Variational Forces of Modularity: Coupled Macro and Micro Patterns in the Innovation Ecosystem

Macro Patterns

Micro Patterns

Bill Schindel,
INCOSE Patterns Working Group
ICTT System Sciences
schindel@ictt.com

Abstract

- This session describes the real and impactful patterns of force which naturally emerge in connection with any ecosystem of competitive innovation, including commerce, defense, and the natural world.
- These universal systemic patterns occur at both micro and macro levels, interact with each other, and are formally described in the language of system models of configurable patterns, as well as informal summary.
- The resulting neutral reference frameworks describe both effective and ineffective ecosystems, projects, and products, for use by analysts, planners, leaders, and practitioners who need to make progress in a complex world.
- Whether we recognize them or not, we are all caught up in and impacted by these patterns—those who understand and respond to them have a competitive advantage.
- Pursuers of Digital and Product Line Engineering, the Model-Based Enterprise, Machine Learning, Digital Threads and Twins, and similar attractive visions will find their goals are enabled by or entangled with these inherent patterns.
- The long term work described here has been led by the INCOSE MBSE Patterns Working Group, in collaboration with multiple INCOSE working groups and other technical societies.

Contents

- Introduction
- Forces of modularity – at the micro level
- Forces of modularity – at the macro level
- Implications for action
- Discussion, questions

- References

ICTT System Sciences®
Understand your systems.

Product Lines, Patterns, Learning, People

- Conference attendees already know:
  - Product Line Engineering (PLE) benefits from representing and implementing variation of configurations across a product line.
- More broadly, patterns are recurrences, with fixed and variable parts:
  - Recognized & modeled patterns compress description.
  - Patterns simplify a complex world, by parameterized recurrence.
- All laws of the physical sciences--the foundations of the engineering disciplines--are expressions of such patterns:
  - Over the last three centuries, this has worked out well for humanity!
- Patterns are the information proxy for learning, and bring with them powerful tools and theory.

INCOSE MBSE Patterns Working Group

- The INCOSE MBSE Patterns Working Group is concerned with the general application of pattern-based methods for:
  - Explicit model based patterns: descriptive, computational, machine learning, other.
  - Especially for “whole system” patterns (INCOSE is about Systems Engineering).
  - Including patterns of large-scale and small-scale variation of configuration based on selection pressures.
  - Especially for representations (in any language, any tooling) satisfying minimum necessary content for engineering and science (S*Metamodel) over life cycles.
  - Such models are called S*Models, and in recurring cases, S*Patterns.
- All Patterns Working Group projects are collaborations, with others:
  - Other technical societies: ASME, AIAA, ISSS, NAFEMS, IFSR.
  - Other INCOSE Working Groups.

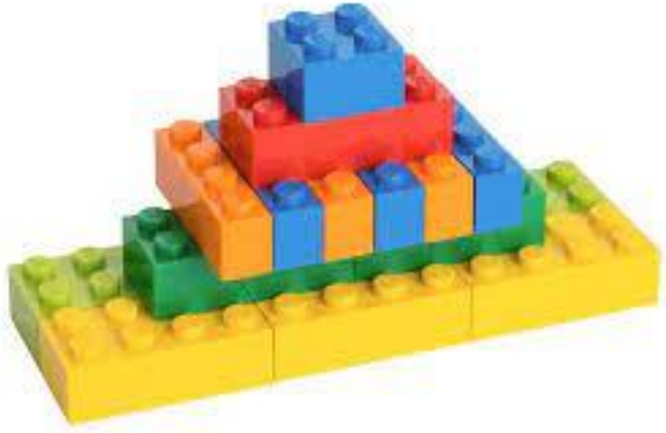
Selection Forces energize competitive ecosystems

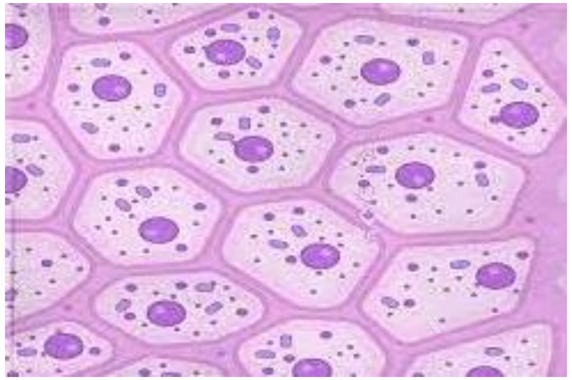
Differentially impact survival, growth, success, or elimination of products, species, enterprises.

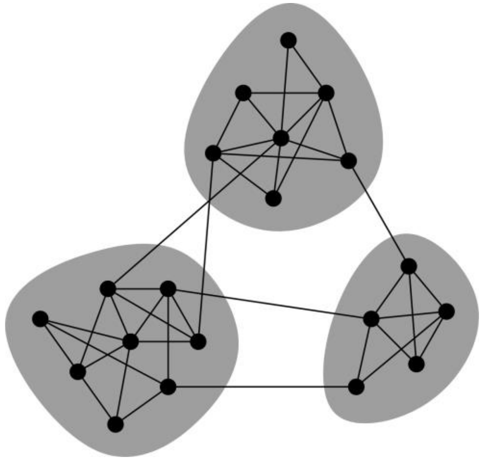
Situation/Setting	Types of Selection	Selection Agents
Consumer Market	Retail purchase selection	Individual Consumer; Overall Market
Operational Use	Decision to use product A or use product B	User
Military Conflict	Direct conflict outcome; threat assessment	Military Engagement
Product design	Design trades	Designer
Commercial Market	Preferred performance, cost, support	Buyer
Biological Evolution	Natural selection	Environmental Competition
Product Planning	Opportunity selection	Product Manager
Market Launch	Optimize choice across alternatives	Review Board
Securities Investing	What to buy, what to sell, acceptable price	Individual Investor; Overall Market
College-Student "Matching Market"	Selection of individuals, selection of class profile, selection of school	Admissions Committee; Student & Family
Life choices	Ethical, moral, religious, curiosities, interests	Individual
Democratic election	Voting	Voters; Voting Blocks
Business	Risk management, decision theory	Risk Manager, Decision Maker

Adaptability, agility, and selection forces

- Particularly in dynamically changing environments, the relative agility of competitors can improve their ability to adapt to selection forces.
- Modularity describes the idea that seemingly complicated things may be built up from (or simplified by) relatively simple patterns of external interaction between modules.
- In an ecosystem, modules may come from different enterprises, and complement each other combinatorially, resulting in different economic types of modularity: Super Modularity, Unique Modularity, etc.







Think bigger: Wider meaning of Selection and Features in an ecosystem

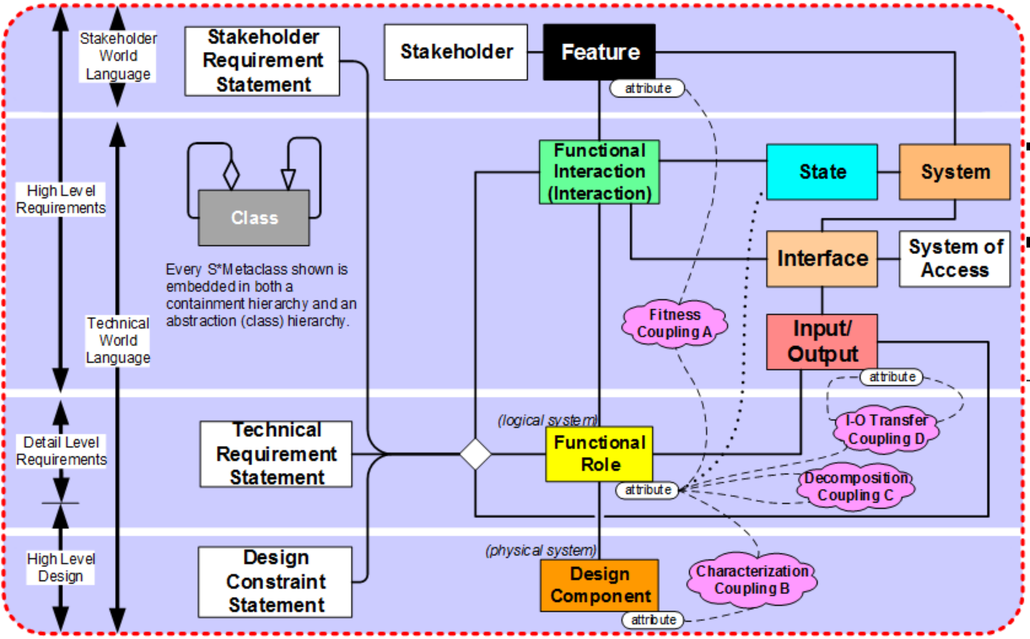
- The Innovation Ecosystem Pattern shows us that Features can have a wider meaning than just variant management:
  - This can further reduce complexity across several major areas;
  - With insightful modeling of Features, major additional payoffs.
- In a competitive ecosystem, modeled Features can unify/integrate:
  - Stakeholder Value Trade Space in which competition and competitive selection occur;
  - The Risk Management Space, in which the Effects ("E") of FMECAs are described;
  - The Variant Configuration Space, describing configurations of the system of interest.
- Integrated, these cross-fertilize each other, as to completeness and rigor.
- But, it requires *thinking bigger about Selectable Features vs. just as variants*:
  - Hint: All intended variation is for some stakeholder reason.
  - Hint: All risk is stakeholder risk.
  - Hint: All value is stakeholder value.

8

For purposes of engineering and science, that reduces effort to plan and manage variation

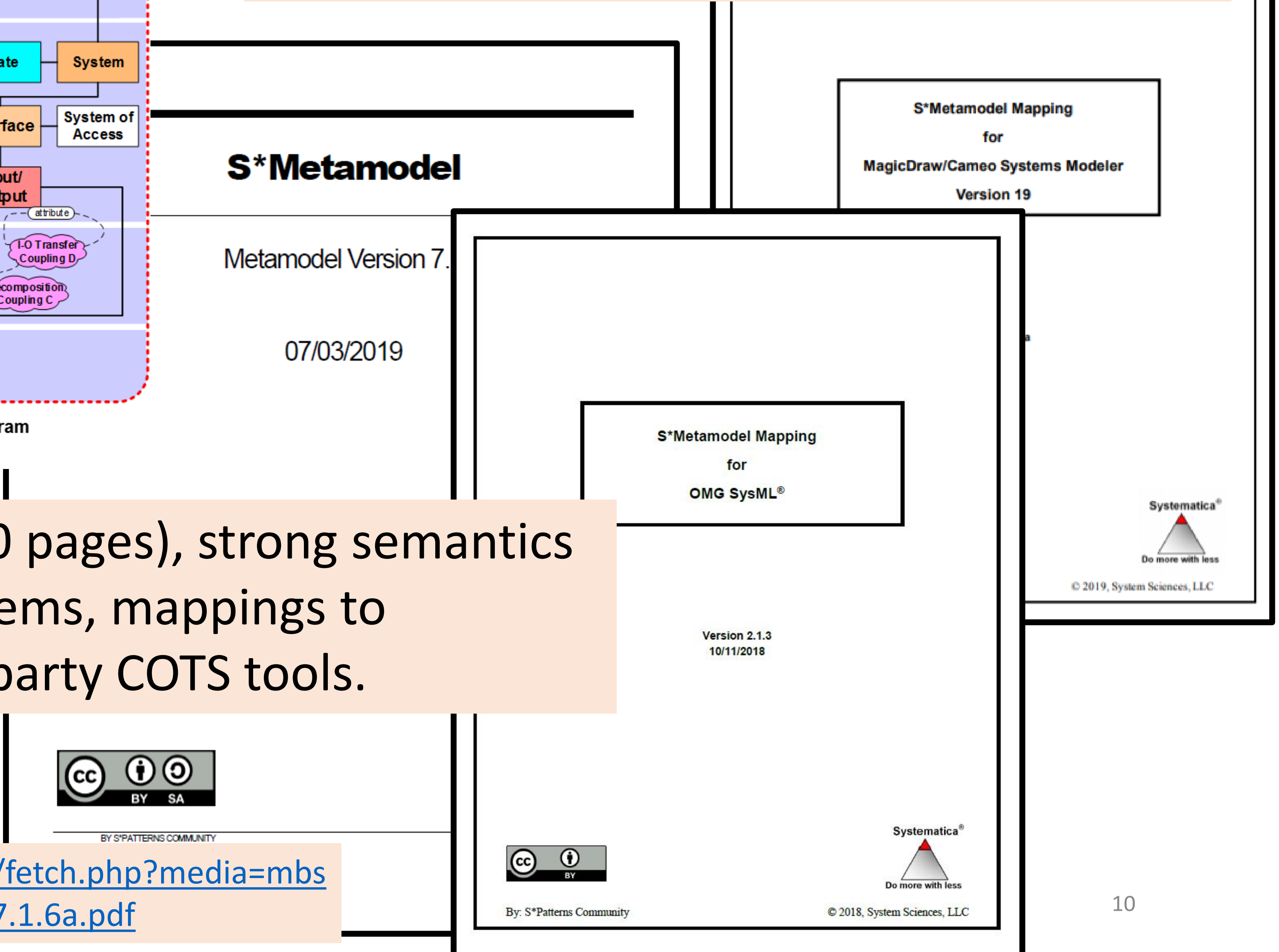
- If what you are describing are any of the artifacts of life cycle management of a system, the payoffs are:
  - The underlying ontology of a model of <u>any</u> system for any life cycle management purpose is a highly constrained pattern structure (if we recognize the pattern).
  - That is the purpose of a pattern called the S*Metamodel—generating the "smallest models" for purposes of engineering and science—called S*Models
- If your system is described by an S*Model, more of its variation management pattern is inherent in the model layers separate from the Stakeholder Features that drive the variation.
- Bottom line: We don't really have as many degrees of freedom as is commonly perceived; not recognizing that adds work, complexity, and contradiction that can be squeezed out.

https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:systematica_mapping_for_magicdraw_csm_v1.9.1a.pdf



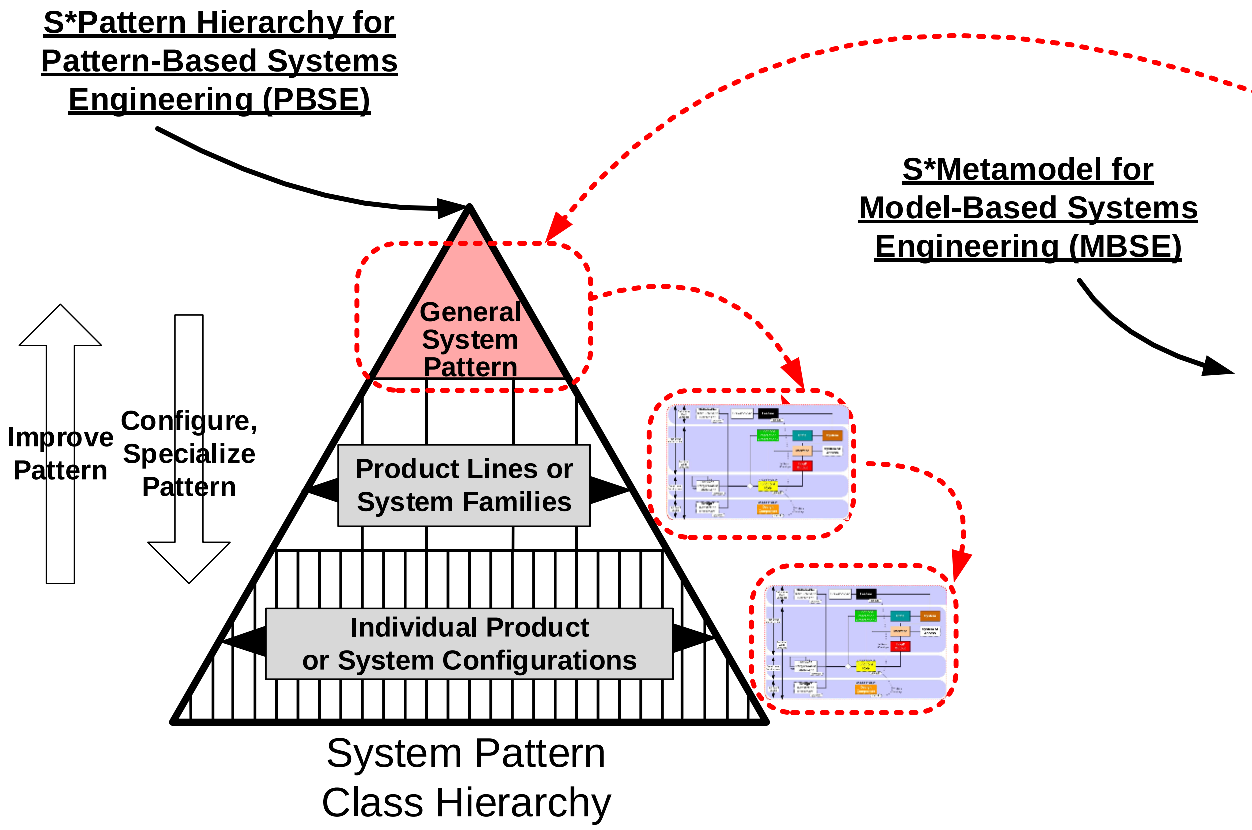
S*Metamodel informal summary pedagogical diagram
(formal S*Metamodel includes additional details.)

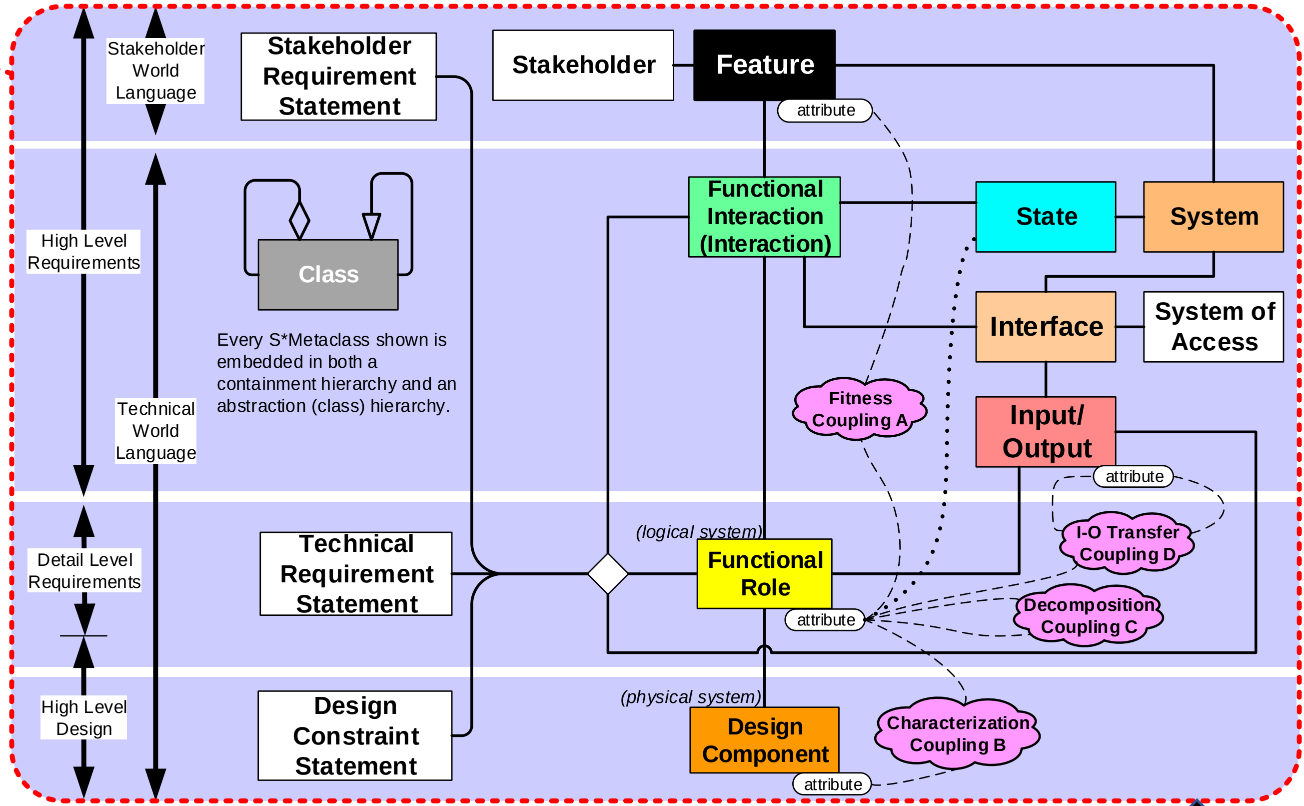
Formal S*Metamodel (100 pages), strong semantics inspired by physics of systems, mappings to individual languages, 3rd party COTS tools.



https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:systematica_5_metamodel_v7.1.6a.pdf

S*Patterns: Configurable, re-usable S*Models across the life cycle—requirements, designs, failure modes & effects, risks, etc.





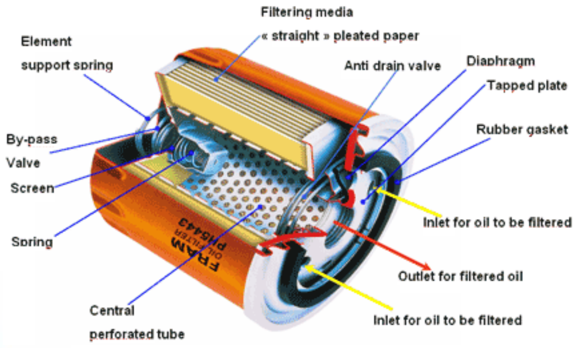
S*Metamodel informal summary pedagogical diagram
(formal S*Metamodel includes additional details.)

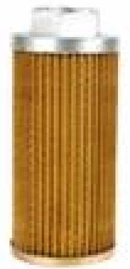
Tool & Language Agnostic: Formally mapped into multiple third party COTS tools, languages

Includes inherent variant propagation paths

Simple example: Oil Filter Family

Architecture 1: Laminated and Accordion Pleated Filtration Media, Flow Orthogonal to Plane of Media, Additive Impregnated



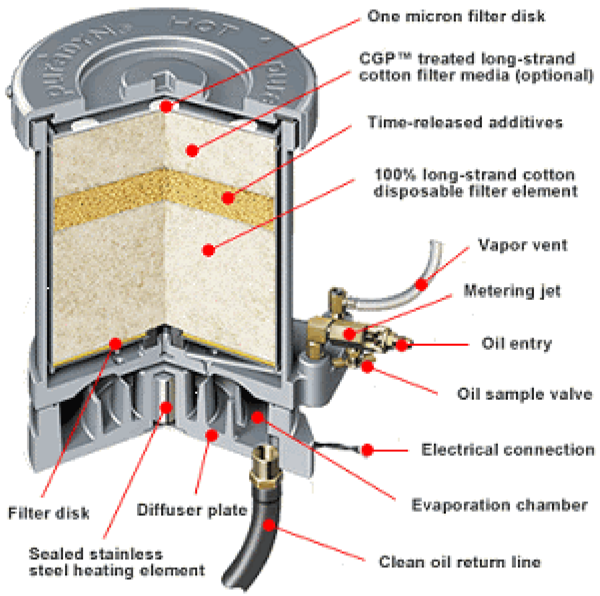


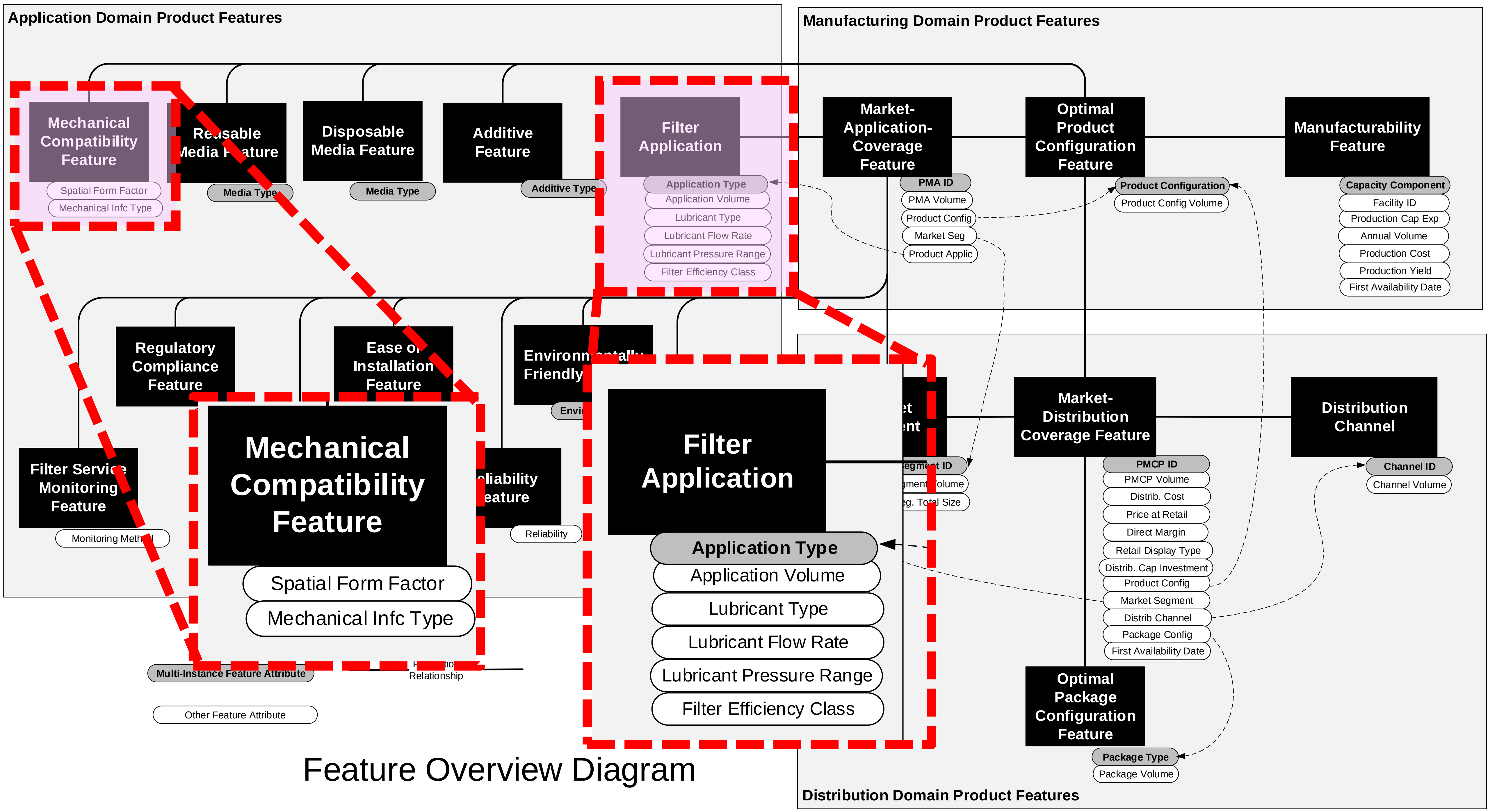
Paper
Filter Media

Synthetic
Filter Media

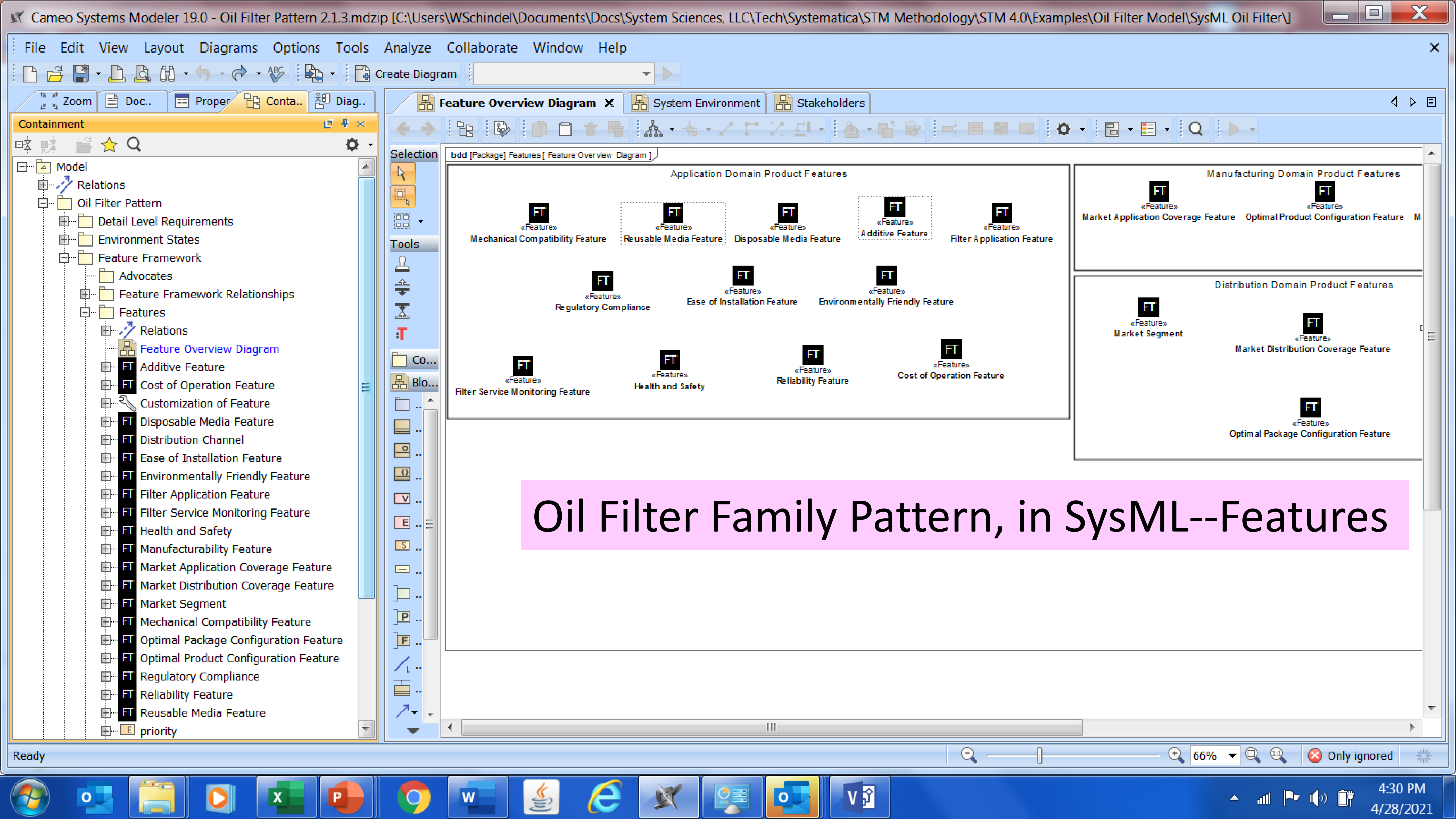
Stainless Steel
Filter Media

Architecture 2: Wound Filtration Fiber, Flow Orthogonal to Plane of Windings, Additive Impregnated





Feature Overview Diagram


Oil Filter Family Pattern, in SysML--Features
Cameo Systems Modeler 19.0 - Oil Filter Pattern 2.1.3.mdzip [C:\Users\WSchindel\Documents\Docs\System Sciences, LLC\Tech\Systematica\STM Methodology\STM 4.0\Examples\Oil Filter Model\SysML Oil Filter\]
File Edit View Layout Diagrams Options Tools Analyze Collaborate Window Help
Create Diagram
Feature Overview Diagram
System Environment
Stakeholders
Containment
Model
Relations
Oil Filter Pattern
Detail Level Requirements
Environment States
Feature Framework
Advocates
Feature Framework Relationships
Features
Relations
Feature Overview Diagram
Additive Feature
Cost of Operation Feature
Customization of Feature
Disposable Media Feature
Distribution Channel
Ease of Installation Feature
Environmentally Friendly Feature
Filter Application Feature
Filter Service Monitoring Feature
Health and Safety
Manufacturability Feature
Market Application Coverage Feature
Market Distribution Coverage Feature
Market Segment
Mechanical Compatibility Feature
Optimal Package Configuration Feature
Optimal Product Configuration Feature
Regulatory Compliance
Reliability Feature
Reusable Media Feature
priority
bdd [Package] Features [Feature Overview Diagram]
Application Domain Product Features
«Feature» Mechanical Compatibility Feature
«Feature» Reusable Media Feature
«Feature» Disposable Media Feature
«Feature» Additive Feature
«Feature» Filter Application Feature
«Feature» Regulatory Compliance
«Feature» Ease of Installation Feature
«Feature» Environmentally Friendly Feature
«Feature» Filter Service Monitoring Feature
«Feature» Health and Safety
«Feature» Reliability Feature
«Feature» Cost of Operation Feature
Manufacturing Domain Product Features
«Feature» Market Application Coverage Feature
«Feature» Optimal Product Configuration Feature
Distribution Domain Product Features
«Feature» Market Segment
«Feature» Market Distribution Coverage Feature
«Feature» Optimal Package Configuration Feature
Ready
66%
Only ignored
4:30 PM
4/28/2021

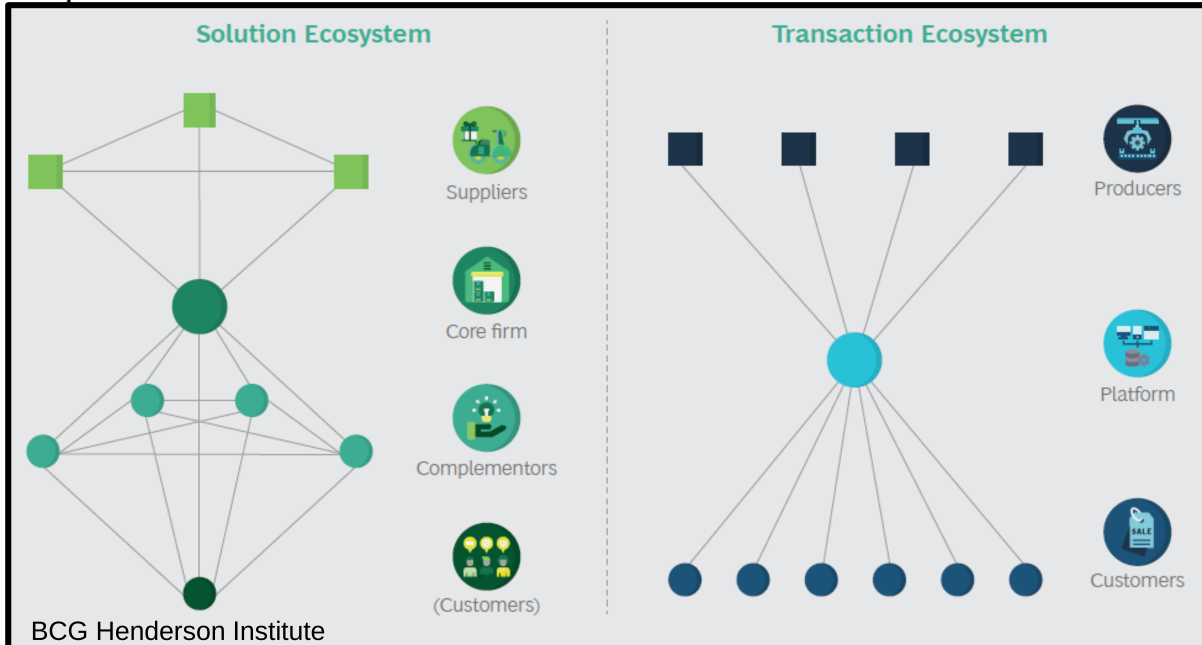
Forces of modularity – at the macro level

- This conference's PLE community knows that some enterprise macro principles and structures are also necessary for full PLE success.
- Exploiting modularity at the micro level likewise depends on macro level structure, process--including ecosystem modularity, configurability, learning, adaptation.
- Patterns and compression as group learning—bringing in the issues of cross-program persisting IP value--opposite of a "projects only" culture.
- The enterprise and extended ecosystem can become first-class modularized, configurable, learning systems in their own right.

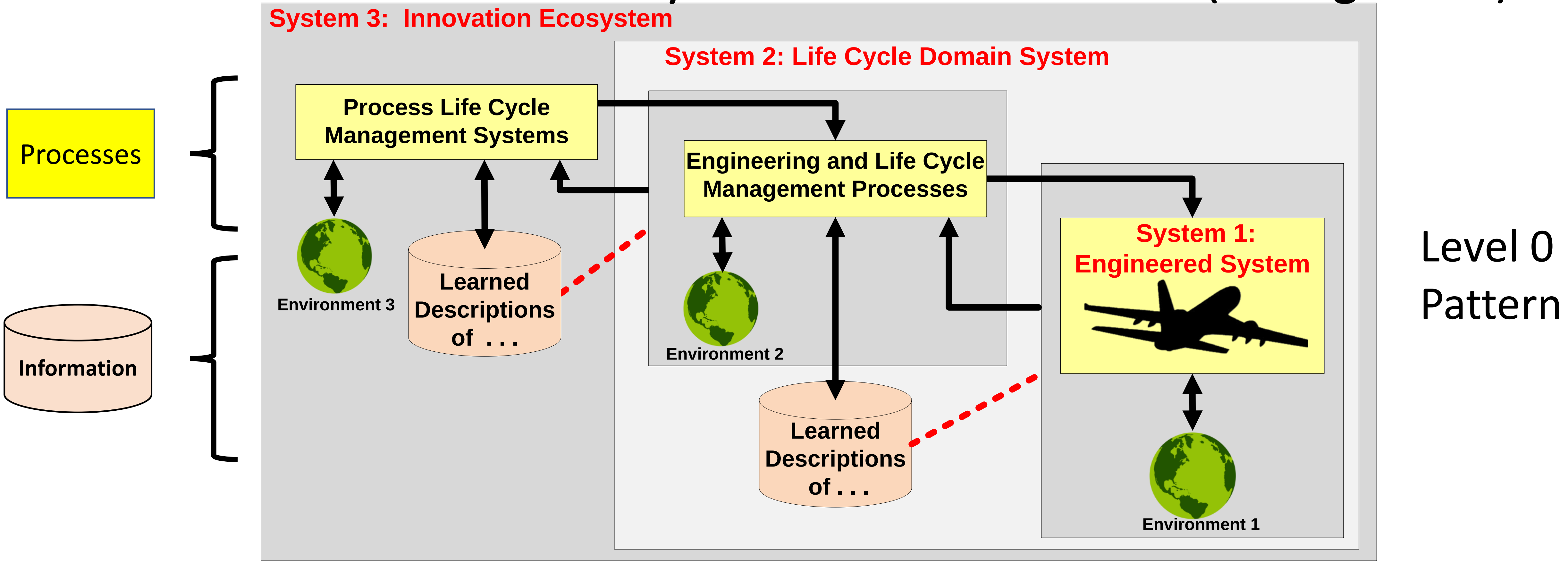
Ecosystems:
Recognizing, exploiting macro level forces

- Interest (especially by customers such as US DoD) in “Innovation Ecosystems”, expanded beyond captive linear supply chains.
- Enabled by Super-Modular complementary products, enterprises.

Combinatorial Power



Describing <u>any</u> ecosystem—including yours: the INCOSE Innovation Ecosystem Reference Pattern (Configurable)



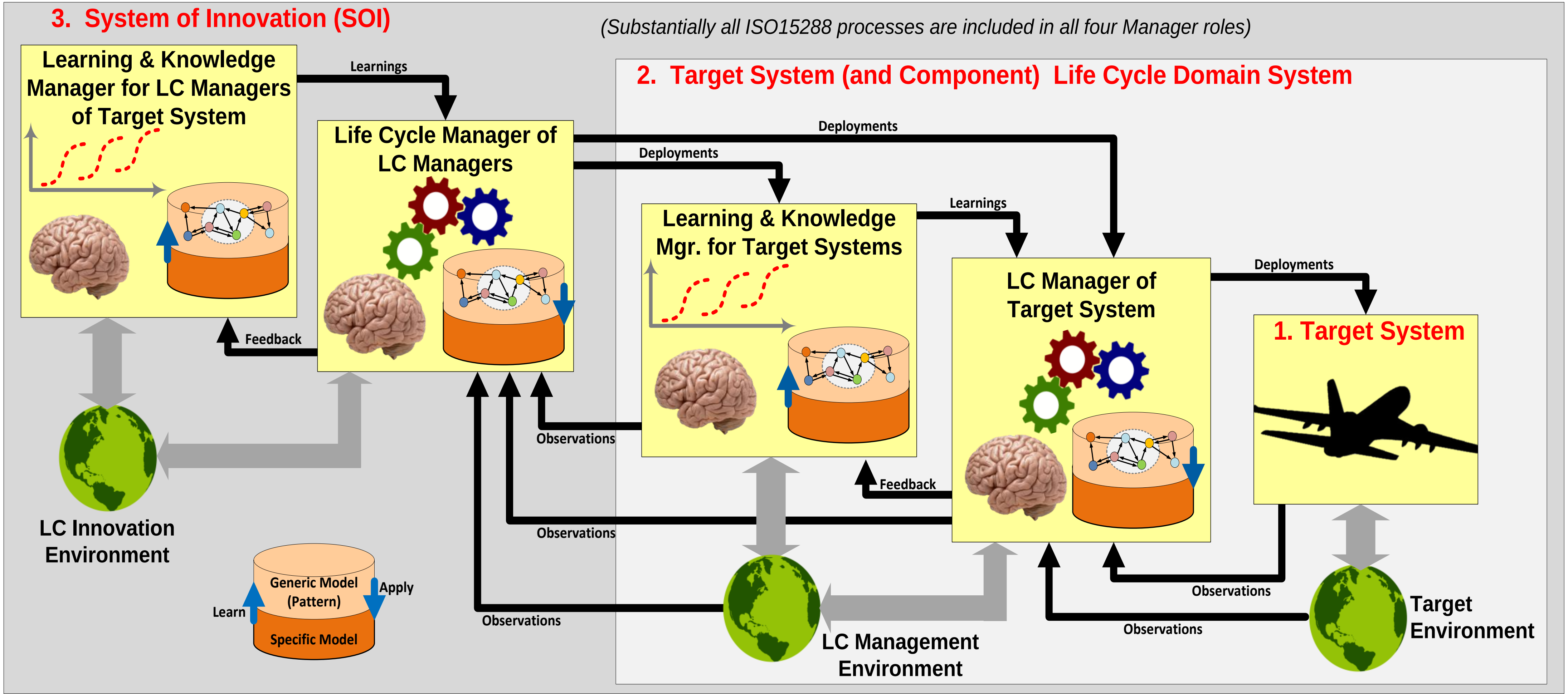
Level 0 View, INCOSE ASELCM Pattern

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

Engineering, production, support, science

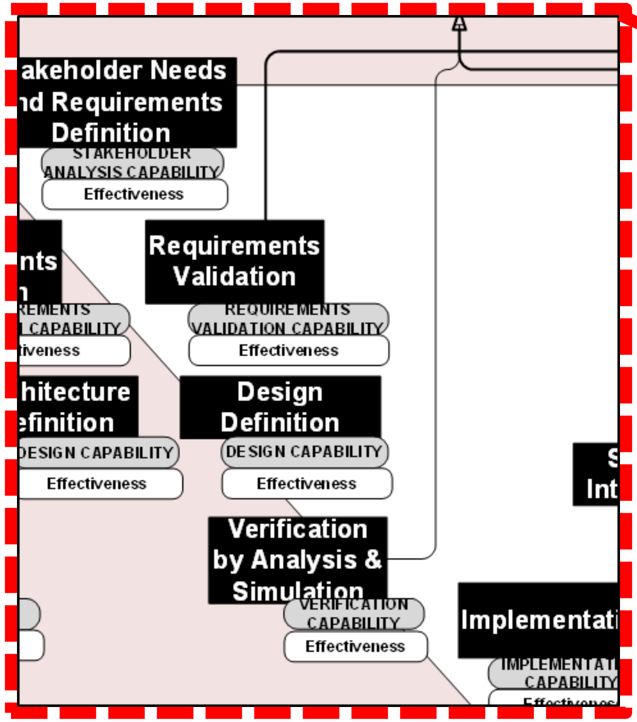
Products that we design; the markets they inhabit; Nature

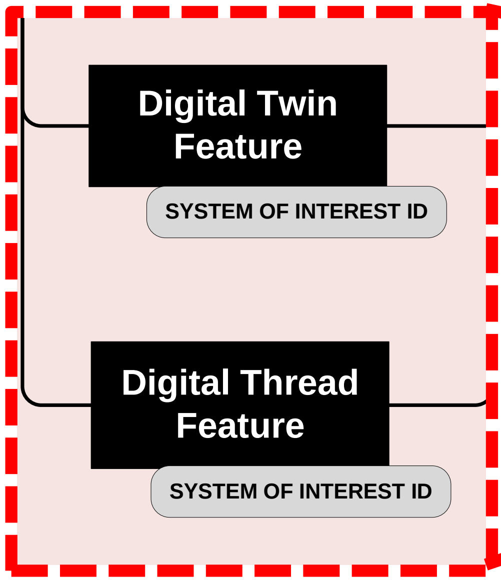
- Describes ability to learn and execute on that learning—not just accumulation of information.
- Substantially all the 30+ ISO15288 processes appear *inside* each of the four blocks:

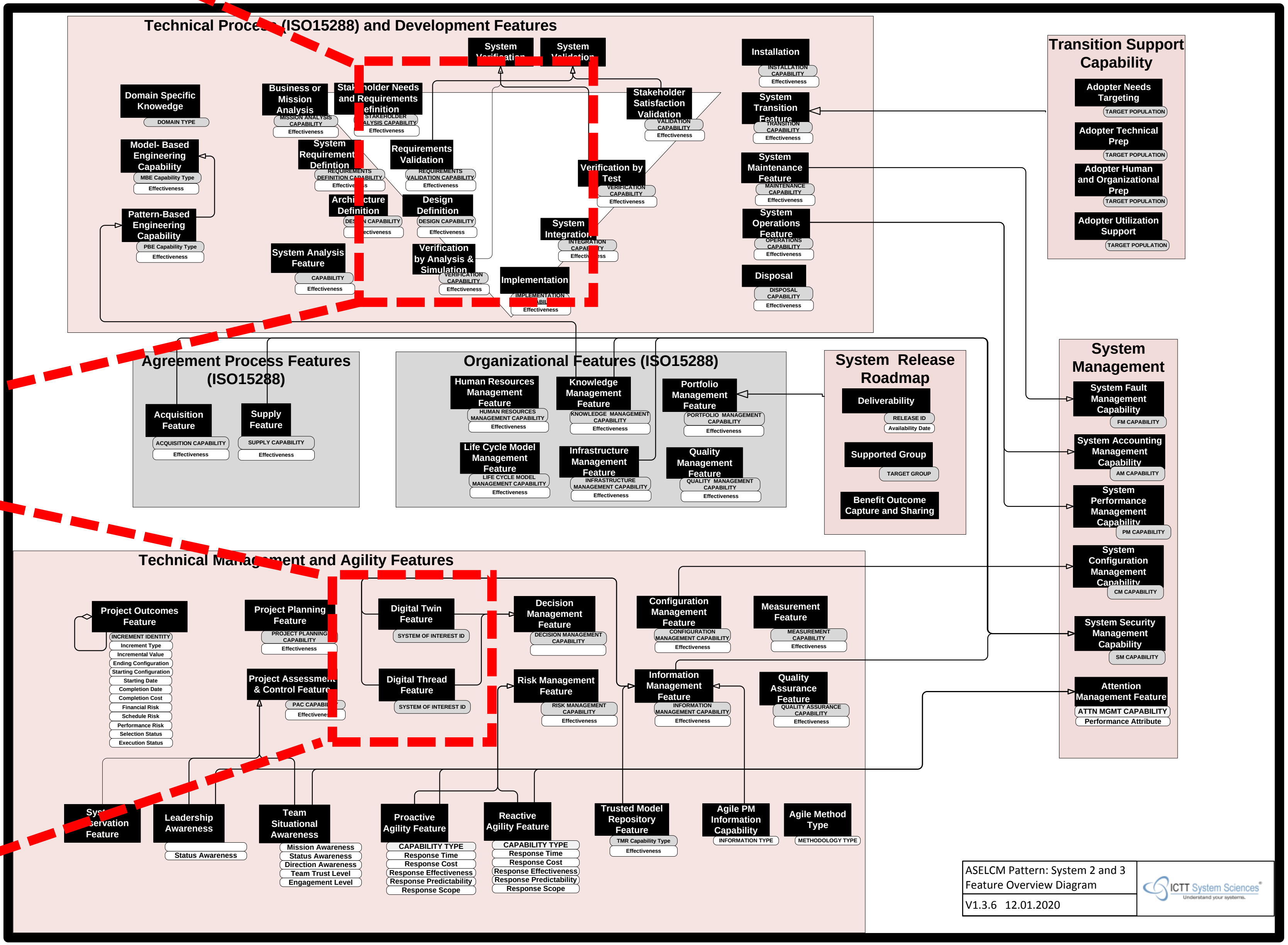


Level 1 Pattern

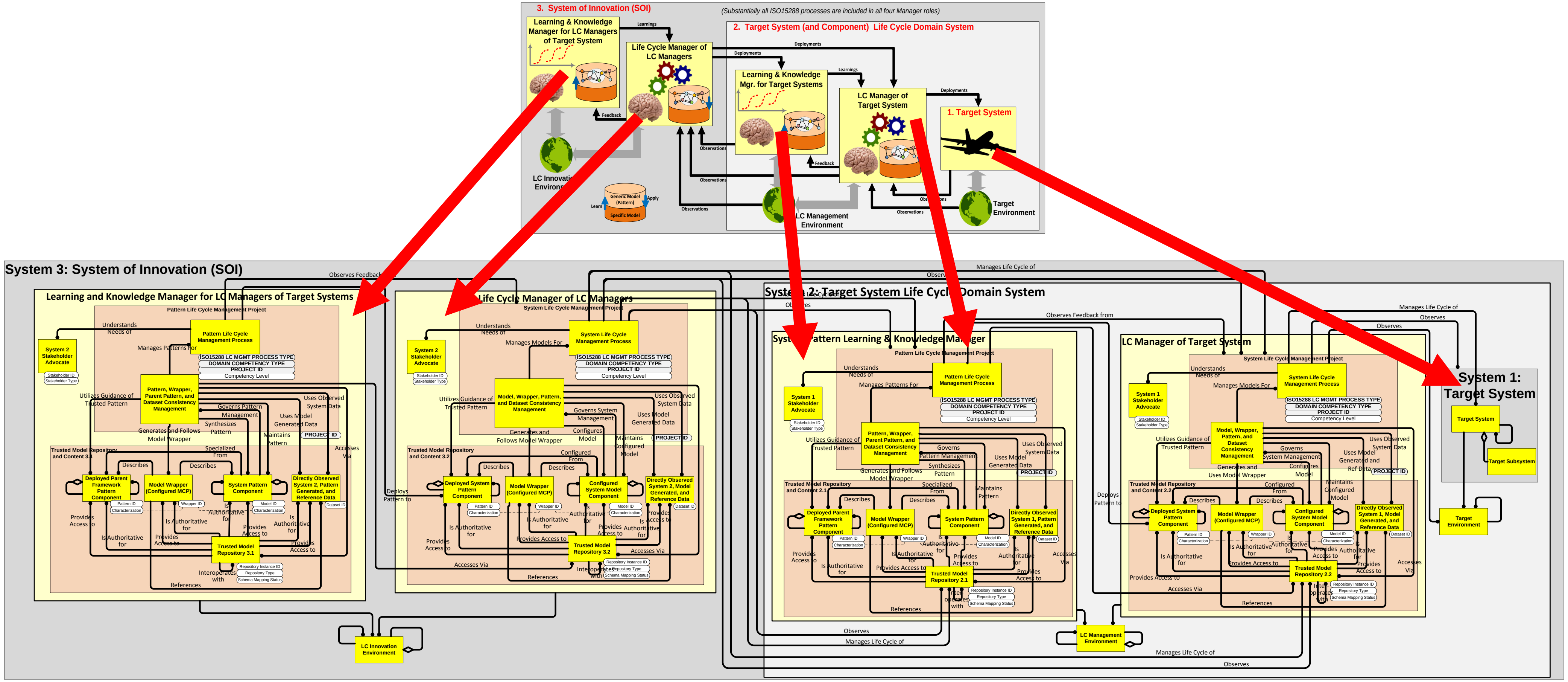
Configurable Stakeholder Features (capabilities) of System 2, 3







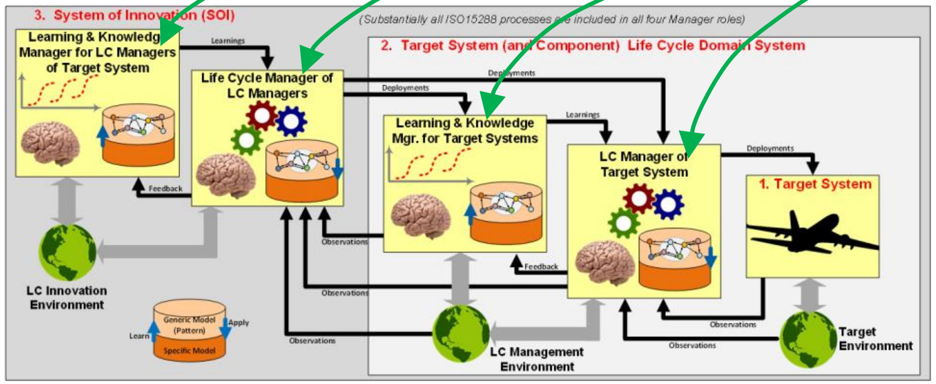
Progressive configurable levels remain descriptive, not prescriptive, in SysML or other languages, tooling



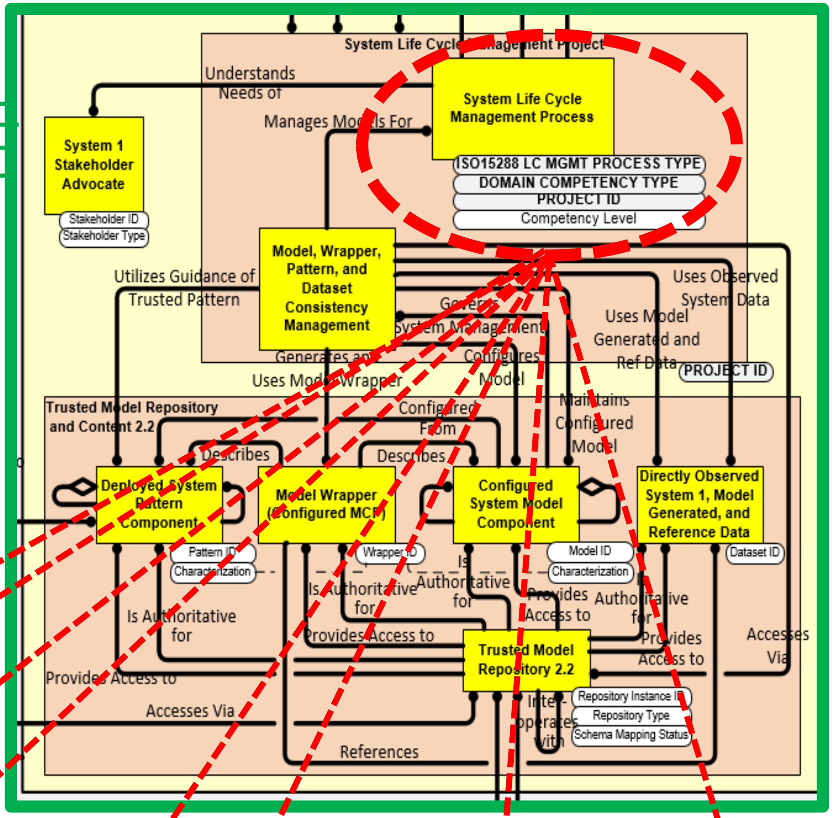
ASELCM
Level 1

ASELCM
Level 2

Learning & Execution pattern appears 4 times in ASELCM Ecosystem Reference Pattern

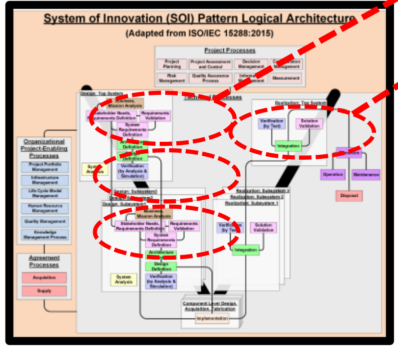


ASELCM Ecosystem Reference Pattern

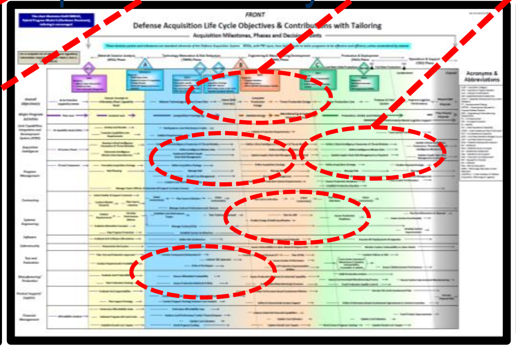


ASELCM Ecosystem Reference Pattern: Configurable to *all* life cycle management models---

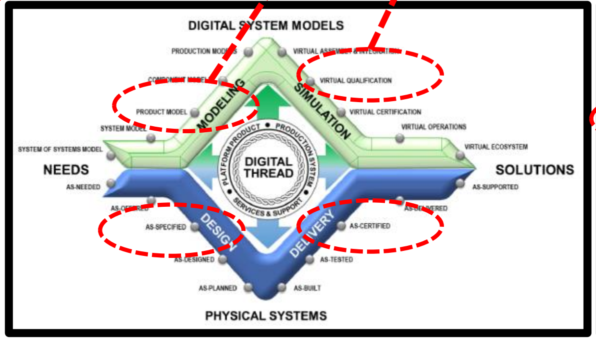
ISO15288 Life Cycle "Vee" Model[1]



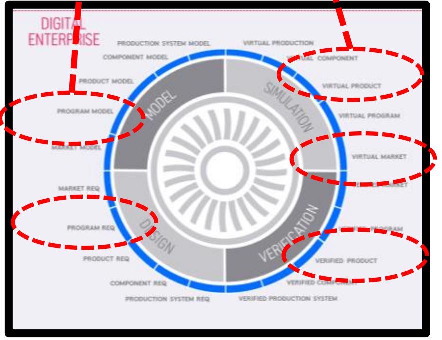
DoD 5000 Defense Acquisition Life Cycle Model[2]



Boeing "Diamond" Model[3]



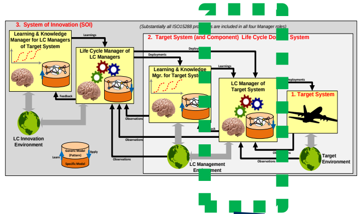
Rolls-Royce "O" Model[4]

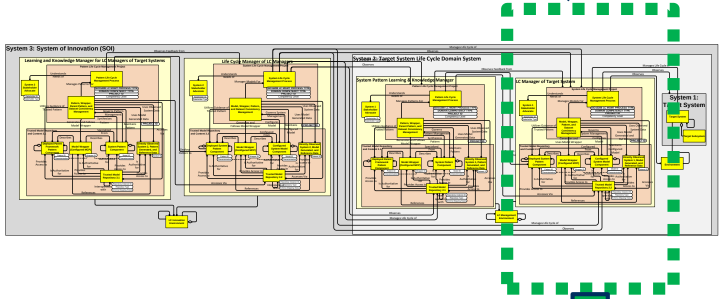


Excerpted or adapted from: (1) ISO15288 and INCOSE SE Handbook; (2) DoD5000 Wall Chart; (3) AIAA Sci Tech, 01.2020, J. Matakeyama; (4) AIAA DEIC Digital Twin Subcommittee, 04.08.19 Donaldson, Flay, French, Matlik, Myer, Pond, Randjelovic

Consistency Management as a Digital Life Cycle Management Paradigm

Process



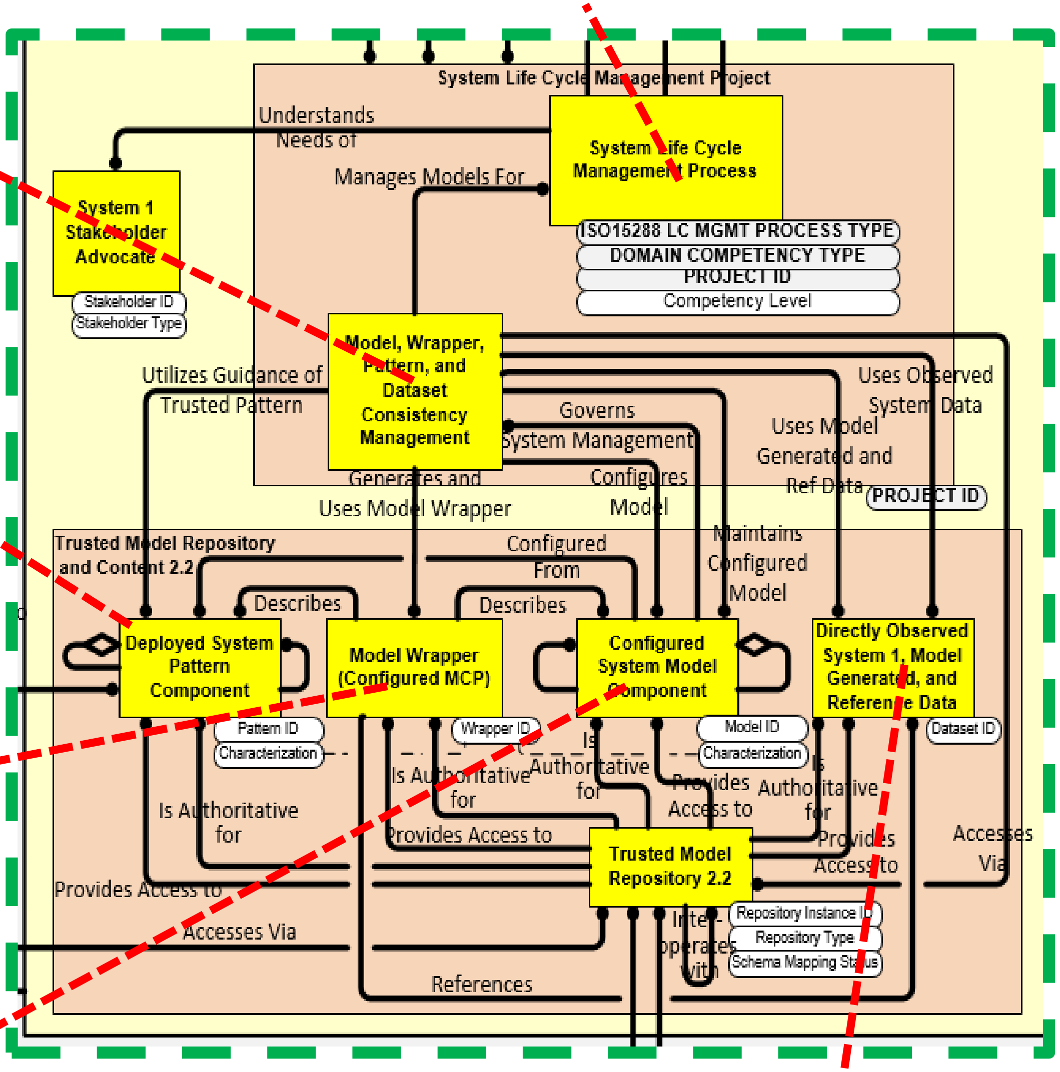


Business Processes: ISO15288 or otherwise

Consistency Manager Role: Manages the consistency of the four information sets below with each other as well as with several external areas.

Configurable Patterns That can Generate or Validate Configured Models of System 1

Model Wrappers (MCP Metadata) Describing Models, Patterns, and Datasets.

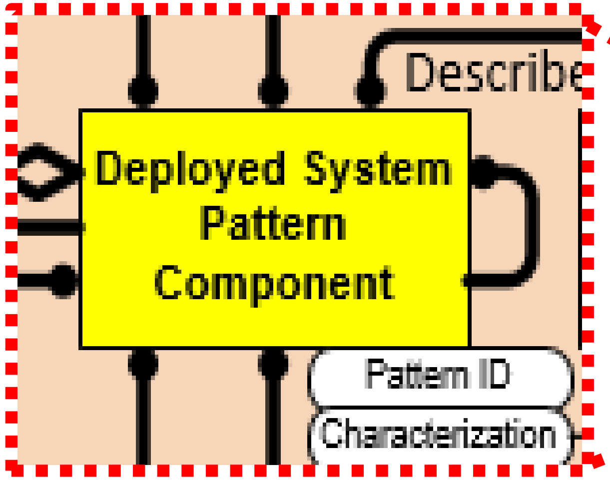


Information

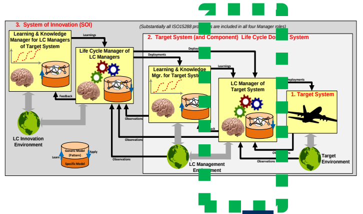
Configured Models: Computational and other (MBSE, etc.) of System 1

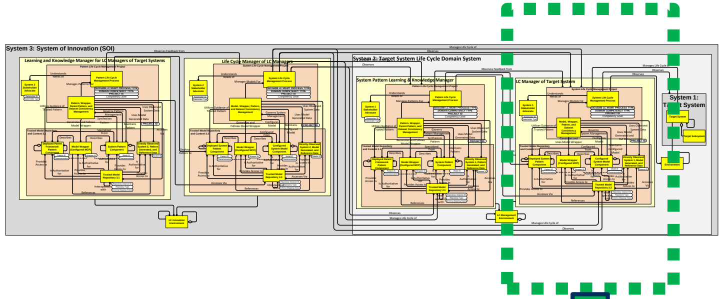
Datasets Generated by Computational Models of System 1 (Simulations) and by Empirical Observations / Tests / Measurements of System 1 (Digital Twin Pair Data)

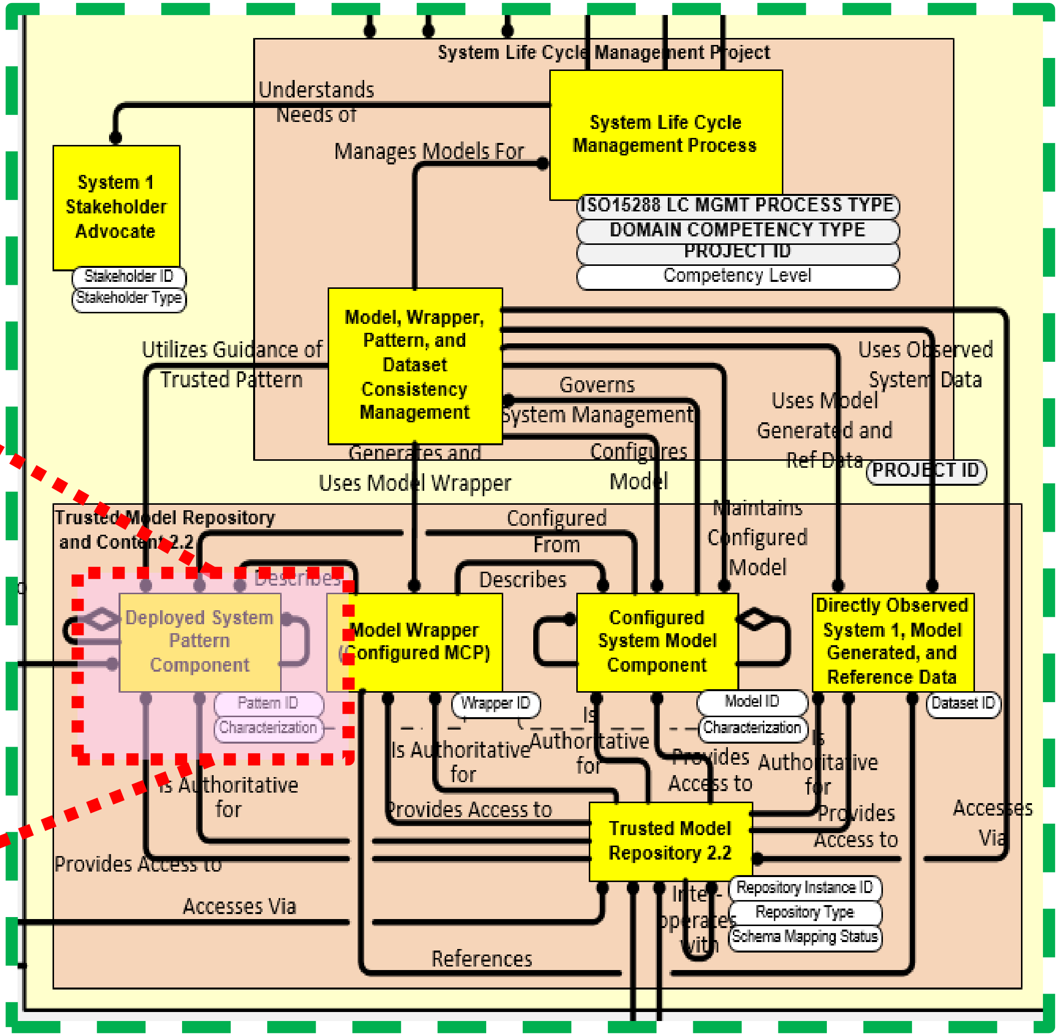
Micro Pattern (for System 1) appears in Macro Pattern (for System 2)



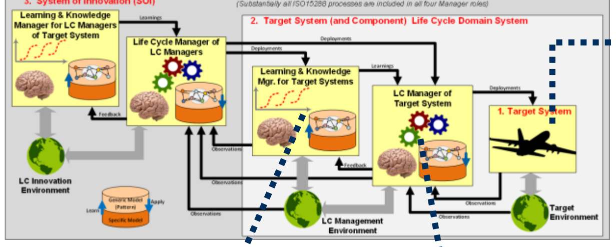
Process



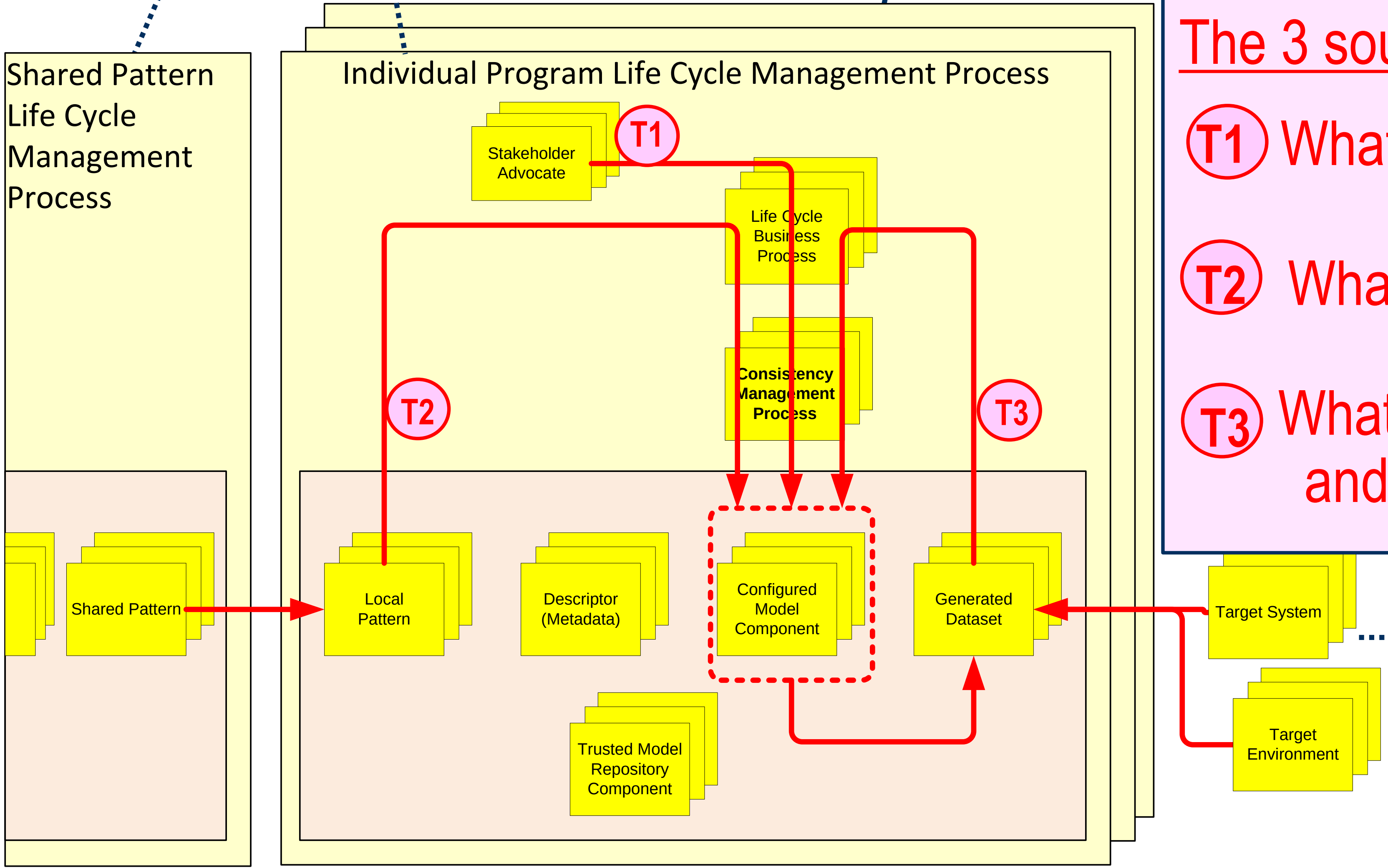




Information



<u>Consistency Management</u>, in multiple forms, occurs throughout the life cycle, to manage differences (inconsistencies) originating from <u>3 sources of authority</u>; <u>*it is at the abstract heart of life cycle management:*</u>



<u>The 3 sources of model credibility</u>

T1 What stakeholders say, want

T2 What past learning says

T3 What the observed real world and its simulation say

Applying the Ecosystem Reference Pattern: Recent / Current Configuration Studies

- INCOSE Agile Systems Engineering Case Studies (Lockheed Martin, Northrup Grumman, Rockwell Collins, US Navy)
- AIAA-INCOSE Digital Twin Implementation Studies
- AIAA-INCOSE Digital Thread Consistency Management Case Studies
- V4I-IDN-USAF Manufacturing Supply Chain Digital Thread
- ASME-INCOSE Collaboration on Standard for the Model-Based Enterprise
- INCOSE-ASME-NAFEMS-V4I Model Characterization Pattern Collaboration

Implications for action

- **Your System 1**: Uncover the Pattern™: 90 days to your own S*Patterns
- **Your System 2, 3:** Ecosystem Reference Pattern Roadmap Planner
- **Participate:** in INCOSE Patterns Working Group Collaboration Projects
- **Visit:** ICTT System Sciences booth at Momentum 2021

- Bill Schindel,
- INCOSE Patterns Working Group
- ICTT System Sciences
- schindel@ictt.com

ICTT System Sciences®
Understand your systems.

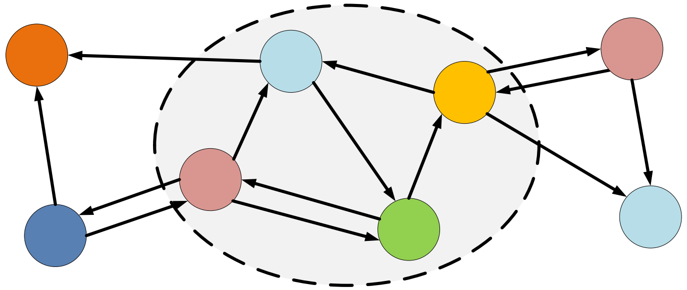
Questions, discussion

ICTT System Sciences®
Understand your systems.

References

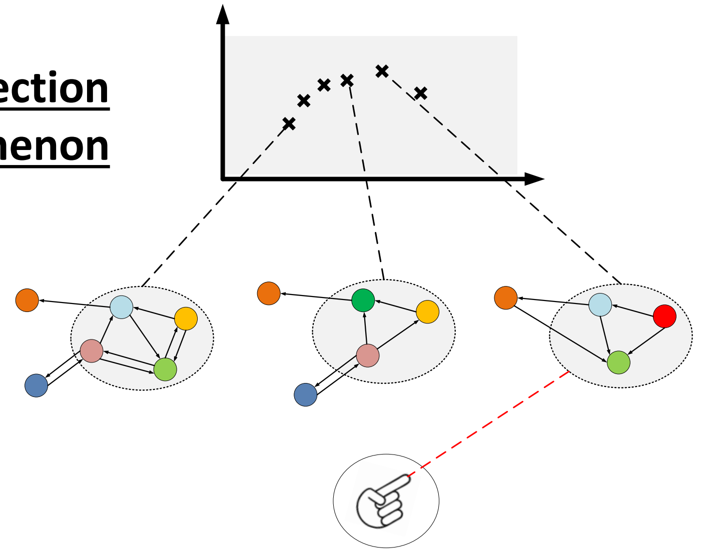
1. “Introduction to the INCOSE Agile Systems Engineering Life Cycle Management (ASELCM) Pattern”, 2016. https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:is2016_intro_to_the_aselcm_pattern_v1.4.8.pdf
2. Model Characterization Pattern: https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:model_characterization_pattern_mcp_v1.9.3.pdf
3. “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
4. (US DoD 2021) “Fiscal Year 2020 Industrial Capabilities: Report to Congress”, Jan, 2021; retrieve from https://media.defense.gov/2021/Jan/14/2002565311/-1/-1/0/FY20-INDUSTRIAL-CAPABILITIES-REPORT.PDF
5. Jacobides, M. G., et al. “Towards a theory of ecosystems (with phenomenological preamble)”; Keynote presentation at *5th International Conference of the Armand Peugeot Chair*. Paris, FR, Dec, 2017. Retrieve from https://chairgovreg.fondation-dauphine.fr/sites/chairgovreg.fondation-dauphine.fr/files/attachments/JCG%20CAP%20Paris%202017%20presentation%20S.pdf

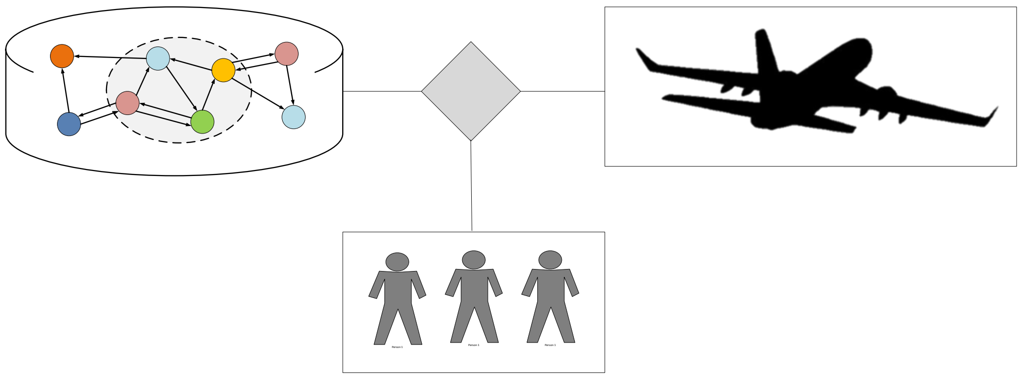
Putting Systems Engineering on an observable real phenomena-based foundation, joining the other physical-sciences-based engineering disciplines



1. <u>The System Phenomenon</u>

2. <u>The Value Selection Phenomenon</u>





3. <u>The Model Trust by Groups Phenomenon</u>