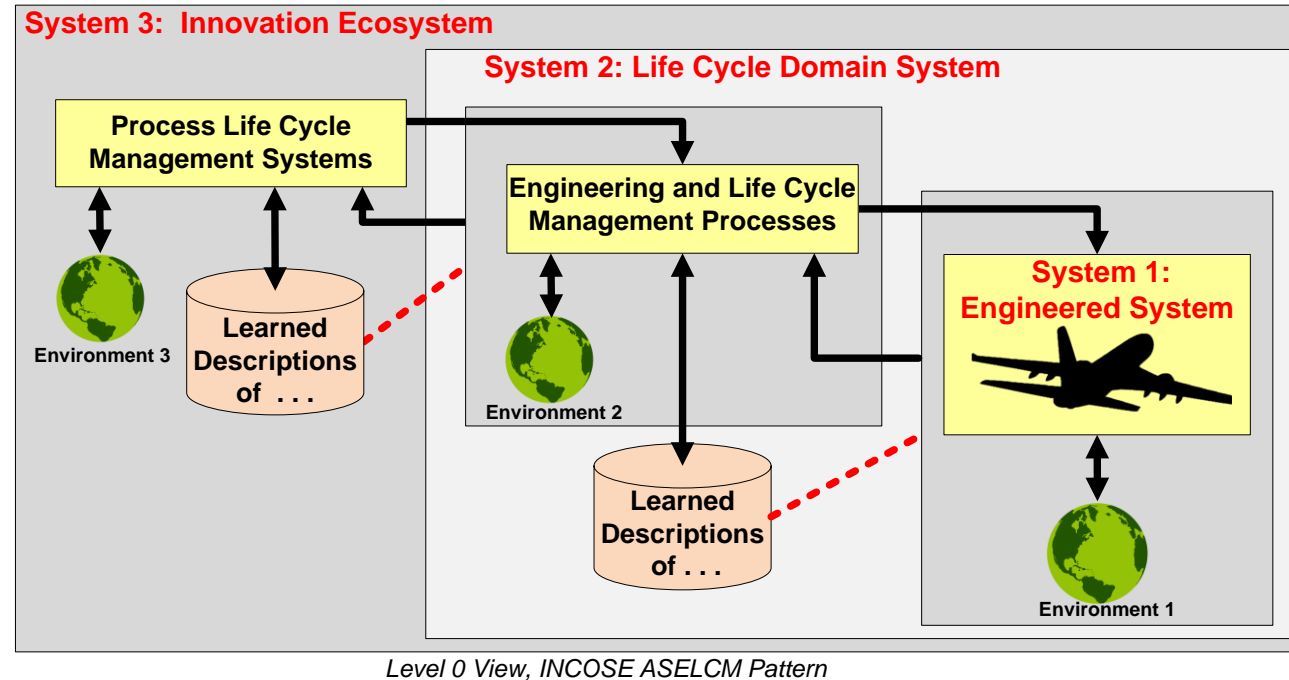


The Innovation Ecosystem: Introduction to the INCOSE ASELCM Pattern



INCOSE North Texas Chapter Meeting
December 14, 2021
V1.2.2



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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 talk 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. Represented as a configurable model-based formal pattern created by the INCOSE MBSE Patterns Working Group, it was initially applied in a related INCOSE collaboration project led by the Agile Systems Engineering Working Group.
- Aspects of the resulting framework have subsequently been elaborated and applied 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.

Contents

- The INCOSE MBSE Patterns Working Group
- The Innovation Ecosystem Pattern: Early history
- Current applications and value
- Brief tour through the Ecosystem Pattern concepts and implications
- The SysML version
- Interested? How to get involved
- Q&A

- References
- Speaker background

The INCOSE MBSE Patterns Working Group

- Originated in 2013 as one of the INCOSE-OMG MBSE Initiative challenge teams, advancing in 2016 to INCOSE Working Group.
- Focused on model-based representation of recurring, configurable system-level patterns.
- History of projects emphasizing collaboration with other technical societies & INCOSE Working Groups.
- Numerous publications and resources available for download from Patterns Working Group web site--
<https://www.omgwiki.org/MBSE/doku.php?id=mbse:patterns:patterns> *(Note this is on OMG Wiki!)*
- You are invited to participate!

The screenshot shows the top of a web page from the OMG Standards Development Organization. The header includes the OMG logo, the text "Standards Development Organization MBSE Wiki", and a search bar. Below the header are links for "Recent Changes", "Media Manager", and "Sitemap". A breadcrumb trail reads: "Trace: · agile_systems_engineering_life_cycle_management_aselcm_discovery_project_with_ase_wg · pbse_introduction_basic_subjects_tutorials_education · patterns". The main content area has a title "INCOSE/OMG MBSE Patterns Working Group" and a paragraph of introductory text. To the right is a "Table of Contents" with several links. The text below the table of contents is partially visible.

INCOSE/OMG MBSE Patterns Working Group

The MBSE Patterns Working Group (formerly the Pattern-Based Systems Engineering (PBSE) Challenge Team) is a component of the INCOSE/OMG Model-Based Systems Engineering (MBSE) Initiative (<http://www.omgwiki.org/MBSE/doku.php>). The approved [INCOSE Working Group Charter](#) is a 2016 update of the original 2013 team INCOSE/OMG charter. The base INCOSE working group page for the MBSE Patterns Working Group is found here: <http://www.incose.org/ChaptersGroups/WorkingGroups/transformational/mbse-patterns>.

1. Purpose:

1.1. Conceptual Summary:

As used here, System Patterns are configurable, re-usable System Models that would otherwise be like those expected and found in the practice of MBSE (not limited to, but including, SysML models). Through the availability and use of System Patterns, the outcomes targeted by MBSE models are made more accessible, in terms of ease (and skill) of generation and use, associated modeling cost, schedule, risk, completeness, and consistency, etc. Over time, System Patterns become points of accumulation of organizational learning and expertise. Because they are configurable and re-usable models of families or classes of systems, model-based System Patterns involve some additional methods and

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

See also: Attached References pages.

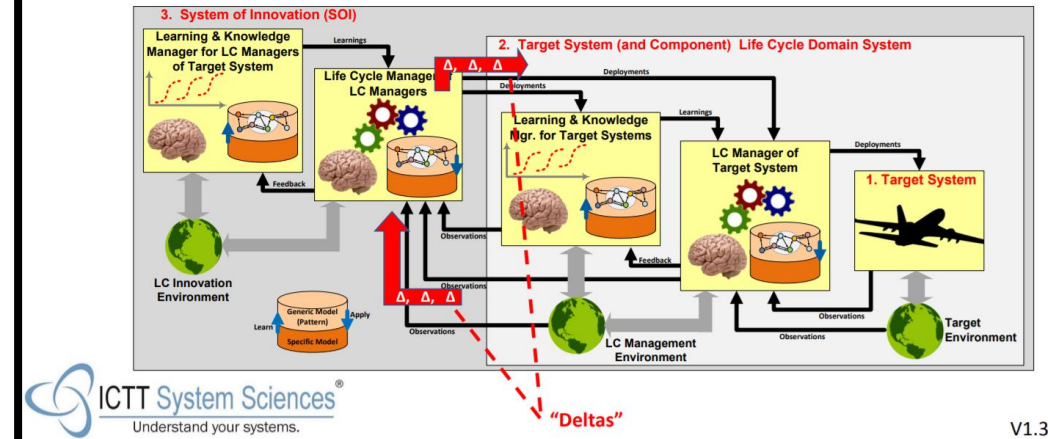
The Innovation Ecosystem Pattern: Early history

- Originally introduced in a series of 2012, 2013 INCOSE papers on the emergence of purpose and pathologies in innovation environments.
- Elaborated during multi-year collaboration with the Agile SE Working Group, as an analysis framework in that study of four mil/aero enterprises demonstrating forms of agility in projects.
- Subsequently built out as an analysis and planning framework for innovation ecosystems to study supply chains, digital engineering, digital threads, and digital twins, and for digital engineering analysis and planning across various industrial clients.
- Currently being used by AIAA in a series of studies and reports on aerospace industry digital twins and digital threads.
- Represented by a formal underlying MBSE pattern (configurable model) in OMG SysML—but also presented in iconic graphic form.

Current applications and values

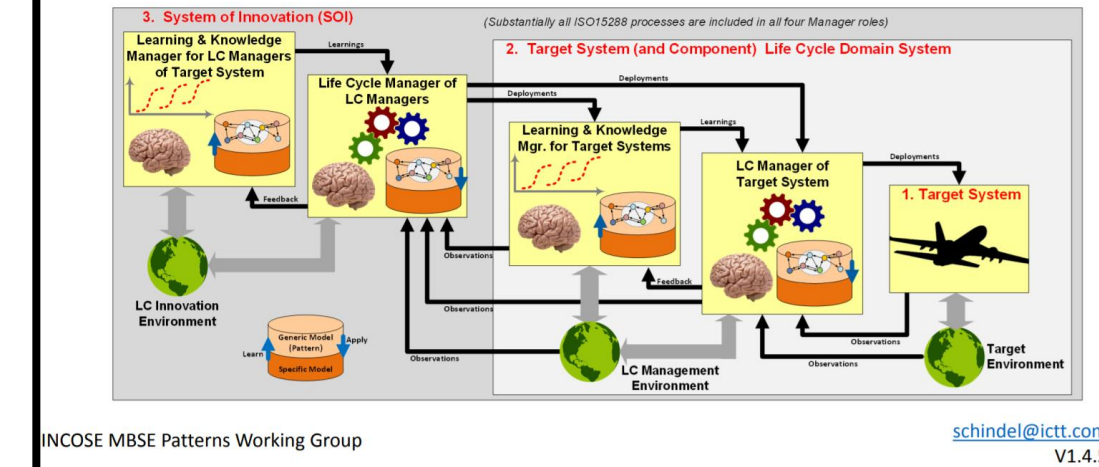
- Analysis of existing enterprises, supply chains, innovation ecosystems, engineering processes, life cycle management processes, methodologies, tool chains, digital engineering, digital threads, digital twins associated with any of the ISO15288 life cycle management processes.
- Planning of future releases, deployments, progressive roadmaps of engineering and life cycle management processes, tool chains, methodologies, digital engineering ecosystems.
- Currently being used as general reference model for a series of AIAA case studies of digital twin implementations and digital thread principles.
- Privately applied by individual commercial enterprises to improve their innovation ecosystem performance and collaboration capabilities.
- Refer to the References.

Attachment I: Example Use of ASELCM Pattern for Analyzing Current State, Describing Future State, and Constructing Incremental Release Roadmap to Future



https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:example_evolutionary_roadmap_v1.3.3a.pdf

ASELCM Reference Pattern: Reference Configuration Stages for Models, Model Patterns, and the Real Systems They Represent

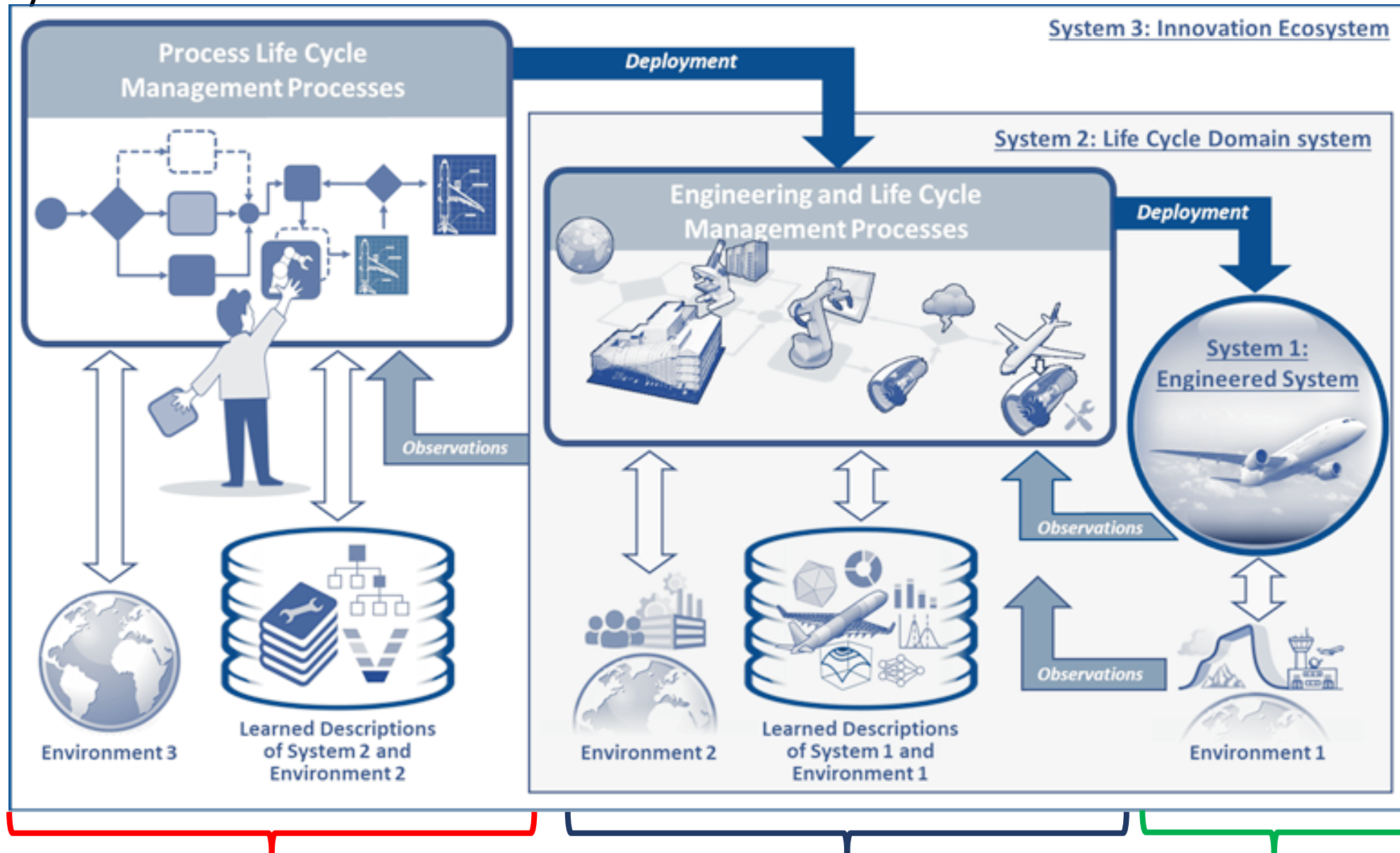


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Brief tour through the Ecosystem Pattern concepts and implications

1. Ecosystem level capabilities' connections to underlying interactions
2. Connecting historically represented business processes to evolving digital infrastructure
3. Consistency Management's connection to realizing the promise of digital engineering
4. Managing the proliferation of virtual model diversity and instances
5. Effectiveness of distributed, multi-level group learning
6. Group trust in the credibility of models
7. Effective evolution of the ecosystem itself

System reference boundaries structure: Level 0

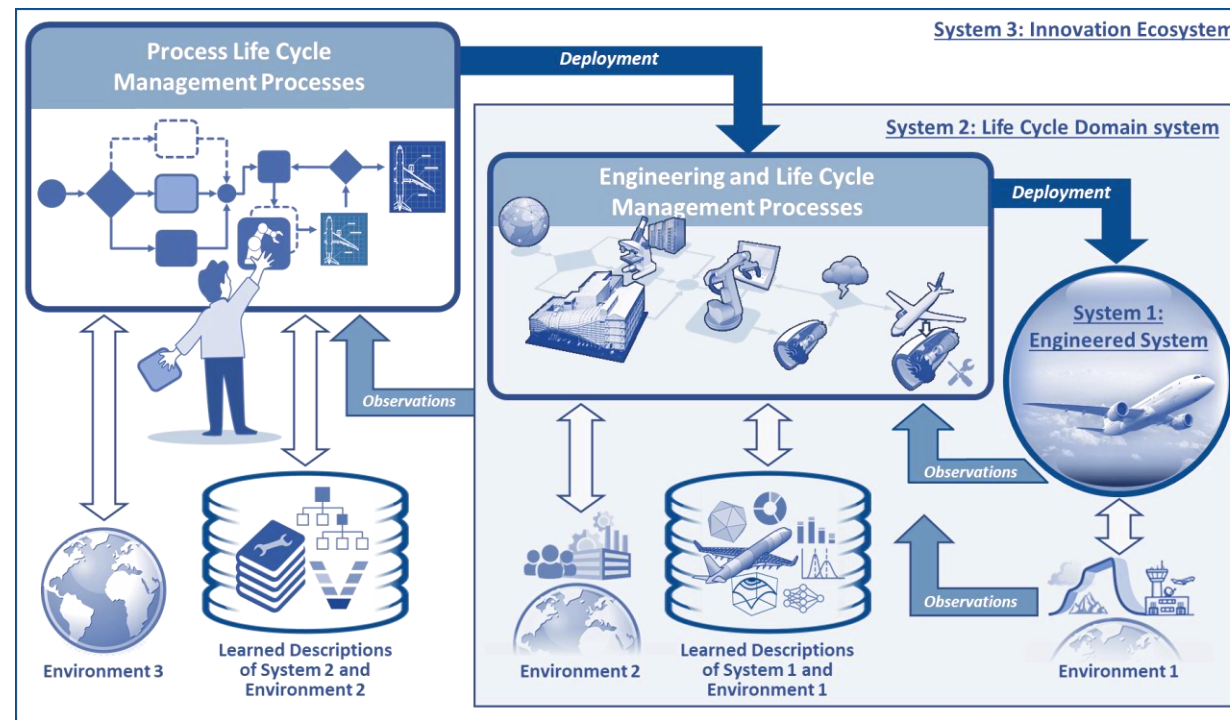


System 3: Life Cycle Manager of System 2

System 2: Life Cycle Manager of System 1

System 1: Engineered System

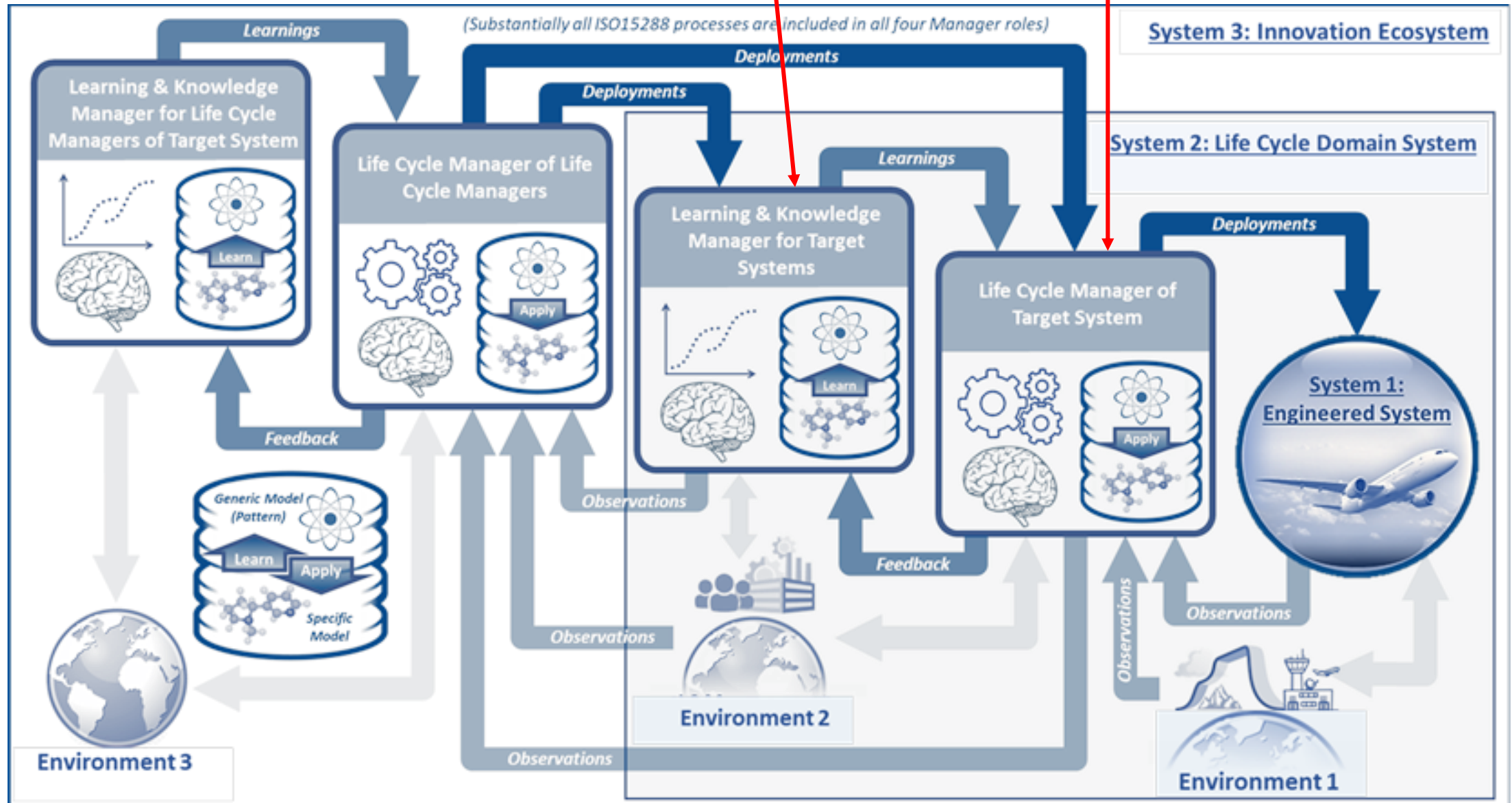
INCOSE ASELCM Level 0 Reference Model



- **System 1--Engineered System**: The subject system (or system of systems) to be planned, designed, analyzed, produced, operated, sustained, improved, etc. May be a manufactured product(s), operated service, or other system of interacting components.
- **System 2—Life Cycle Domain System**: The total environment in which System 1 will exist, consisting of all the domain elements with which System 1 will interact at some point during its life cycle. Includes in particular the life cycle management systems responsible for System 1. That means System 2 includes all the engineering, production, distribution and deployment, support, operations, and other systems responsible for System 1. System 2 is responsible to learn about System 1 and its environment, and to use that learning effectively. System 2 contains, among other things, all the life cycle management processes of ISO 15288 (that is, those found in the INCOSE Systems Engineering Handbook or similar enterprise descriptions of the life cycle management systems).
- **System 3—Innovation Ecosystem**: The total environment in which System 2 will exist, including all the things with which System 2 interacts. Includes in particular the systems responsible for managing the life cycle of System 2. That means that System 3 is responsible to plan, analyze, construct, deploy, and support System 2. For example, System 3 is responsible to represent (document) System 2 engineering, production, distribution, support, and other System 2 processes. System 3 is responsible to observe and learn about System 2 and its environment, and effectively use that learning. The System 3 ecosystem can contain many System 2 instances, interacting, collaborating.

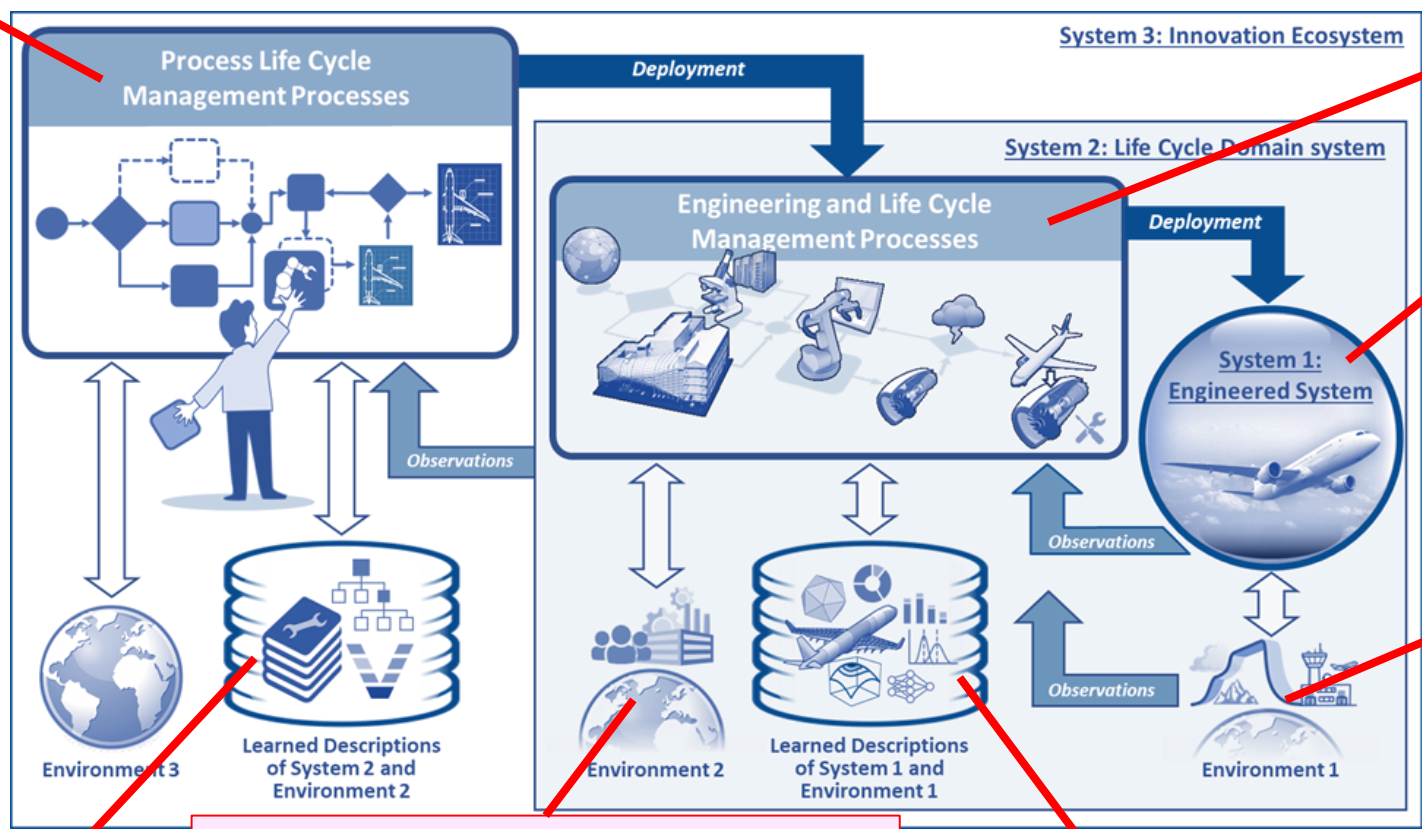
INCOSE ASELCM Level 1 Reference Model

(Separation of learning new information from acting on what is already known.)



Examples: Engineering Education, Engineering Methods Owner, Engineering Tooling Architect, HR Department, Engineering Procedures Author, INCOSE, IEEE, ASME

Examples: Systems Engineering Department, Senior Electrical Engineer, Design Review, Simulation Platform, Engineering Toolchains, Learning Machines, Digital Threads, Digital Twins, Manufacturing Process, Service Delivery Process, PLM system, Production MES.



• **Examples:** Aircraft, landing gear, bearings, avionics.

EXAMPLES

• **Examples:** Atmosphere, weather, runways

INCOSE ASELCM Level 0 Reference Model

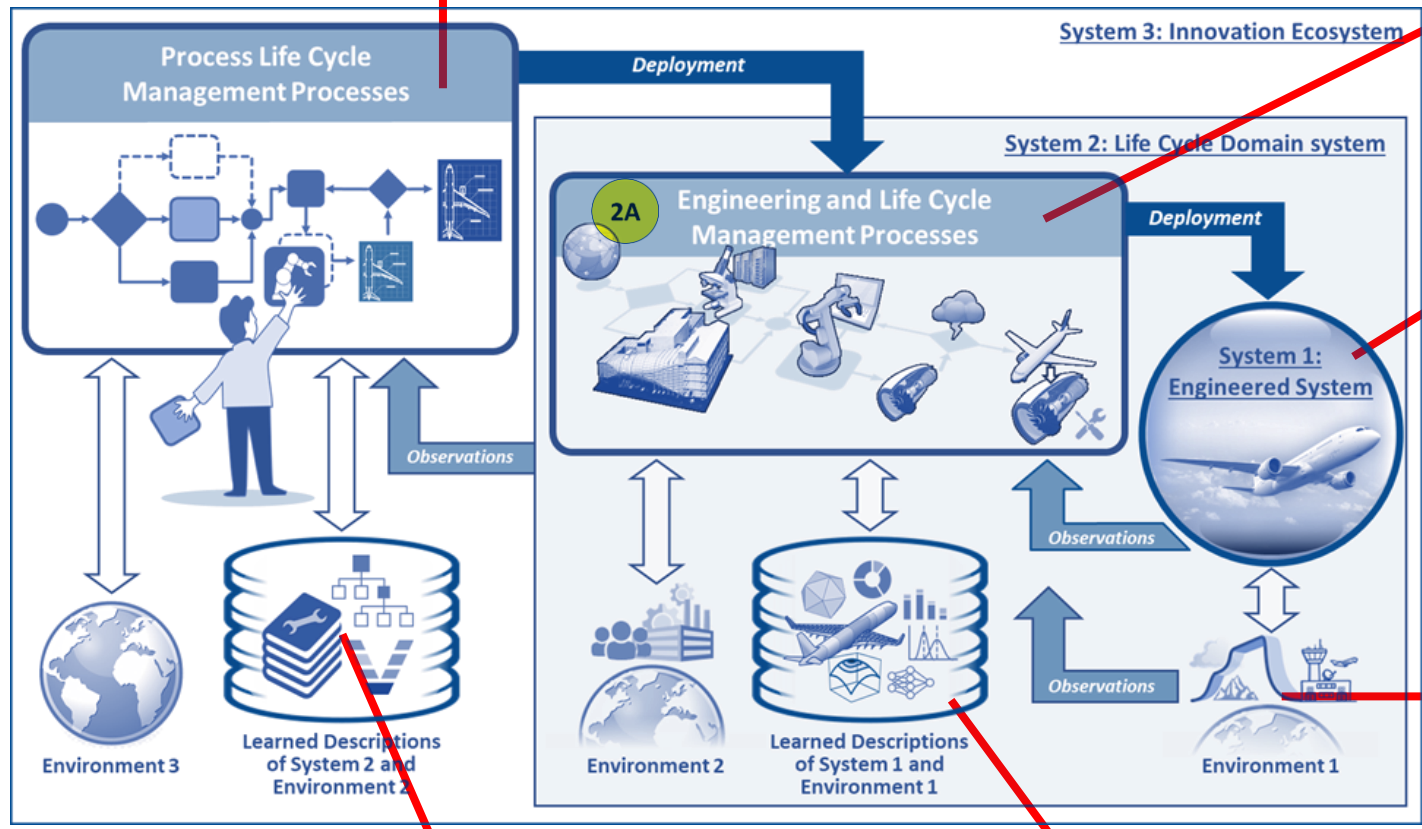
• **Examples:** COVID19 Pandemic, Industry Funding, Job Market

• **Examples:** Enterprise Procedures, Job Descriptions, Organization Charts, Policies, INCOSE Handbook, SEBoK, Methodology Primers, Personal & Tribal Process Knowledge

• **Examples:** Landing Gear Requirements, Designs, Schematics, MBSE Models, CFD Simulations, Part Prints, Production Recipes, Assembly Diagrams, Raw Materials Lists, Physics, Personal & Tribal Landing Gear Knowledge

- Systems & processes responsible to learn about, describe, understand System 2A and Environment 2, or to plan, engineer, develop, educate, deploy, integrate, install, maintain, or retire System 2A. People, tools, facilities.

- Systems & processes responsible to learn about, describe, understand System 1 and Environment 1, or to engineer, develop, fabricate, integrate, distribute, deploy, install, maintain, or retire System 1. Includes people, tools, facilities.



- Any engineered system, including manufactured products, service-providing systems; or any object of scientific study.
- Includes systems-of-systems, subsystems, or components.

DEFINITIONS

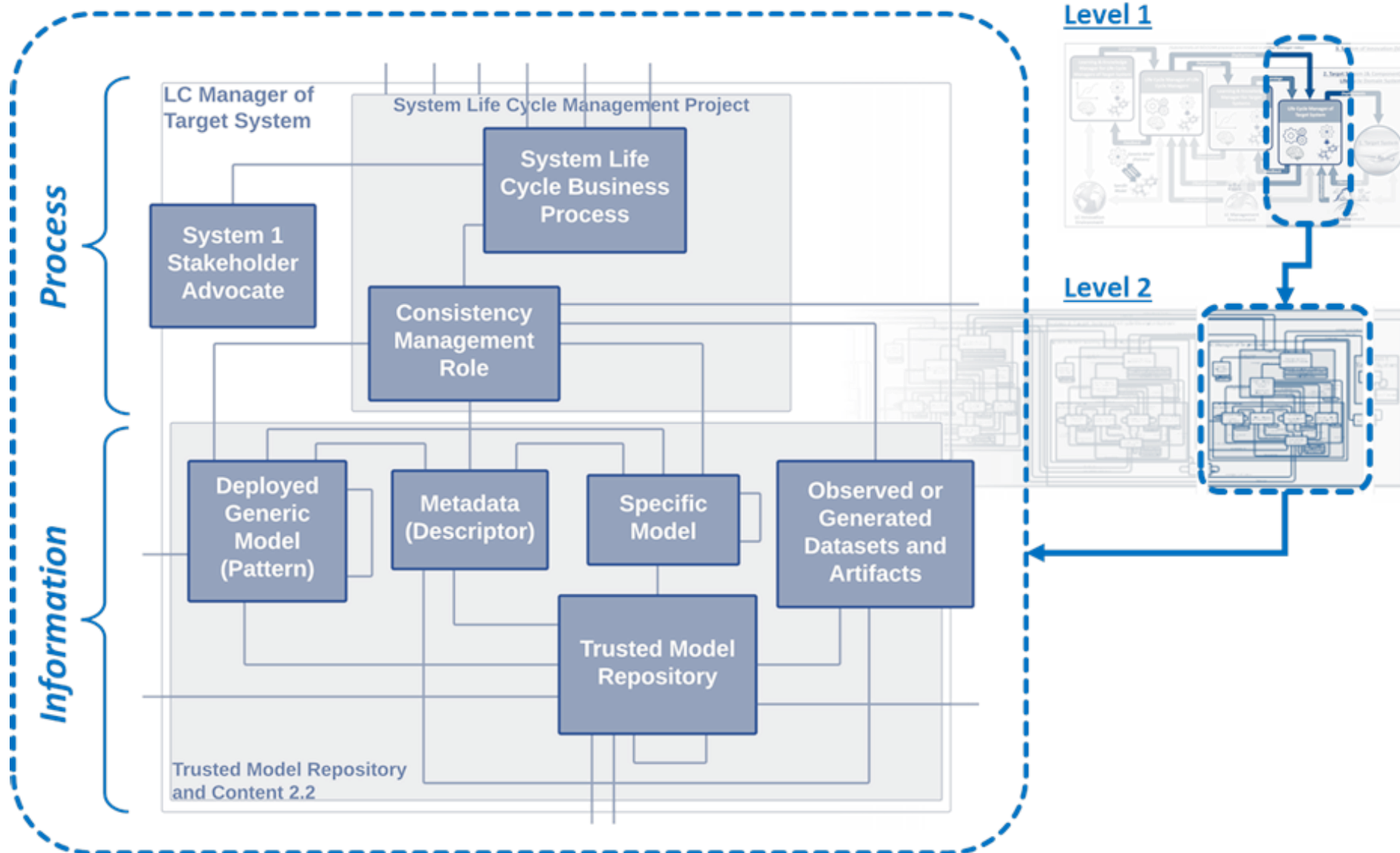
- The environment in which System 1 is operated, sustained, distributed, manufactured, or retired.
- Anything that directly interacts with System 1 during its life cycle.

- Accumulated knowledge of System 2A and Environment 2, including explicit procedures, work instructions, organization charts, models, implicit and tribal knowledge, captured empirical data or simulations, plans, prints, diagrams, prose, or other descriptions.

- Accumulated knowledge of System 1 and Environment 1, including explicit models, prose descriptions, implicit and tribal knowledge, captured empirical data or simulations, plans, prints, diagrams, prose, or other descriptions.

INCOSE ASELCM Level 2 Reference Model

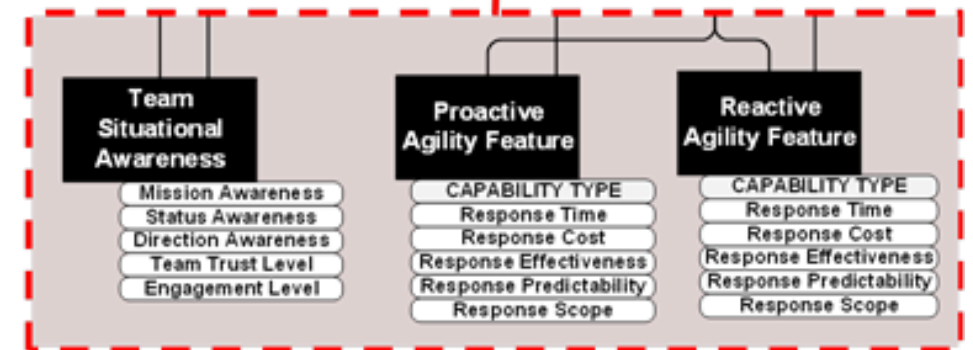
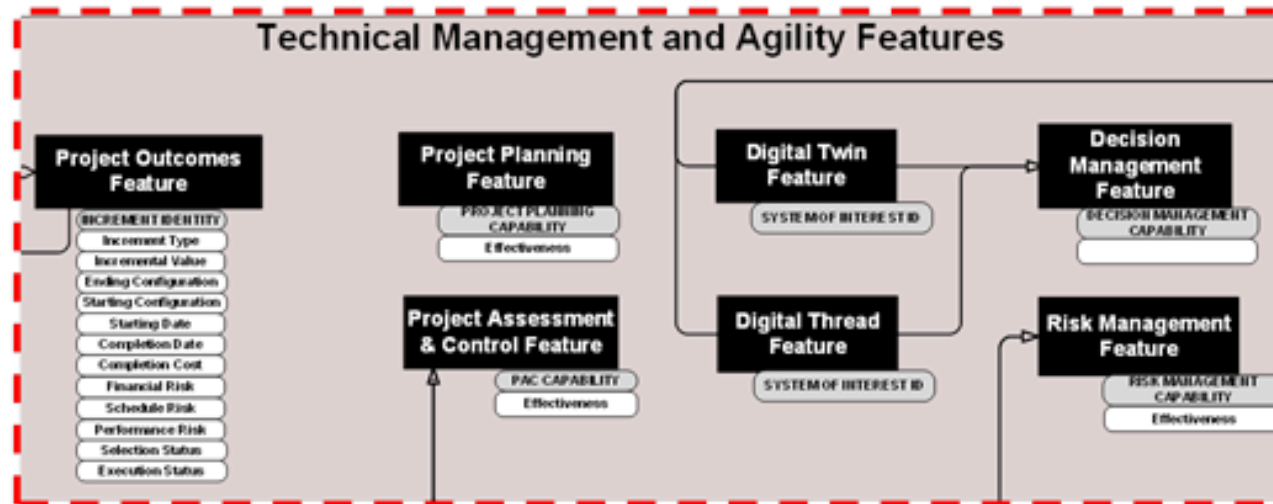
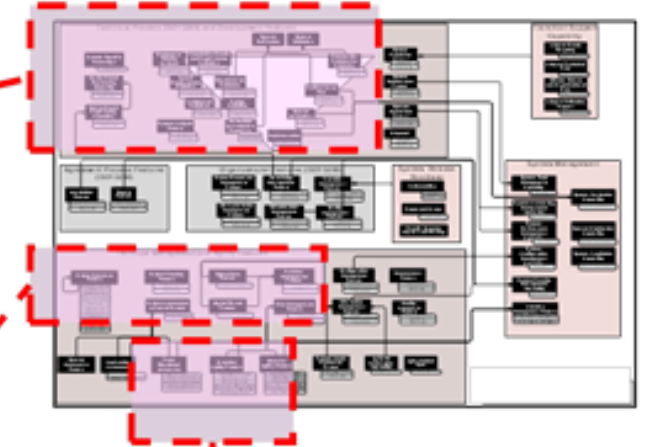
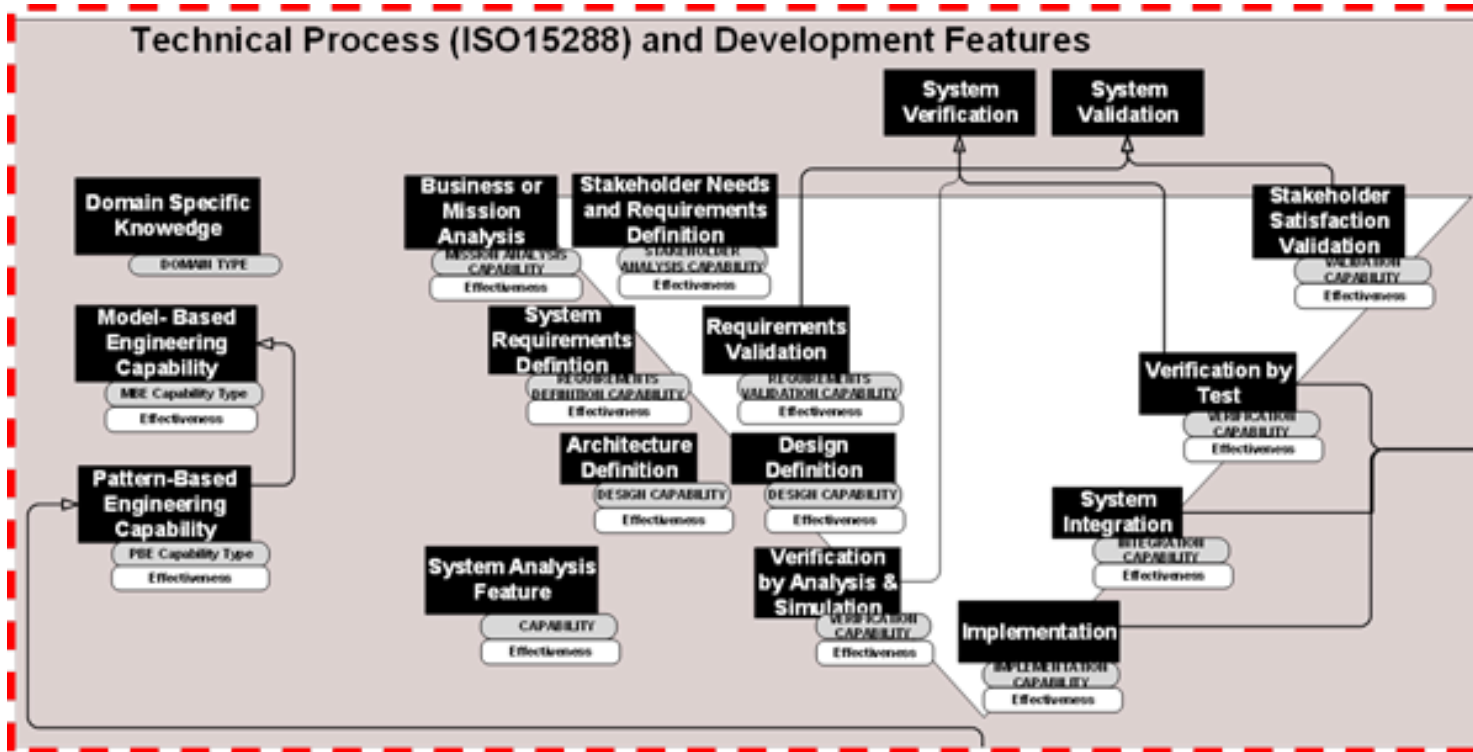
(Segment for Application of “Already Learned” Information)



1. Ecosystem level capabilities' connections to underlying interactions

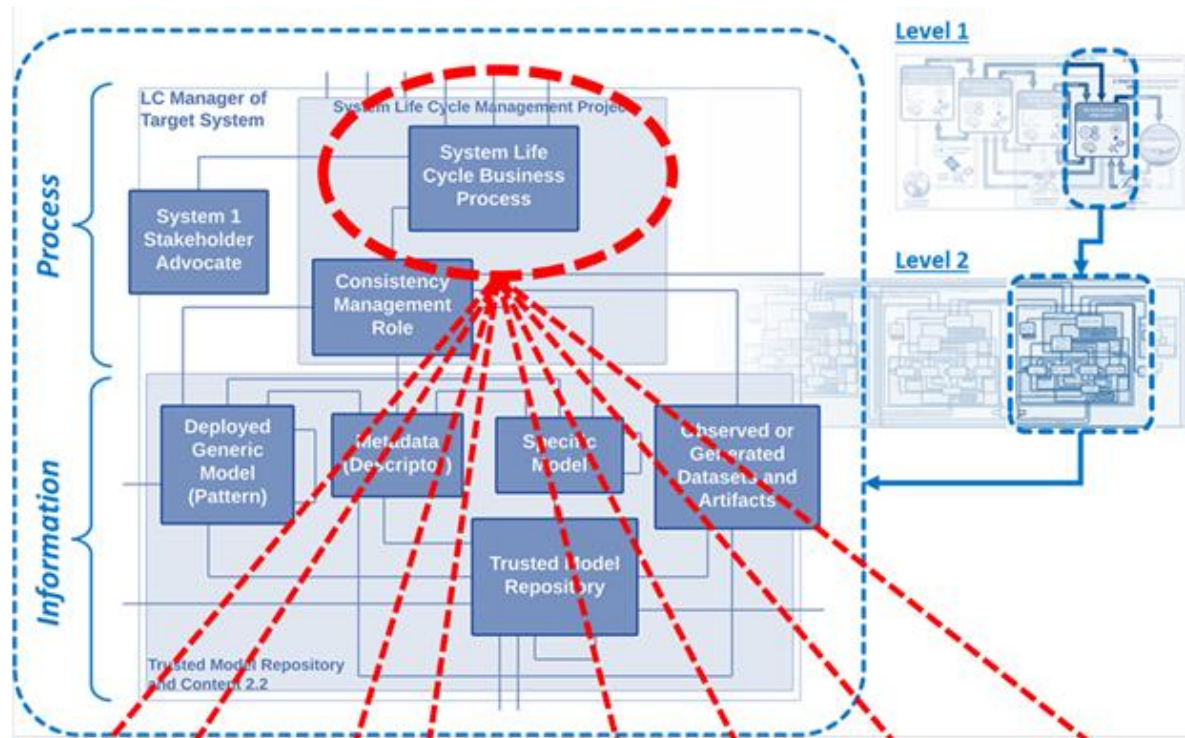
- Innovation Ecosystem “capabilities” are described for both System 2 and System 3 using selectable (configurable) “Stakeholder Features”.
- Not all of these will apply to all ecosystems.
- By populating them or depopulating them, and setting their attribute values, we can “configure” the Ecosystem Pattern to represent a particular (real or desired, current or future) Innovation Ecosystem.
- This is analogous to a “configurable product line of ecosystems”.

Selectable Stakeholder Features (Capabilities) of System 2



2. Connecting historically represented business processes to evolving digital infrastructure

- Every enterprise, supply chain, or ecosystem will have somewhat different business process structure and nomenclature.
- Generic models exist (e.g., ISO 15288, DoD 5000, etc.), but we often want to map to the internally familiar specific nomenclature of a particular business, supply chain, or ecosystem instance.
- This is provided for by the generic model . . .



Configurable to specific life cycle management models---

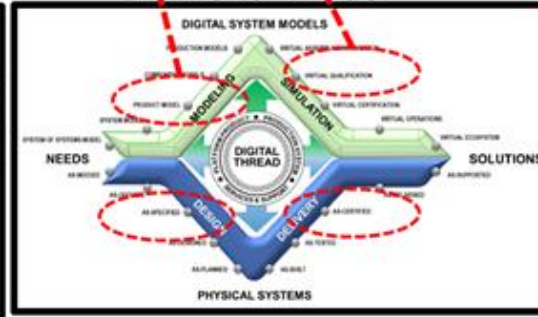
ISO15288 Life Cycle
"Vee" Model¹



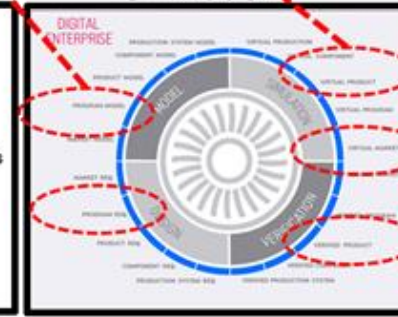
DoD 5000 Defense
Acquisition Life Cycle Model²



Boeing
"Diamond" Model³



Rolls-Royce
"O" Model⁴

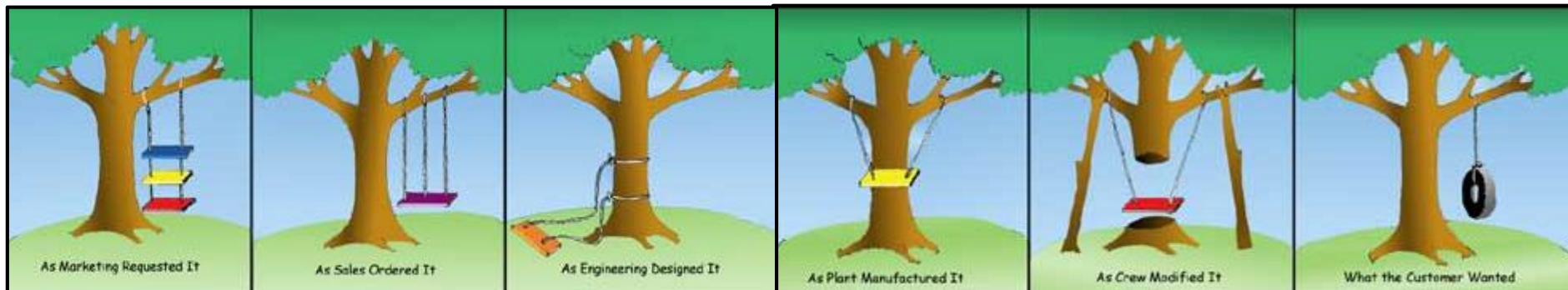
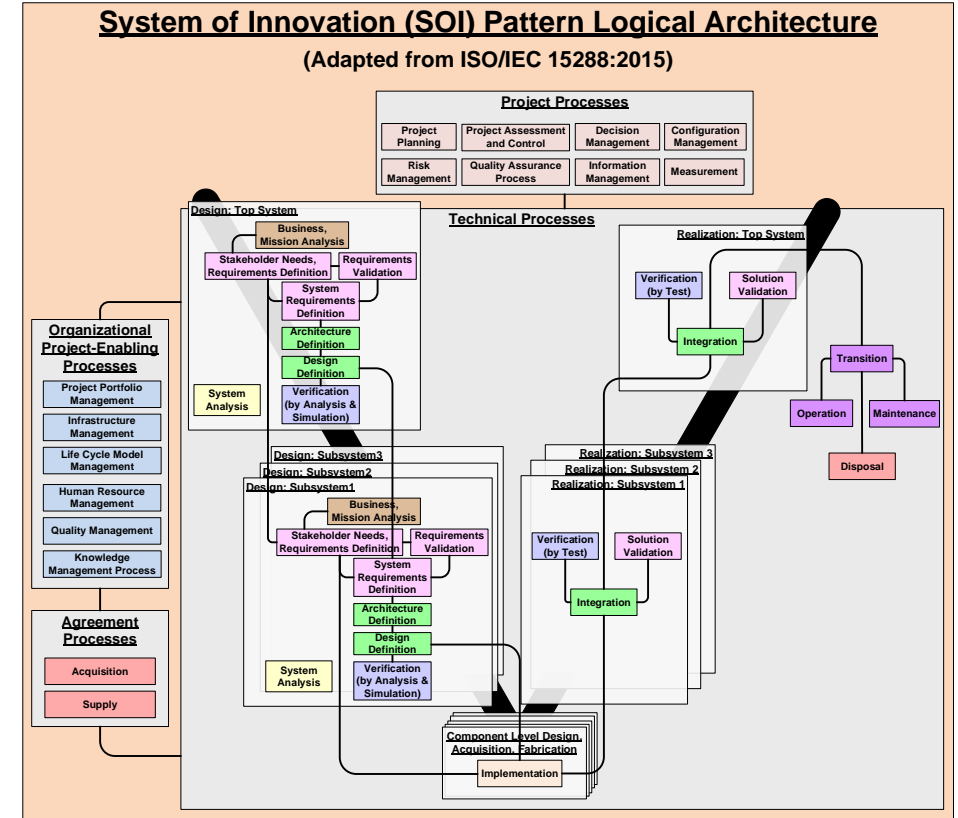


Excerpted or adapted from: (1) ISO15288 and INCOSE SE Handbook; (2) DoD5000 Wall Chart; (3) AIAA Sci Tech, 01.2020, J. Matakaeyama; (4) AIAA DEIC Digital Twin Subcommittee, 04.08.19 Donaldson, Flay, French, Matlik, Myer, Pond, Randjelovic

3. Consistency Management's connection to realizing the promise of digital engineering

Terms such as “Systems Engineering Vee Model” and “Digital Thread” remind us visually that engineering and other parts of the life cycle of systems are heavily about:

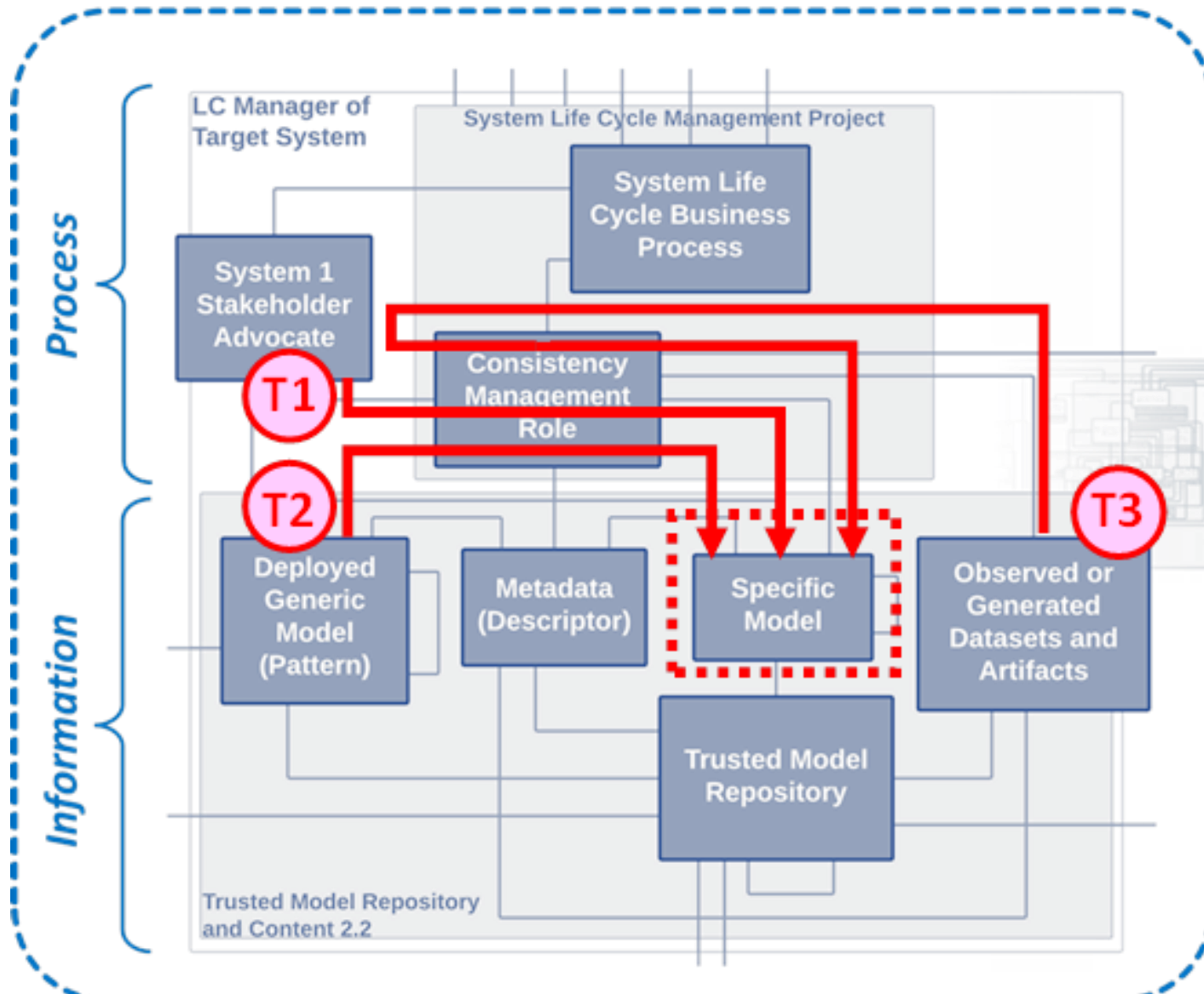
- Finding and resolving gaps, shortcomings, or inconsistencies.



Examples of Managed Consistencies

- Consistency of system requirements with stakeholder needs
- Consistency of system designs with system requirements
- Consistency of virtual simulations with empirical measurements (model VVUQ)
- Consistency of system component production with system design
- Consistency of system performance with system requirements
- Consistency of system operation with system requirements and design
- Consistency of system sustainment with system requirements and design
- Consistencies of many aspects with applicable technical standards, regulation, and law
- Consistencies of System 2 ecosystem partners, as to capabilities, incentives, conflicts
- Consistencies of many aspects with learned experiences, formal patterns of requirements and design, physical science, product line rules, architectural frameworks, shared ontologies, domain specific languages, and model semantics
- Managed consistencies of the Digital Thread and Digital Twin
- Many other types of consistencies . . .

These 3 sources will disagree frequently—reconciling those differences is a major part of life cycle management.

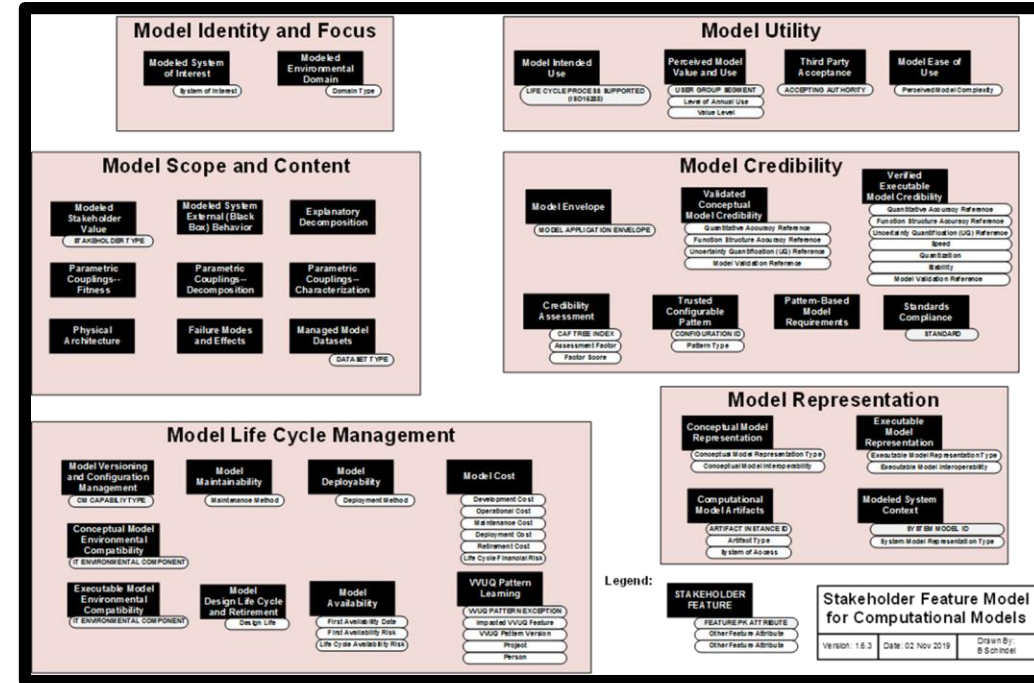


The 3 sources of credibility

- T1** What stakeholders now say / want
- T2** What past learning says
- T3** What the observed real world and its simulation now say

4. Managing the proliferation of virtual model diversity and instances

- Importance of model metadata, as a “model wrapper”
- Configurable universal model metadata pattern: Model Characterization Pattern (MCP)

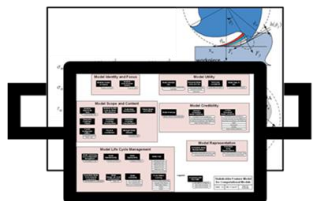
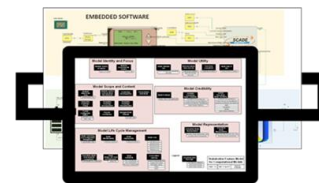
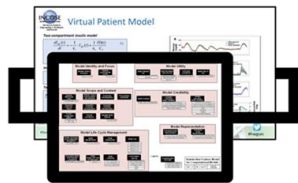
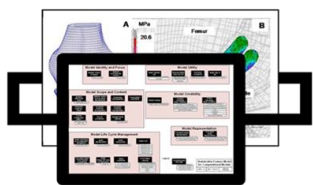


FEA Model

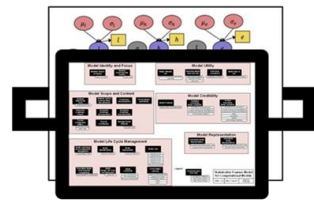
ODE Model

CFD Model

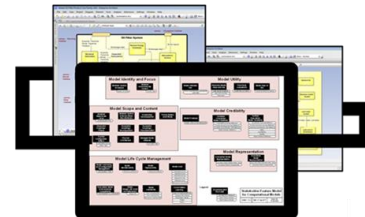
Multi-Domain System Model



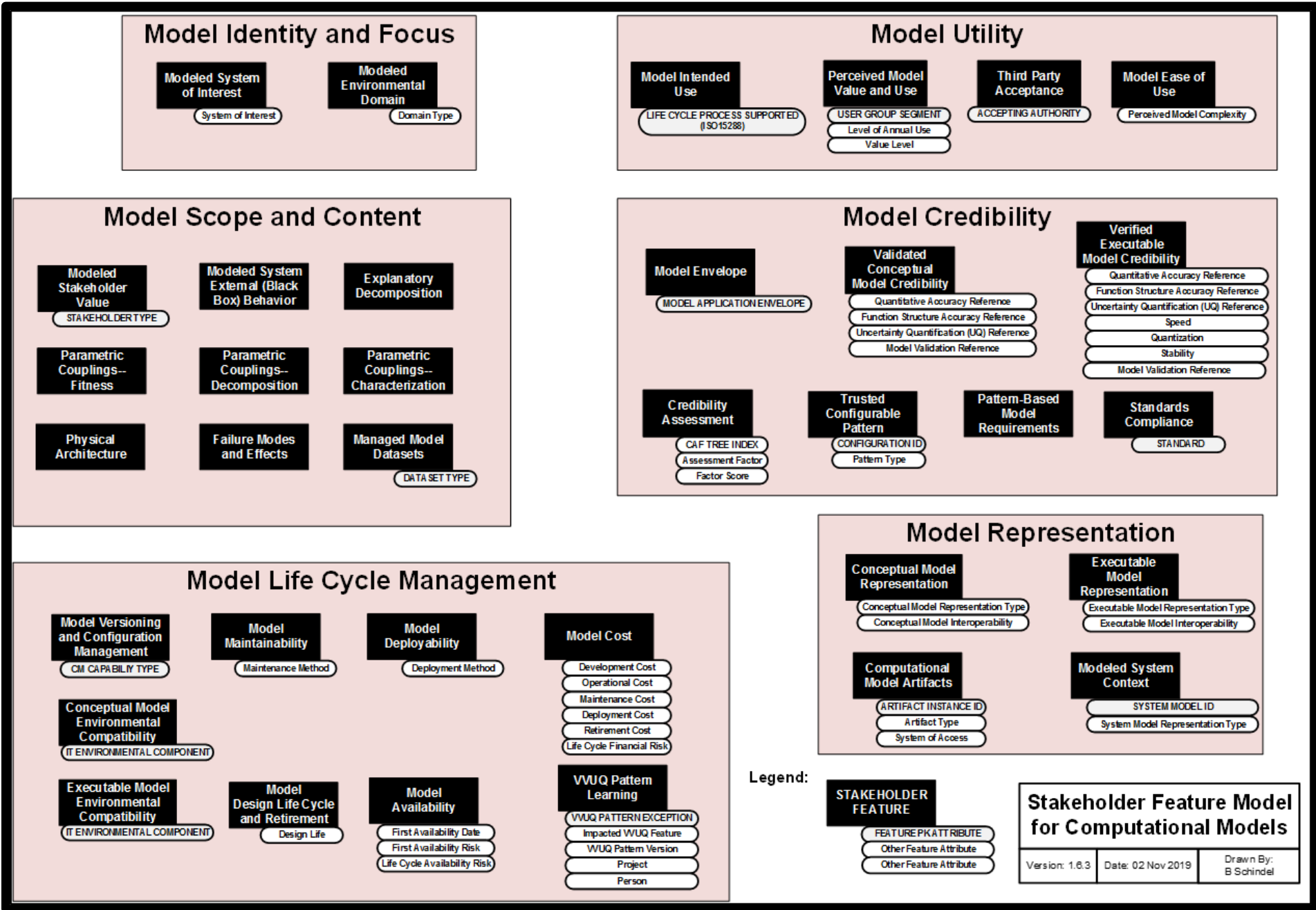
Physics-Based PDE Model



Data-Driven Bayesian Network Model

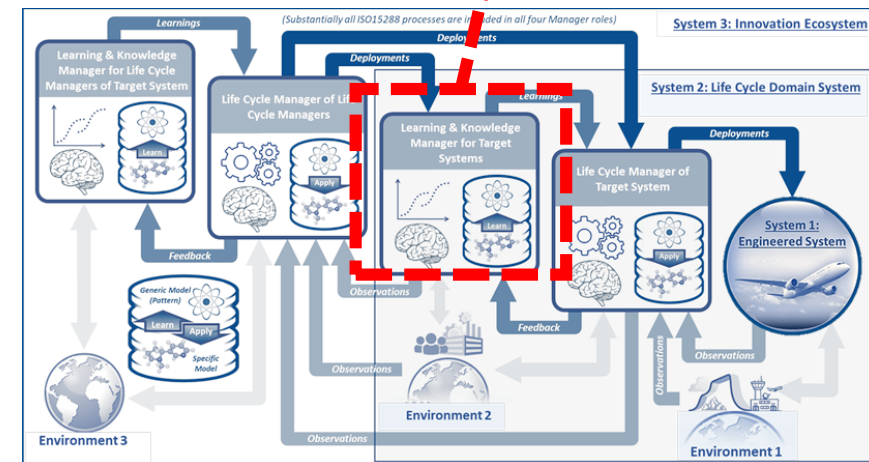
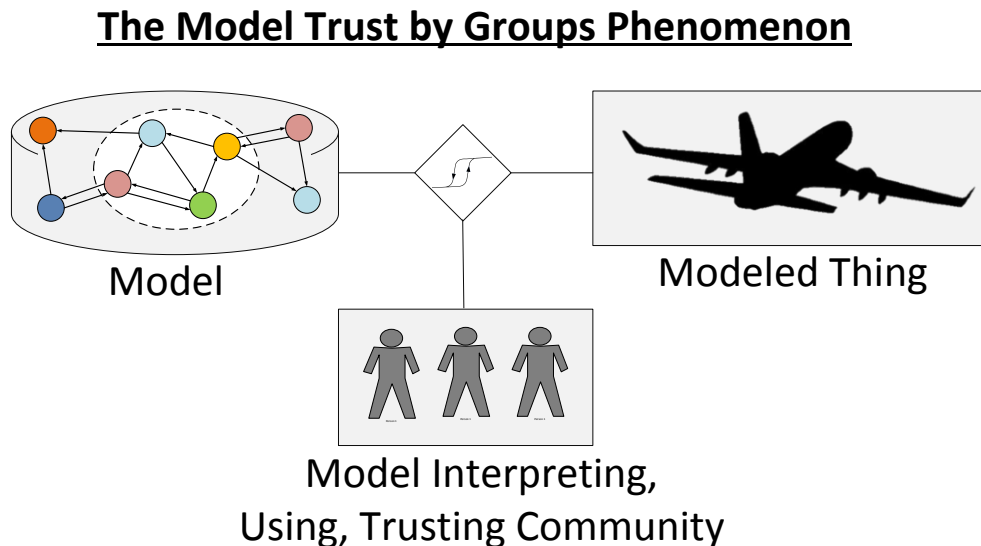


MBSE Model

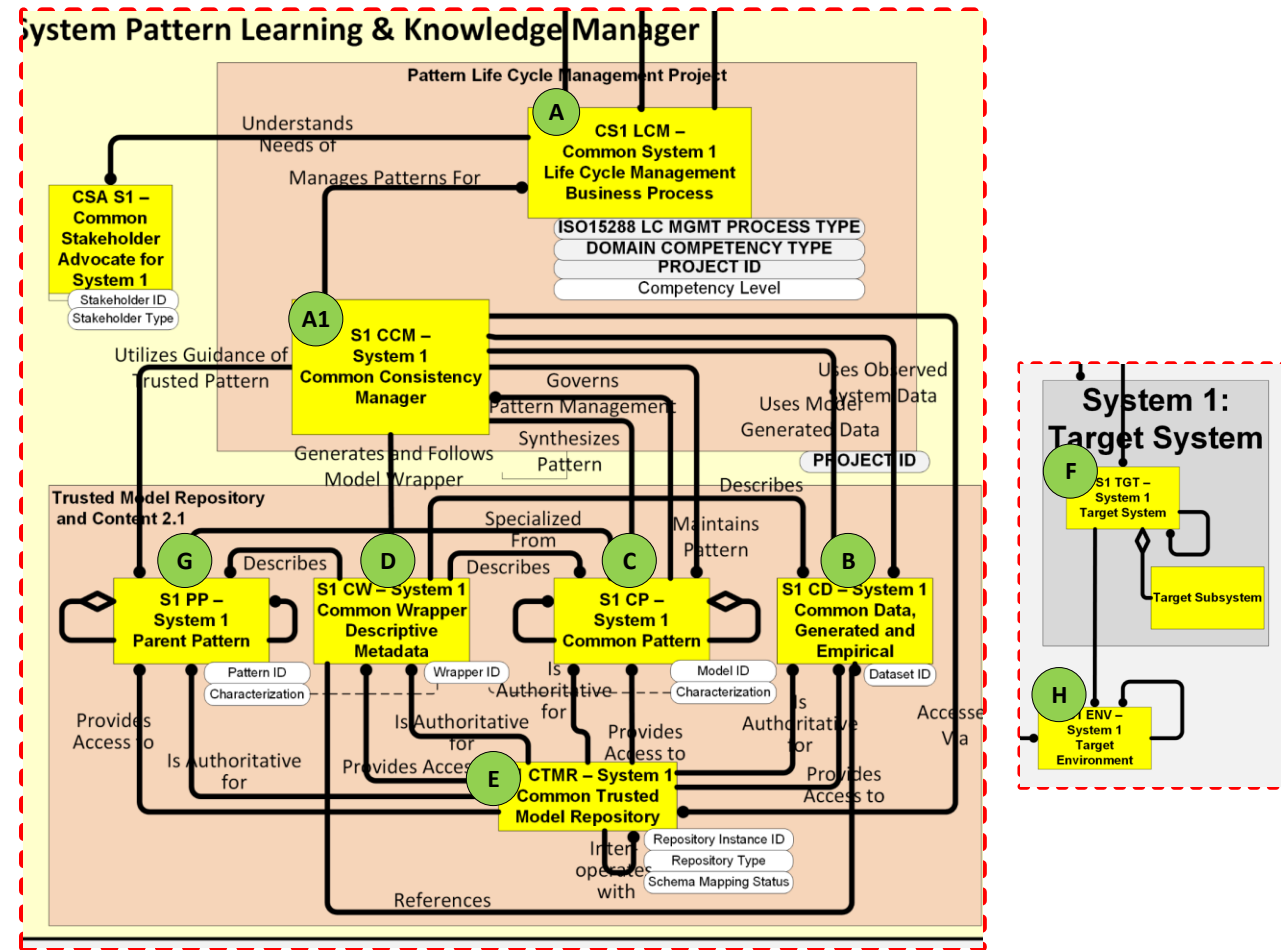
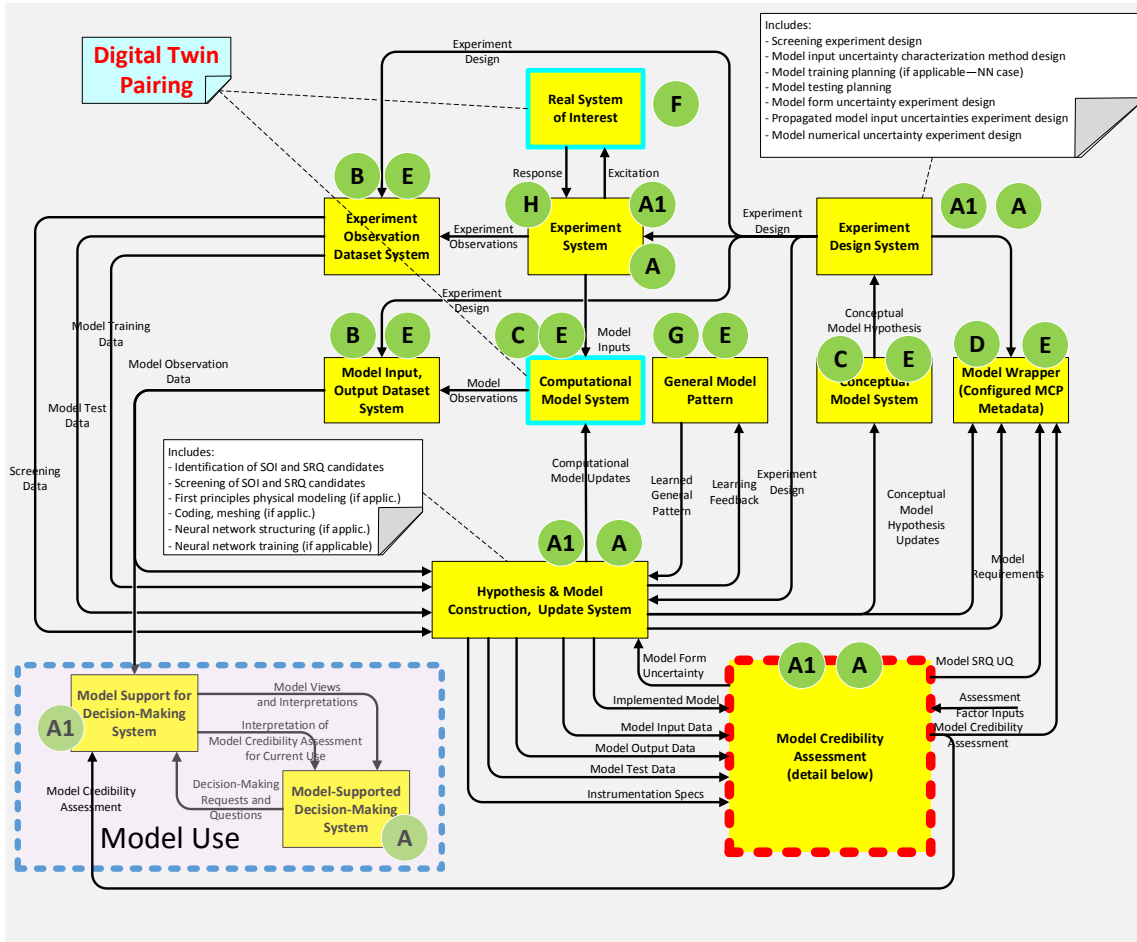


5. Effectiveness of distributed, multi-level group learning

- Group learning: Not accumulation of information, but improvement of group performance based on experience of some (possibly other) group.
- Model trust and group learning converge.

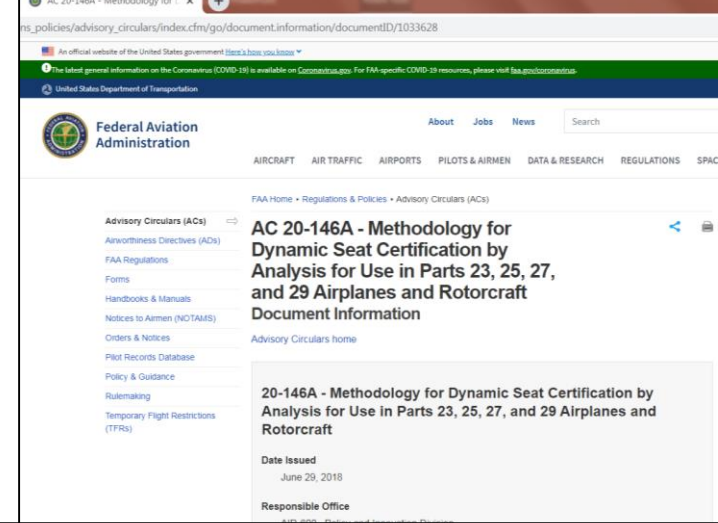


System 2, Level 3: Learning Segment

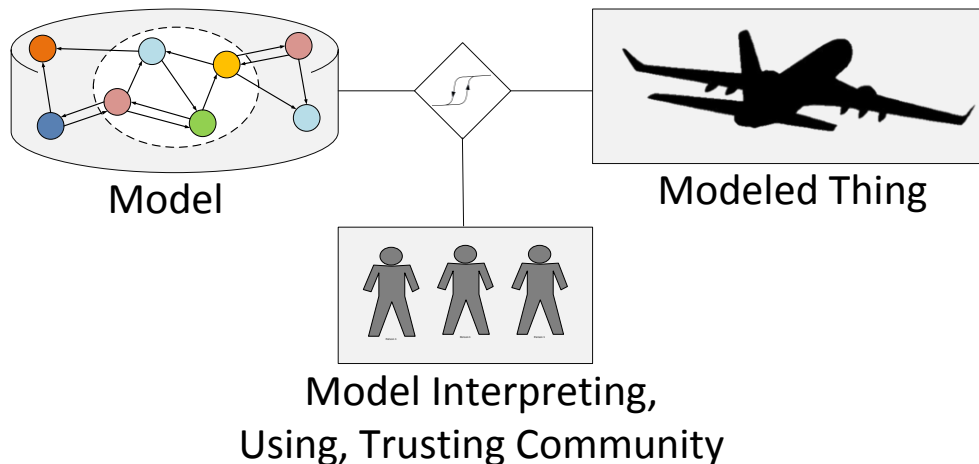


6. Group trust in the credibility of models

- Group learning and management of group trust converge in ASELCM.
- Ongoing evolution, in regulated and other markets, of interest in model trust.
- Credibility Assessment Frameworks (CAFs) as a record of rationale for rewarding trust (or not).



The Model Trust by Groups Phenomenon



Reporting of Computational Modeling Studies in Medical Device Submissions

Guidance for Industry and Food and Drug Administration Staff

Document issued on: September 21, 2016.

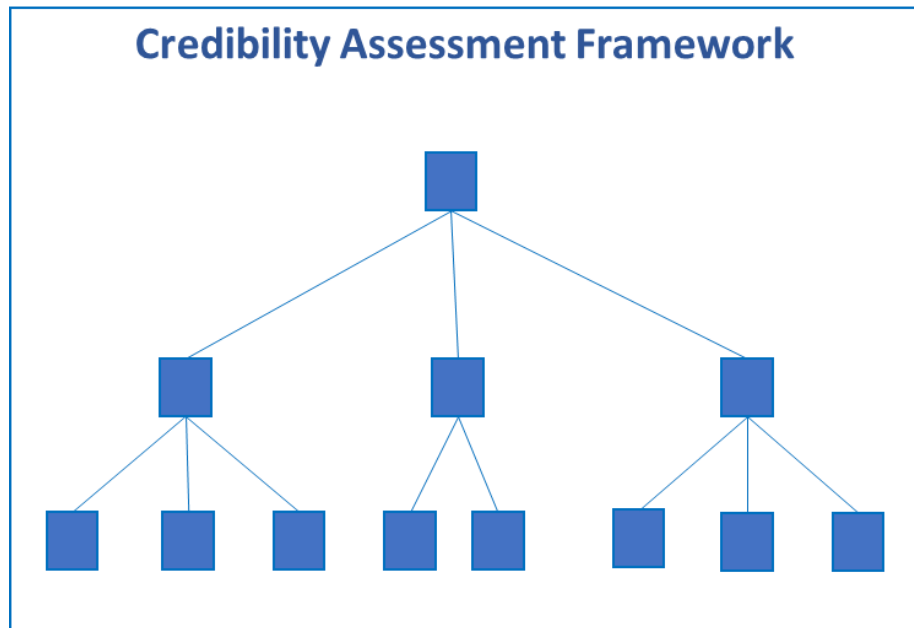
The draft of this document was issued on January 17, 2014.

For questions about this document, contact Tina M. Morrison, Ph.D., Division of Applied Mechanics, Office of Science and Engineering Laboratories, (301) 796-6310, tina.morrison@fda.hhs.gov.

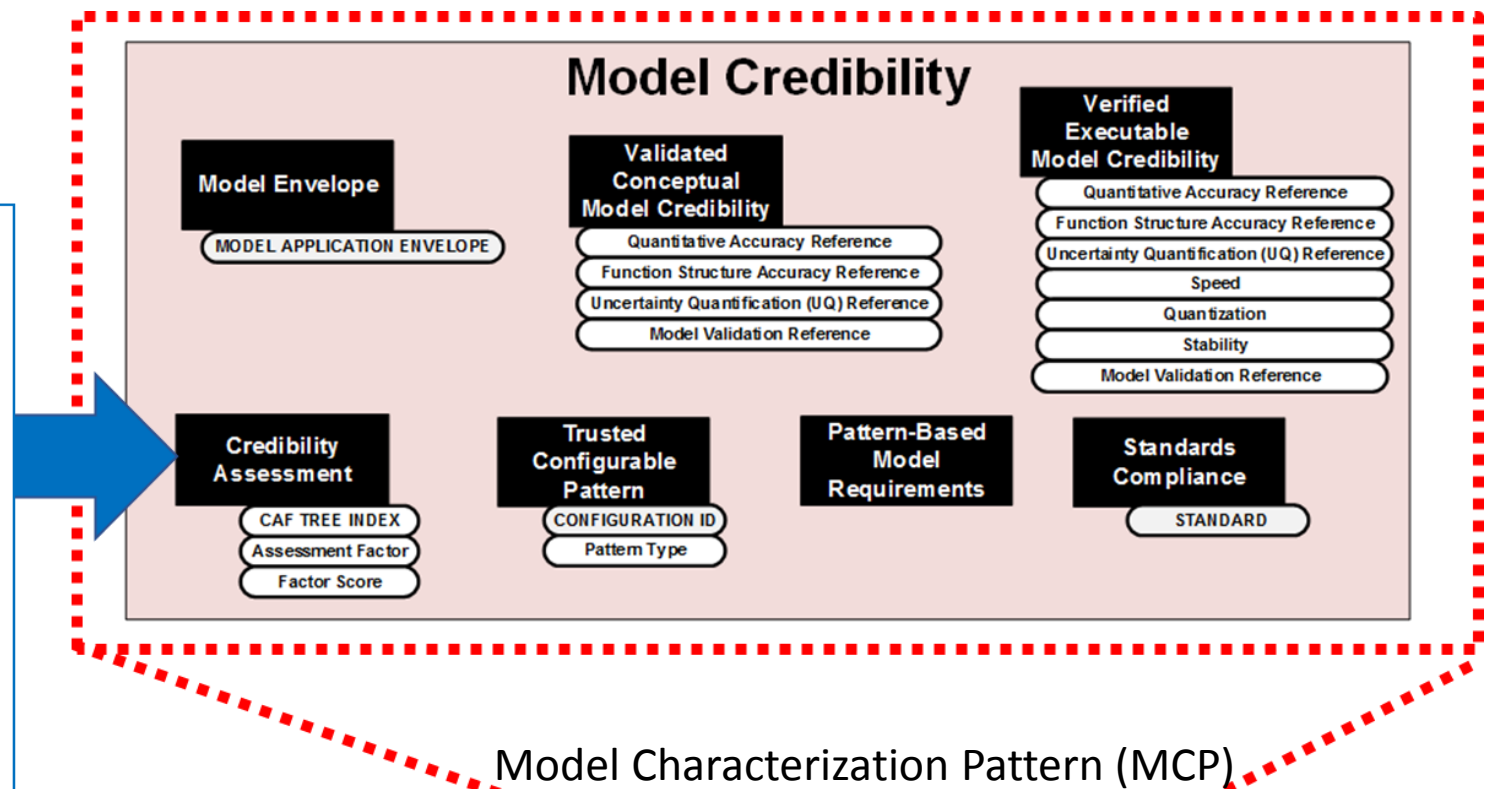


U.S. Department of Health and Human Services
Food and Drug Administration
Center for Devices and Radiological Health
Office of Device Evaluation
Office of Science and Engineering Laboratories

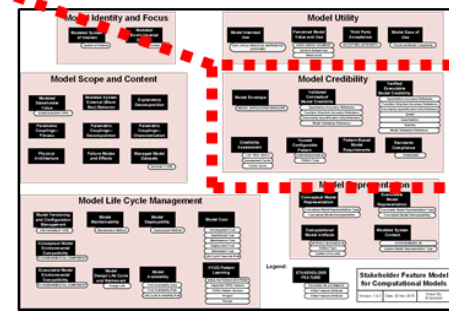
Credibility Assessment Framework: A tree-based framework rolling up weighted credibility assessment factors (both objective and subjective) with recorded scores, used to create a more transparent representation of what a model's credibility assessment included and what was its outcome—becomes part of the model metadata, as in Model Characterization Pattern (MCP).



<https://cstools.asme.org/csconnect/FileUpload.cfm?View=yes&ID=54674>

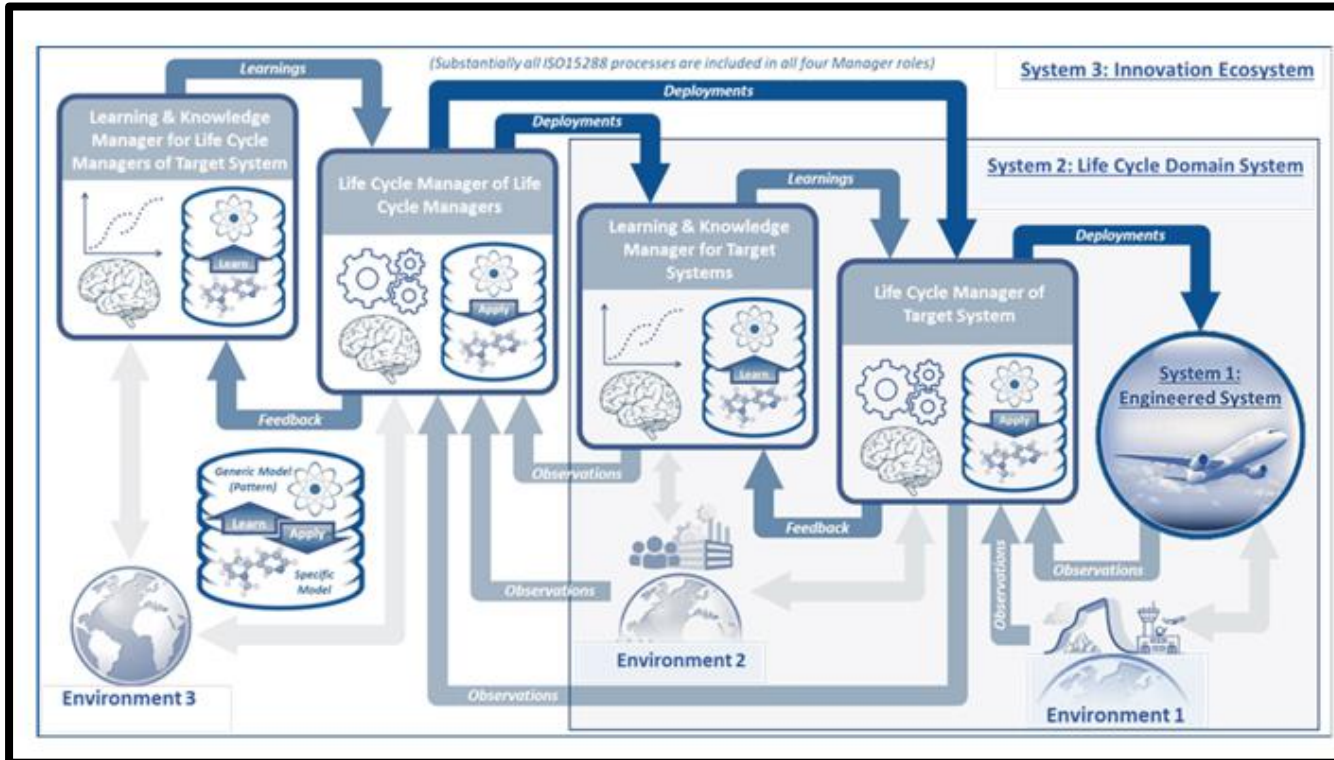


Model Characterization Pattern (MCP)

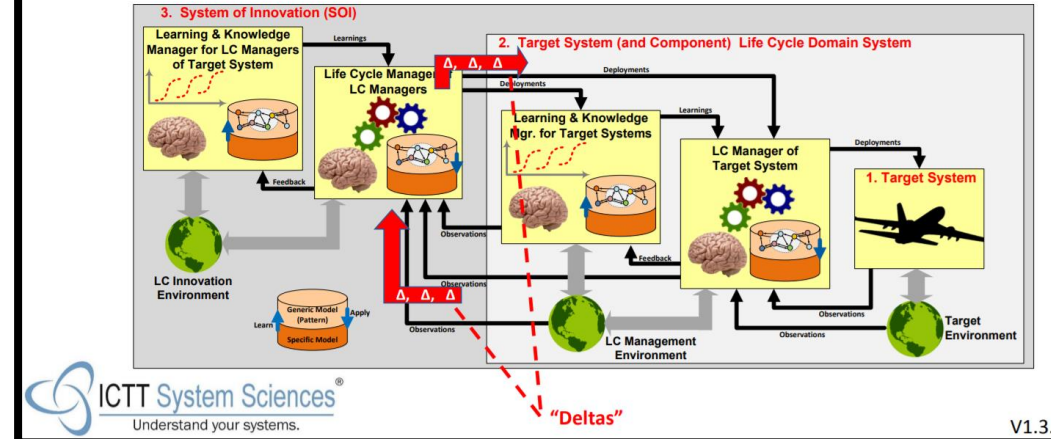


7. Effective evolution of the ecosystem itself

The role of System 3

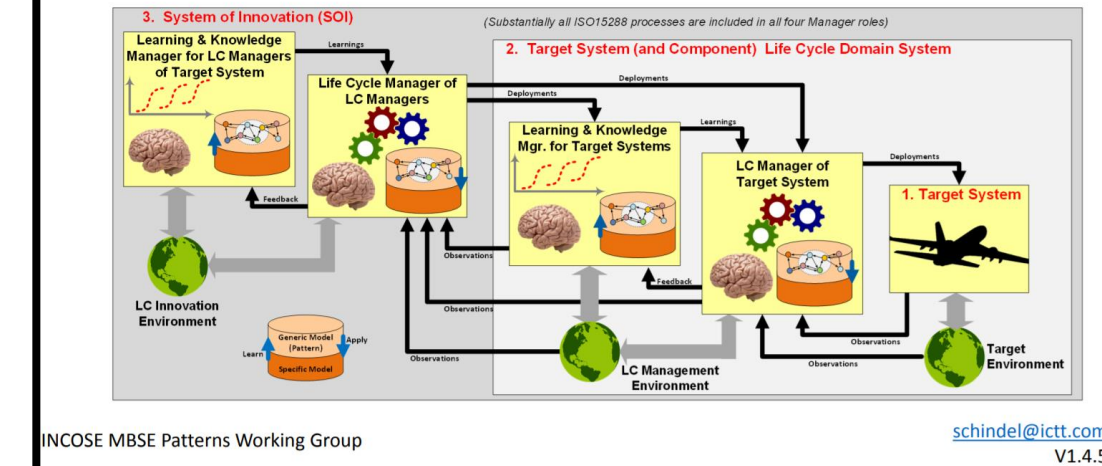


Attachment I: Example Use of ASELCM Pattern for Analyzing Current State, Describing Future State, and Constructing Incremental Release Roadmap to Future



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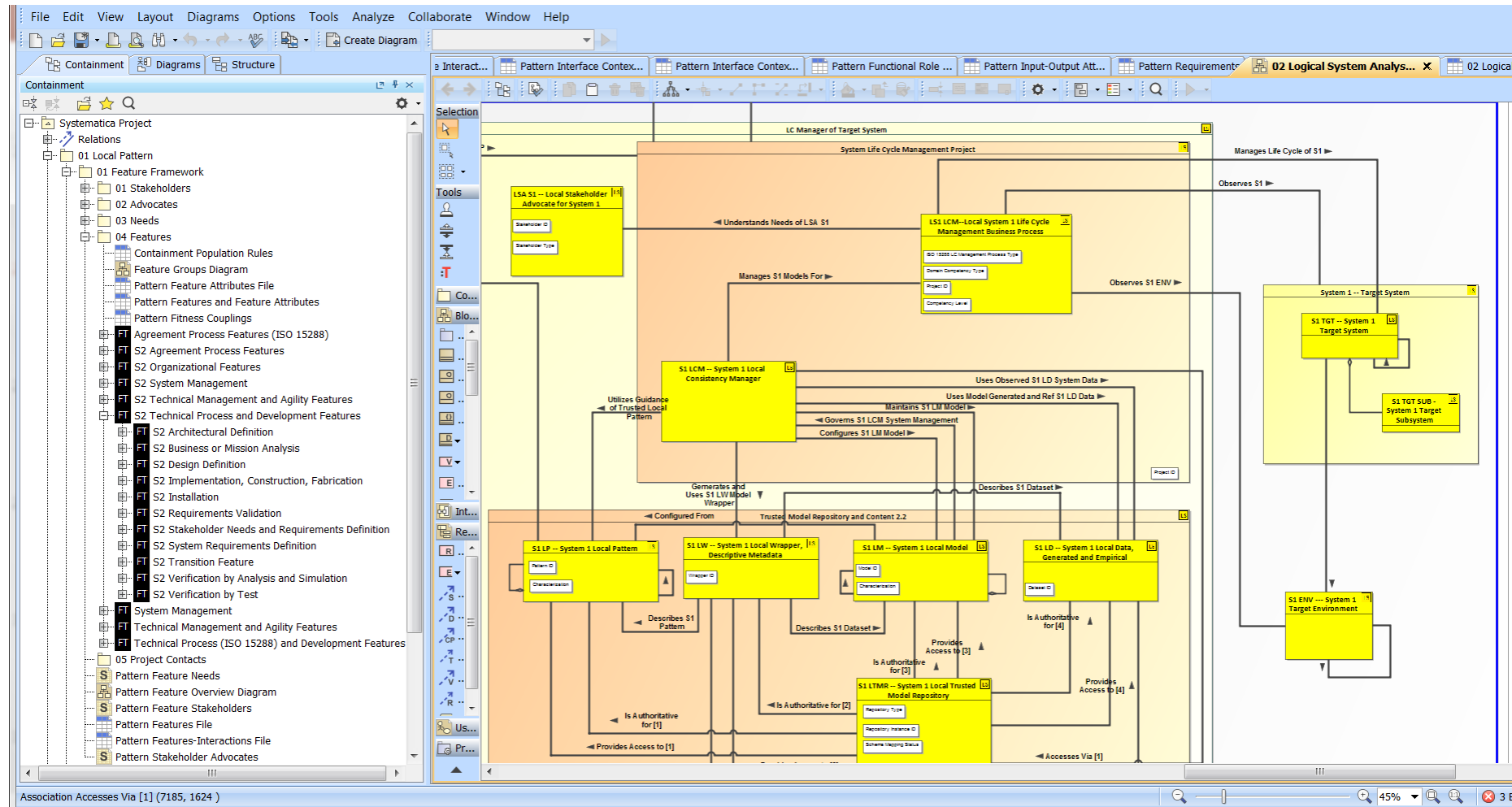
ASELCM Reference Pattern: Reference Configuration Stages for Models, Model Patterns, and the Real Systems They Represent



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The ASELCM Ecosystem Pattern in OMG SysML

- Migrated to SysML in early 2021, currently in test, for release through the Patterns Working Group web site.
- Creative Commons CC BY SA license.



Interested? How to get involved

- Contact Bill Schindel schindel@icct.com

Discussion and questions

-
-
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Thank you!



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Speaker background

- Bill Schindel is president of ICTT System Sciences. His engineering career began in mil/aero systems with IBM Federal Systems, included faculty service at Rose-Hulman Institute of Technology, and founding of three systems enterprises.
- He chairs the INCOSE MBSE Patterns Working Group, and served on the lead team of the INCOSE Agile Systems Engineering Life Cycle Discovery Project. He is an active member of the ASME VV50 working group on model credibility in advance manufacturing, and the AIAA digital thread and digital twin case study teams.
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