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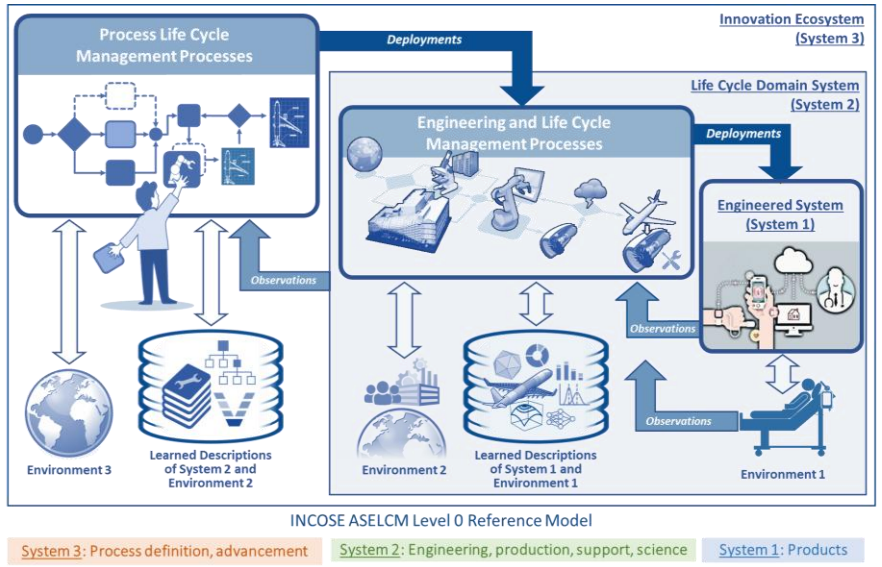
- Remove this page before use in the ATP Session.
- This is a configurable class template, not for use without configuring first.
- Globally replace items identified in arrows as shown: <<XYZ>>
  - includes company-specific names, logos, and homework pattern file names and locations

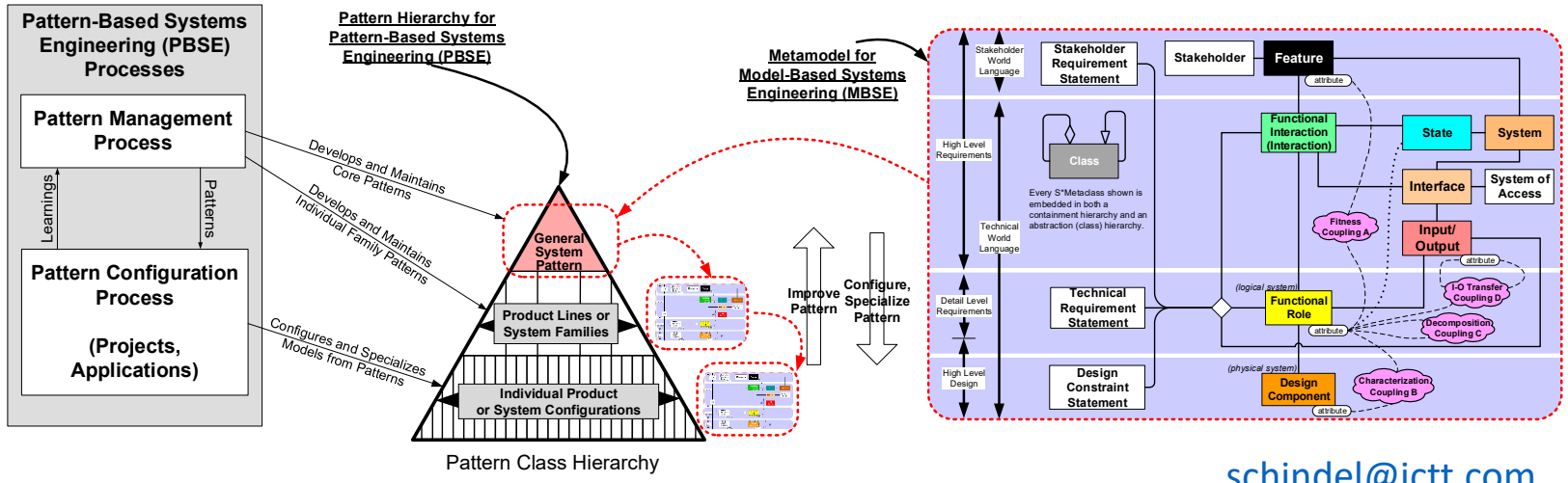
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Phase II Session 1

Introduction to S*Models, S*Metamodel, S*Patterns, Mappings to Languages & Tools, S*Configuration Wizard, ASELCM S*Pattern

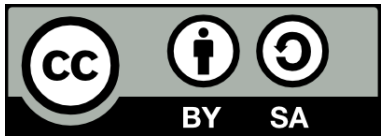




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Contents

- Recap of previous session:
  - Sessions 5-6 take-aways, discussion, questions
- Phase II Session 1 Class Content
- References

Recap of Sessions 5-6:
Take-aways impacting actual practices

What consistent practices seem possible *across this team*, *across different systems*, *customers*, and *projects*?

1. Most, if not all, customers would benefit from more effective ability to deliver future system models out of the learning products of past projects:
   - by others in the same enterprise, and . . .
   - at the top system level--not just subsystems/components
2. Product Line Engineering (PLE) as practiced today is mainly about configurability, not so much about model completeness for life cycle and group learning:
   - Both are needed;
   - Patterns can be points of accumulation for both.
3. Configurability can be driven entirely from degrees of freedom in Stakeholder Value Feature space.

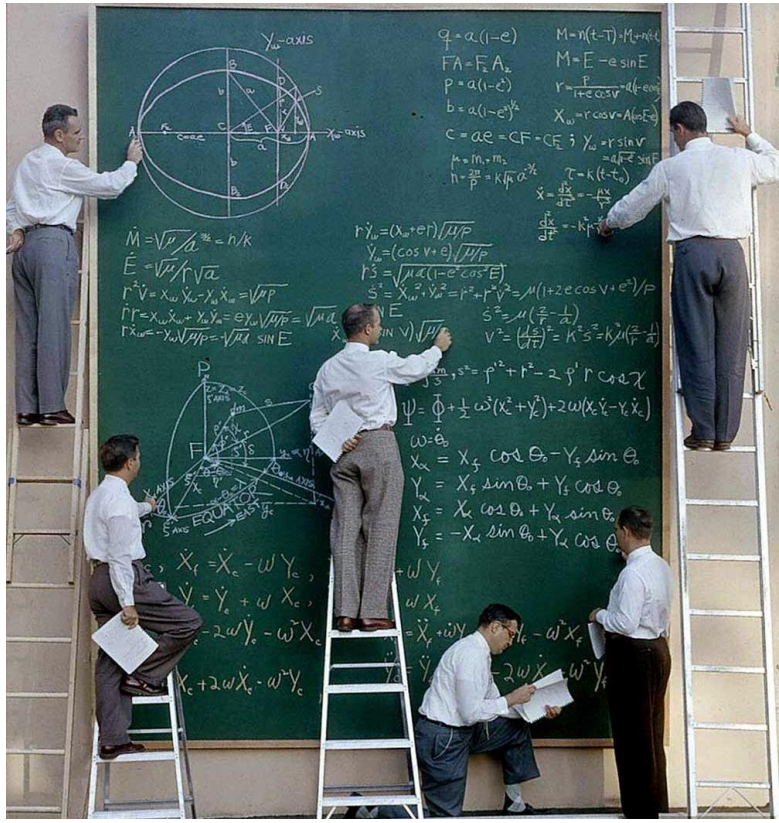


- Can a creative, talented team *align* its work?
- What should be *standard* about this, in your customer work?
- What should be *configurable* about this, in your customer work?



Session 6 Homework Discussion

- Use just CSM and the International Power Converter model file, provided for this class/homework session. Do the CSM export tables report generation as described earlier in this table and the S* Patterns CSM Support Guide.
- Use just CSM and the set of configured model files provided for this class/homework session. Run the Model HLR DLR import map group and inspect the resulting CSM model in the CSM browser. Run additional map groups as well.
- For additional HW, perform the all of the steps for a complete end-to-end configuration.



Phase II Class Sessions: Accountability, Macrostructure of Model-Based Ecosystem (4 Sessions, 3 hours each)

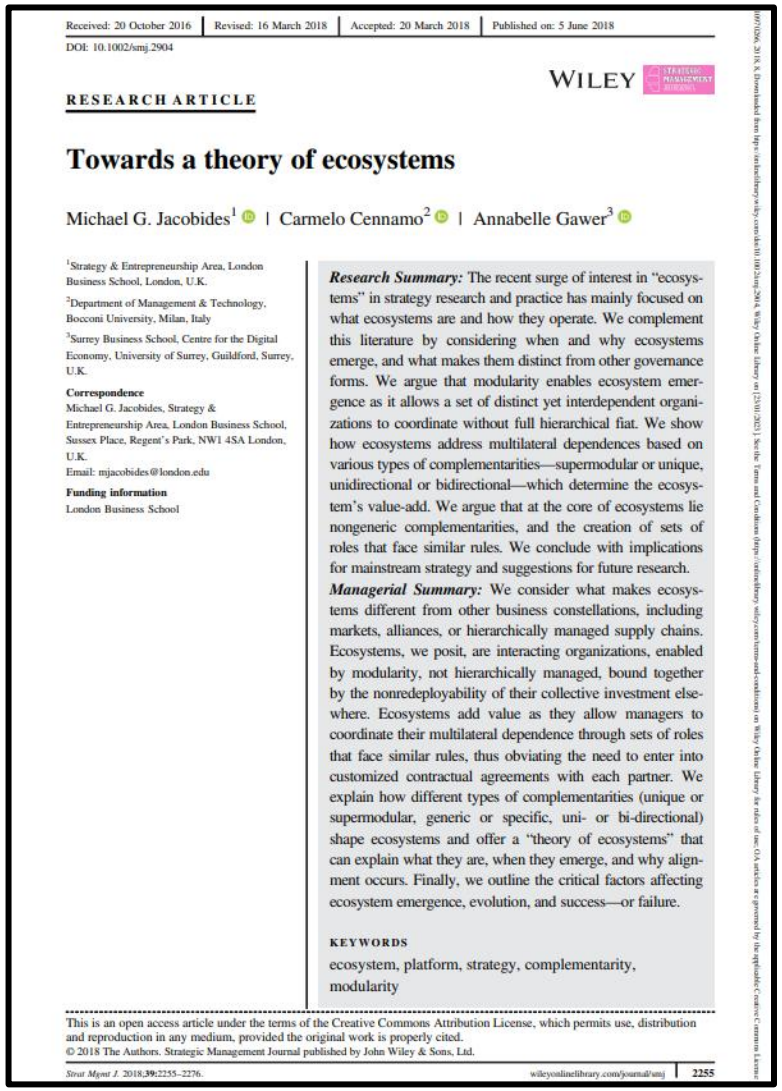
- ASELCM Ecosystem S*Pattern: Nature, Intended Uses, Levels 0-4 Logical Arch
  - Session 1 

- ASELCM Features, Interactions, Roles, Resources, Use in Consistency Mgmt.
  - Sessions 2-3
- ASELCM Configuration Stages and Accountability
  - Session 4
- Homework Presentation and Feedback
  - Distributed over above sessions

ASELCM Ecosystem S*Pattern: Nature, Intended Uses, Levels 0-4 Logical Arch

- Wide interest in describing the innovation ecosystem
- Motivating background/purpose of ASELCM Pattern
- Problem statement: Experiences of participating team
- Uses by INCOSE, AIAA, AIA, ASME, AFRL, private enterprise
- Introduction to the ASELCM Pattern Logical Architecture:
  - Levels 0, 1, 2, 3, 4
- What uses shall we make of this framework?
- Homework assignment 1
- Discussion, Q&A.

Wide interest in describing the Innovation Ecosystem



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WILEY

RESEARCH ARTICLE

Towards a theory of ecosystems

Michael G. Jacobides[1] | Carmelo Cennamo[2] | Annabelle Gawer[3]

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[2]Department of Management & Technology, Bocconi University, Milan, Italy
[3]Surrey Business School, Centre for the Digital Economy, University of Surrey, Guildford, Surrey, U.K.

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London Business School

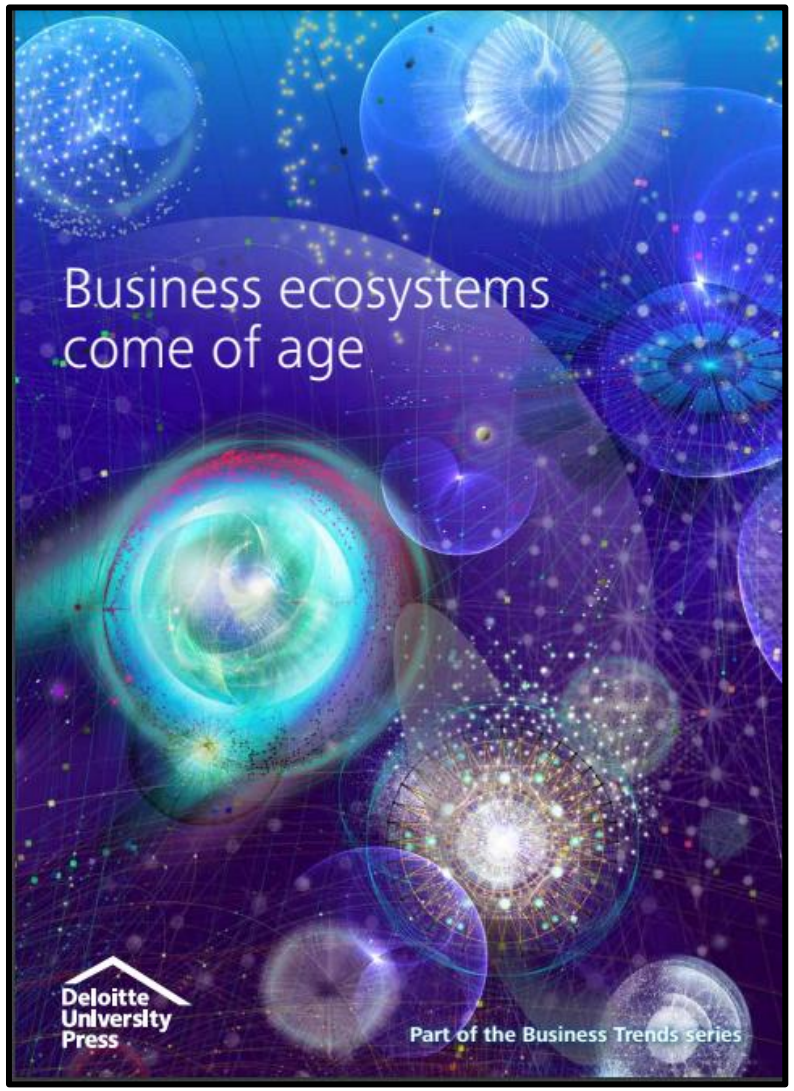
Research Summary: The recent surge of interest in "ecosystems" in strategy research and practice has mainly focused on what ecosystems are and how they operate. We complement this literature by considering when and why ecosystems emerge, and what makes them distinct from other governance forms. We argue that modularity enables ecosystem emergence as it allows a set of distinct yet interdependent organizations to coordinate without full hierarchical fiat. We show how ecosystems address multilateral dependences based on various types of complementarities—supermodular or unique, unidirectional or bidirectional—which determine the ecosystem's value-add. We argue that at the core of ecosystems lie nongeneric complementarities, and the creation of sets of roles that face similar rules. We conclude with implications for mainstream strategy and suggestions for future research.

Managerial Summary: We consider what makes ecosystems different from other business constellations, including markets, alliances, or hierarchically managed supply chains. Ecosystems, we posit, are interacting organizations, enabled by modularity, not hierarchically managed, bound together by the nonredeployability of their collective investment elsewhere. Ecosystems add value as they allow managers to coordinate their multilateral dependence through sets of roles that face similar rules, thus obviating the need to enter into customized contractual agreements with each partner. We explain how different types of complementarities (unique or supermodular, generic or specific, uni- or bi-directional) shape ecosystems and offer a "theory of ecosystems" that can explain what they are, when they emerge, and why alignment occurs. Finally, we outline the critical factors affecting ecosystem emergence, evolution, and success—or failure.

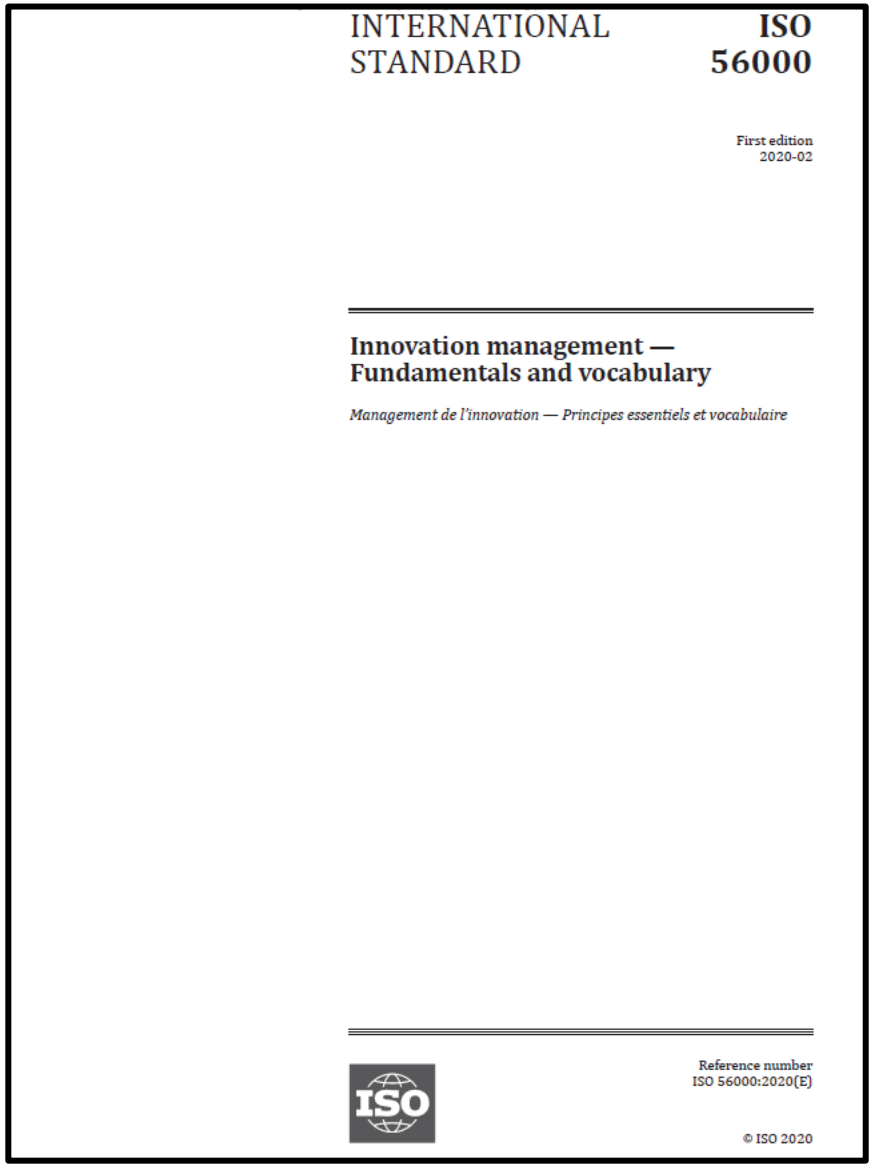
KEYWORDS
ecosystem, platform, strategy, complementarity, modularity

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https://onlinelibrary.wiley.com/doi/epdf/10.1002/smj.2904



https://www2.deloitte.com/us/en/insights/focus/business-trends/2015/business-ecosystems-come-of-age-business-trends.html



INTERNATIONAL STANDARD **ISO 56000**

First edition
2020-02

Innovation management — Fundamentals and vocabulary

Management de l'innovation — Principes essentiels et vocabulaire

ISO

Reference number
ISO 56000:2020(E)

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https://www.iso.org/standard/69315.html

. . . as well as subsystems of that Innovation Ecosystem, in context:



[Digital Twin Implementation White Paper | AIAA]

AIAA Digital Twins White Paper, Using ASELCM Pattern: Final Publication (Reference Model, Case Studies, Recommendations--69 pages)

AIAA Digital Threads White Paper, Using ASELCM Pattern: Final Publication (Reference Model)—34 pages



[Digital Thread White Paper | AIAA]

Motivating background/purpose for ASELCM Pattern

- Reference model to study innovation in general and group learning, adaptation, agility of groups more specifically.
- Descriptive, not prescriptive.

- Does not assume use of MBSE, Digital Engineering, Patterns, S*Metamodel, etc.—but leverages them if present:
  - The ASELCM Pattern is *represented* as an S*MBSE Pattern.
  - That does *not* mean that the related enterprise processes and information it represents make any use of MBSE, S*Models, or S*Patterns!
  - Do you see the difference?
  - Allows us to use this pattern to analyze any current or planned enterprise.

The Innovation Ecosystem Pattern: History

- Originally introduced in a series of 2012, 2013 INCOSE papers on the emergence of purpose in engineered systems, and pathologies in innovation environments.
- Elaborated during 2016-2018 collaboration project with the Agile SE Working Group, as an analysis framework in that study of four major mil/aero enterprises demonstrating forms of agility in projects including US Navy SPAWAR System Center Pacific (SSC-Pac), Lockheed Martin, Northrop Grumman, and Rockwell Collins.
- 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—one being US Naval Information Warfare Center (NIWC) Atlantic .
- Provided the framework for AFRL-funded 2020 pilot of Digital Thread for Manufacturing by a consortium of midwestern companies, with special emphasis on *group learning*, *workforce development*, and improved *ecosystem collaboration*, including Cummins, Inc., Purdue University, a small Manufacturer, and Indiana Defense Network.
- AIAA use as the reference model for series of studies and reports on aerospace industry digital twins and digital threads (Boeing, Rolls-Royce, others).
- Model Credibility portions being elaborated in joint ASME-AIAA-INCOSE-NAFEMS standards project on differences in VVUQ standards – Rosetta Stone Project.
- Represented by a formal underlying MBSE pattern (configurable model) in OMG SysML—but also represented in iconic graphic form.

INCOSE BEST PAPER AWARD

27th Annual INCOSE International Symposium (IS 2017)
Adelaide, Australia, July 15-20, 2017

Case Study: Agile SE Process for Centralized SoS Sustainment at Northrop Grumman

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28th annual INCOSE international symposium
Washington, DC, USA
July 7 - 12, 2018

Case Study: Agile Systems Engineering at Lockheed Martin Aeronautics Integrated Fighter Group

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The Lockheed Martin Aeronautics Integrated Fighter Group (IFG), in Fort Worth, Texas, was motivated to move to an agile system engineering (SE) development methodology by the need to meet urgent defense needs for faster-changing threat situations. IFG has and is tailoring a baseline Scaled Agile Framework (SAFe®) systems engineering process for a portfolio of mixed hardware/software aircraft weapon system extensions, involving some 1,200 people in the process from executives, through managers, to developers. Process analysis in October 2015 reviewed two years of transformation experience, updated in this article to 2017 status. Notably, the SE process is facilitated by a transformation to an Open System Architecture aircraft-system infrastructure, enabling reusable cross platform component technologies and facilitating faster response to new system needs. The process synchronizes internal tempo-based development intervals with an external mixture of agile/waterfall subcontractor development processes. This article emphasizes

11th ANNUAL IEEE INTERNATIONAL SYSTEMS CONFERENCE Montréal, Québec, Canada, April 24-27, 2017

Case Study: Agile Hardware/Firmware/Software Product Line Engineering at Rockwell Collins

Rick Dove, *Fellow/Member INCOSE, Member IEEE*, William Schindel, *Fellow/Member INCOSE*, Robert (Will) Hartney

Abstract—Rockwell Collins, in Cedar Rapids, Iowa, is using a product line approach for a family of radios they produce for military and international markets, with an agile systems engineering process tailored individually for synchronized software, firmware, and hardware development. This mixed-discipline engineering group encompasses some 350 employees working on multiple projects simultaneously for multiple customers. The product line approach provides an agile systems target-context for the agile systems engineering process – re-using common product-line hardware, firmware, and software whenever possible, evolving the product line with both internally-funded development and opportunities presented by customer project work, and accommodating special customer needs that grow the knowledge and capability base for potential later use in product-line extension. This article focuses on the mixed-discipline agile systems engineering process reviewed in the September, 2015, INCOSE Agile Systems Engineering Life Cycle Model (ASELCM) discovery workshop, and doesn't address the proprietary strategy and detail of the product line architecture. Notable elements that will be discussed include a parallel evolving product line roadmap as

26th Annual INCOSE International Symposium (IS 2016)
Edinburgh, Scotland, UK, July 18-21, 2016

Agile Systems Engineering Process Features Collective Culture, Consciousness, and Conscience at SSC Pacific Unmanned Systems Group

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Copyright © 2015 by Rick Dove and Bill Schindel. Chris Scrapper's contribution was as an employee of the U. S Government. Published and used by INCOSE with permission.

Abstract. SPAWAR System Center Pacific (SSC-Pac) in San Diego has established an Unmanned System Integration, Test, and Experimentation (UxSITE) capability to facilitate agile development of unmanned systems. This capability utilizes a unique agile systems engineering process with 6-month overlapping "waves" consisting of four phases: development by multiple-subcontractors, and operational management of systems architecture evolution, capability integration, and validation testing. The UxSITE capability supports a portfolio of projects, and has three years of respected and effective results. Most notably, the process puts a prime emphasis on enabling and facilitating team effectiveness: creating an embraced culture of engagement, a collective consciousness emerging from comprehensive real-time information support, and a team conscience on a mission for the end users.

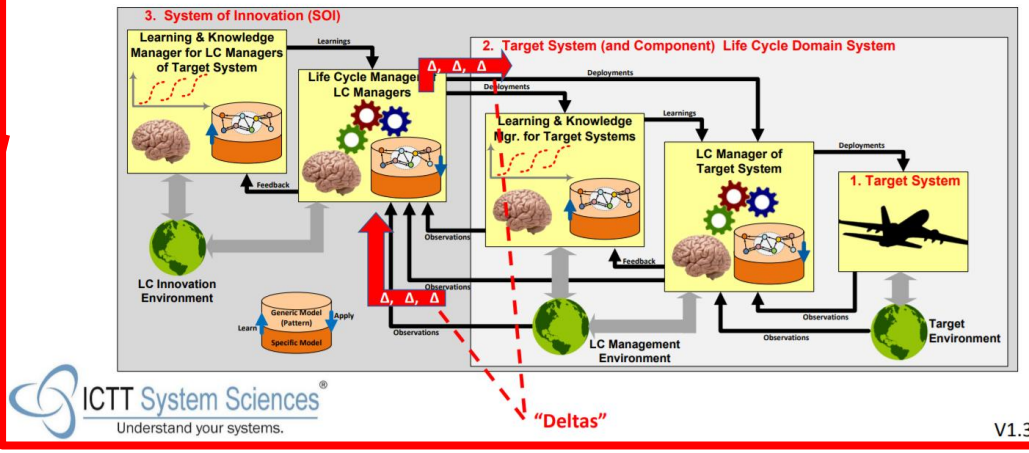
INCOSE Agile Systems Engineering Life Cycle Management Project: Case Studies Series, 2016-2018

Applications and values

- Descriptive, not prescriptive, reference model for . . .
- 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.
- Appeared in 2022 INCOSE INSIGHT Digital Engineering Special Issue, flowing into INCOSE SE Handbook 5th Edition.
- Refer to these guidance aids in References.

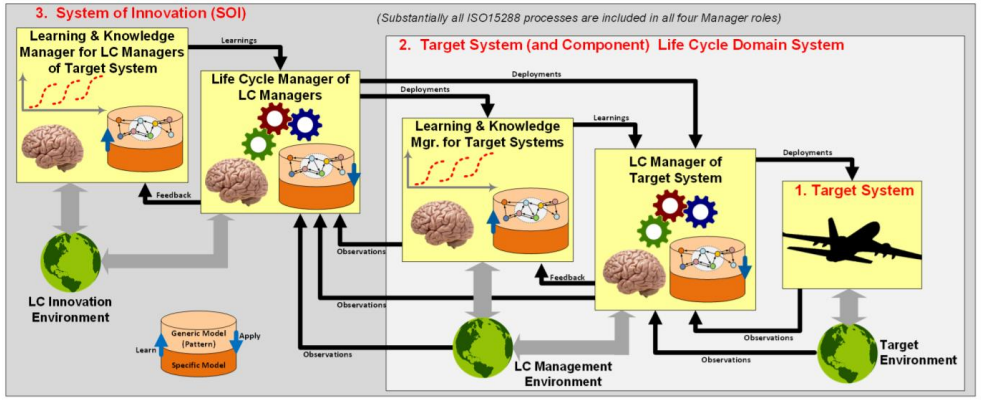
Application Guidance

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



PBSE Deployment Guidance

https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:configuration_stages_v1.5.8c.pdf

Problem statement discussion: Experiences of participating team



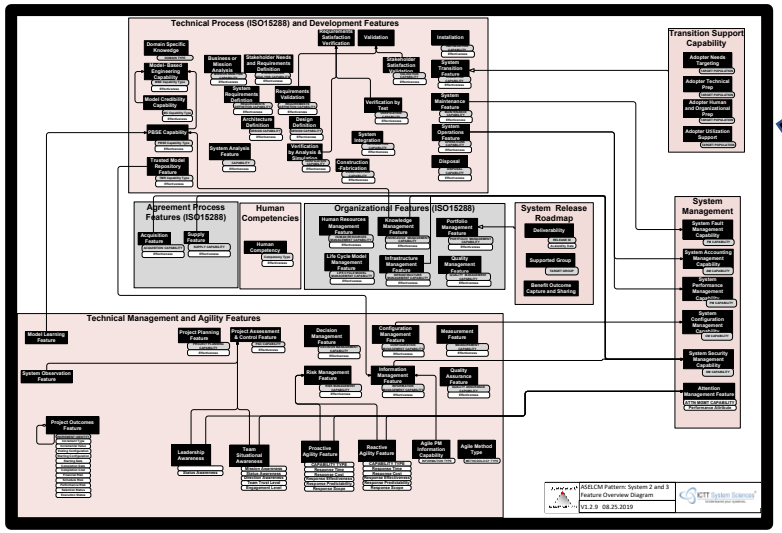
- Team experiences with the enterprise and industry ecosystems (R&D, engineering & life cycle management environments, culture, methods, organizations) effectiveness, group understanding, accountability, and related issues.
- Team's business interests in this space:
  -
  -
  -
  -



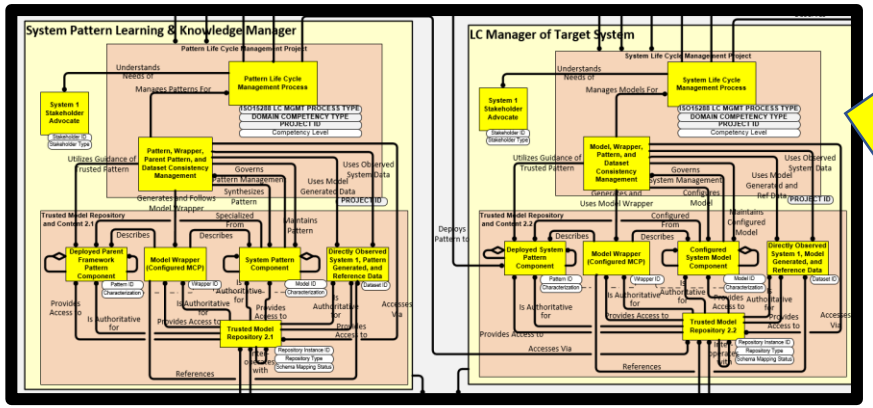
What kinds of model components make up the ASELCM Pattern?

- Today's session introduces the ASELCM Logical Architecture and the related ASELCM Functional Roles:
  - While this is most familiar, do not assume it is the whole model!
- Other ASELCM model components for additional sessions:
  - Stakeholder Features / Ecosystem Capabilities (drive all configurability)
  - Functional Interactions
  - Requirements
  - States, Input-Outputs, Artifacts, Interfaces, Design Components

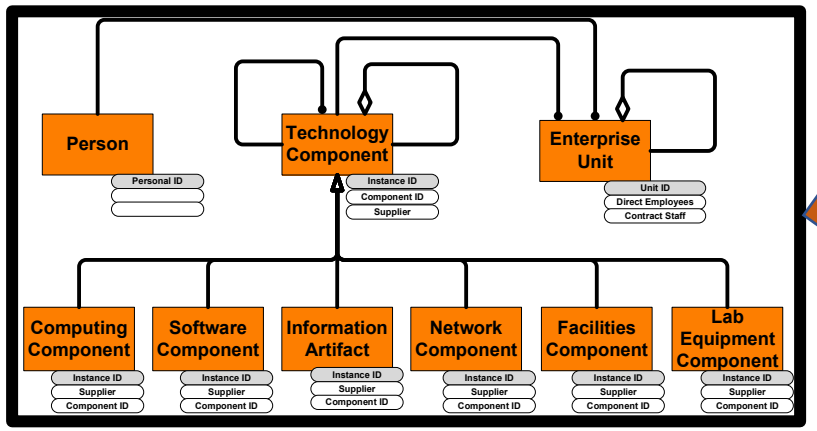
Model Component of the S*Pattern of System 2 & 3 (the Ecosystem Pattern)



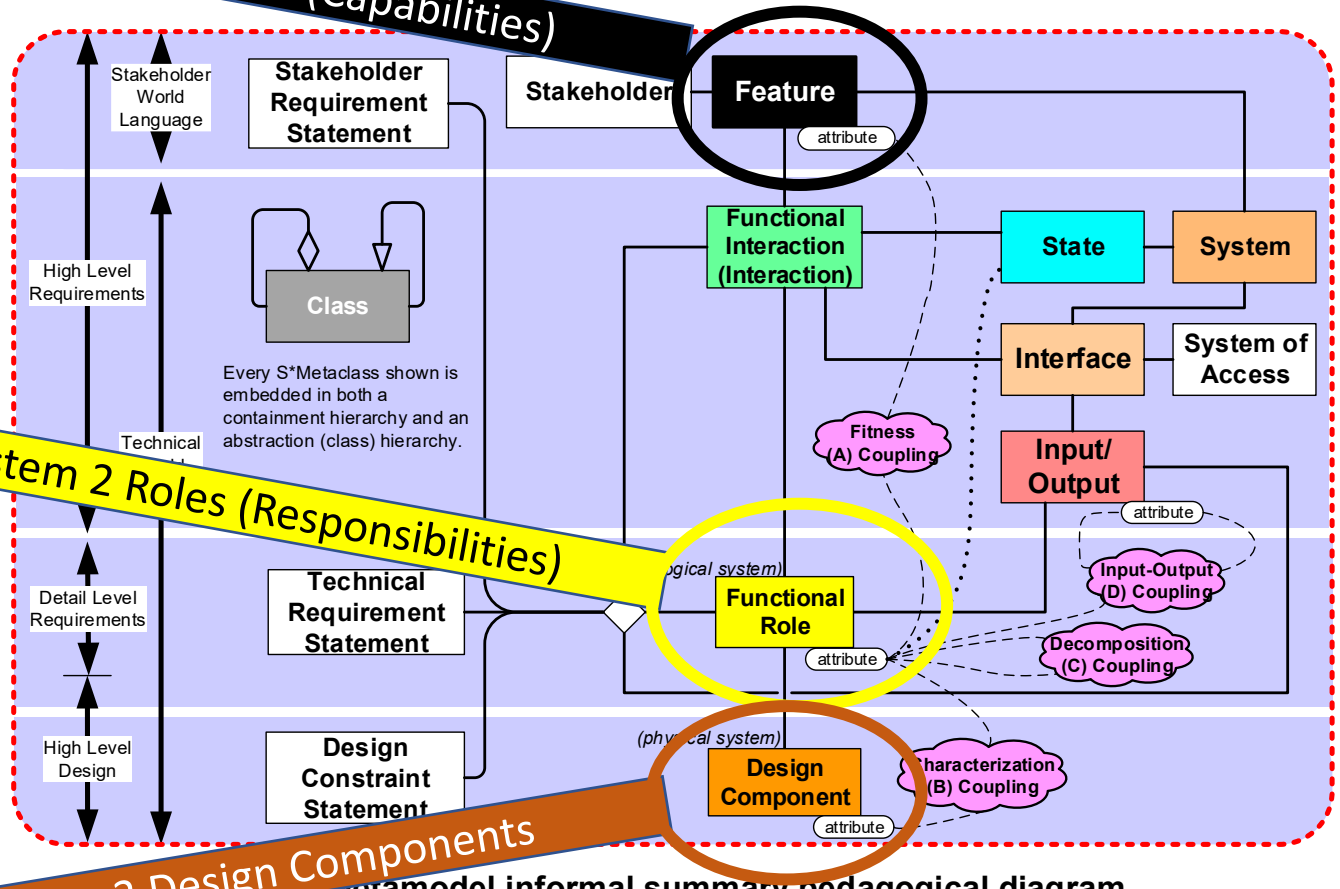
System 2 Features (Capabilities)



System 2 Roles (Responsibilities)



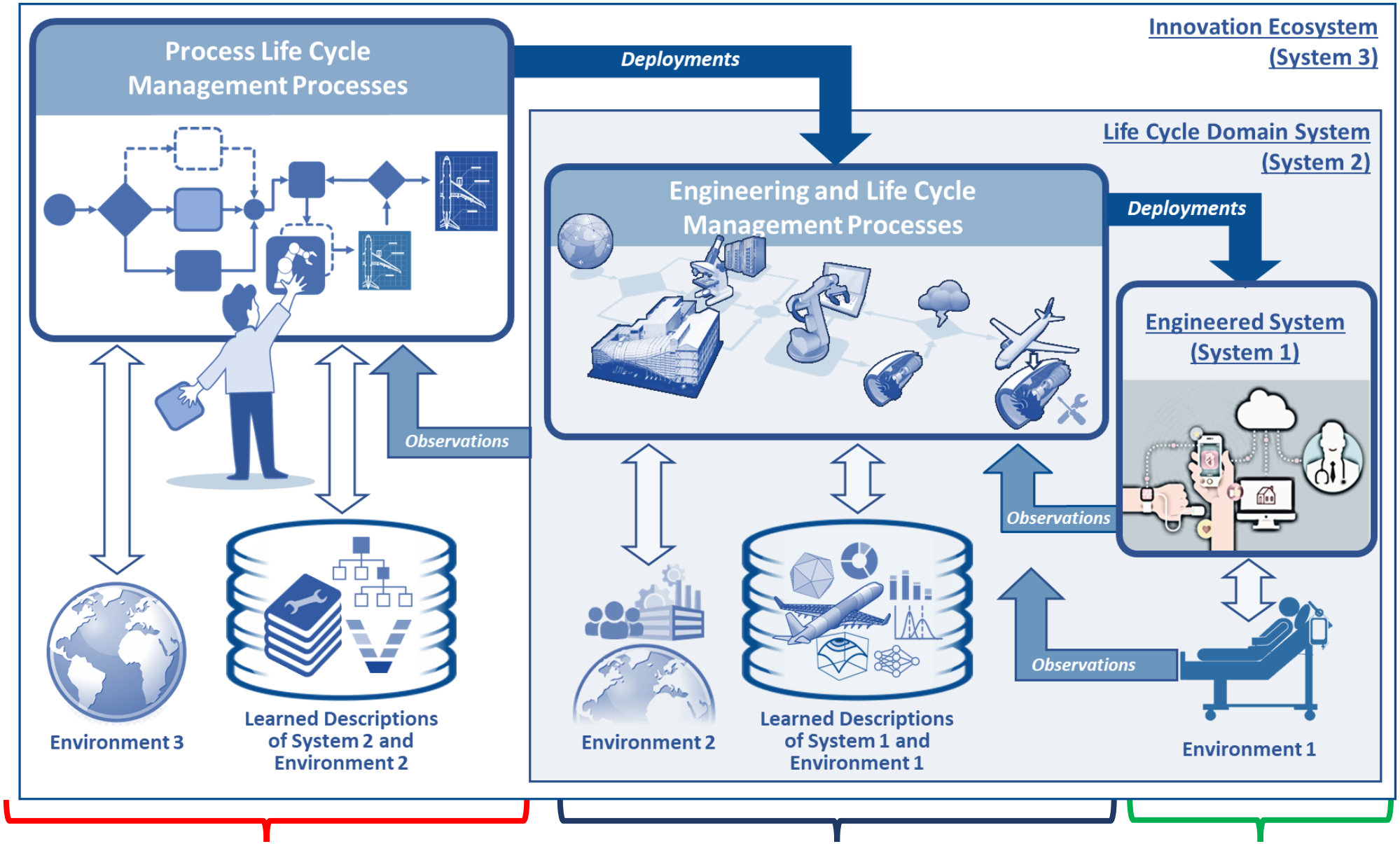
System 2 Design Components



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

Does not assume the Ecosystem players make any use of S*Models, or even MBSE!

ASELCM Pattern Logical Architecture: Level 0

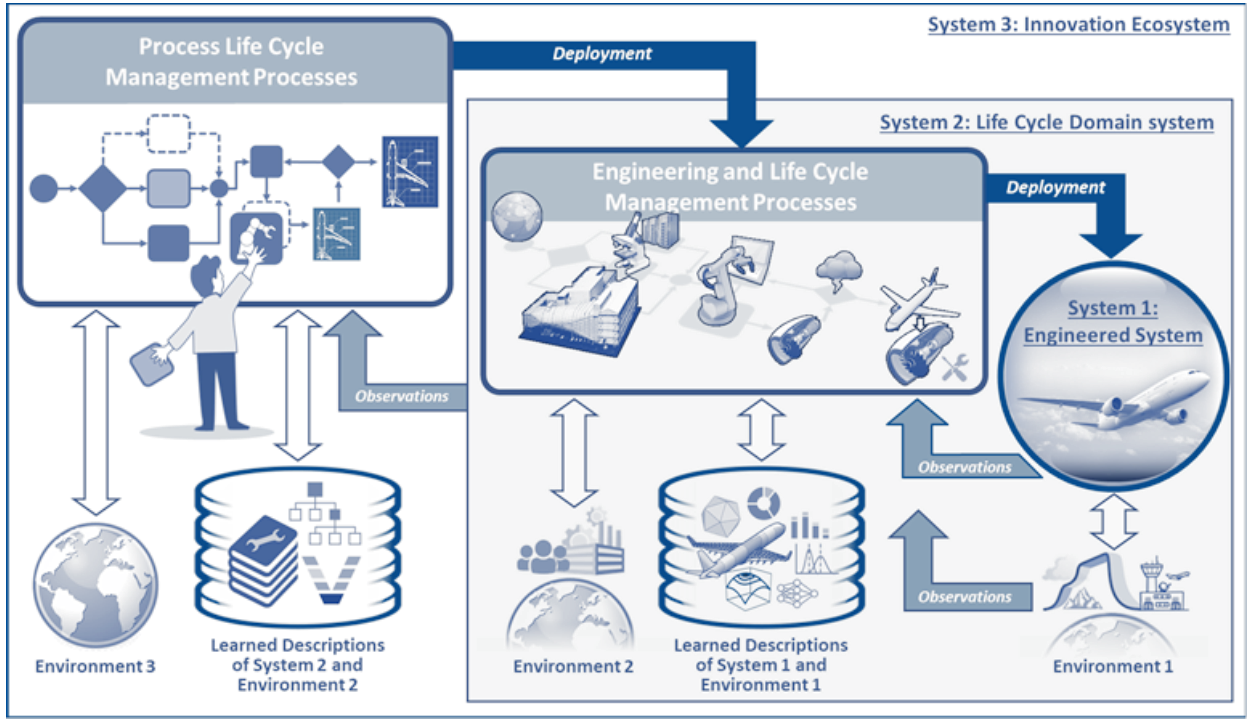


System 3: Life Cycle Manager of System 2

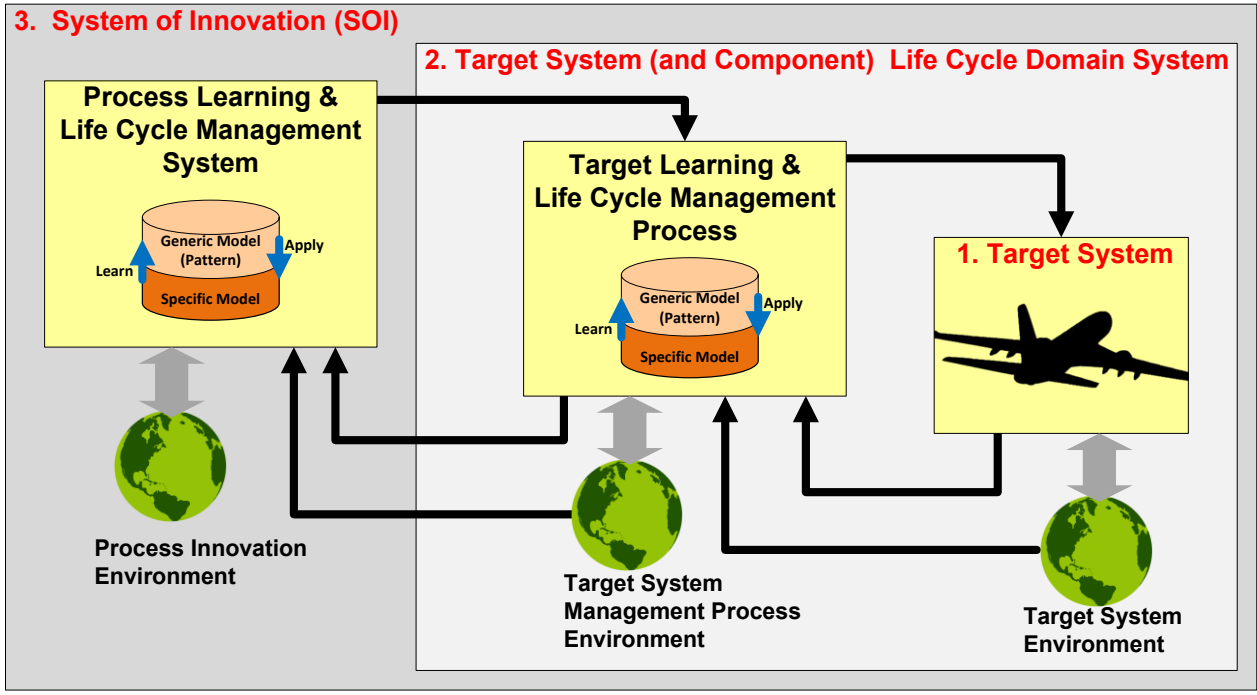
System 2: Life Cycle Manager of System 1

System 1: Engineered System

Same pattern concepts, rendered in various visual styles (including SysML)



Level 0 View, INCOSE ASELCM Pattern



Level 0 View, INCOSE ASELCM Pattern

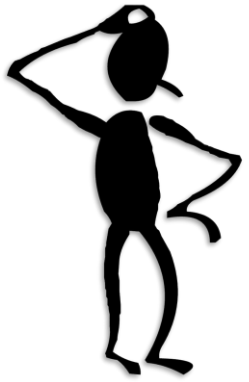
System 1: An engineered / life cycle managed system of interest. May be a product, service, , system of Systems (SoS).

System 2: The Life Cycle Domain System in which System 1 will exist, including all the entities with which System 1 will interact at some time in its life cycle. Includes in particular the socio-technical systems responsible for engineering and life cycle management of System 1. Responsible to learn about System 1 and its environment, and to effectively apply that knowledge.

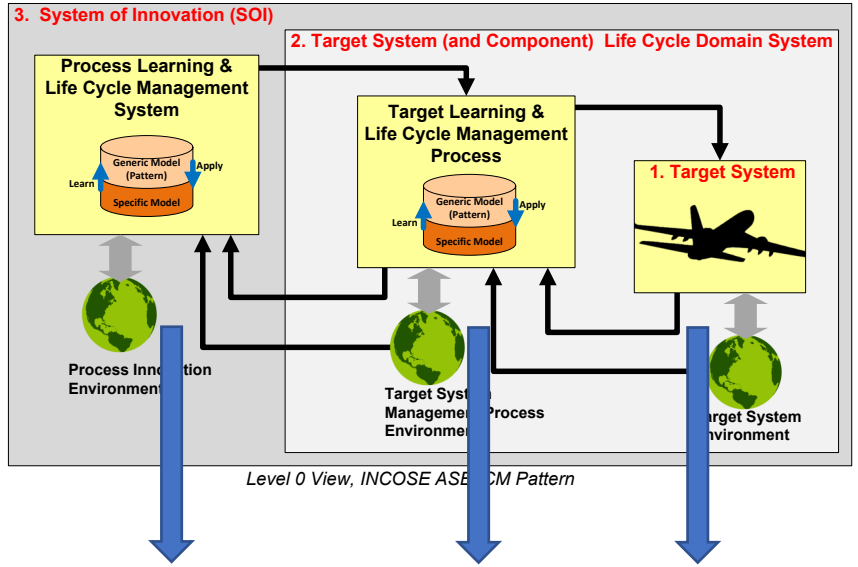
System 3: The Innovation Ecosystem in which System 2 will exist, including all the entities with which System 2 will interact at some time in its life cycle. Includes in particular the socio-technical systems responsible for engineering and life cycle management of System 2. Responsible to learn about System 2 and its environment, and to effectively apply that knowledge.

Decomposition of ASELCM Pattern Logical Architecture, Levels 0-4

- This logical architecture is further decomposed into more detailed levels (Level 0, 1, 2, 3, and 4).
- *Do not confuse Systems 1, 2, and 3, with decomposition levels 1, 2, and 3!*



This is Level 0

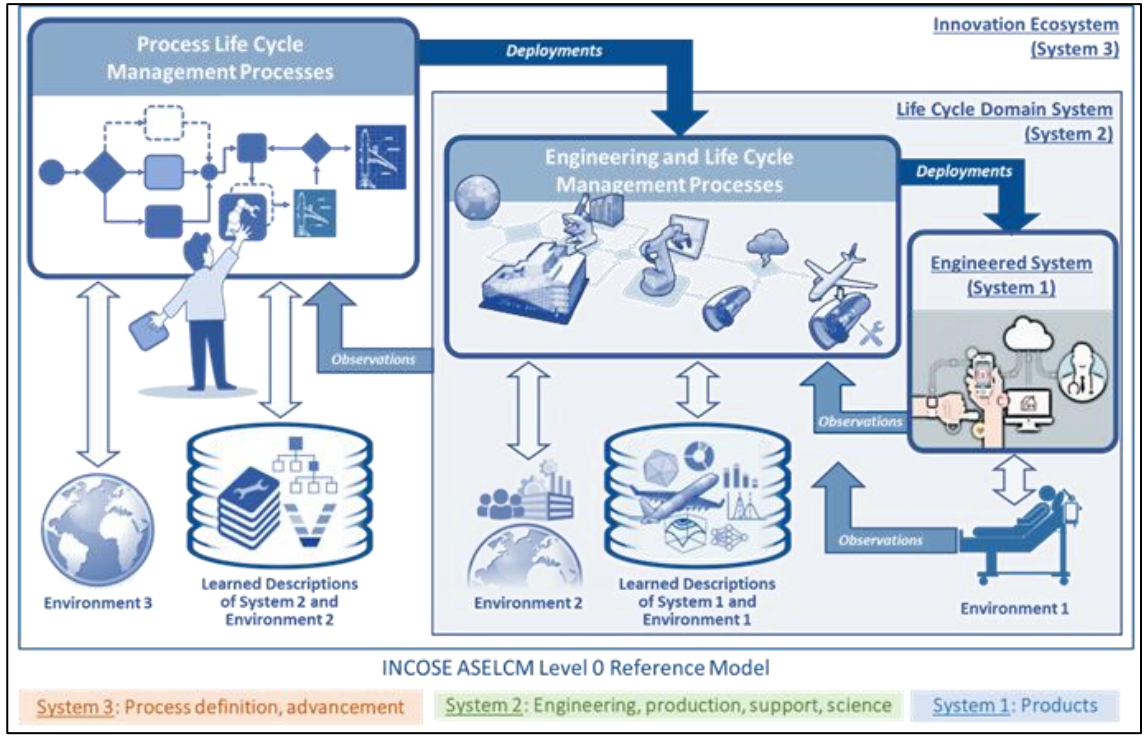


Level 0 View, INCOSE ASELCM Pattern

Levels of decomposition

	System 3	System 2	System 1
Level 0			
Level 1			
Level 2			
Level 3			
Level 4			

Same Level 0 view, with additional points of discussion



- **System 1--Engineered System**: The subject system (or system of systems) to be planned, designed, analyzed, produced, operated, sustained, improved, retired 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.

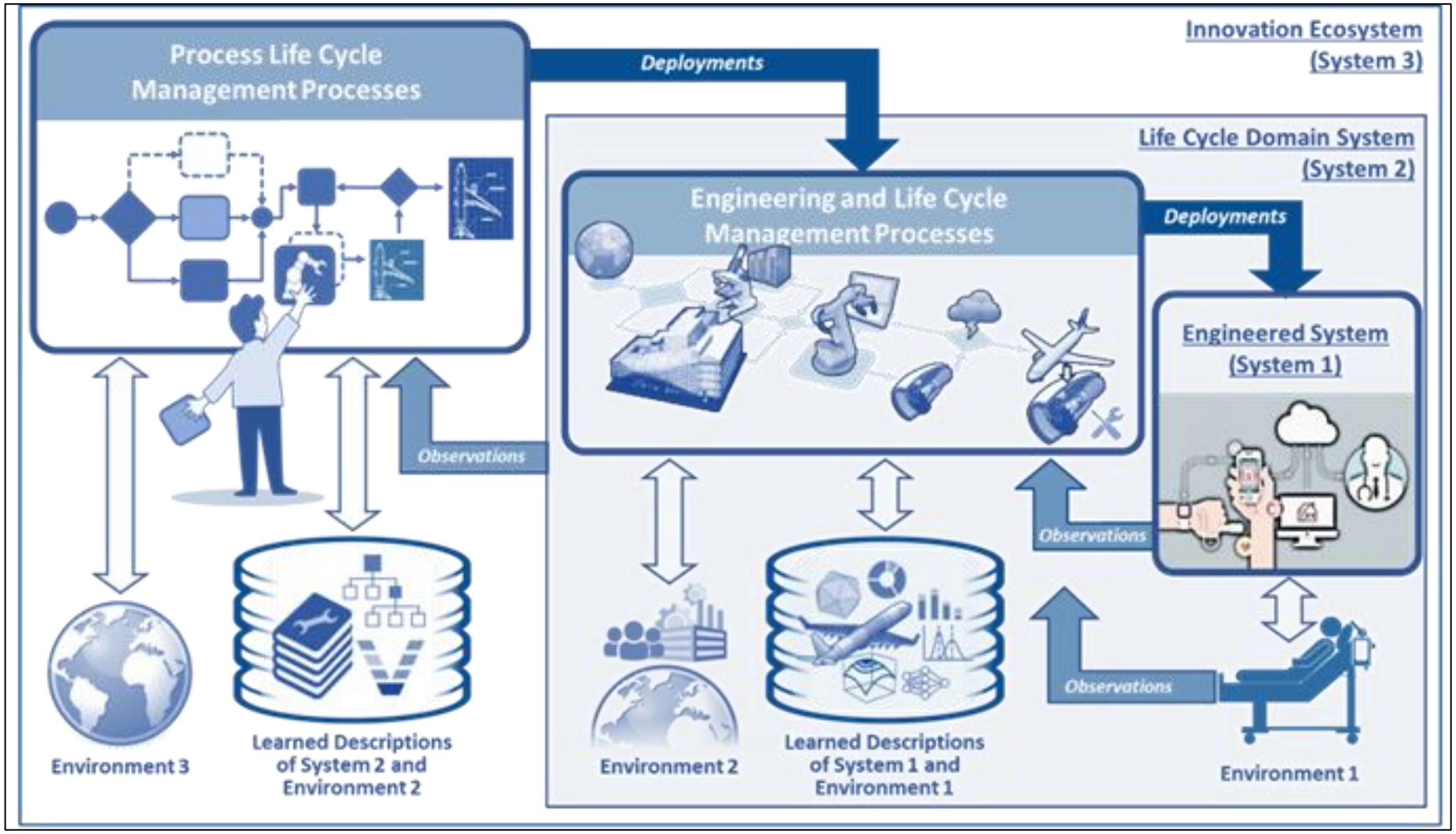
Process vs. Information: Rebalancing the Historical *Process* Emphasis

Processes

(Many different approaches for same Information)

Information

(More fundamental and invariant)



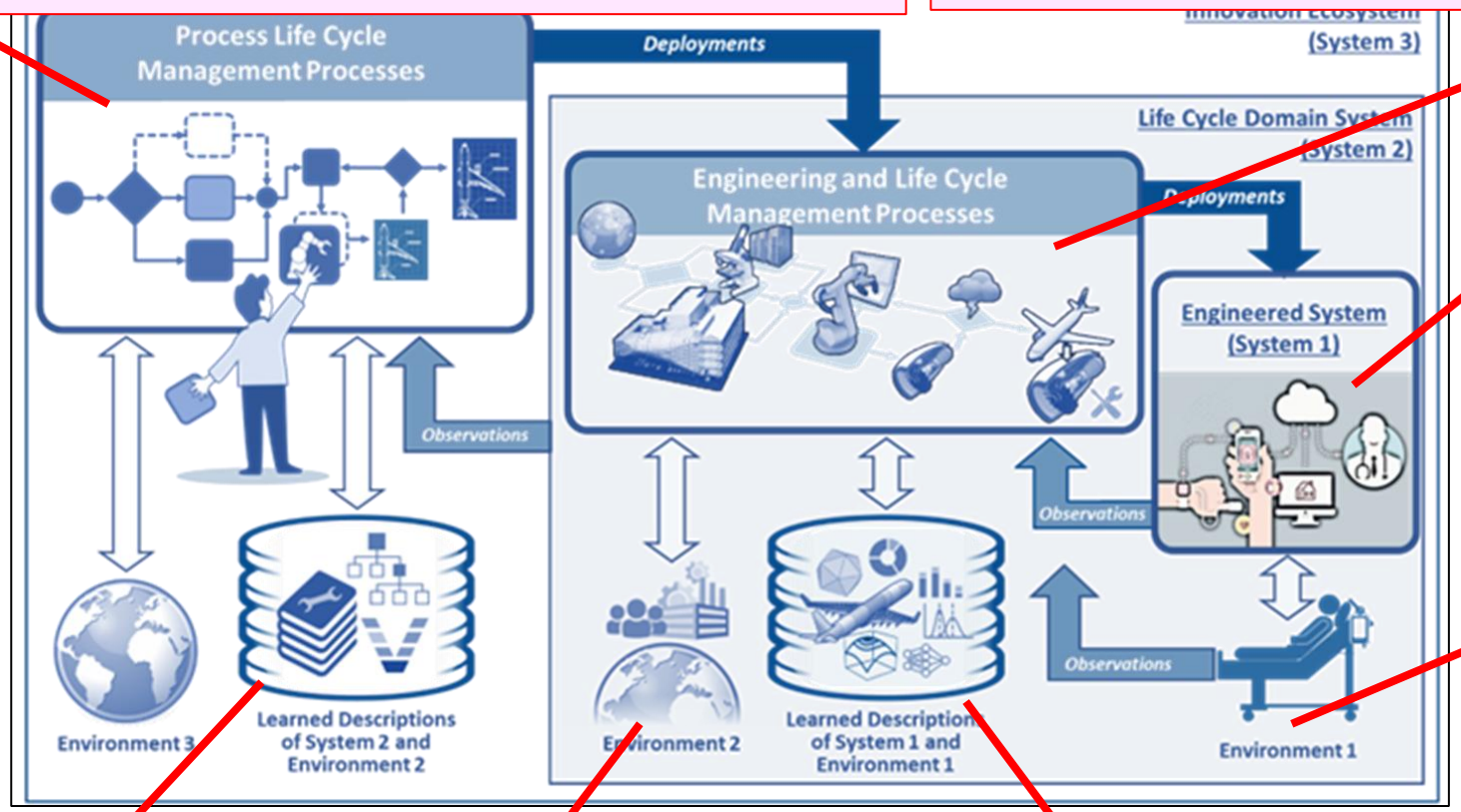
Definition, advancement of engineering, production, support, scientific methods

Engineering, production, support, science

Products we design; markets; Nature

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.



INCOSE ASELCM Level 0 Reference Model

- **Examples**: Hospital, data network, pump, controller.

EXAMPLES

- **Examples**: Power grid, hospital staff, storage

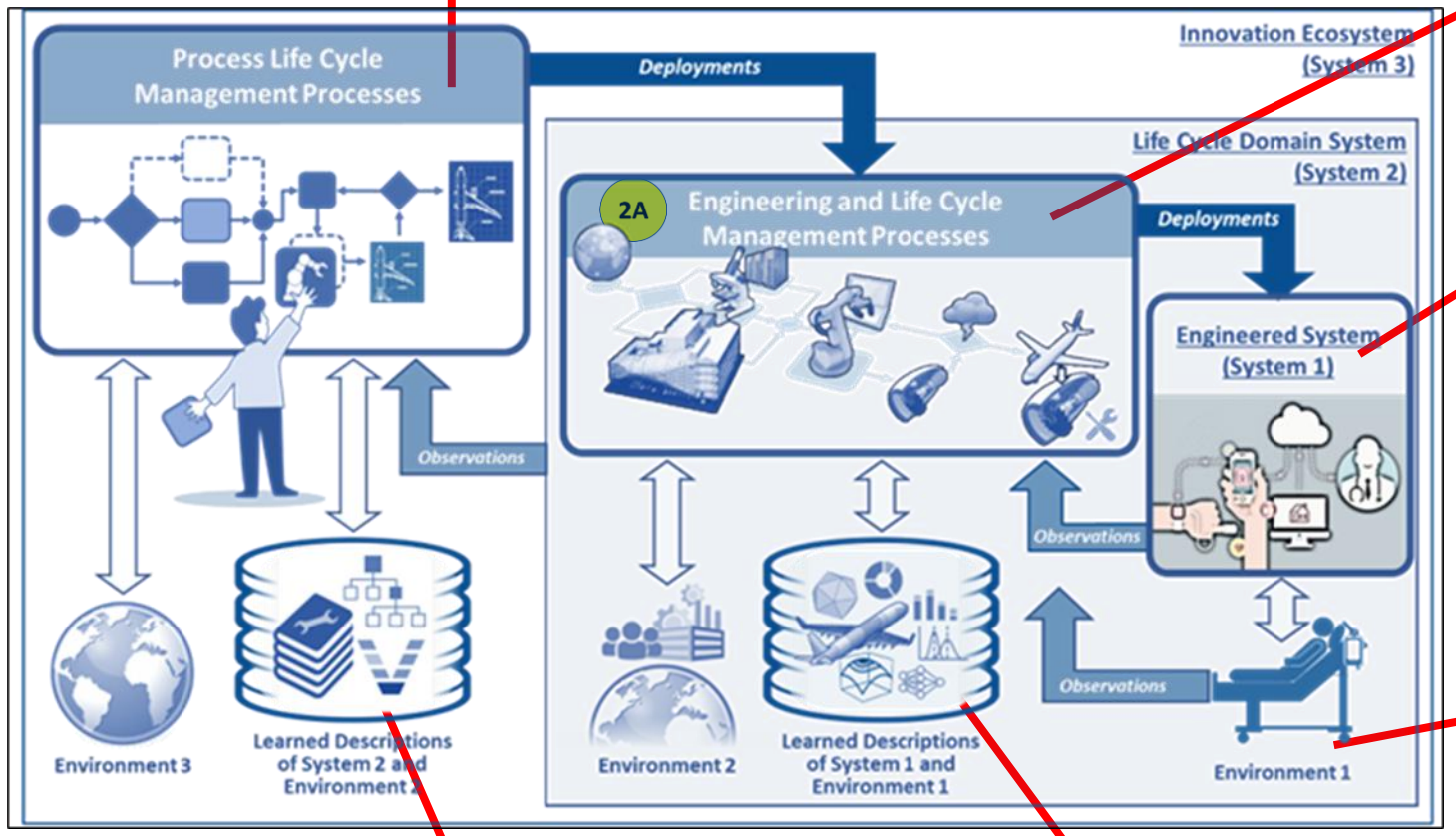
- **Examples**: COVID19 Pandemic, Industry Funding, Job Market

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

- **Examples**: Pump Requirements, Designs, Schematics, MBSE Models, CFD Simulations, Part Prints, Production Recipes, Assembly Diagrams, Raw Materials Lists, Physics, Personal & Tribal Pump 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.

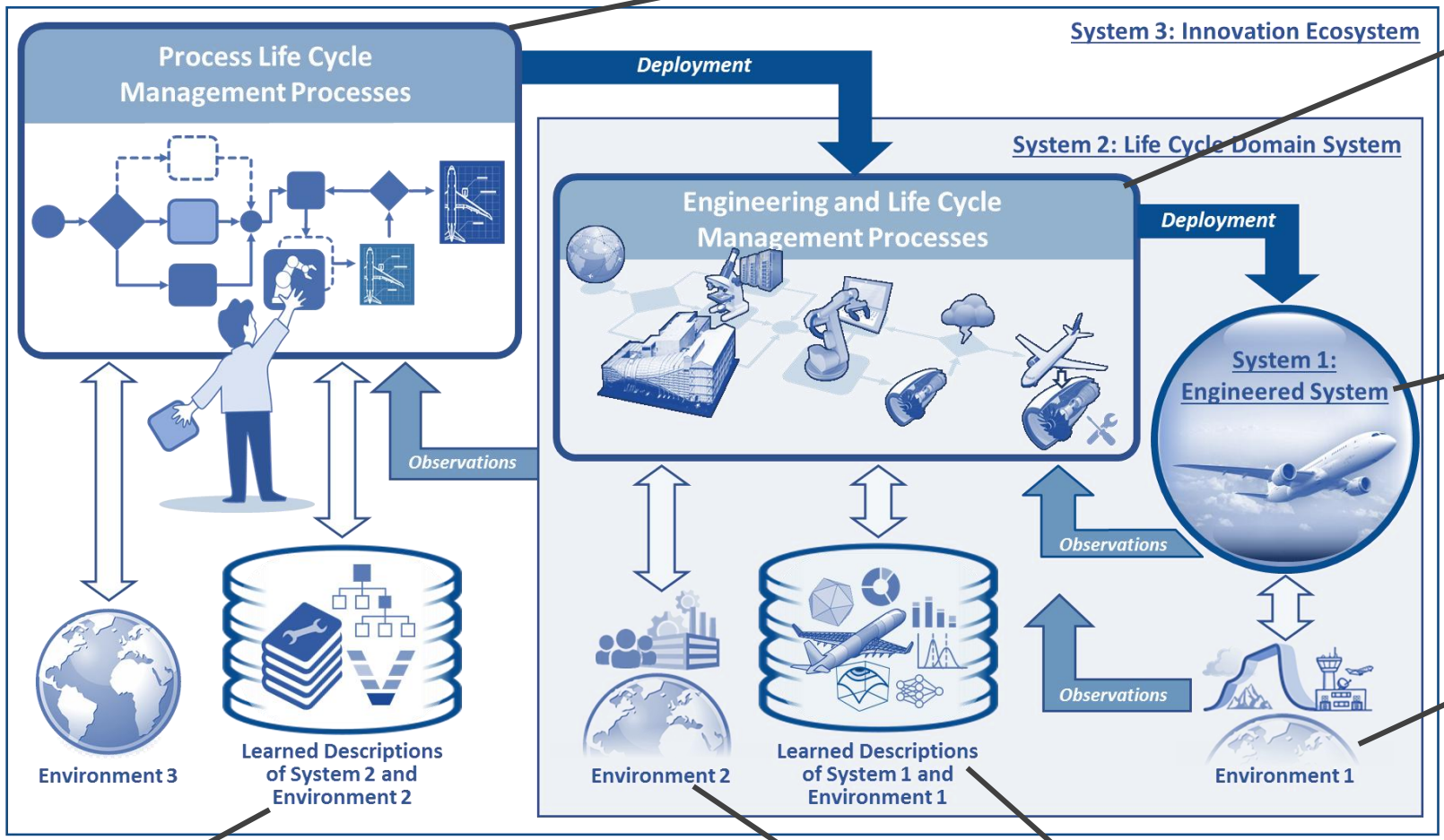
DEFINITIONS

- 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.

- Engineering Education, Engineering Methods Owner, Engineering Tooling Architect, HR Department, Engineering Procedures Author, AIAA, INCOSE, IEEE, ASME



- Mission Engineering Department, Senior Electrical Engineer, Design Review, Simulation Platform, Engineering Toolchains, Learning Machines, Service Delivery Process, PLM system, Production MES, Digital Twin Simulation and Data.

- Cygnus Launch Vehicle
- Aircraft with Composite Structures
- Rotary Drive Aircraft
- Aircraft Passenger Seating
- GaTech Campus Building

- Launch and ISS Rendezvous Systems
- 2, 3. Atmospheric Buffeting
- Manufacturing Floor and Materials
- Passengers, Aircraft Structures
- Campus Traffic, Weather

- Enterprise Procedures, Job Descriptions, Organization Charts, Policies, INCOSE SE Handbook, SEBoK, Methodology Primers, Personal & Tribal Process Knowledge

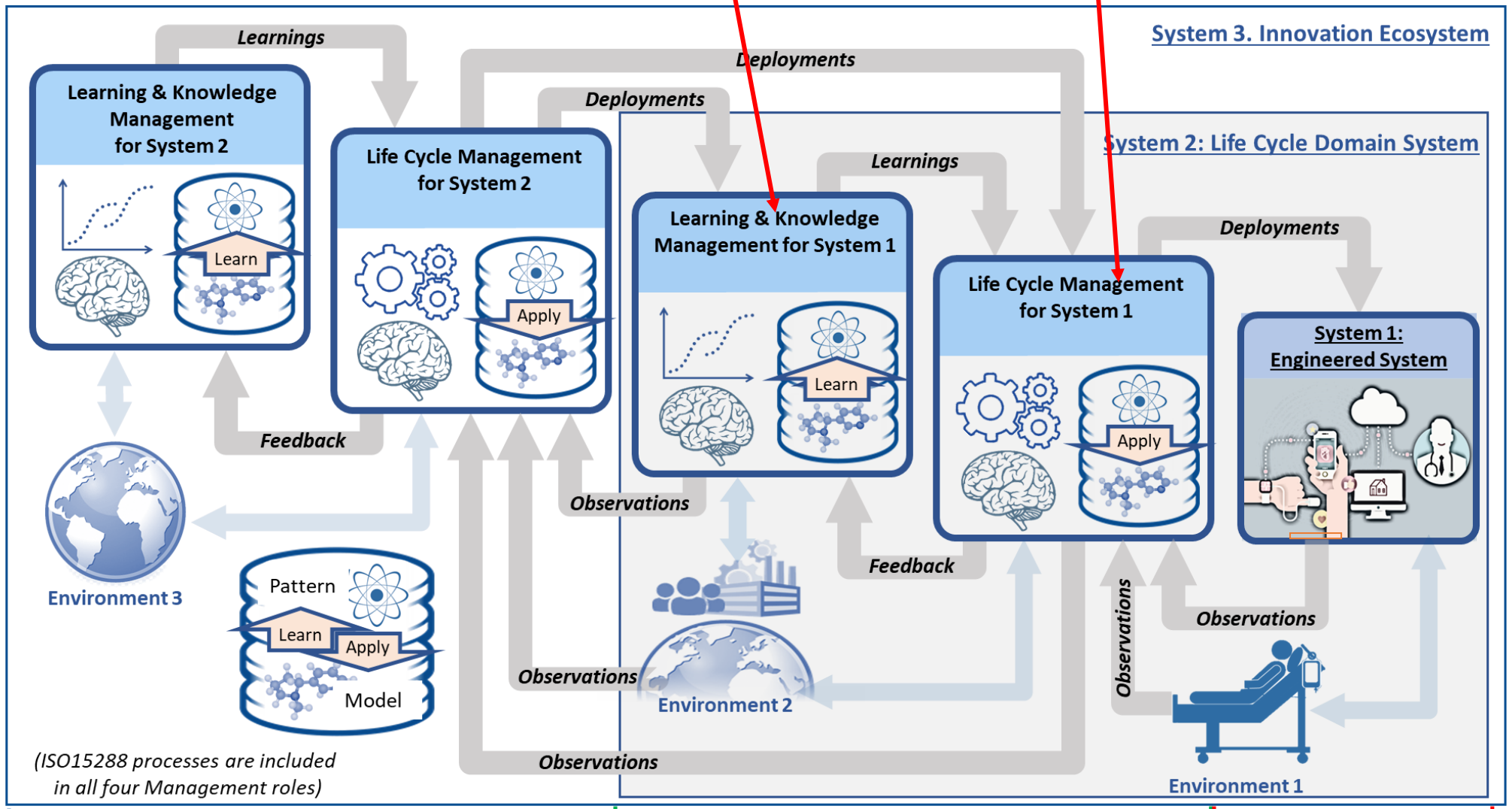
- Job Market, COVID19 Pandemic, Industry Funding, Workplace

- Maneuvering Requirements, Designs, Schematics, MBSE Models, CFD Simulations, Part Prints, Production Recipes, Assembly Diagrams, Raw Materials Lists, Physics, Personal & Tribal Domain Knowledge

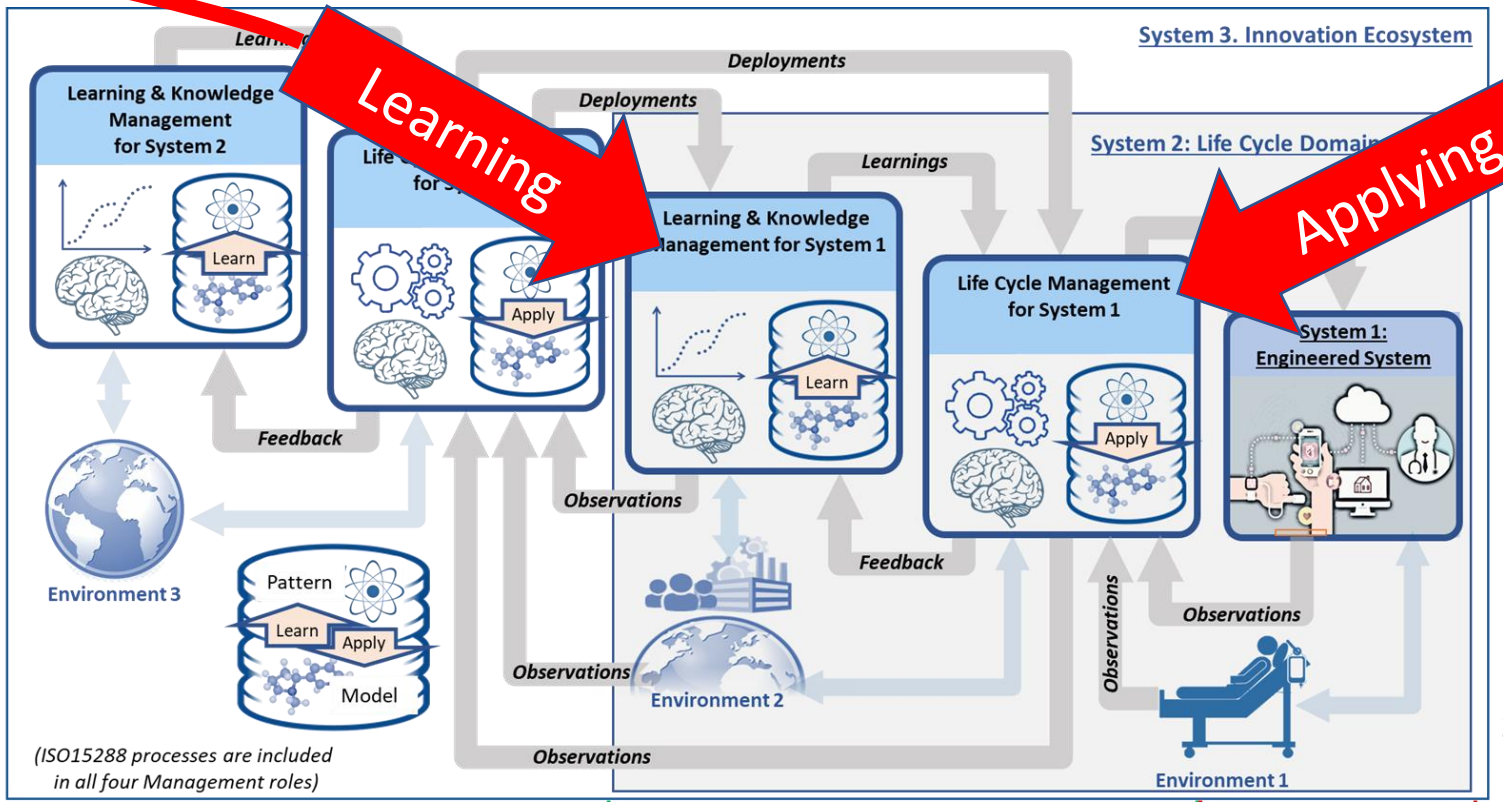
From AIAA case studies of Digital Twins

INCOSE ASELCM Level 1 Reference Model

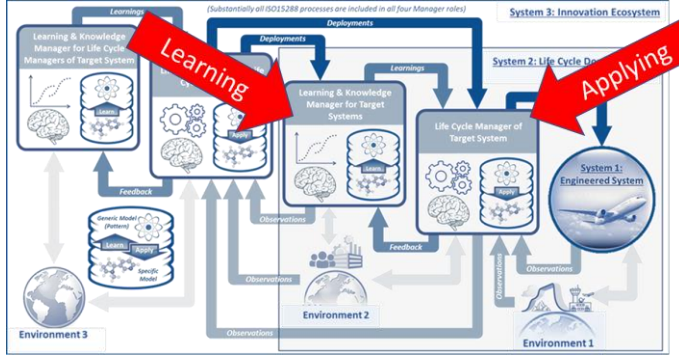
(Separation of ***learning new information*** from ***acting on what is already known***.)



- Everything we do in Engineering & Life Cycle Management that is ***based on what we already know*** (or think we may know) about System 1 and its interaction with its environment..
- Everything we do in Engineering & Life Cycle Management that ***involves learning new things*** about System 1 and its interaction with its environment—including validation of that knowledge or our uncertainty about it.
- Both activities may be ***concurrent***, and may even be performed by the ***same people*** or teams—they are just different roles (responsibilities, behaviors).
- ***Group Learning***: In the most general case, these can be **widely separated people and times**.



Why the "separation" of Learning & vs. Application of what is learned?

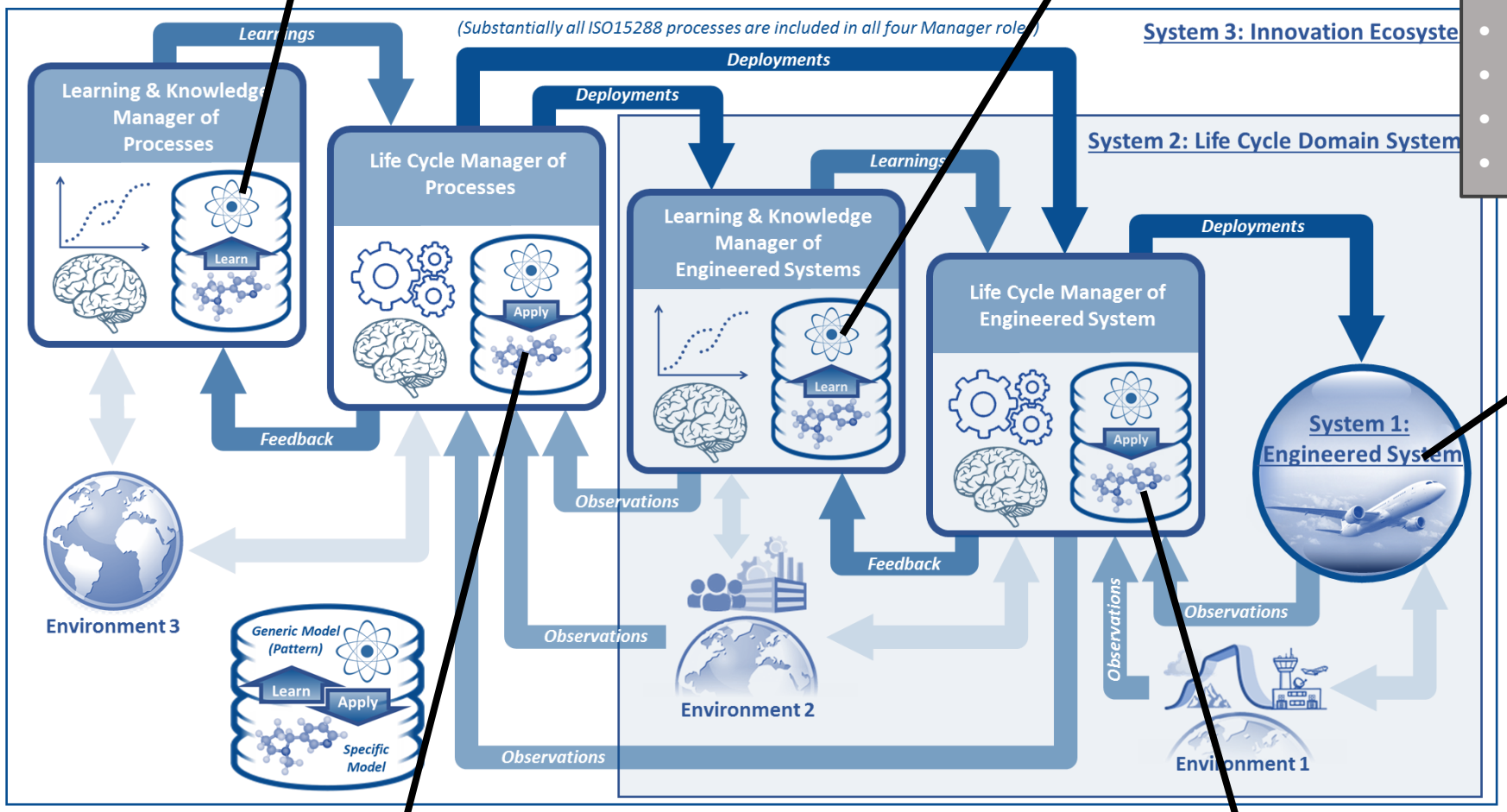


- The widely-used description of systems engineering (e.g., ISO 15288-like standards, INCOSE SE Handbook, enterprise descriptions, textbooks, etc.) all go into detail to tell us all the things we should do to generate all the information known to be vital to successful engineering and life cycle management:
  - So, this framework is *not for that purpose*, and in fact those standards and descriptions are *built into this framework*, which references them but does not repeat their details.
- *However*, all those references are relatively silent on the question "What about what we *already* know?"
  - They generally leave it to us to find practical means to blend the combination of existing and to-be-learned knowledge.
  - The ASELCM Pattern is especially about describing the macro-level implications of *effective combination* of both parts.
  - The origin of the INCOSE Patterns Working Group is focused on this issue.

- Configurable Project Framework
- Digital Twin Infrastructure Framework

- Generic Configurable Parametric Models
- System Templates
- Trusted Credible Model Families

- Cygnus Launch Vehicle
- Aircraft with Composite Structures
- Rotary Drive Aircraft
- Aircraft Passenger Seating
- GaTech Campus Building



Recent examples from the AIAA studies of Digital Twins, analyzed in ASELCM

- Configured project-specific guidance
- Configured Digital Twin Plan

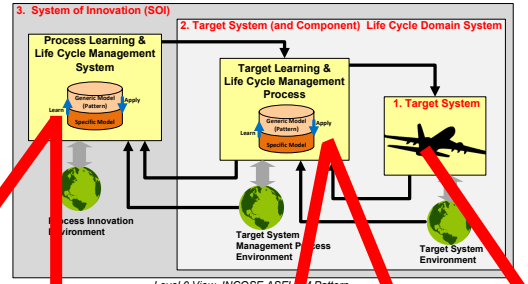
- Configured Computational Models
- Empirical Measurement Datasets
- System Models
- Mechanical, Electrical, Sftw Models

Level 0

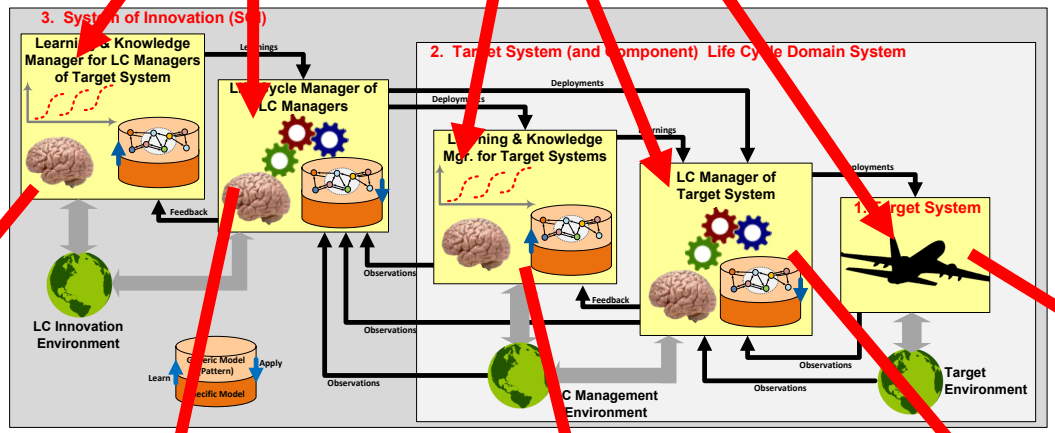
Level 1

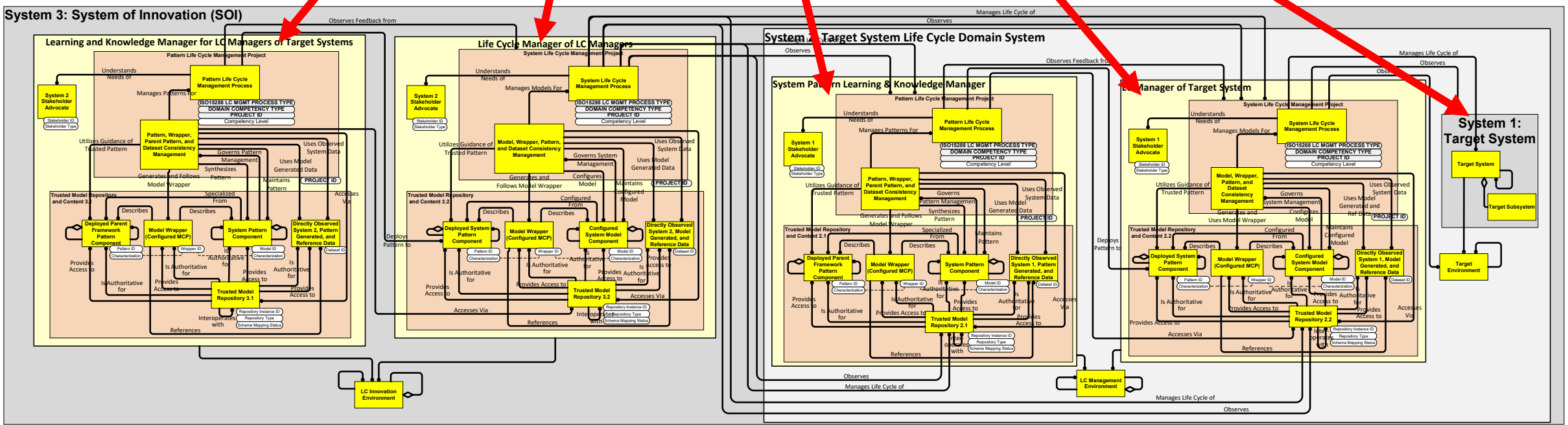
Level 2

Moving to Level 2 . . .

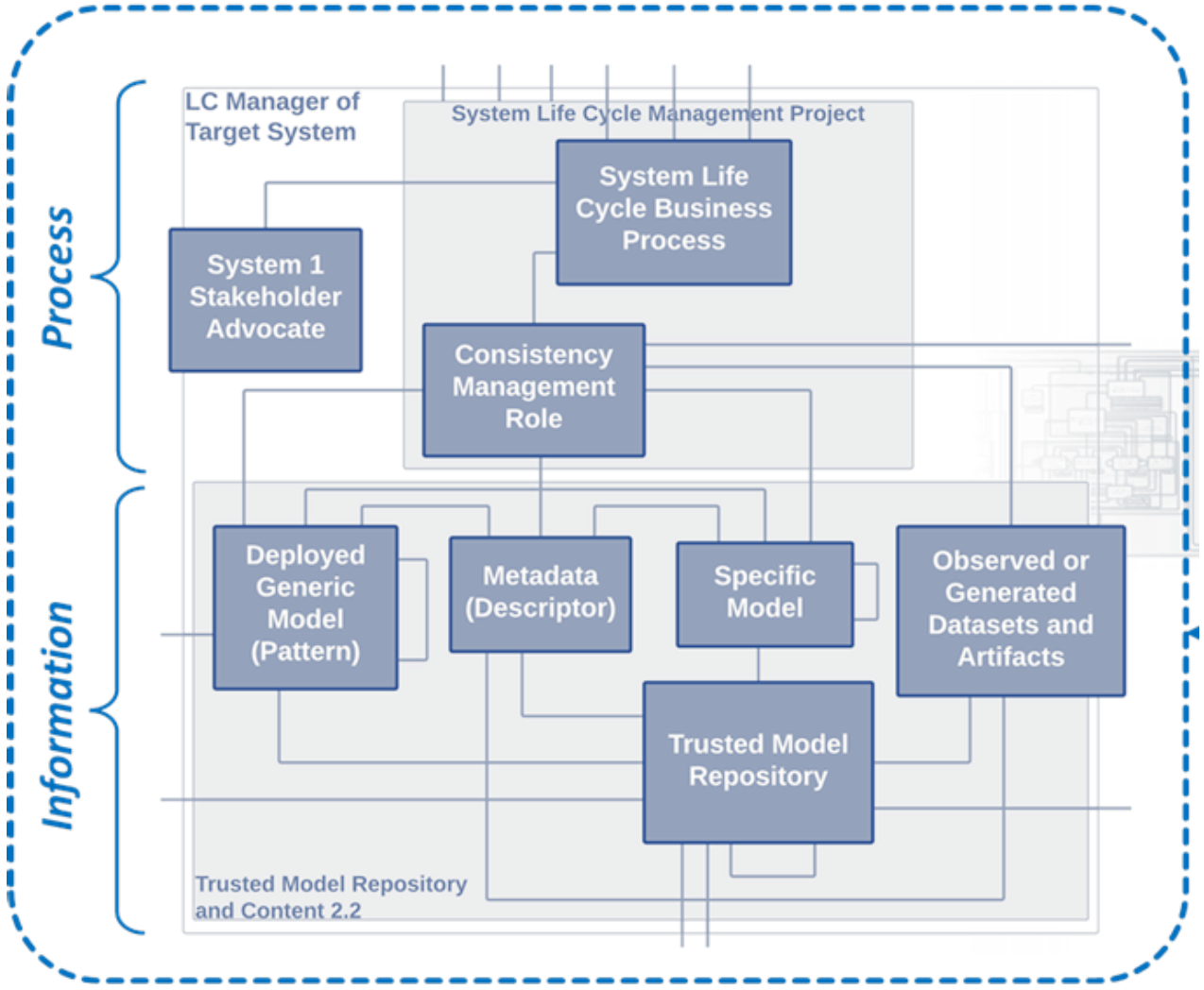


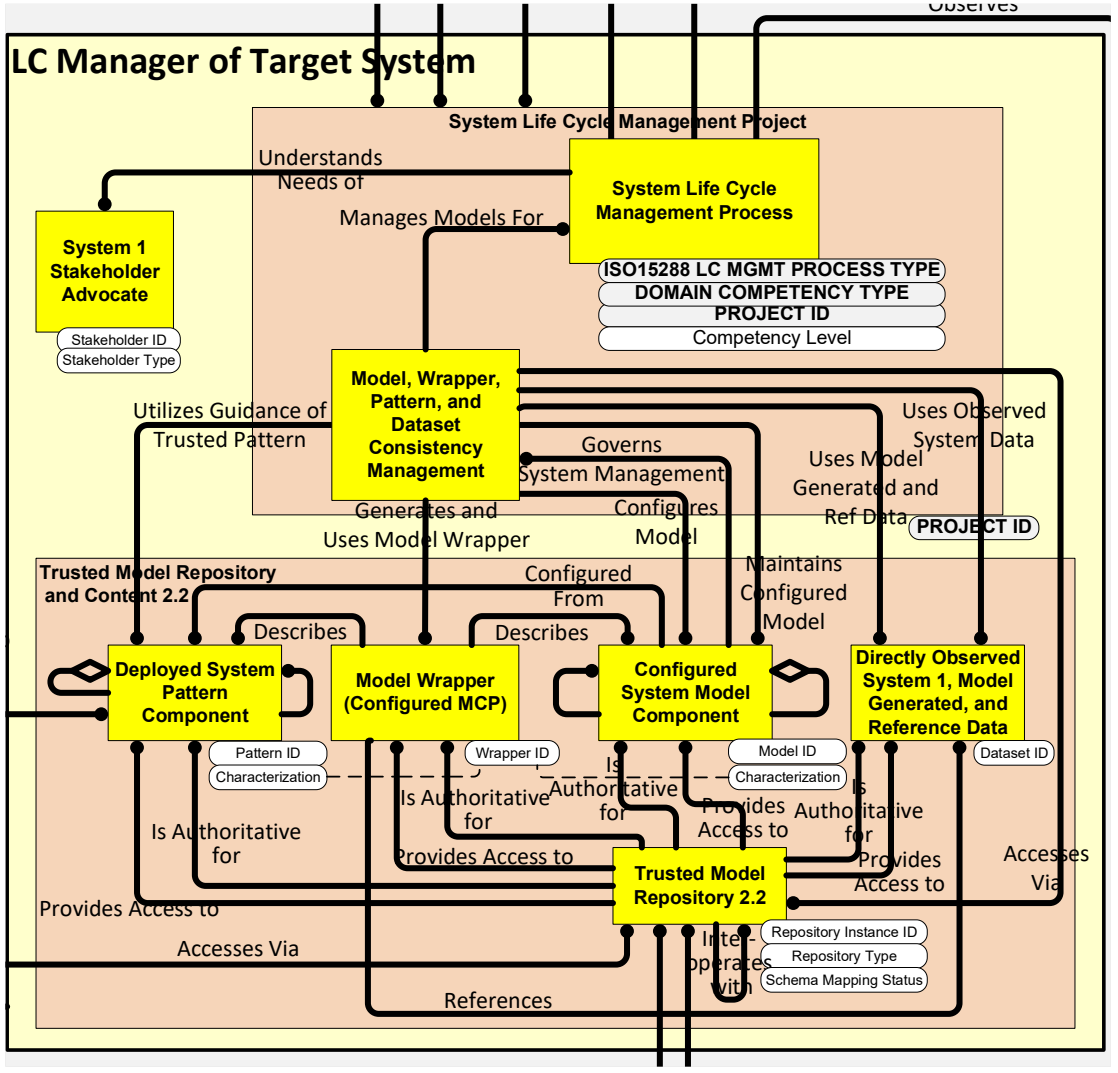
Level 0 View, INCOSE ASELM Pattern





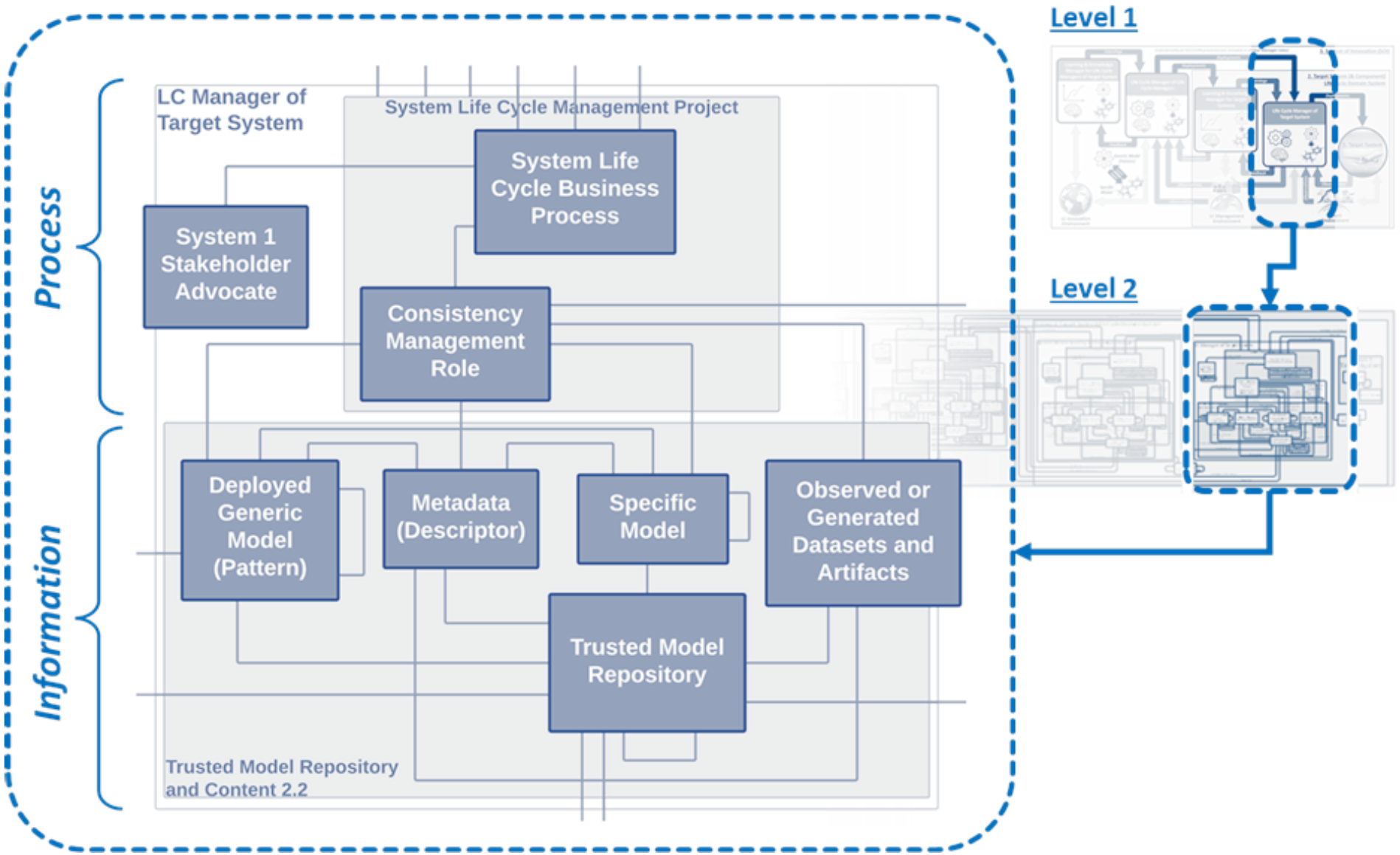
Level 2 of ASELCM – Two diagram styles, same 8 Roles.





INCOSE ASELCM Level 2 Reference Model

(Segment for Application of "Already Learned" Information)



INCOSE ASELCM Level 2 Reference Model

(Segment for Application of "Already Learned" Information)

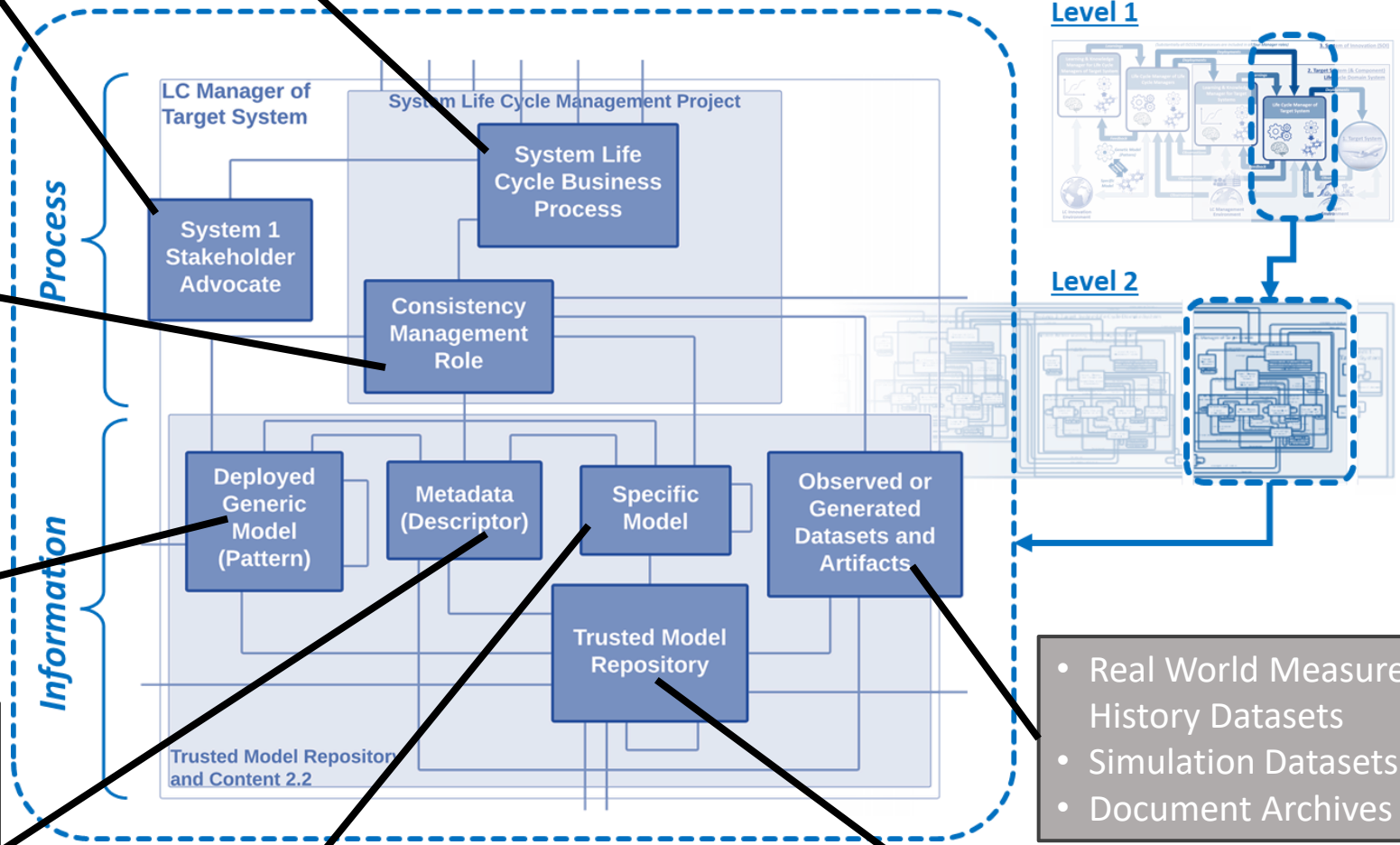
- Commercial Customer
- Passenger
- Taxpayer
- Building Occupant
- Defense Service Branch

- Mission Planning
- Requirements Management
- Design Process
- Production
- Operations

- Needs-Plans Reconciliation
- Design-Requirements Align
- Production-Design Coord
- As Design-As Used Alignment
- Aging State-Mission Planning Coordination

- Configurable generic models to generate Specific Models
- Patterns, Ontologies
- Standards, Frameworks, Schema

- Describes Specific Models
- Describes Generic Models (Patterns)
- Describes Datasets
- Includes Credibility Assessment et al
- "Model Wrapper" / Label



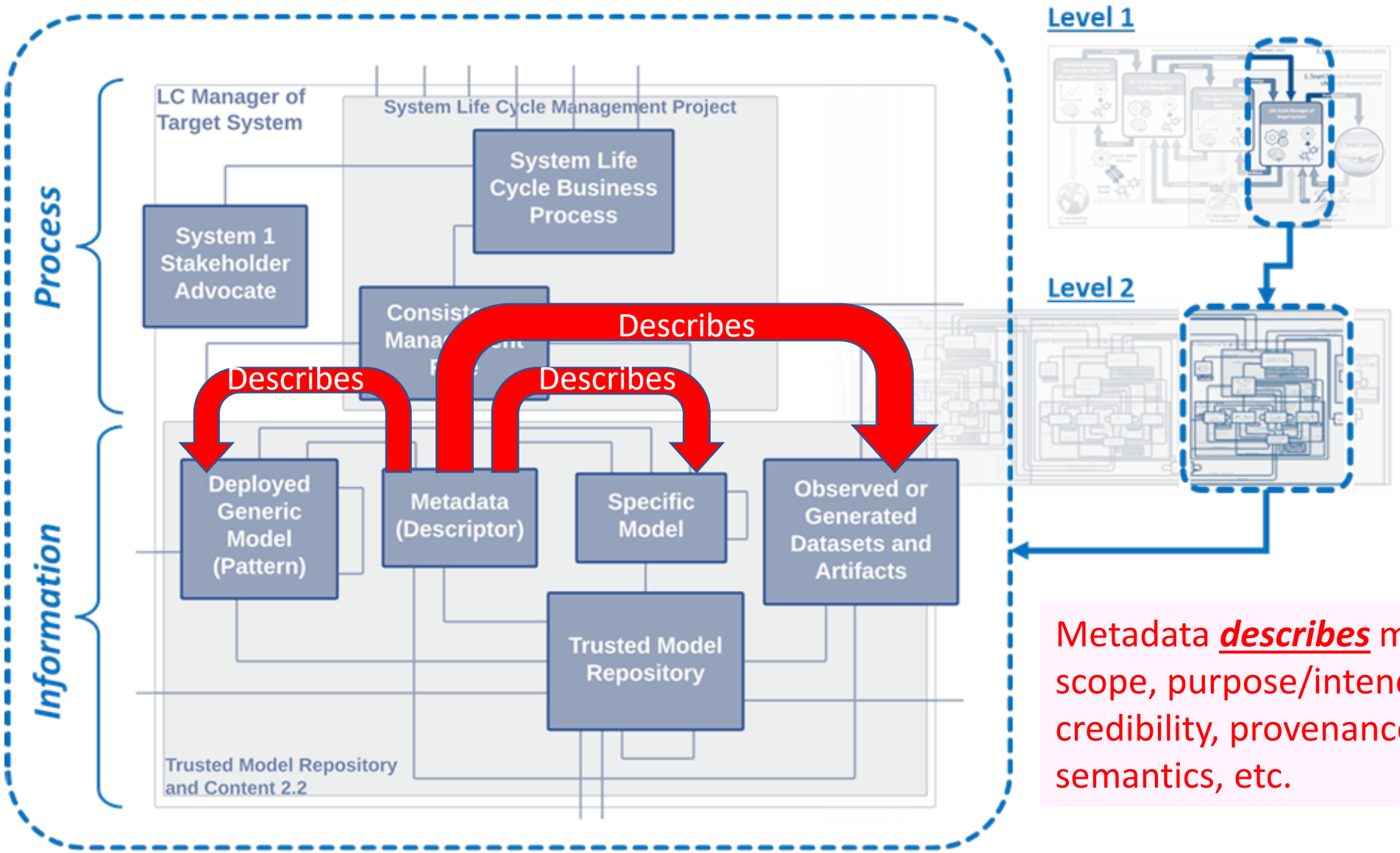
- Simulation/Computational Models
- MBSE Models
- Learning Machines

- Info Service Platforms

- Real World Measurement History Datasets
- Simulation Datasets
- Document Archives

INCOSE ASELCM Level 2 Reference Model

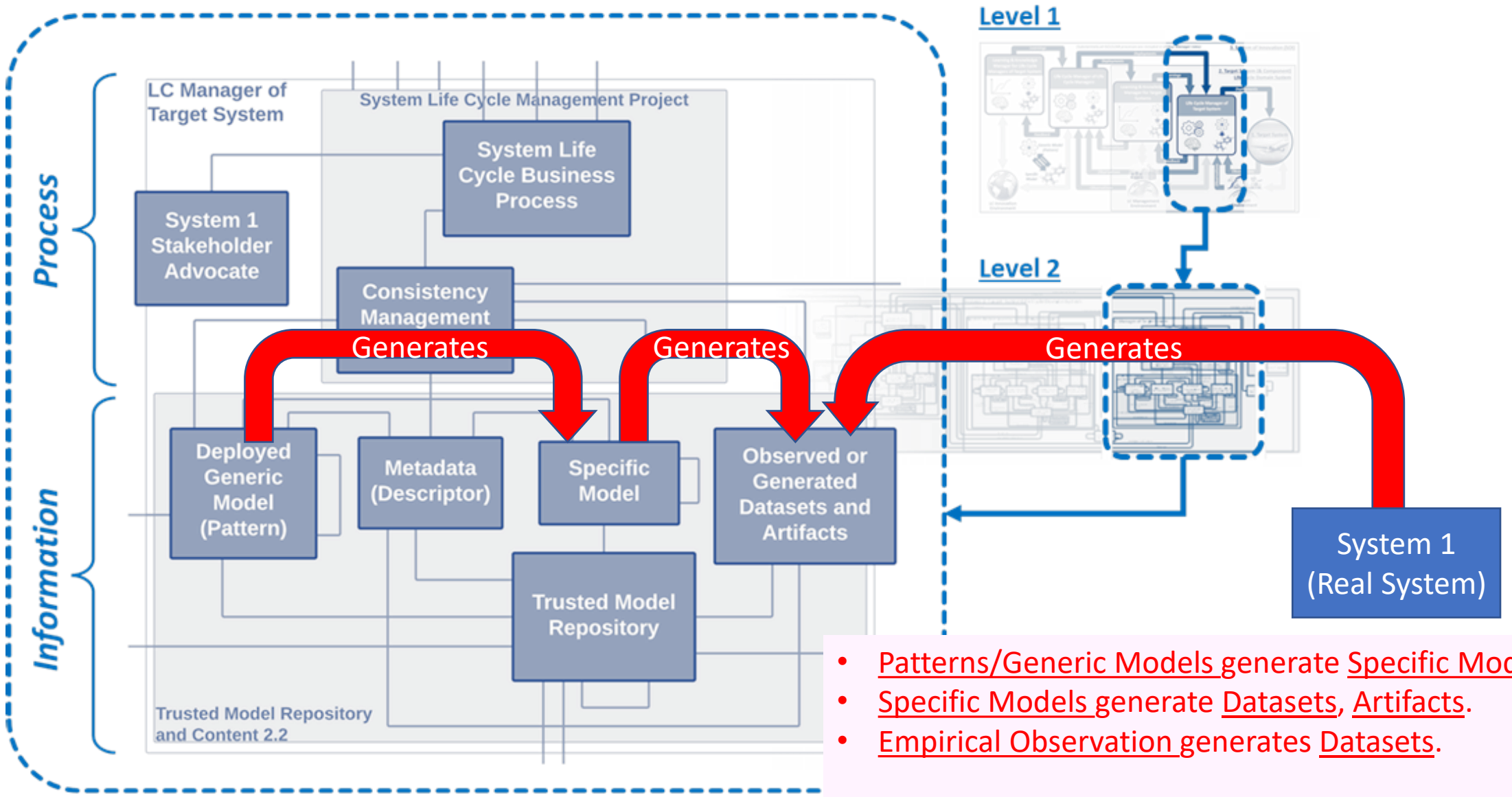
(Segment for Application of "Already Learned" Information)



Metadata ***describes*** model and data scope, purpose/intended use, credibility, provenance, language, semantics, etc.

INCOSE ASELCM Level 2 Reference Model

(Segment for Application of "Already Learned" Information)

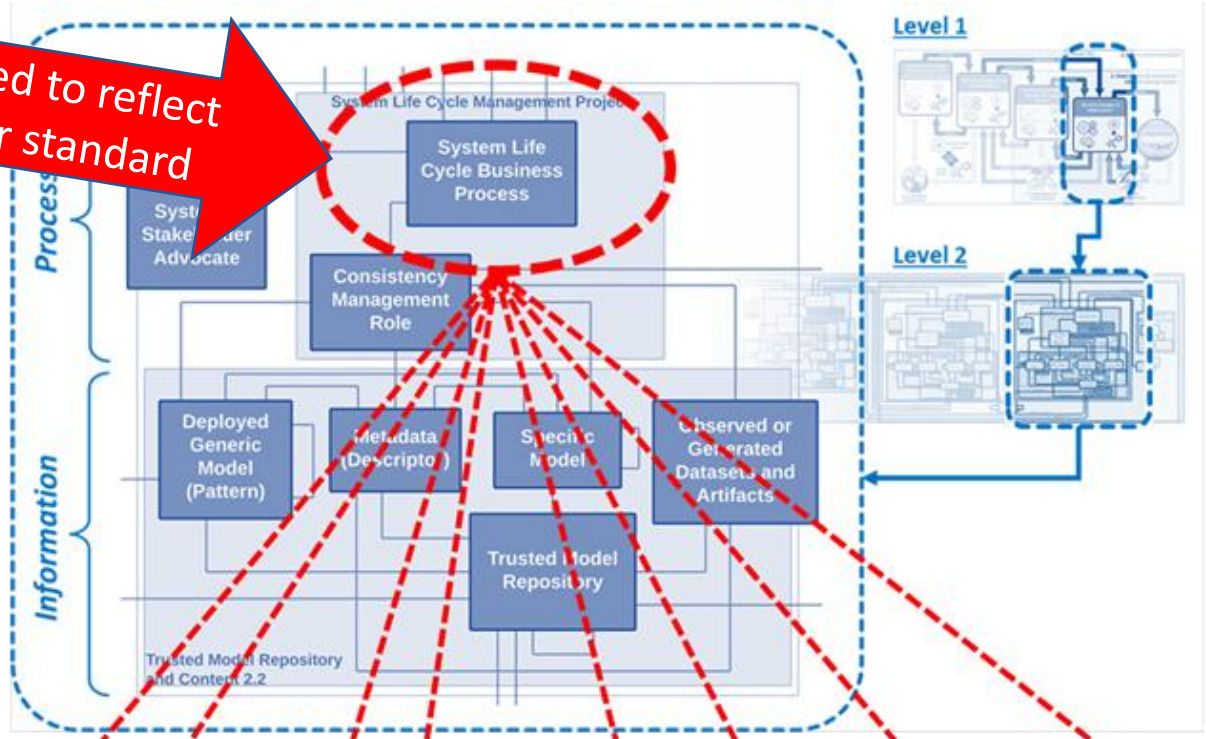


- Patterns/Generic Models generate Specific Models.
- Specific Models generate Datasets, Artifacts.
- Empirical Observation generates Datasets.

Connecting historically represented business processes to evolving digital infrastructure

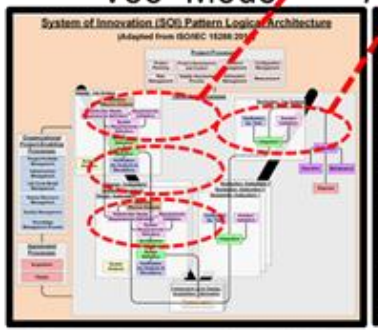
- Every enterprise, supply chain, or ecosystem will have somewhat different business process structure and nomenclature.
- Generic models exist (e.g., ISO 15288, DoD 5000, etc.), but we often want to map to the internally familiar specific nomenclature of a particular business, supply chain, or ecosystem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

Instances populated to reflect local ecosystem or standard



Configurable to specific life cycle management models---

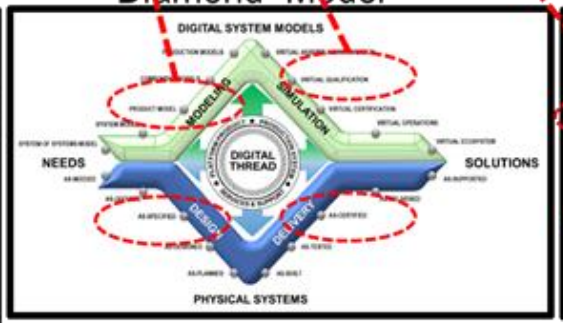
ISO15288 Life Cycle "Vee" Model[1]



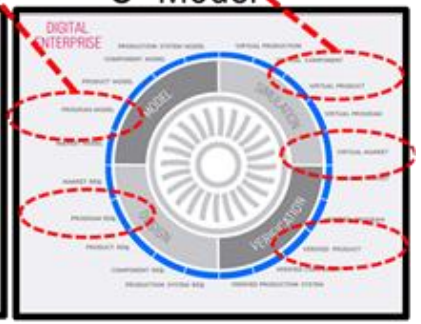
DoD 5000 Defense Acquisition Life Cycle Model[2]



Boeing "Diamond" Model[3]

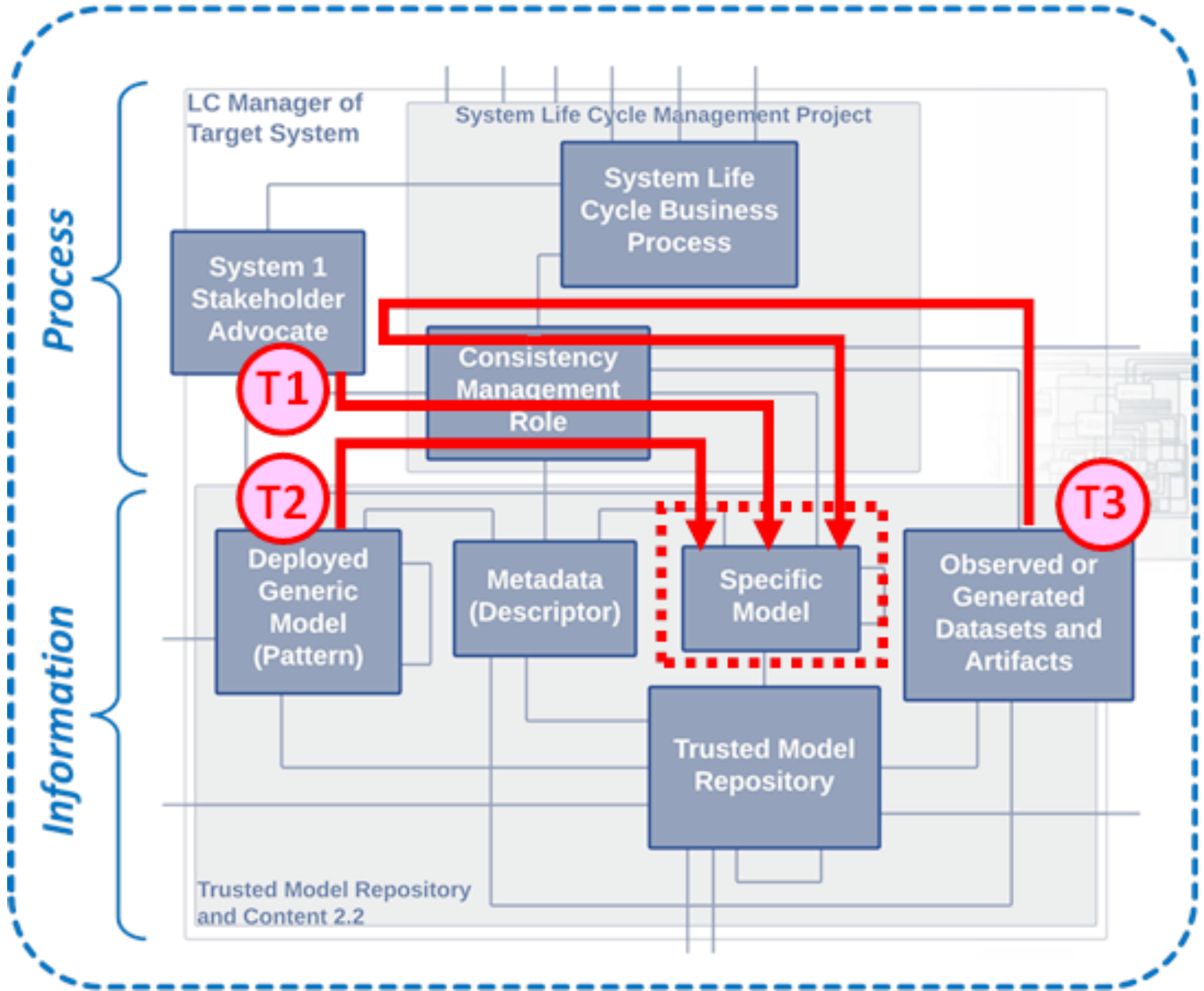


Rolls-Royce "O" Model[4]



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

The 3 sources of model credibility: Disagree with each other frequently; *reconciling those differences is a major part of life cycle management*



The 3 sources of credibility

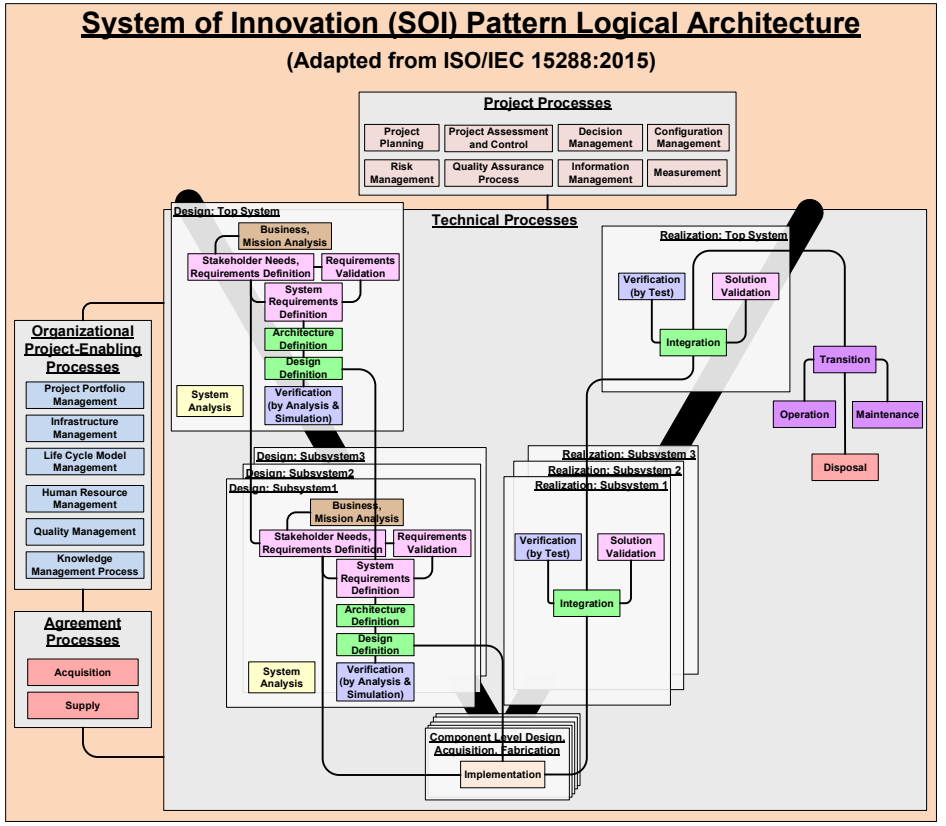
- **T1** What stakeholders now say / want
- **T2** What past learning says
- **T3** What the observed real world and its simulation now say

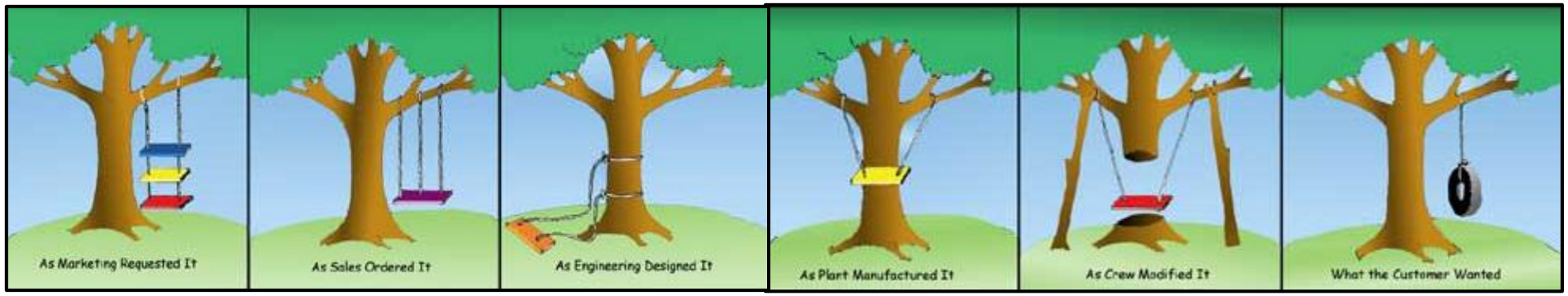
Consistency Management's connection to realizing the promise of digital engineering

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.



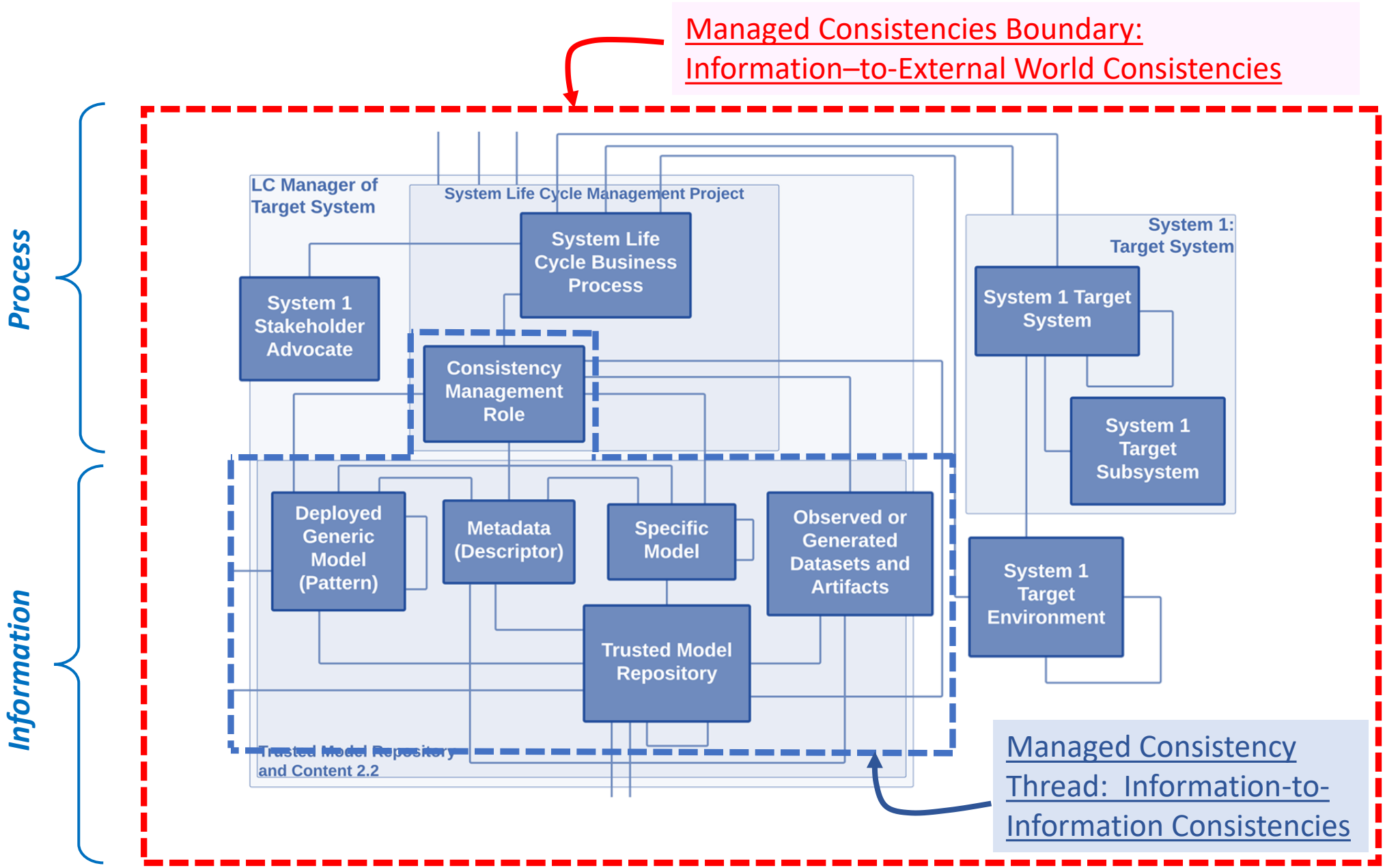




Examples of Managed Consistencies

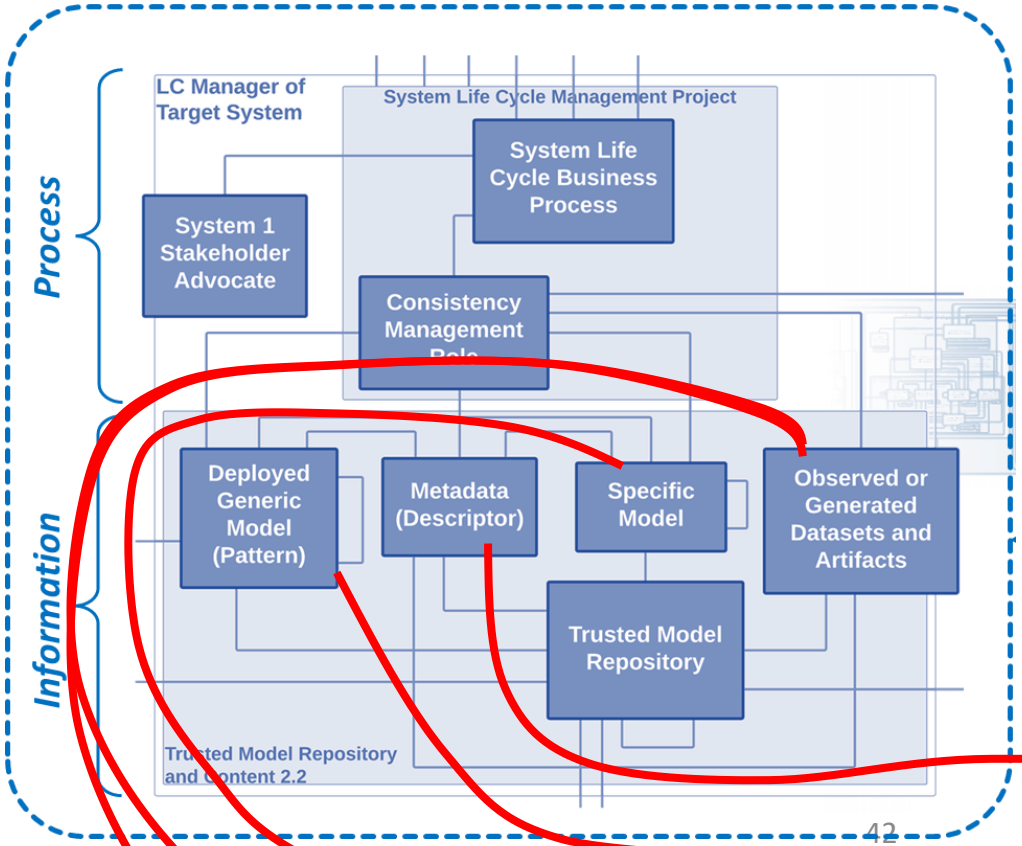
- Consistency of system requirements with stakeholder needs
- Consistency of system designs with system requirements
- Consistency of virtual simulations with empirical measurements (model VVUQ)
- Consistency of system component production with system design
- Consistency of system performance with system 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 . . .

Digital Threads & Twins: A Prominent Example of Consistency Management



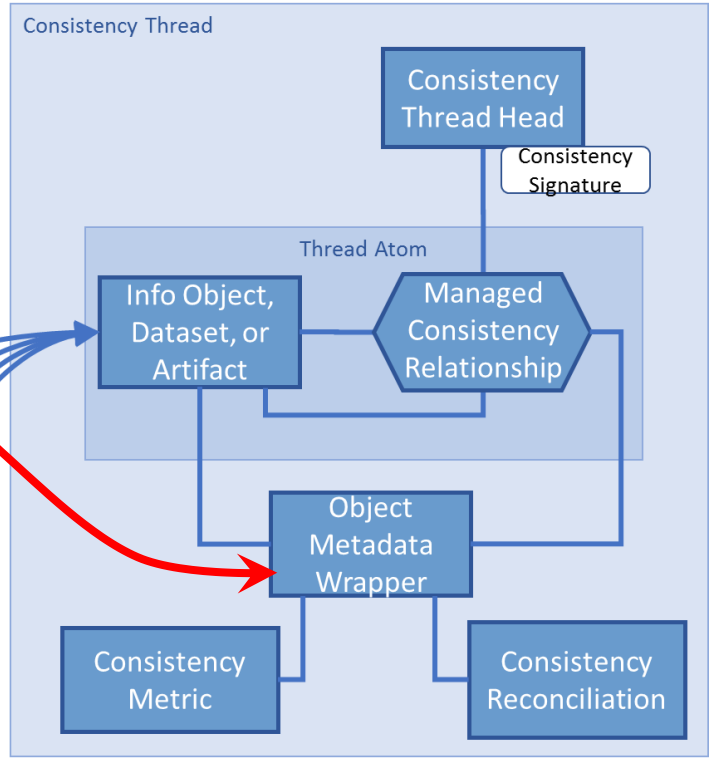
Managed "Consistency Thread" (Digital or Not) System Boundaries

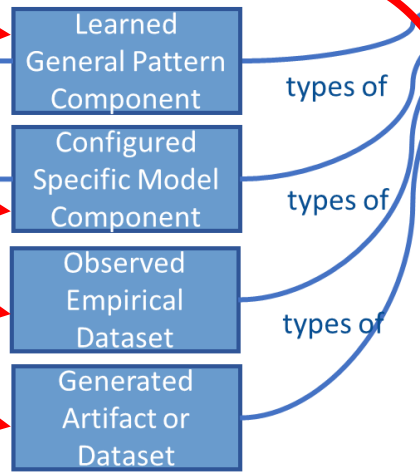
INCOSE ASELCM Level 2 Reference Model

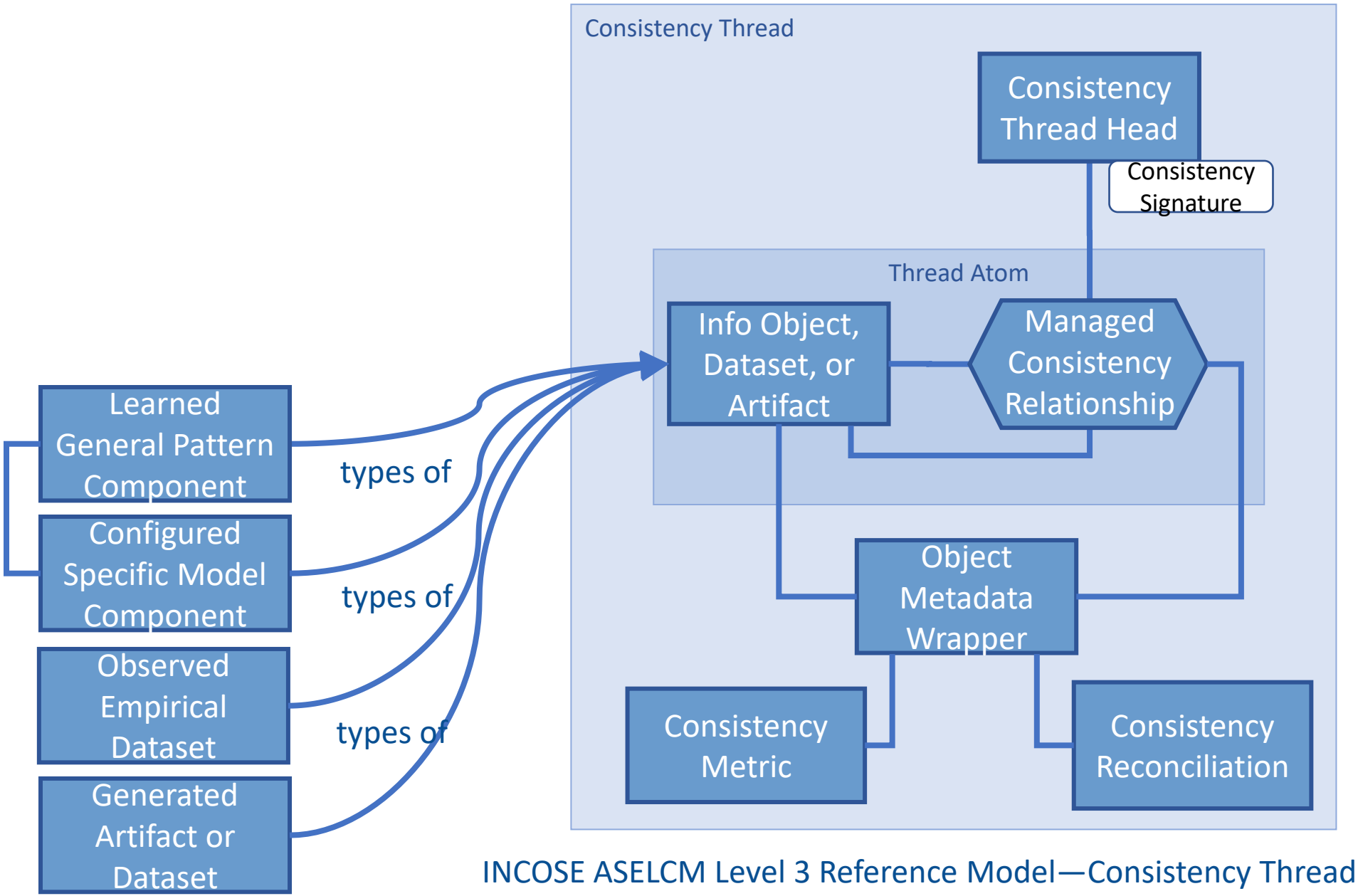


42

INCOSE ASELCM Level 3 Reference Model—Consistency Thread Section





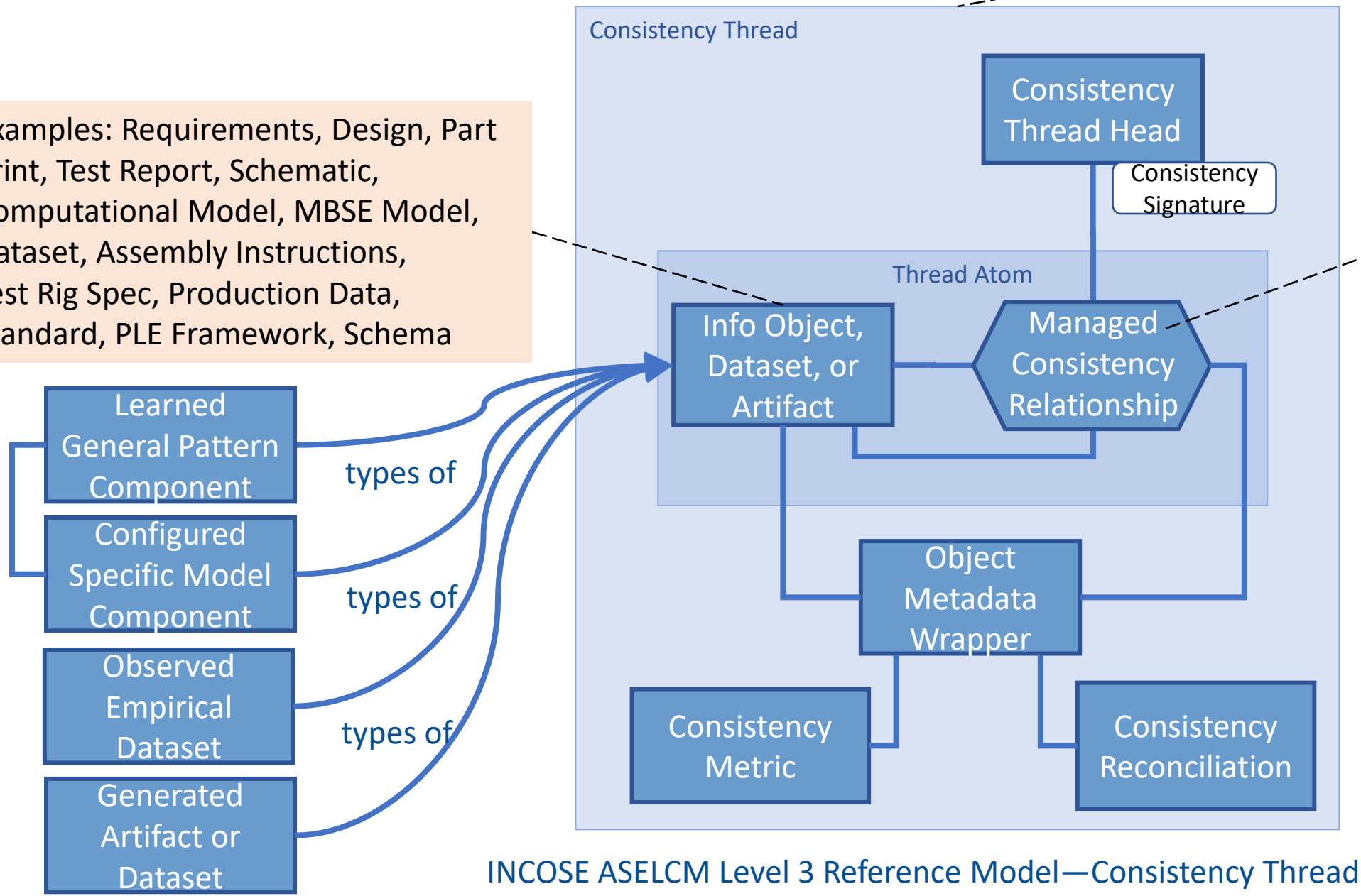


INCOSE ASELCM Level 3 Reference Model—Consistency Thread Section

Examples: O-Ring Seal Thread, Hydraulic Pump Thread

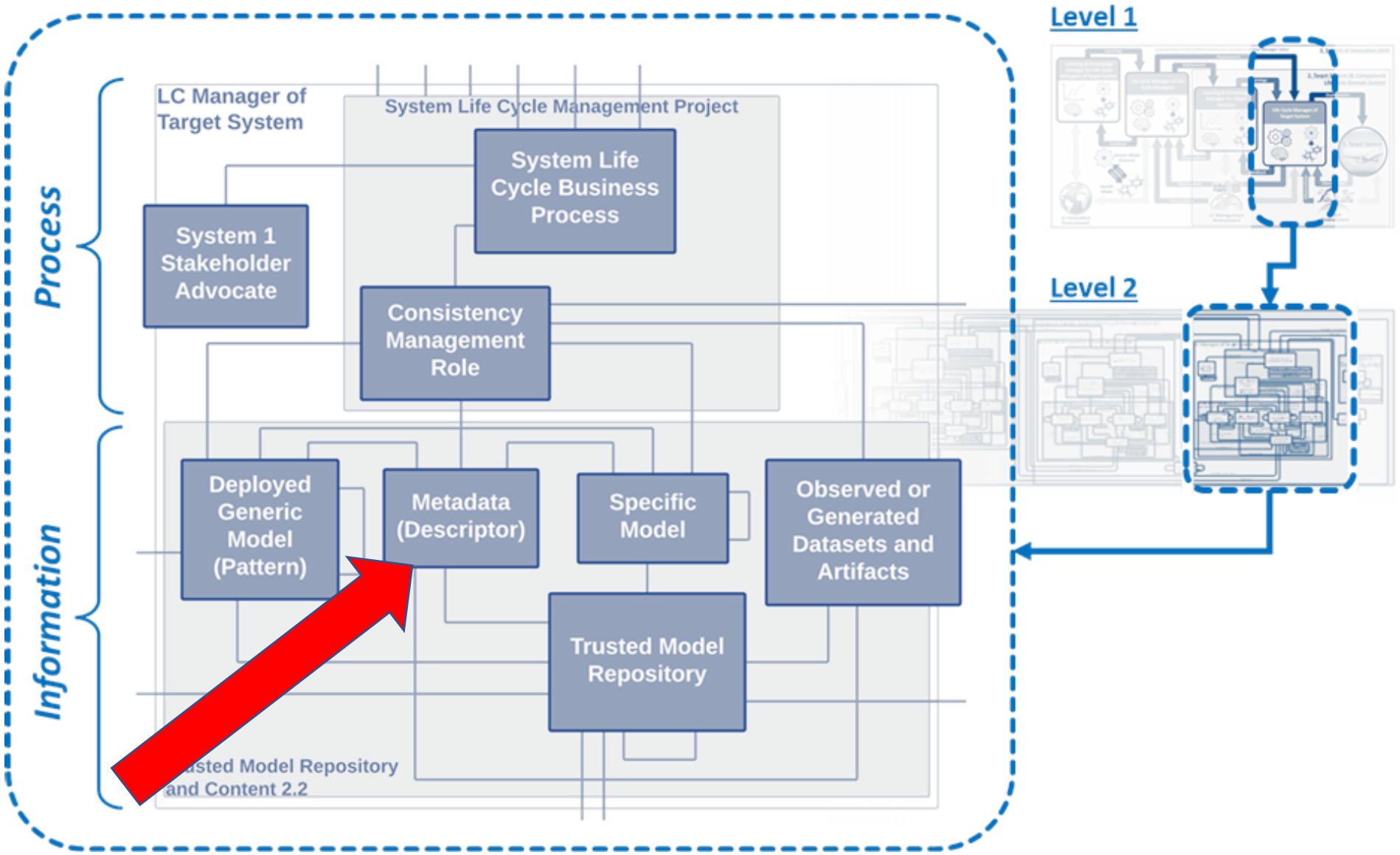
Examples: Requirements, Design, Part Print, Test Report, Schematic, Computational Model, MBSE Model, Dataset, Assembly Instructions, Test Rig Spec, Production Data, Standard, PLE Framework, Schema

Examples: Requirements-Design Consistency; Product-Design Consistency; Utilization-Requirements Consistency



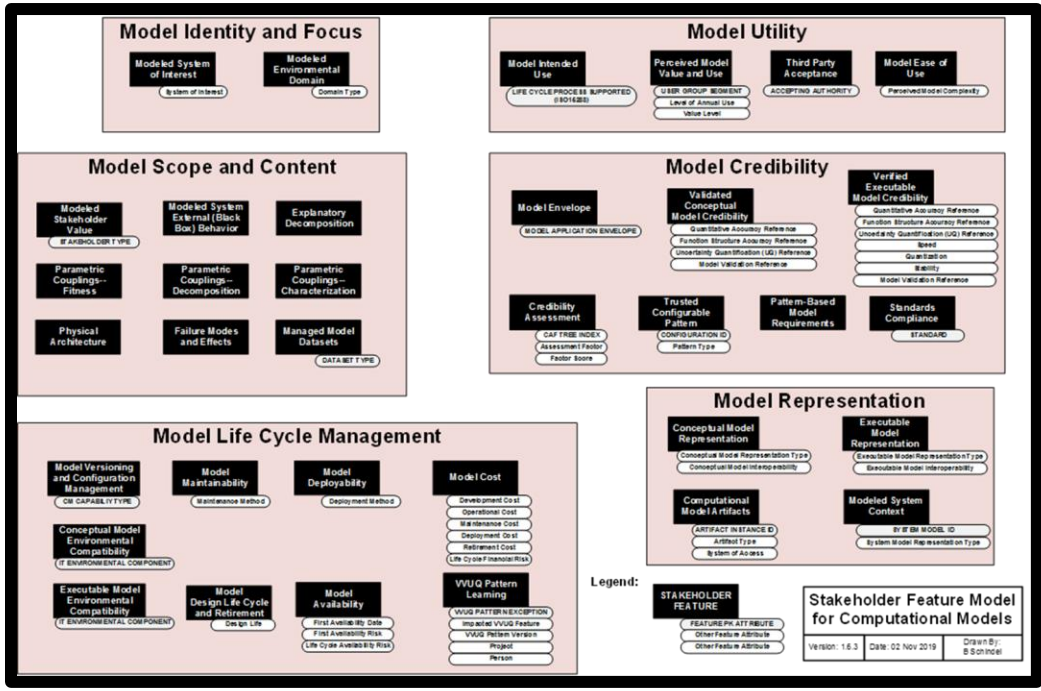
INCOSE ASELCM Level 3 Reference Model—Consistency Thread Section

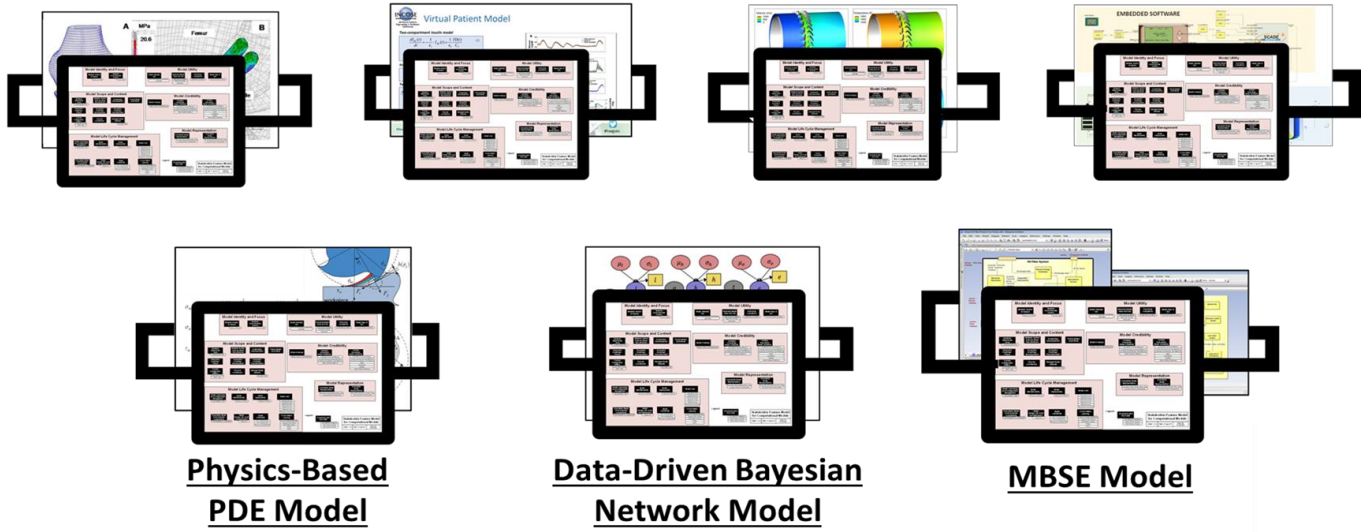
Metadata: Managing the proliferation of virtual model diversity and instances

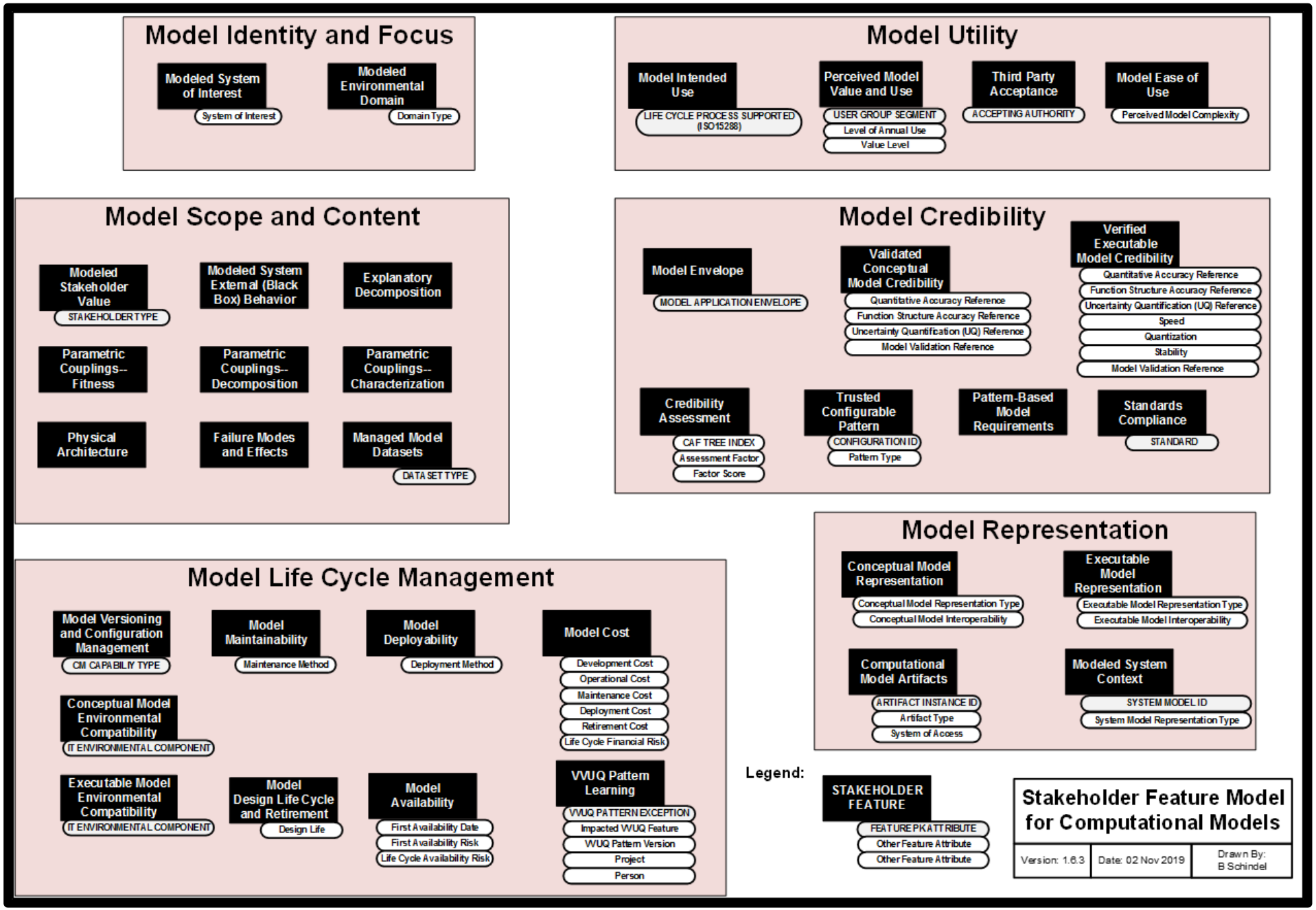


Metadata: Managing the proliferation of virtual model diversity and instances

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



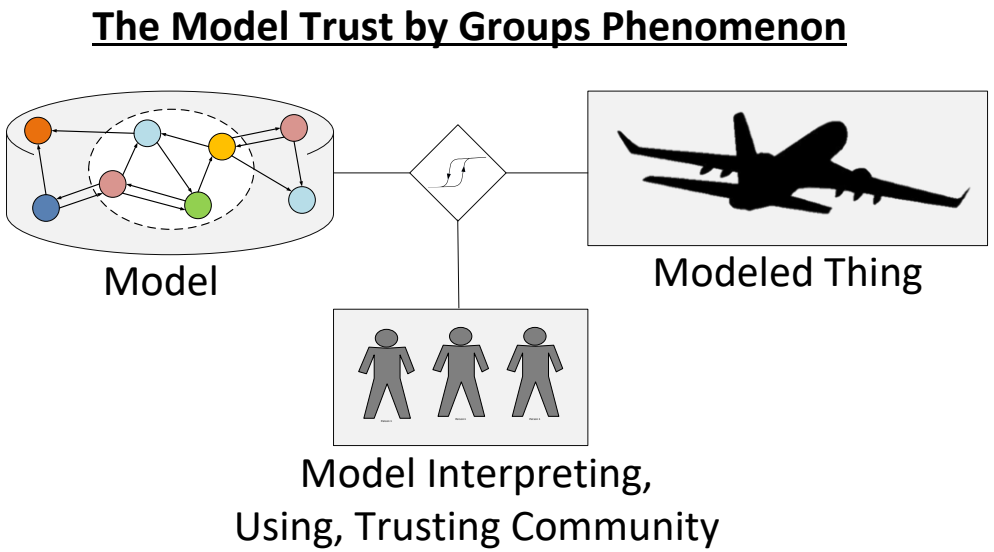




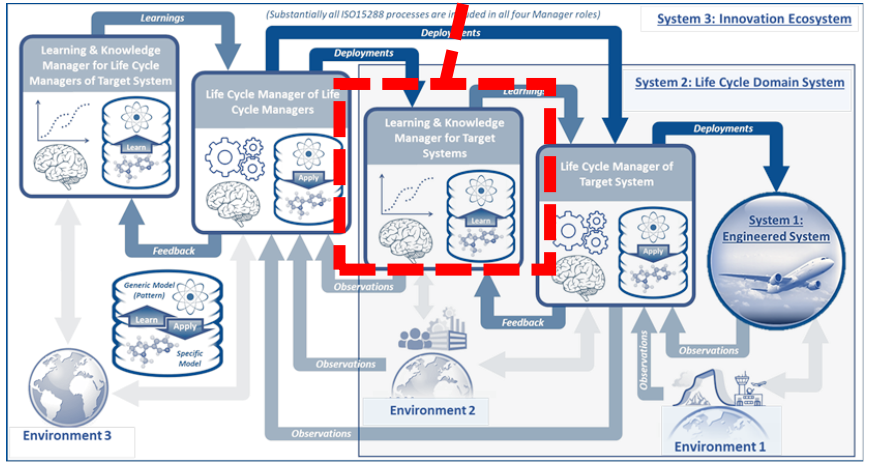
https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:model_characterization_pattern_--_summary_guide_v1.2.1.pdf
and https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:model_characterization_pattern_mcp_v1.9.3.pdf

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.







V&V of *Models*, Per Emerging ASME Model V&V Standards

Does the underlying Model adequately describe what it is intended to describe? (Building the right model?)

Model Validation

Model validated?

Model verified?

Model Verification

Model

Describes Some Aspect of

Does the Model implementation adequately represent what the underlying Model described? (Implementing the model right?)

V&V of *Systems*, Per ISO 15288 & INCOSE Handbook

Do the System Requirements describe what stakeholders need? (Planning the right system?)

System Requirements Validation

Requirements validated?

System of Interest

Design verified?

System Design Verification

Does the System Design define a solution meeting the System Requirements? (Implementing the system right?)

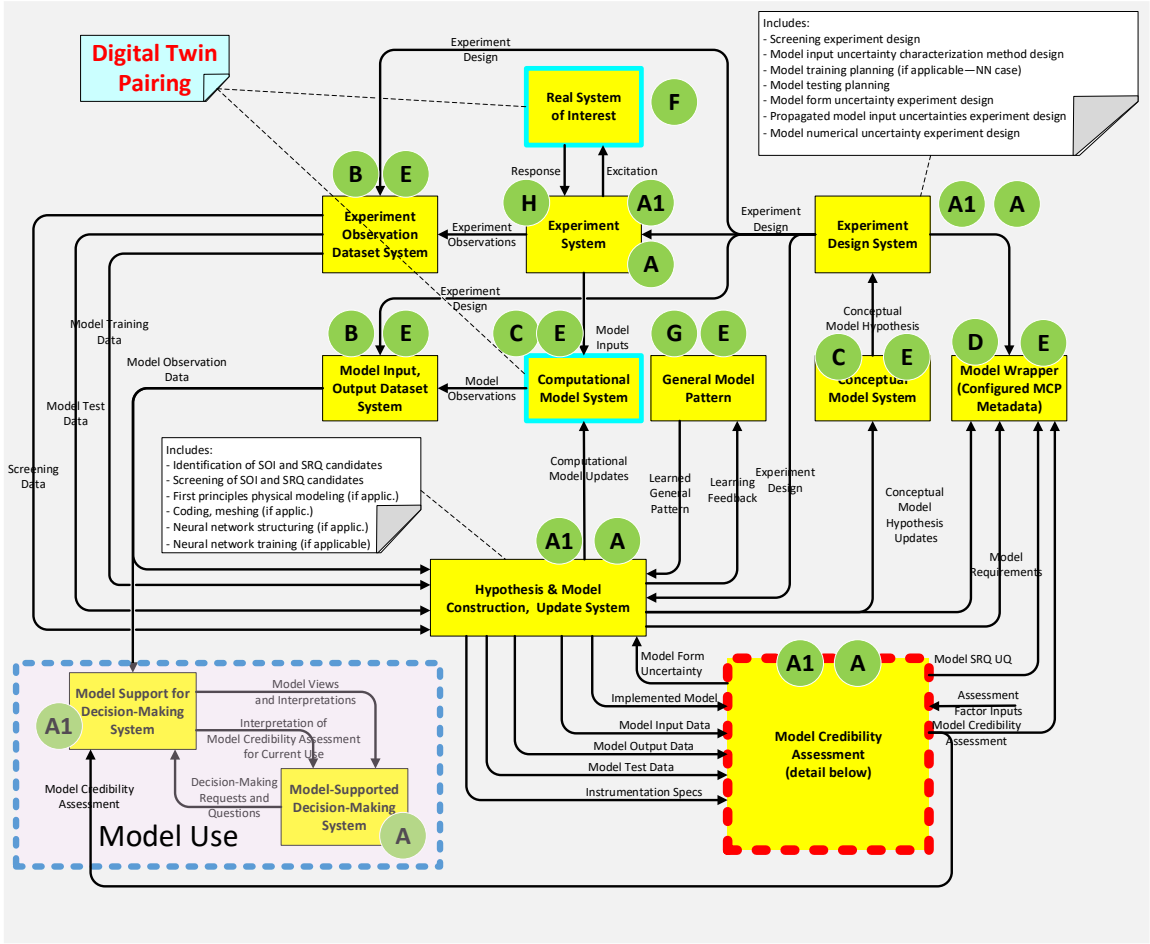
A *model* (on the left) may be used for *system* verification or validation (on the right).

	System 3	System 2	System 1
Level 0			
Level 1			
Level 2			
Level 3			
Level 4			

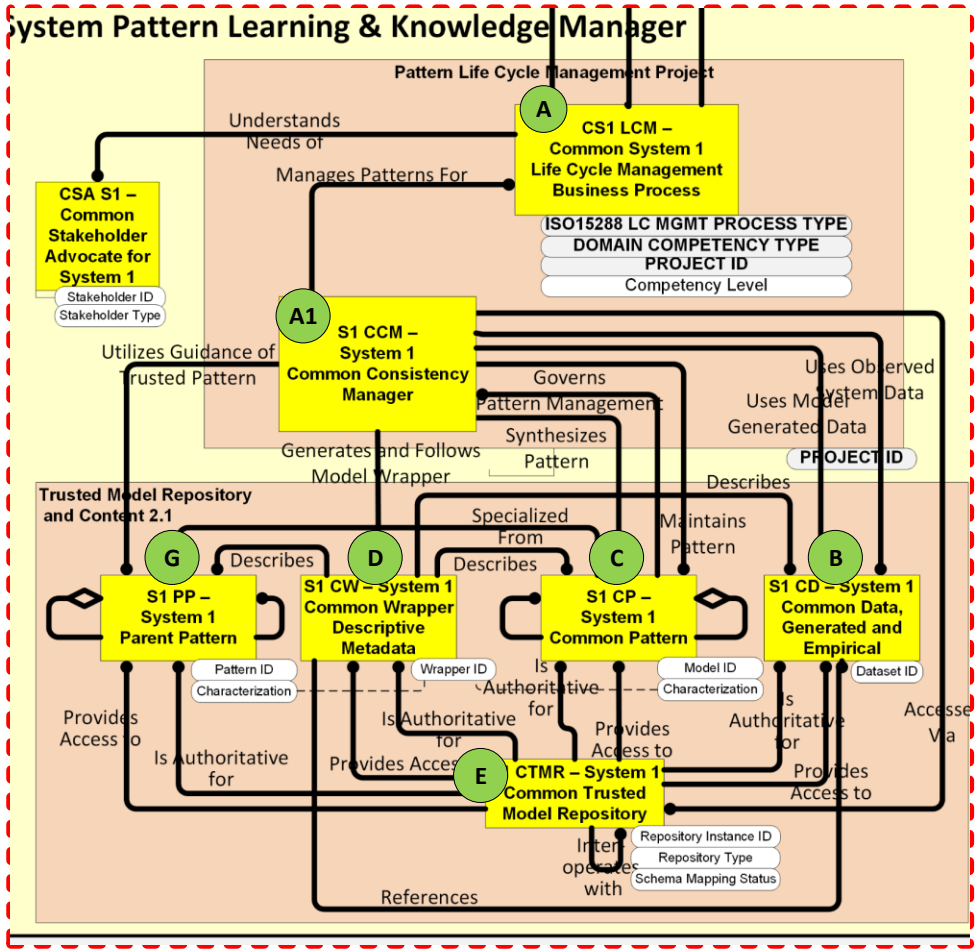
Level 2

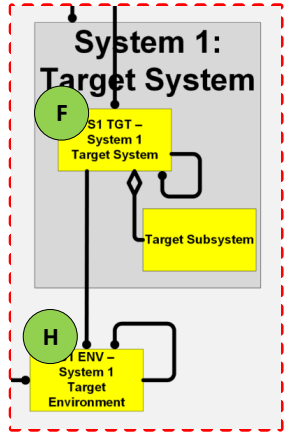
Level 3

System 2, Level 3: Learning Segment



System 2, Level 2, Learning Segment

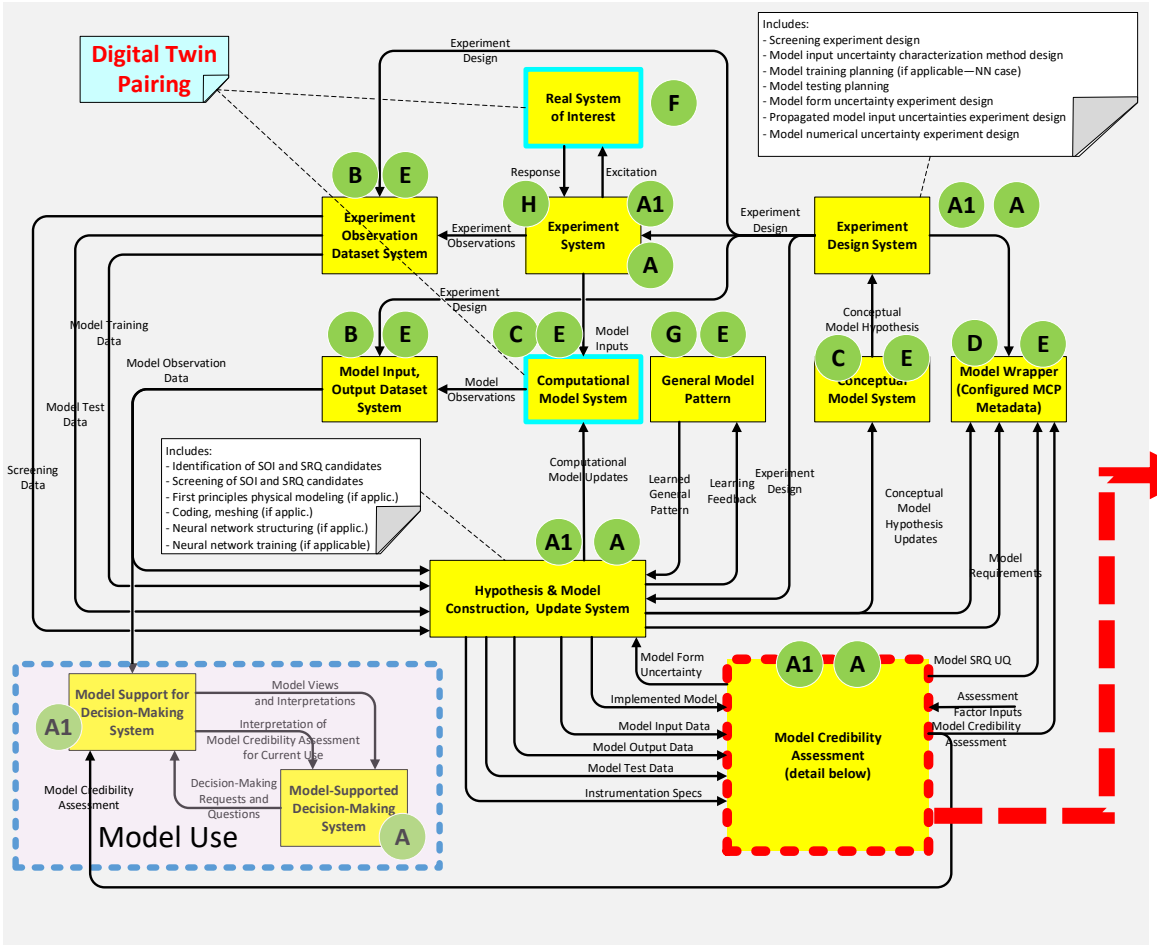


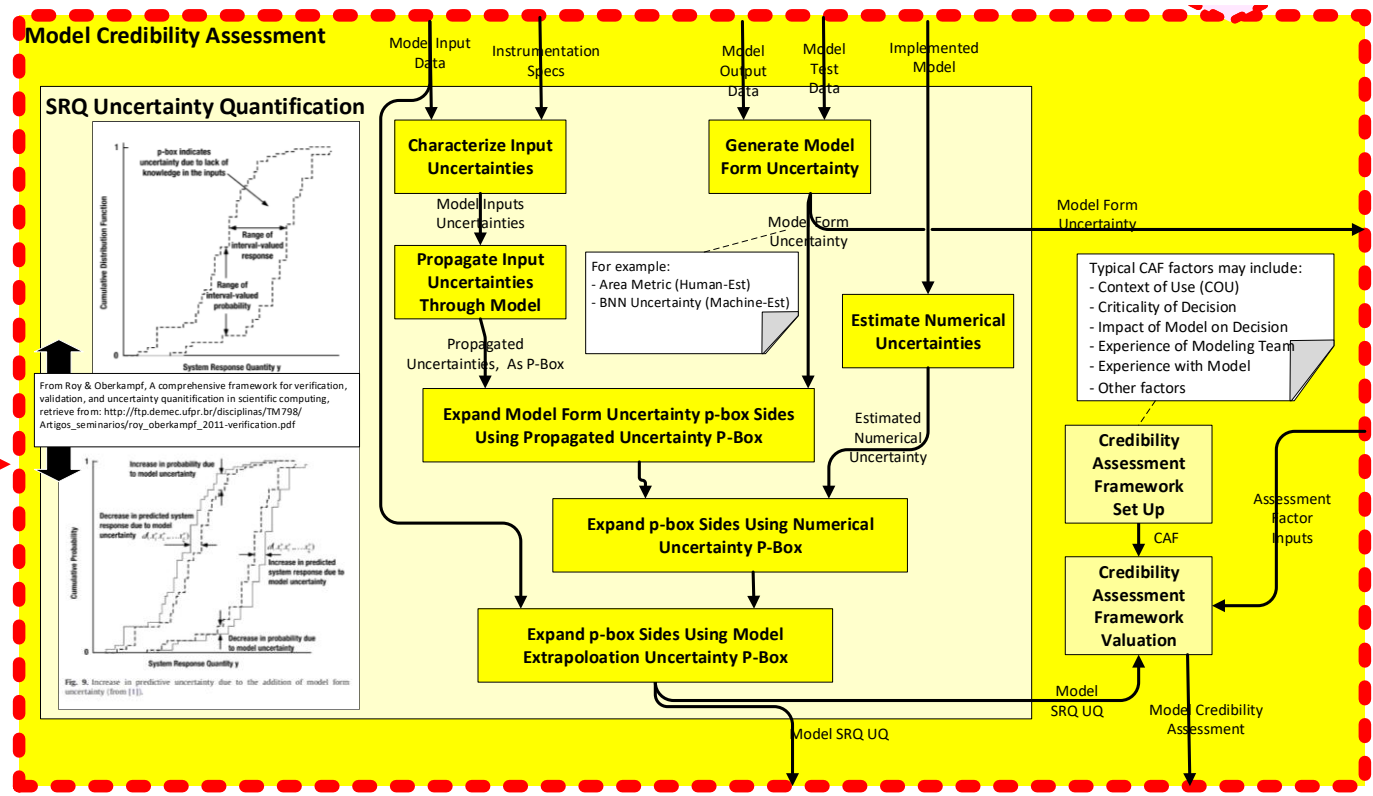


	System 3	System 2	System 1
Level 0			
Level 1			
Level 2			
Level 3		Level 3	
Level 4		Level 4	

System 2, Level 3: Learning Segment

System 2, Level 4, Learning Segment

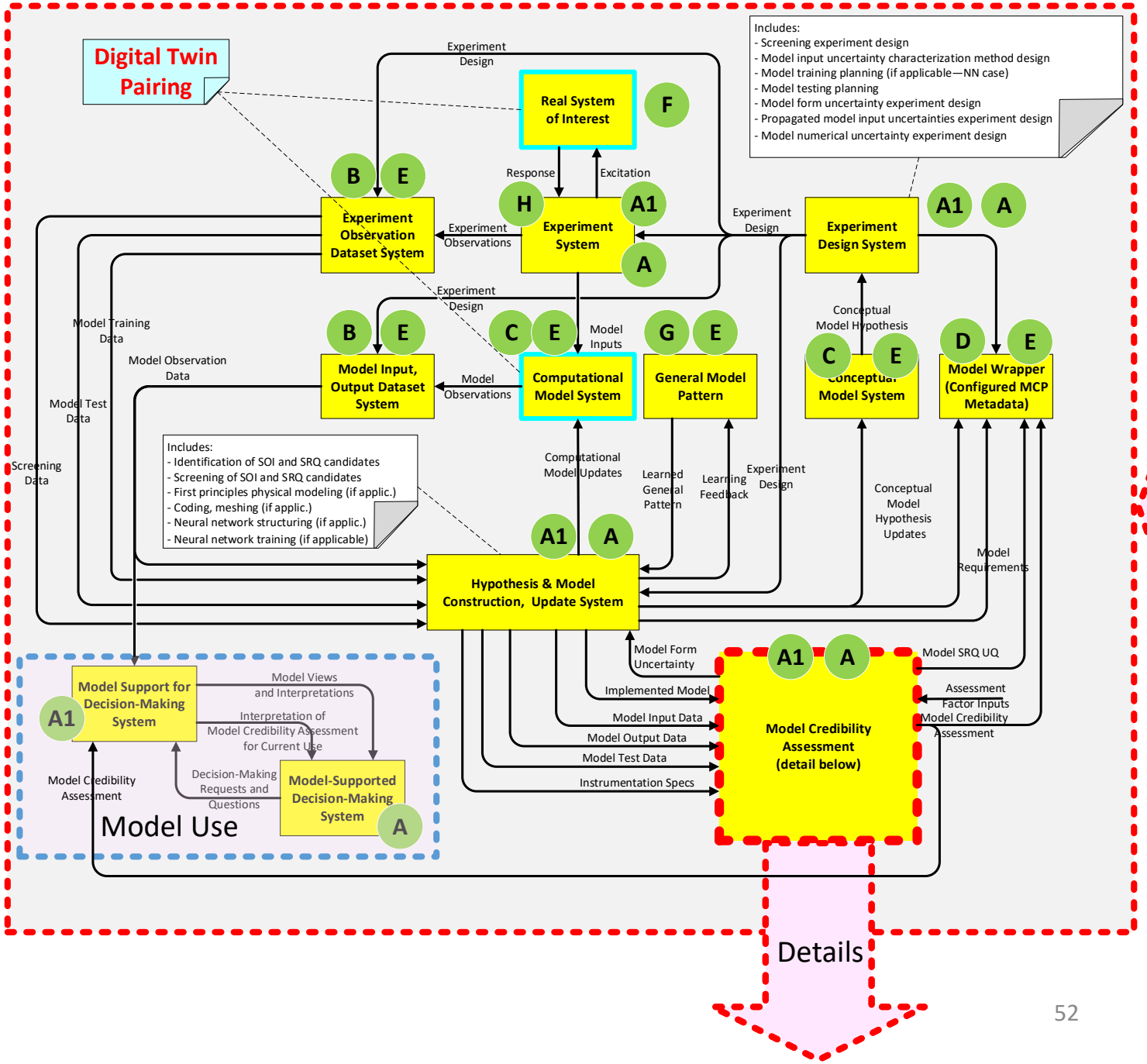




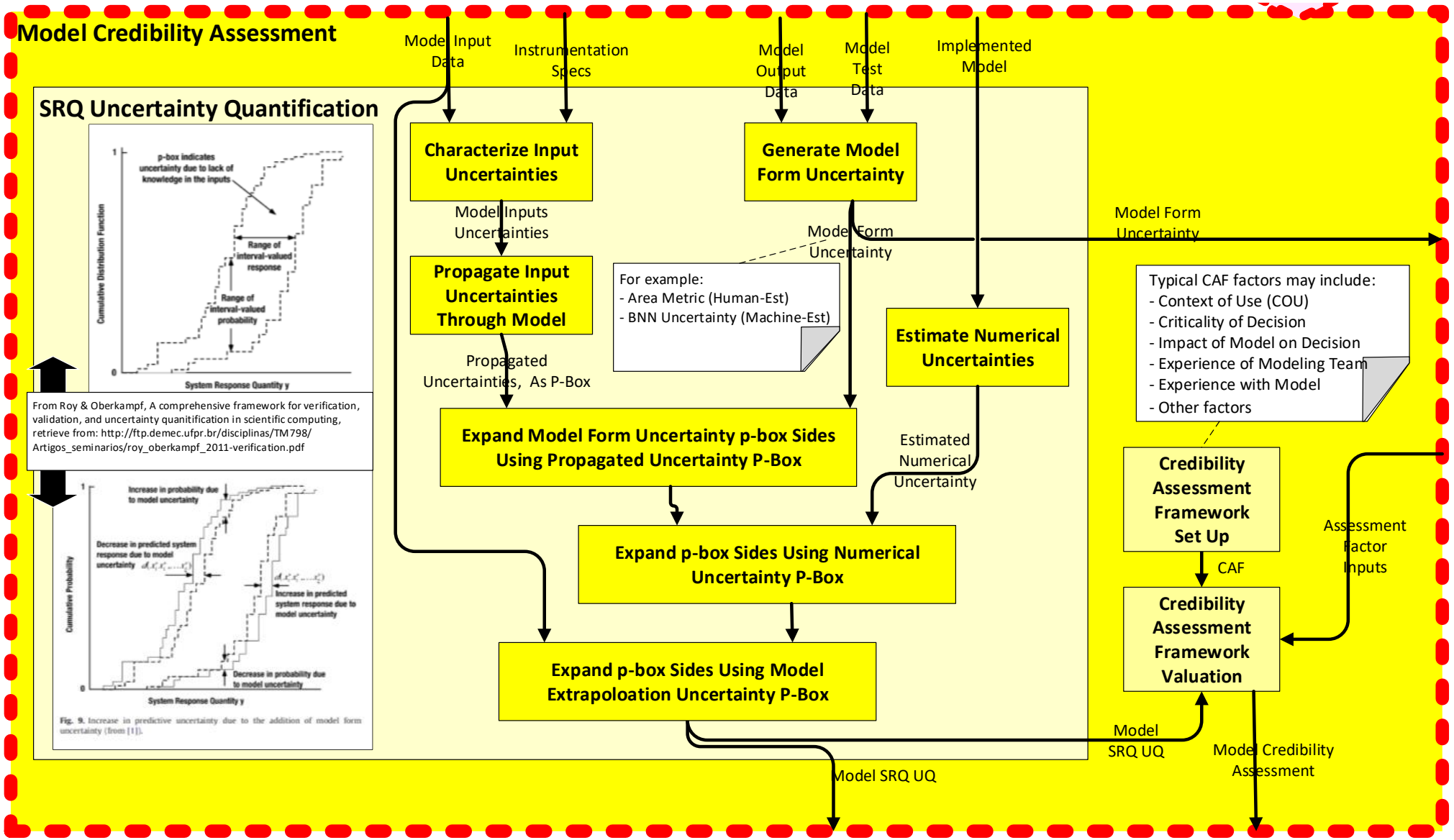
Virtual Model Credibility Assessment-- including Model Verification, Validation, Uncertainty Quantification (VVUQ)

Level 3 of learning segment

System 2: Overview of Virtual Model Creation, Validation, and Utilization

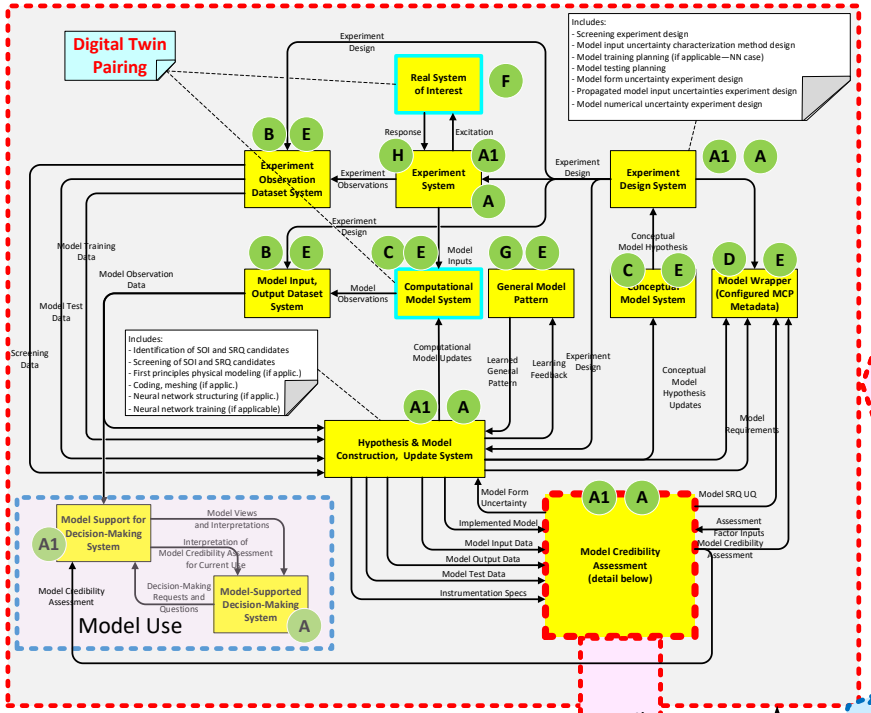


Level 4 of learning segment



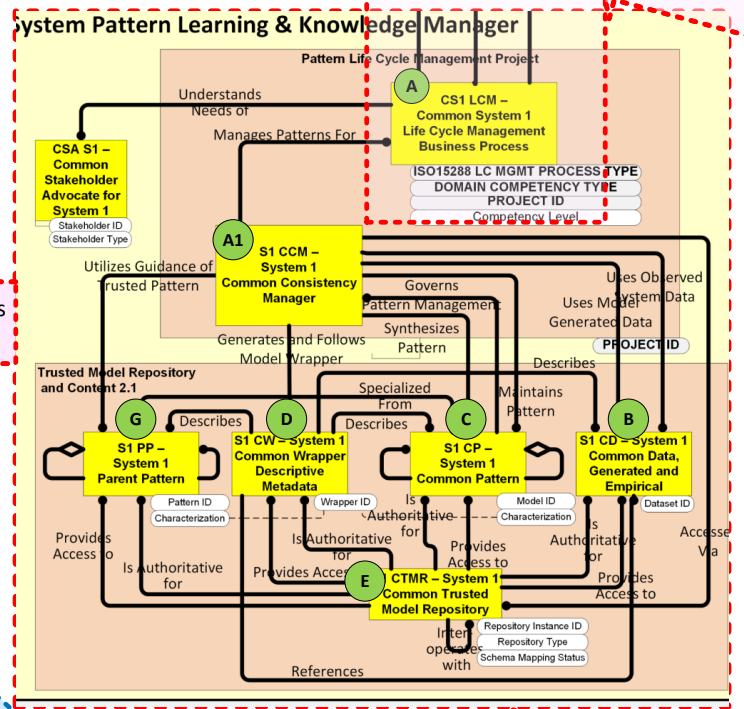
Virtual Model Credibility Assessment-- including Model Verification, Validation, Uncertainty Quantification (VVUQ)

System 2: Overview of Virtual Model Creation, Validation, and Utilization

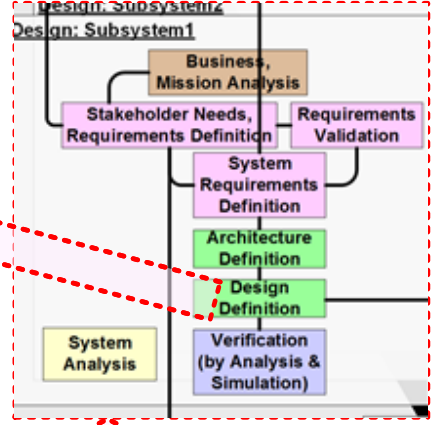


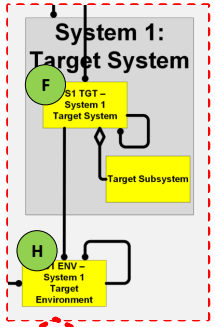
Details

System 2: Each ISO15288 Process Can Interact with Virtual Model Data



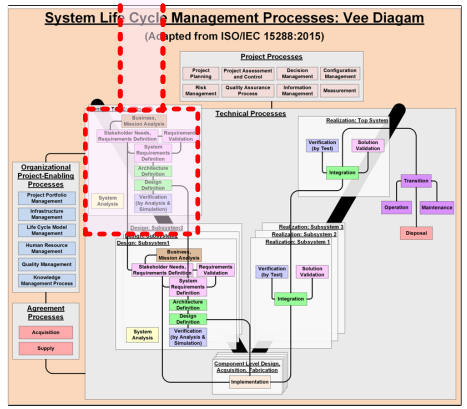
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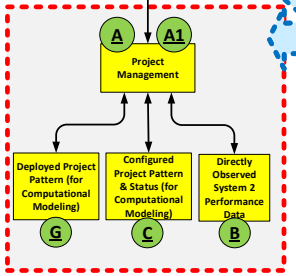


Details

ISO15288 Processes ("Vee Diagram") – Basis of the INCOSE SE Handbook



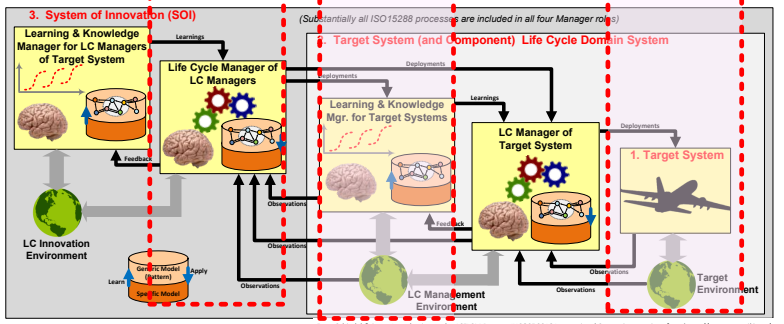
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System 3:
Configures Project from Learned Pattern, Tracks and Controls Project, "Scores" Project Performance, Learns More

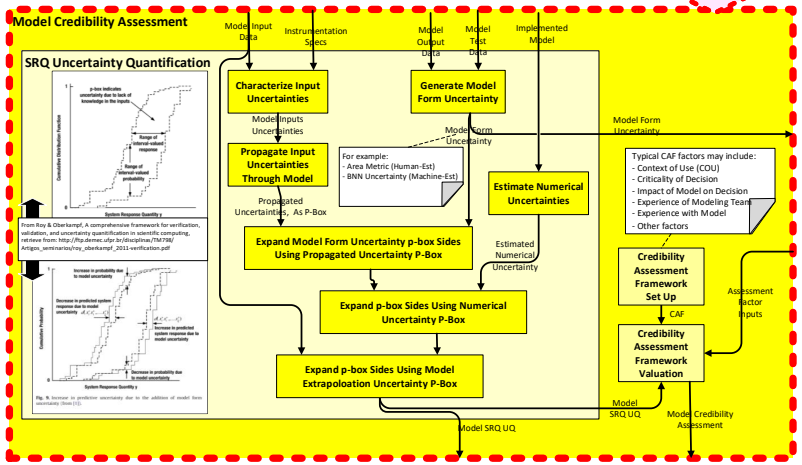
Populates

Details



From Schindel & Dove, Introduction to the ASELCM Pattern, INCOSE 2016 International Symposium, retrieve from https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:is2016_intro_to_the_aselcm_pattern_v1.4.8.pdf

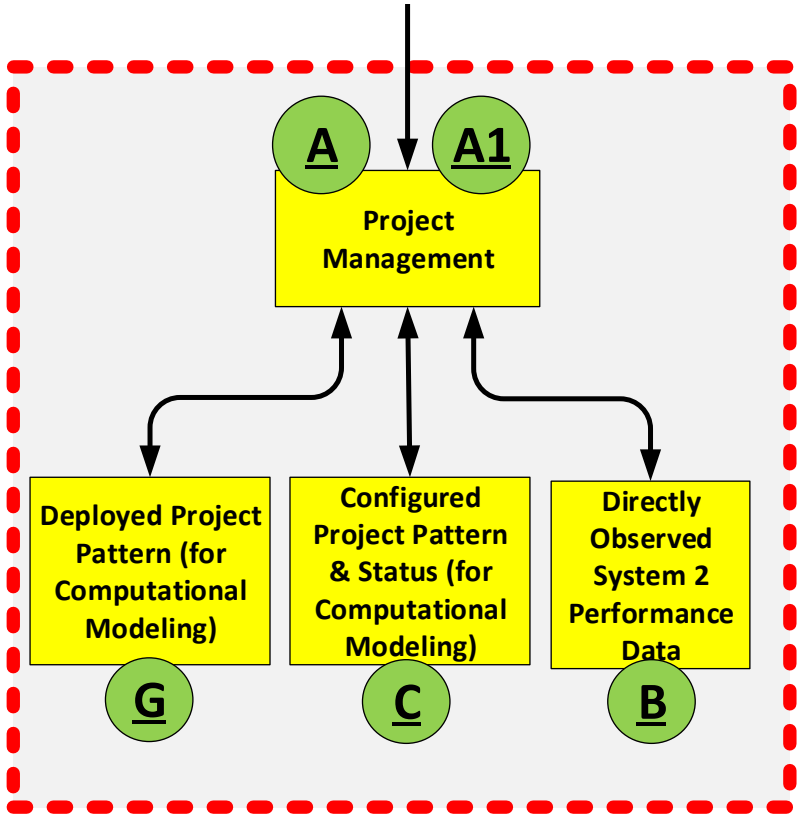
INCOSE ASELCM Pattern
Virtual Learning Ecosystem Framework



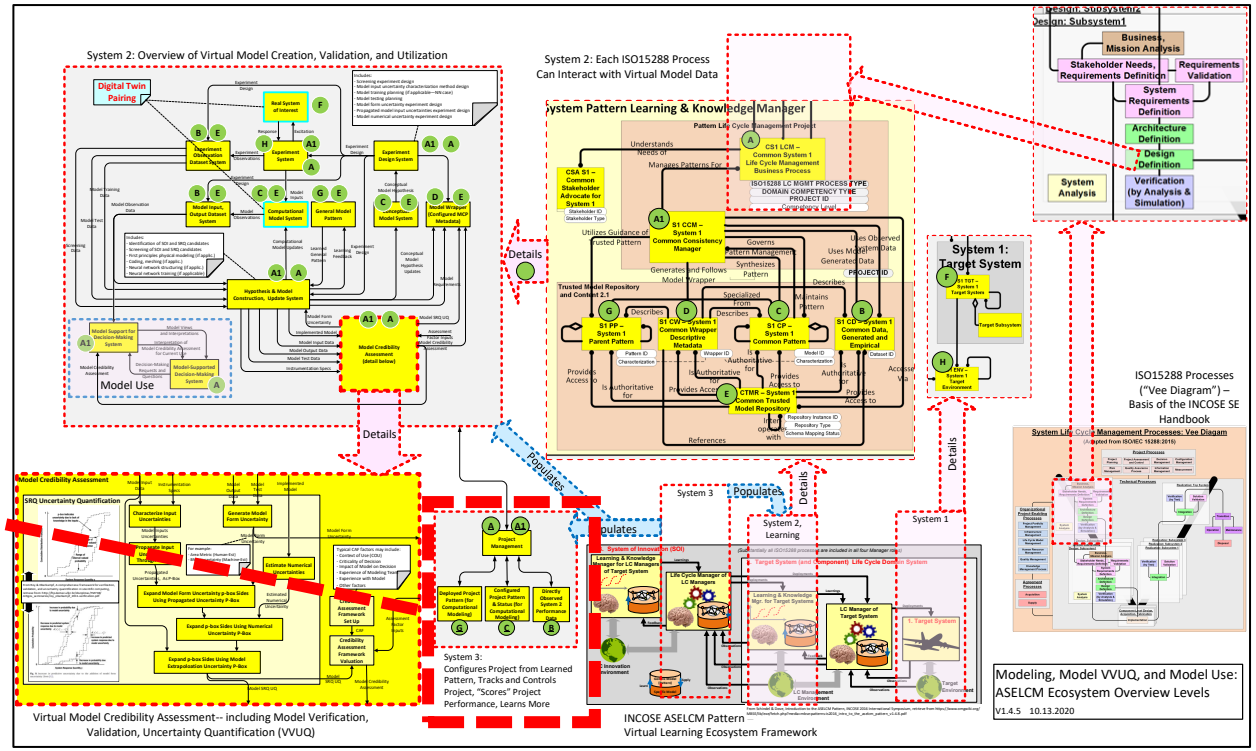
Virtual Model Credibility Assessment-- including Model Verification, Validation, Uncertainty Quantification (VVUQ)

Modeling, Model VVUQ, and Model Use: ASELCM Ecosystem Overview Levels

V1.4.5 10.13.2020



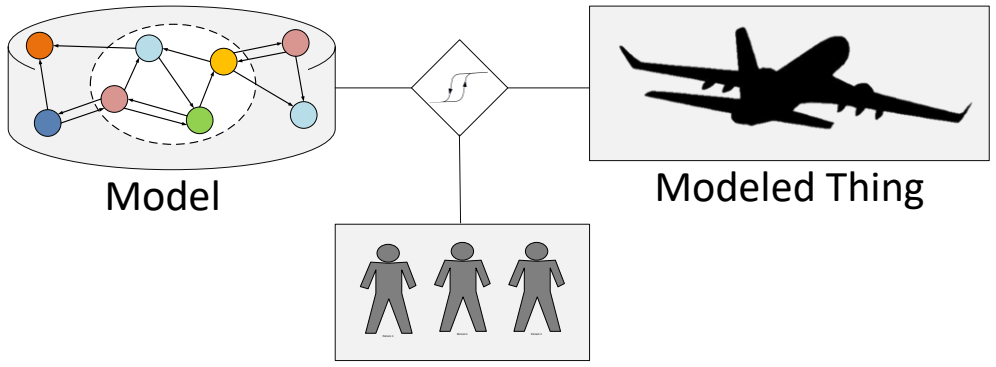
System 3:
Configures Project from Learned Pattern, Tracks and Controls Project, “Scores” Project Performance, Learns More

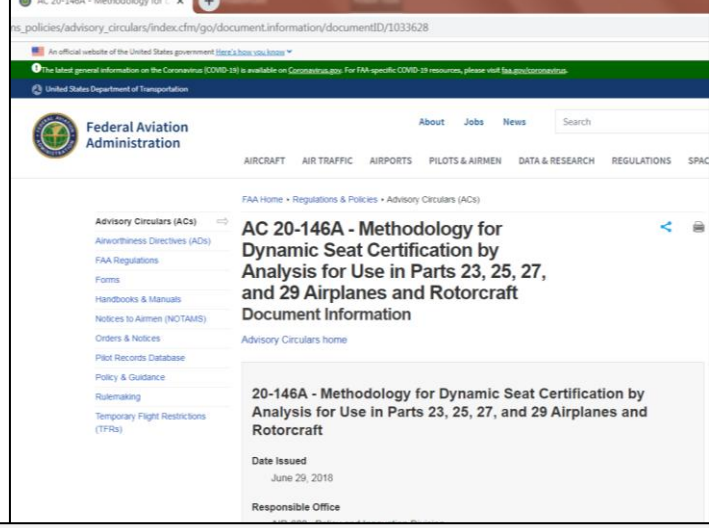


Group trust in the credibility of models

- 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).

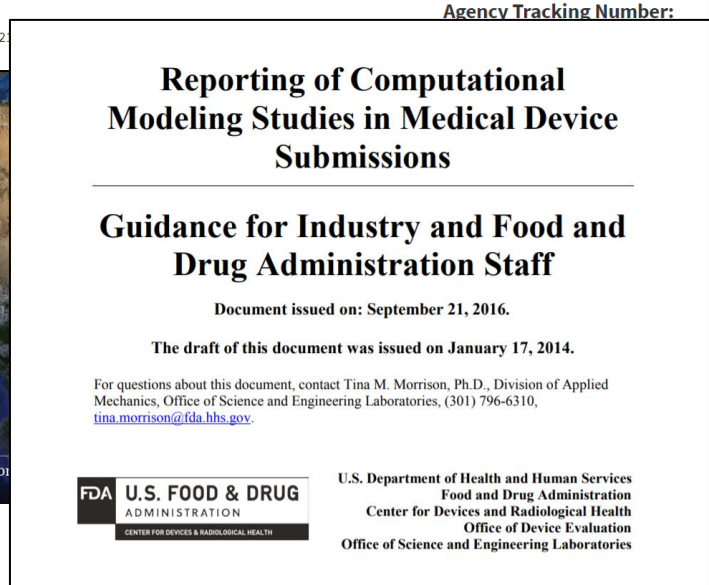
The Model Trust by Groups Phenomenon



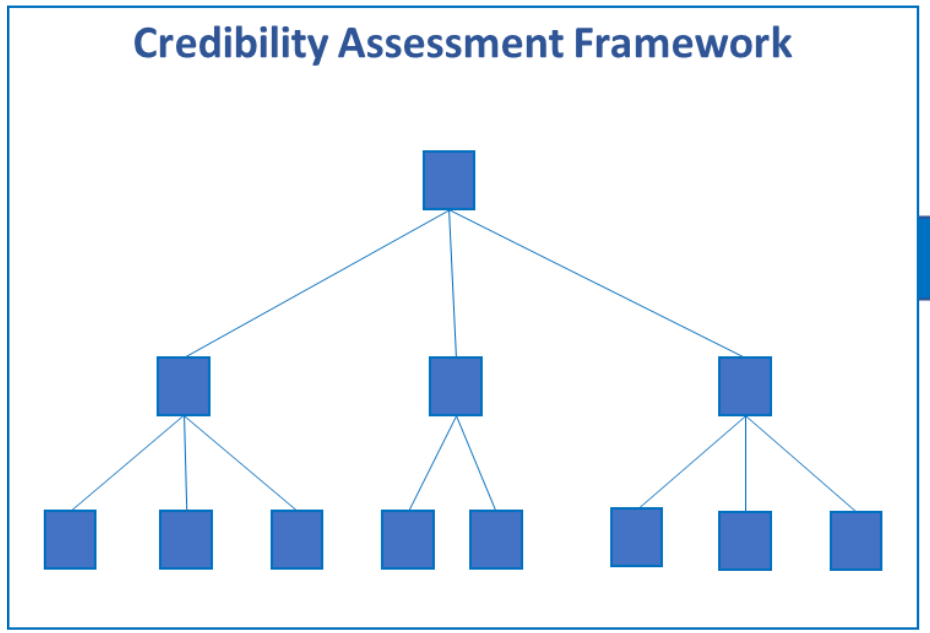


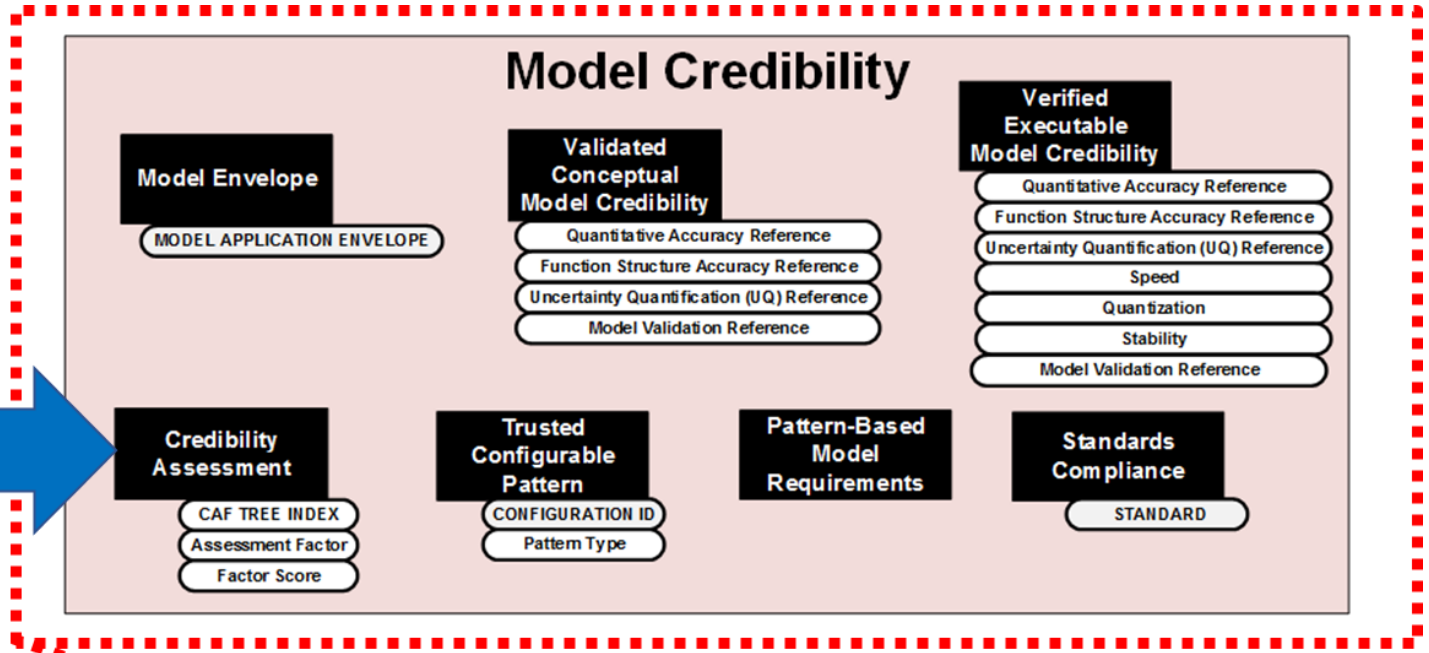




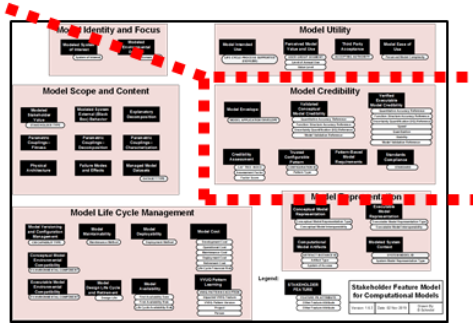


Credibility Assessment Framework: A tree-based framework rolling up weighted credibility assessment factors (both objective and subjective) with recorded scores, used to create a more transparent representation of what a model's credibility assessment included and what was its outcome—becomes part of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





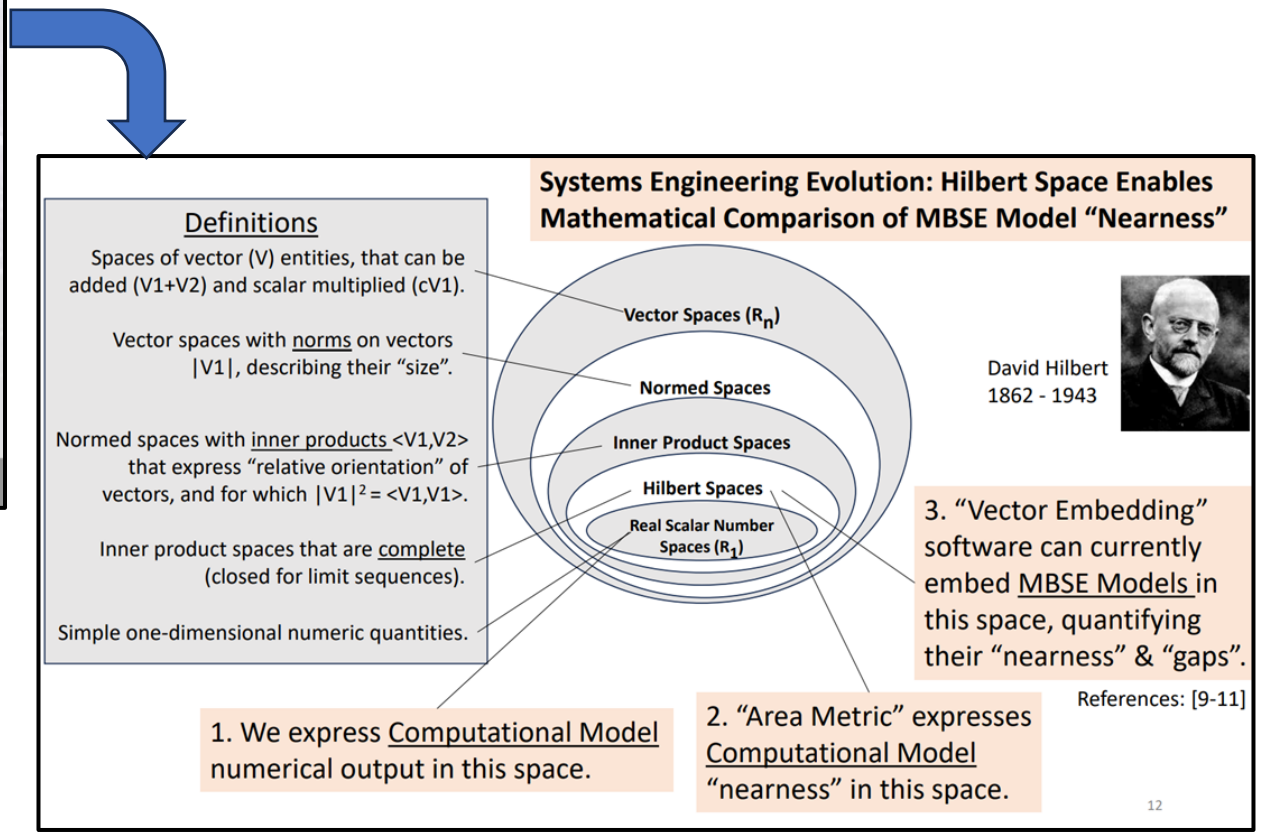
Model Characterization Pattern (MCP)



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Rosetta Stone Project; Confidence in Models

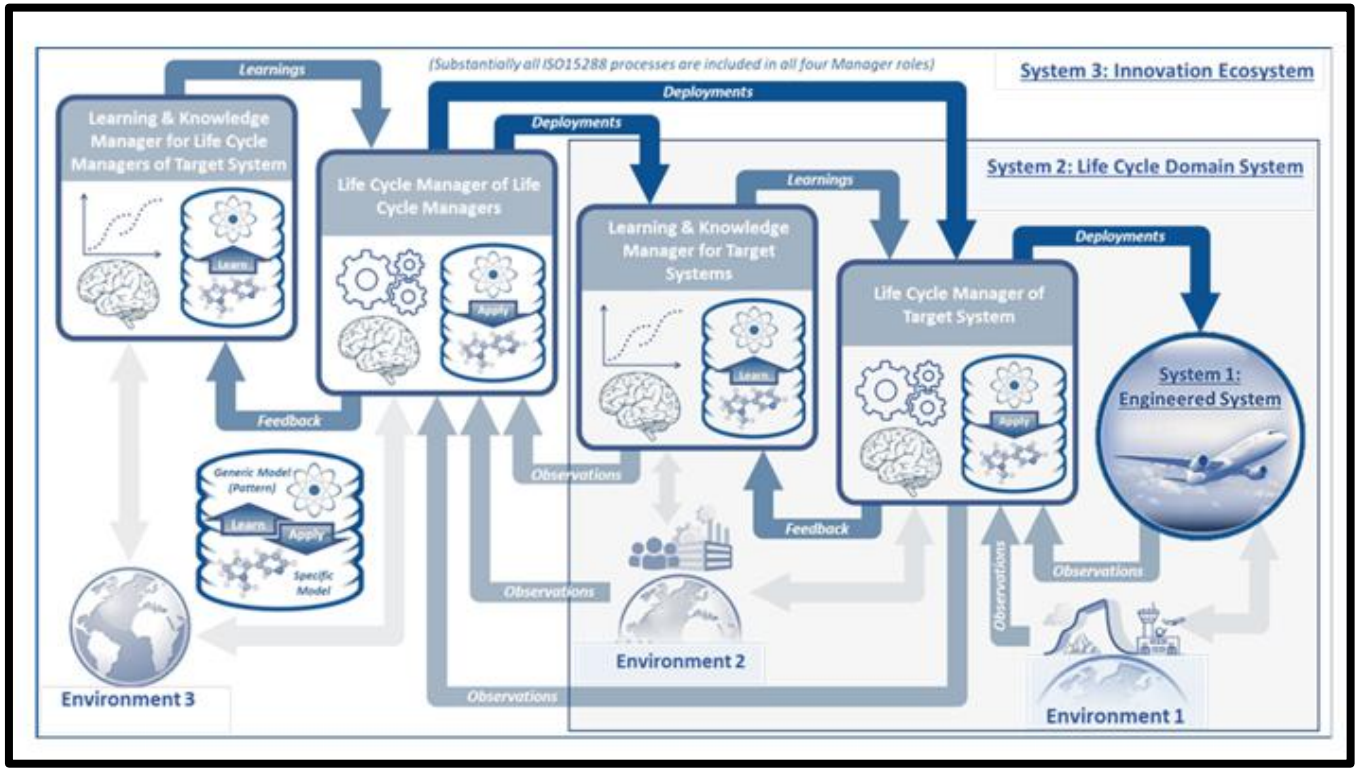




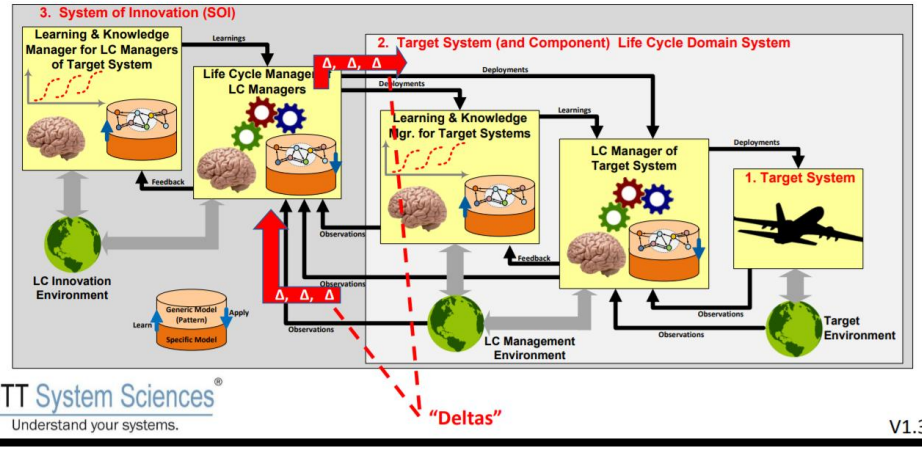
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Effective evolution of the ecosystem itself

The role of System 3

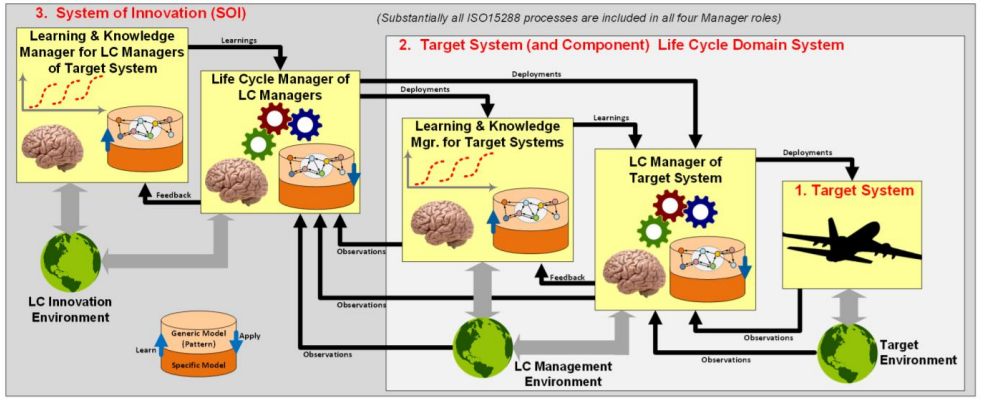


Attachment I: Example Use of ASELCM Pattern for Analyzing Current State, Describing Future State, and Constructing Incremental Release Roadmap to Future



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

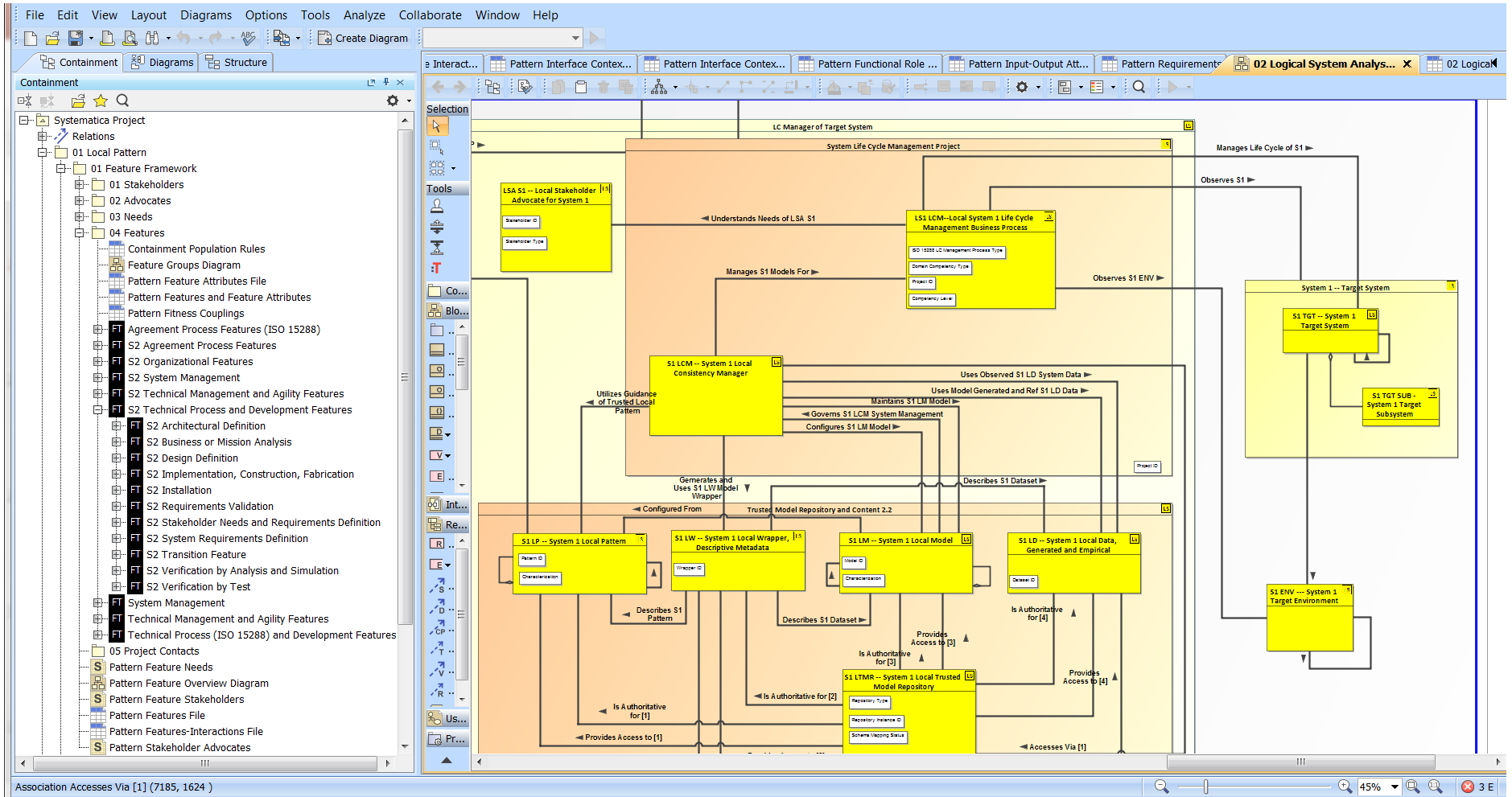
ASELCM Reference Pattern: Reference Configuration Stages for Models, Model Patterns, and the Real Systems They Represent



https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:configuration_stages_v1.5.8c.pdf

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.



In-Class Exercise

Navigate within the ASELCM Pattern to locate Features, Interactions, Roles, Requirements, and/or Design Components of interest to your projects, your roles, your business, and its future evolution.

Homework assignment

For one or more specific client/project(s) you have worked, are working, or plan to work, . . .

1. List the most important "System 1 consistency management" cases. What are the key consistencies to be aligned?
2. List the most important "System 2 consistency management" cases. Whare are the key consistencies to be aligned?
3. List the most important "System 1 Variant" aspects. What different System 1 configurations apply?
4. List the most important "System 2 Variant" aspects. What different System 2 configurations apply?

Discussion, Q&A.

- What, if any, uses shall we make of this framework?
- Which customers have issues in this space?
-
-
-
-



Introductory Grouped ASELCM Reference Sets

A. Introductory materials on ASELCM Ecosystem Reference Pattern:
   - https://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_v1.2.2.pdf
   - https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:configuration_stages_v1.5.8c.pdf
B. Introductory summary to some uses of it in analyzing and planning the ecosystem and its progress over time:
   - https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:example_evolutionary_roadmap_v1.3.3a.pdf
   - https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:risk_and_agility_as_optimal_control_and_estimation_v1.7.2.pdf
   - https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:model_based_maturitiy_planning_asme_incose_may_2017.pdf
C. INCOSE case studies specific to agility, using aspects of the ecosystem pattern:
   - is2016_--_autonomous_vehicle_development_navy_spawar.pdf
   - is2017--northrup_grumman_case_study_dove_and_schindel_bp.pdf
   - is2018_-_aselcm_lmc_case_study.pdf
   - pap170424syscon-casestudyrc.pdf
D. Summary of a “digital thread with learning” demonstration project, via collaborating large OEM and supply chain small to medium manufacturers:
   - https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:team_top_gun_idn_presentation_06.09.2021_v2.1.1.pdf
E. Not about the ASELCM pattern specifically, but rather about all patterns, and related pattern-based methods, which can occur “inside” the ecosystem:
   - 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:pbse_tutorial_glrc_2016_v1.7.4.pdf

More complete related subject references, by source

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