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

V1.1.3

Abstract

- Gaining benefits of Digital Engineering is not only about implementing digital technologies. An ecosystem for innovation is a system of systems in its own right, only partly engineered, subject to risks and challenges of evolving socio-technical systems.
- The subject of this paper is a formal, configurable, model-based reference pattern for describing such systems--an aid to planning, analyzing, implementing, and improving innovation ecosystems. Collaborating INCOSE working groups initially applied it to targeted INCOSE case studies. It was subsequently elaborated and applied to diverse commercial and defense ecosystems, including AIAA case studies in aerospace.
- Explicating the recurrent theme of Consistency Management underlying all historical engineering, it is revealing of Digital Engineering’s special promise in that area, while enhancing understanding of historical as well as future engineering and life cycle management.
- It includes preparation of human and technical resources to effectively consume and exploit digital information assets, not just create them, capability enhancements over incremental release trains, and evolutionary steering using feedback and group learning.

Contents

Collaborating Working Groups and Societies

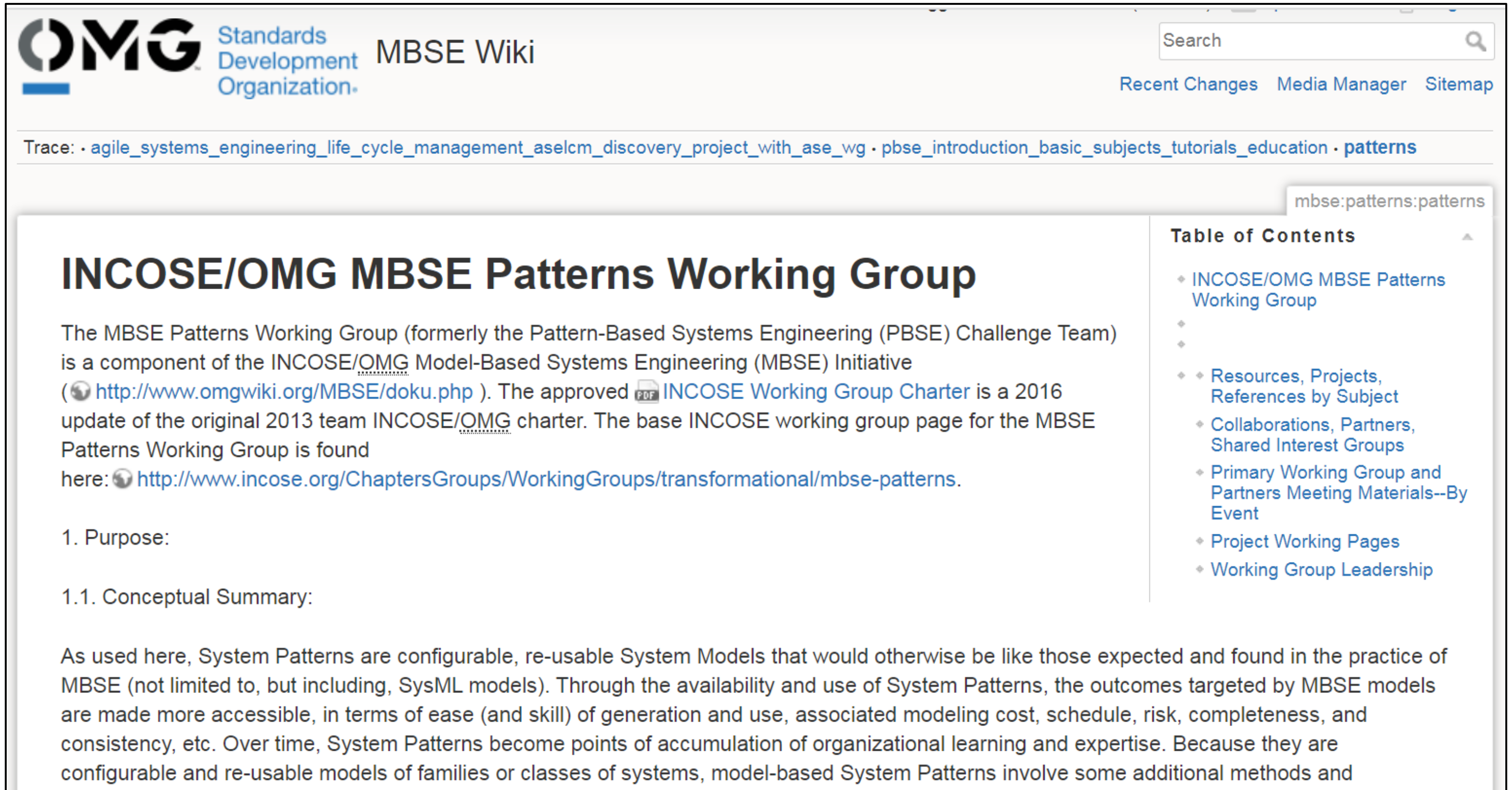
- **INCOSE**:
  - MBSE Patterns Working Group
    - -For the Generic ASELCM Innovation Ecosystem Pattern
  - Agile Systems Engineering Working Group
    - -For Agile SE Applications of the ASELCM Pattern

- **AIAA**:
  - Aerospace Digital Thread Reference Team
  - Aerospace Digital Twin Reference Team
    - \- For Aerospace-Specific Applications

- **ASME**:
  - Standard VV50 Working Group for Model Life Cycle
    - \- For Advanced Manufacturing Applications Using the ASELCM Model Characterization Pattern

The INCOSE MBSE Patterns Working Group

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



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

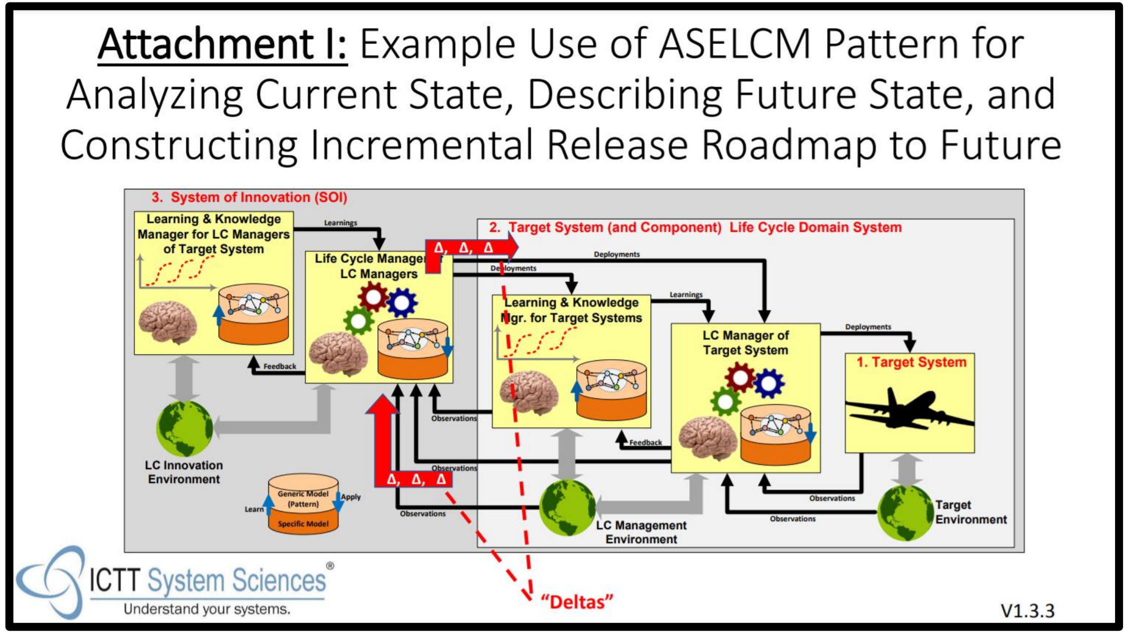
See also: Attached References pages.

The Innovation Ecosystem Pattern: Early history

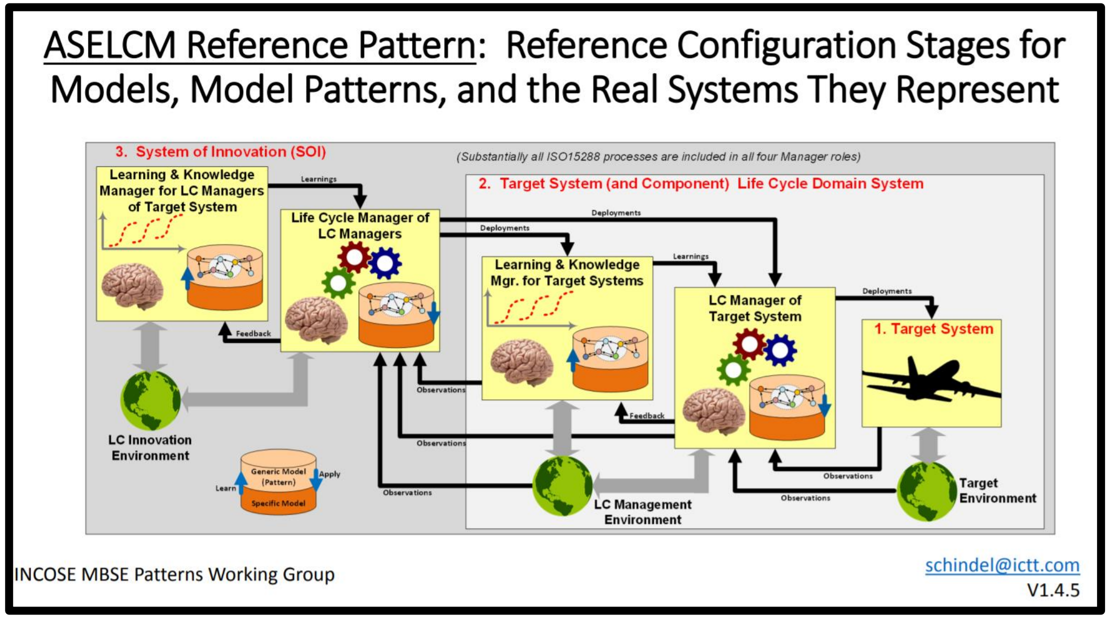
- Originally introduced in a series of 2012, 2013 INCOSE papers on the emergence of purpose and pathologies in innovation environments.
- Elaborated during multi-year collaboration with the Agile SE Working Group, as an analysis framework in that study of four mil/aero enterprises demonstrating forms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

Current applications and values

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



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

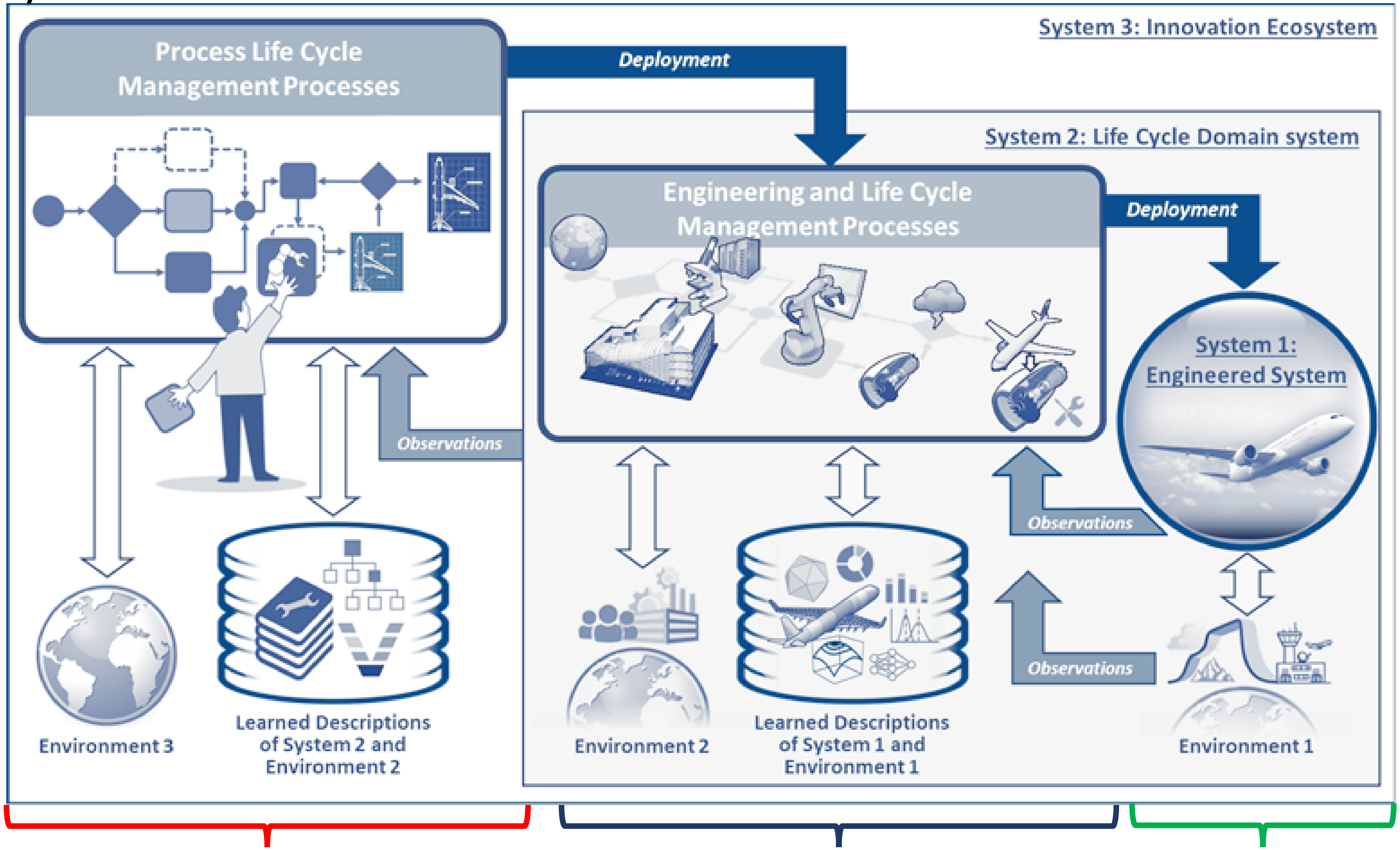


https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:configuration_stages_v1.4.5.pdf

Brief tour through the Ecosystem Pattern concepts and implications

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

System reference boundaries structure: Level 0

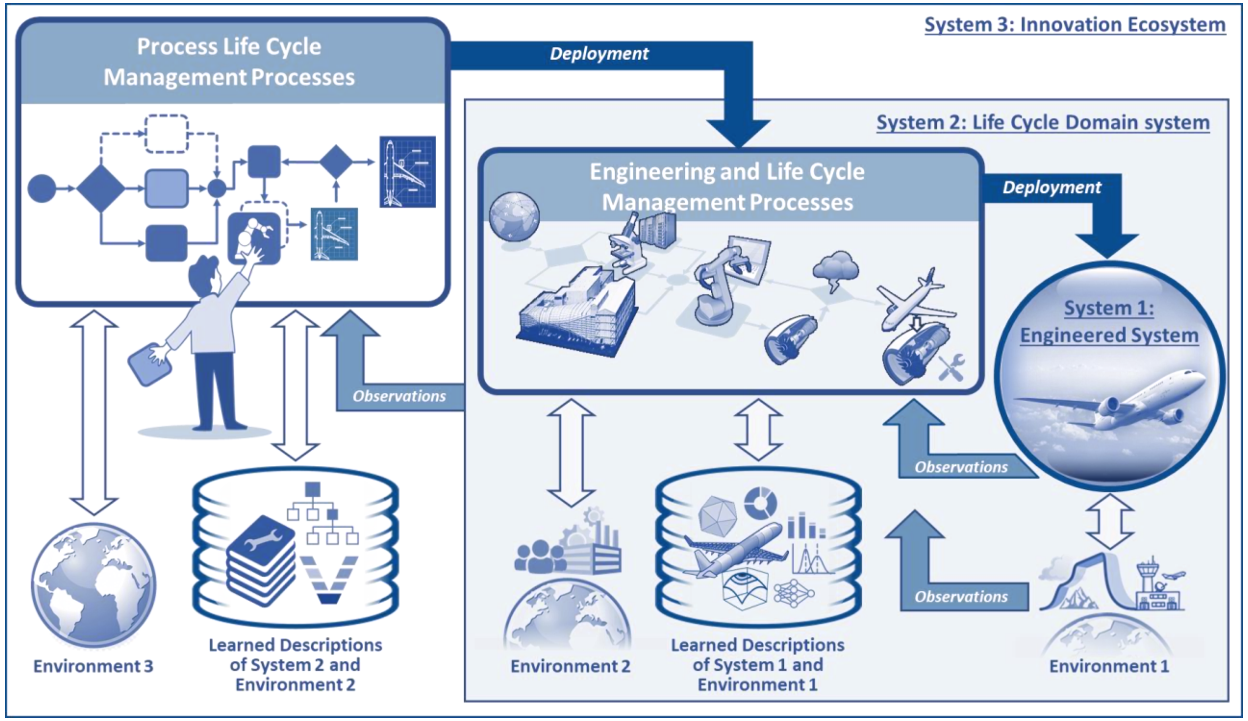


System 3: Life Cycle Manager of System 2

System 2: Life Cycle Manager of System 1

System 1: Engineered System

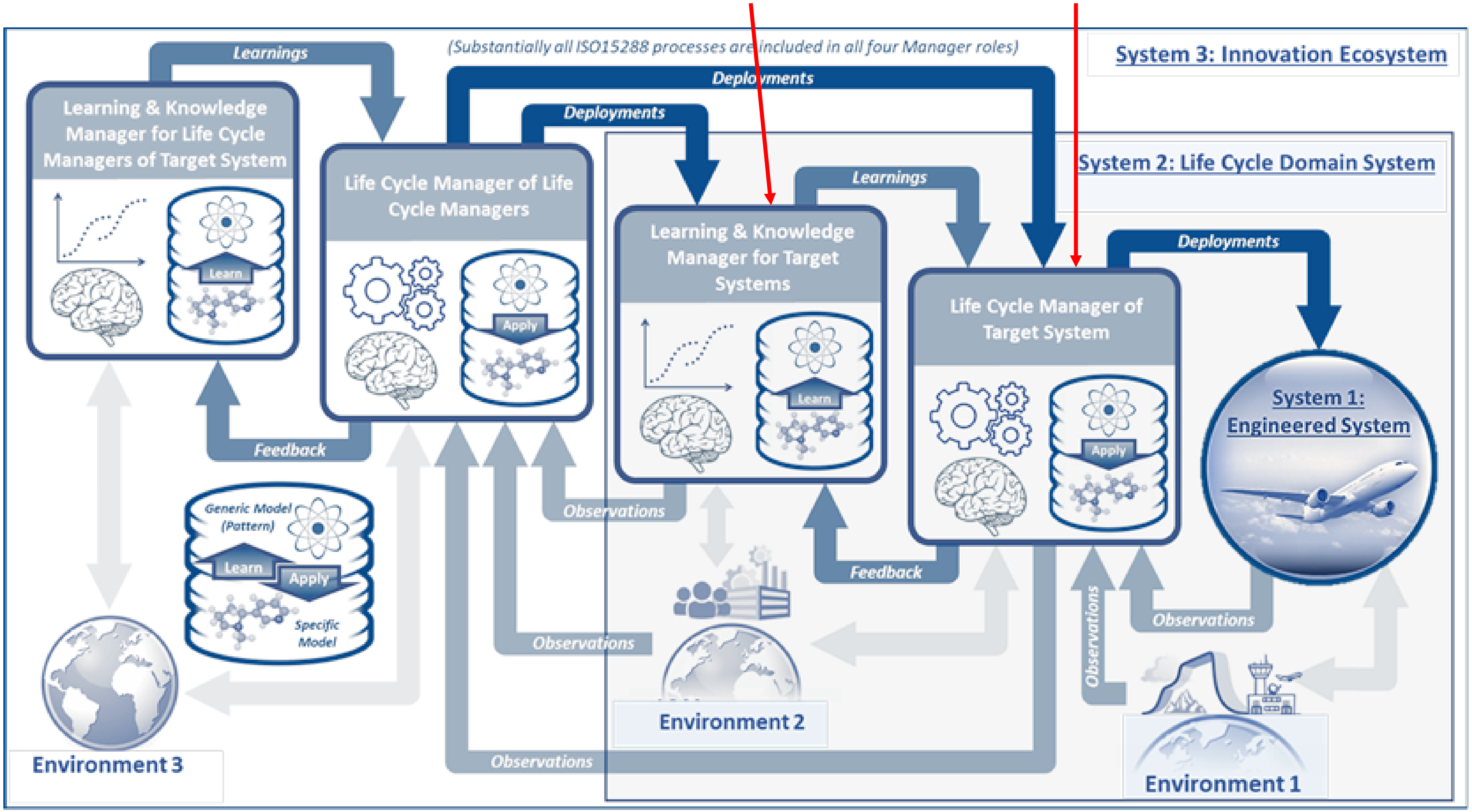
INCOSE ASELCM Level 0 Reference Model



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

INCOSE ASELCM Level 1 Reference Model

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

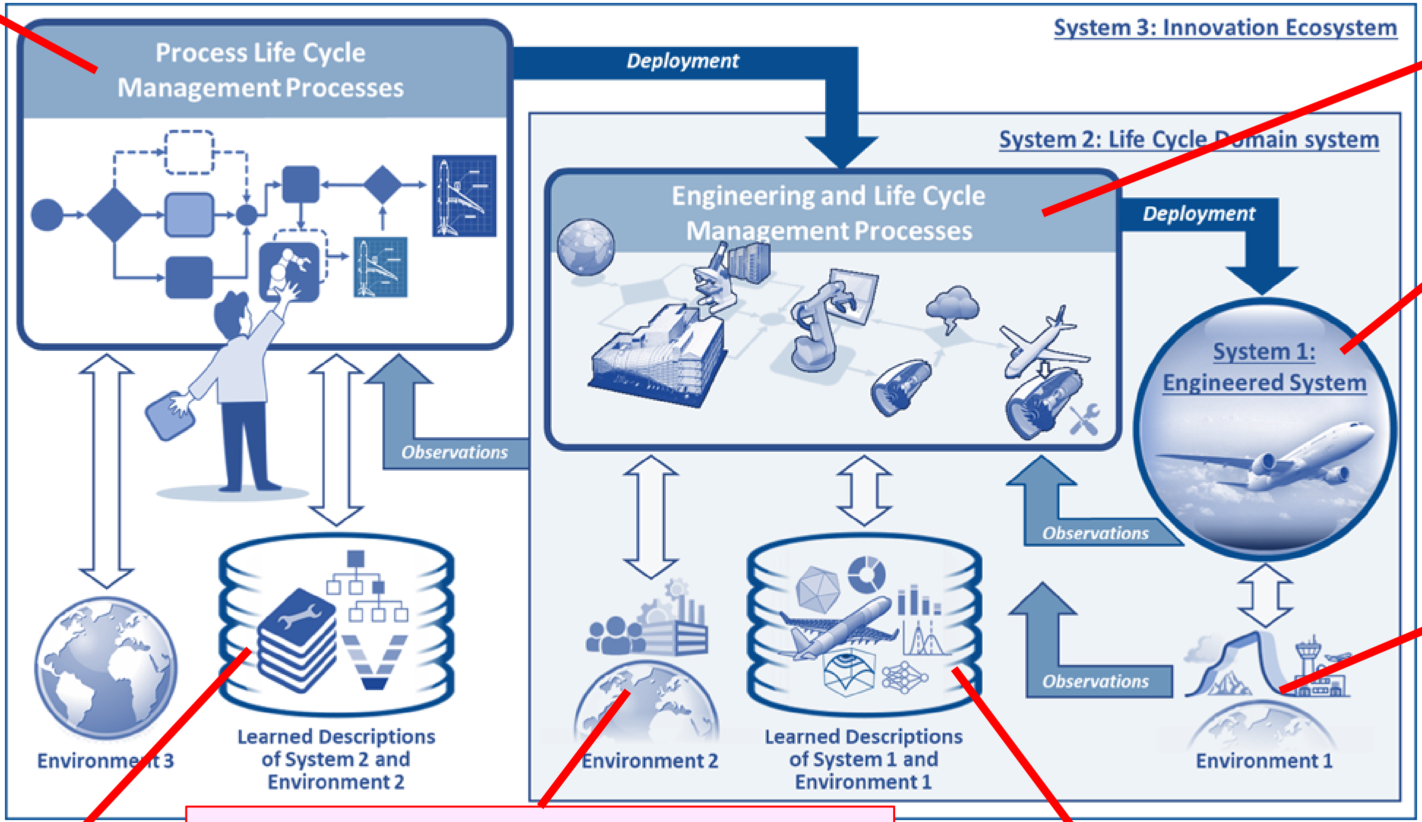


Examples: Engineering Education, Engineering Methods Owner, Engineering Tooling Architect, HR Department, Engineering Procedures Author, INCOSE, IEEE, ASME

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

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

EXAMPLES



- **Examples**: Atmosphere, weather, runways

INCOSE ASELCM Level 0 Reference Model

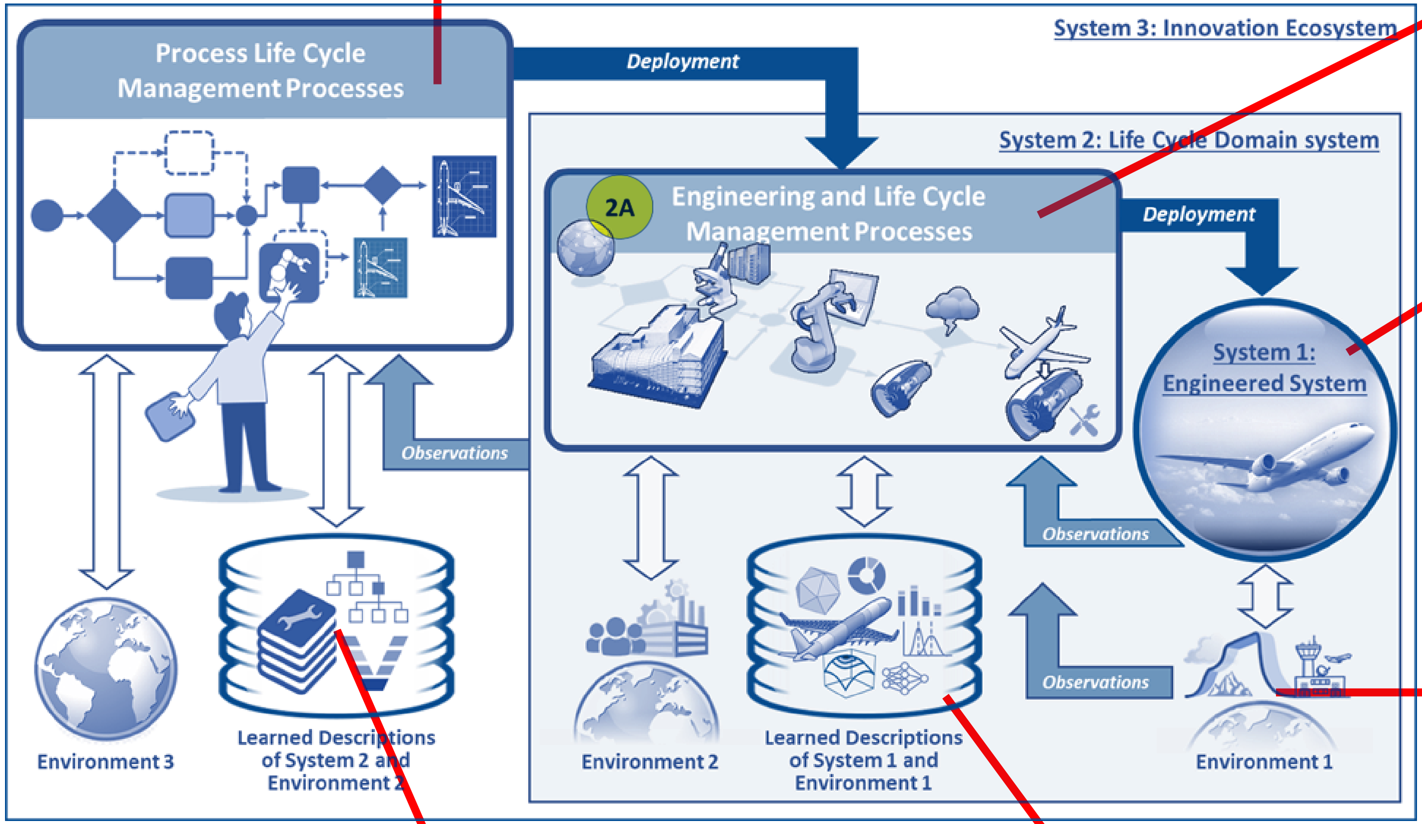
- **Examples**: COVID19 Pandemic, Industry Funding, Job Market

- **Examples**: 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

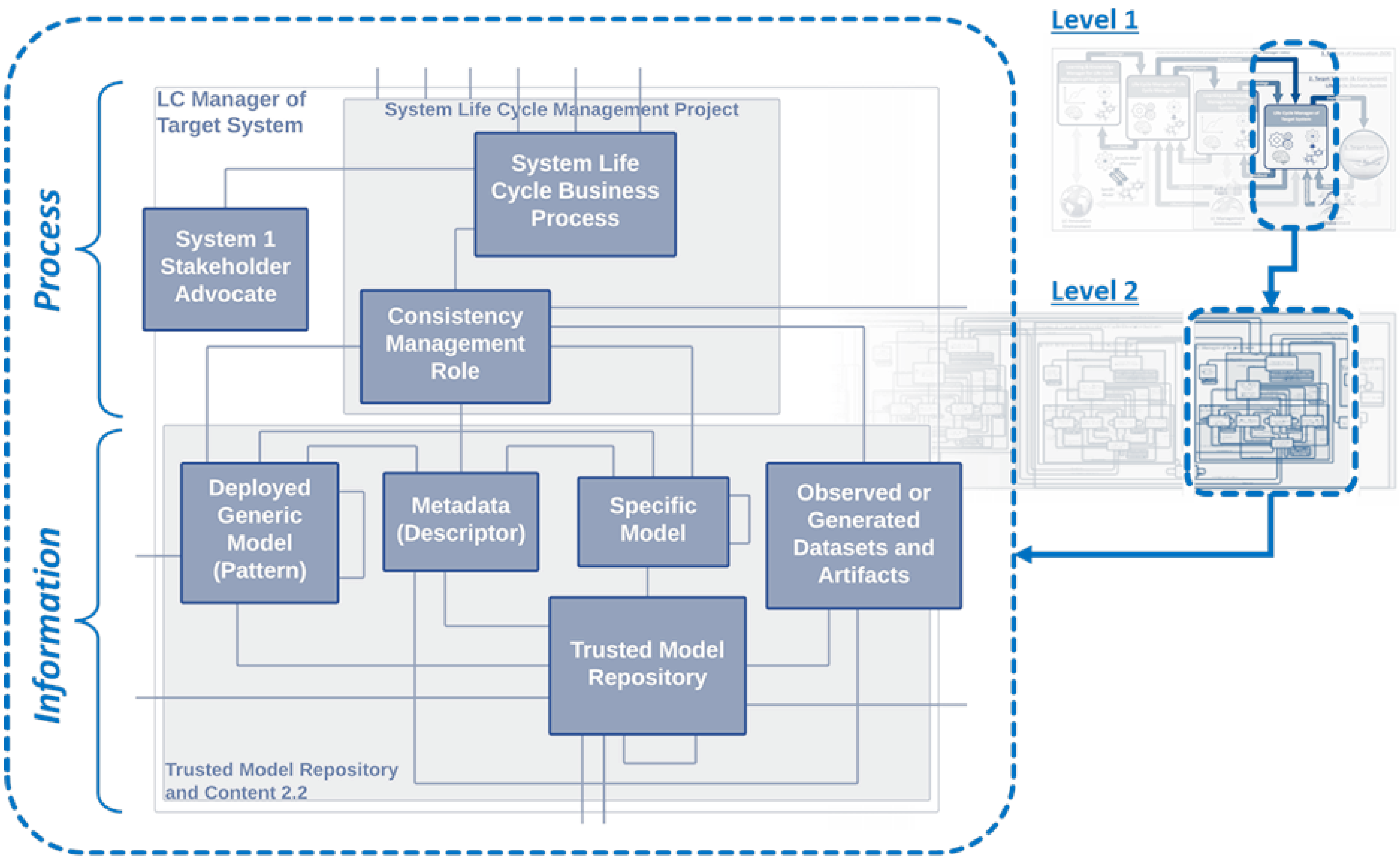
- The environment in which System 1 is operated, sustained, distributed, manufactured, or retired.
- Anything that directly interacts with System 1 during its life cycle.

- 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.

INCOSE ASELCM Level 2 Reference Model

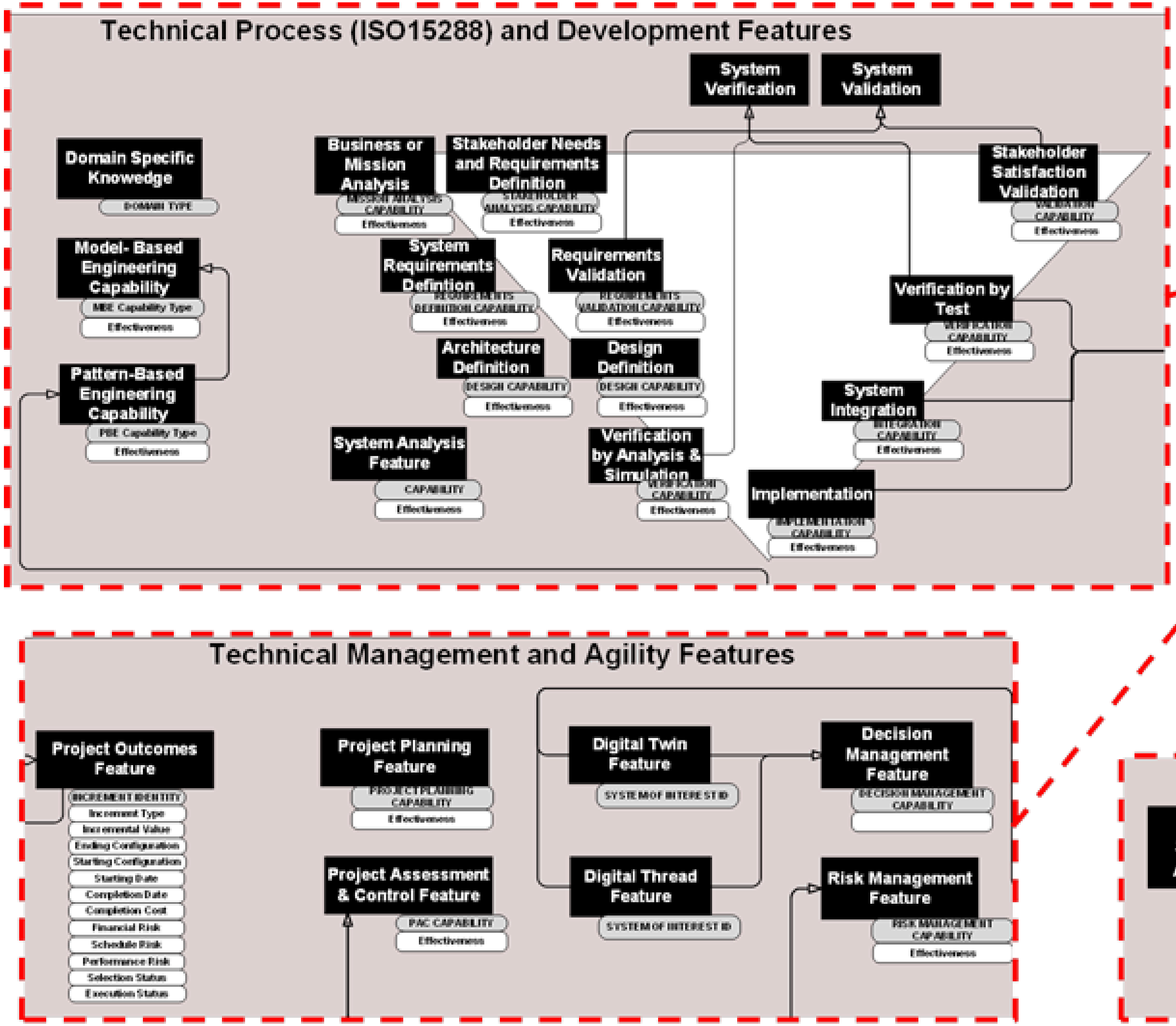
(Segment for Application of "Already Learned" Information)

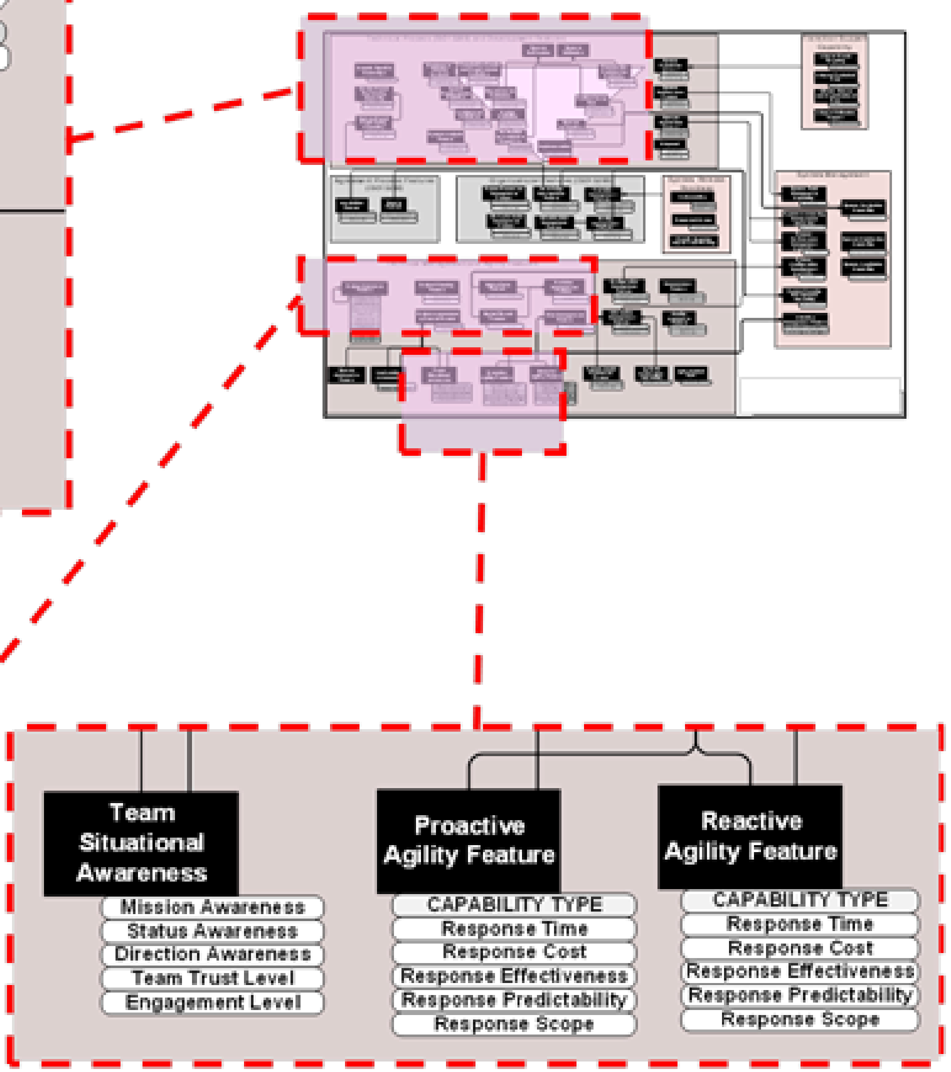


1. Ecosystem level capabilities' connections to underlying interactions

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

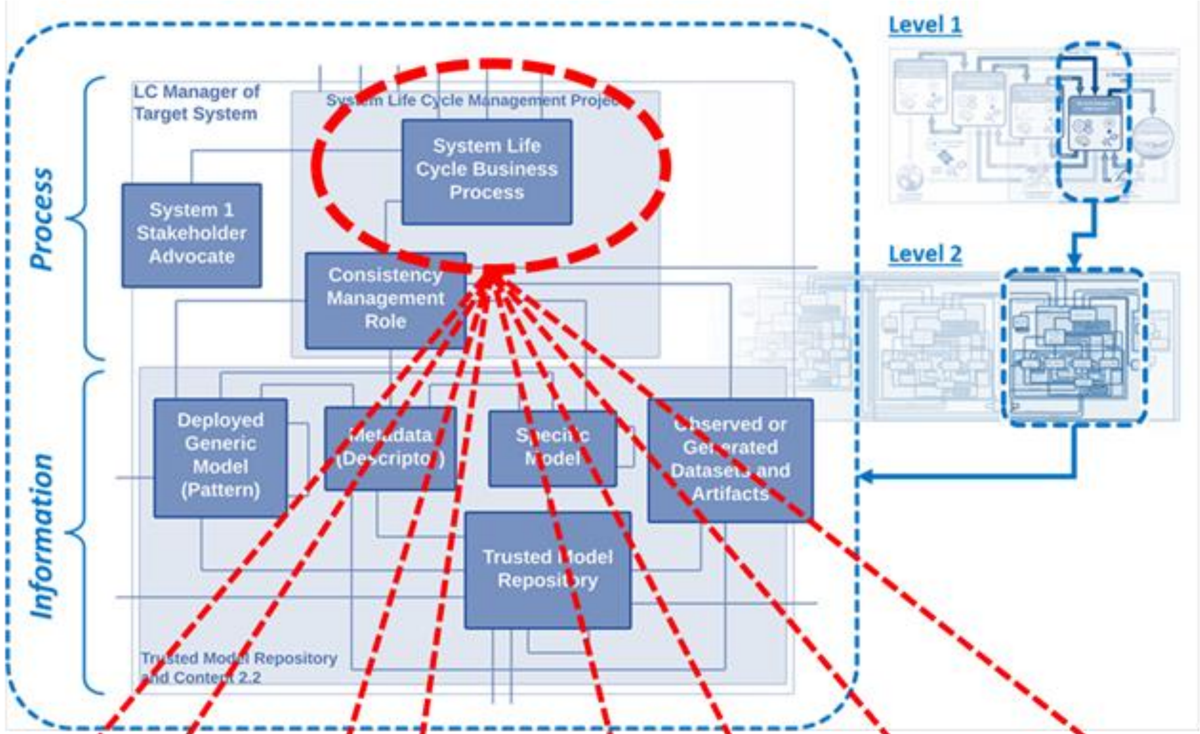
Selectable Stakeholder Features (Capabilities) of System 2



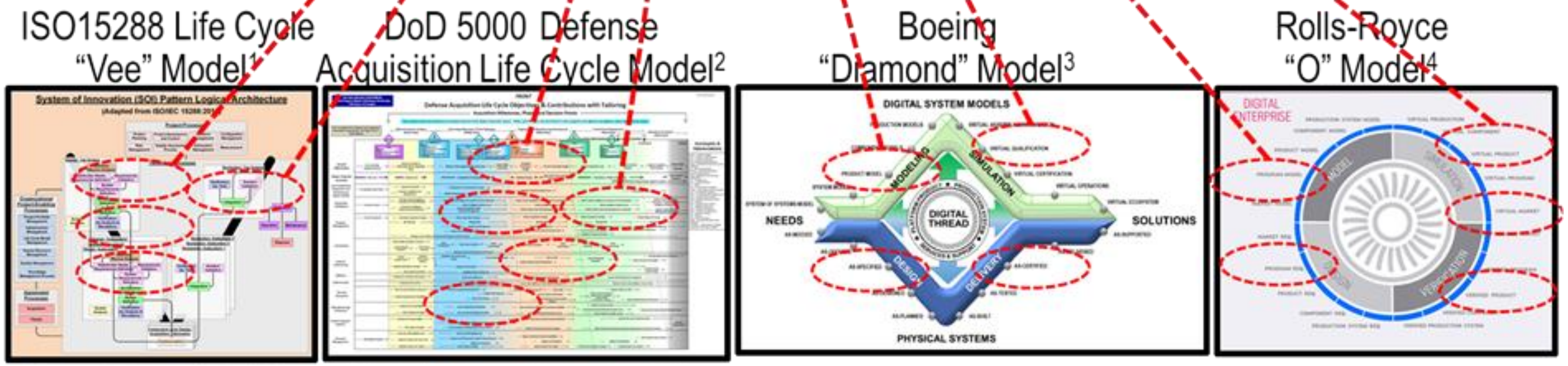


2. Connecting historically represented business processes to evolving digital infrastructure

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



Configurable to specific life cycle management models---

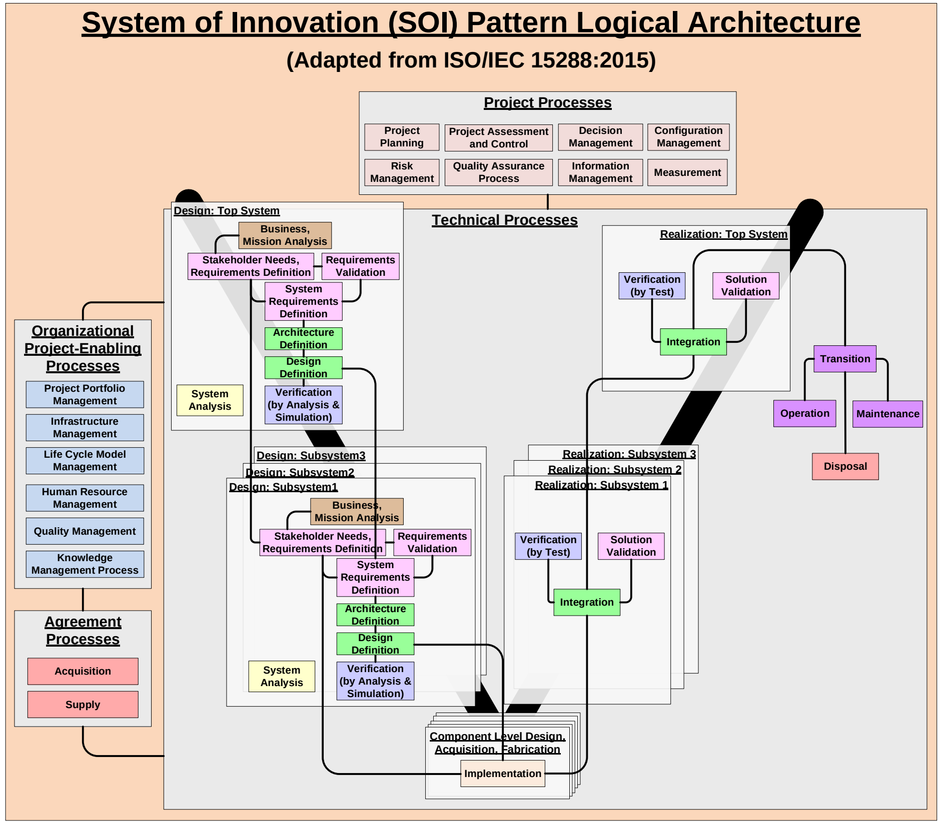


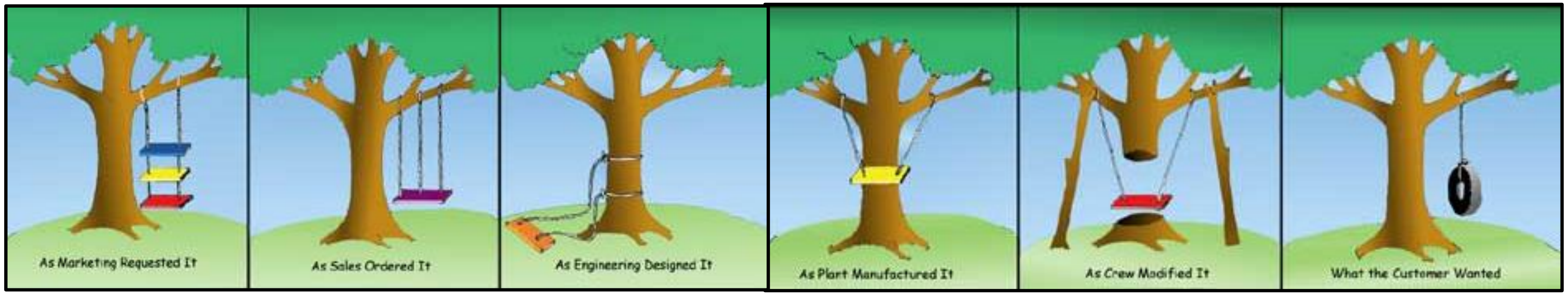
Excerpted or adapted from: (1) ISO15288 and INCOSE SE Handbook; (2) DoD5000 Wall Chart; (3) AIAA Sci Tech, 01.2020, J. Matakeyama; (4) AIAA DEIC Digital Twin Subcommittee, 04.08.19 Donaldson, Flay, French, Matlik, Myer, Pond, Randjelovic

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

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

- Finding and resolving gaps, shortcomings, or inconsistencies.

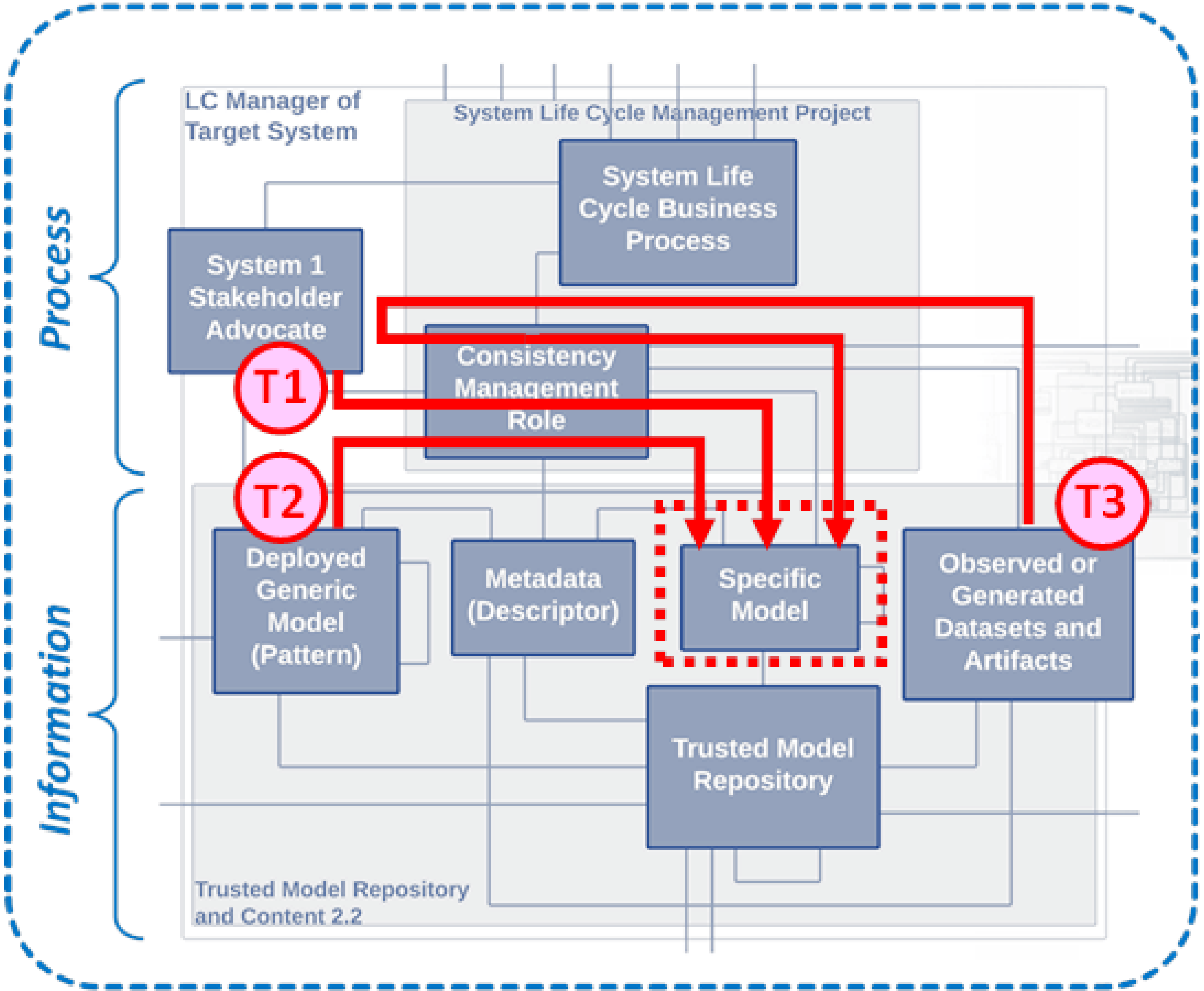




Examples of Managed Consistencies

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

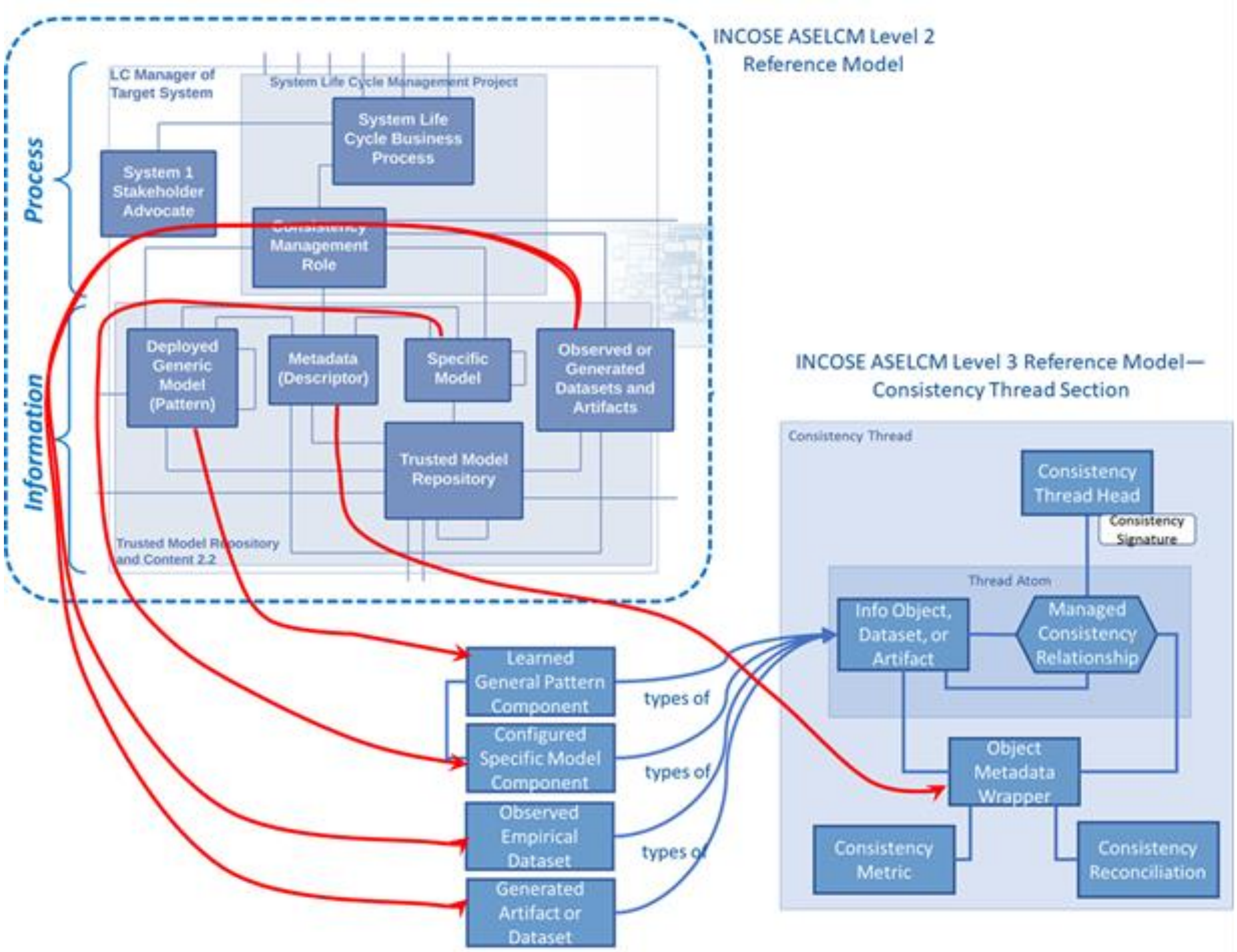
These 3 sources will disagree frequently—reconciling those differences is a major part of life cycle management.



The 3 sources of credibility

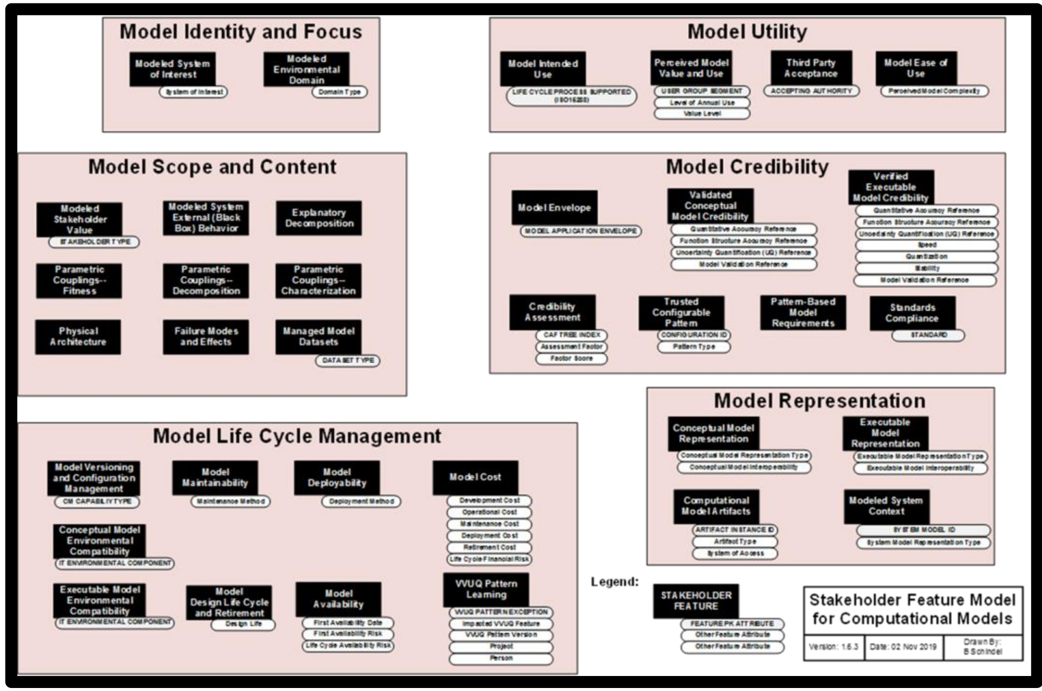
- **T1** What stakeholders now say / want
- **T2** What past learning says
- **T3** What the observed real world and its simulation now say

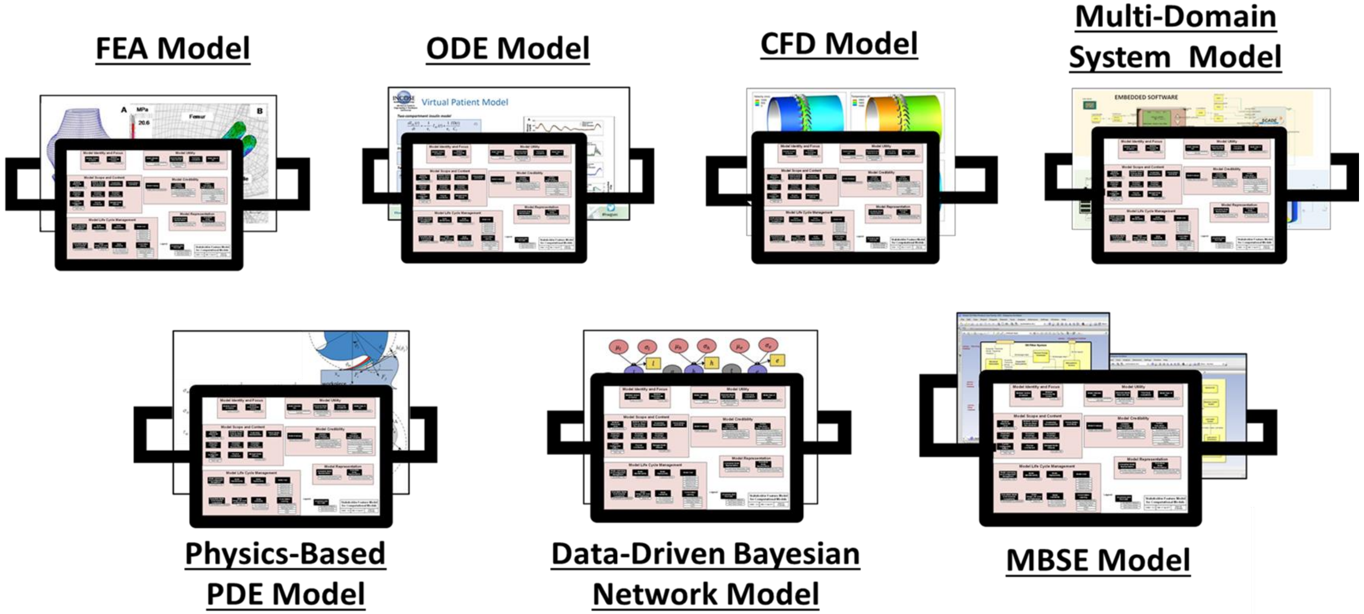
The Consistency Thread: Behind the Digital Thread (and Historical) Curtain

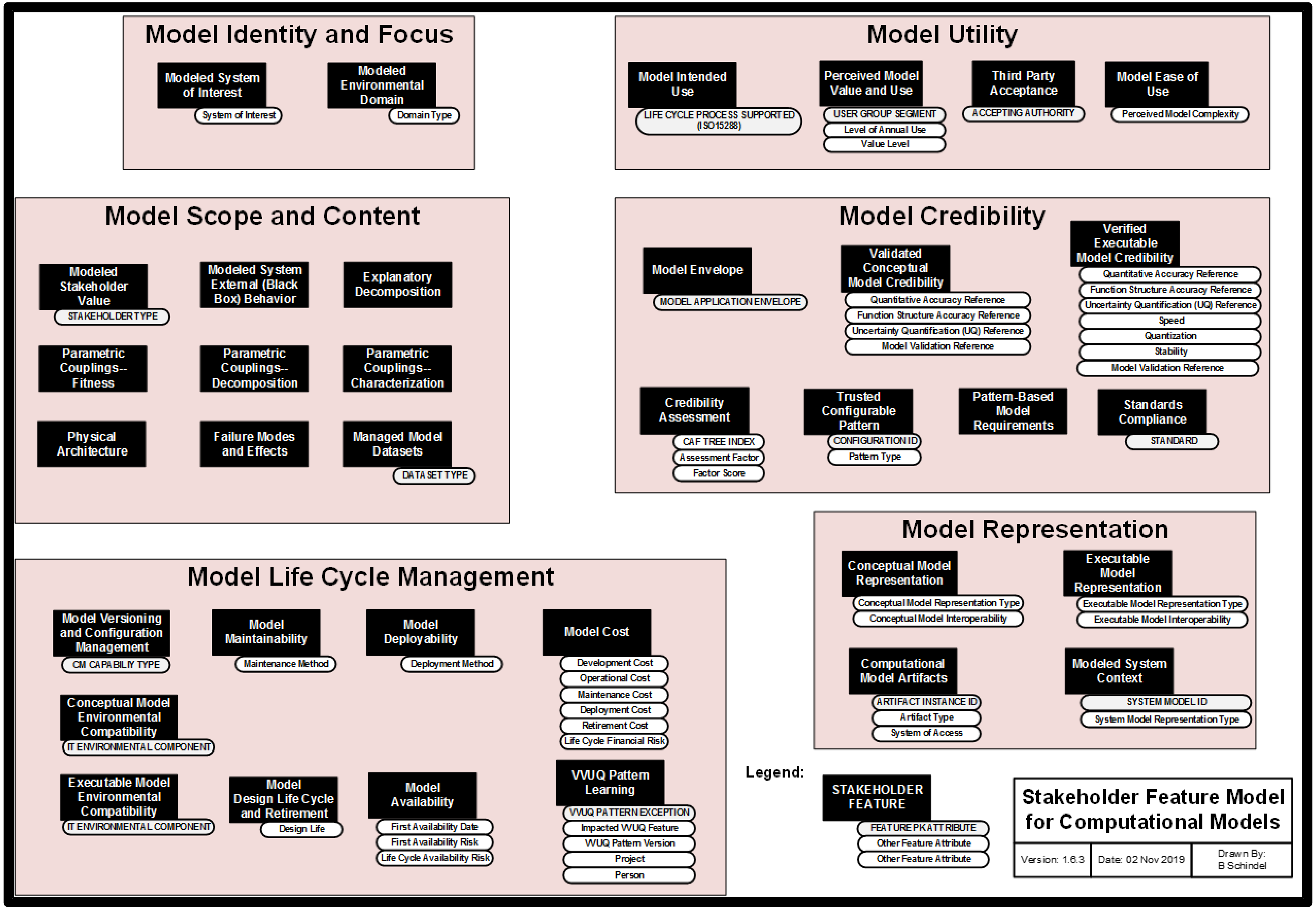


4. Managing the proliferation of virtual model diversity and instances

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



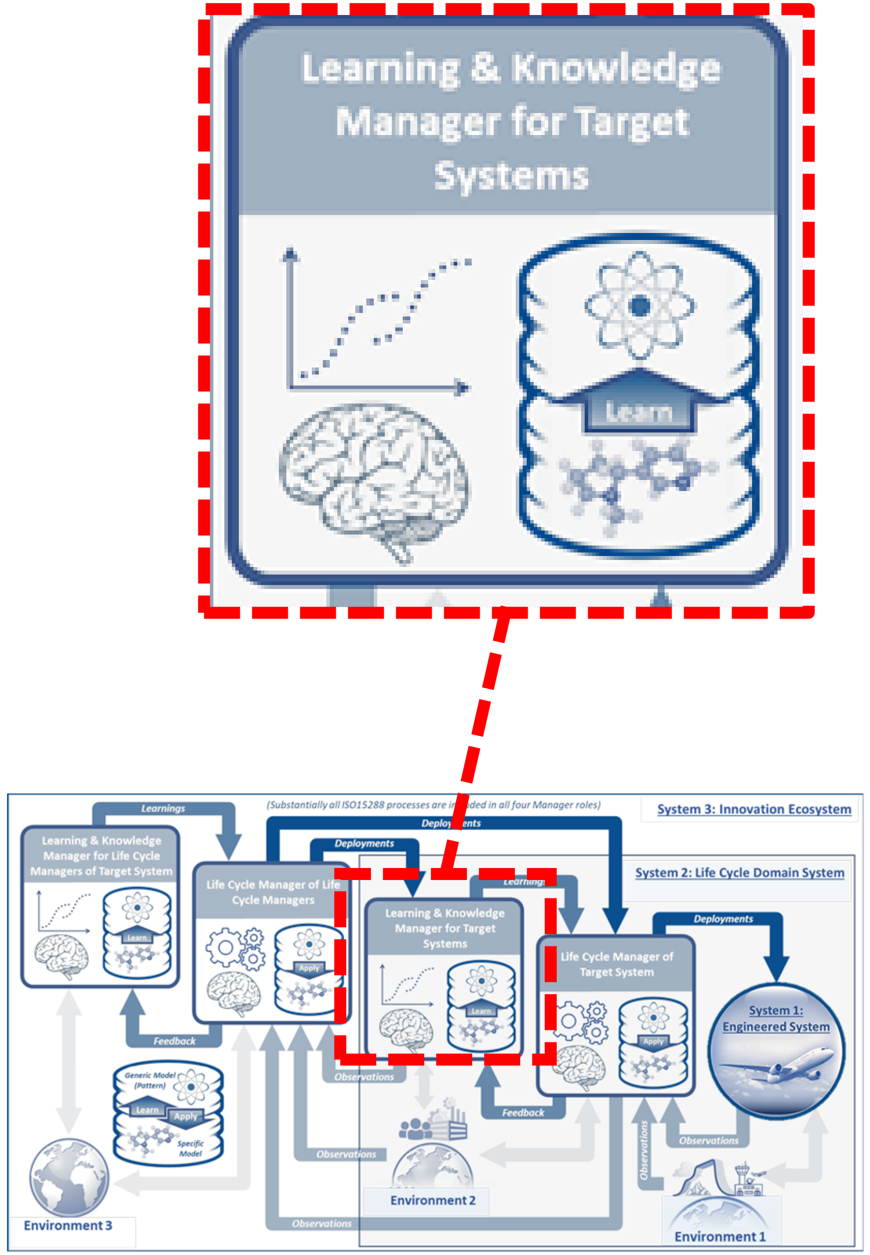




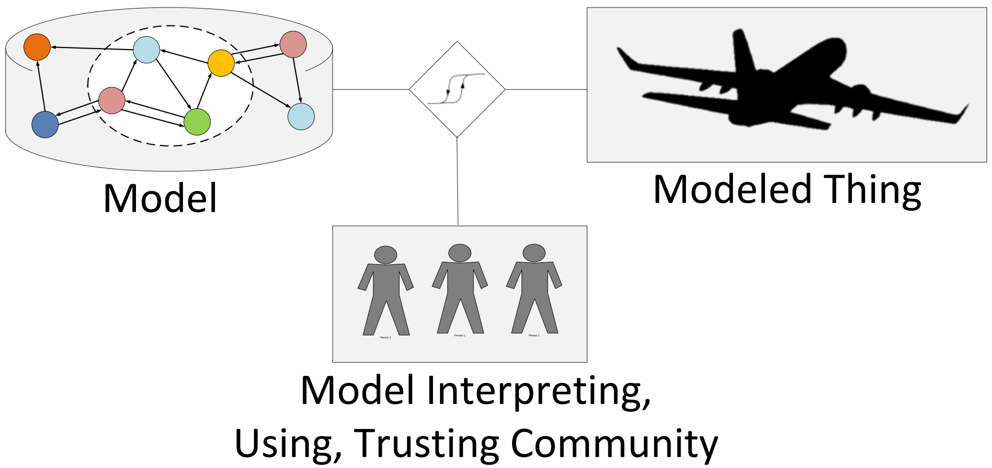
https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:model_characterization_pattern_--_summary_guide_v1.2.1.pdf and https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:model_characterization_pattern_mcp_v1.9.3.pdf

5. Effectiveness of distributed, multi-level group learning

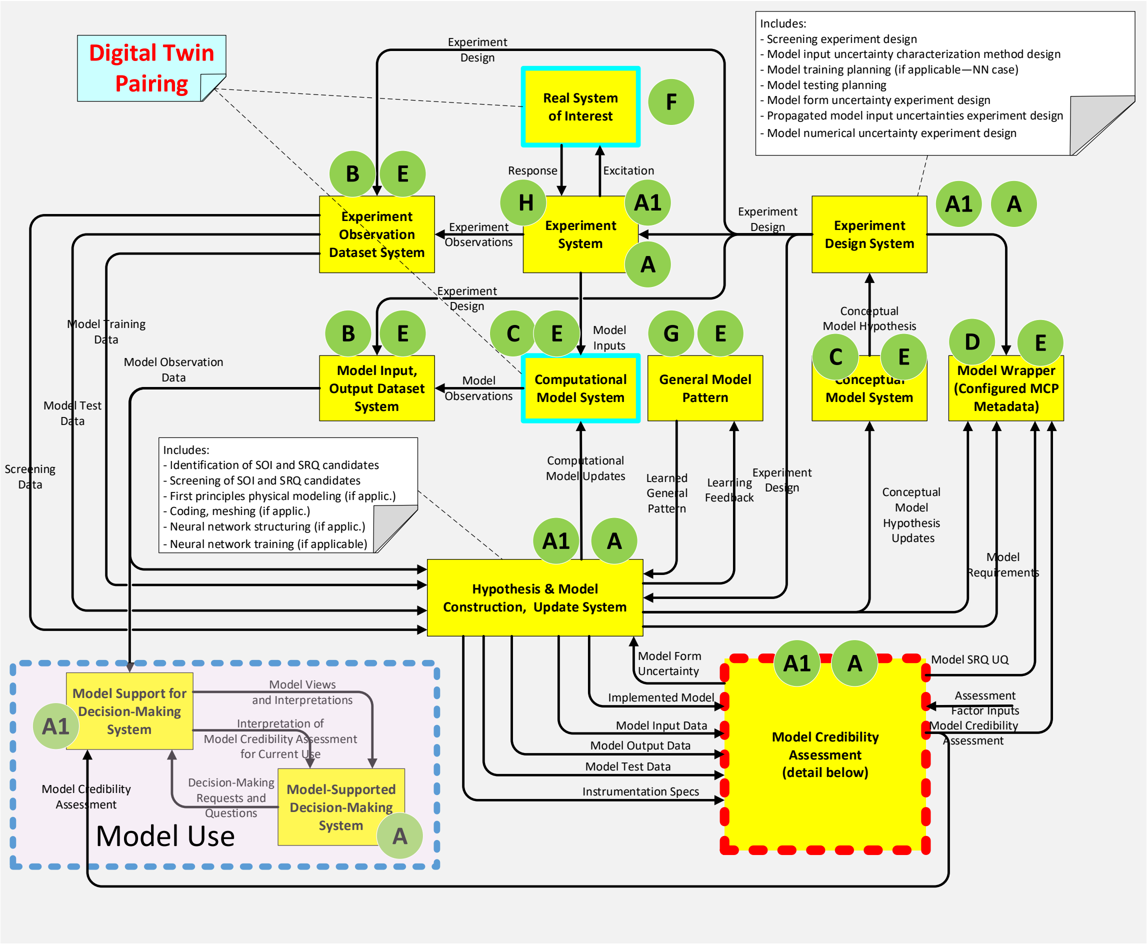
- Group learning: Not accumulation of information, but improvement of group performance based on experience of some (possibly other) group.
- Model trust and group learning converge.

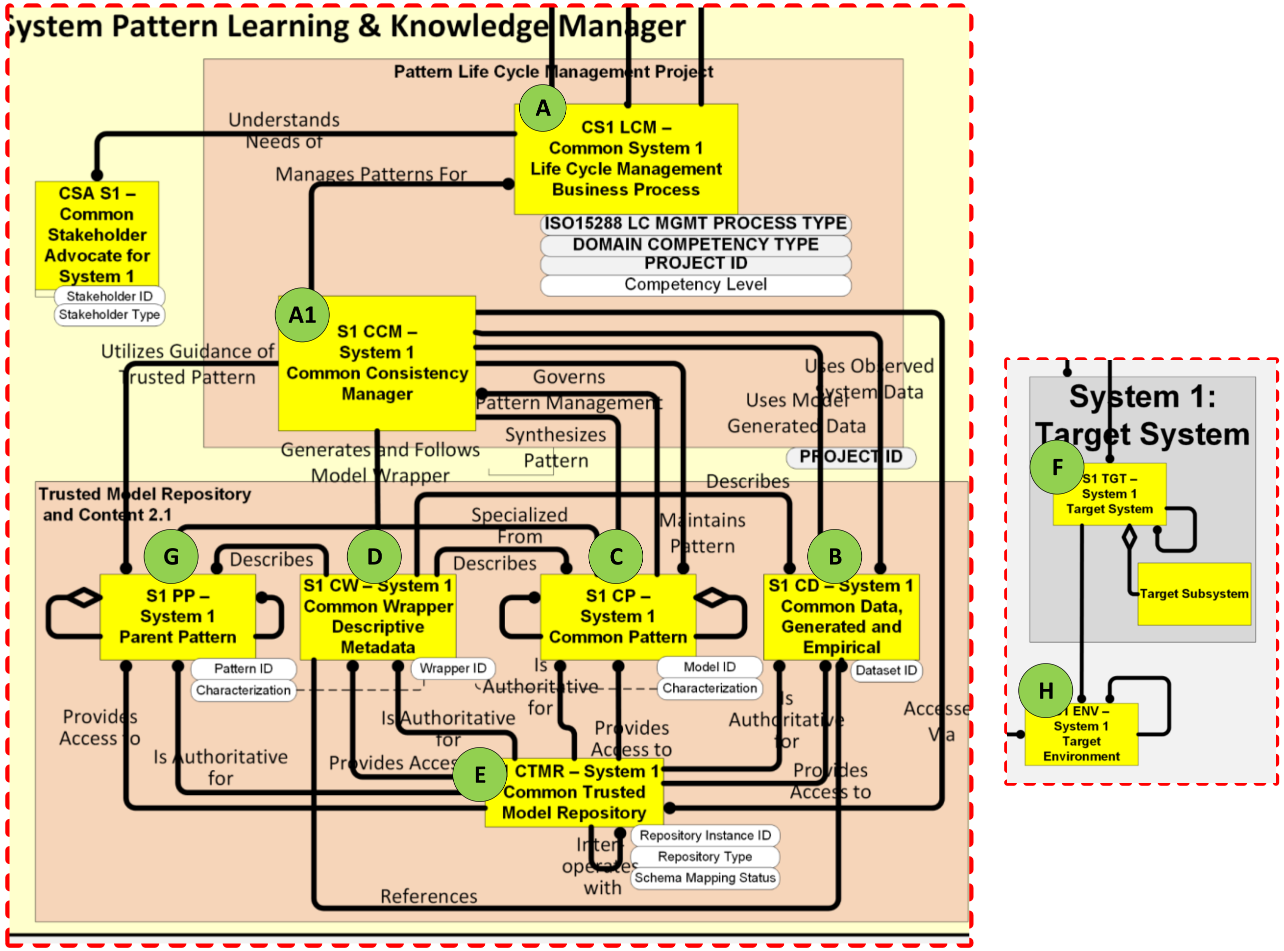


The Model Trust by Groups Phenomenon



System 2, Level 3: Learning Segment

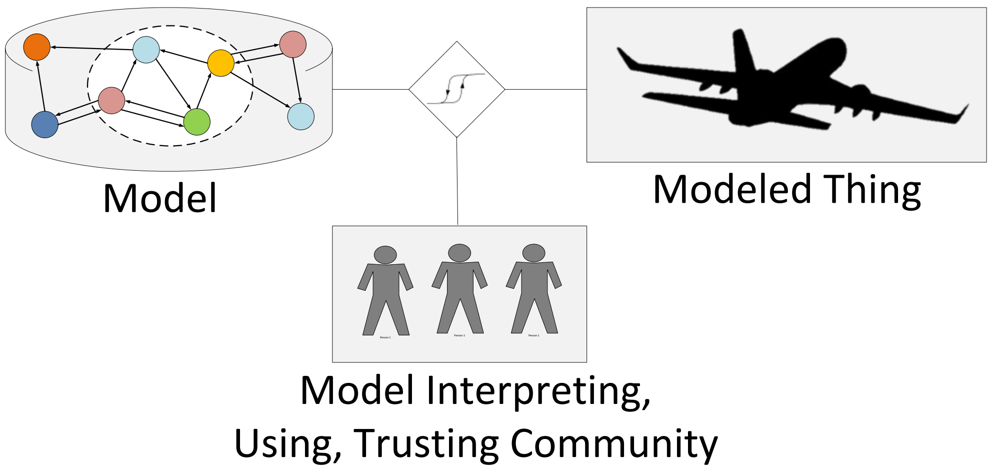




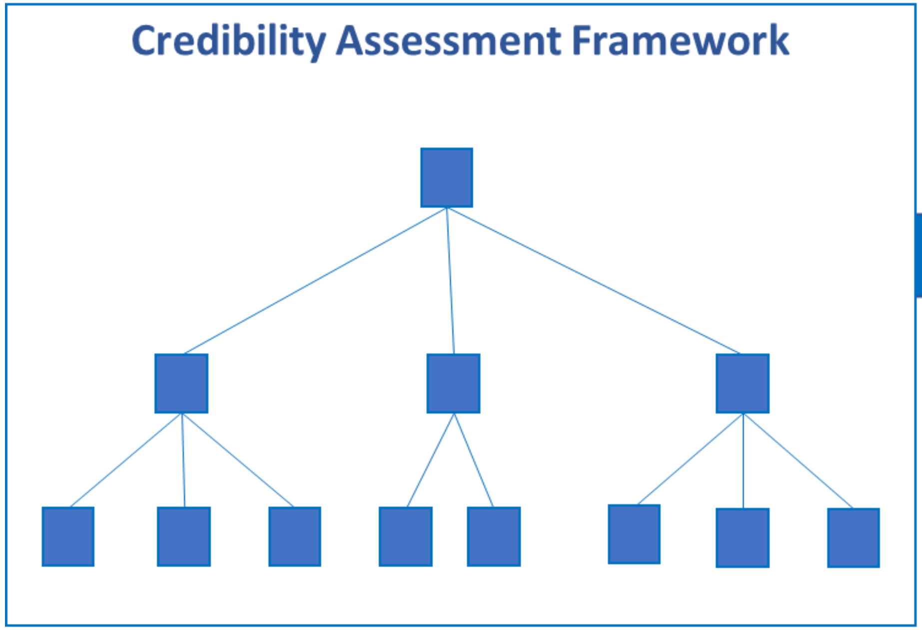
6. Group trust in the credibility of models

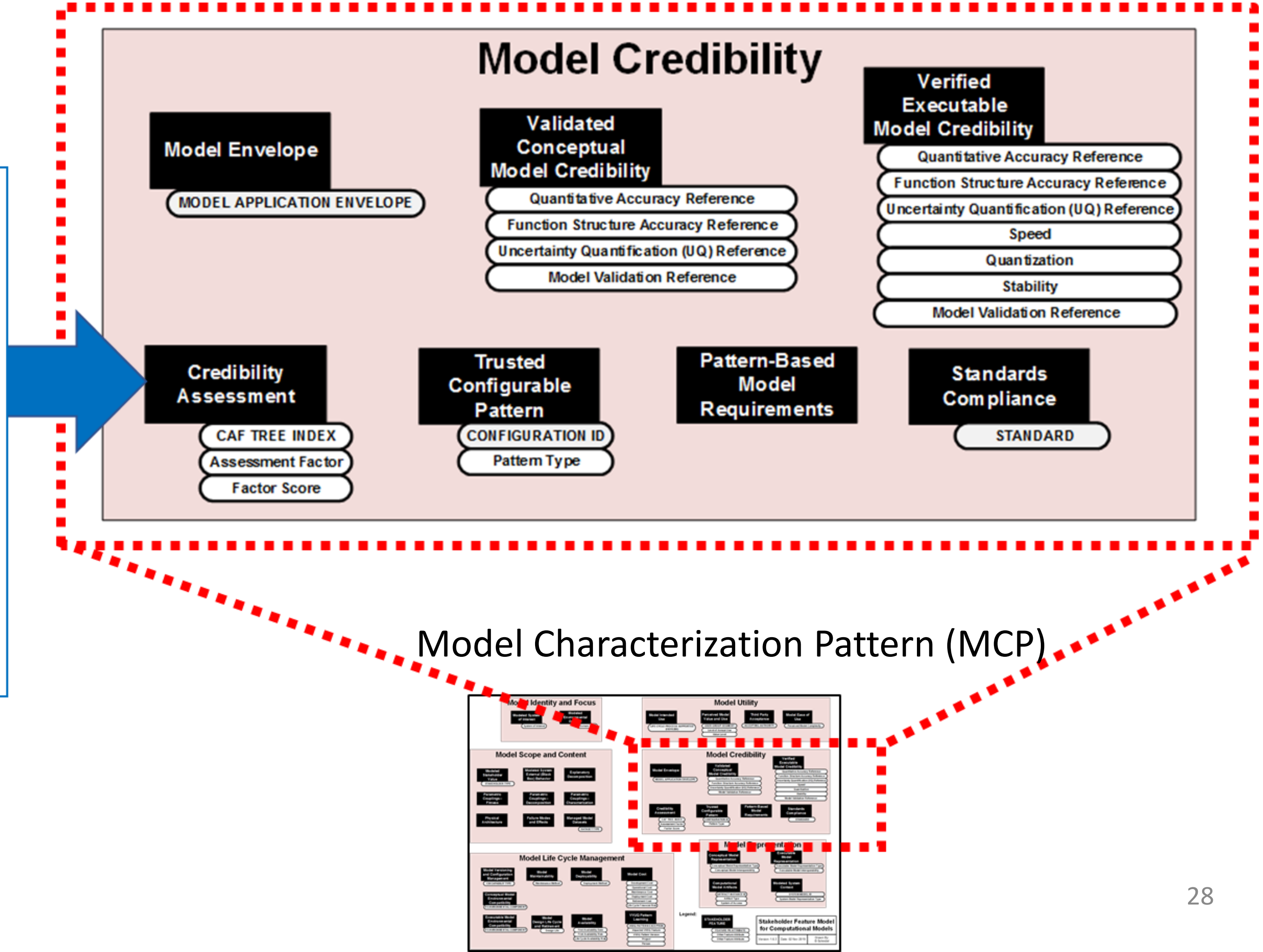
- Group learning and management of group trust converge in ASELCM.
- Ongoing evolution, in regulated and other markets, of interest in model trust.
- Credibility Assessment Frameworks (CAFs) as a record of rationale for rewarding trust (or not).

The Model Trust by Groups Phenomenon



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

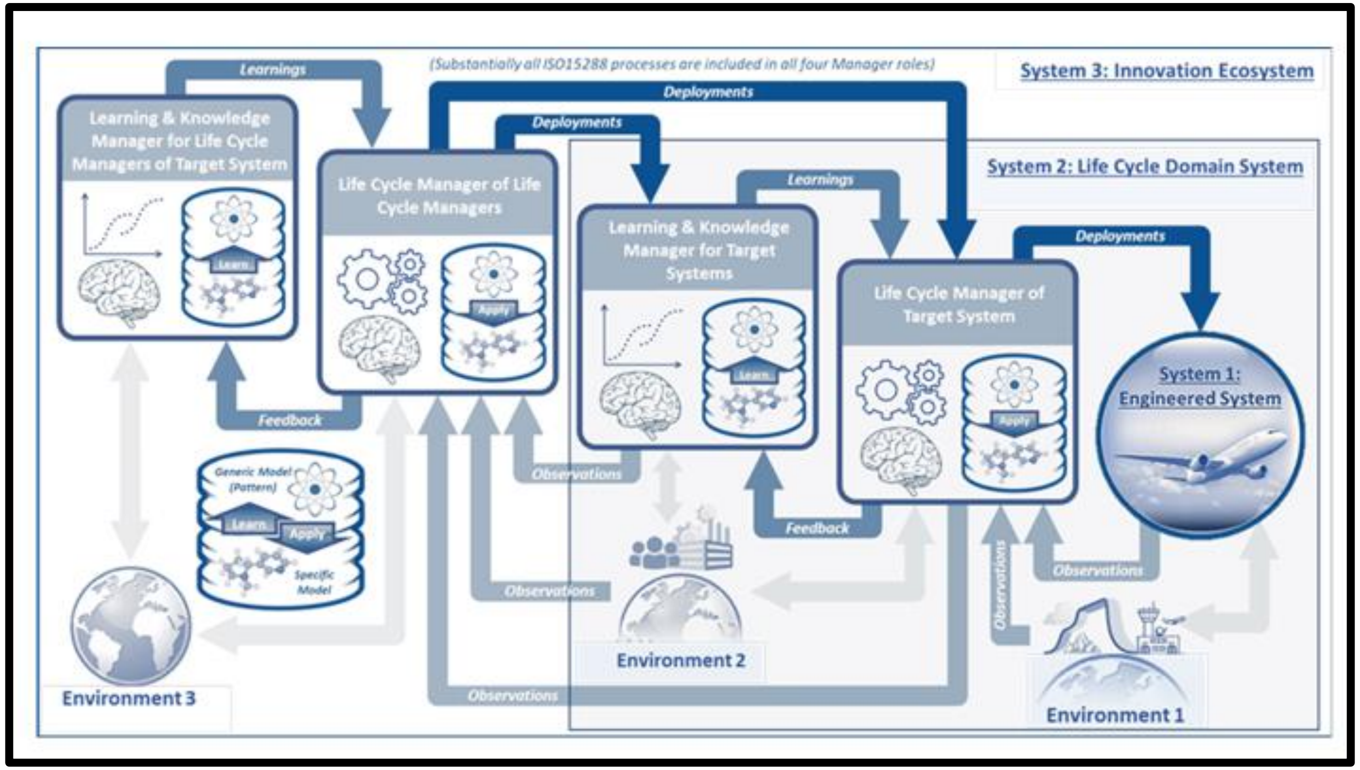




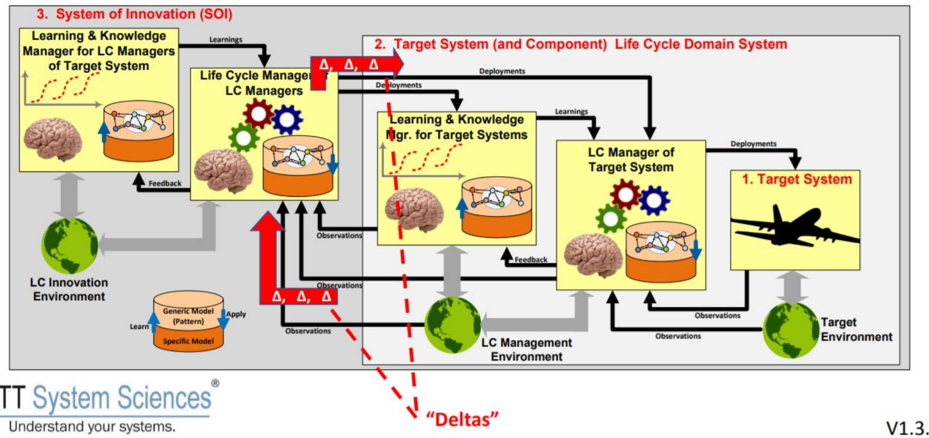
https://cstools.asme.org/csconnect/FileUpload.cfm?View=yes&ID=54674

7. Effective evolution of the ecosystem itself

The role of System 3



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

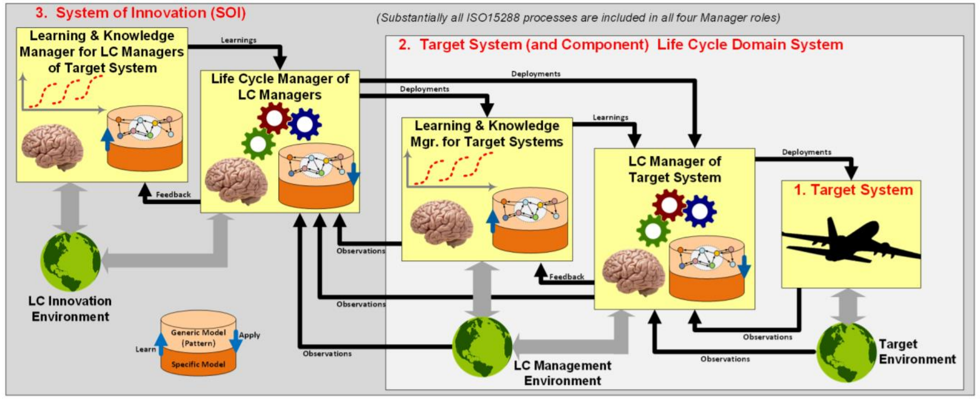


ICTT System Sciences®
Understand your systems.

V1.3.3

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



INCOSE MBSE Patterns Working Group

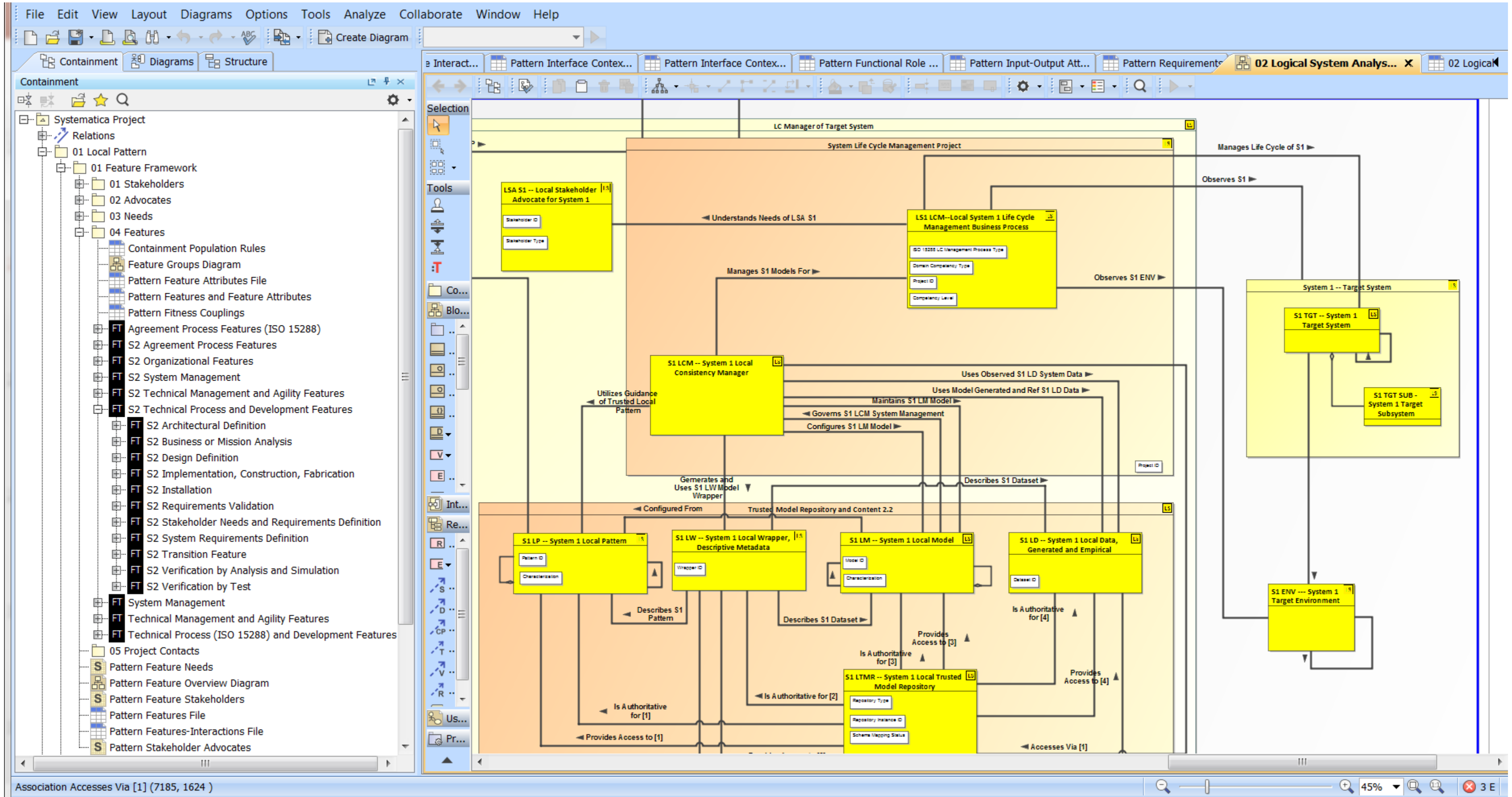
schindel@ictt.com

V1.4.5

https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:configuration_stages_v1.4.5.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.



Interested? How to get involved

- Contact Bill Schindel schindel@ictt.com

Discussion and questions

-
-
-
-
-
-
-

32nd Annual INCOSE
international symposium

hybrid event

Detroit, MI, USA
June 25 - 30, 2022

www.incose.org/symp2022

Thank you!

References

1. AIAG. 2006. "APQP & PPAP Requirements for Automotive". https://www.techstreet.com/standards/aiag-ppap-4?product_id=1257705
2. ASME. 2018. "VV40: Assessing Credibility of Computational Modeling through Verification and Validation: Application to Medical Devices". https://www.asme.org/codes-standards/find-codes-standards/v-v-40-assessing-credibility-computational-modeling-verification-validation-application-medical-devices
3. Beihoff, B., and Schindel, W. 2011. "Systems of Innovation I: Summary Models of SOI Health and Pathologies". Paper presented at the INCOSE International Symposium, July. https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:systems_of_innovation_i--health_pathology_in_systems_of_innovation_v1.11.1.pdf
4. CRS. 2021. "Joint All-Domain Command and Control (JADC2): Background and Issues for Congress". https://crsreports.congress.gov/product/pdf/R/R46725/2
5. Dove, R., Schindel, W. 2019. "Agile Systems Engineering Life Cycle Model for Mixed Discipline Engineering". Paper presented at INCOSE International Symposium on Systems Engineering. Orlando, FL. July. https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:pap190720is19-aselcm_findings-wip19-finalpaperchanges.pdf
6. Dove, R, Schindel, W. 2017. "Case study: Agile SE Process for Centralized SoS Sustainment at Northrop Grumman". Paper presented at International Symposium of International Council on Systems Engineering. Adelaide, AU. July. https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:is2017--northrup_grumman_case_study_dove_and_schindel_bp.pdf
7. Dove, R., Schindel, W., Garlington, K. 2018. "Case Study: Agile Systems Engineering at Lockheed Martin Aeronautics Integrated Fighter Group". Proceedings International Symposium. International Council on Systems Engineering. Washington, DC, 7-12 July. https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:is2018_-_aselcm_lmc_case_study.pdf
8. Dove, R., Schindel, W., Hartney, W. 2017. "Case Study: Agile Hardware/Firmware/Software Product Line Engineering at Rockwell Collins". Paper presented at 11th Annual IEEE International Systems Conference. Montreal, Quebec, Canada, 24-27 April. https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:pap170424syscon-casestudyrc.pdf
9. Dove, R., Schindel, W. Scrapper, C. 2016. "Agile Systems Engineering Process Features Collective Culture, Consciousness, and Conscience at SSC Pacific Unmanned Systems Group". Paper presented at International Symposium of International Council on Systems Engineering. Edinburgh, Scotland. 8-21 July. https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:is2016_--_autonomous_vehicle_development_navy_spawar.pdf
10. Göknur, S., Paredis C. Yannou, B., Coatanéa, E. Landel, E. 2015. "A Model Identity Card to Support Engineering Analysis Model (EAM) Development Process in a Collaborative Multidisciplinary Design Environment". *IEEE Systems Journal*, IEEE, 2015, 9 (4), pp.1151-1162. ff10.1109/JSYST.2014.2371541ff. ffhal-01184938f. https://hal.archives-ouvertes.fr/hal-01184938/document
11. 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

12. Herzig, S., Qamar, A., Paredis, C. 2014. "Inconsistency Management in Model-Based Systems Engineering", Proc of Global Product Data Interoperability Summary, 2014, retrieve http://gpdisonline.com/wp-content/uploads/past-presentations/AC45_GeorgiaTech-SebastianHerzig-InconsistencyManagementInMBSE.pdf

13. Walden, D. ed. 2015. *Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities*. Fourth Edition. Revised by D. Walden, G. Roedler, K. Forsberg, R. Hamelin, and T. Shortell. San Diego, US-CA: INCOSE.

14. ISO. 2015. ISO 15288:2015. "Systems and Software Engineering — System Life Cycle Processes". Geneva, CH: ISO. https://www.iso.org/standard/63711.html

15. ISO. 2016. "ISO 13485: 2016 Medical devices — Quality Management Systems — Requirements for Regulatory Purposes". https://www.iso.org/standard/59752.html

16. Jacobides, M. et al. 2017. "Towards a Theory of Ecosystems (with Phenomenological Preamble)"; Keynote presentation at 5th International Conference of the Armand Peugeot Chair. Paris, FR. Retrieve from https://chairgovreg.fondation-dauphine.fr/sites/chairgovreg.fondation-dauphine.fr/files/attachments/JCG%20CAP%20Paris%202017%20presentation%20S.pdf

17. Kaizer, J. 2018. "Credibility Assessment Frameworks - Personal Views". https://cstools.asme.org/csconnect/FileUpload.cfm?View=yes&ID=54674

18. Kerstetter, M., Woodham, K. 2014. "SAVI Behavior Model Consistency Analysis", Presented at Global Product Data Interoperability Summit. http://gpdisonline.com/wp-content/uploads/past-presentations/AVSI-Kerstetter-SAVIBehaviorModelConsistencyAnalysis-CAE-Open.pdf

19. Kotter, J. 2014. *Accelerate: Building Strategic Agility for a Faster-Moving World*, Cambridge, MA, Harvard Business Review Press.

20. Leitmann G. 1975. "Cooperative and Non-Cooperative Differential Games". In: Leitmann G., Marzollo A. (eds) *Multicriteria Decision Making. International Centre for Mechanical Sciences (Courses and Lectures)*, vol 211. Springer, Vienna. https://doi.org/10.1007/978-3-7091-2438-3

21. NAE. 2012. "Assessing the Reliability of Complex Models: Mathematical and Statistical Foundations of Verification, Validation, and Uncertainty Quantification". National Academy of Engineering (NAE). https://www.nap.edu/catalog/13395/assessing-the-reliability-of-complex-models-mathematical-and-statistical-foundations

22. Patterns WG. 2021. INCOSE MBSE Patterns Working Group Web Site: https://www.omgwiki.org/MBSE/doku.php?id=mbse:patterns:patterns

23. Patterns WG. 2019a. "The Model Characterization Pattern: A Universal Characterization & Labeling S*Pattern for All Computational Models", V1.9.3. https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:model_characterization_pattern_mcp_v1.9.3.pdf

24. Patterns WG. 2019b. “Methodology Summary: Pattern-Based Systems Engineering (PBSE), Based On S*MBSE Models” https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:pbse_extension_of_mbse--methodology_summary_v1.6.1.pdf

25. Patterns WG. 2020a. “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_v1.4.5.pdf

26. Patterns WG. 2020b. “Consistency Management as an Integrating Paradigm for Digital Life Cycle Management with Learning”. 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

27. Patterns WG. 2020c. “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

28. Redman, D. 2014. “Importance of Consistency Checking in the SAVI Virtual Integration Process (VIP)”, Presentation at Global Product Data Interoperability Summary, 2014, retrieve via http://gpdisonline.com/wp-content/uploads/past-presentations/SE_67_AVSI-Redman-ConsistencyCheckingInSAVI.pdf

29. Rhodes, D. 2018. “Interactive Model-Centric Systems Engineering (IMCSE) Phase 5 Technical Report SERC-2018-TR-104”. https://apps.dtic.mil/sti/pdfs/AD1048003.pdf

30. SAE. 2016. “AS9145: APQP & PPAP Requirements for Aerospace and Defense” https://www.sae.org/standards/content/as9145/

31. Schindel, W. 2013. “Systems of Innovation II: The Emergence of Purpose”. Paper presented at INCOSE International Symposium, July. https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:systems_of_innovation--the_emergence_of_purpose_v1.3.6.pdf

32. ---------. 2021. “Variational Forces of Modularity: Coupled Macro and Micro Patterns in the Innovation Ecosystem”. Presented at PLE Momentum 2021 Conference. https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:the_forces_of_modularity_v1.3.3.pdf

33. -------. 2017a. “MBSE Maturity Assessment: Related INCOSE & ASME Efforts, and ISO 15288”. Presented at MBSE World Symposium, Allen, TX. https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:model_based_maturitiy_planning_asme_incose_may_2017.pdf

34. -------. 2017b. “Innovation, Risk, Agility, and Learning, Viewed as Optimal Control & Estimation”. Paper presented at INCOSE International Symposium. Adelaide, AU. July. https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:risk_and_agility_as_optimal_control_and_estimation_v1.7.2.pdf

35. -------. 2020. “SE Foundation Elements: Implications for Future SE Practice, Education, Research”. P21-22 https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:science_math_foundations_for_systems_and_systems_engineering--1_hr_awareness_v2.3.2a.pdf

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

37. Schindel, W., Peterson, T. 2016. “Introduction to Pattern-Based Systems Engineering (PBSE): Leveraging MBSE Techniques”. https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:pbse_tutorial_glrc_2016_v1.7.4.pdf

38. Schindel, W. , Seidman, M. 2021. "Applying Digital Thread Across the Product Life Cycle". Project presented at IN Defense Network Technical Interchange Meeting, June 9-10, 2021. https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:team_top_gun_idn_presentation_06.09.2021_v2.1.1.pdf

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 for advanced manufacturing, and the AIAA digital thread and digital twin 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