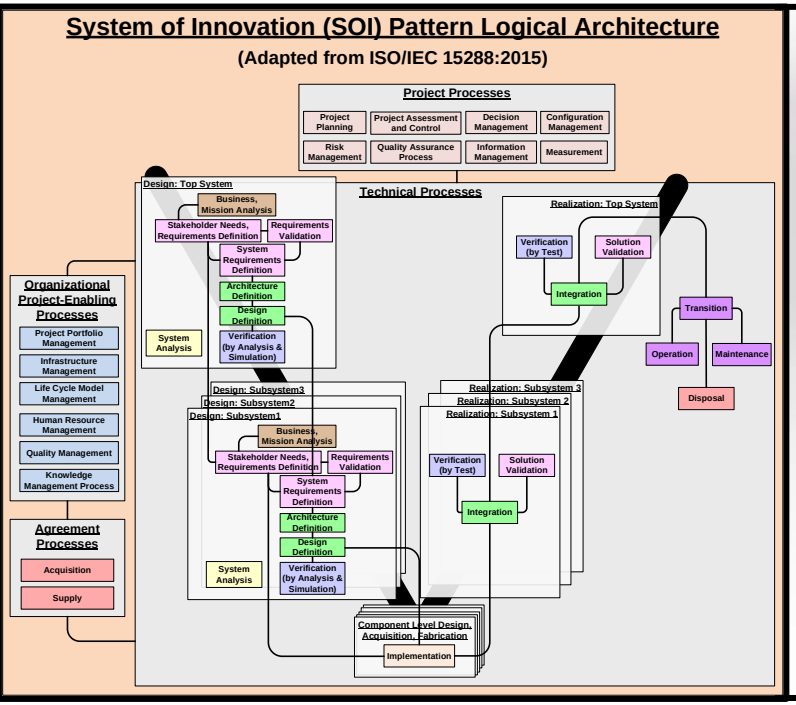
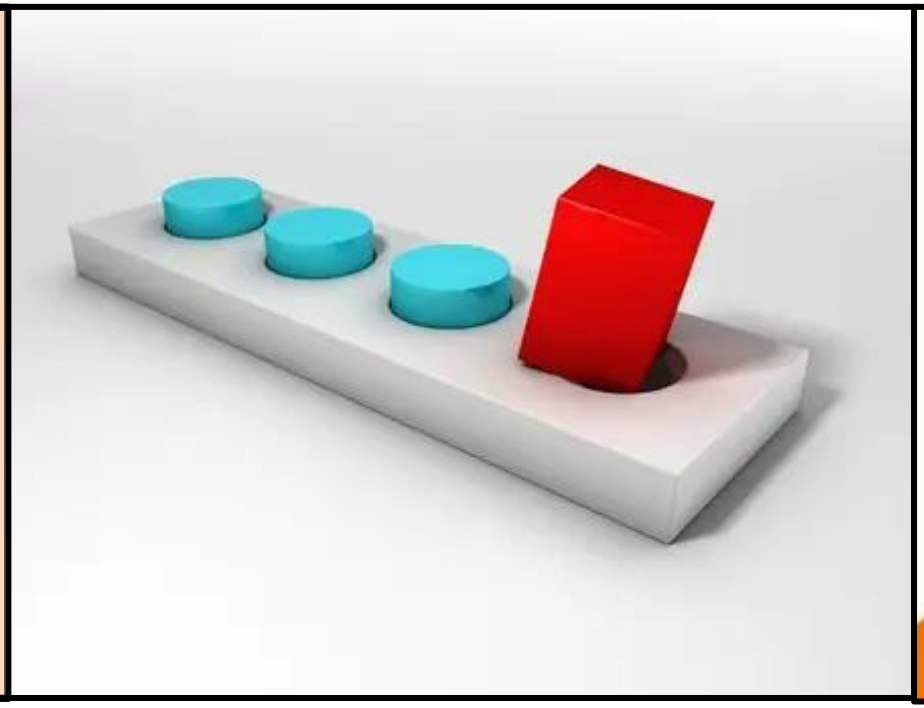
All Decisions Across Life Cycles of Systems Are Reconciliations of Inconsistencies

Life Cycle Mgmt. Decisions



Inconsistencies



Decisions

INCOSE North Texas Chapter Meeting

August 8, 2023 V1.2.2

Bill Schindel

INCOSE Patterns Working Group

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Abstract

- Systems engineering teaches us about a diverse array of decisions occurring during system development, production, distribution, operation, sustainment, retirement.
- Because of their diversity, it is challenging to become knowledgeable about the full range of these decisions, made by different decision-makers over a long time.
- It is therefore surprising to realize that these decisions can be seen in a unified way as *reconciliations of recurring inconsistencies*.
- The INCOSE Patterns Working Group and Decision Analysis Working Group have recognized and begun capitalizing on this paradigm, which springs from the INCOSE Innovation Ecosystem Pattern.
- In this talk, we will examine these decisions in the Digital Engineering context, and how they represent instances of a shared configurable pattern. This has in-practice implications for the Digital Twin, Digital Thread, management of model credibility, collective learning by enterprise teams, and automation of innovation assistance.
- It also provides theoretical insight into the performance of large scale programs and projects confronted with complexity challenges.

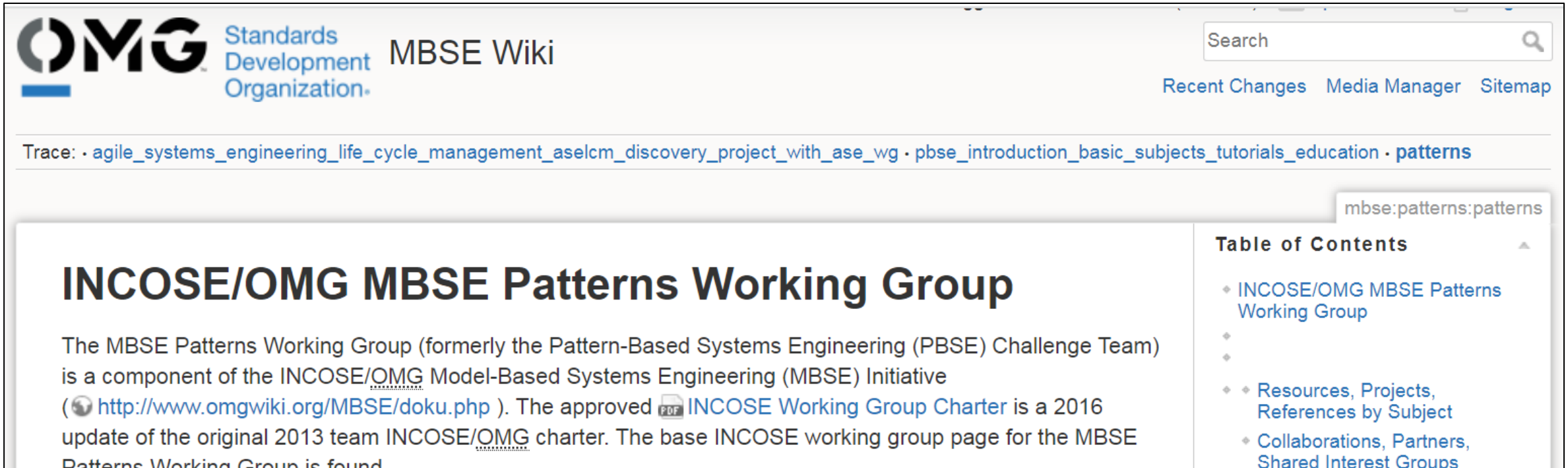
Contents

- The INCOSE MBSE Patterns Working Group
- Decisions Across the Life Cycle of Systems
- Consistency Management and the Decision Management Pattern
- Insights for Improving Group Learning
- Human and Machine Learning, System Energy and Complexity
- Interested? How to get involved
- Questions, discussion

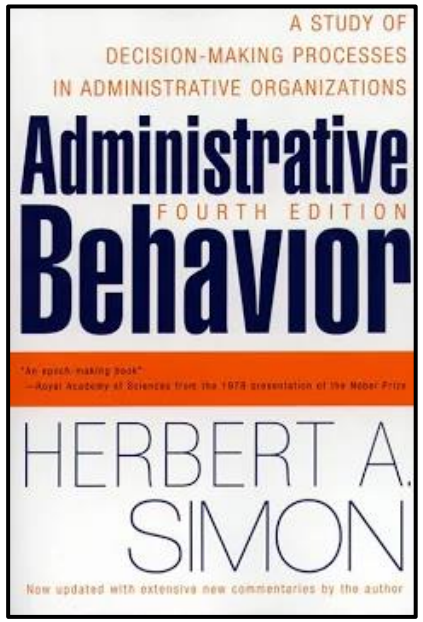
- References
- Speaker background

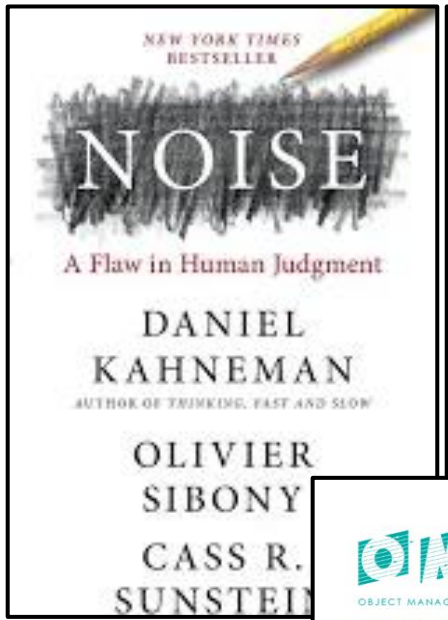
The INCOSE MBSE Patterns Working Group

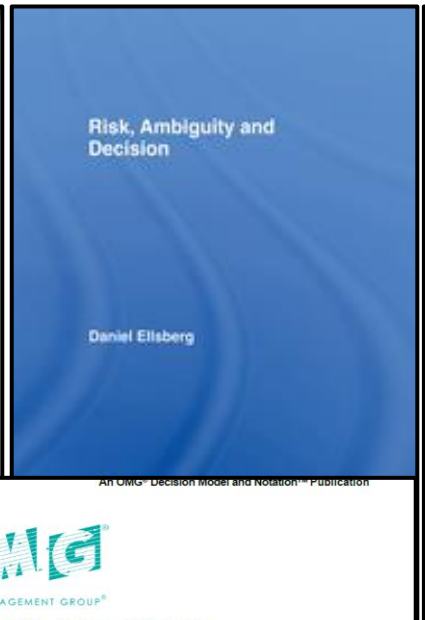
- Originated in 2013 as one of the INCOSE-OMG MBSE Initiative challenge teams, advancing in 2016 to INCOSE Working Group.
- Focused on model-based representation of recurring, configurable system-level patterns.
- History of projects emphasizing collaboration with other technical societies & INCOSE Working Groups.
- This has recently included collaboration with the INCOSE Decision Analysis Working Group, in which we have pursued a Decision Analysis Pattern that is related but somewhat different from their work.
- Numerous publications and resources available from INCOSE MBSE 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!

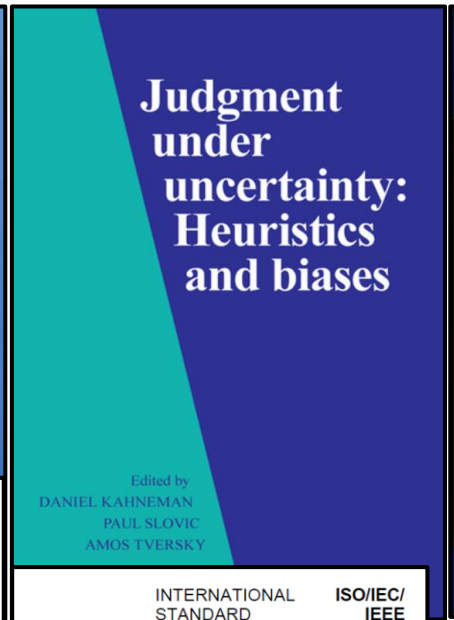


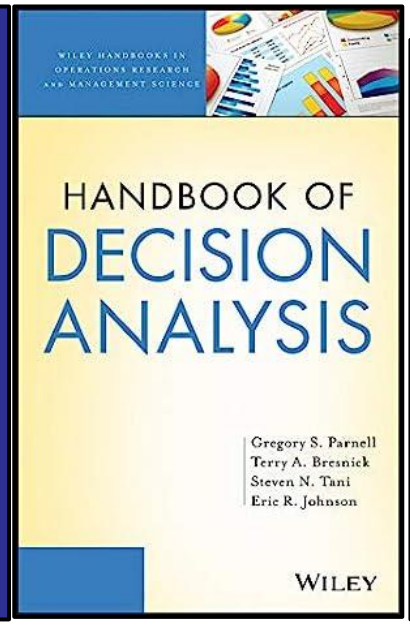
Decision Analysis: Subject of Extensive Historical Work, Multiple Nobel Prizes, Numerous Theories, Pragmatics, References

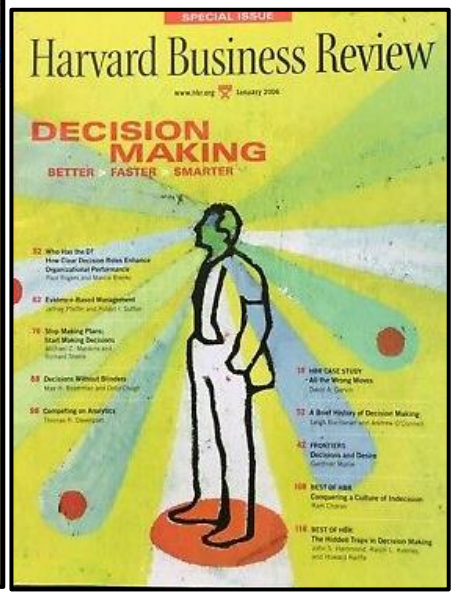


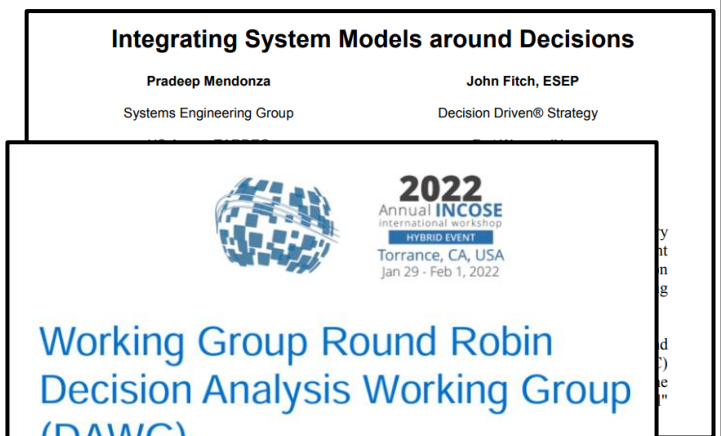


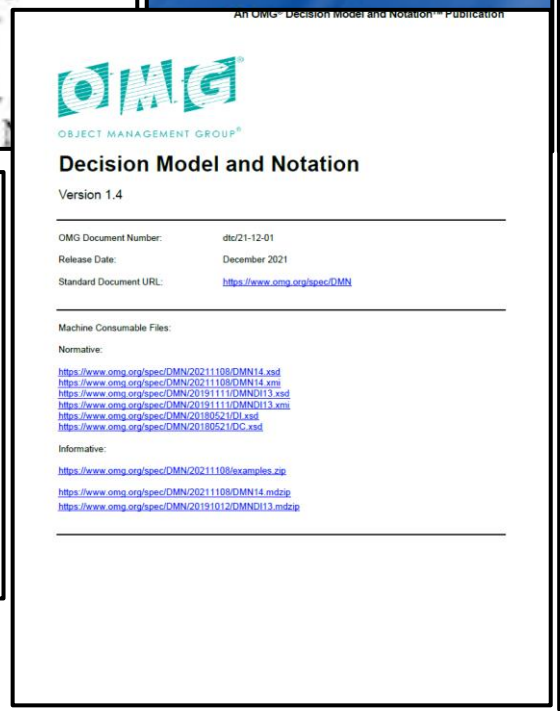


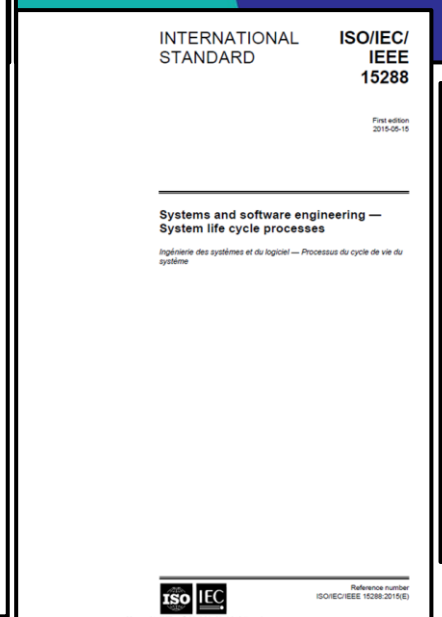


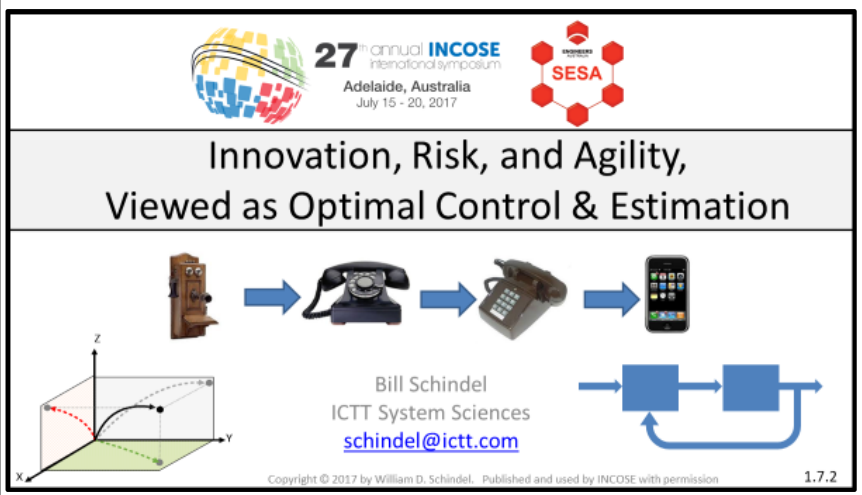






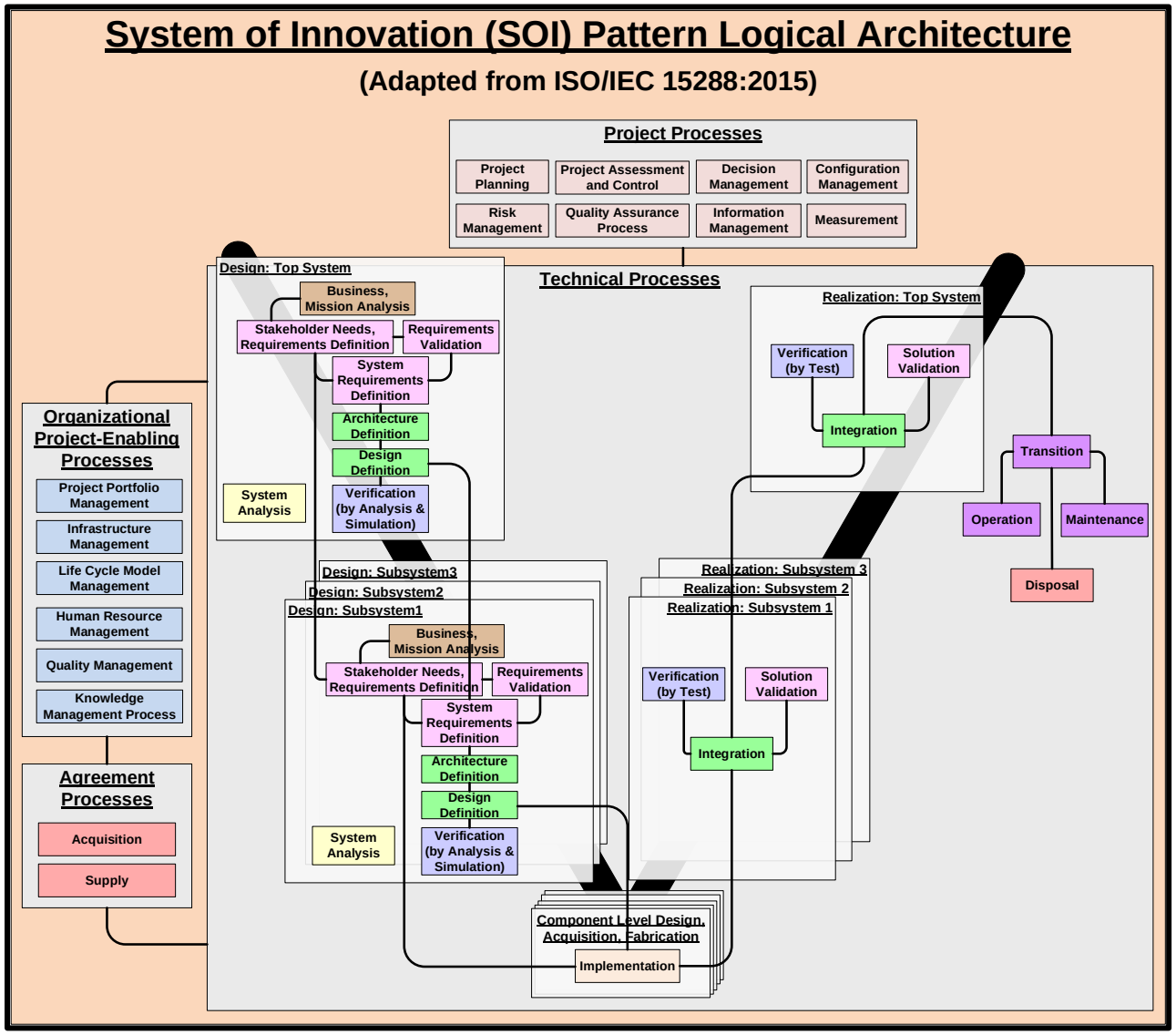


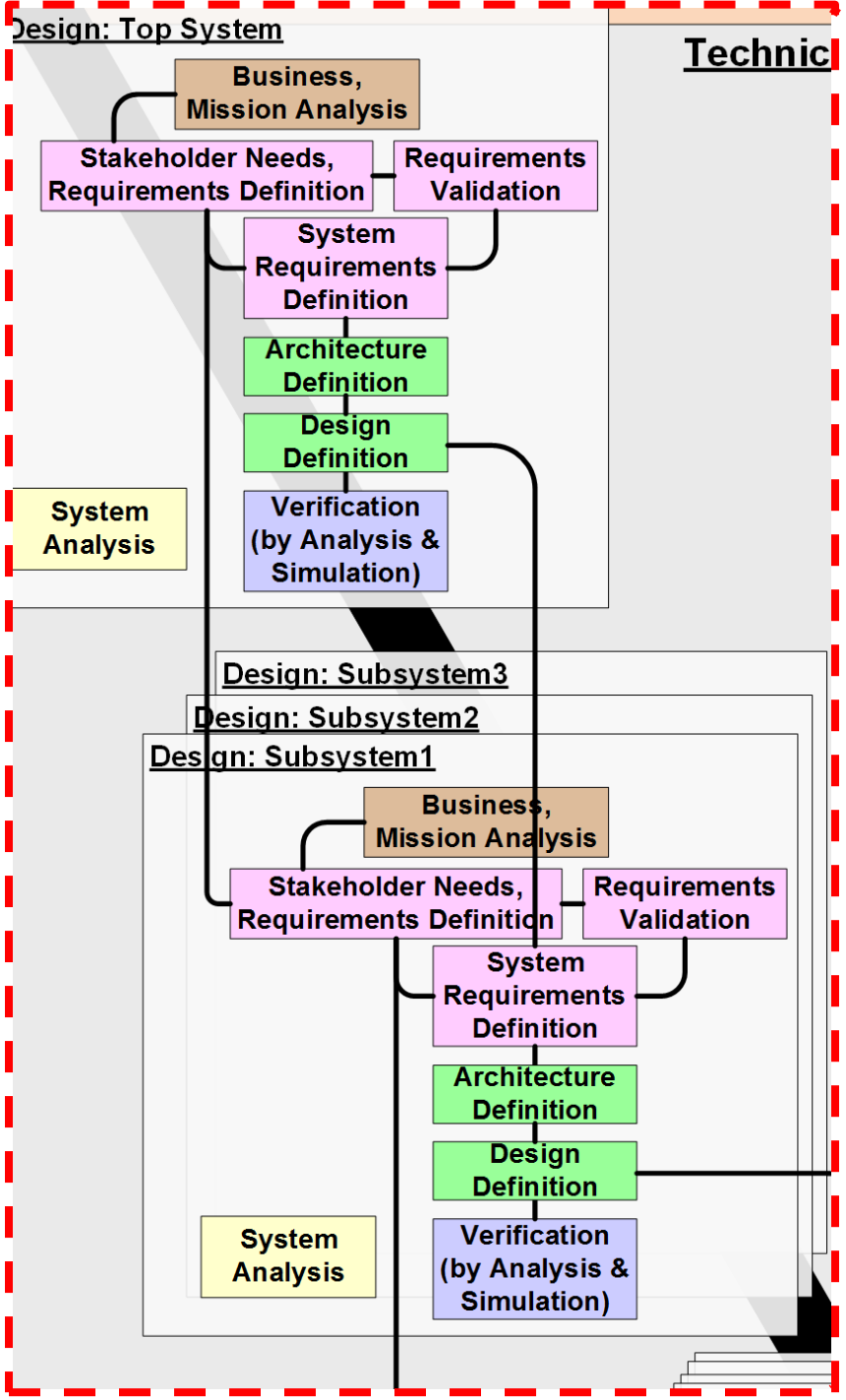


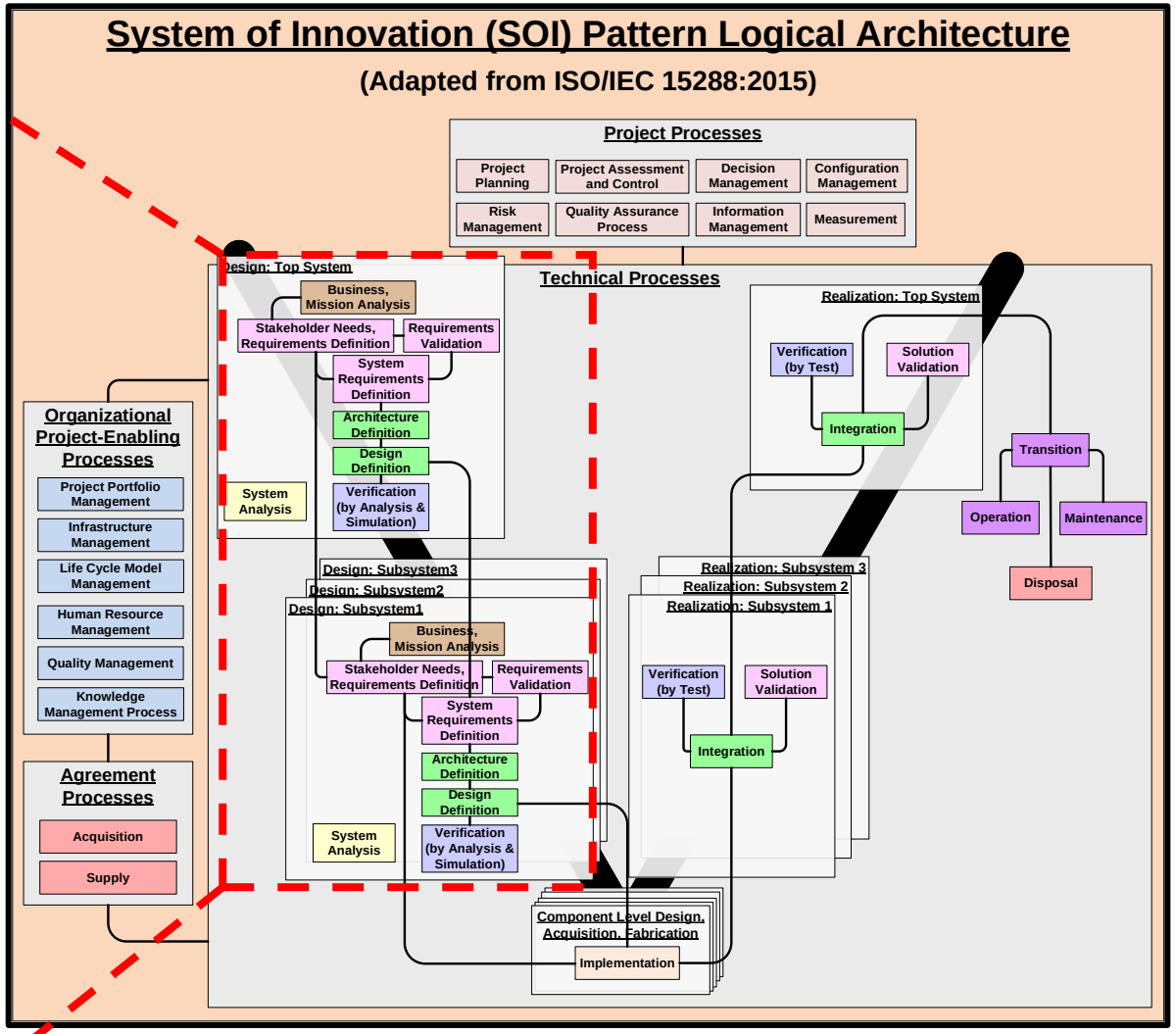


Decision Analysis: Special cases of interest

- The Patterns Working Group's interest in Decisions has been limited to a focus on the decisions which are made across managing the life cycle of systems; see--
  - See INCOSE SE Handbook or
  - ISO/IEC 15288
- Even those decisions are still relatively diverse—but they are not "decisions in general".
- So, what recurring pattern content can be discerned?





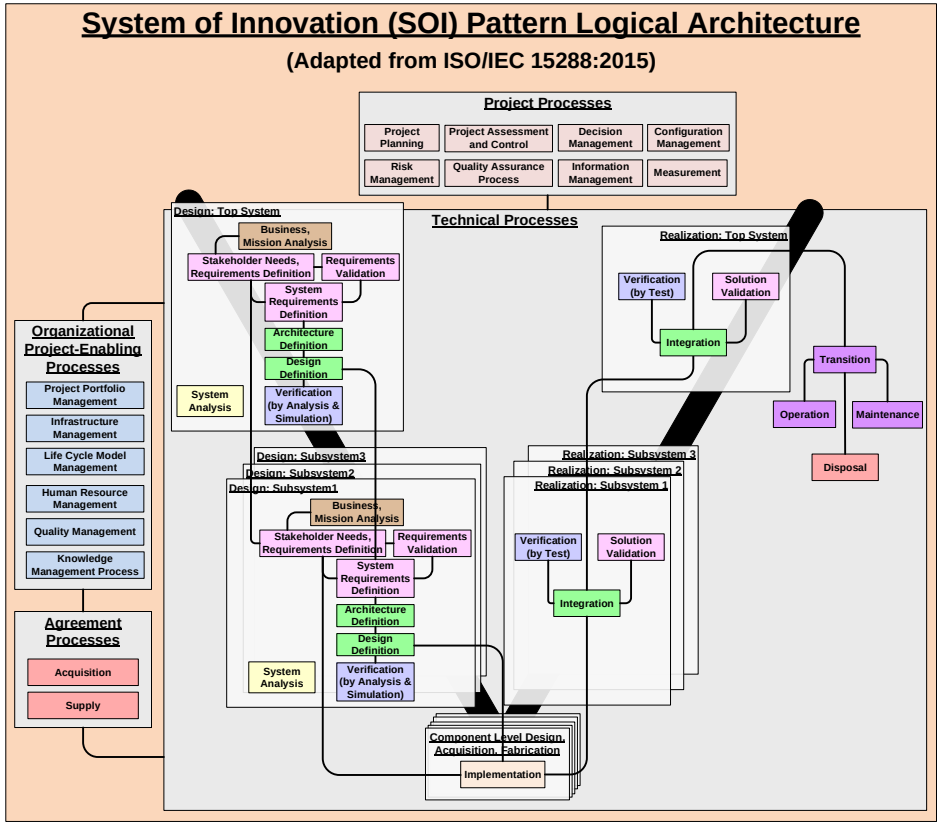


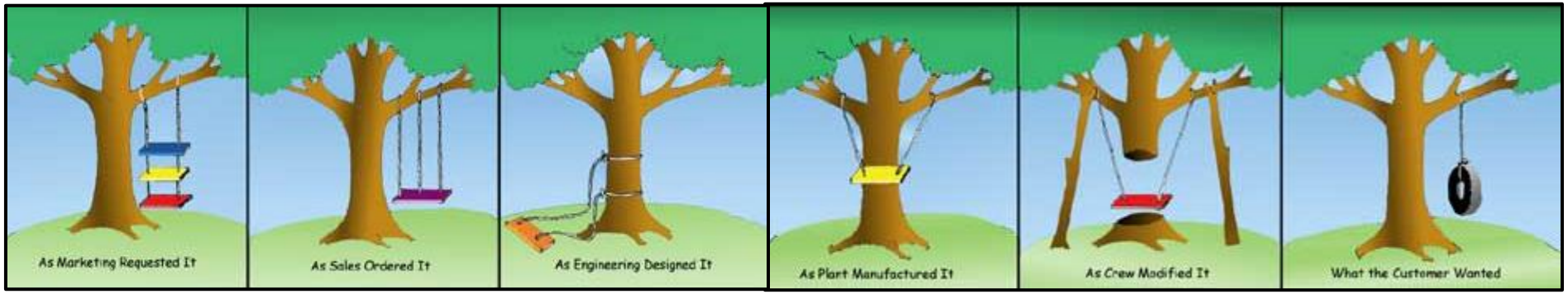
Examples: “Stage Gate” and “Agile Development” decisions seem diverse by nature—but how are they also abstractly similar?

Discussed during Dec 2021 North TX chapter program: Consistency Management

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.

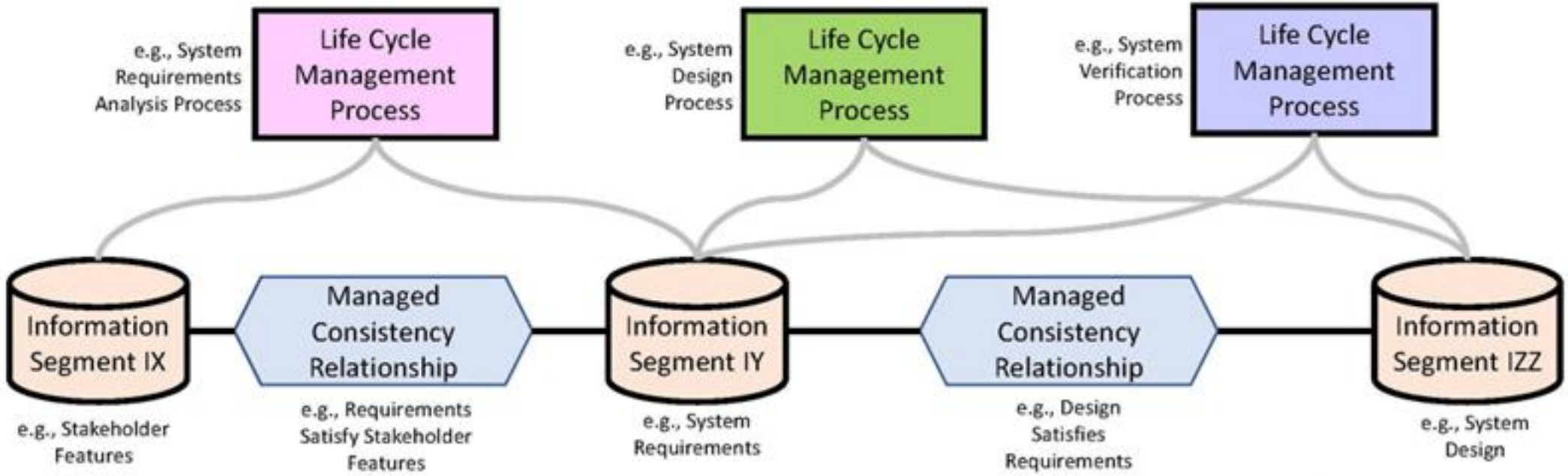


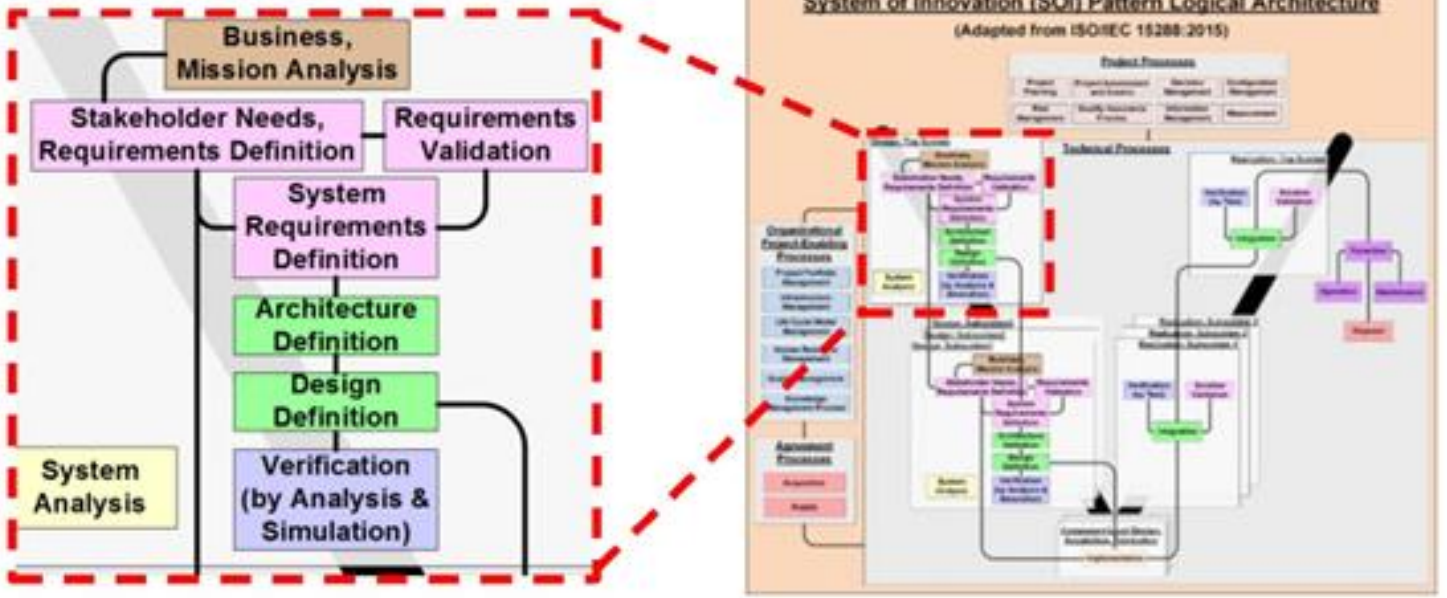


Examples of Managed Consistencies

- 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
- Future: Managed consistencies of the Digital Thread and Digital Twin
- Many other types of consistencies, recorded along "***consistency threads***" . . .

Example of Section of Consistency Thread





It turns out that Energy is another way to think about Consistency!

From

A Tutorial on Energy-Based Learning

Yann LeCun, Sumit Chopra, Raia Hadsell,
Marc'Aurelio Ranzato, Fu-Jie Huang
The Courant Institute of Mathematical Sciences
New York University

2006

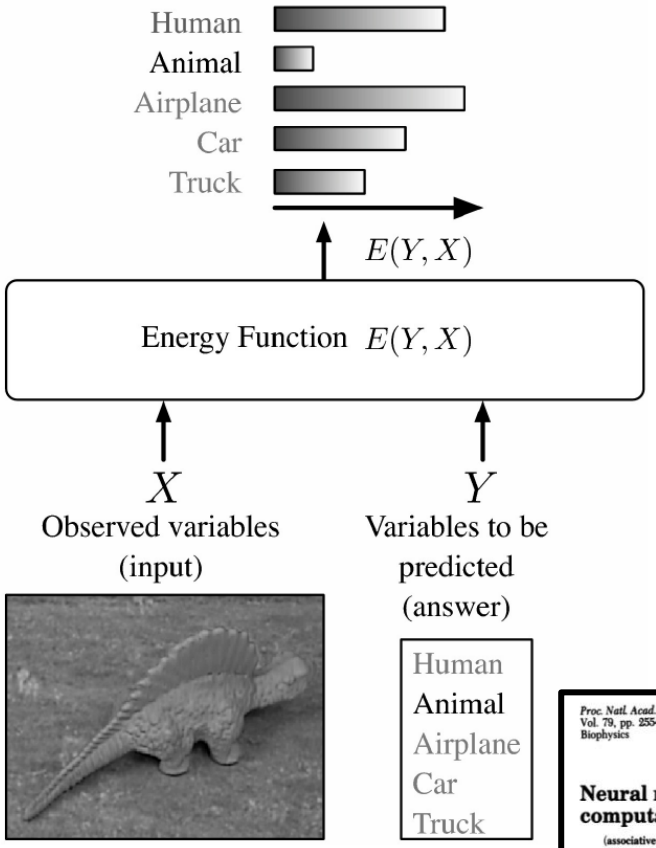
http://yann.lecun.com
http://www.cs.nyu.edu/~yann

Machine Learning

Yann LeCun

New York University

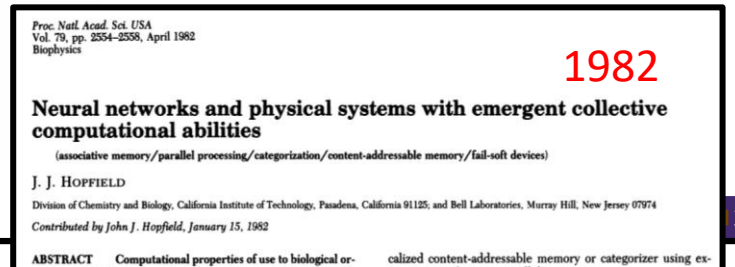
Energy-Based Model for Decision-Making



- **Model:** Measures the compatibility between an observed variable X and a variable to be predicted Y through an energy function E(Y,X).

$$Y^* = \text{argmin}_{Y \in \mathcal{Y}} E(Y, X).$$

- **Inference:** Search for the Y that minimizes the energy within a set $\mathcal{Y}$
- If the set has low cardinality, we can use exhaustive search.



Proc. Natl. Acad. Sci. USA
Vol. 79, pp. 2554–2558, April 1982
Biophysics

1982

Neural networks and physical systems with emergent collective computational abilities

(associative memory/parallel processing/categorization/content-addressable memory/fail-soft devices)

J. J. HOPFIELD

Division of Chemistry and Biology, California Institute of Technology, Pasadena, California 91125; and Bell Laboratories, Murray Hill, New Jersey 07974

Contributed by John J. Hopfield, January 15, 1982

ABSTRACT Computational properties of use to biological or- calized content-addressable memory or categorizer using ex-

Yann LeCun

New York University

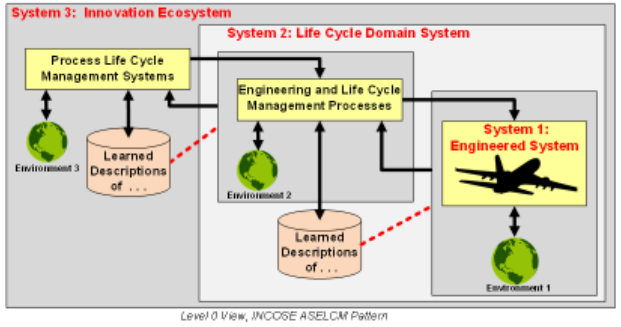
From J. Hopfield to Y. LeCun:

- "Compatibility" ~ Consistency.
- Energy (Hamiltonian-like) and Consistency: Both are scalar functions of (possibly high dimension) state variables.

Decisions Across the Life Cycle of Systems

- The “Consistency Management” pattern can be studied as part of the larger System of Innovation Pattern discussed in the chapter program of Dec., 2021.
- That descriptive, not prescriptive, configurable pattern describes any system of innovation, and helps us understand the nature of Consistency Management:

The Innovation Ecosystem:
Introduction to the INCOSE ASELCM Pattern



Level 0 View, INCOSE ASELCM Pattern

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

Bill Schindel
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https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:incose_north_texas_pgm_12.14.2021_v1.2.2.pdf

32nd Annual INCOSE international symposium
hybrid event
Detroit, MI, USA
June 25 - 30, 2022

Planning, Implementing, and Evolving the Ecosystem

Realizing the Promise of Digital Engineering

William D. Schindel
ICTT System Sciences
schindel@ictt.com

www.incose.org/symp2022

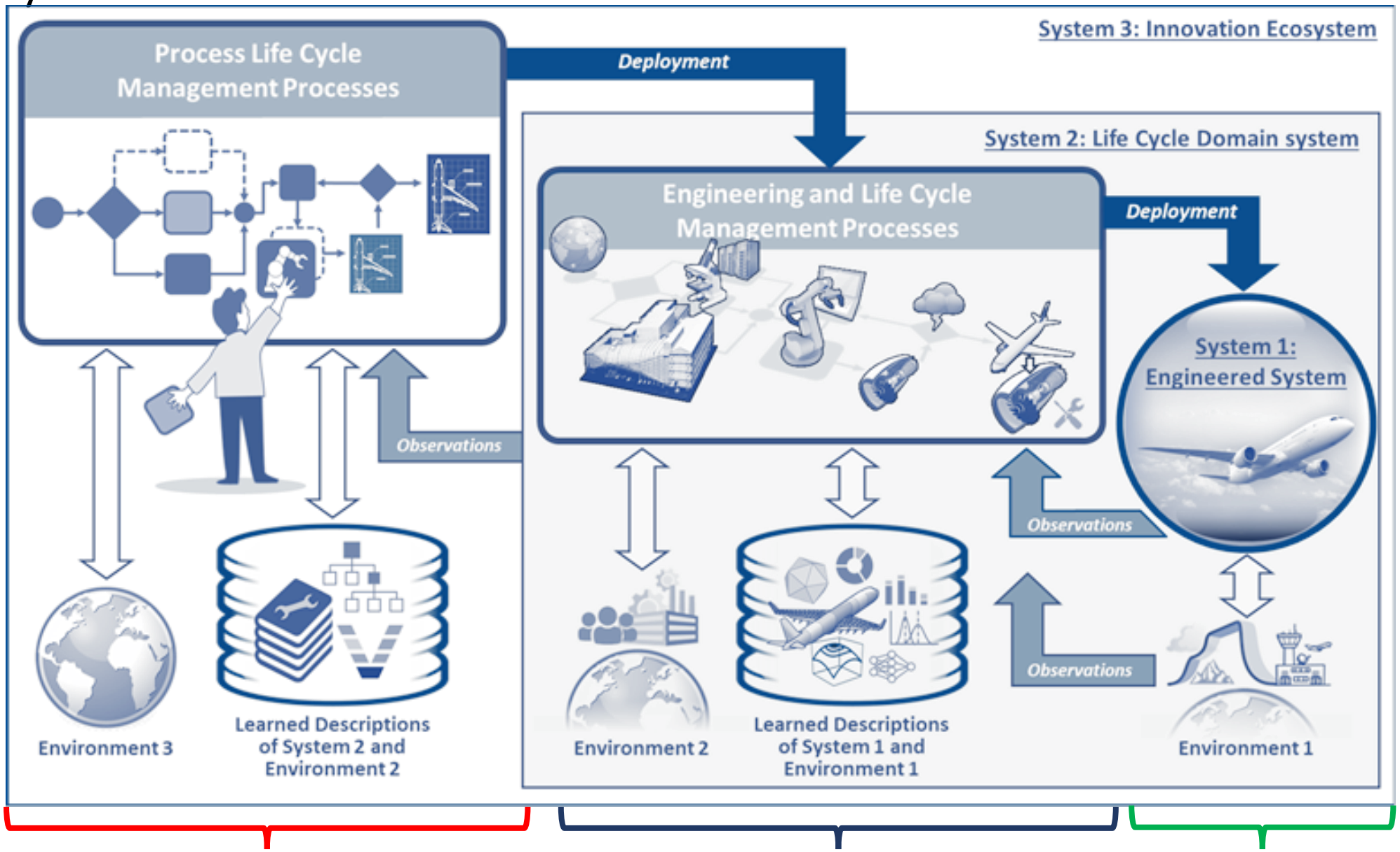
V1.1.3

https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:incose_is2022_realizing_the_promise_of_digital_engineering_v1.1.3.pdf

Goals of the Consistency Management pattern

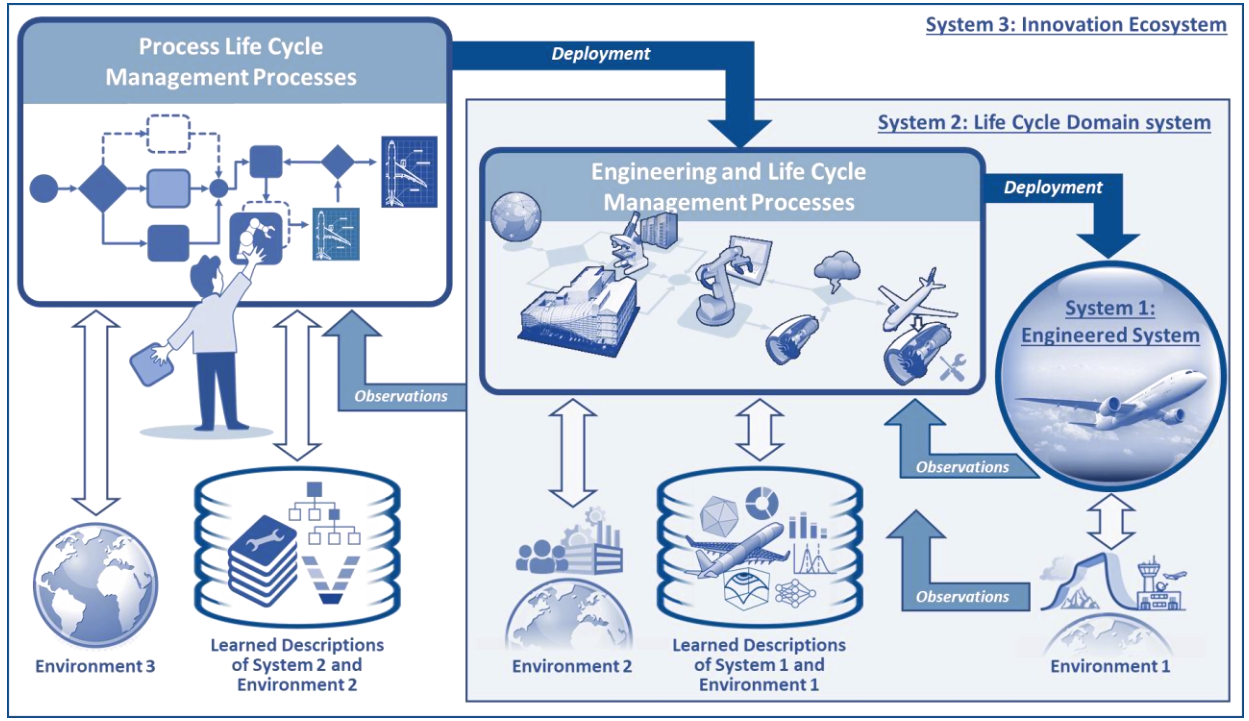
1. A descriptive, not prescriptive, reference model that represents (after configuration of the pattern to specific case) actual decision-making occurring in any real innovation ecosystem—whether the outcomes are bad or good, well-performed or not, independent of specific implementations.
2. A guide for establishing the structure of Digital Threads that encourage learning and adaptation.
3. A framework that describes manual (human-performed), automated or semi-automated, and AI-based decision-making for life cycle management—along with hybrids thereof.
4. A theoretical foundation for understanding systems of innovation based on classical energy-based STEM understanding.

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**

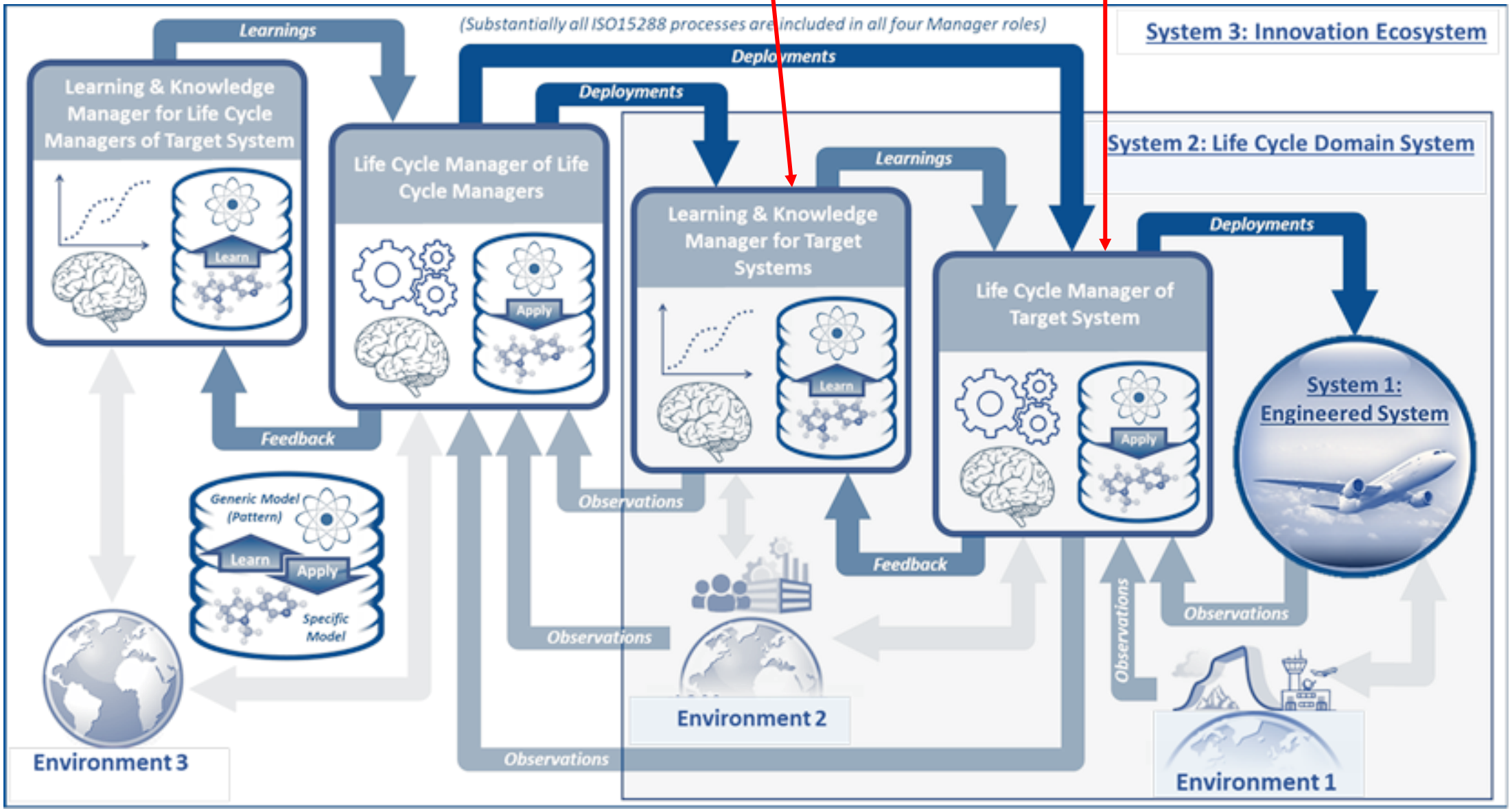
INCOSE ASELCM Level 0 Reference Model



- **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.)



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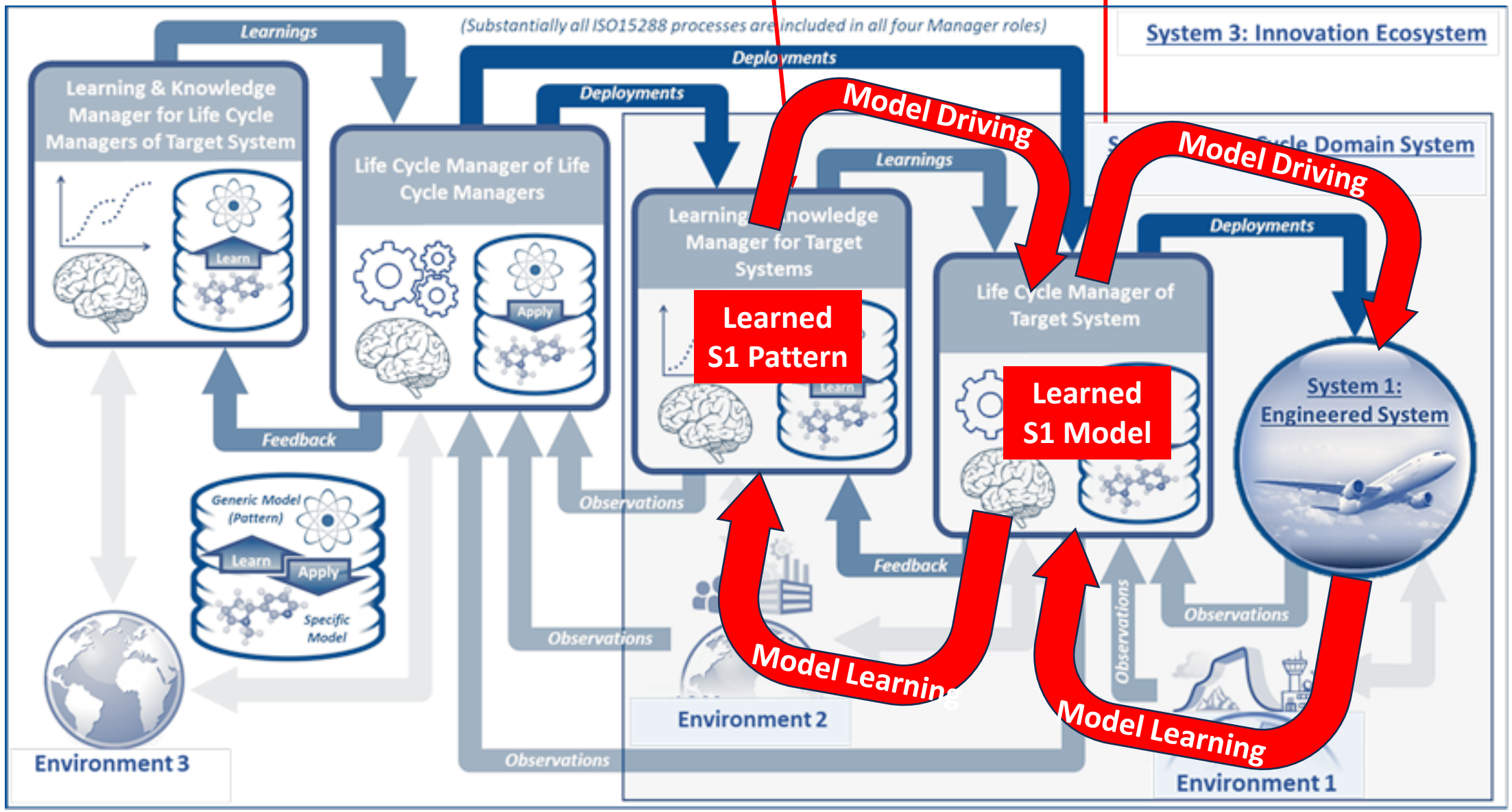
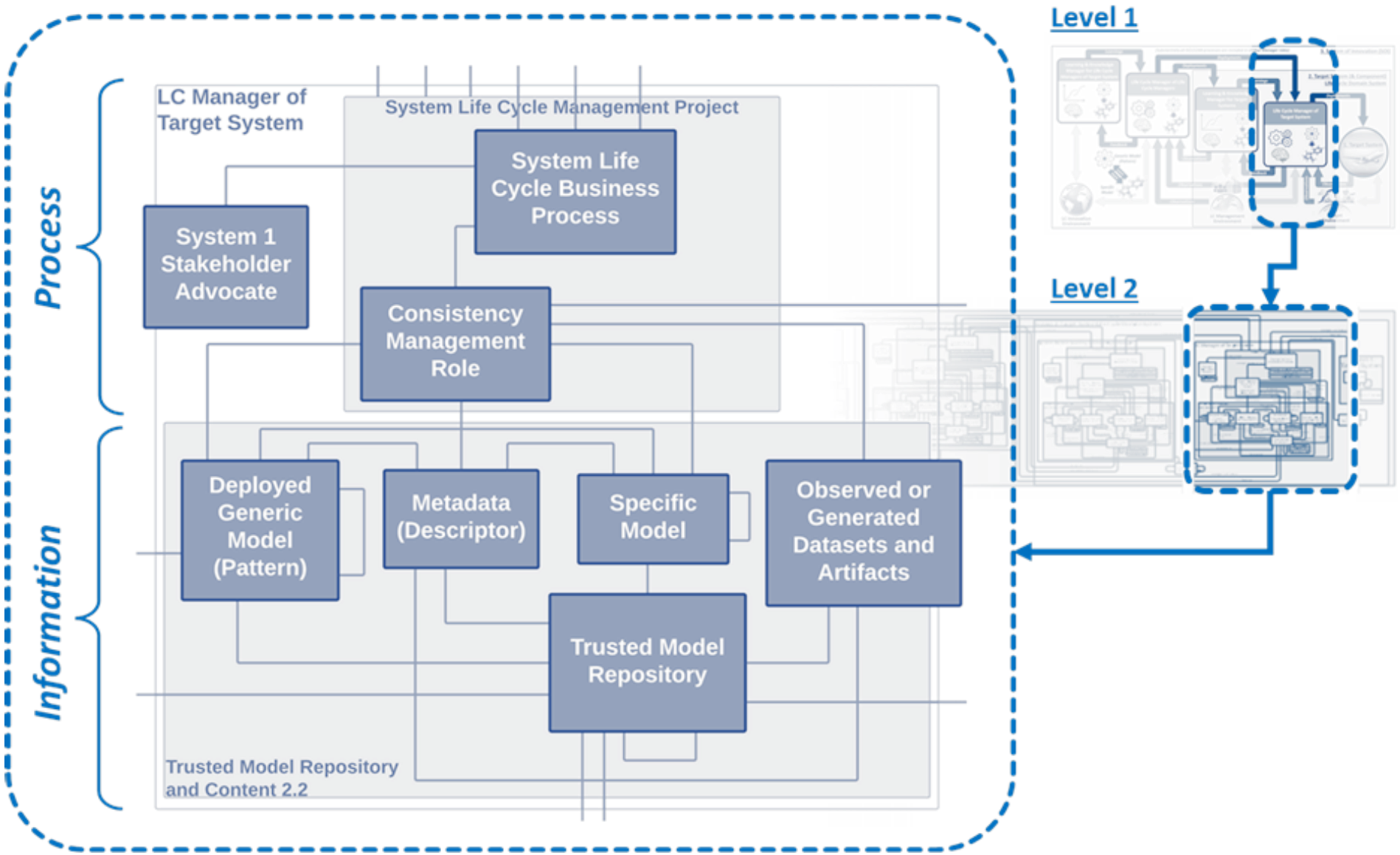


INCOSE ASELCM Level 2 Reference Model

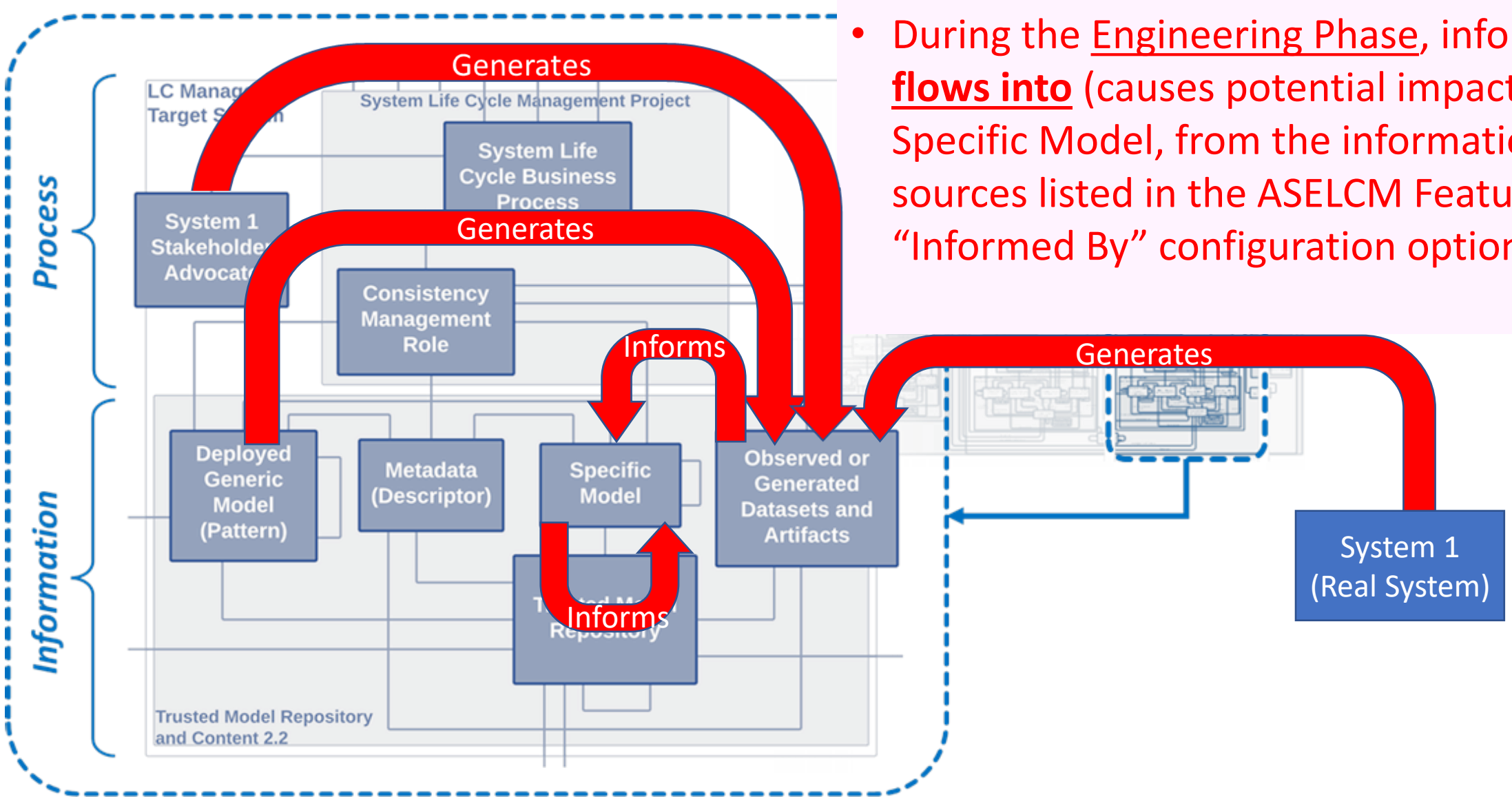
(Segment for Application of "Already Learned" Information)



The SE Information Segments (“InfoSegs”)

- The Systems Engineering (SE) Information Segments (InfoSegs) refer to the logical roles played by packages of information whose consistencies (with themselves, with each other, and with external observation) are managed by the Innovation Ecosystem over the course of a managed system’s life cycle.
- Some InfoSegs are segments of a Specific Model (e.g., Requirements, Design), but other InfoSegs are segments of information from Local Datasets, containing information about various systems.
- These InfoSegs are relatively large assemblies of information that are familiar across diverse methodologies and practices, because they are generic to the nature of innovation ecosystems.
- These InfoSegs are not specific artifacts in themselves, but their content can be allocated to artifacts that are specific to a particular enterprise, program, domain, method, or practice.
- Not all the InfoSegs may need apply to a given program or enterprise.

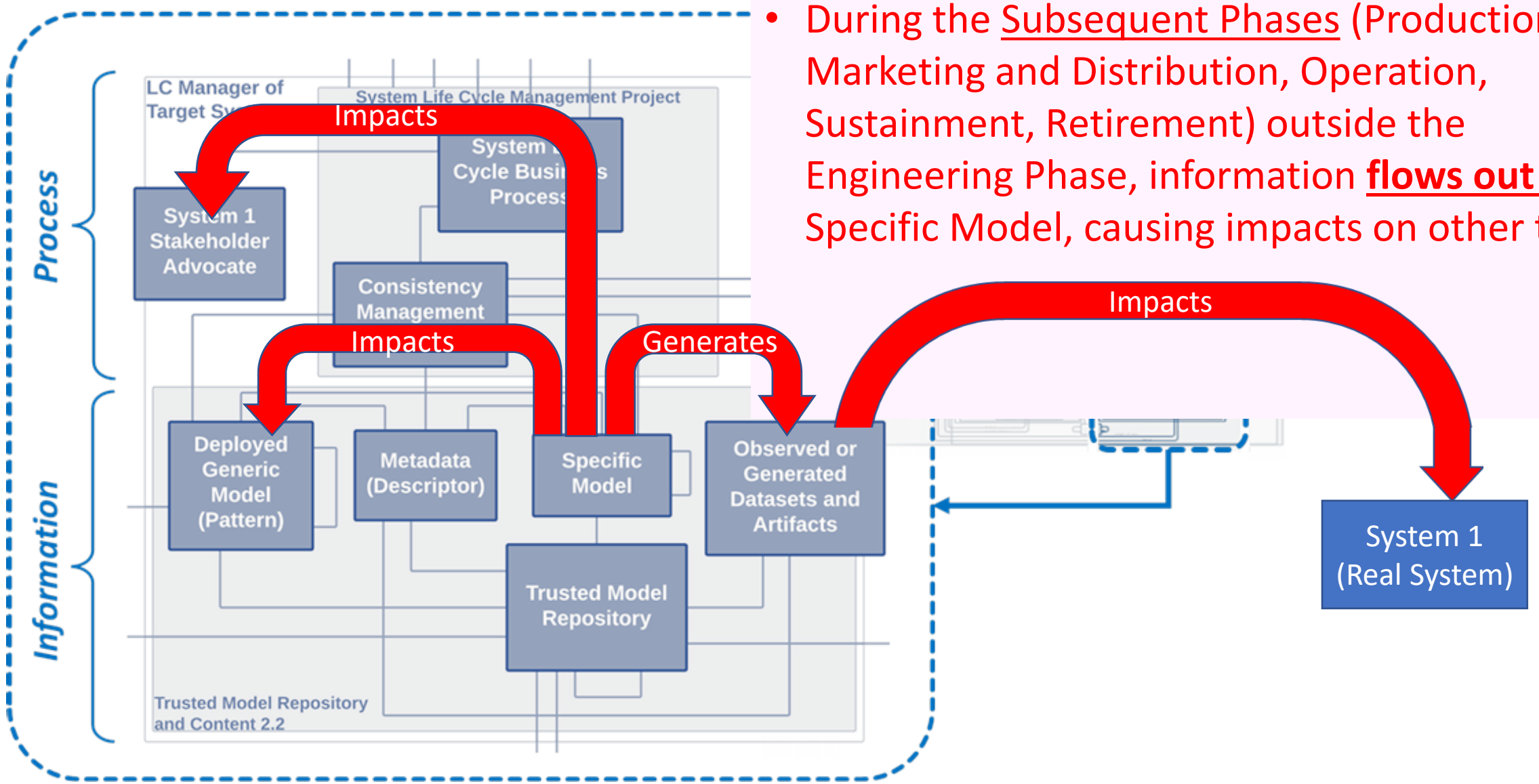
Information Flow Into/Out Of the Specific Model:
Flow/Impact Direction Reverses During Life Cycle



- During the Engineering Phase, information **flows into** (causes potential impact on) the Specific Model, from the information sources listed in the ASELCM Features as "Informed By" configuration options.

Information Flow Into/Out Of the Specific Model:
Flow/Impact Direction Reverses During Life Cycle

- During the Subsequent Phases (Production, Marketing and Distribution, Operation, Sustainment, Retirement) outside the Engineering Phase, information **flows out of** the Specific Model, causing impacts on other things.



INCOSE ASELCM Level 2 Reference Model

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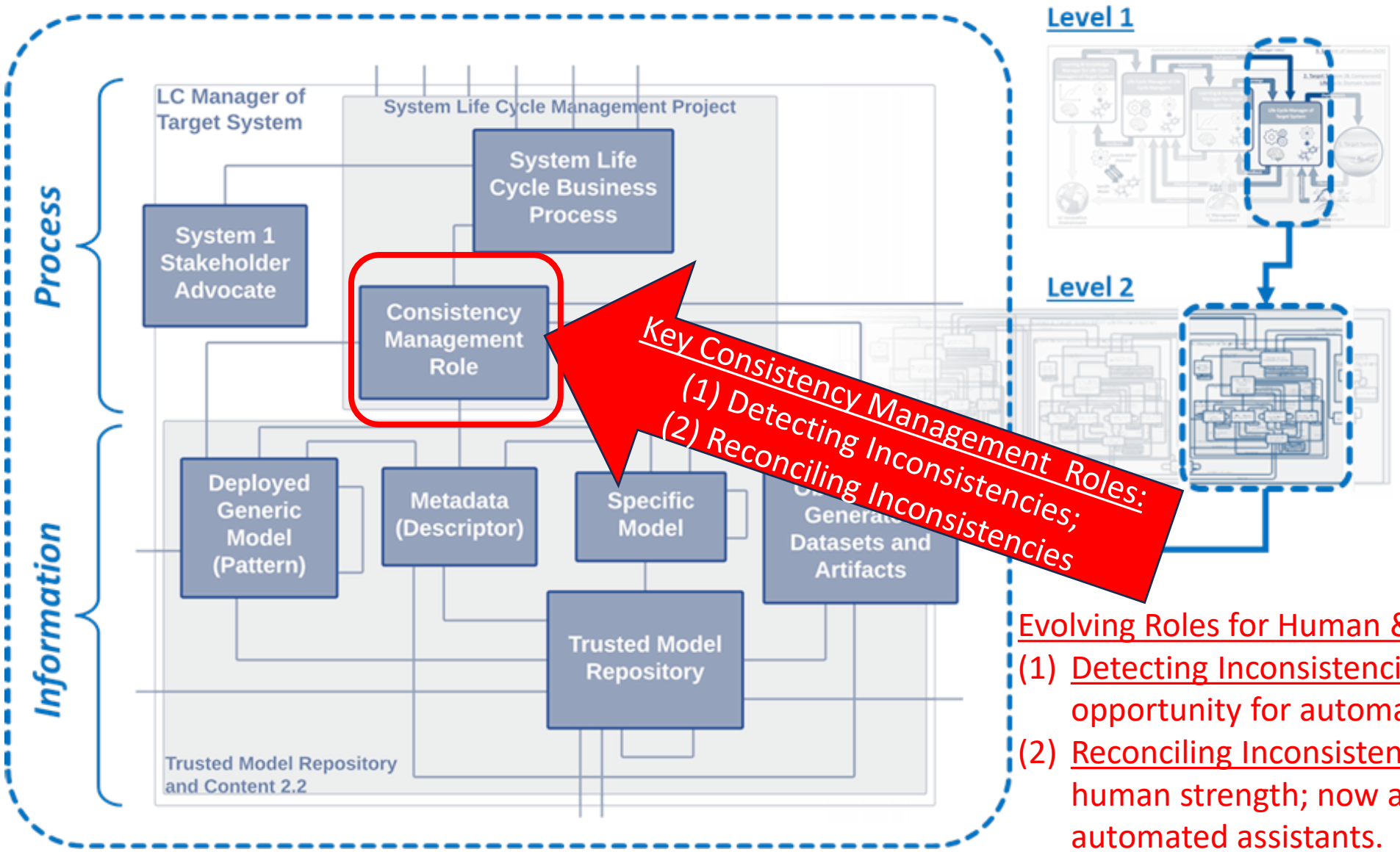
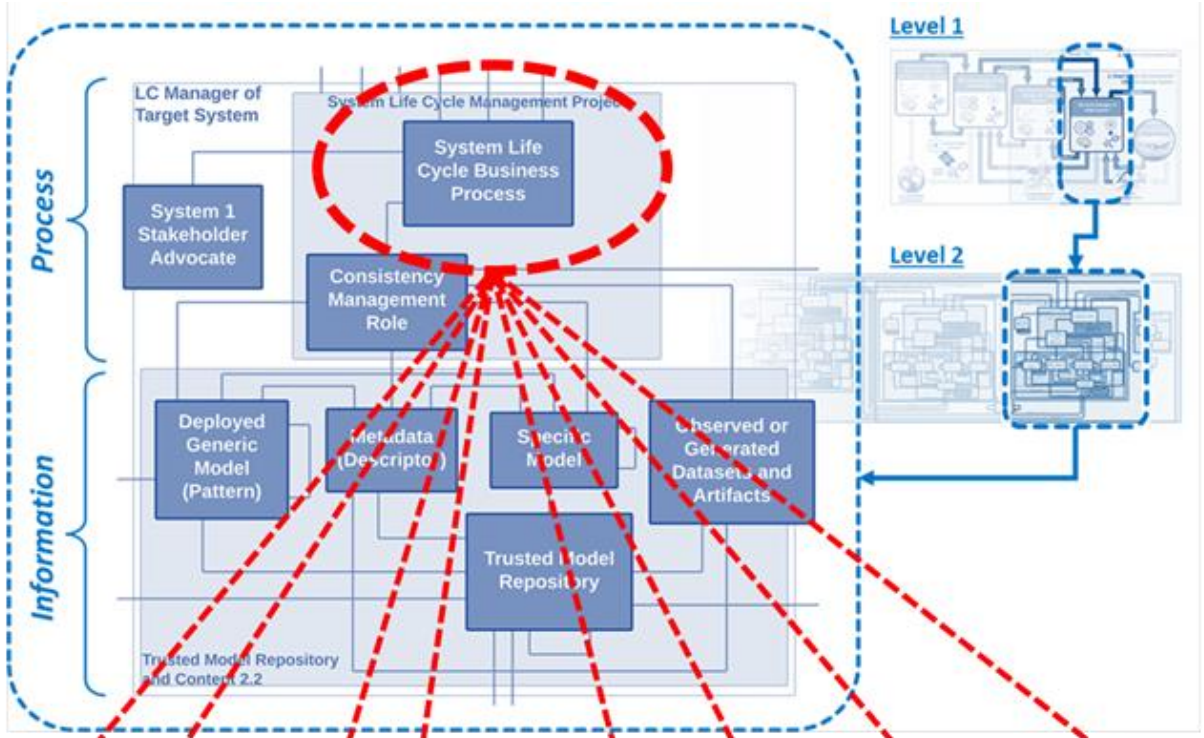


Evolving Roles for Human & Automated Agents:

(1) Detecting Inconsistencies: Near-term opportunity for automated assistants.

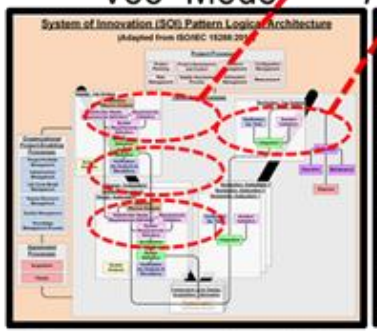
(2) Reconciling Inconsistencies: Traditionally a human strength; now an opportunity for automated assistants.



- There can be multiple process-specific instances of the System Life Cycle Business Process, describing local enterprise processes.
- Our interest here is the "Digital Engineering Underbelly" of those processes, described by the other classes shown.

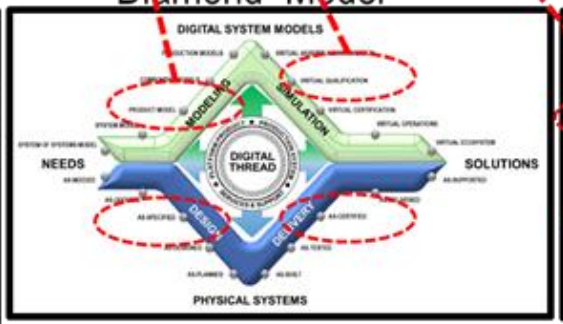
Configurable to specific life cycle management models---

ISO15288 Life Cycle "Vee" Model[1]

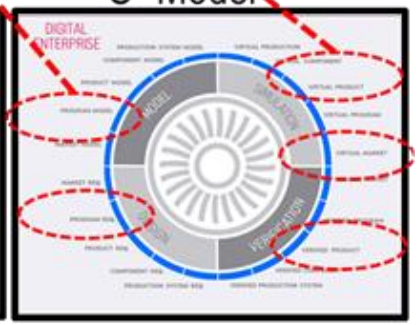


DoD 5000 Defense Acquisition Life Cycle Model[2]

Boeing "Diamond" Model[3]

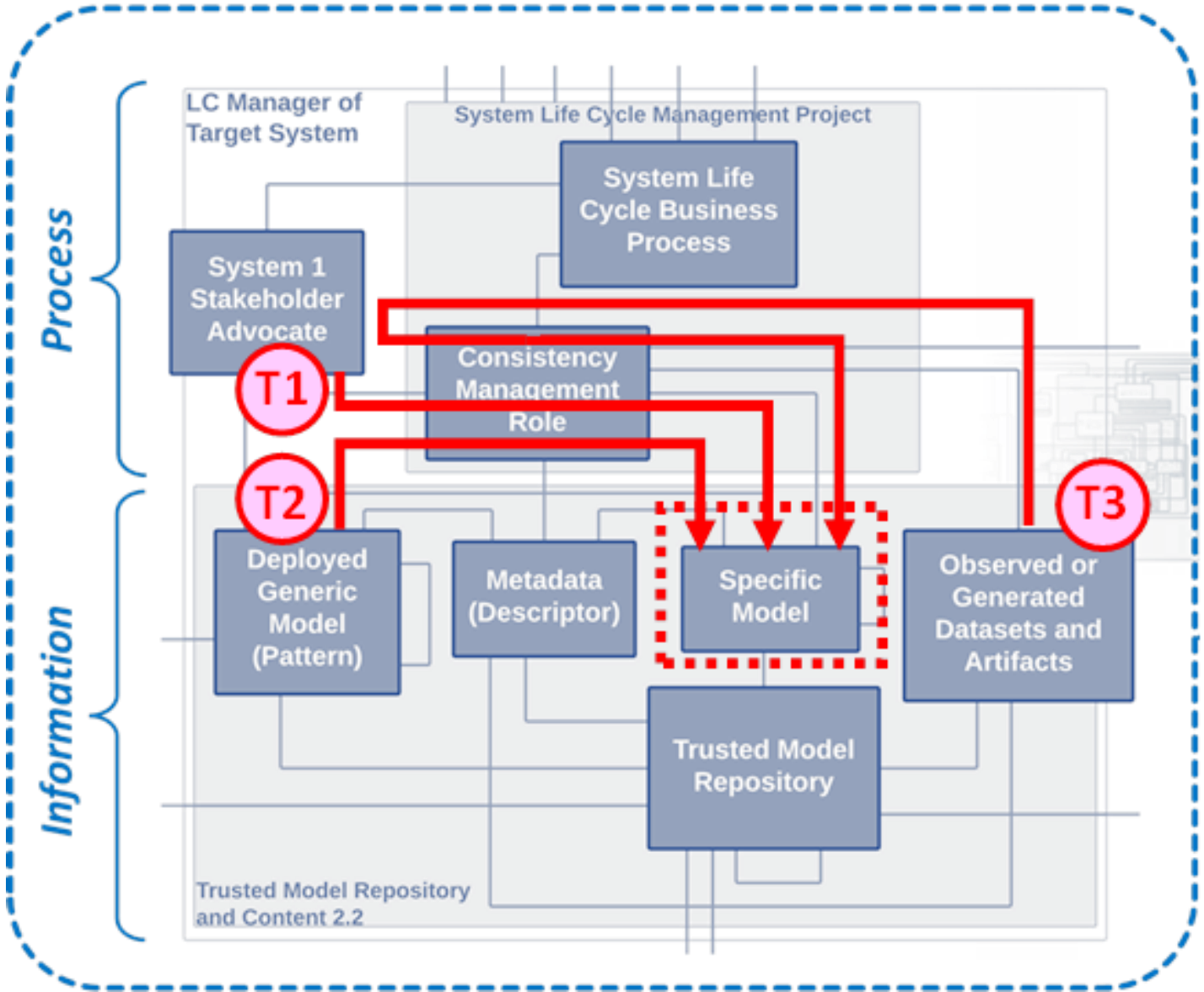


Rolls-Royce "O" Model[4]



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

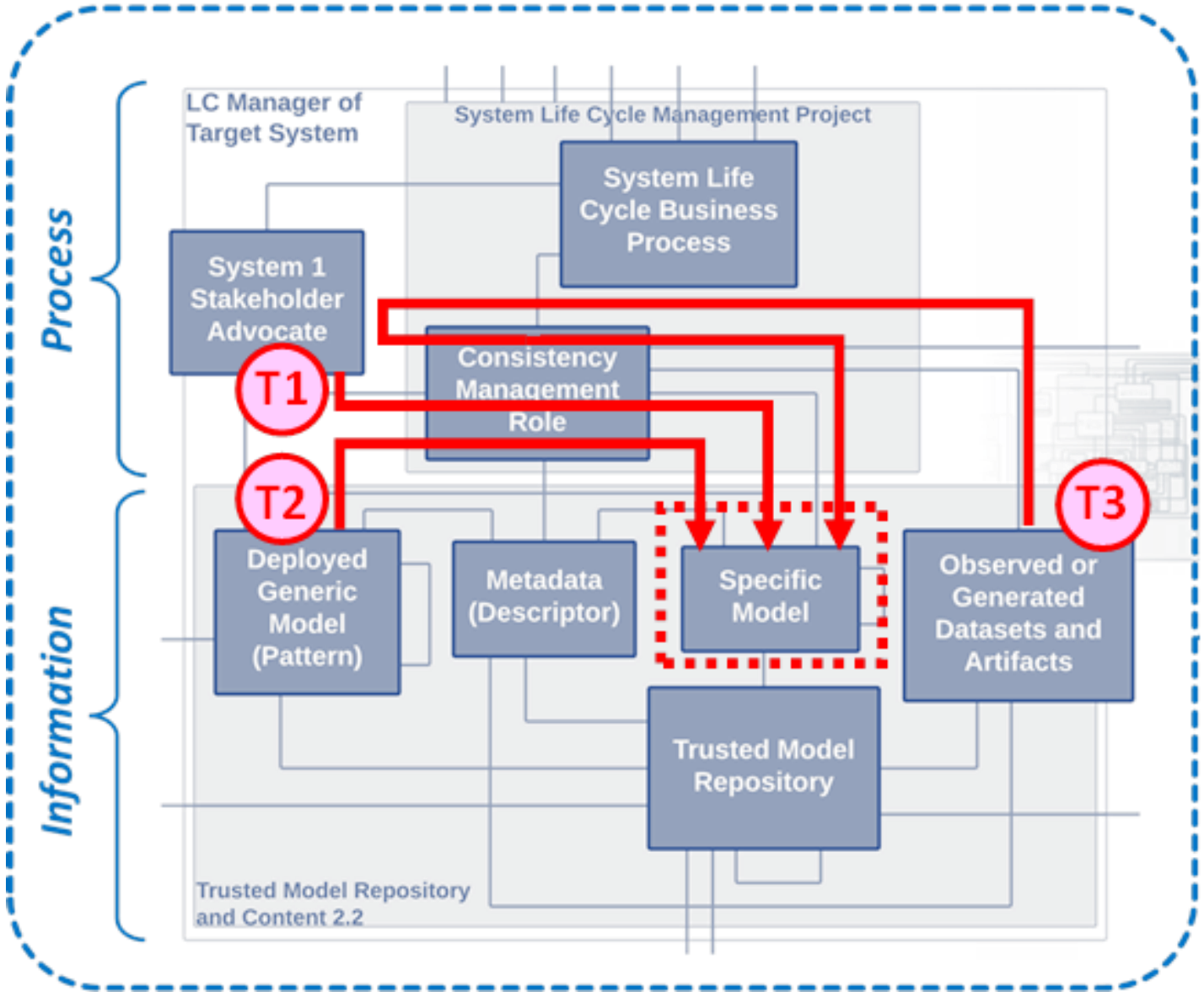
These 3 sources will disagree frequently—reconciling those differences is a major part of life cycle management.



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

This illustrates a more general concept of "reconciliation of inconsistencies" that the Consistency Management Pattern uses.



The 3 sources of credibility

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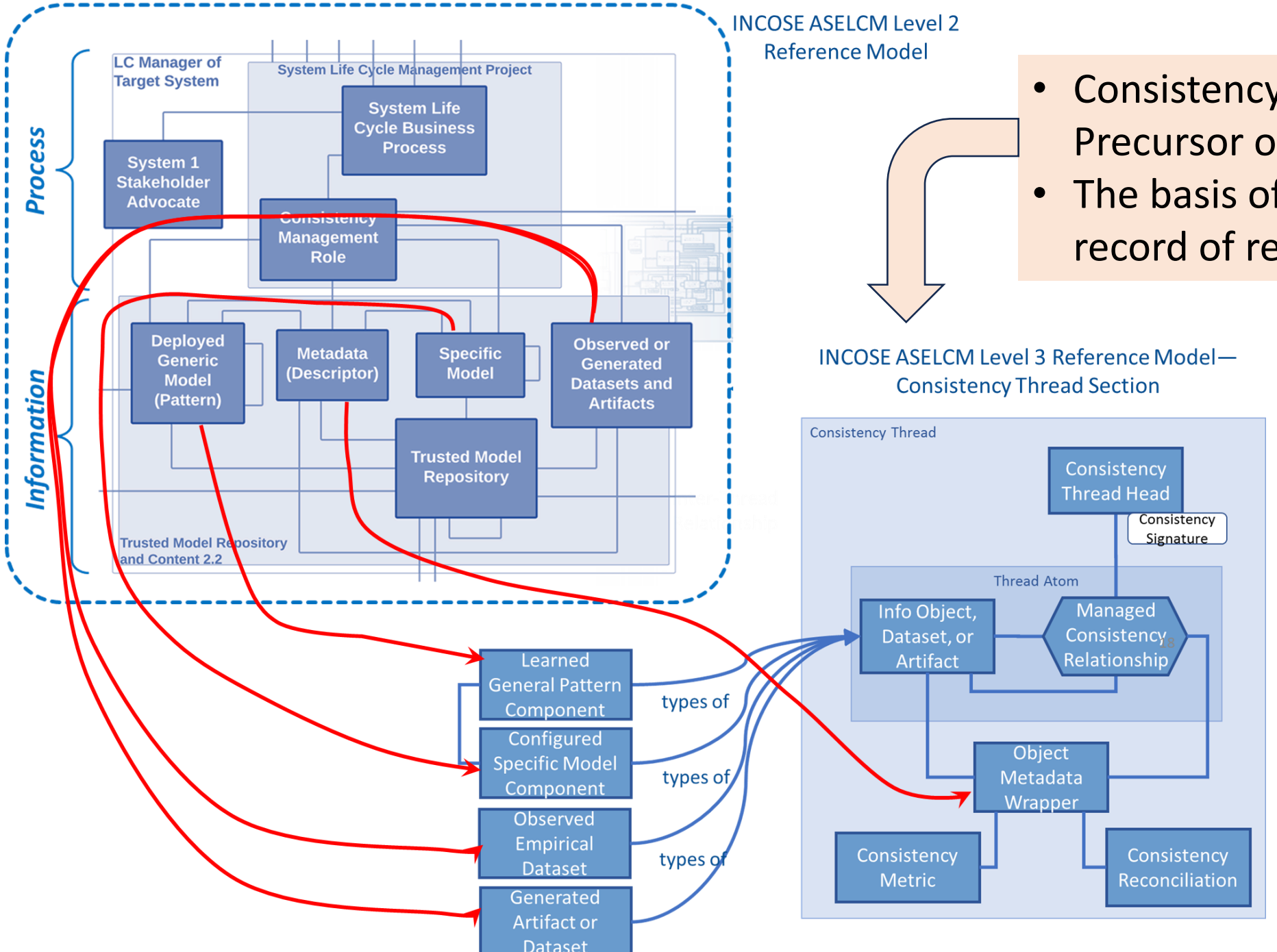
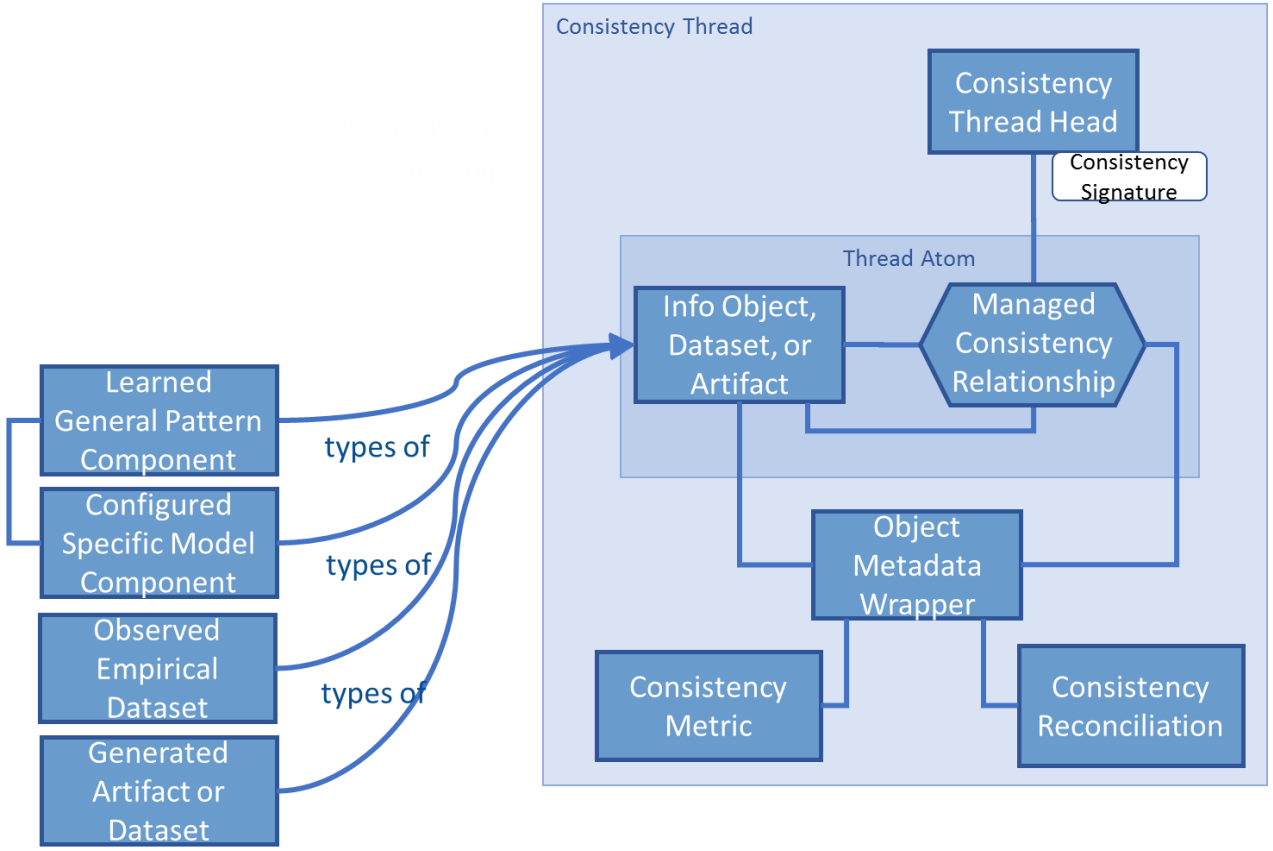
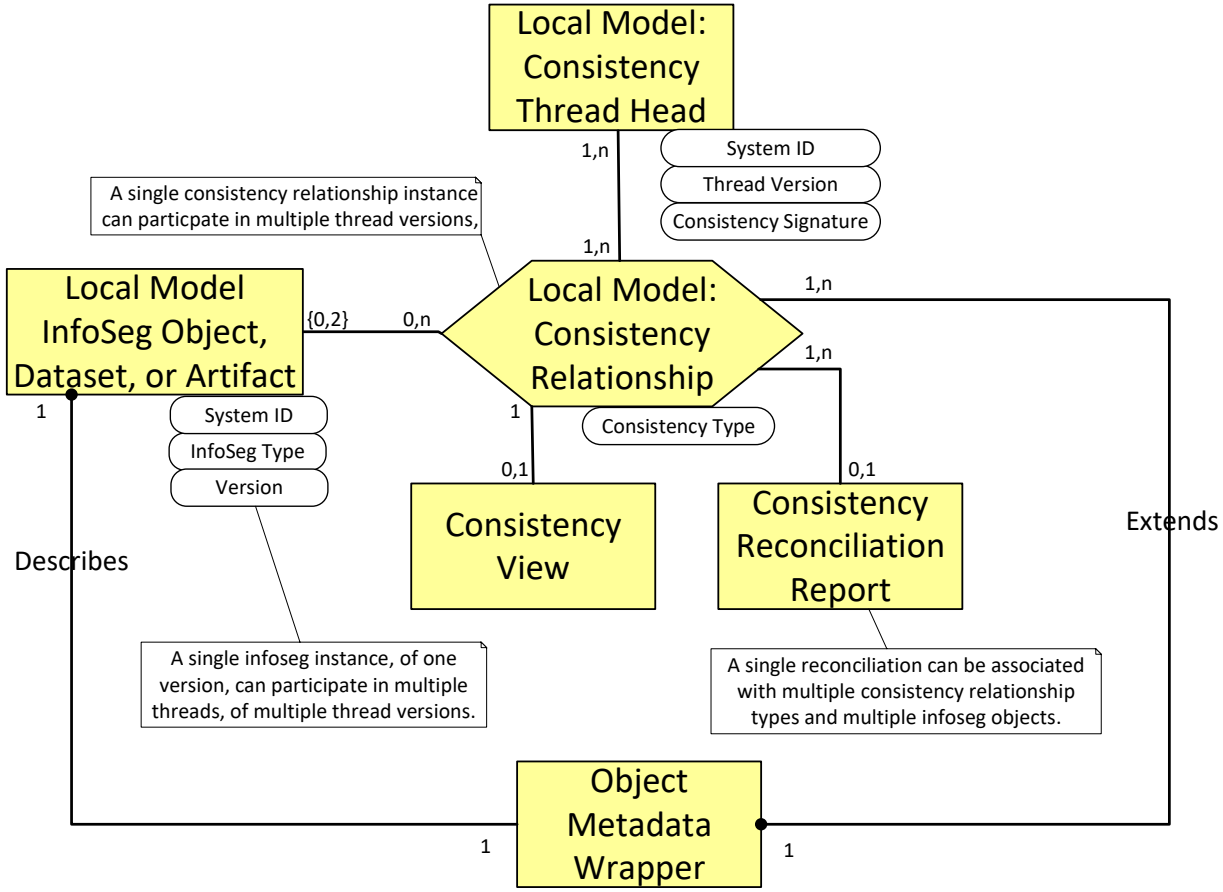


- Consistency Thread: Historical Precursor of the Digital Thread.
- The basis of group learning from record of reconciliations.

Consistency Thread: Informal Conceptual Information Model



Consistency Thread: Formalized Information Model



American Institute of Aeronautics and Astronautics (AIAA) has released both its Digital Thread & Digital Twin Reference Models

June, 2023

Both of these are based on the INCOSE MBSE Patterns Working Group Innovation Ecosystem (ASELCM) Pattern.

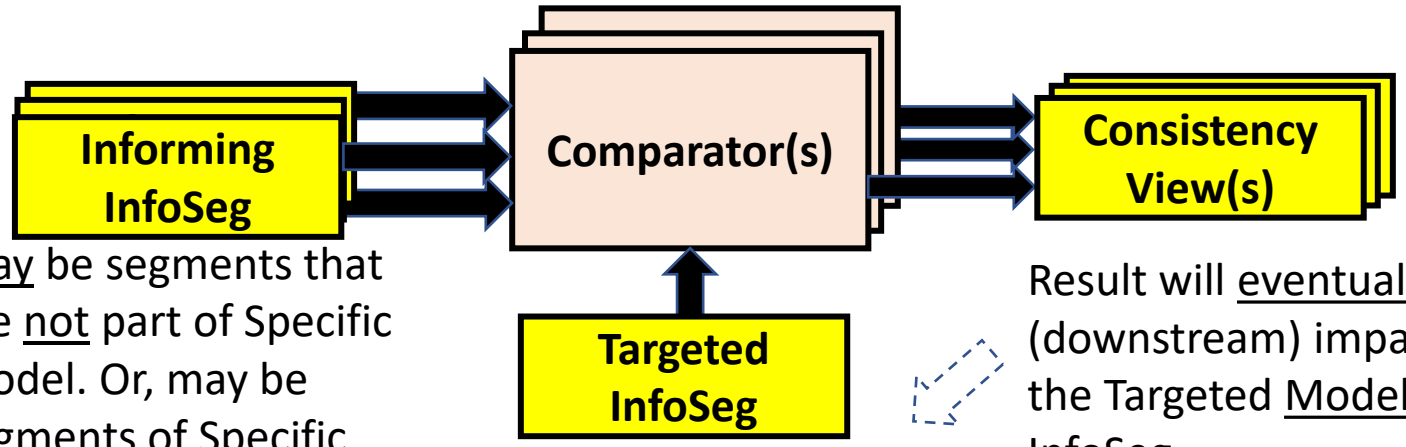
Click to Download Related INCOSE Publication

January, 2023

Click to Download AIAA Digital Thread Reference Model

Click to Download AIAA Digital Twin Reference Model

Consistency Comparisons Made In Model Learning Mode:

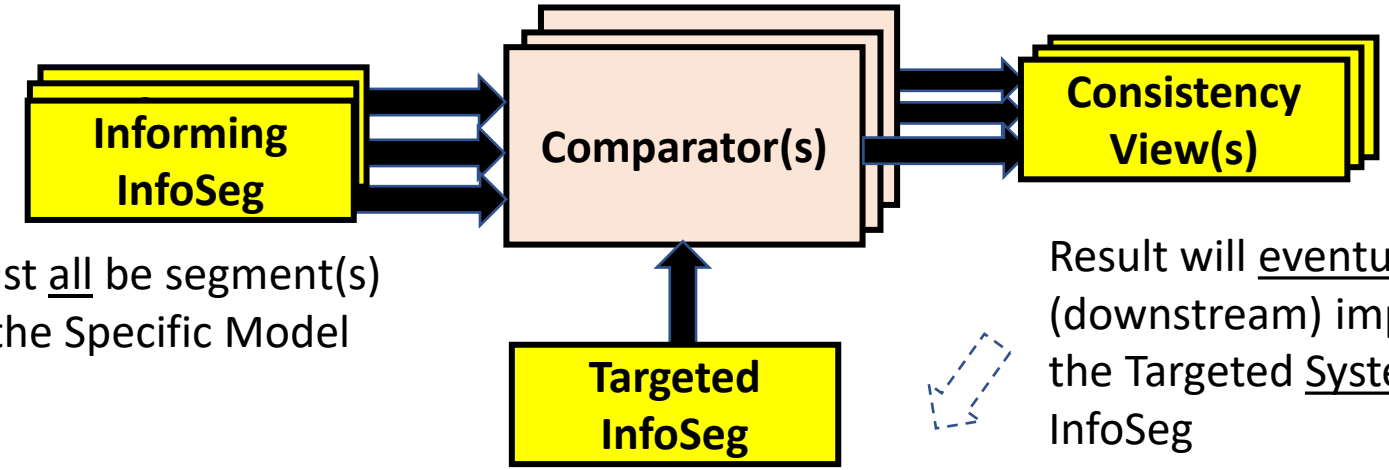


May be segments that are not part of Specific Model. Or, may be segments of Specific Model that are not the Targeted InfoSeg one.

Must be a segment of Specific Model

Result will eventually (downstream) impact the Targeted Model InfoSeg.

Consistency Comparisons Made In Model Driving Mode:



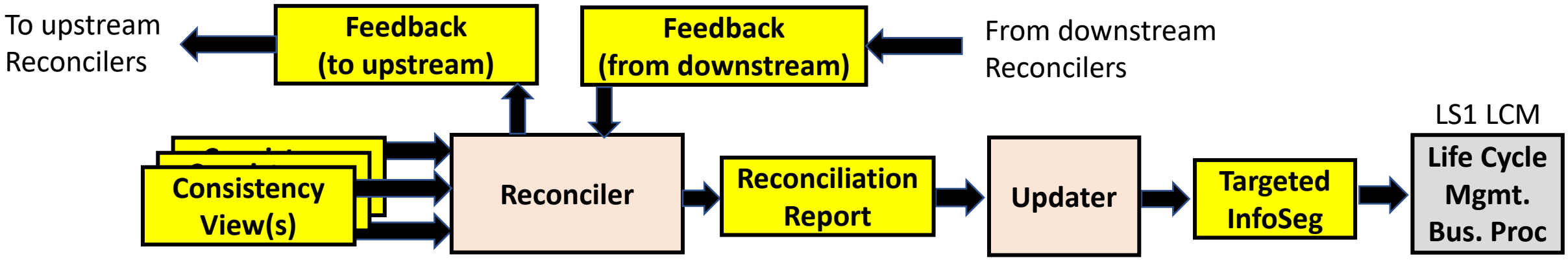
Must all be segment(s) of the Specific Model

Must not be a segment of Specific Model

Result will eventually (downstream) impact the Targeted System InfoSeg

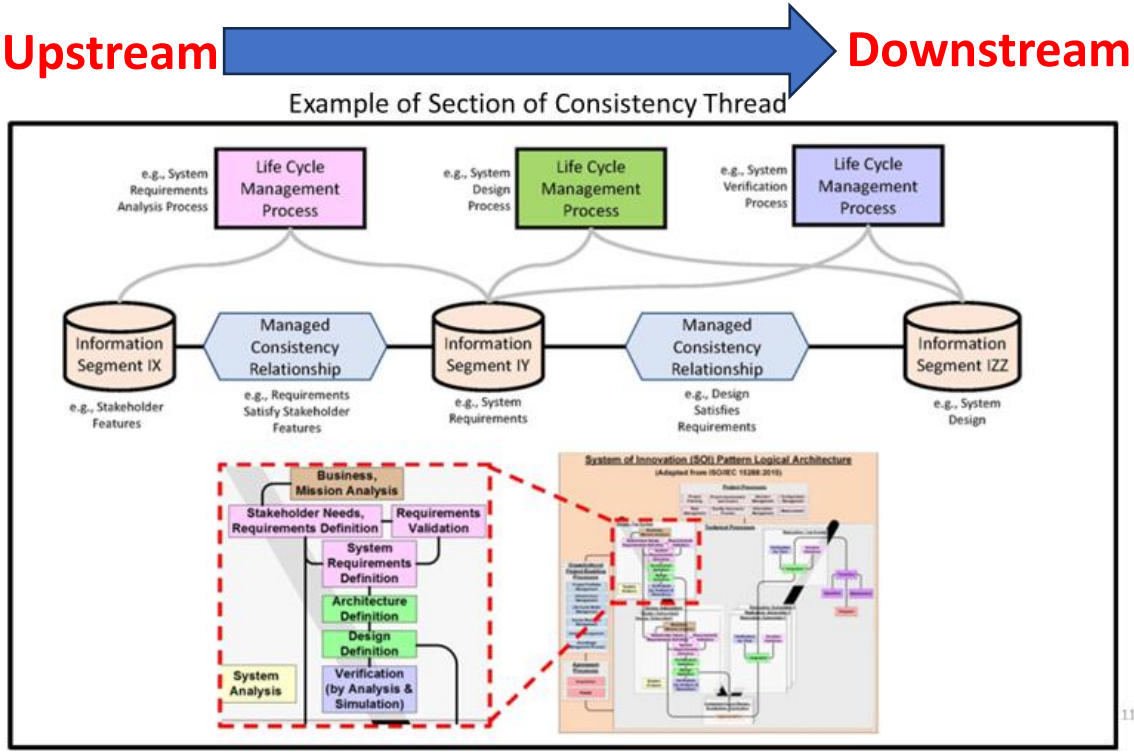
- An InfoSeg may be a segment (e.g., Reqs) of a Specific Model (S1 LM), but it may alternately be a segment of a Dataset (S1 LD) that is created by or that influences a business process (S1 LCM) (e.g., Production Specs, Production Measurements).
- An InfoSeg may be "Informing", in that it informs the update of some other InfoSeg, called the "Targeted" or "Ctrld" InfoSeg.
- A single InfoSeg may be both Informing and Targeted, but not in the same comparison. That is, "Informing" and "Targeted" are different roles that the same InfoSeg can play in different comparisons.
- Each Comparator Instance looks at only one Informing InfoSeg and one Targeted InfoSeg. However, multiple (different) Informing InfoSegs can be compared to the same Targeted InfoSeg by multiple Comparator instances. The Targeted InfoSeg will be "informed by" (potentially impacted by) the Informing InfoSeg(s).
- Comparator is a role of a Consistency Mgr.

Consistency Reconciliation and Update Roles; Feedback

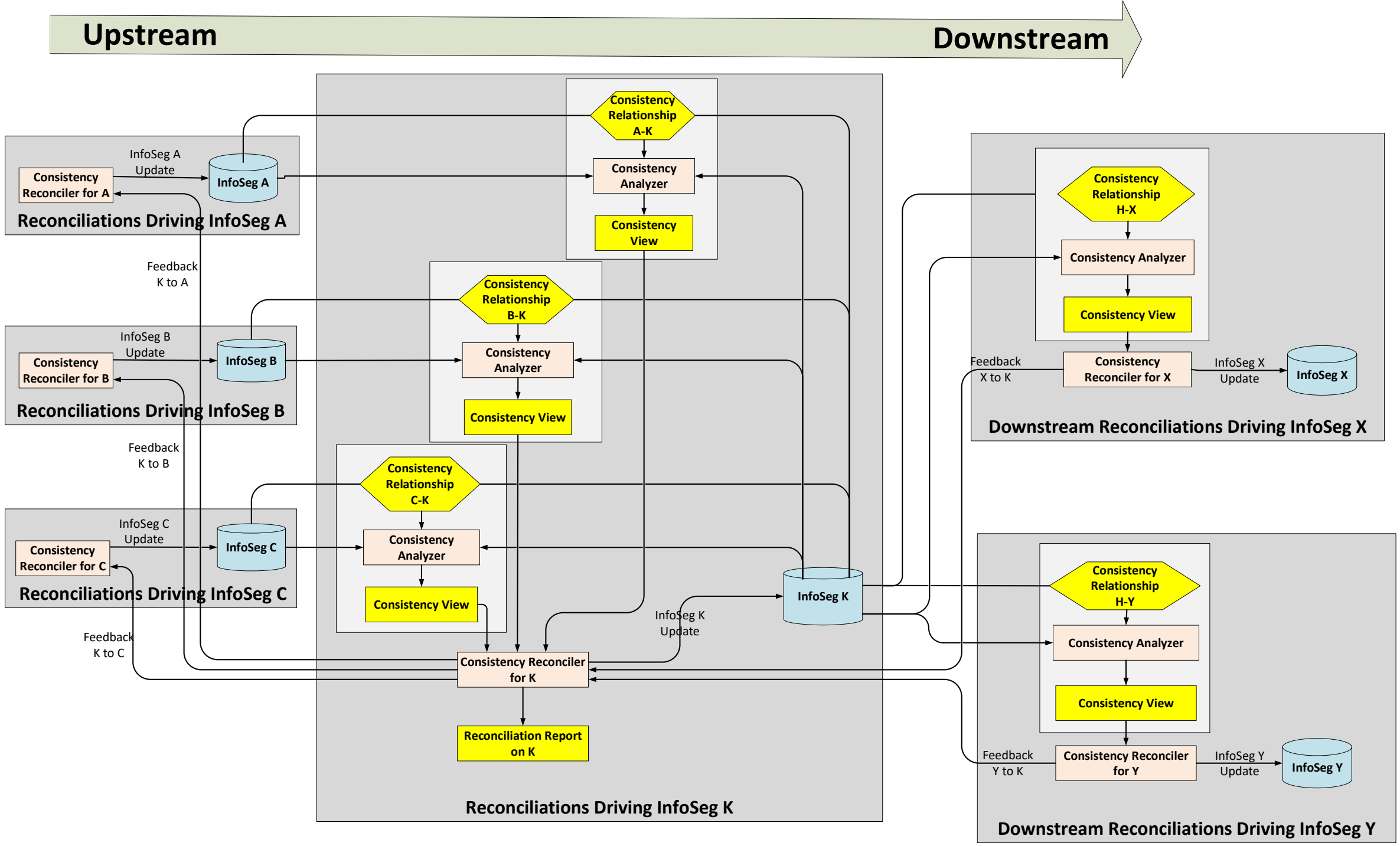


- Multiple Informing InfoSegs may provide contradictory or inconsistent input to different Comparators, implying inconsistent directions as to changes to a Targeted InfoSeg.
- Such inconsistencies are resolved by a Reconciler, which look at all the Consistency Views for a single Targeted InfoSeg and decide what ultimate change is appropriate for thatTargeted InfoSeg.
- There is only one Reconciler for any single Targeted InfoSeg.
- Reconciliations involve compromise and other (typically human-performed) decisions that frequently generate “feedback” to an upstream process responsible for an Informing InfoSeg.
- Upstream, that feedback is one of the several integrated inputs considered by an upstream Reconciler.
- In that way, each Reconciler will not only generate upstream feedback but also receive Feedback from downstream Reconcilers.
- The actual update of a Targeted InfoSeg is performed by an Updater role. The Reconciler “makes the decision” that update (as well as feedback) is appropriate. The Updater “performs the update”.
- Reconciler and Updater are both Consistency Manager roles.

Thread: Upstream and downstream



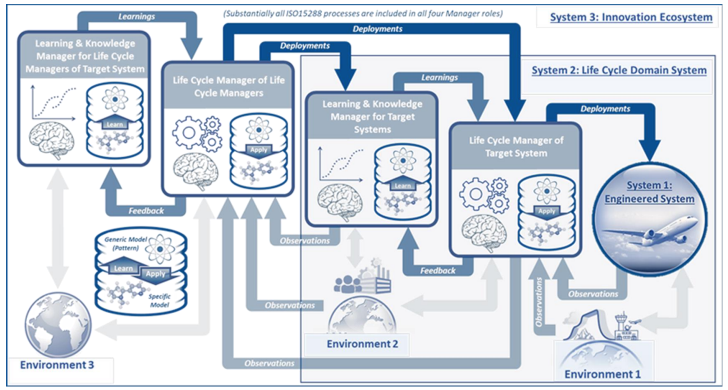
- Think only of information, not process:
  - As if the processes were all concurrent.
- Don't think linear performance of processes with input and outputs—instead, think of "upstream" information that is "more fixed", and downstream information that is "more variable" and whose values are "more determined" by the upstream information:
  - For example, Design Information is downstream from Requirements Information.
- **HOWEVER**: The above term "more" indicates that the flow is not 100% from upstream to downstream—sometimes we have feedback from downstream that causes changes in upstream information:
  - For example, sometimes Requirements have to be adjusted/compromised in order to accommodate feedback from downstream Design Information, such as feasibility or cost.


Upstream
Downstream
Consistency Relationship A-K
Consistency Analyzer
Consistency View
InfoSeg A Update
Consistency Reconciler for A
InfoSeg A
Reconciliations Driving InfoSeg A
Feedback K to A
Consistency Relationship B-K
Consistency Analyzer
Consistency View
InfoSeg B Update
Consistency Reconciler for B
InfoSeg B
Reconciliations Driving InfoSeg B
Feedback K to B
Consistency Relationship C-K
Consistency Analyzer
Consistency View
InfoSeg C Update
Consistency Reconciler for C
InfoSeg C
Reconciliations Driving InfoSeg C
Feedback K to C
InfoSeg K
InfoSeg K Update
Consistency Reconciler for K
Reconciliation Report on K
Reconciliations Driving InfoSeg K
Consistency Relationship H-X
Consistency Analyzer
Consistency View
Feedback X to K
Consistency Reconciler for X
InfoSeg X Update
InfoSeg X
Downstream Reconciliations Driving InfoSeg X
Consistency Relationship H-Y
Consistency Analyzer
Consistency View
Feedback Y to K
Consistency Reconciler for Y
InfoSeg Y Update
InfoSeg Y
Downstream Reconciliations Driving InfoSeg Y

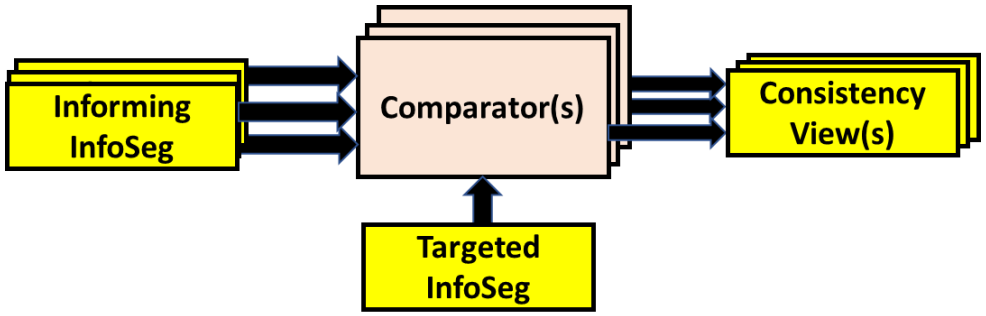
Insights for Improving Group Learning

- Why is learning associated with decision management? Isn't it just a separate capability?
  - Because we rely on our decision-making agents, human or otherwise, to apply what has been learned in the past, by some human or automated agent.
  - We define learning not as simply the accumulation of information, but rather as improving performance based on experience.
- When the decision-making is by some agent other than the one which originally learned, we are talking about group learning.
  - Group learning is a problem area in most organizations and communities, which often "repeat the same mistakes" or "pay again to learn same lessons".
  - Moreover, the reconciliation portion of learning is itself a decision (see human-performed reconciliations, also machine learning algorithms).
- Accordingly, we view the Consistency Management role and the Consistency Thread as key to both decision-making and learning, which are inter-twined.

Architectural Pattern for Human and Machine Learning

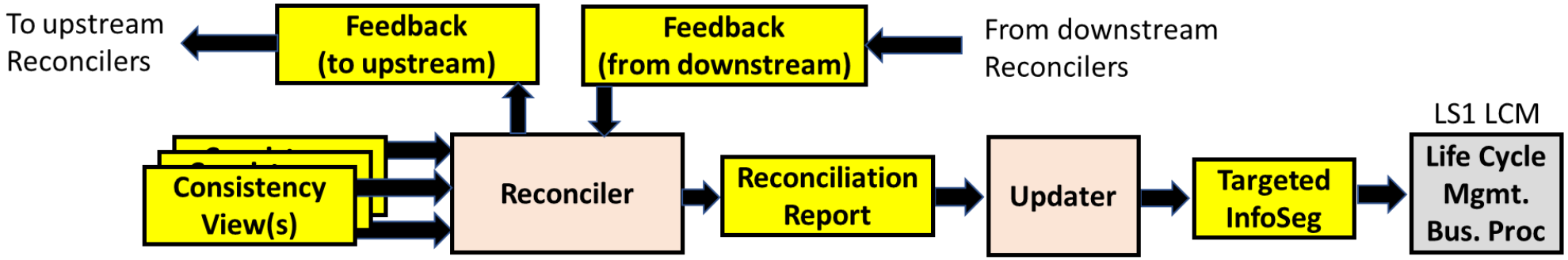


- Roles described can be allocated to humans and (if up to it) to automated agents, including hybrids.
- Includes hybrid human-machine collaboration roles for:
  - Inconsistency Detection: Higher duty cycle even if simpler:



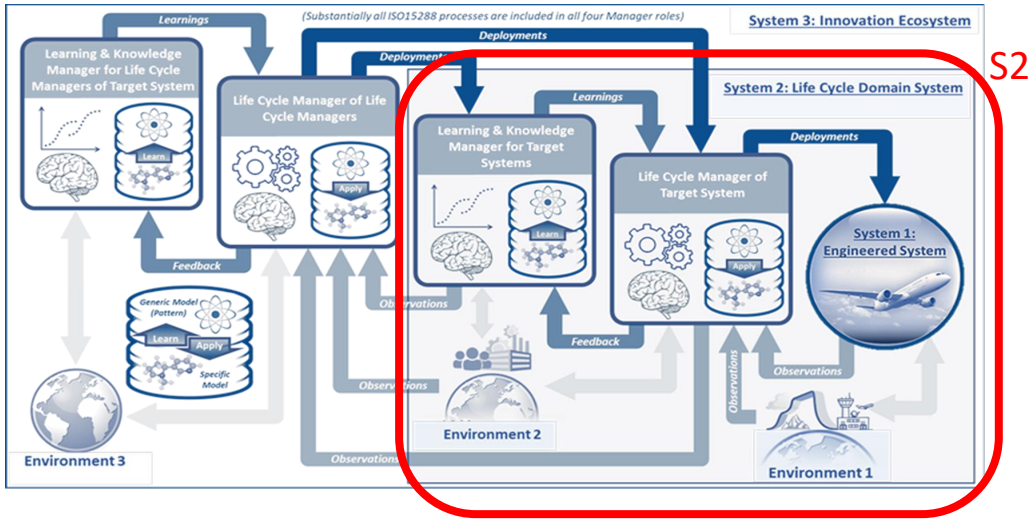
← Demonstrated in INCOSE ST4SE Project, 2022:
[Link to ST4SE Project Report]

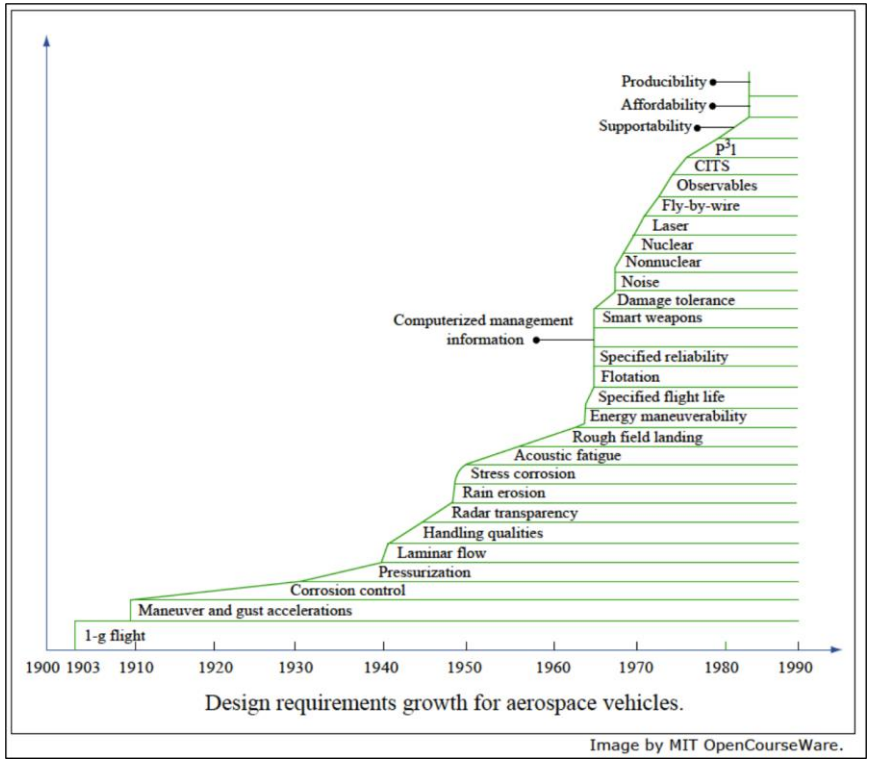
  - Inconsistency Reconciliation: Historically the domain of humans, a lower duty cycle opportunity for machine assistance based on learned patterns:



System 2 Dynamics: Energy and Complexity

- Consider ASELCM System 2 (S2) as a dynamical system in its own right—(Patterns WG's efforts in INCOSE FuSE Foundations).
- Whether effectively or not, at each point in time over S1 life cycle, S2 seeks to minimize the set of "consistency gaps" through selection processes.
- As in the case of energy-based models of learning since John Hopfield, these gaps are thus at the core of a theoretical model of all System 2's.
- See also: Pareto Surfaces.
- S1 Development Difficulty: Complexity of S1 is believed less relevant than the <u>complexity of the consistency gaps to what was already effectively known</u> about S1.





Interested? How to get involved

- INCOSE Patterns Working Group web site: https://www.omgwiki.org/MBSE/doku.php?id=mbse:patterns:patterns

- Current working group projects: https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:mbse_patterns_wg_mtg_iw2023_01.29.2023.v1.1.3_.pdf

Or, just contact Patterns Working Group leaders:

- Bill Schindel schindel@ictt.com
- Troy Peterson Troy Peterson tpeterson@systemxi.com

Questions, discussion

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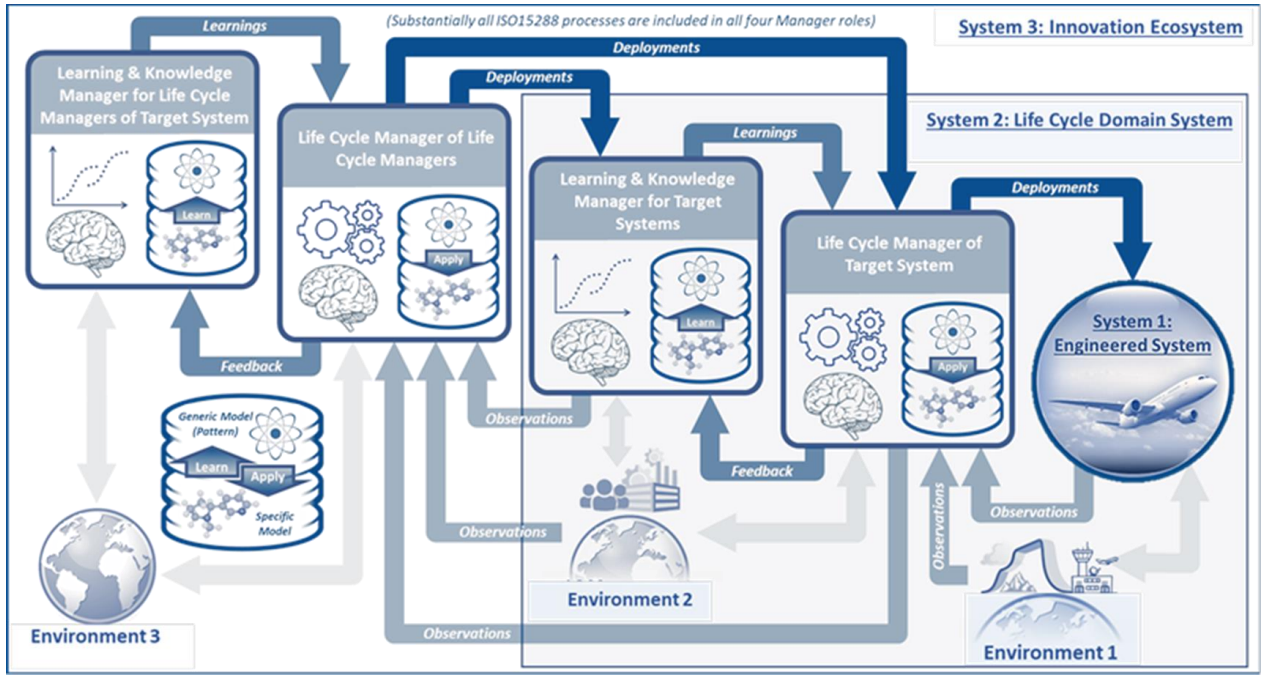
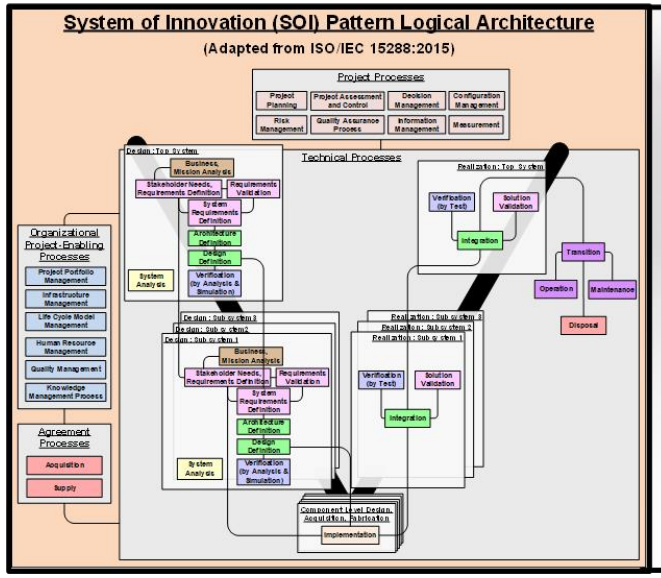
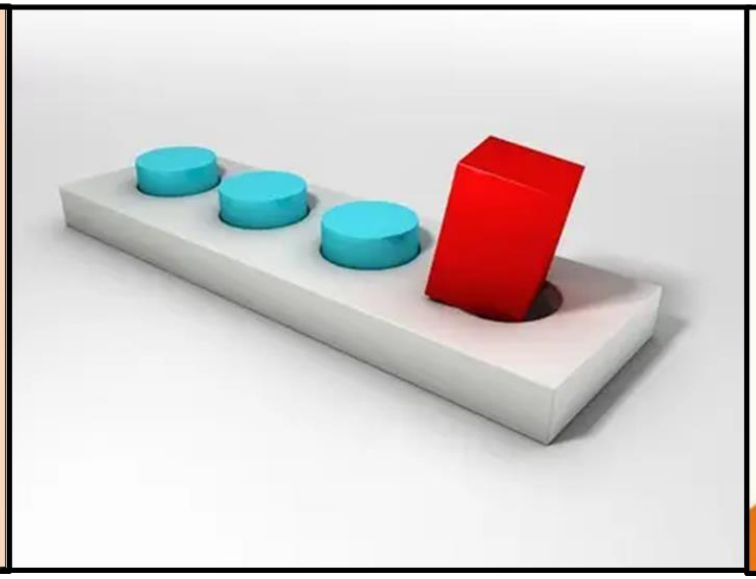


Life Cycle Mgmt. Decisions



Inconsistencies



Decisions

Thank you!

References

ASELCM Pattern:

- Schindel, W., "The Innovation Ecosystem: Introduction to the INCOSE ASELCM Pattern", INCOSE N Texas Chapter, Dec, 2021. https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:incose_north_texas_pgm_12.14.2021_v1.2.2.pdf
- Schindel, "Planning, Implementing, and Evolving the Ecosystem: Realizing the Promise of Digital Engineering", in Proc. of INCOSE 2022 International Symposium, Detroit, MI, 2022. Retrieve from -- https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:incose_is2022_realizing_the_promise_of_digital_engineering_v1.1.3.pdf
- Schindel, W., Dove, R. 2016. "Introduction to the Agile Systems Engineering Life Cycle MBSE Pattern". Paper presented at INCOSE International Symposium. Edinburgh, UK, 18-21 July. Retrieve from -- https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:is2016_intro_to_the_aselcm_pattern_v1.4.8.pdf

Automating Support for Decisions and Consistency Management:

- "INCOSE MBSE Patterns Working Group Report: Semantic Technologies for Systems Engineering (ST4SE) Project", 2022. Retrieve from—Link to ST4SE Project Report
- Herzig, S., Paredis, C. 2014. "A Conceptual Basis for Inconsistency Management in Model-Based Systems Engineering", Paper presented at CIRP Design Conference, 2014, retrieve via https://www.sciencedirect.com/science/article/pii/S2212827114007586/pdf?md5=c9bdd8aba94e820ec43b56330225daa6&pid=1-s2.0-S2212827114007586-main.pdf
- Mendonza, P. and Fitch, J.A. 2013. "Integrating System Models around Decisions", in Proc. of 2013 INCOSE International Symposium, Philadelphia,2013.
- "Decision Model and Notation", Version 1.5 Beta, OMG., retrieve from https://www.omg.org/spec/DMN

AIAA Reference Models for Digital Threads and Digital Twins

- American Institute of Aeronautics and Astronautics (AIAA) has released both its Digital Thread & Digital Twin Reference Models, based on INCOSE ASELCM Innovation Ecosystem Pattern. Link to AIAA Reference Patterns for Digital Thread and Digital Twin
- AIAA Digital Thread Reference Pattern Link to AIAA Digital Thread Reference Model
- AIAA Digital Twin Reference Pattern Link to AIAA Digital Twin Reference Model

References, continued

Historical Decision-Making Literature:

- Kahneman, D., Sibony, O., Sunstein, O. *Noise: A Flaw in Human Judgment*. Little, Brown, Spark. 2021.
- Simon, H., *Administrative Behavior*, 4th Edition. Free Press. 1997.
- Parnell, G., Bresnick, T., Tani, S., Johnson, E., *Handbook of Decision Analysis*, Wiley, 2013.
- *Harvard Business Review*, Special issue on decision-making, January, 2006.
- Ellsberg, D., *Risk, Ambiguity and Decision*, Routledge, 2016.
- Arrow, K., and Herve Raynaud, H., *Social Choice and Multicriterion Decision-Making*, MIT Press, 1986.
- Kahneman, D., Slovic, P., Tversky, A., eds., *Judgment Under Uncertainty: Heuristics and Biases,* Cambridge U Press, 1982.
- See covers page for others

Energy Based Machine Learning:

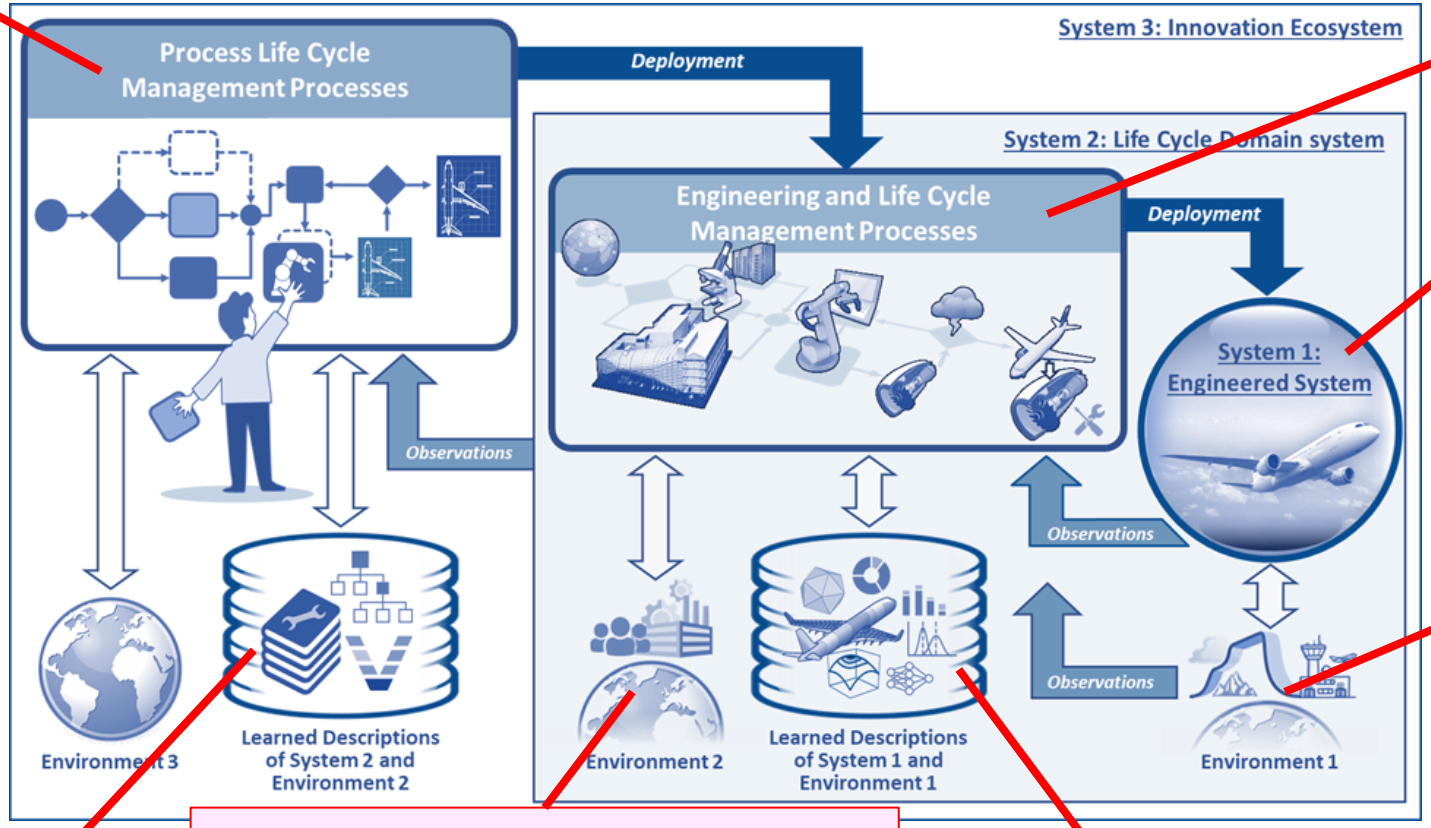
- Hopfield, J. "Neural Networks and Physical Systems with Emergent Collective Computational Abilities", *Proc. of the National Academy of Sciences of the United States of America*. 1982. 79: 2554-8. Retrieve from https://www.pnas.org/doi/10.1073/pnas.79.8.2554
- LeCun, Y., "A Tutorial on Energy-Based Learning", New York University, http://www.cs.toronto.edu/~vnair/ciar/lecun1.pdf
- Schindel, W., " SE Foundations: Applications in the Innovation Ecosystem Context", MBSE Patterns Working Group, March, 2023. Retrieve from https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:se_foundations--applics_in_ecosys_v1.2.2.pdf

INCOSE Working Groups:

- INCOSE MBSE Patterns Working Group:
  - https://www.omgwiki.org/MBSE/doku.php?id=mbse:patterns:patterns
  - https://www.incose.org/incose-member-resources/working-groups/transformational/mbse-patterns
- INCOSE Decision Analysis Working Group: https://www.incose.org/incose-member-resources/working-groups/analytic/decision-analysis

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

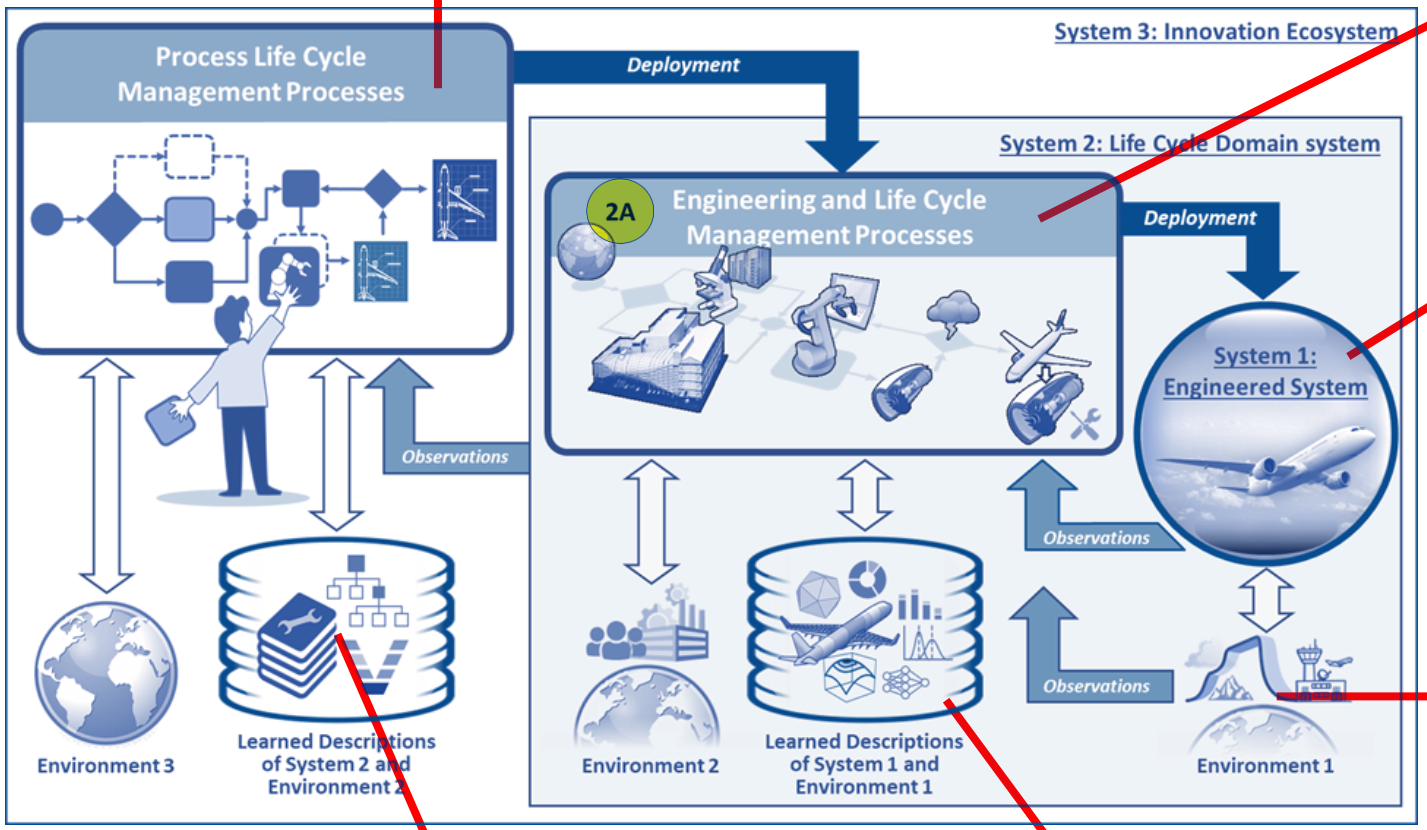
- **Examples**: COVID19 Pandemic, Industry Funding, Job Market

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

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

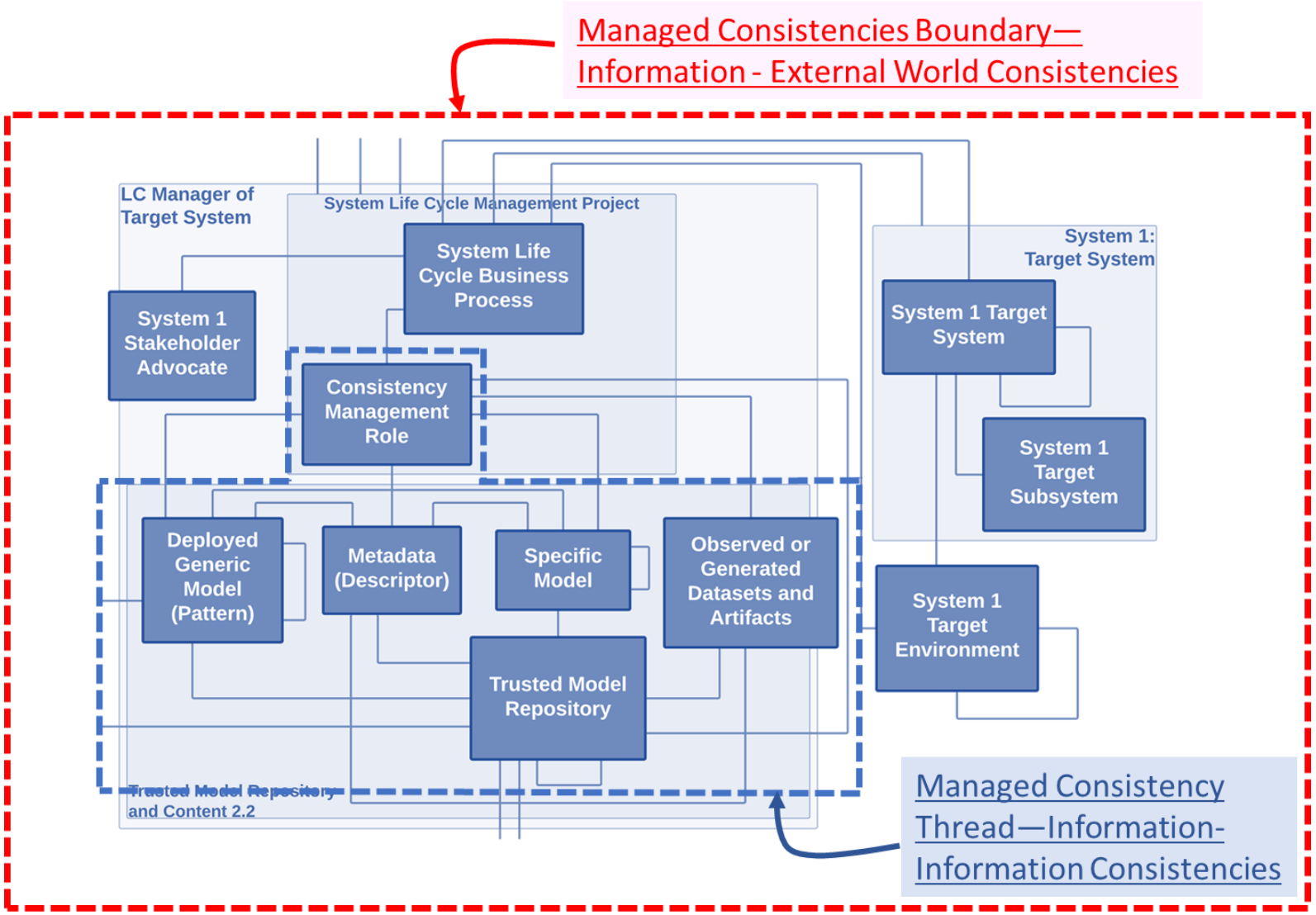
DEFINITIONS

- 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.

From the “internal boundary” perspective shown, the inconsistences will be about inconsistencies of “information segments”:



Managed Consistency Thread System Boundaries

Two Different Kinds of Interdependent Responsibilities

Life Cycle Management Domains:

- Engineering
- Production
- Distribution (incl. Marketing)
- Operations
- Sustainment
- Retirement

Domain-Specific Decision Management (Consistency Management) Features, Interactions

(Newer) Responsible for Consistency of Information-Described Outcomes Within and Across the Domains

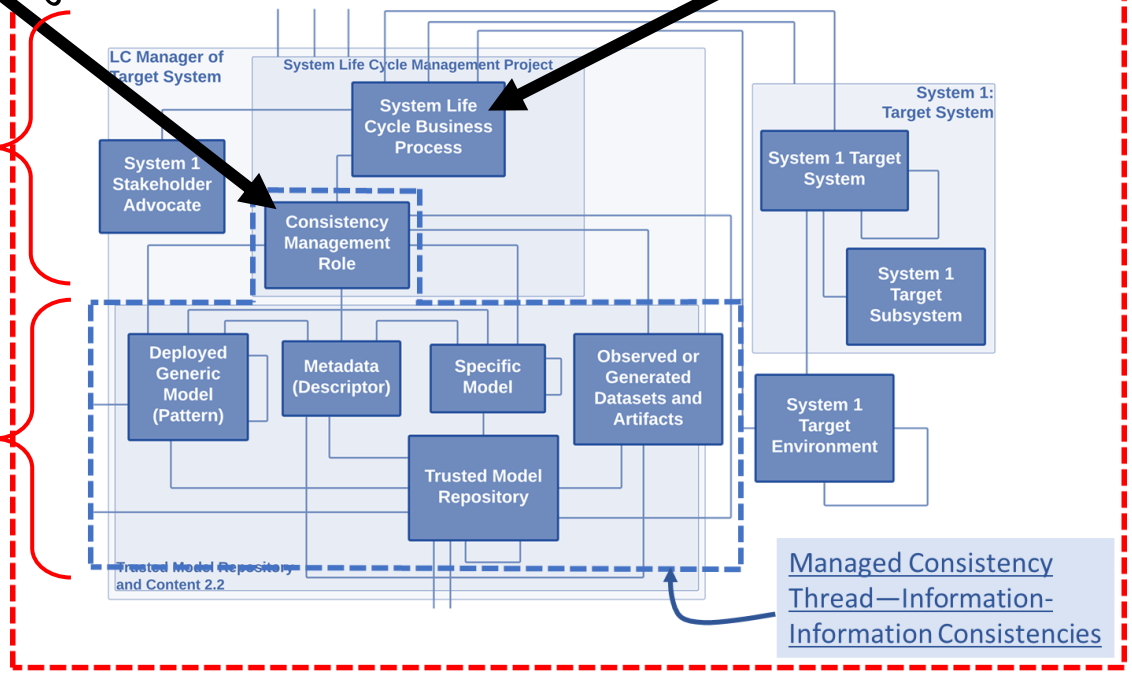
Focal Process Roles

Focal Process Roles

Domain-Specific Life Cycle Management Features, Interactions

(Traditional) Responsible for Connecting Information from/to Exterior "Real" Domain Worlds, and for Domain-Specific Outcomes.

Managed Consistencies Boundary—Information - External World Consistencies



Managed Consistency Thread—Information-Information Consistencies

Managed Consistency Thread System Boundaries

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 reference model and case study teams.
- Schindel is an INCOSE Fellow and CSEP, and is a director and past president of the INCOSE Crossroads of America Chapter.
- schindel@ictt.com