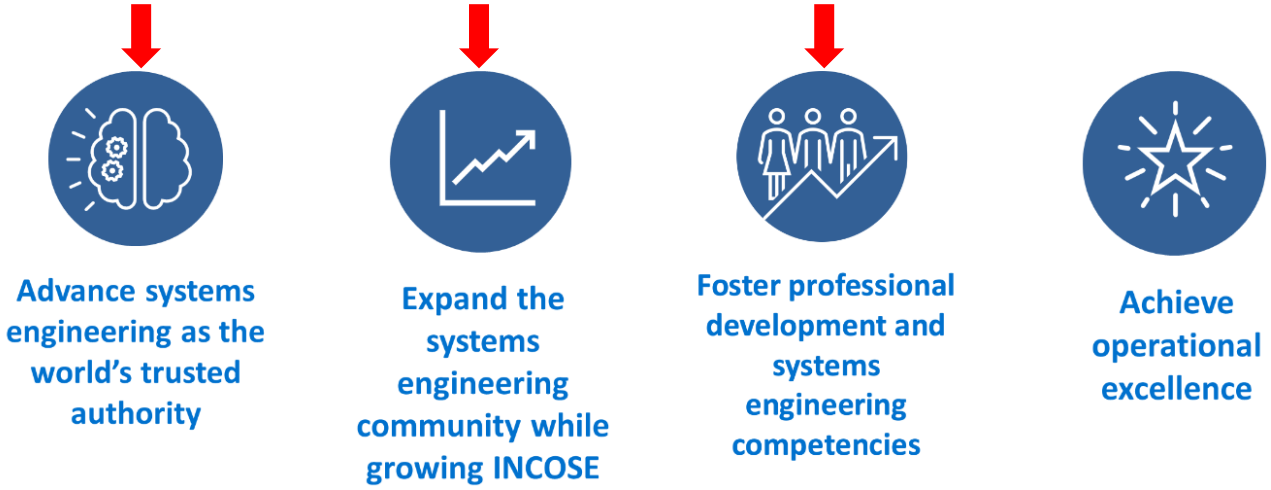
1. Models containing a certain minimal set of elements are called ***S*Models*** (S* is short for “Systematica”).
2. Those underlying elements are called the ***S*Metamodel***, which was inspired by the unmatched success of the physical sciences and impact of STEM.
3. S*Models using those elements may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



2013: Began as Part of INCOSE-OMG Initiative



Today: Aligned with INCOSE Strategic Objectives



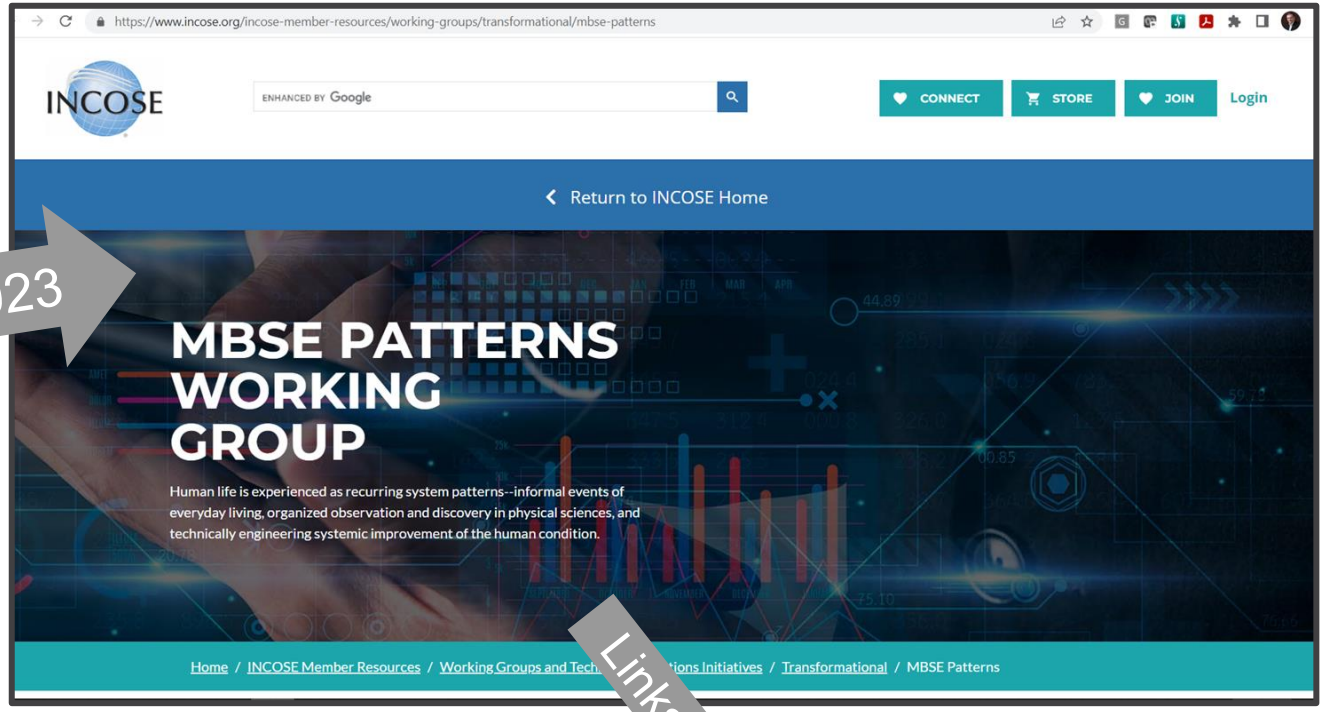
Began 11 years ago, as MBSE Initiative Patterns Challenge Team:

- Started in 2013 as part of the joint INCOSE/OMG MBSE Initiative.
- Three years later (2016), formally became the INCOSE MBSE Patterns Working Group.
- Because of our working group's MBSE focus and continued support of the MBSE Initiative, we continue to also be listed as part of the Joint INCOSE/OMG MBSE Initiative.
  - Our WG's technical web site remains part of joint OMG-INCOSE MBSE wiki.
- Most of our projects are collaborations with other technical societies & other INCOSE WGs.

INCOSE.org MBSE Patterns WG Launch Page:

New (replacement) in 2023

https://www.incose.org/communities/working-groups-initiatives/mbse-patterns

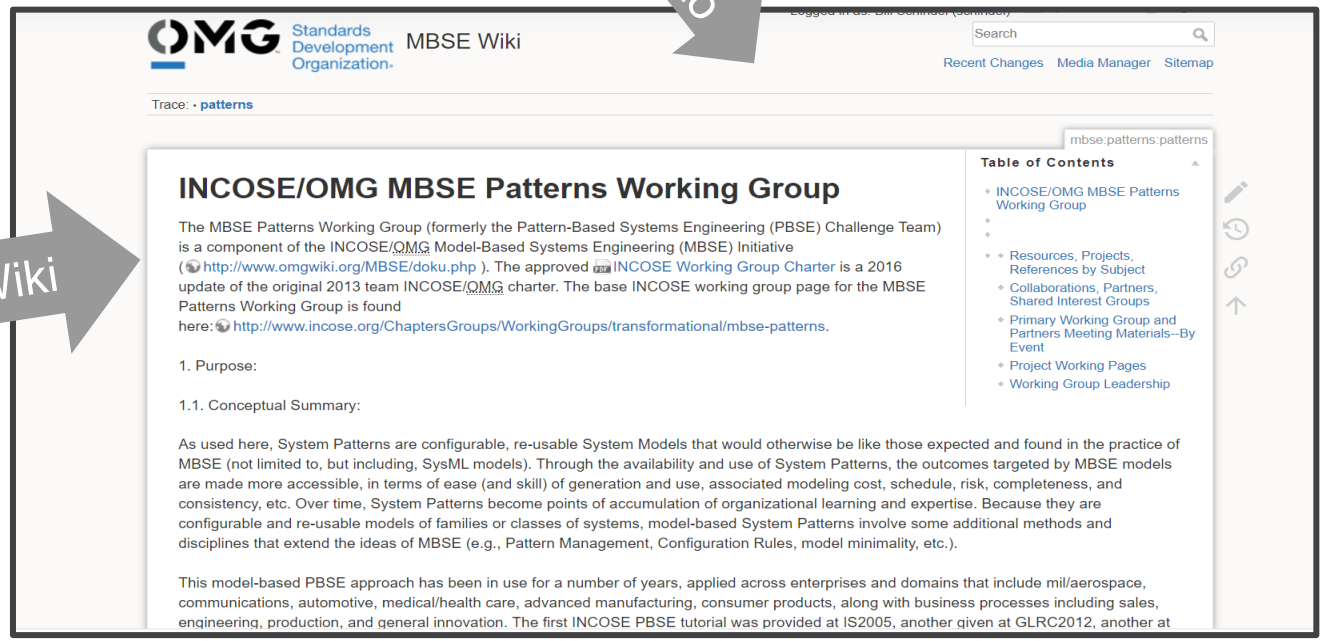


Links to

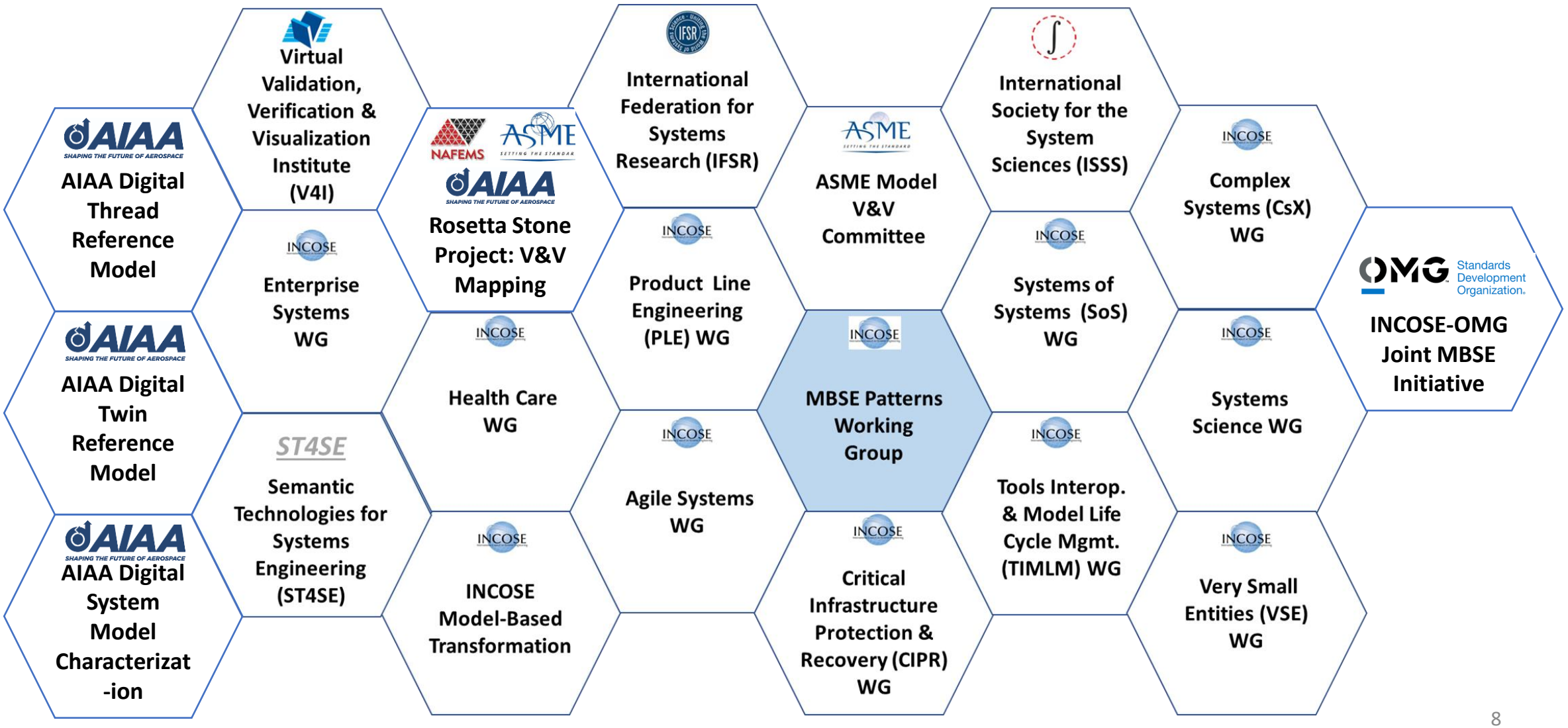
INCOSE-OMG MBSE Joint Initiative Web Site for MBSE Patterns WG:

Part of the OMG MBSE Wiki

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



Nearly all our work projects are collaborations with partner INCOSE WGs or other technical societies



Resources, Projects, References by Subject

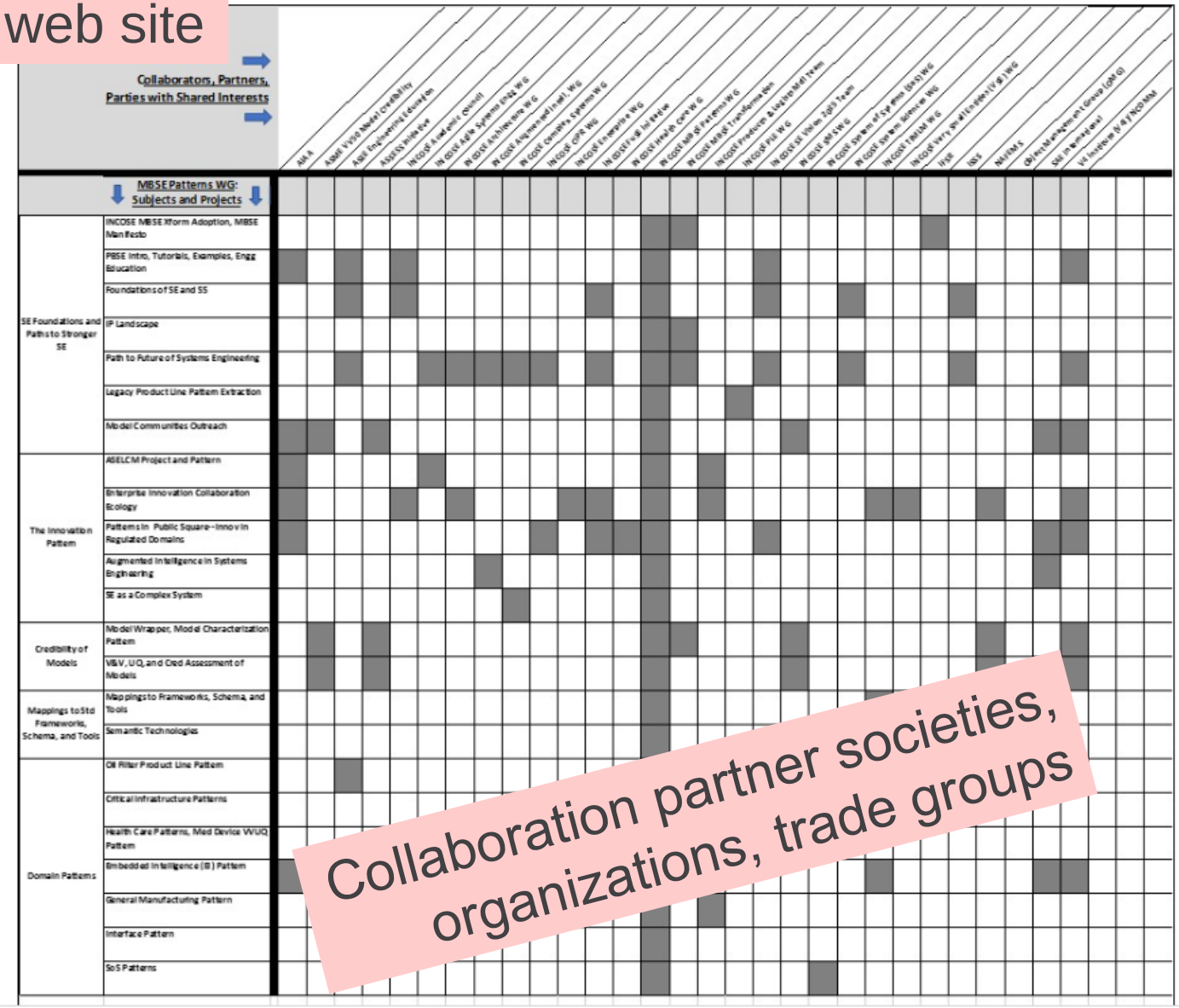
Foundations and Paths to Stronger SE	*How INCOSE and the systems community are visualizing and reaching out to the future. How the INCOSE MBSE Patterns Working Group is applying a stronger foundation based on the System Phenomenon and the history of patterns in the physical sciences and mathematics to 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 ... illustrates S*Patterns across different application domains.*
	General Land Vehicle Pattern
	primary_flight_actuator_pattern_and_autom...
	Oil Filter Product Line Patt...
	Critical ...

On main web site

11 years of generated resource materials, references, by subject & event

Collaborations, Partners, Shared Interest Groups

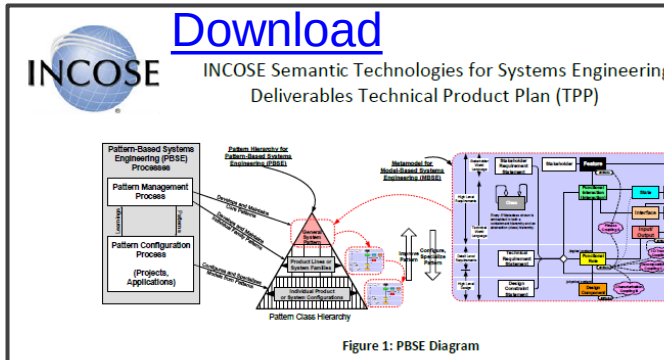
Most of the projects performed by the INCOSE MBSE Patterns WG are performed jointly with other INCOSE Working Groups or with organizations outside INCOSE, having mutual interests. The matrix below summarizes the different entities we work with, and refers to resulting items in the Resources, Activities,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

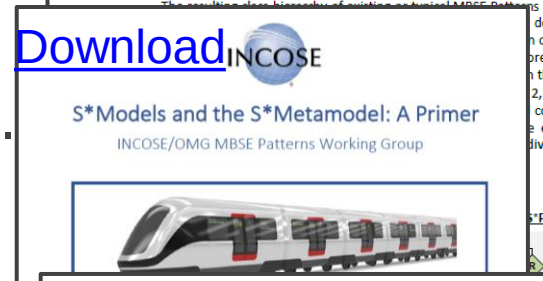


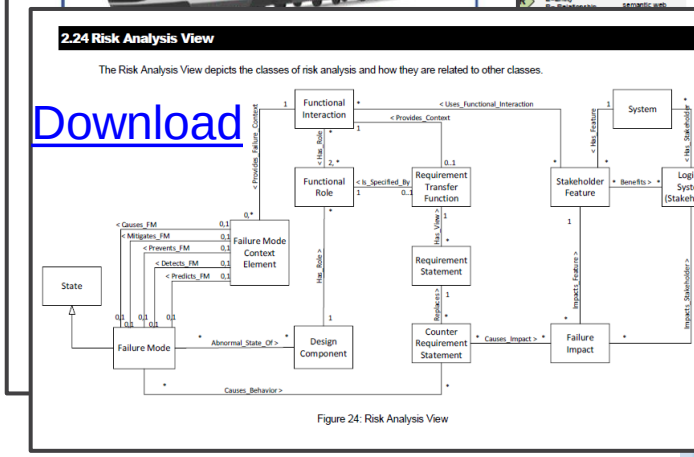
Collaboration partner societies, organizations, trade groups

Created multiple historical and recent assets that could be packaged as INCOSE products

- We have generated valued assets, but in earlier years judged INCOSE processes for product plans and MOUs as sometimes too hard to justify:
  - In recent years, encouraged by INCOSE efforts to streamline.
  - This has led us to consider packaging such products.
- Years of accumulated assets as potential products:
  - Phyllis Marbach encouraging us to pursue this, offering help.
- Recent INCOSE interest in formal INCOSE Standards:
  - Encouraged us to suggest the S*Metamodel as a matured (21 years old) practical formal standard we have continued to apply across most of the WG projects, improving steadily.
  - Already formalized (120 pages), supported by resources.
  - Currently provided under Creative Commons CC BY SA license that permits INCOSE derived version branding.
  - Is there interest in pursuing this?







Current/recent working group projects, activities (See Attachment)

Patterns & Technologies:

1. Adaptive Learning Ecosystem Pattern—the INCOSE ASELCM Reference Framework (in use by AIAA, others).
2. Trust in Models: The Rosetta Stone Project—across four technical societies (ASME, AIAA, NAFEMS, INCOSE).
3. Semantic Technologies for Systems Engineering (ST4SE) Project.
4. Universal Model Metadata Wrapper: Model Characterization Pattern (MCP), w/ASME VV Stds Cmte & AIAA.
5. S*Pattern Configuration Wizard.

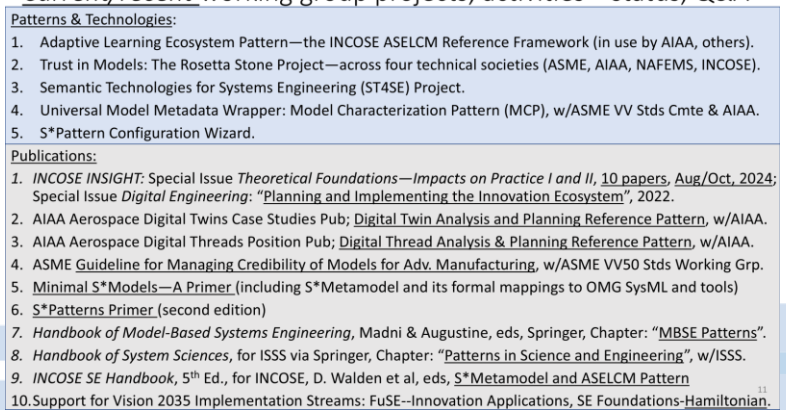
Publications:

1. *INCOSE INSIGHT:* Special Issue *Theoretical Foundations—Impacts on Practice I and II*, 10 papers, Aug/Oct, 2024; Special Issue *Digital Engineering*: "Planning and Implementing the Innovation Ecosystem", 2022.
2. AIAA Aerospace Digital Twins Case Studies Pub; Digital Twin Analysis and Planning Reference Pattern, w/AIAA.
3. AIAA Aerospace Digital Threads Position Pub; Digital Thread Analysis & Planning Reference Pattern, w/AIAA.
4. ASME Guideline for Managing Credibility of Models for Adv. Manufacturing, w/ASME VV50 Stds Working Grp.
5. Minimal S*Models—A Primer (including S*Metamodel and its formal mappings to OMG SysML and tools)
6. S*Patterns Primer (second edition)
7. *Handbook of Model-Based Systems Engineering*, Madni & Augustine, eds, Springer, Chapter: "MBSE Patterns".
8. *Handbook of System Sciences*, for ISSS via Springer, Chapter: "Patterns in Science and Engineering", w/ISSS.
9. *INCOSE SE Handbook*, 5th Ed., for INCOSE, D. Walden et al, eds, S*Metamodel and ASELCM Pattern
10. Support for Vision 2035 Implementation Streams: FuSE--Innovation Applications, SE Foundations-Hamiltonian.

Questions, discussion

-
-
-
-
-

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



Patterns & Technologies:

1. Adaptive Learning Ecosystem Pattern—the INCOSE ASELCM Reference Framework (in use by AIAA, others).
2. Trust in Models: The Rosetta Stone Project—across four technical societies (ASME, AIAA, NAFEMS, INCOSE).
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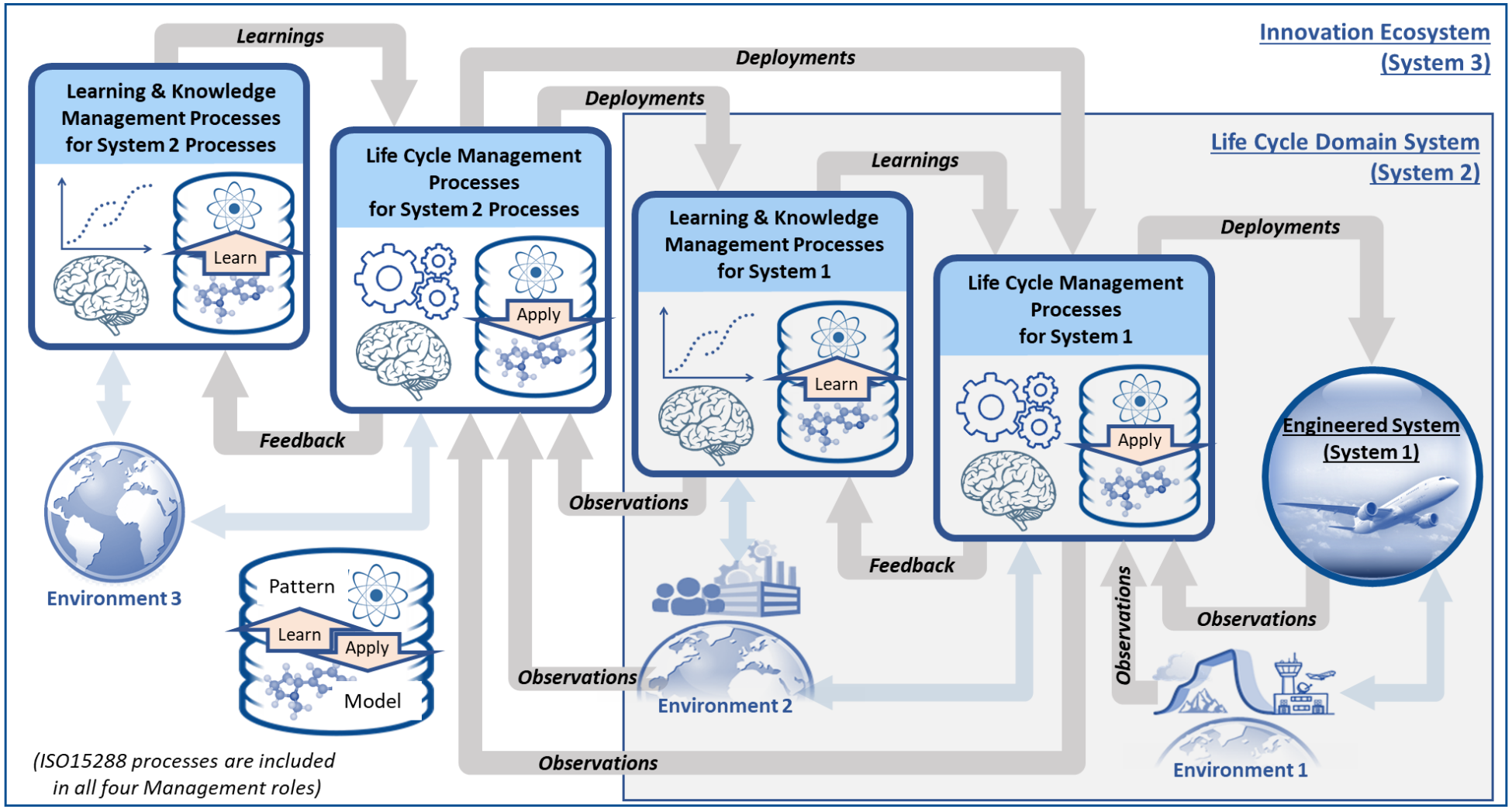
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10. Support for Vision 2035 Implementation Streams: FuSE--Innovation Applications, SE Foundations-Hamiltonian.

11

Attachment:
Additional information on those WG projects

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



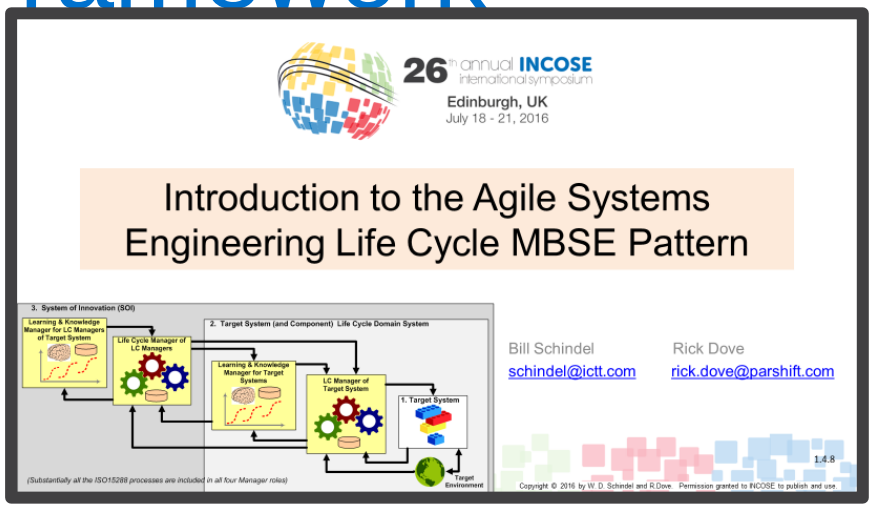
ASELCM Pattern Description

AIAA's Related Application (Digital Threads, Twins)

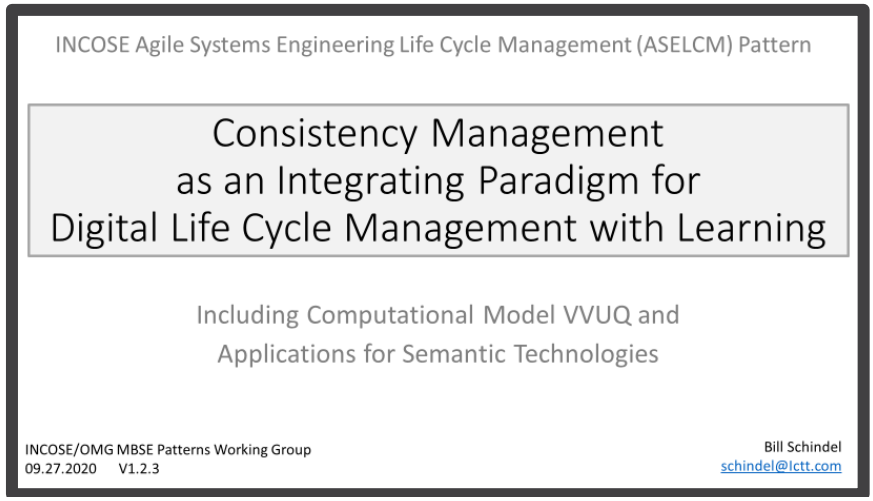
Used as foundation of the AIAA Digital Thread and AIAA Digital Twin Reference Models. Most downloaded AIAA publication on record.

Adaptive Learning Ecosystem Pattern—Innovation 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.

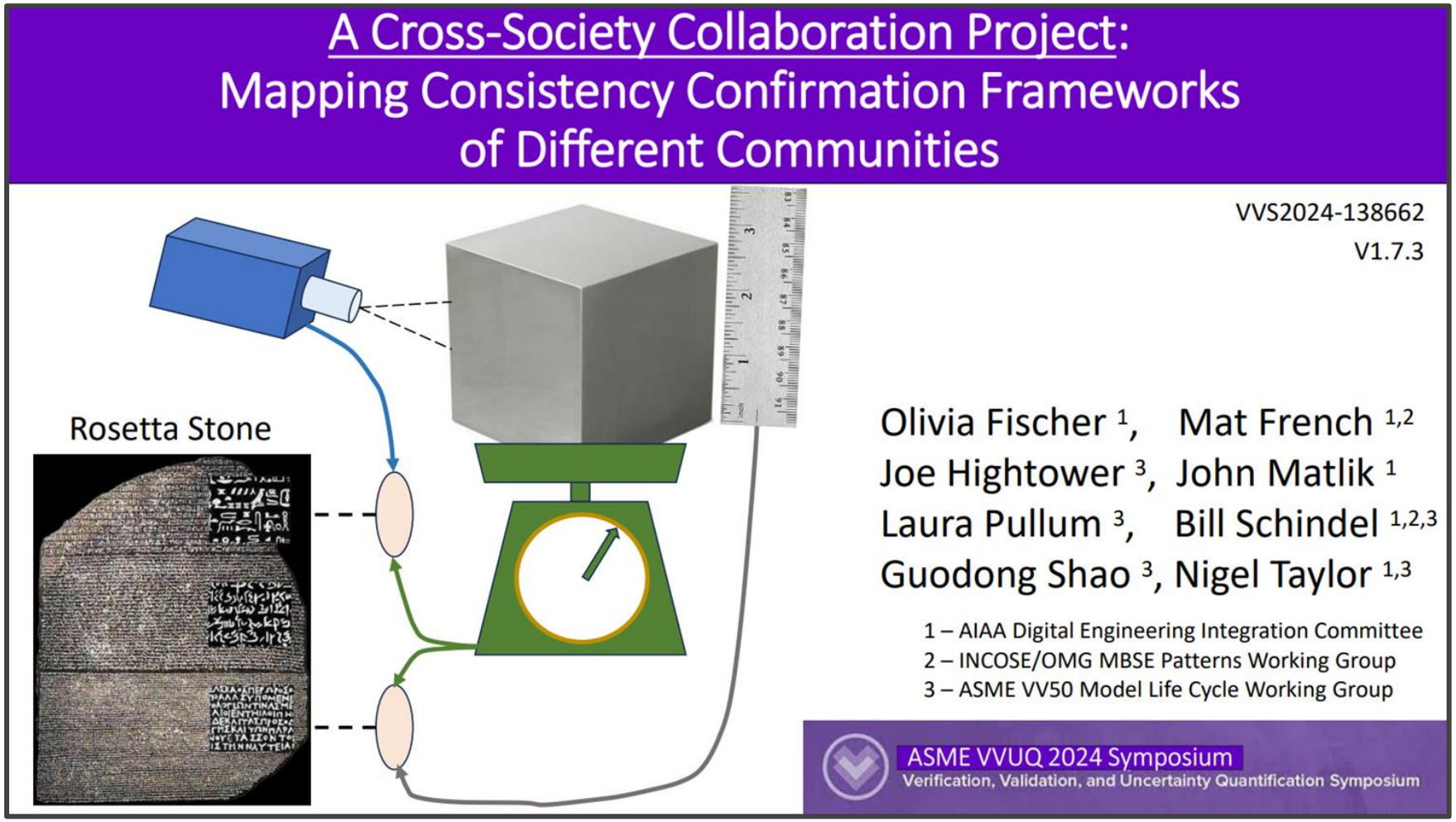


http://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:is2016_intro_to_the_aselcm_pattern_v1.4.8.pdf



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

“Rosetta Stone” Project: Collaboration project by ASME-INCOSE-AIAA-NAFEMS



2024 Project

https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:asme_vvuq_2024_slides_schindel_et_al_v1.7.3.pdf

Semantic Technologies for Systems Engineering (ST4SE)

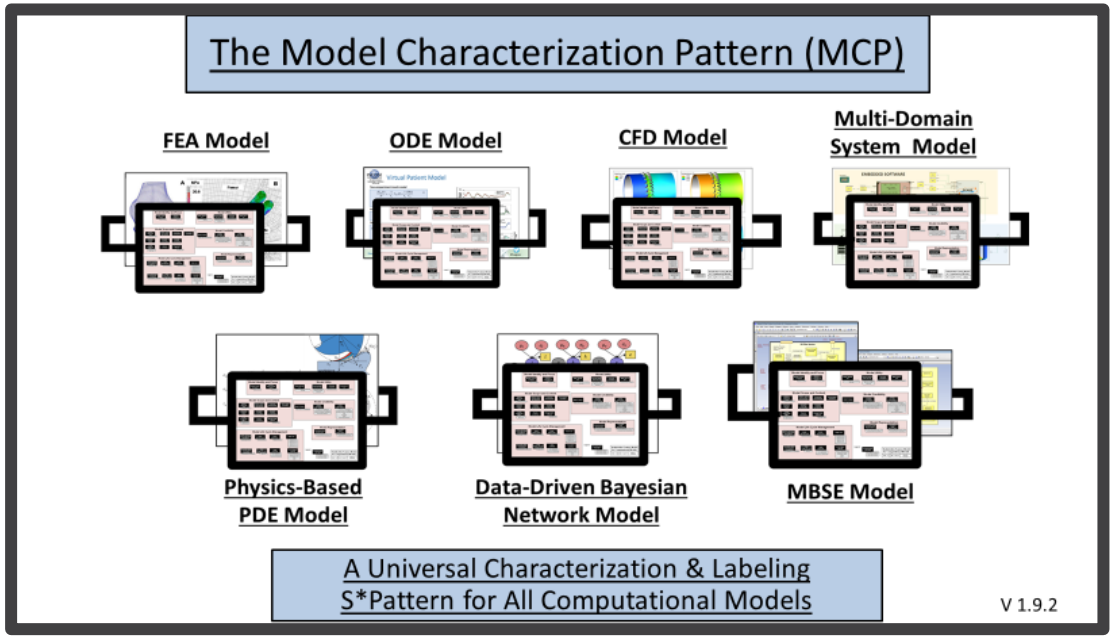
https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:incose_patterns_wg_report--st4se_project--1.10.6.pdf

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.

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

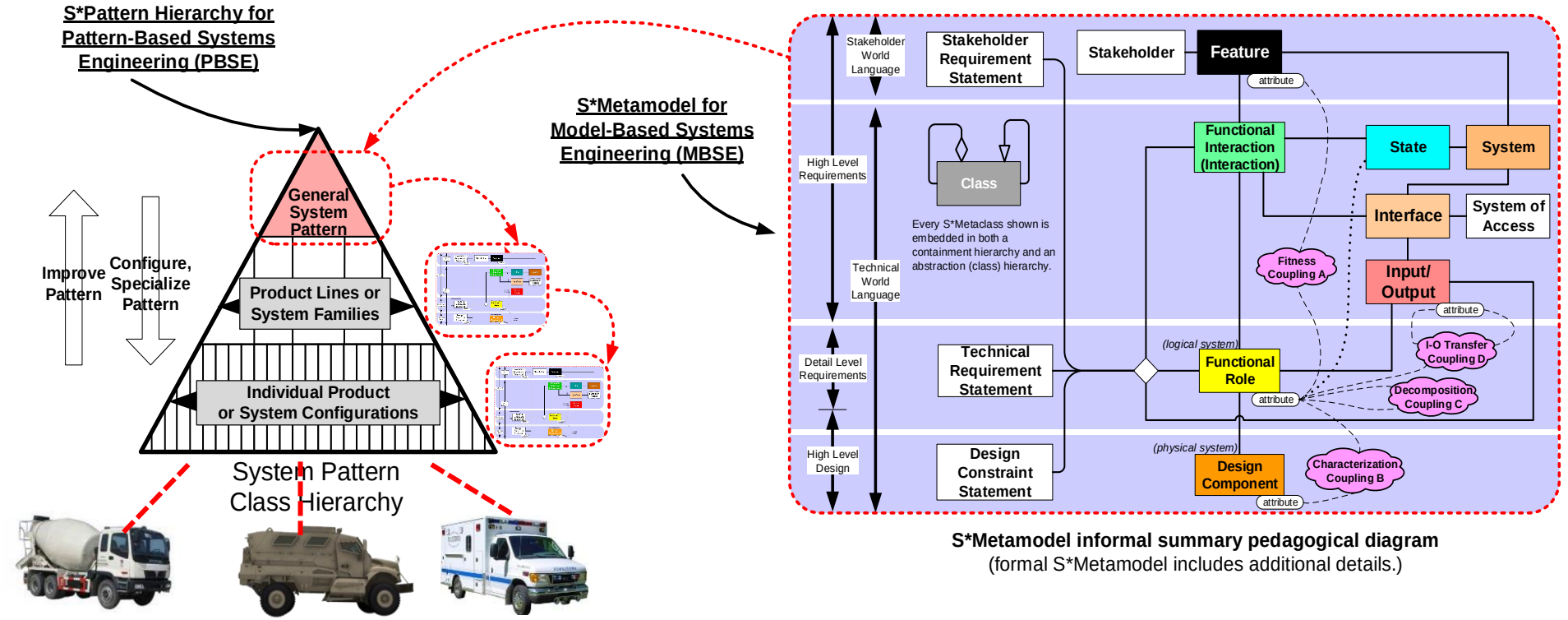
- Collaborating with ASME Standards Committee on Model Credibility, VV50 Subcommittee, Patterns WG created a configurable pattern for representing metadata on any virtual model, including Machine Learning, Simulation (FEA, CFD, SD, ODE), MBSE, otherwise. Auto generates Reqs for models. (ASME WG led by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

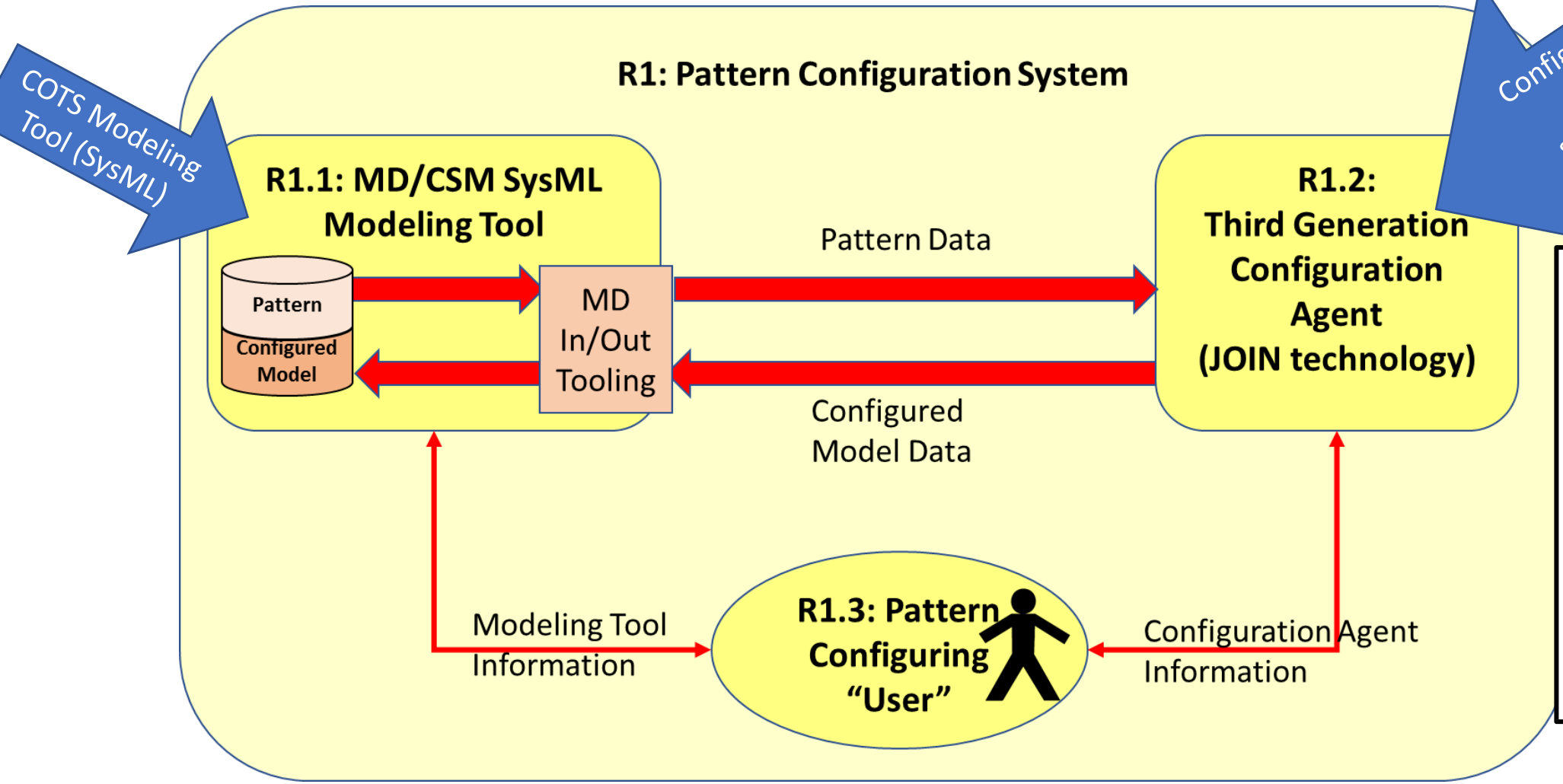
S*Pattern Configuration Wizard

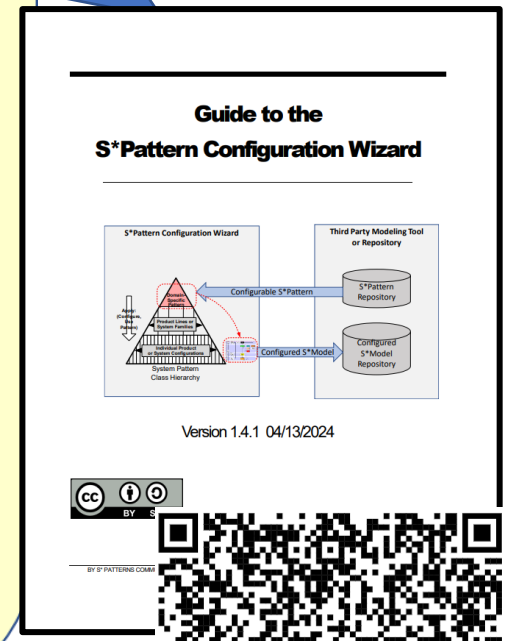
- Auto-generates MBSE model in SysML tool, as configuration of Pattern.
- Extendable to any modeling tool.
- Configuration algorithm encodable in any JOIN-supporting environment.
- Configurable patterns for products, enterprise ecosystems, other models.
- Currently in use in ST4SE Project, to be distributed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



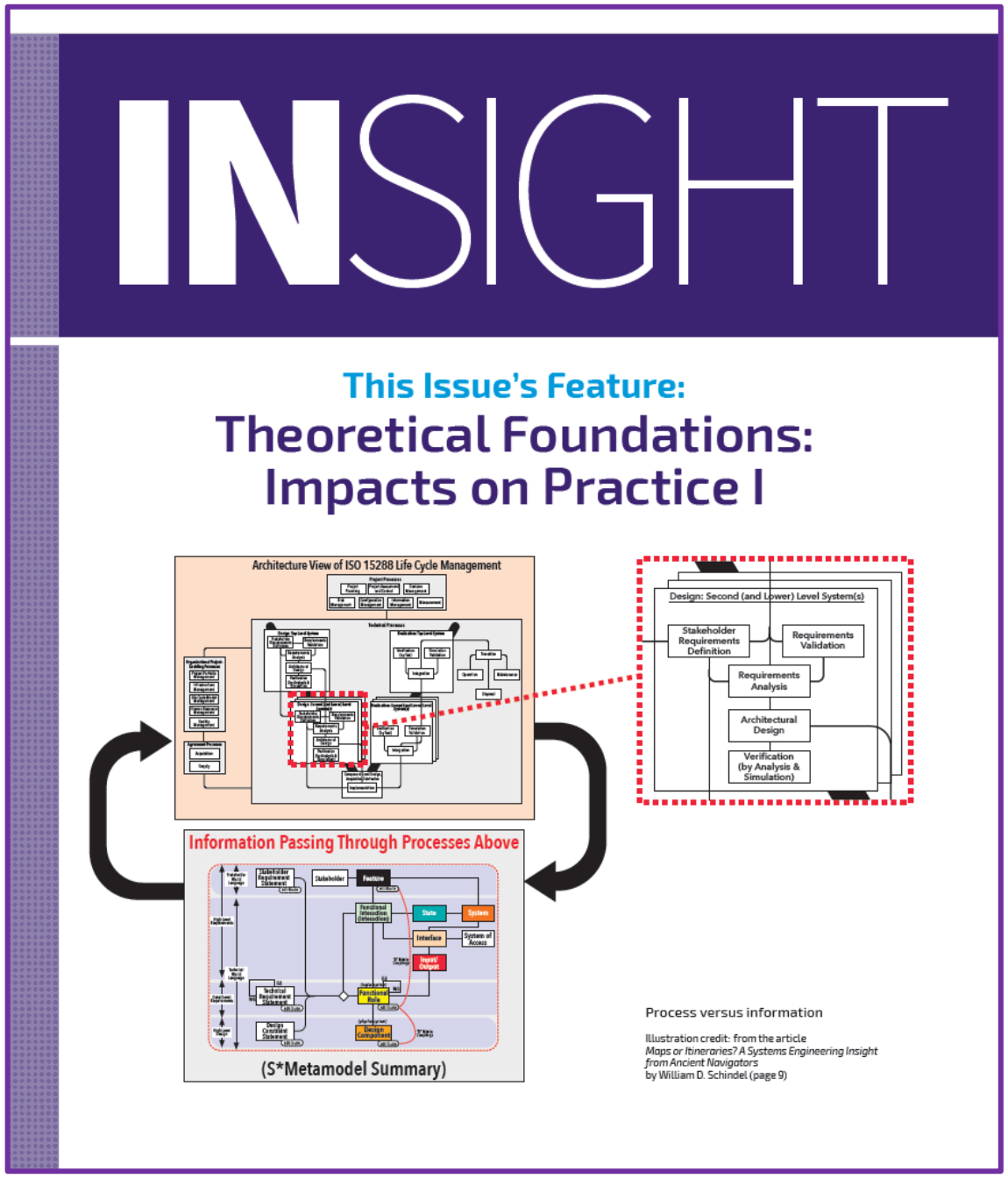
S*Metamodel informal summary pedagogical diagram
(formal S*Metamodel includes additional details.)

S*Pattern Configuration Wizard





[Download Configuration Wizard Guide]



Aug, Oct 2924 Special Issues: "Theoretical Foundations: Impacts on Practice I and II"

- Featuring retrospective of 10 International Symposium papers on SE foundations and their impact on practice, from Patterns WG
- William Miller, special issues editor and INSIGHT editor in chief.

AIAA Aerospace Digital Twins Reference Model Publication and AIAA Aerospace Digital Thread Reference Model Publication

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

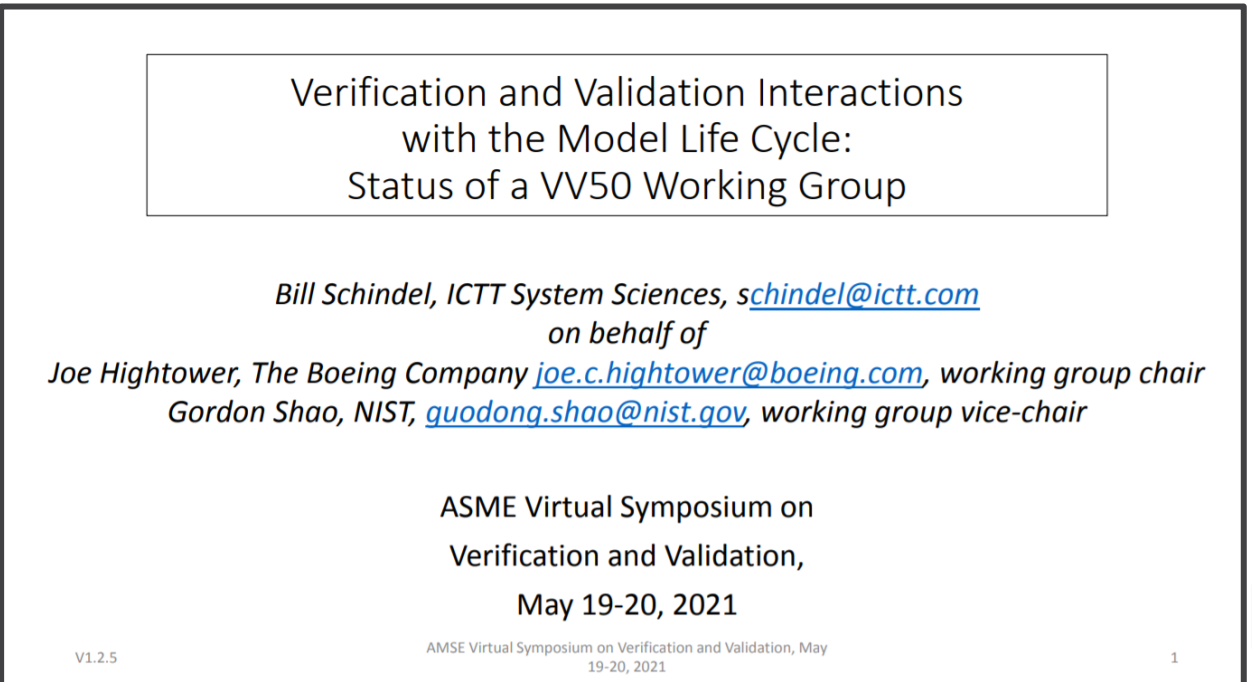
https://www.aiaa.org/resources/digital-thread-white-paper



Most downloaded AIAA publication on record.

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.
- Ballot passed VVUQ50 subcmte; Standards Committee Ballot in 2024.



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

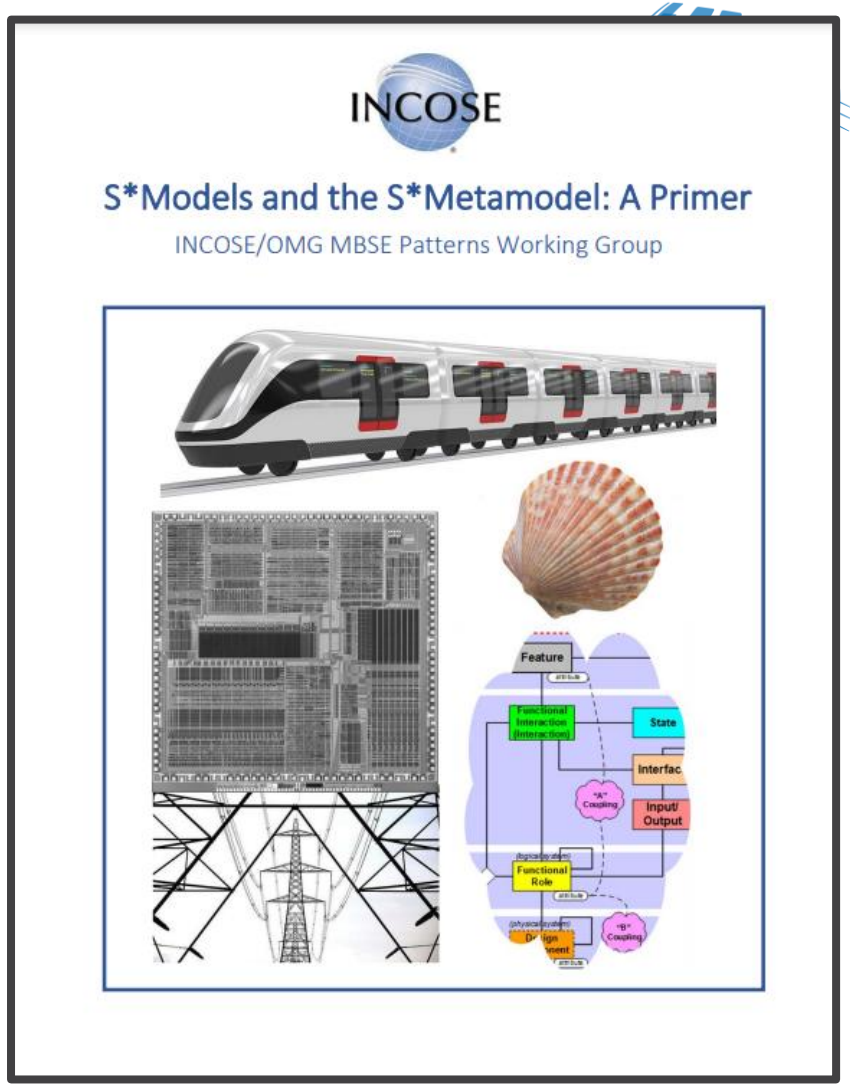
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https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:model_life_cycle_working_group_status_v1.2.5.pdf

Minimal S*Models—A Primer

Review Phase Starting

- 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.

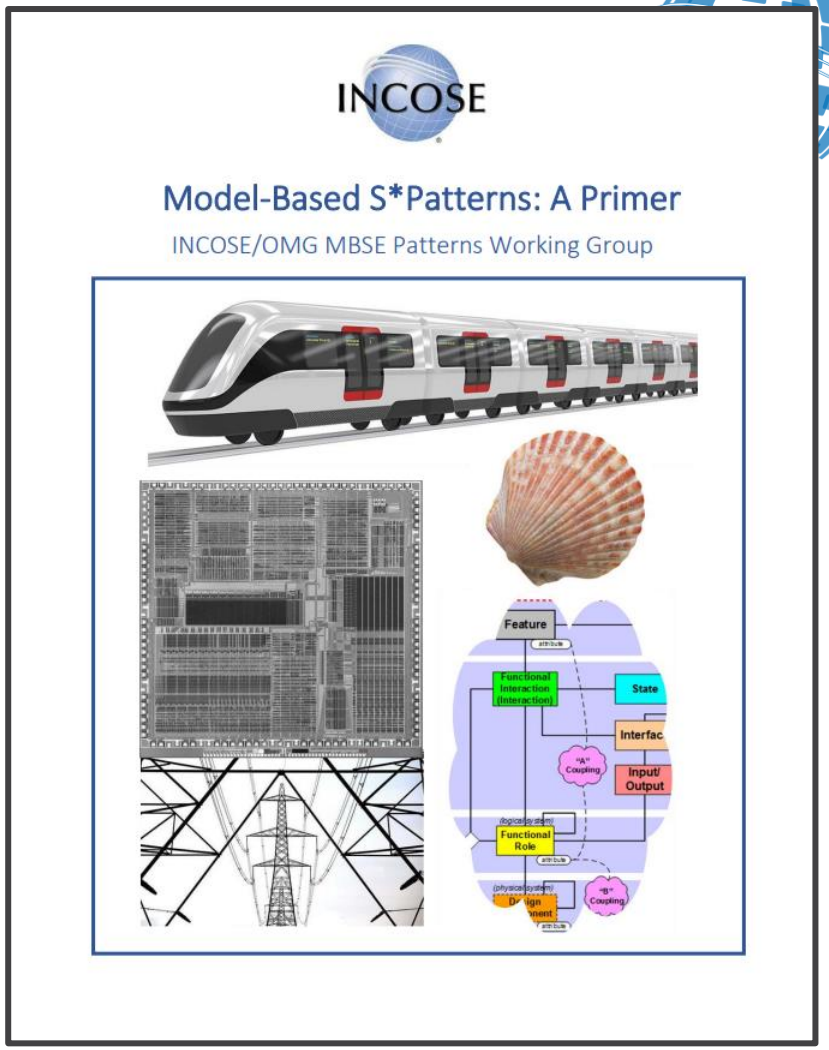


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S*Patterns Primer (second edition)

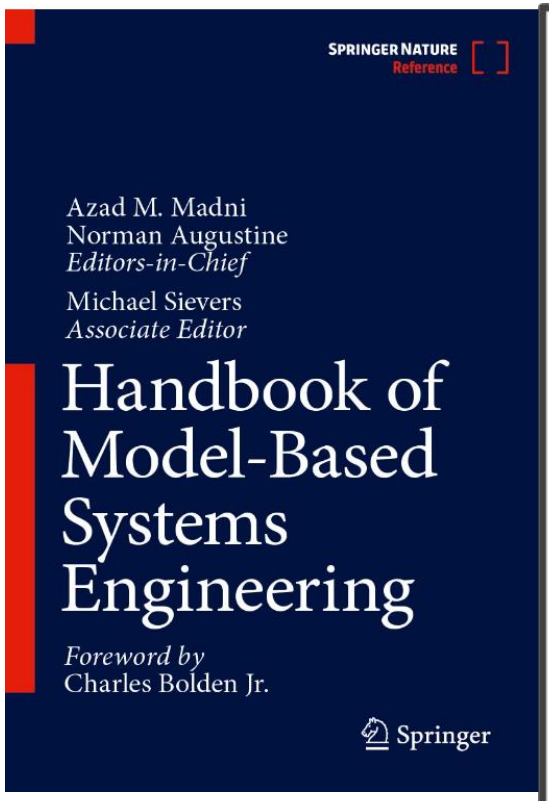
Review Phase Starting

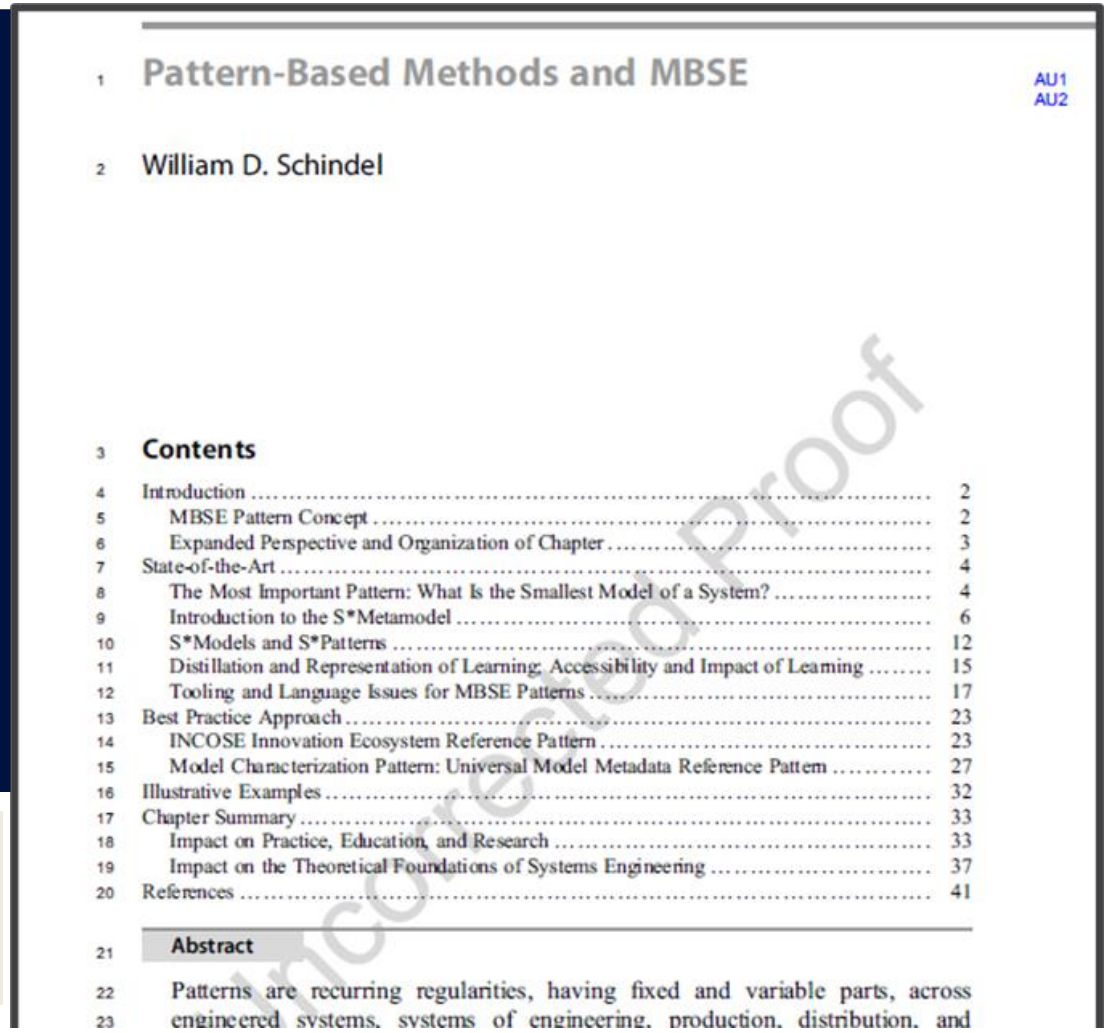
- The Patterns WG generated an introduction and overview of pattern-based methods and their relationships with other subjects—this was several years ago and before the emergence of newer INCOSE Tech Ops approaches to INCOSE Technical Product “primers” on various subjects supported by the working groups.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



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

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





Pattern-Based Methods and MBSE

AU1
AU2

William D. Schindel

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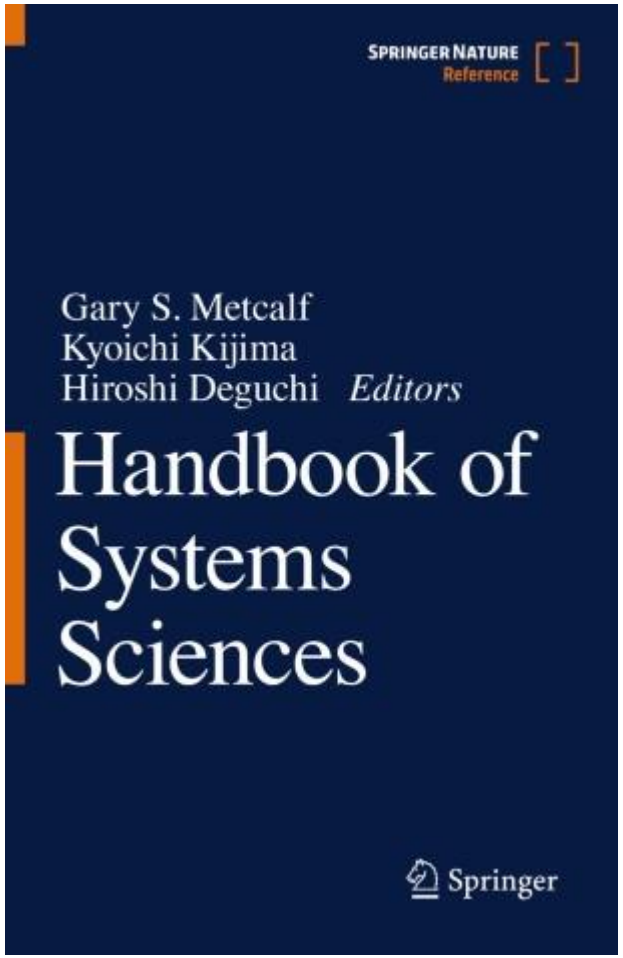
Abstract

Patterns are recurring regularities, having fixed and variable parts, across engineered systems, systems of engineering, production, distribution, and

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

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

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



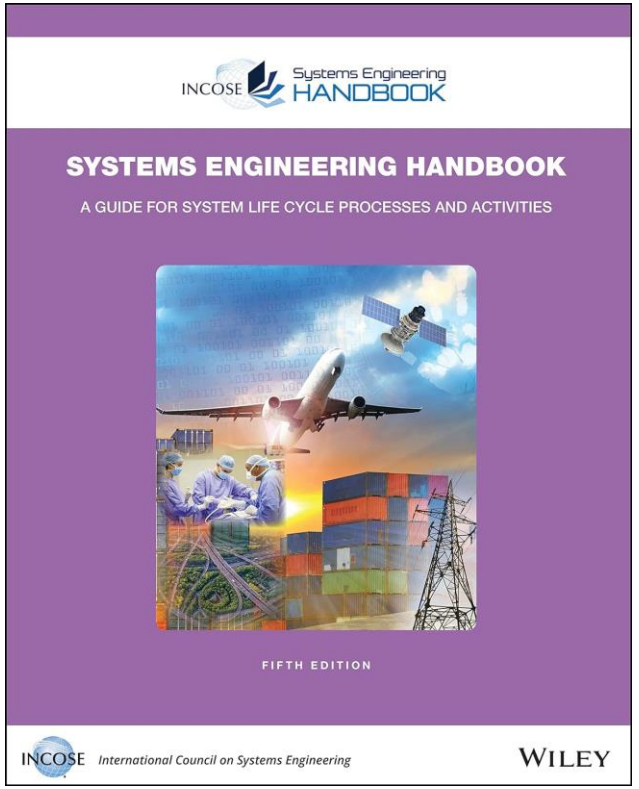


- ISSS Reference Textbook project supported by Patterns Working Group.
- Chapter on “System Patterns in Engineering and Science”
- An ISSS-INCOSE effort.

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

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.
- New content on S*Patterns and S*Metamodel.
- Overall project led by INCOSE Handbook Editorial Team, chaired by Dave Walden.



New (5th) Edition

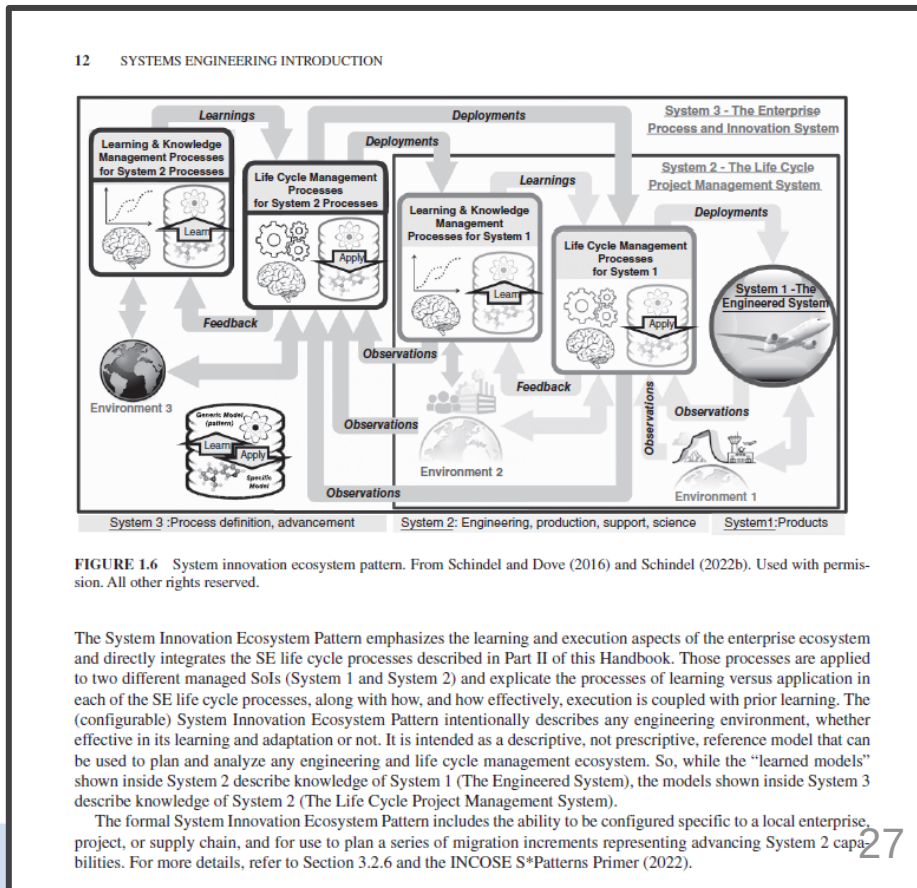


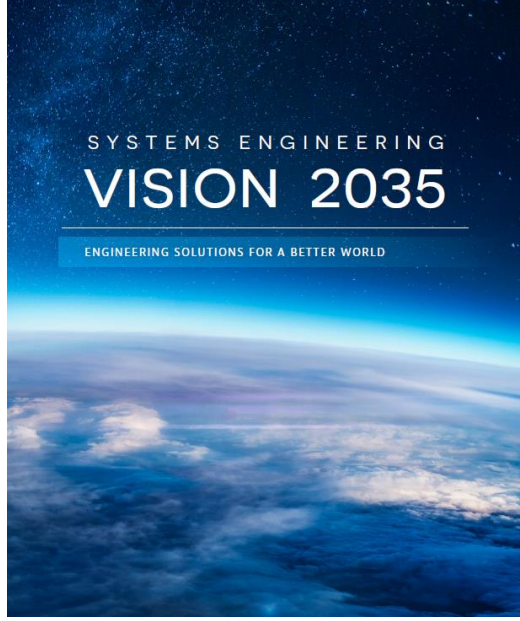
FIGURE 1.6 System innovation ecosystem pattern. From Schindel and Dove (2016) and Schindel (2022b). Used with permission. All other rights reserved.

The System Innovation Ecosystem Pattern emphasizes the learning and execution aspects of the enterprise ecosystem and directly integrates the SE life cycle processes described in Part II of this Handbook. Those processes are applied to two different managed SoIs (System 1 and System 2) and explicate the processes of learning versus application in each of the SE life cycle processes, along with how, and how effectively, execution is coupled with prior learning. The (configurable) System Innovation Ecosystem Pattern intentionally describes any engineering environment, whether effective in its learning and adaptation or not. It is intended as a descriptive, not prescriptive, reference model that can be used to plan and analyze any engineering and life cycle management ecosystem. So, while the "learned models" shown inside System 2 describe knowledge of System 1 (The Engineered System), the models shown inside System 3 describe knowledge of System 2 (The Life Cycle Project Management System).

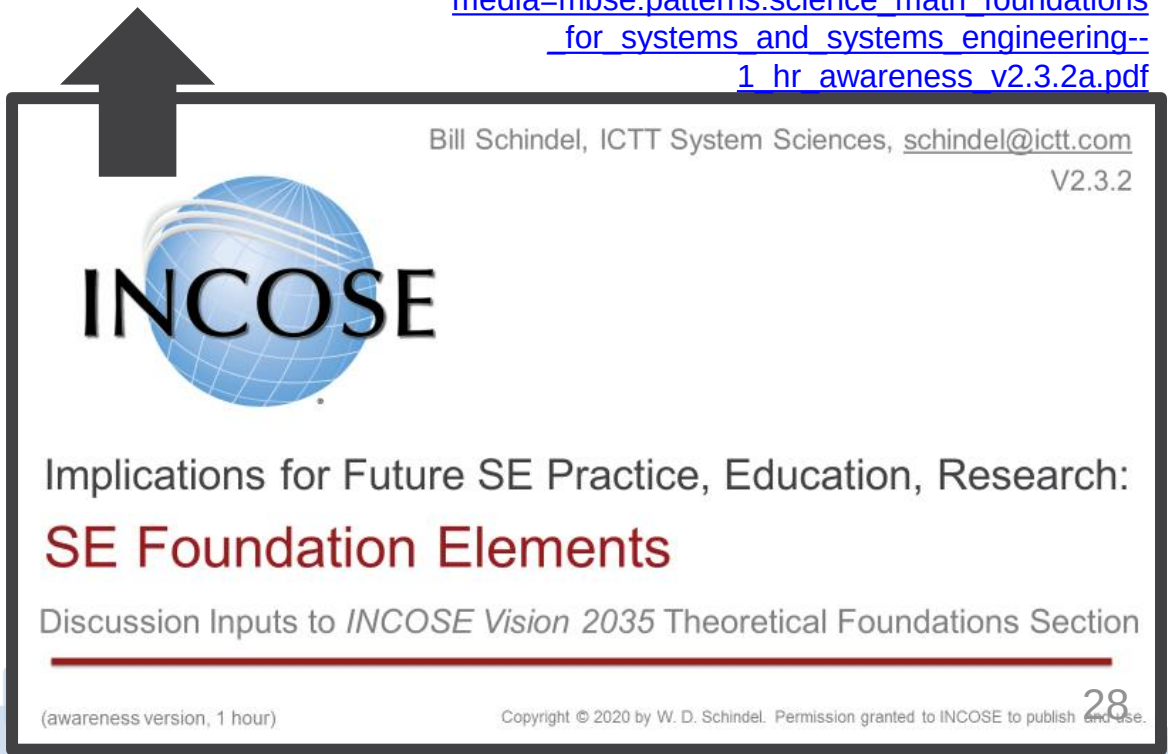
The formal System Innovation Ecosystem Pattern includes the ability to be configured specific to a local enterprise, project, or supply chain, and for use to plan a series of migration increments representing advancing System 2 capabilities. For more details, refer to Section 3.2.6 and the INCOSE S*Patterns Primer (2022).

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

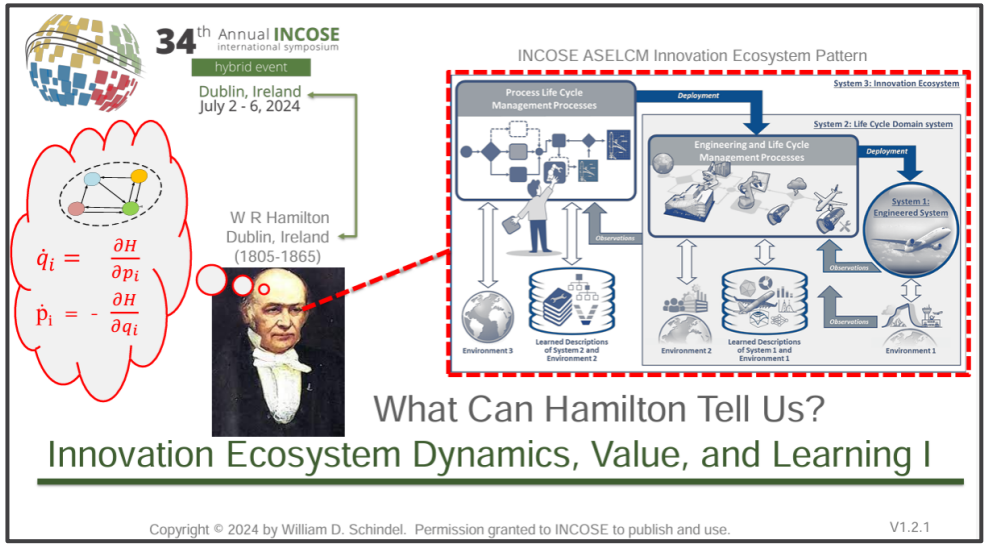


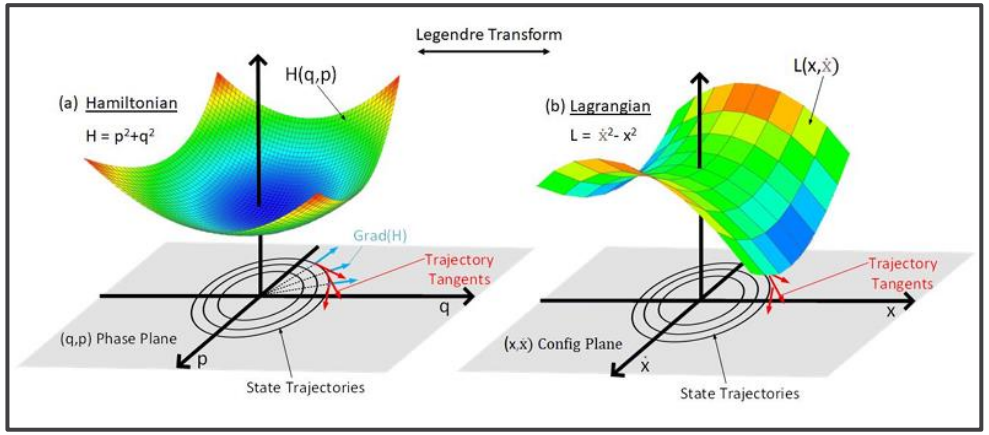
http://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:science_math_foundations_for_systems_and_systems_engineering--1_hr_awareness_v2.3.2a.pdf



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, Ireland, was Hamilton's home, and this IS2024 paper session expanded on the above during IS2024 in Dublin.





Download Hamiltonian Ecosystems Paper