TEAM TOP GUN: APPLYING DIGITAL THREAD ACROSS THE PRODUCT LIFECYCLE

INDIANA DEFENSE NETWORK

Technical Interchange Meeting (TIM)

June 9-10, 2021

V2.1.1

Susan Carlock, Mursix Corp. - Co-owner/VP of Business Development

SMM Production Model represented in the collaboration scenario
Sample Prototype and Production Parts

Steve Stahley, Cummins - Director of Measurement Excellence

OEM Product Model represented in the collaboration scenario

Dr Joe Fuehne, Director - Purdue Polytechnic Columbus

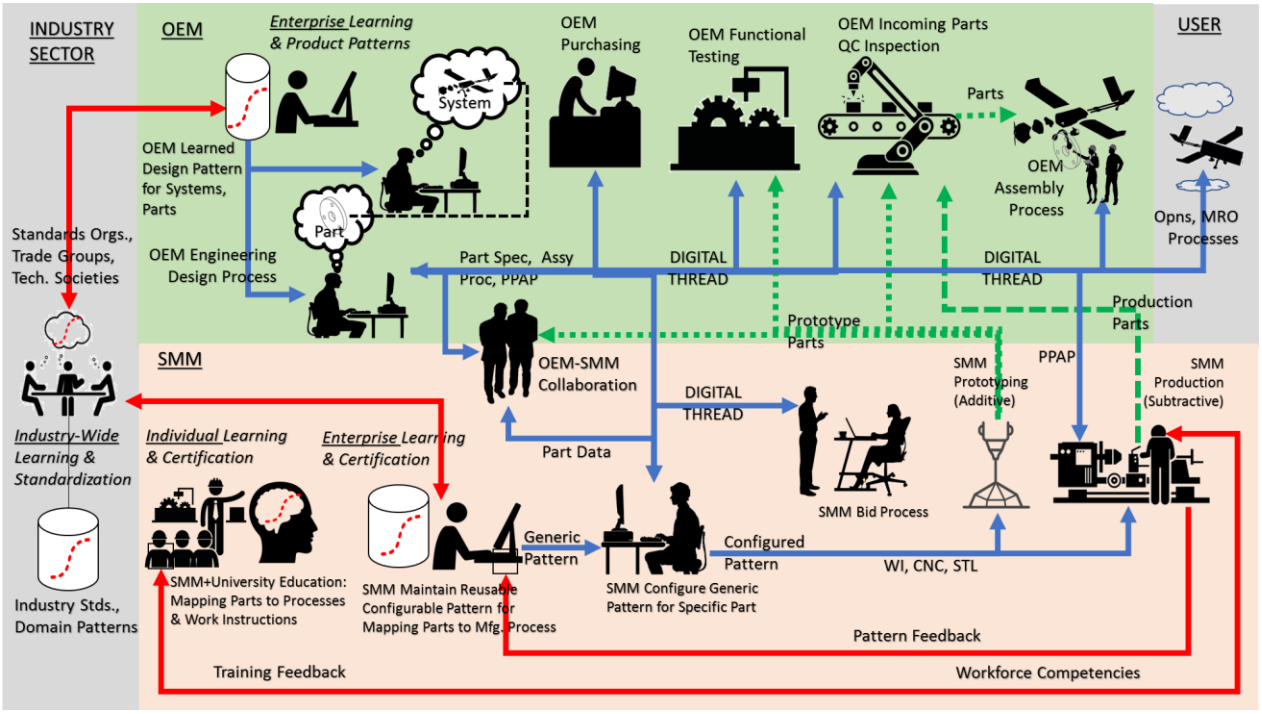
Capstone Curriculum
Columbus Student Team representing the OEM
Anderson Student Team representing the SMM

Mark Seidman, founder – Inteladvise

Economic Impact Study to Assess the Value of
Digital Thread Implementation across the Regional Ecosystem

Bill Schindel, Founder -ICTT System Sciences

INCOSE ASELCM Pattern and Associated
Metadata Wrappers as a Digital Thread Framework



Our project's 4 goals for enhanced Digital Thread ecosystems:

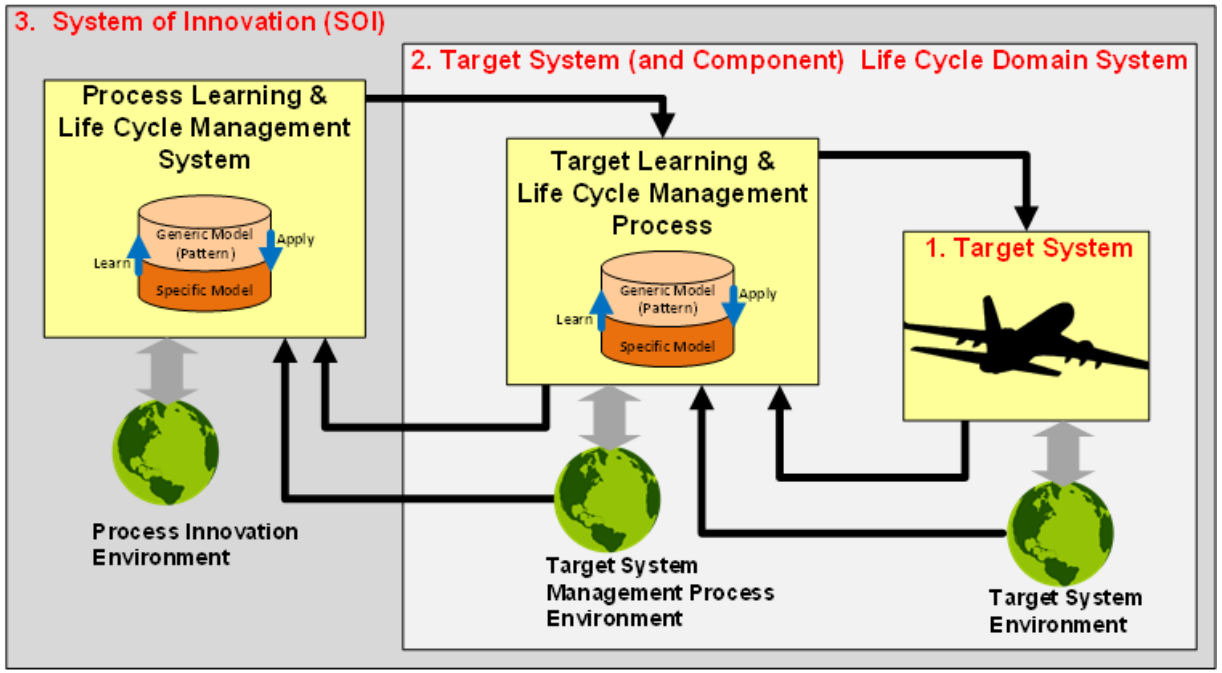
1. Improved collaboration: SMM – OEM
2. Improved learning: for workforce individuals, enterprises, region/sector
3. Improved delivery of needed information across life cycle – "HUD"
4. Improved framework for standardization of Digital Thread

Our example SMM-OEM system of systems

described by . . .

Universal INCOSE ASELCM innovation ecosystem descriptive reference pattern

Used by INCOSE, AIAA, others, for planning & analyzing agility, digital threads & twins, ecosystems of all types



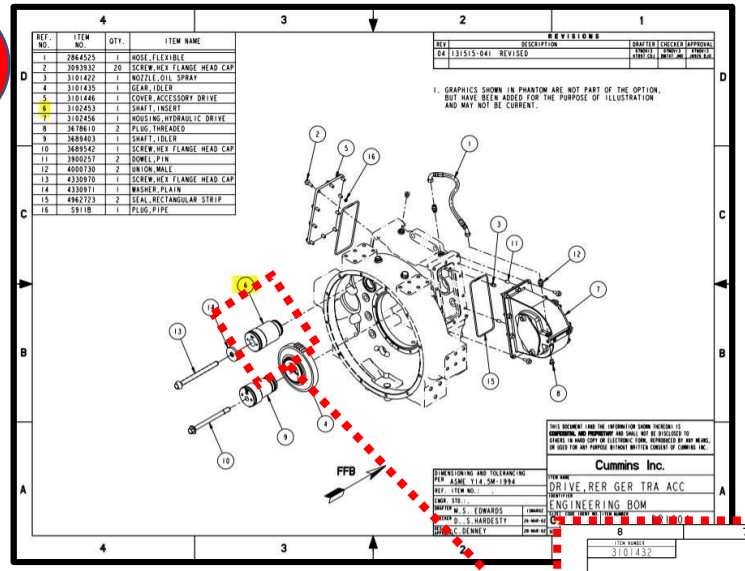
Level 0 View, INCOSE ASELCM Pattern

Our project: System product (hydraulic drive) exploded physical architecture-a type of model.

Behavior (function), value, and other types of system product (SysML) models

O-Ring seal performance described by parametric model.

1



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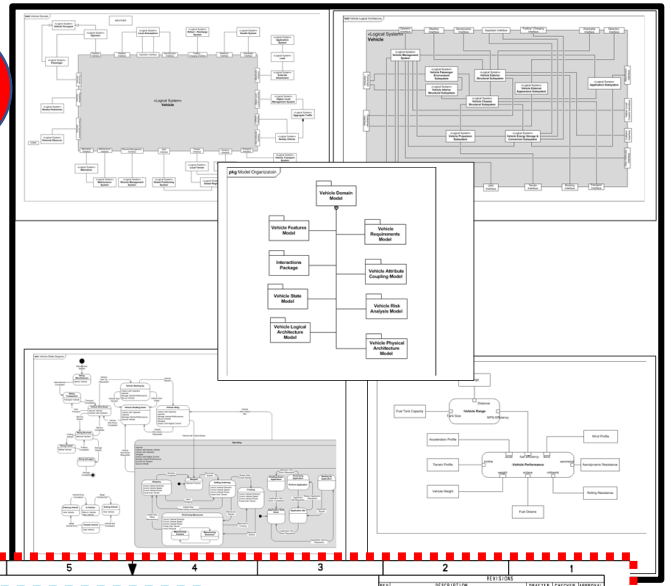

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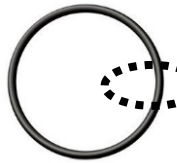
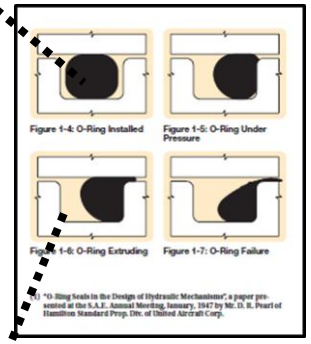


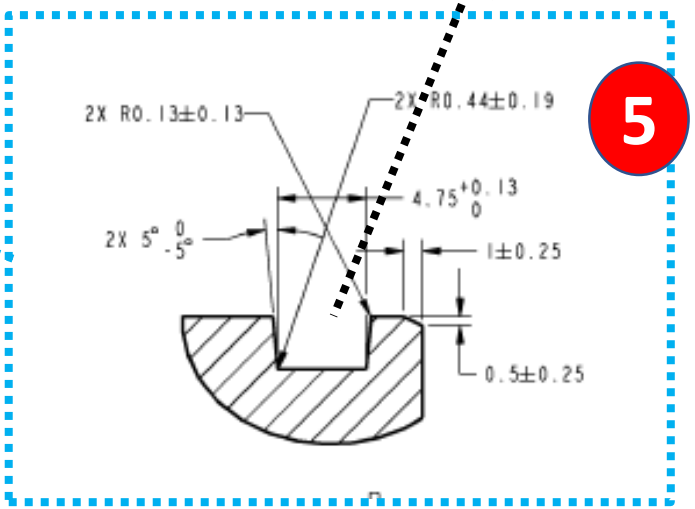
O-Ring

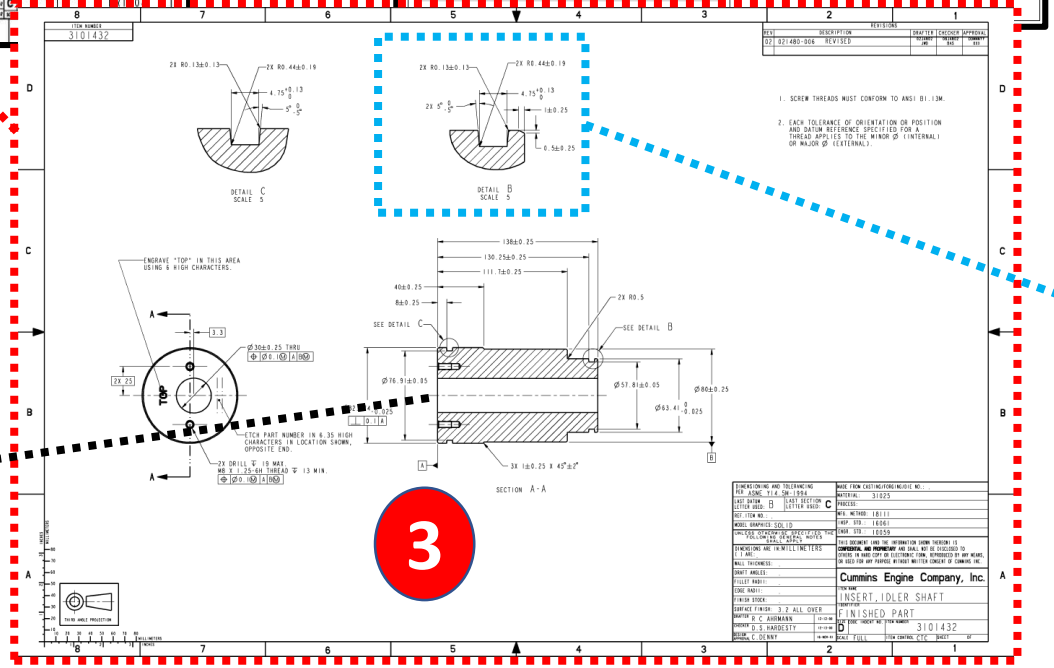
Installed O-Ring Cross Section



Machined Gland Slot for O-Ring

5





3

Dimensioned component print--a type of model

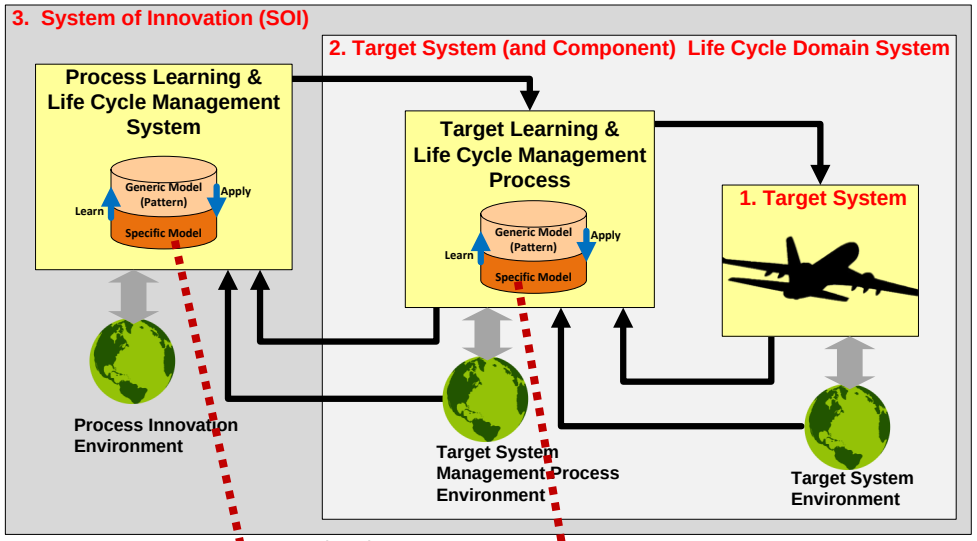
O-Ring installation

4

Manufactured 31 parts during project

Critical dimensional tolerances, related **collaborations, decisions**: O-Ring Seal slot dimensional tolerance

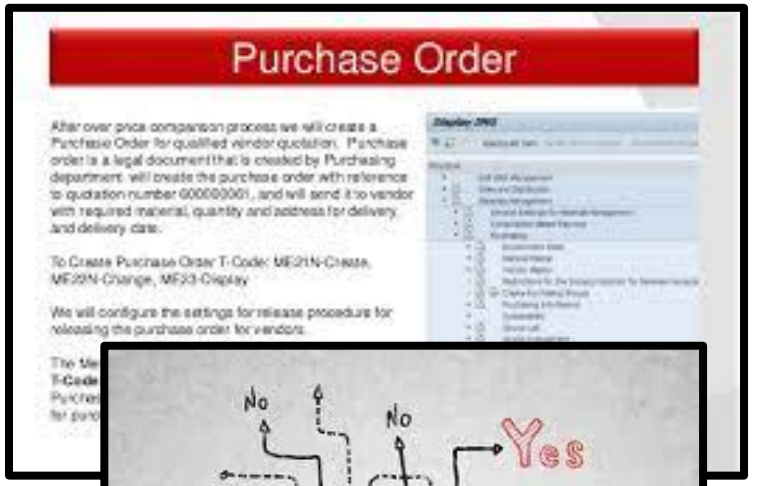
Overview in Digital Thread Setting



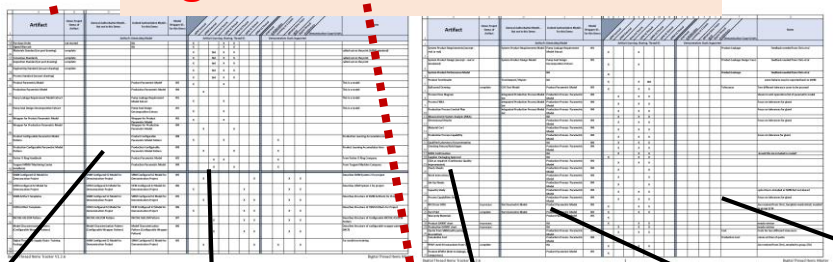
Level 0 View, INCOSE ASELCM Pattern

Innovation Ecosystem

Supply Chain Operations



Digital Thread Items Tracker

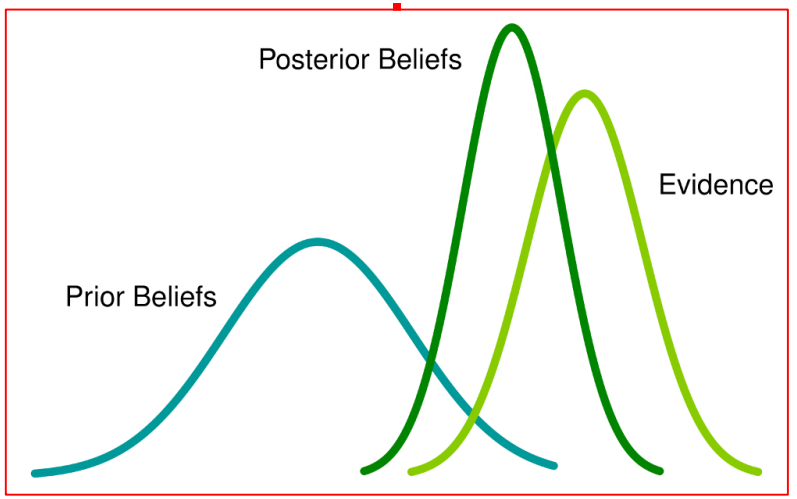


Supply Chain Digital Thread "HUD"

DT Artifact 1 | DT Artifact 2 | DT Artifact 3 | DT Artifact 4 | DT Artifact 5

Model A | Model B | Model C

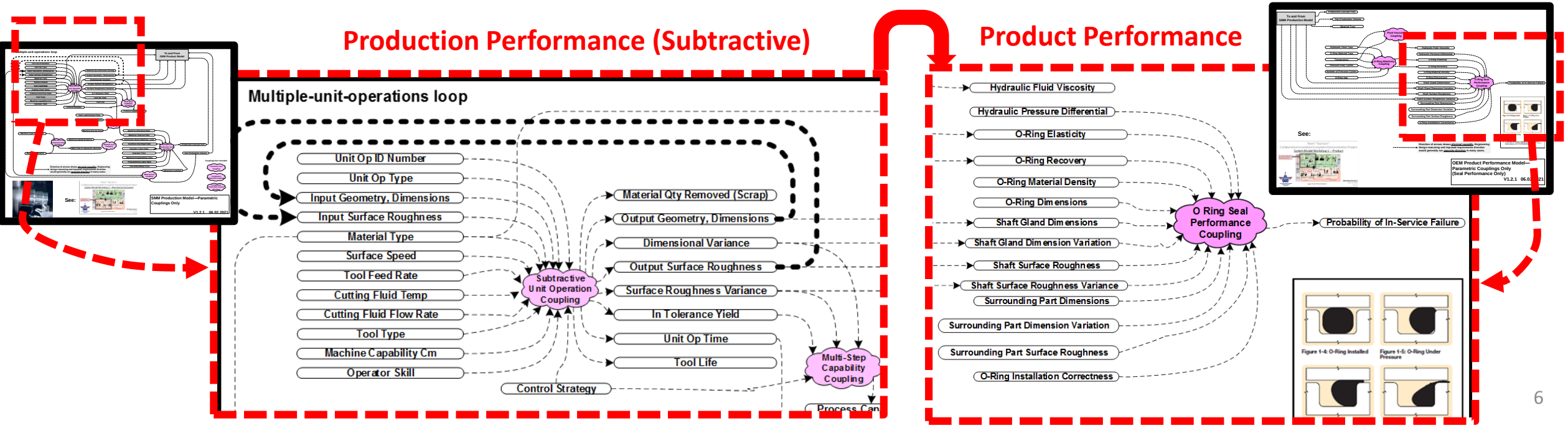
TIME



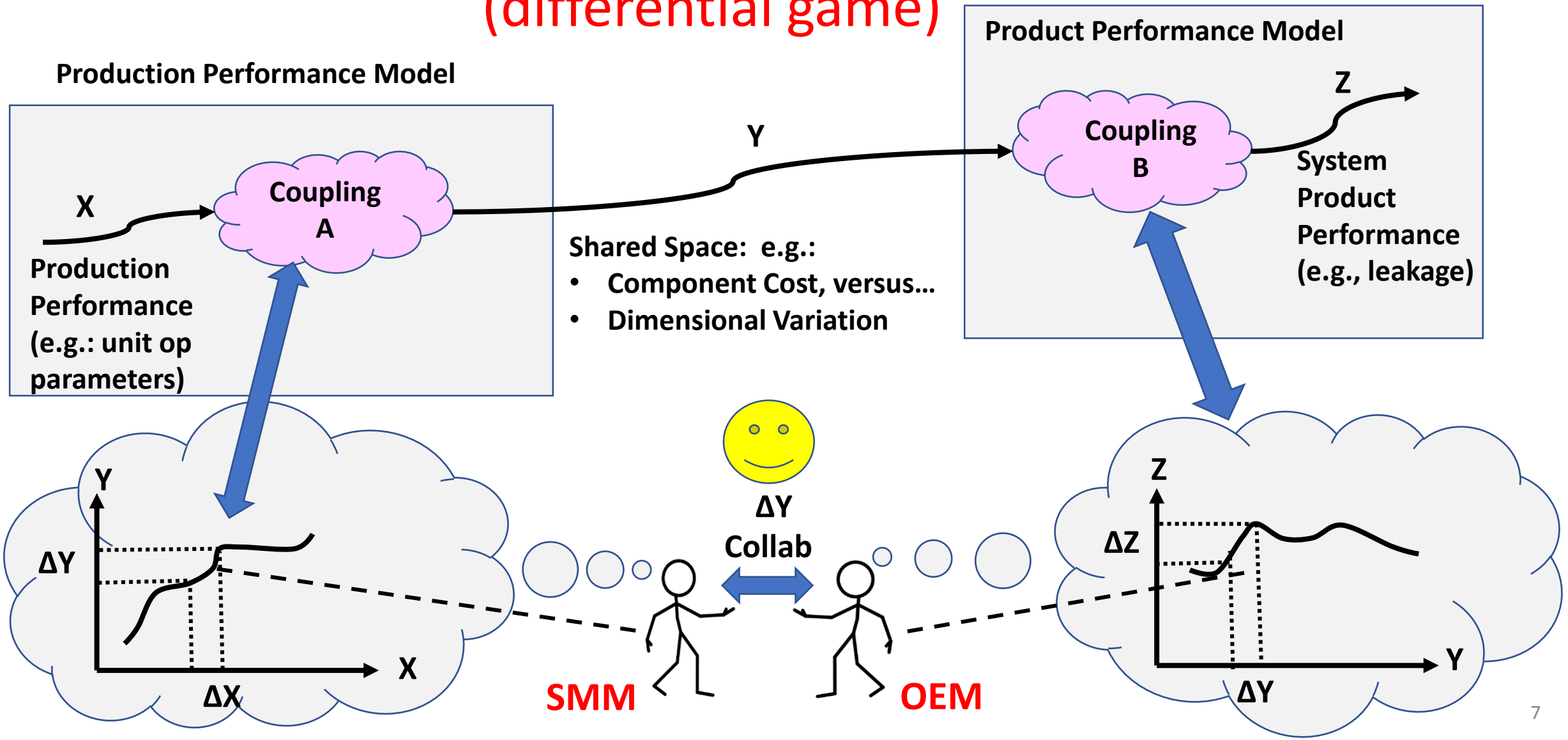
Bayesian Estimator

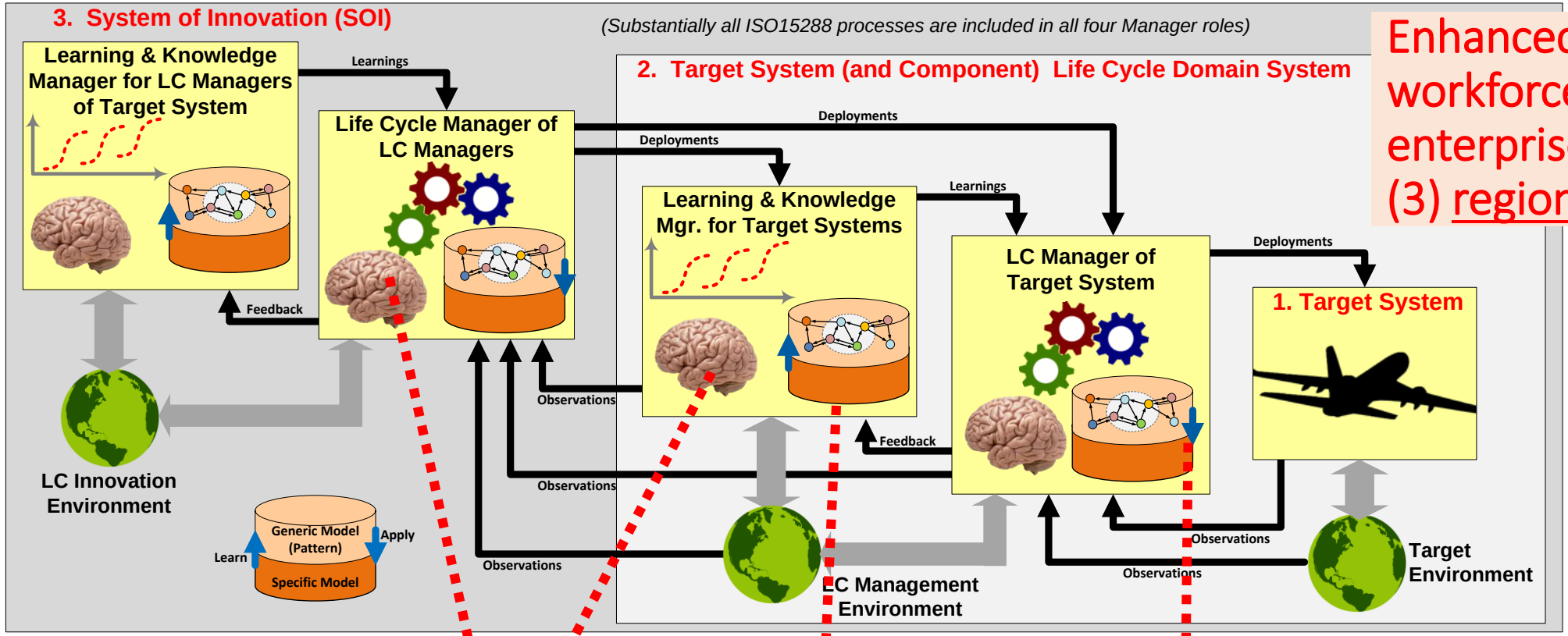
- General collaboration framework:
  - SMM and OEM each make use of their own internal learned but explicit model-based patterns (recurring configurable models, a newer practice to them),
  - which are also tied to their traditional artifacts (not new practice to them).

- In our simple simulated pilot, model-based patterns are the parametric models for the OEM Product Performance and SMM Production Performance:



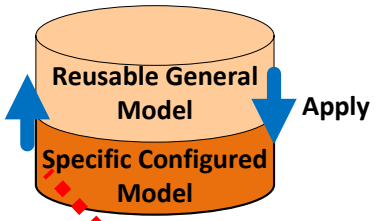
Optimized collaboration, enabled by explicit, model-based patterns—may be private to each enterprise (differential game)





Enhanced learning by (1) workforce individuals, (2) enterprise teams, partners, (3) region/sector

Future workforce



Learning is not accumulation of information—it is improvement of performance.

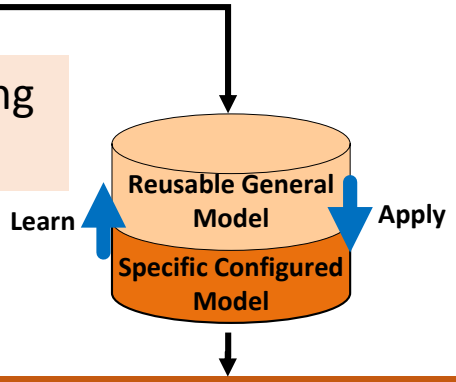
Group Learning (team, enterprise, ecosystem, sector) – use of explicit configurable patterns, for both System 1 (products) and System 2 (ecosystem), bypasses the "lessons learned report" failure syndrome.

Individual Learning: Our project team includes 8 Purdue Poly students and 2 lead professors, across 2 student teams at different campuses.

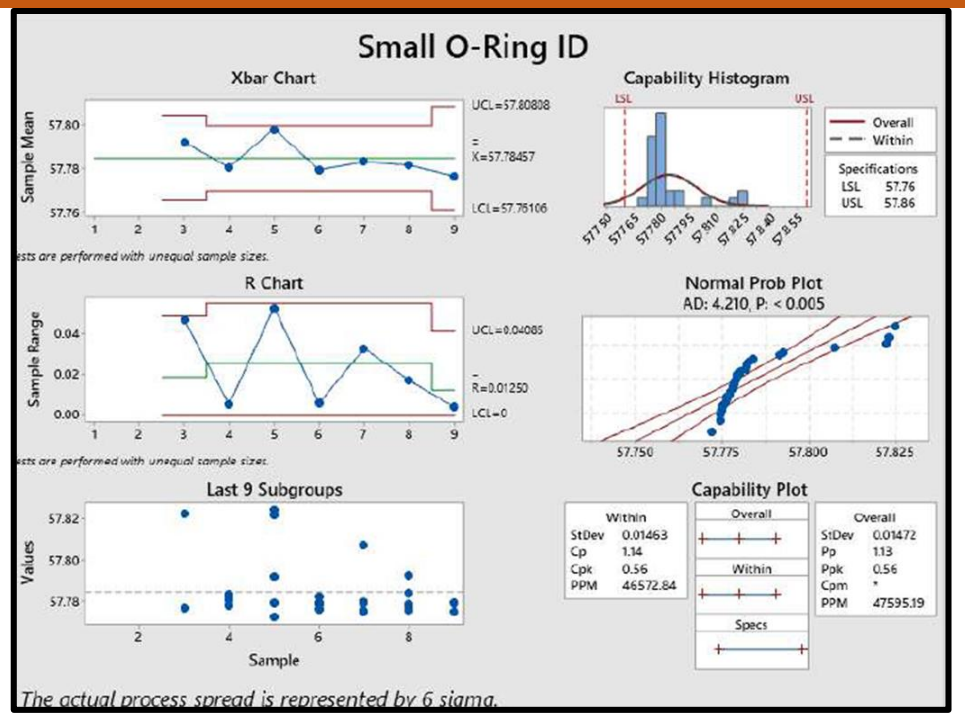
Improve group learning: Teams, enterprises, ecosystems, region

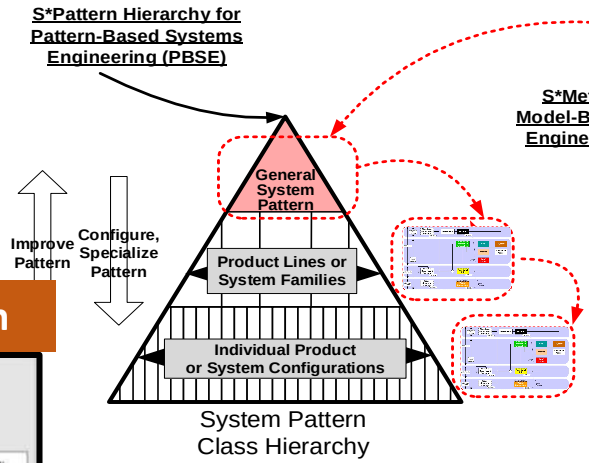
- Differential games
- Discrete modular games

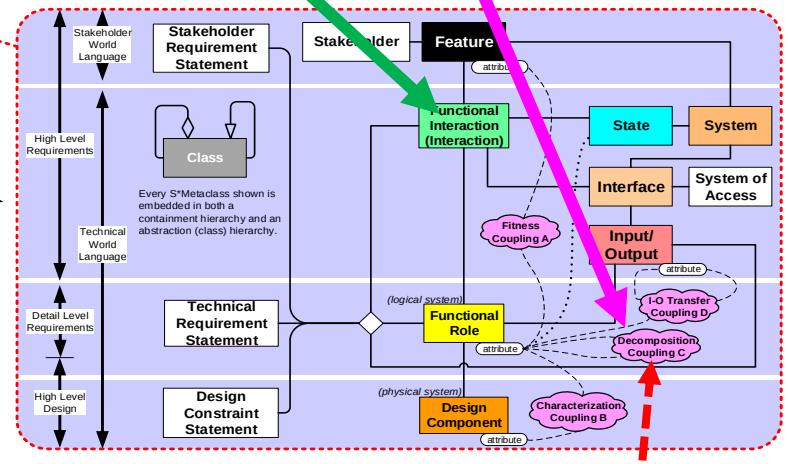
Manufacturing Pattern



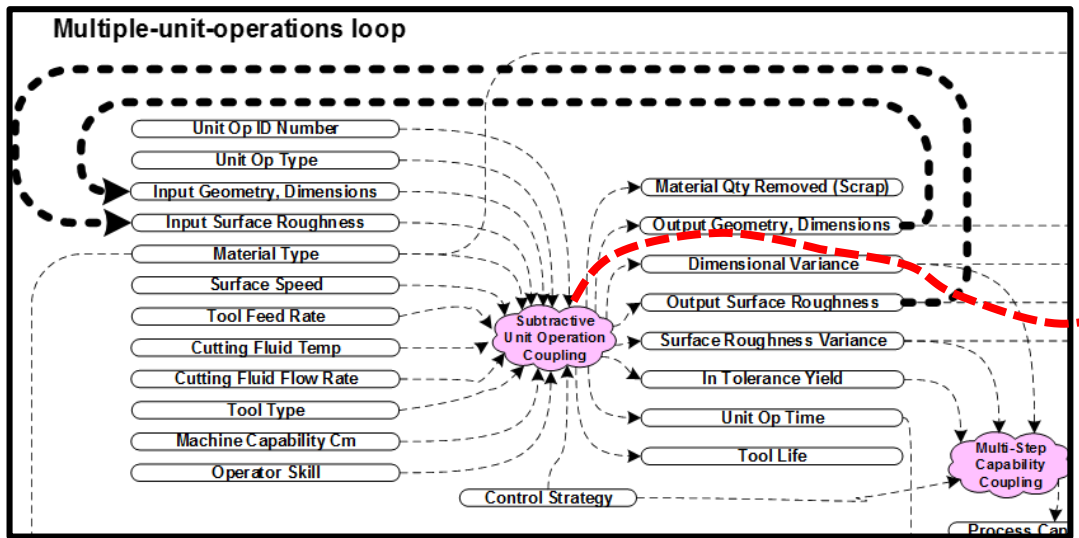
Machining Process Capability Check Against Pattern







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



HUD Metaphor: The General Setting

Aerospace Ecosystem
Flight Mission Operations

Innovation Ecosystem
Supply Chain Operations

HUD = Heads Up Display

The general setting . . .

. . . whether for aircraft pilot, supply chain actor, or other decision-makers . . .

. . . is supporting optimal estimation and control decisions for timely actions, in the presence of significant uncertainty and dynamically changing states.

This includes awareness of current level of uncertainty, time urgency, and risk impact.

“HUD” example for release of materials PO

Flying over terrain: Translates to “flying” over project GANTT chart

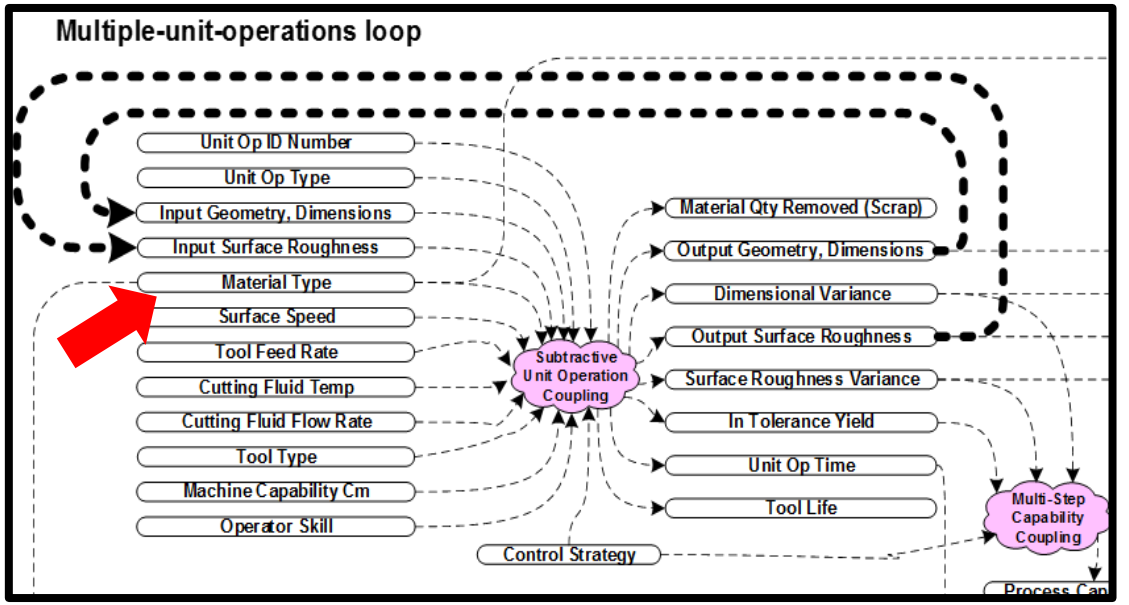
Digital Thread Pilot

Team Top Gun
Mark Seidman

Project Start: Tue, 9/1/2020
Display Week: 1

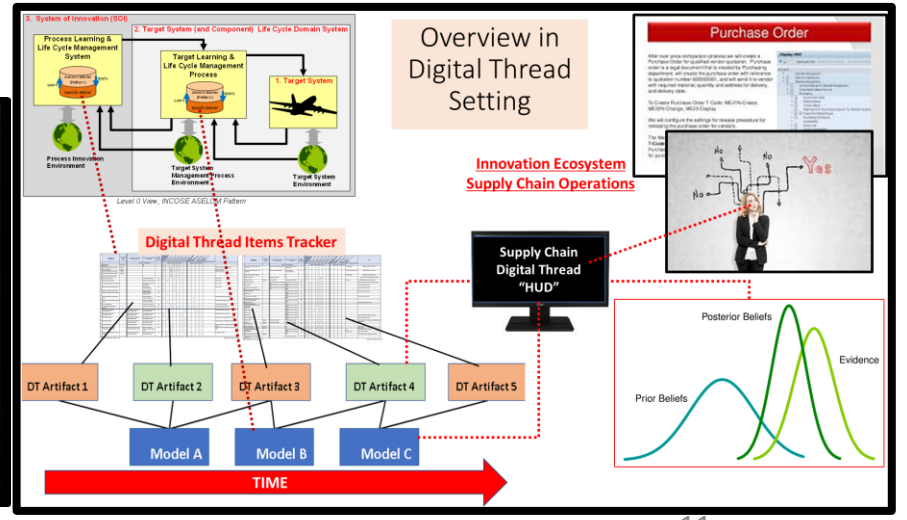
TASK	PROGRESS	START	END
Gate 2	100%		
Gage / Fixture Design Review	100%	2/23/2021	2/23/2021
Release Gage / Fixture Design	100%	2/24/2021	2/24/2021
Review Material Quotes	100%	2/19/2021	2/22/2021
Order Sample Material	100%	2/22/2021	3/5/2021
Order Gage Material Stock List	100%	2/22/2021	3/5/2021
Gage / Fixture Construction	100%	3/5/2021	3/8/2021
Gaging / Fixturing Completed - issue to QC	100%	3/8/2021	3/9/2021
Gage / Fixture R & R / Instructions	100%	3/8/2021	3/9/2021
Schedule Equipment for Set-Up Program, Debug	100%	3/9/2021	3/10/2021
Initial Tool Samples to QC	100%	3/10/2021	3/11/2021
Initial tool Sample QC Approval	100%	3/12/2021	3/15/2021

ProjectSchedule | About



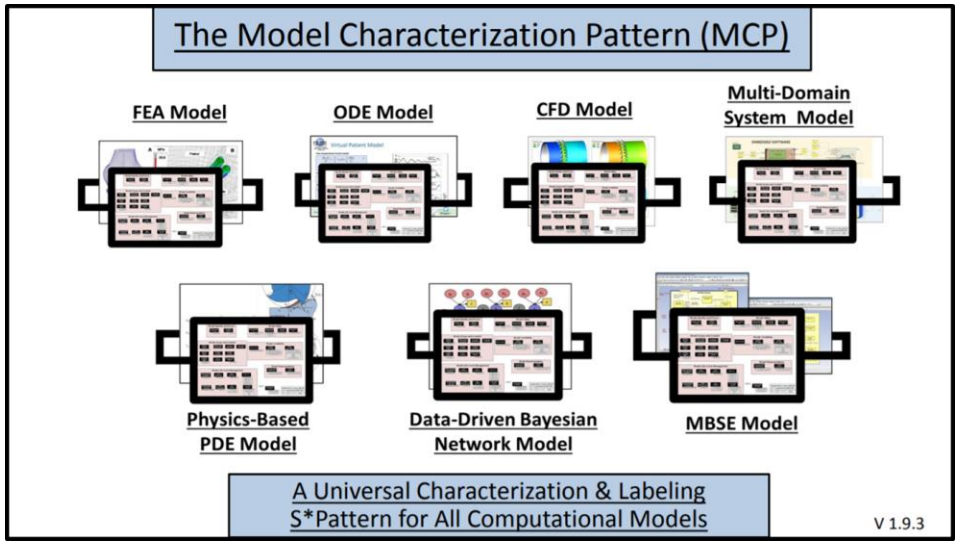
M75: Order Sample Material

	Go/No Go	Value	Uncert
Time to Event	2 Days		
Material Type			
Unit Material Cost			
Tooling Wear			
In Tolerance Yield			
Unit Production Cost			



Improved framework for standardization of Digital Thread

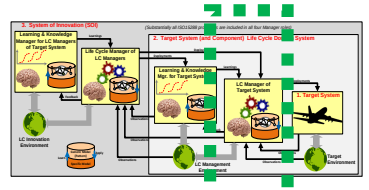
- There are relevant standards for limited aspects of the Digital Thread (References).
  - However, the state of the art in digital models is evolving rapidly.
- This project illustrates additional approaches that can strengthen semantic interoperability:
  - The Model Characterization Pattern (MCP) provides a universal, configurable “model wrapper” used to plan, label, use, exchange digital models of all types—MBSE, FEA, CFD, Machine Learning (e.g., BNN), etc.
- Consistency Management as a paradigm for engineering and life cycle management across the Digital Thread:
  - Leading to wrapper-based Consistency Signature support for Decision-Making.
- Digital Thread Items Tracker for this project illustrates overview of multiple Model Wrappers across Digital Thread.
- Open versus closed standards: fenced in by slow changing standards, versus dynamically evolving wrappers.
- Configurable (SysML) ASELCM Pattern provides scalable approach applicable to planning, managing complex ecosystems, products, and services.
  - In use by INCOSE, AIAA, enterprises for analyzing System 2, 3 ecosystems, Digital Threads, Digital Twins.
- A second Digital Thread: Planning and managing System 2, including Digital Thread 1.
- S3 forever—not just one time speed up



ASELCM Ecosystem Neutral Reference Pattern (Level 2)

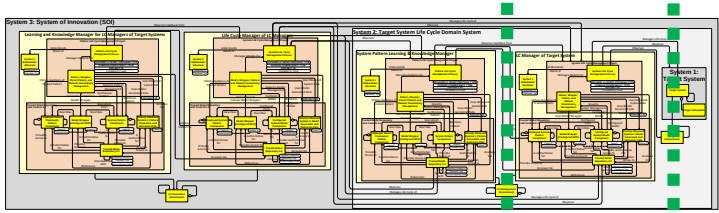
Business Processes:
ISO15288 or otherwise

Process



L1

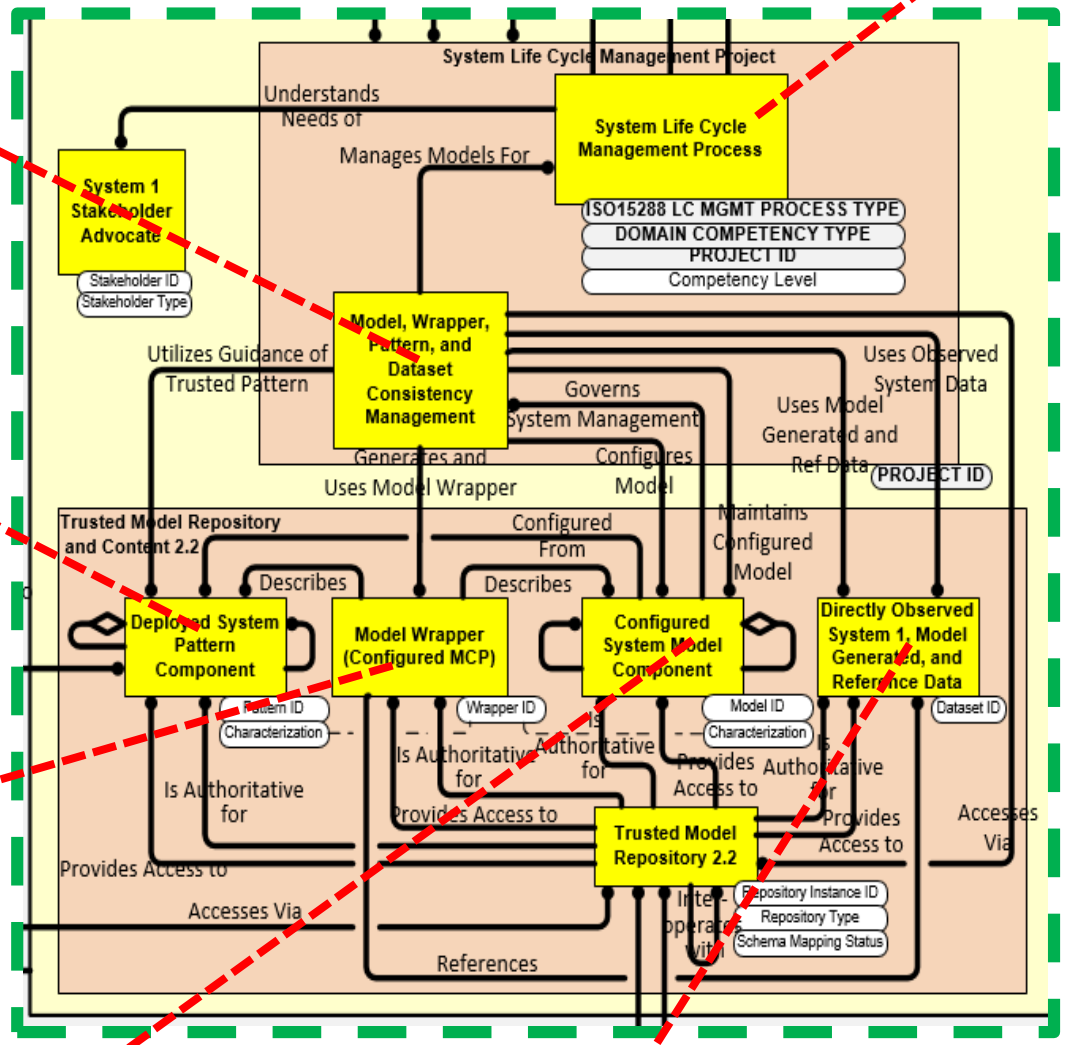
L2



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 (Digital Thread)

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)

Project Status and Next Steps

- Framework Orientation and Enterprise Exchange Workshops ☑
- Part Production and Metrology Completed thereby providing critical data points for the parametric couplings in our project scenario ☑
- Qualitative in-depth interviews complete and executive summary submitted ☑, quantitative digital questionnaire is in distribution 🔄
- Example information system mapping report drafts and both configured part model and manufacturing process metadata wrappers 🔄
- Plans for education and progress modules (S3) from June 1 team meeting
  - Purdue Capstone Course ☑
  - Additional Curriculum Formats 🔄
- Recommendations with Final Project Report Package 🔄

References—with download links (continued)

1. "Variational Forces of Modularity: Coupled Macro and Micro Patterns in the Innovation Ecosystem", Momentum 2021 Conference, May, 2021. https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:the_forces_of_modularity_schindel_v1.3.3.pdf
2. "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
3. Model Characterization Pattern: https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:model_characterization_pattern_mcp_v1.9.3.pdf
4. "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
5. "Consistency Management as a Digital Life Cycle Management Paradigm", INCOSE MBSE Patterns Working Group, retrieve from 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
6. 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_1 .

7. ISO 10303 STEP: computer interpretable information for product manufacturing https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=821600
8. ISO 10303 AP233 Systems Engineering information exchange
9. ISO 10303 AP238 STEP-NC (replaces M & G Codes with semantically based machine step libraries)
10. ISO 10303 AP242 Model-Based 3D Engineering
11. ISO 10303 AP239 Information Required to Support a Product Over its Life Cycle
12. ISO 13399 Manufacturing Tooling Information
13. ANSI Quality Information Framework (QIF) https://www.nist.gov/system/files/documents/2018/04/10/4drp6_campbell_qif_summary_20180330.pdf
14. MT Connect : Machine tool data collection interfaces
15. AIAG PPAP: APQP & PPAP Requirements for Automotive: https://www.techstreet.com/standards/aiag-ppap-4?product_id=1257705
16. SAE AS9145: APQP & PPAP Requirements for Aerospace and Defense https://www.sae.org/standards/content/as9145/
17. ISO 13485: Medical devices — Quality management systems — Requirements for regulatory purposes: https://www.iso.org/standard/59752.html
18. For the portion of the Digital Thread related to manufacturing, the related ISO 23247 draft standard for Manufacturing Digital Twins has (limited scope) value.
19. Current NIST efforts toward standards for the Digital Thread https://www.nist.gov/programs-projects/extended-digital-thread