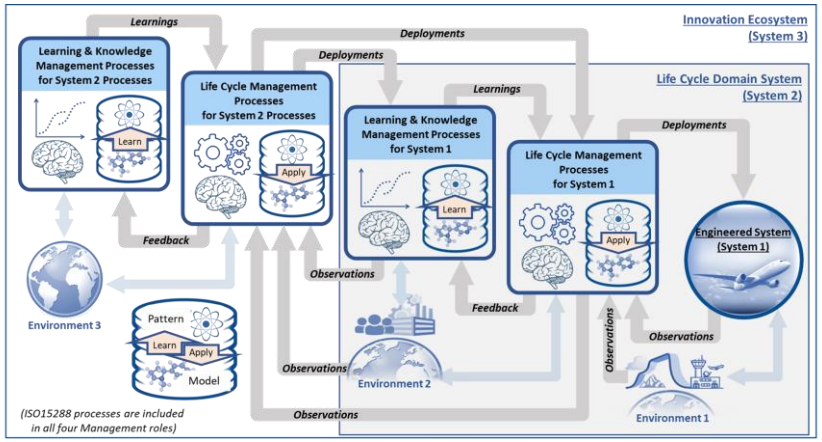
2023 Annual INCOSE international workshop

HYBRID EVENT

Torrance, CA, USA

January 28 - 31, 2023



ASELCM Level 1 Reference Model

Attachments

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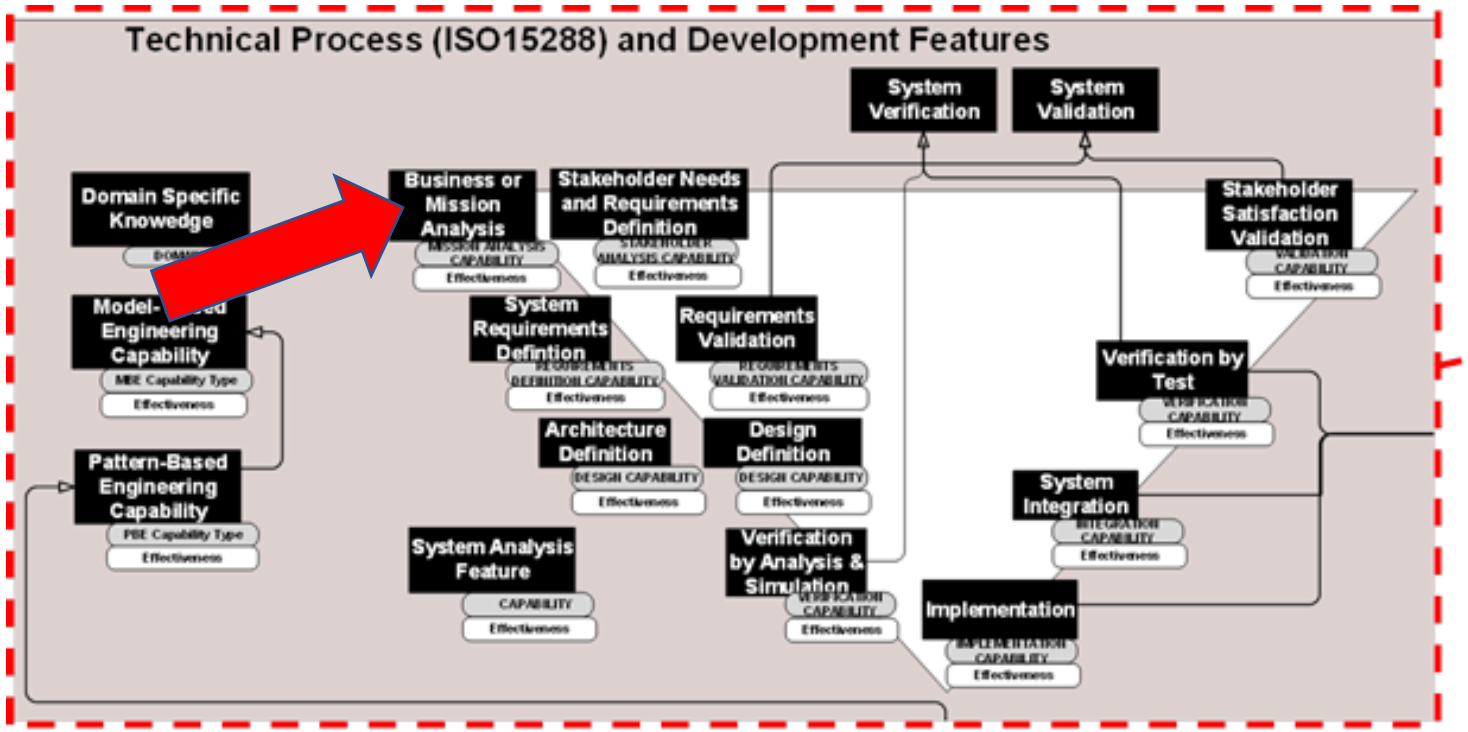
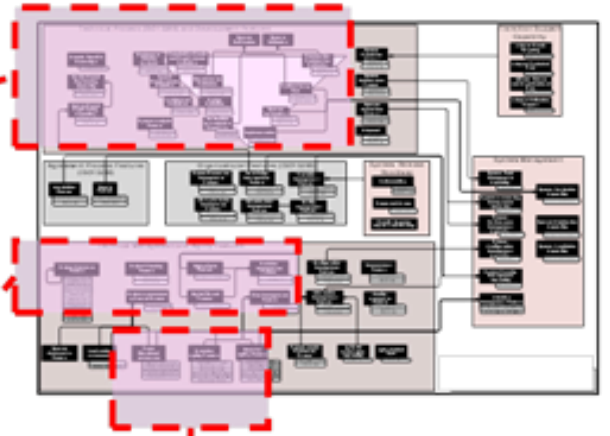
- Attachment 1: More details on example configurations of the formal pattern:
  - Mission Planning potential example
  - Stakeholder Needs and Requirements potential example
- Attachment 2: Additional aspects worth considering
- Attachment 3: Observations on the earlier draft (2022) DA WG Trade Study Example that Help Us Understand the More General Ecosystem Pattern

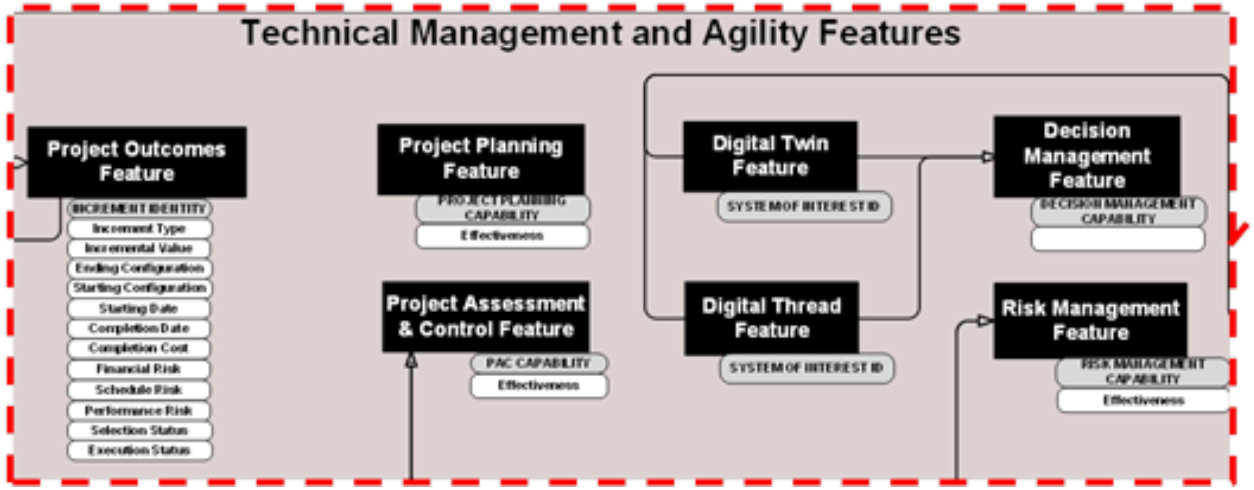
Attachment 1: More details on example configurations of the formal pattern

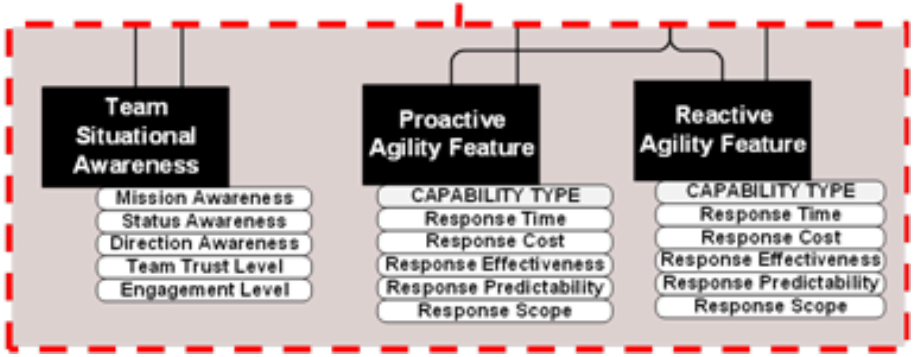
- Mission Planning potential example
- Stakeholder Needs and Requirements potential example

CLAIM: The following pages' interactions <u>are what performs</u> the Business or Mission Analysis Stakeholder Feature of S2.



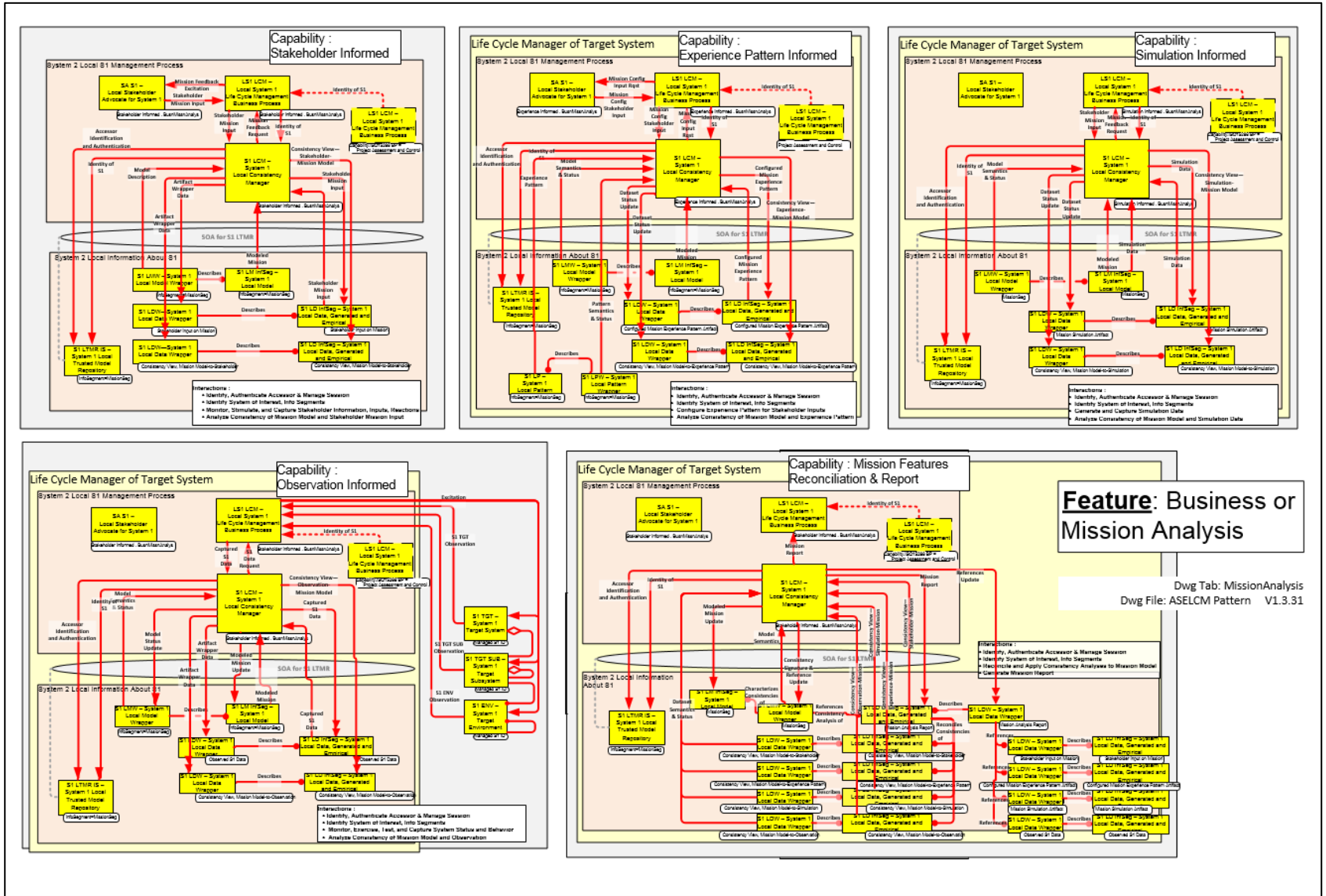


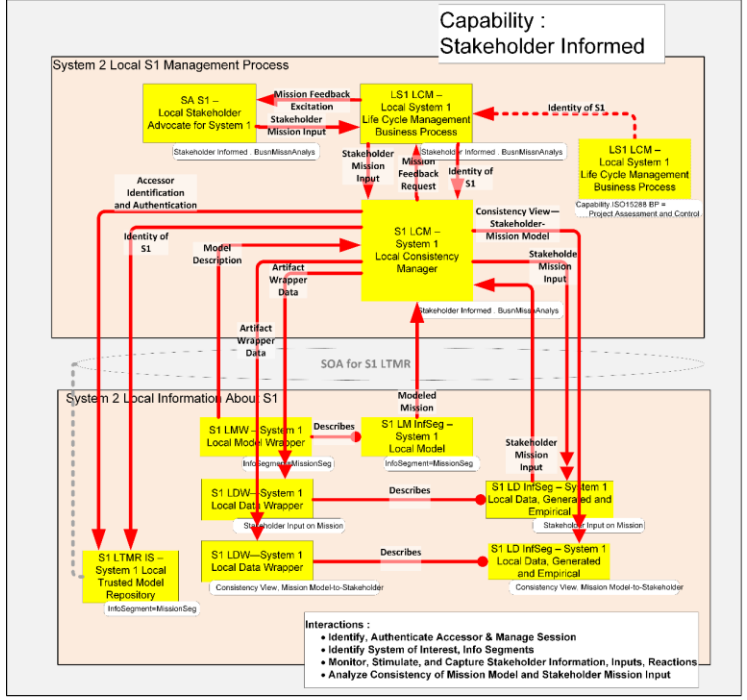


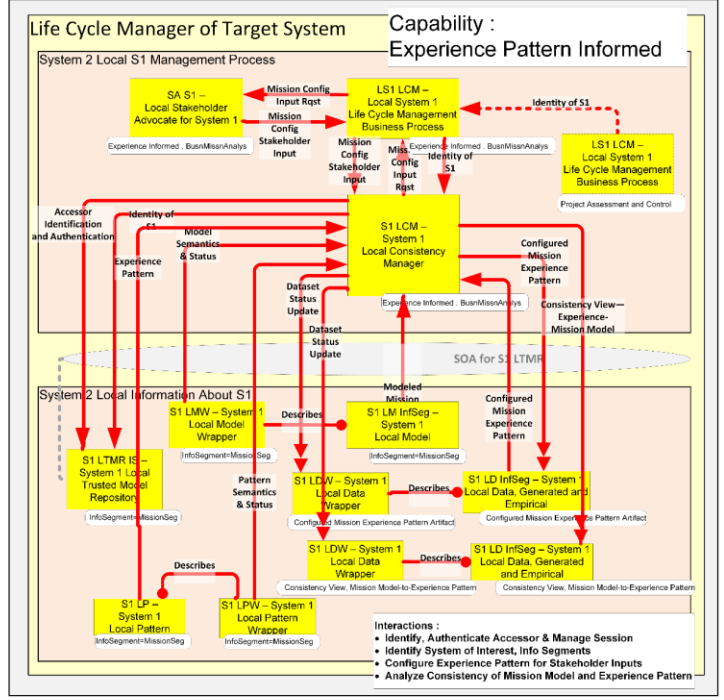


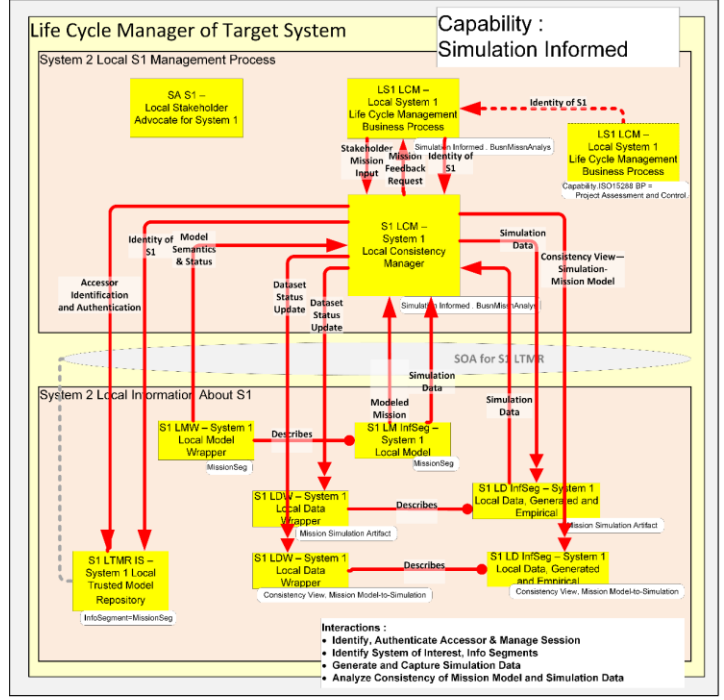
Generic configurable ASELCM Level 2 process roles (e.g., Consistency Managers, Business Processes) and generic ISO15288 Information Segments (e.g., System 1 Mission, Stakeholder Requirements, System Requirements, Architecture, etc.)

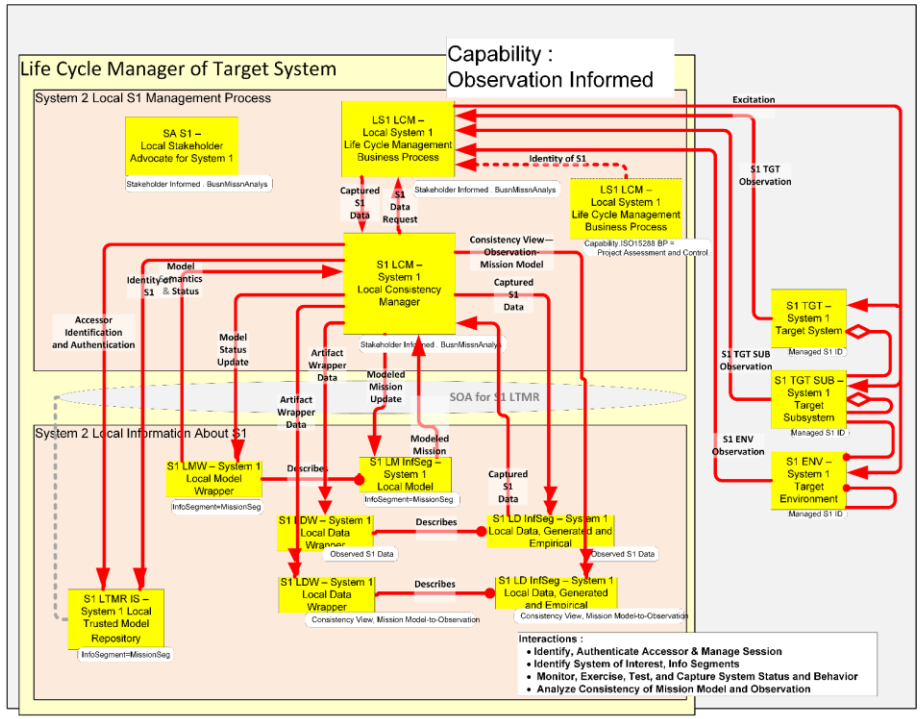
- No assumptions as to specific form of information, use of MBSE models or legacy artifacts, etc.
- However, broad classes of inter-dependent information are denoted, as “segments” of overall information base, neutral as to methodology.
- Descriptive info “wrappers” (metadata) are likewise described, supporting generic information management and risk management, digital threads, and digital twins.

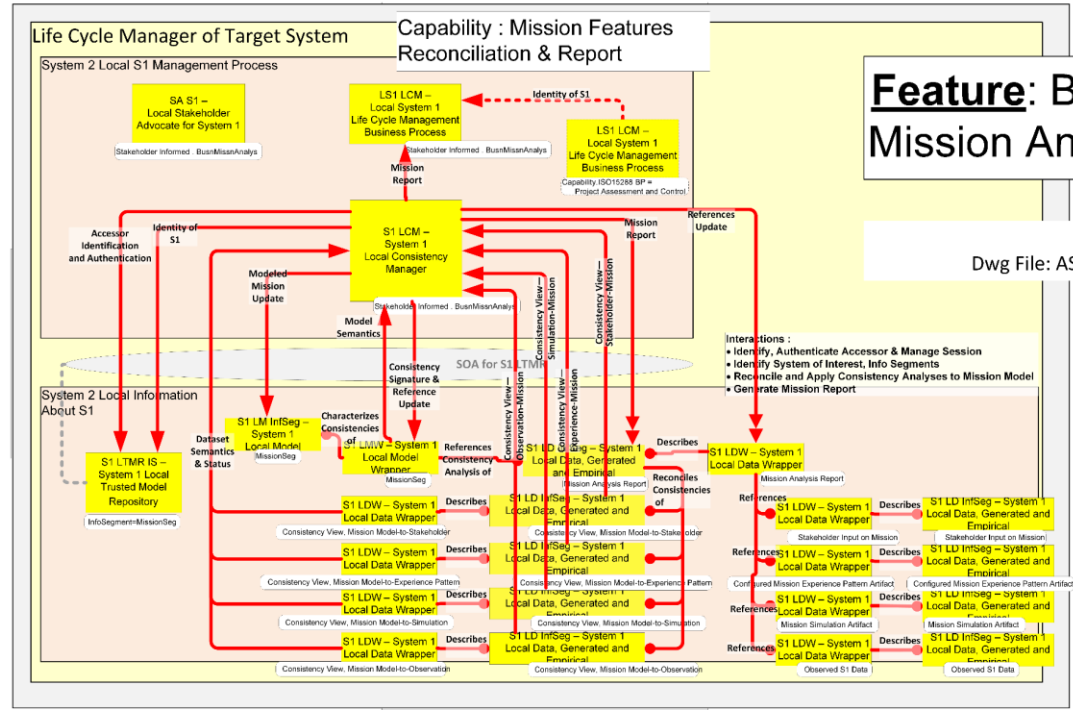












Feature: Business or Mission Analysis

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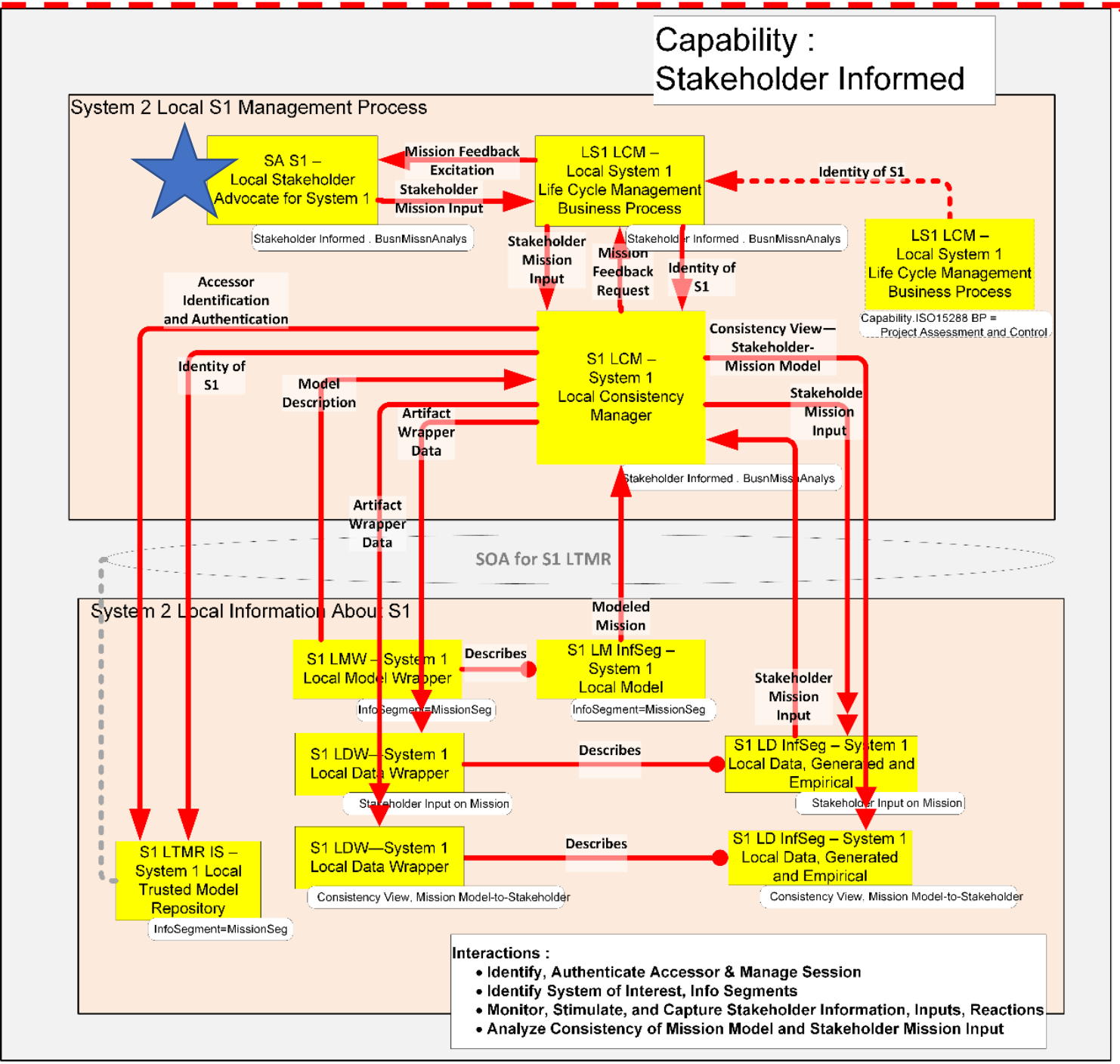
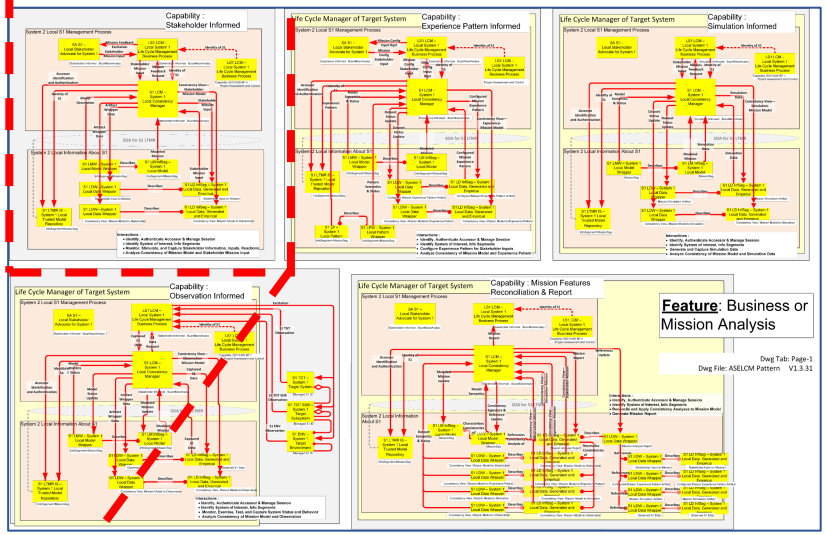
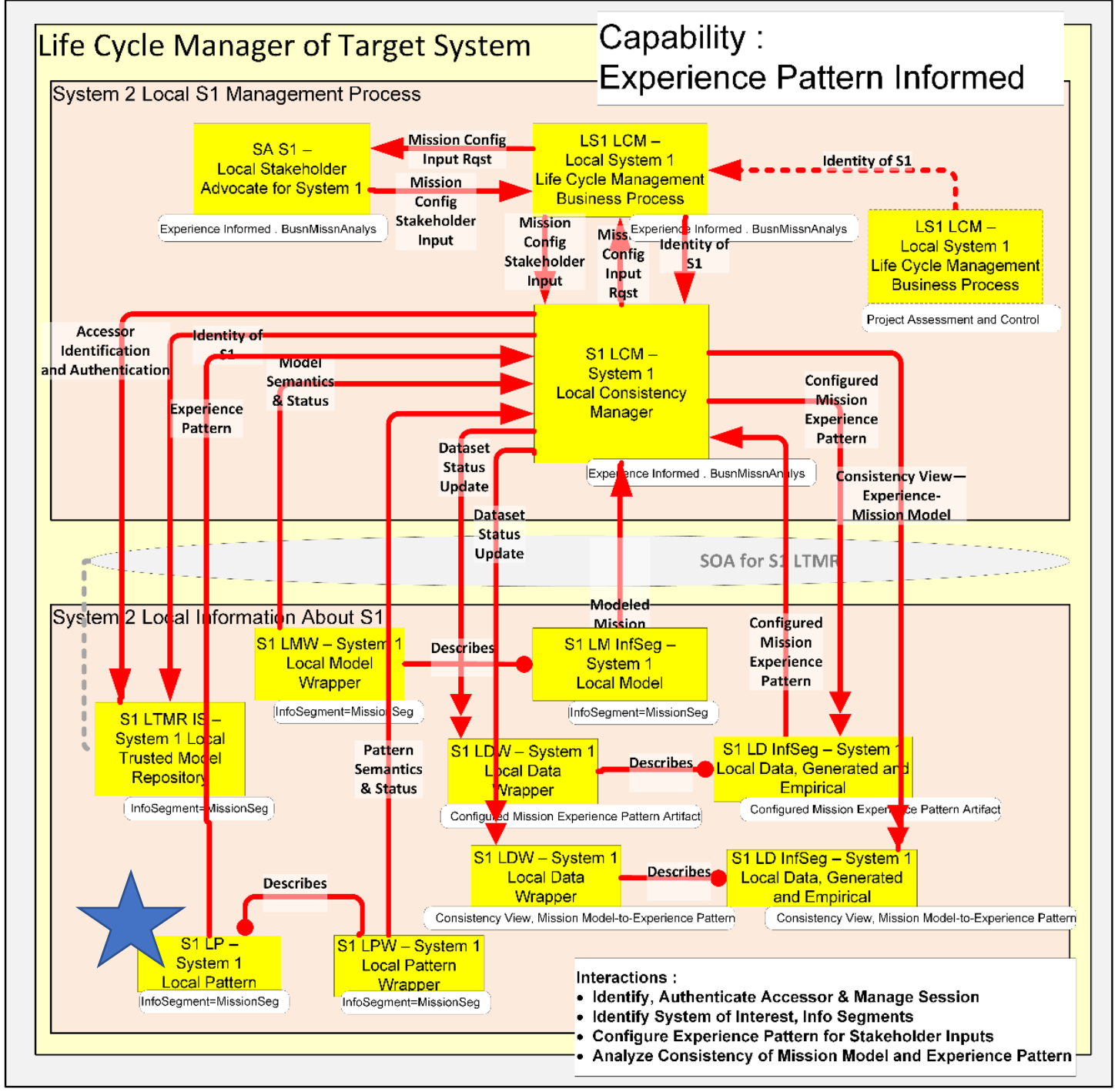


- This Capability includes four interactions of Process roles and Information roles.
- It generates a Dataset-stored consistency view of the modeled Mission versus the Stakeholder Advocate's inputs on Mission.
- Configuring in this Capability populates those roles in the overall Ecosystem.



Overall ASELCM ISO 15288 Feature: Business or Mission Analysis, with five configurable Capabilities.



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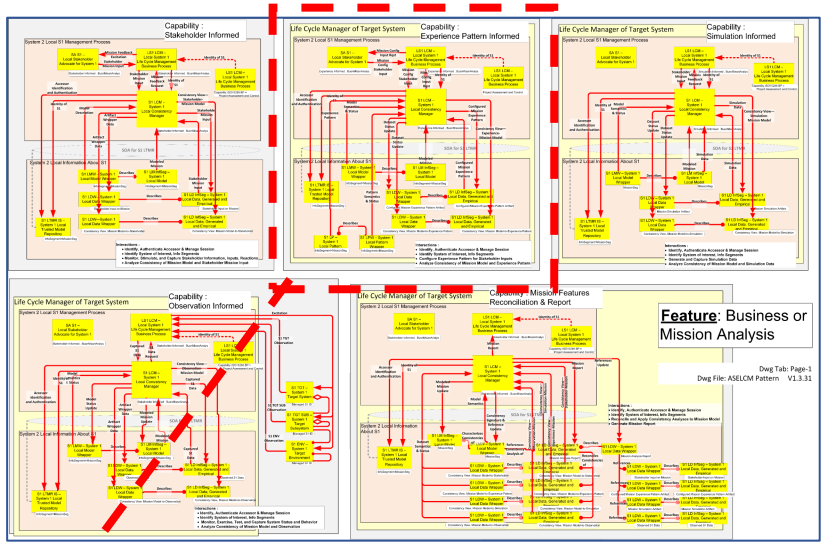

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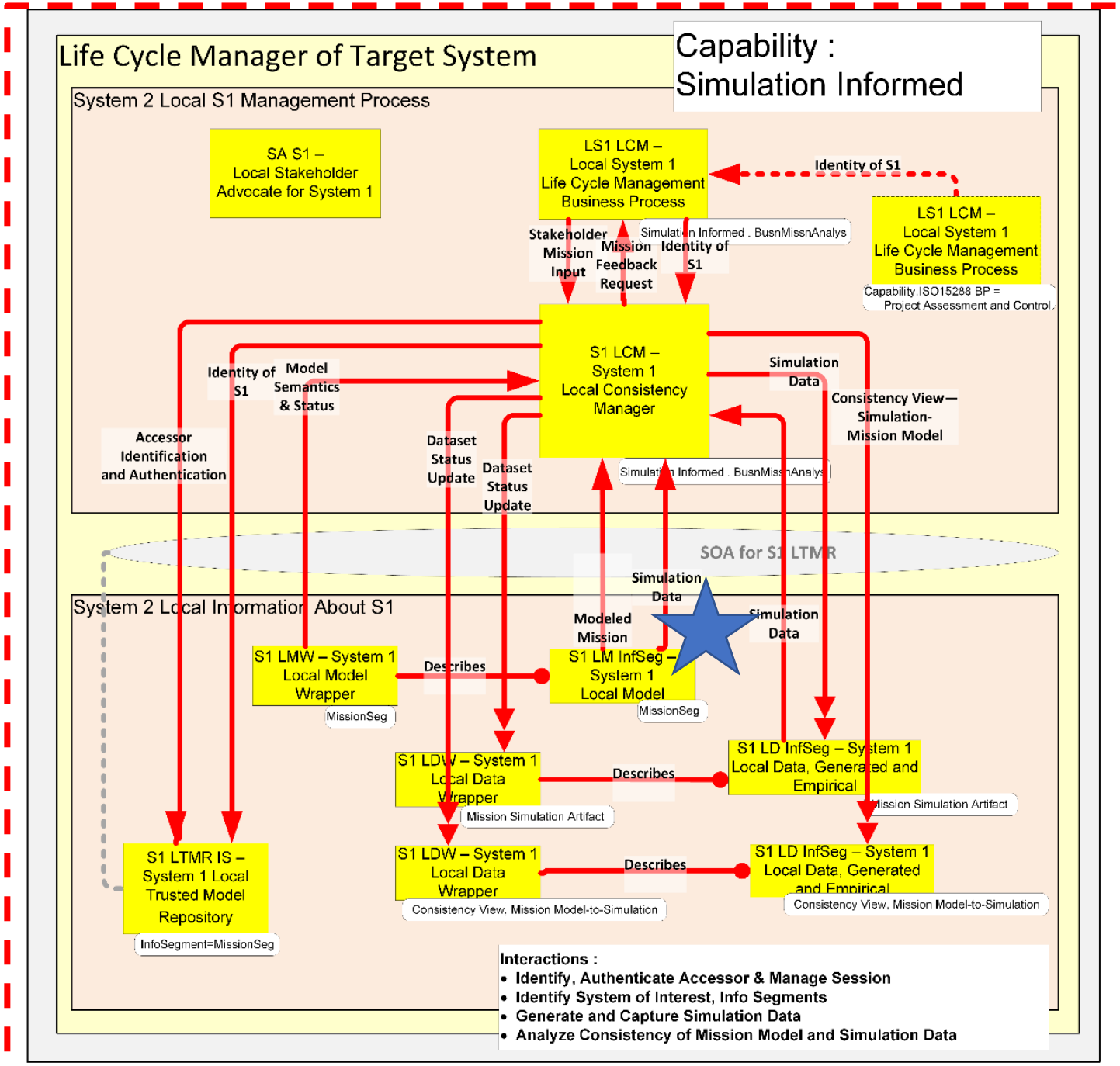

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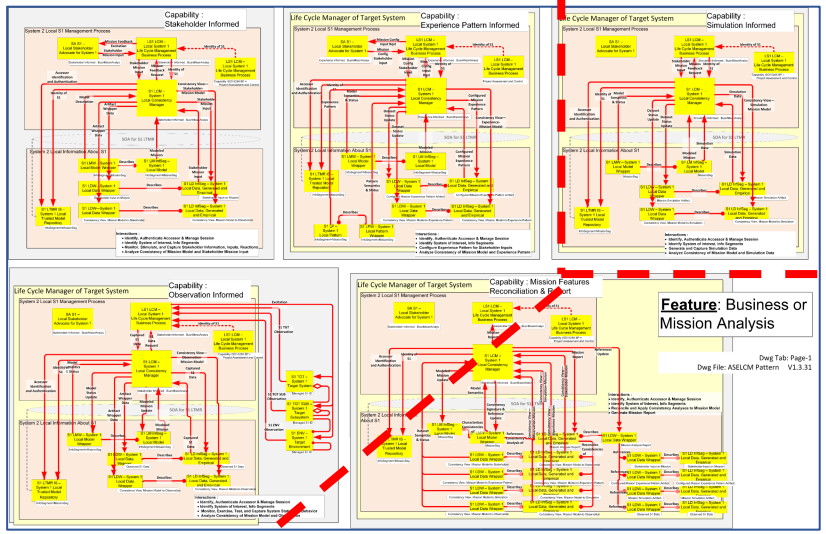

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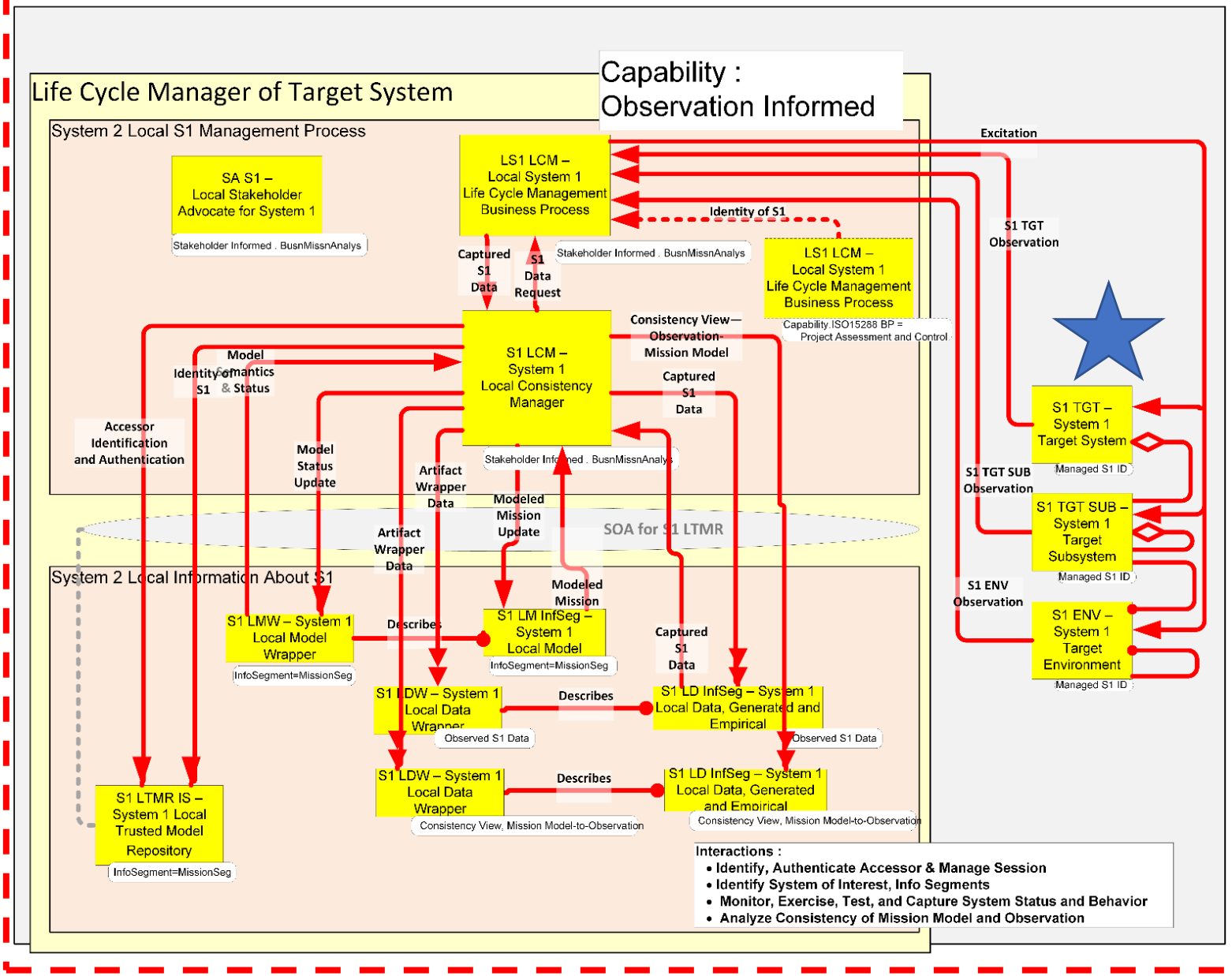

This Capability includes four interactions of Process roles and Information roles.

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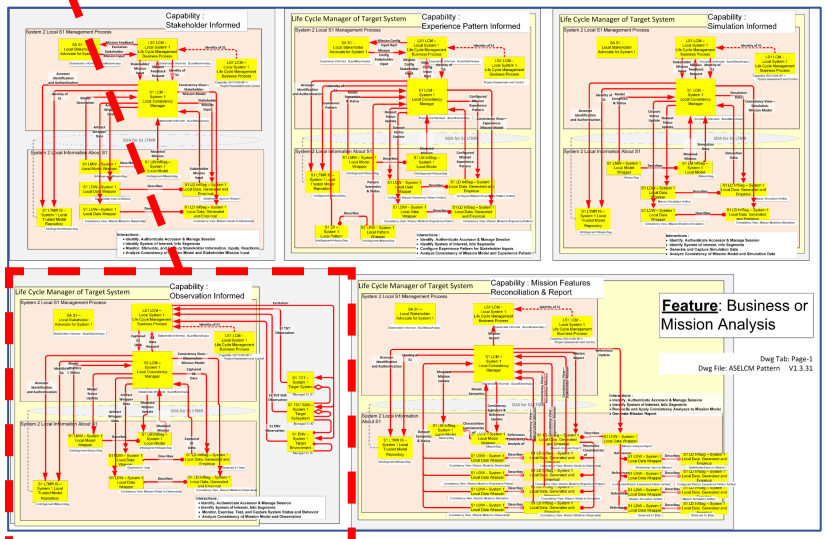

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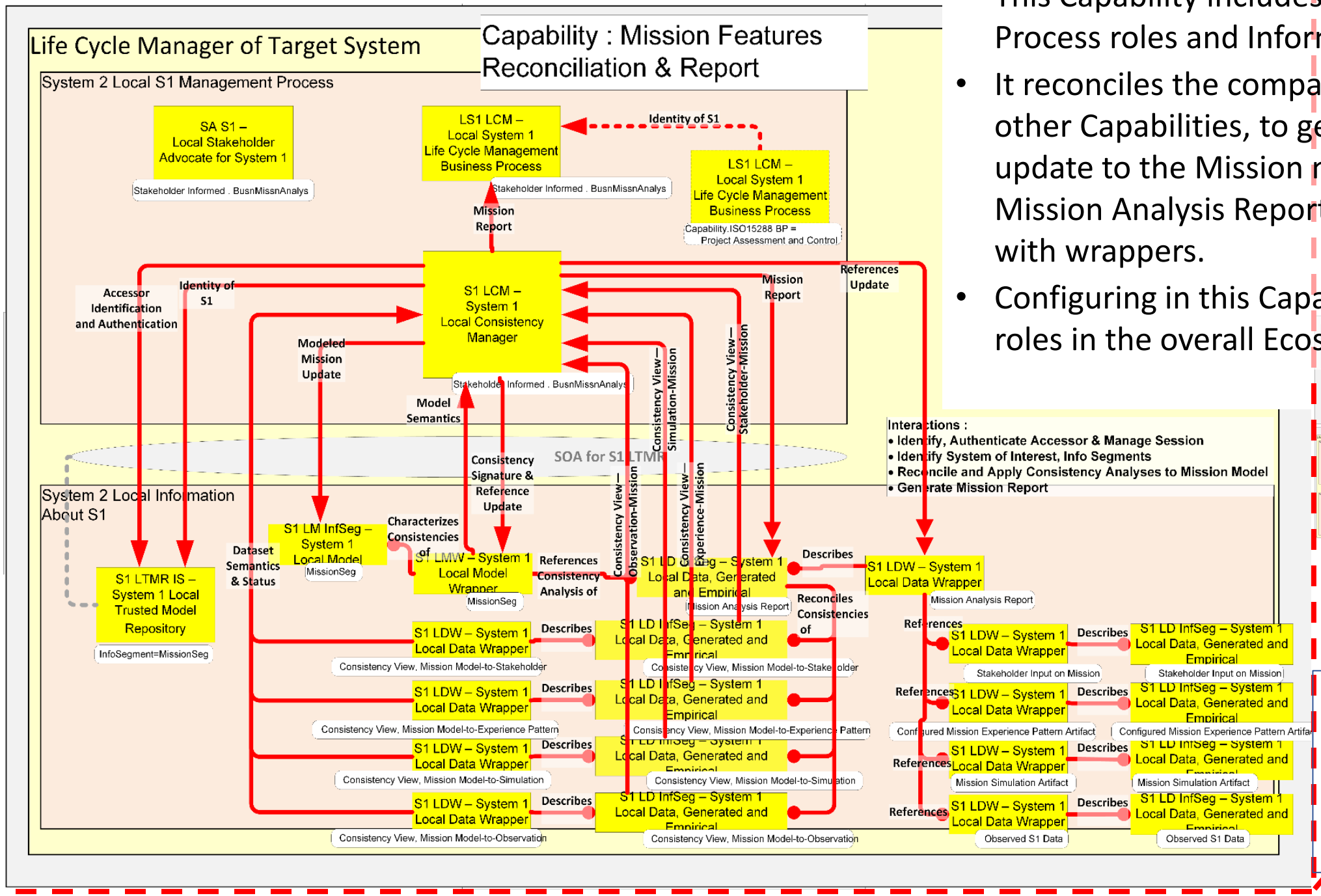

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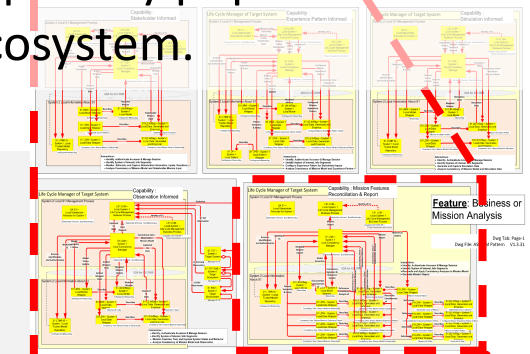

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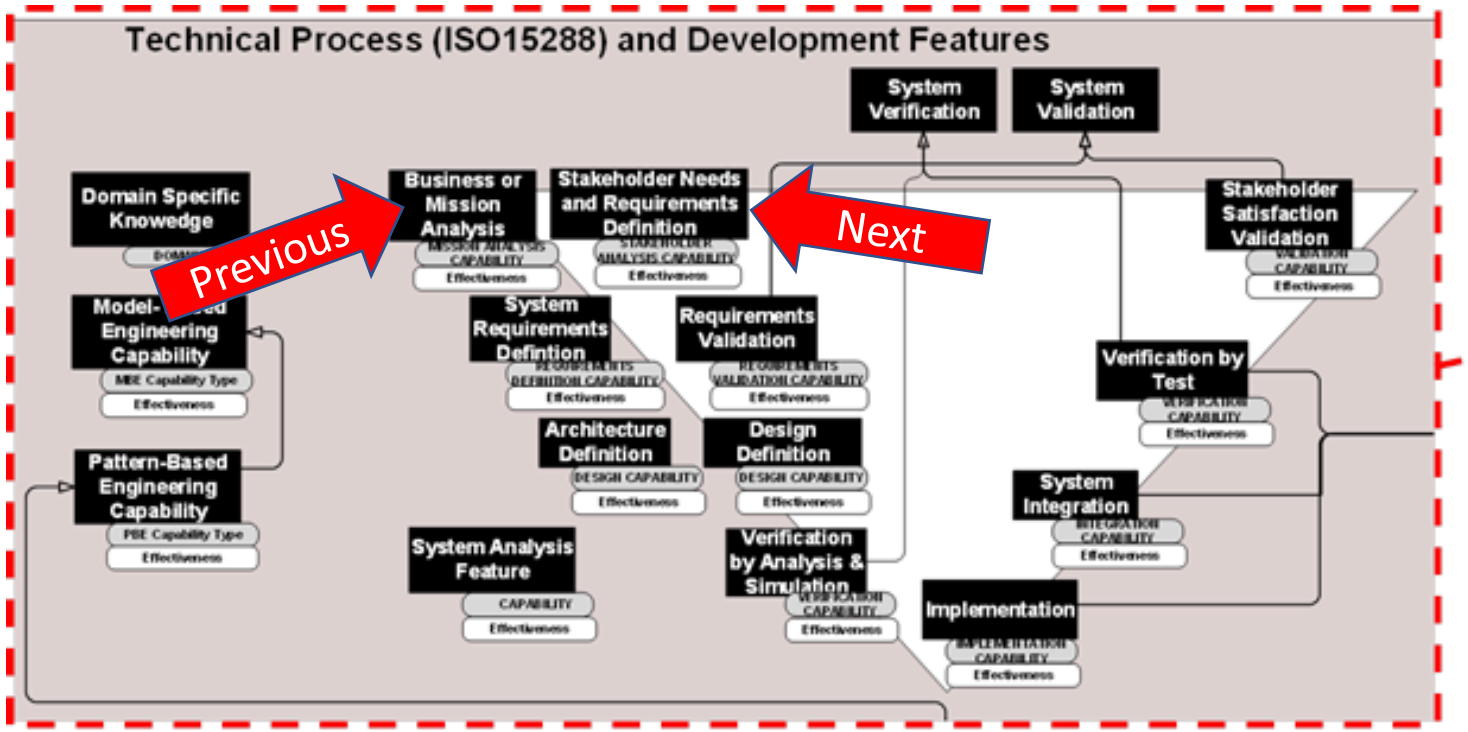
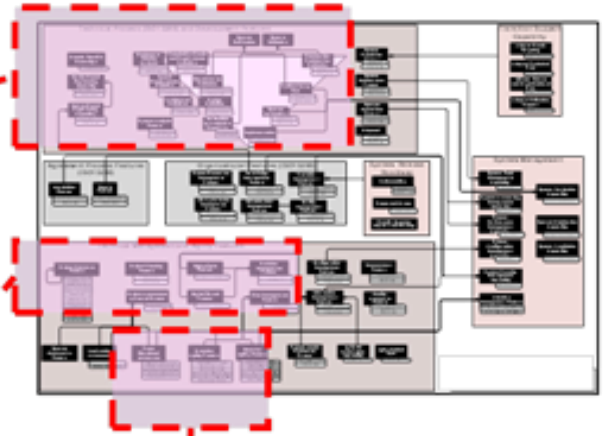
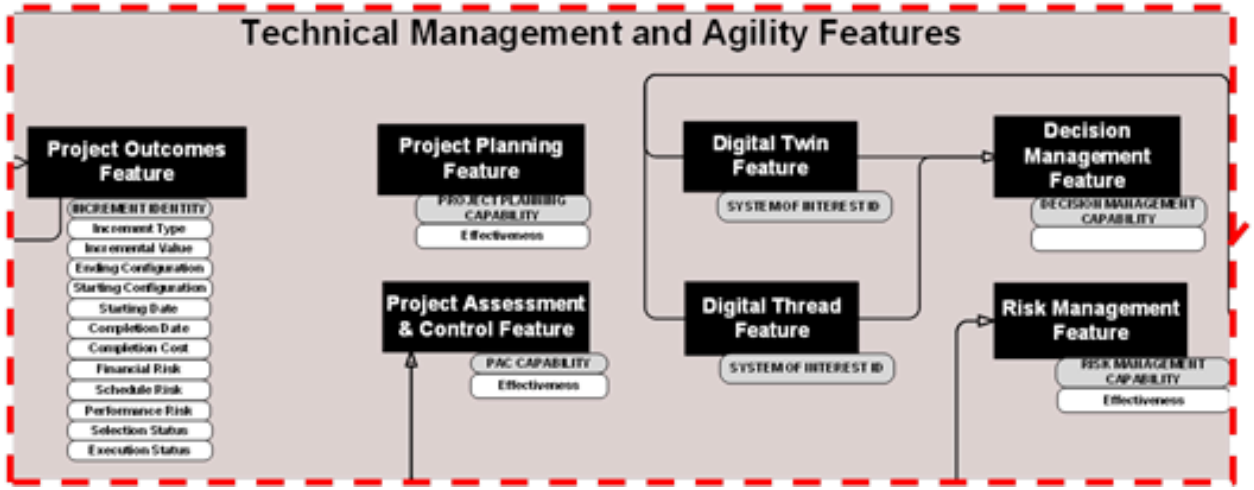
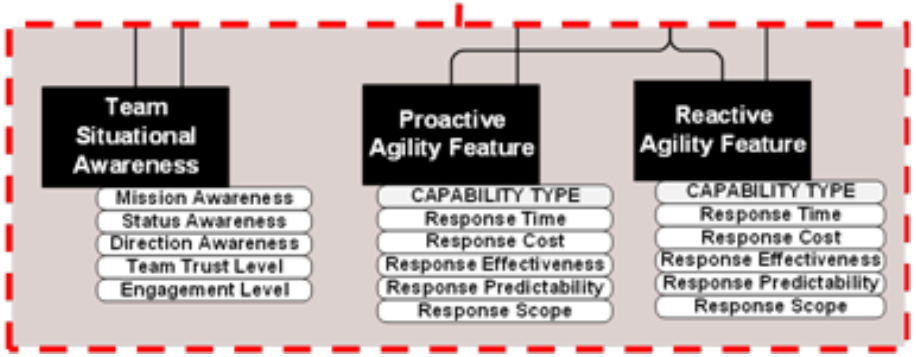
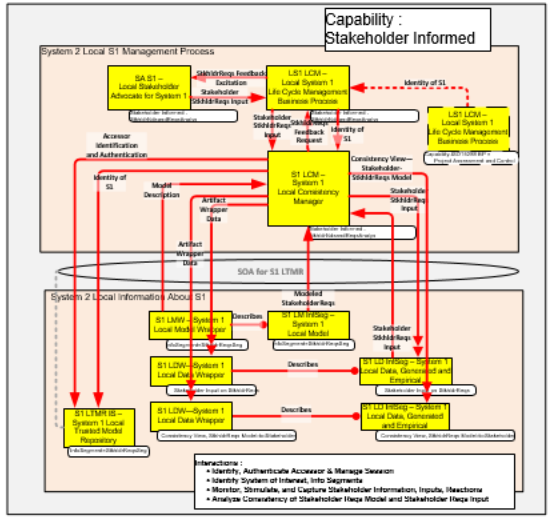


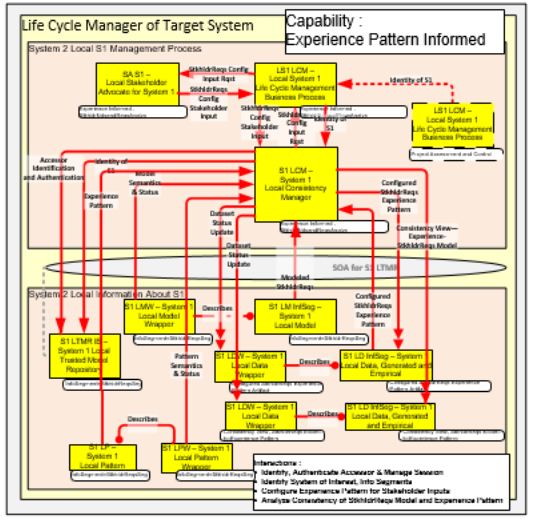


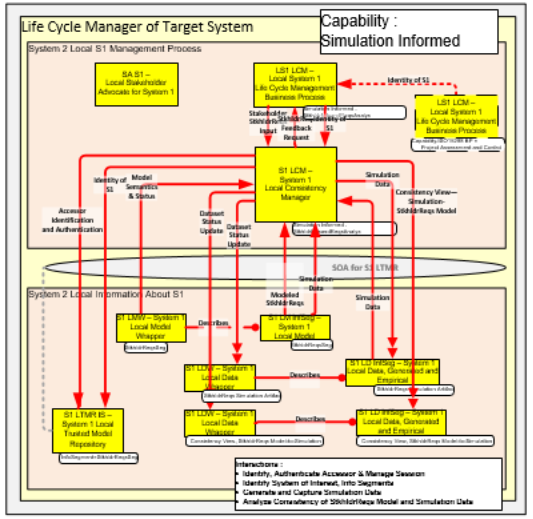


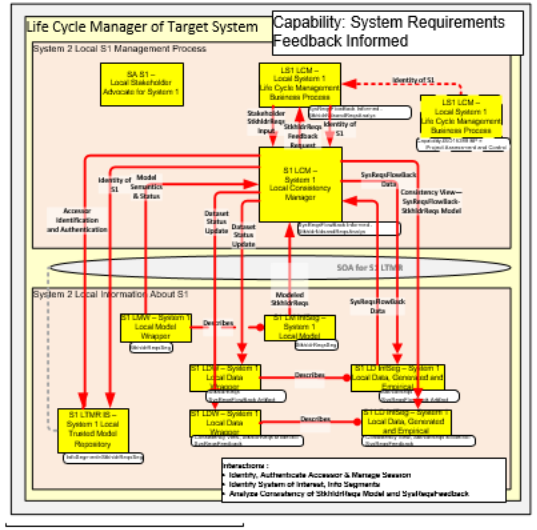


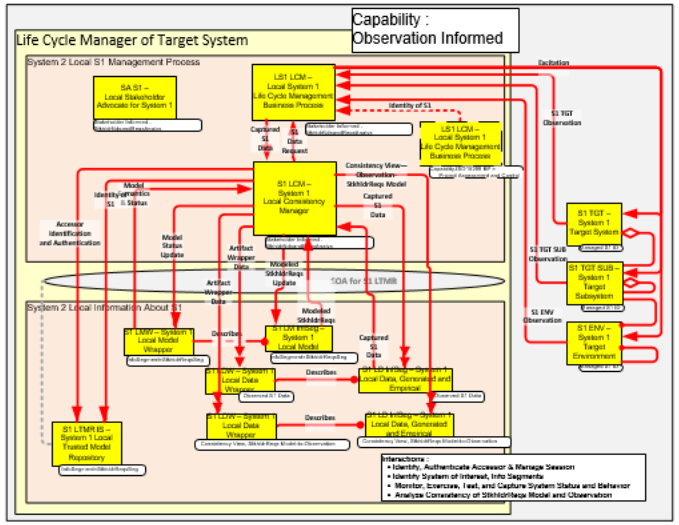
Seven Configurable Capabilities of the Stakeholder Needs and Requirements Definition Feature

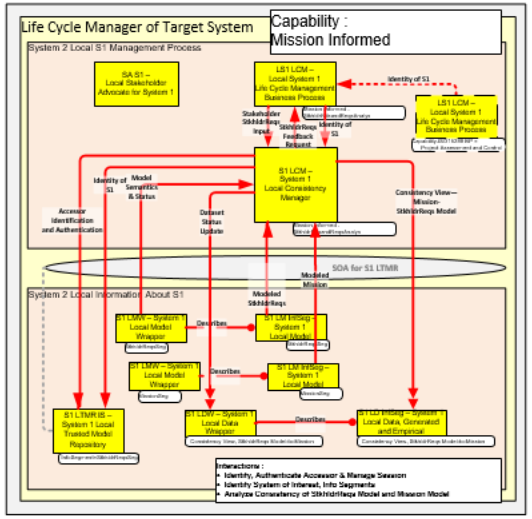


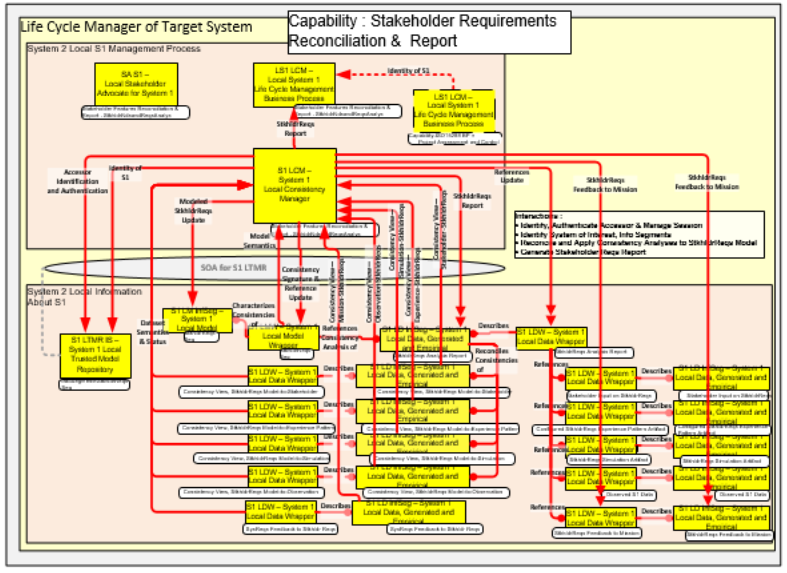


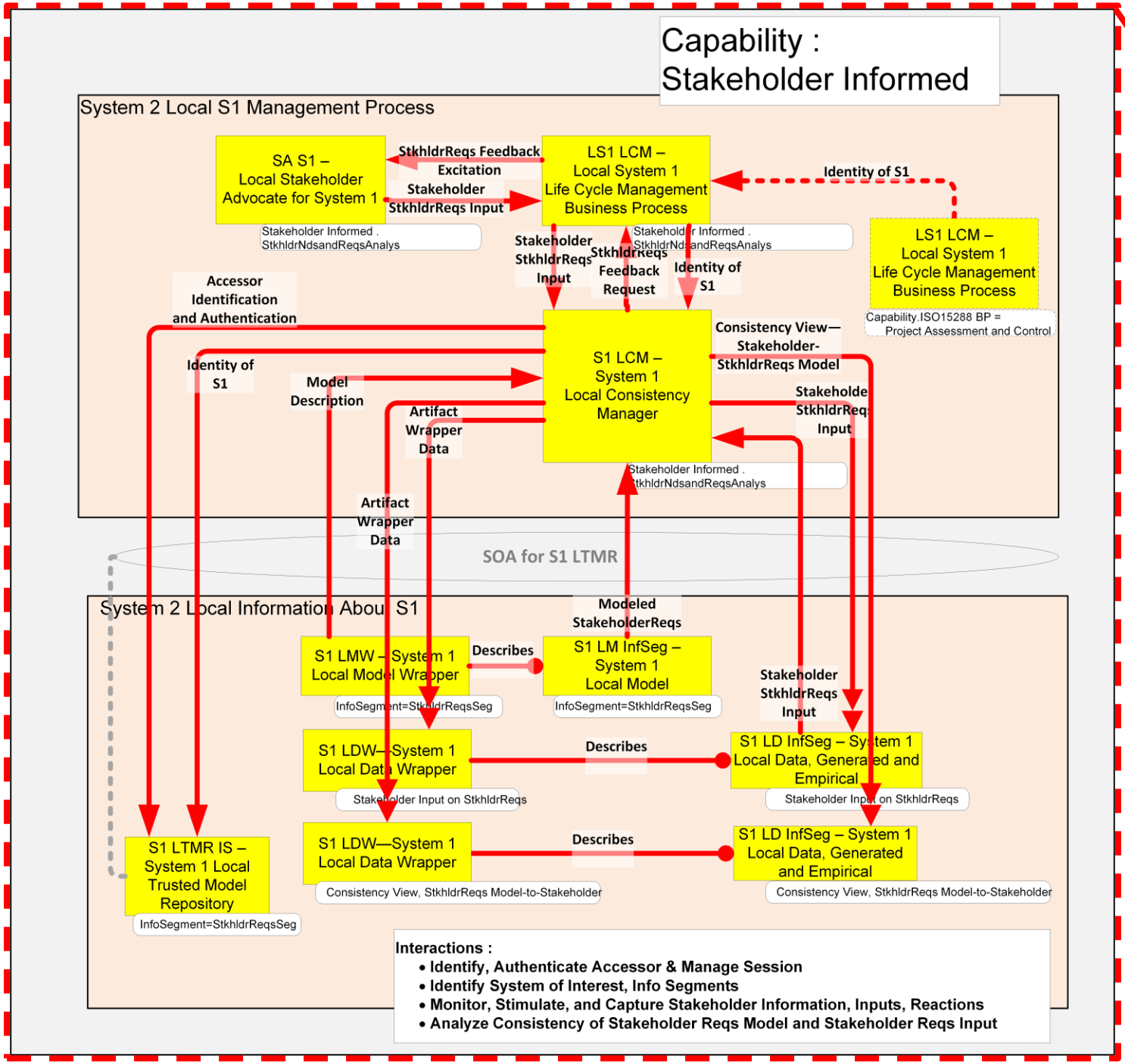












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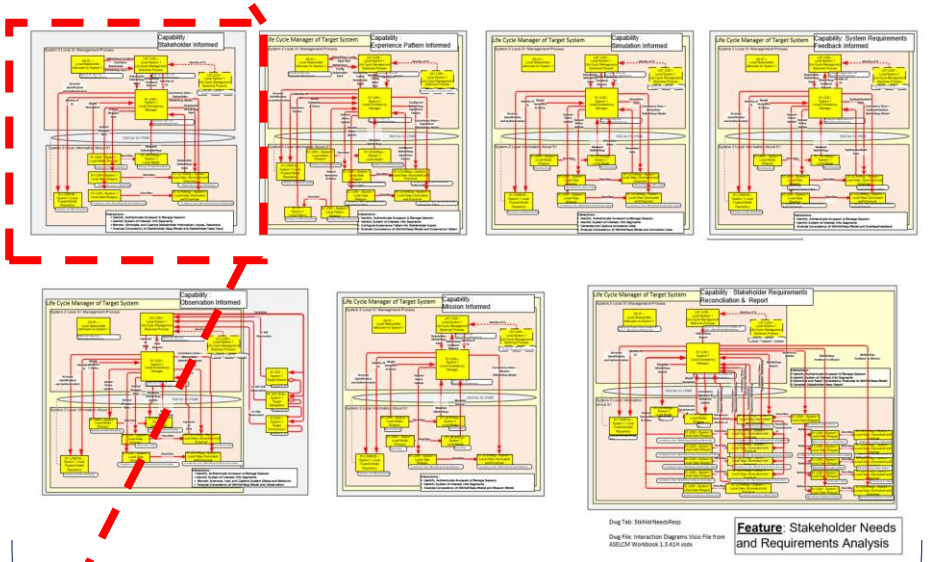
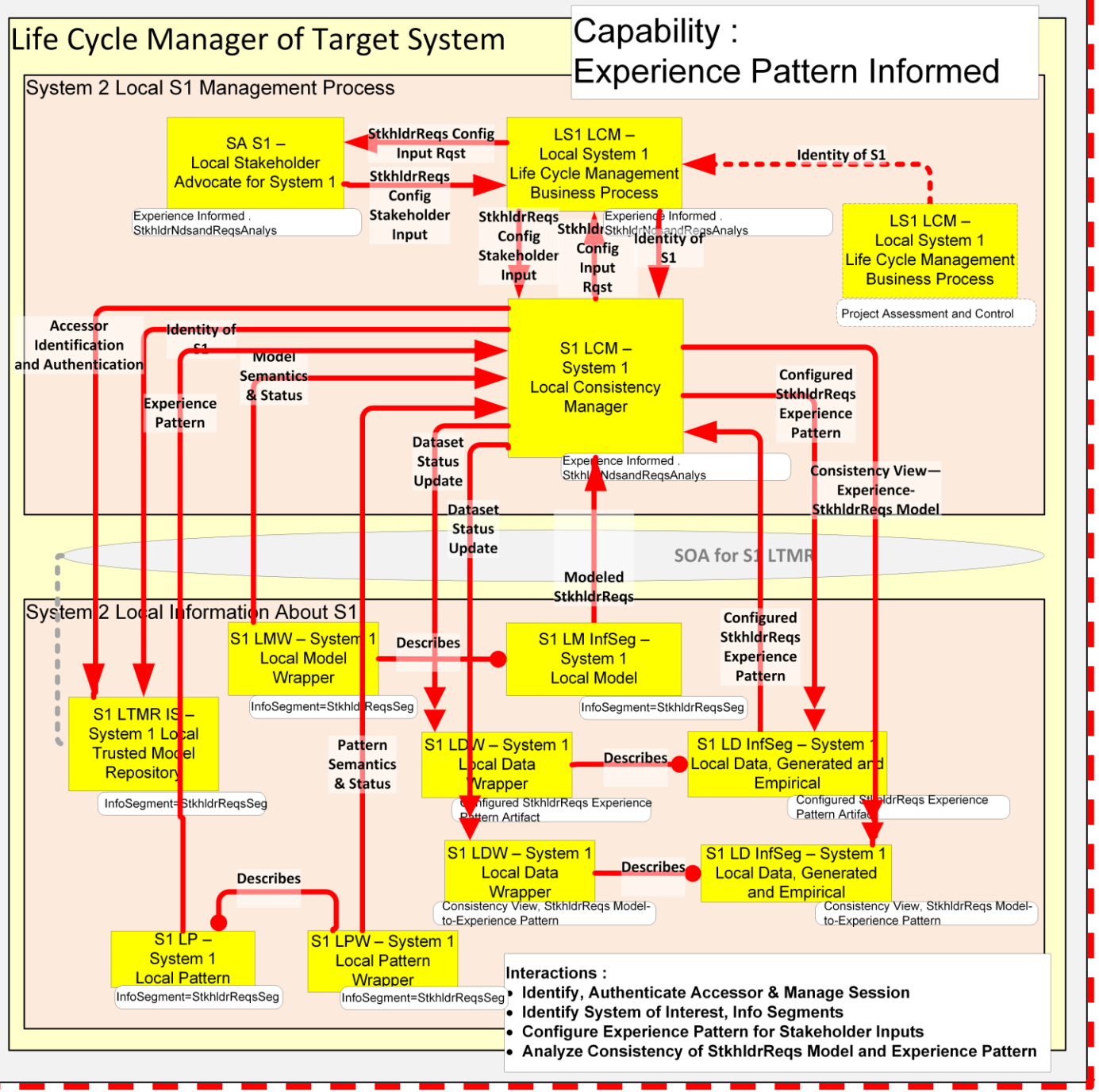


Overall ASELCM ISO 15288 Feature: Stakeholder Needs and Requirements Definition, with seven configurable Capabilities.



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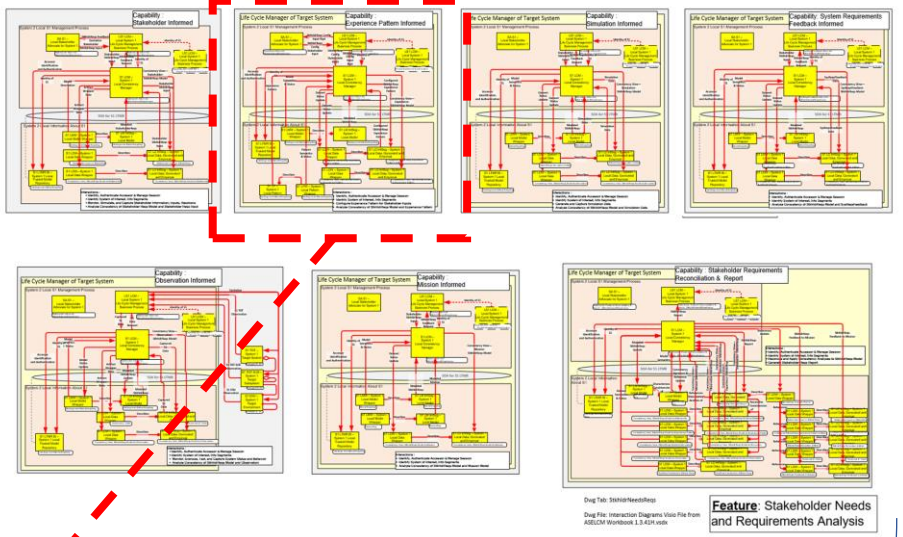

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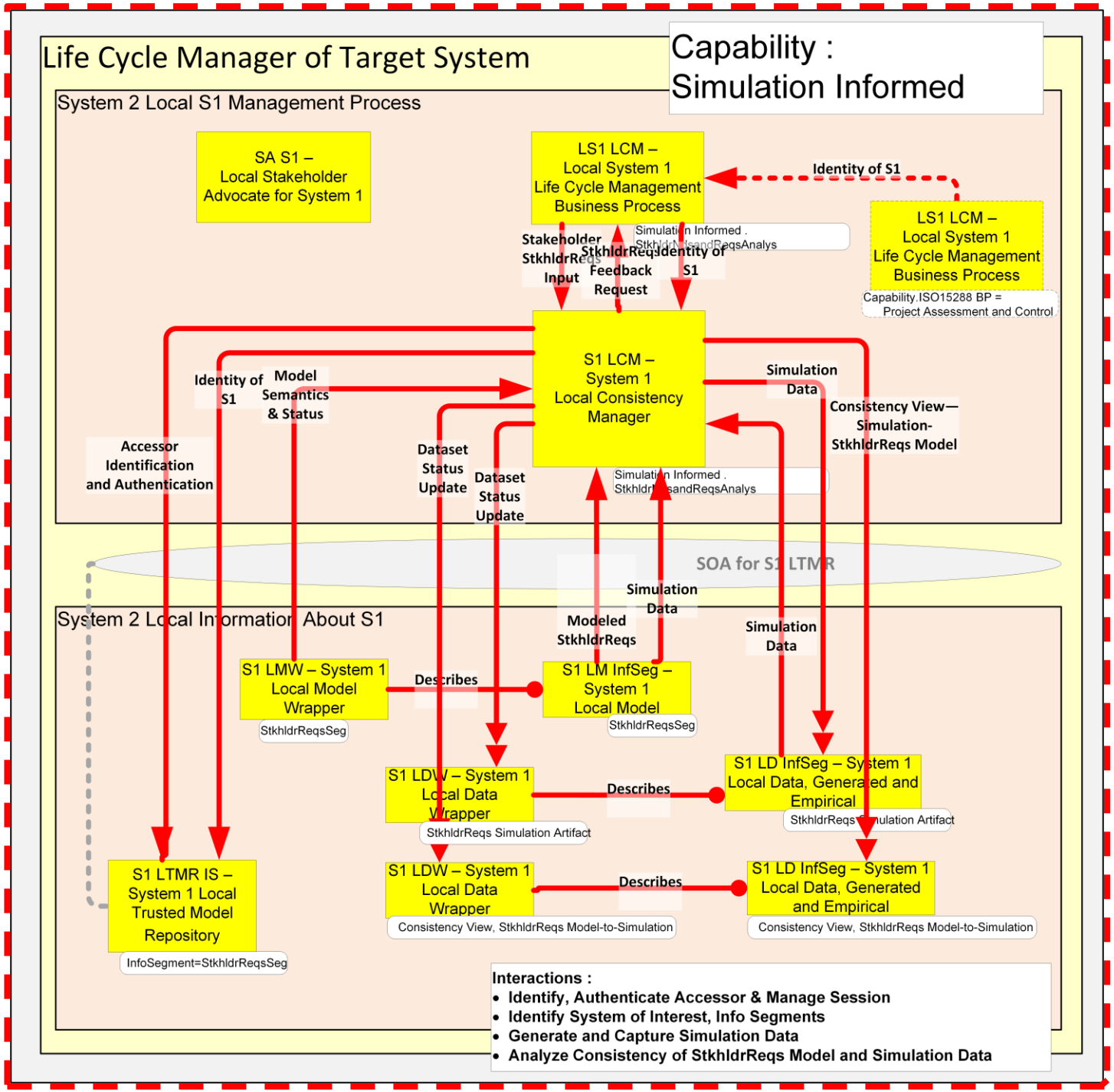

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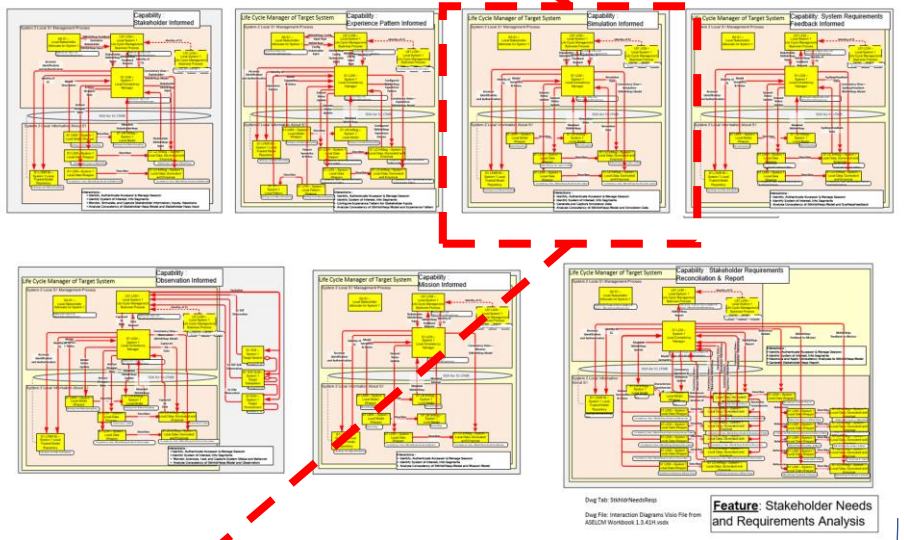

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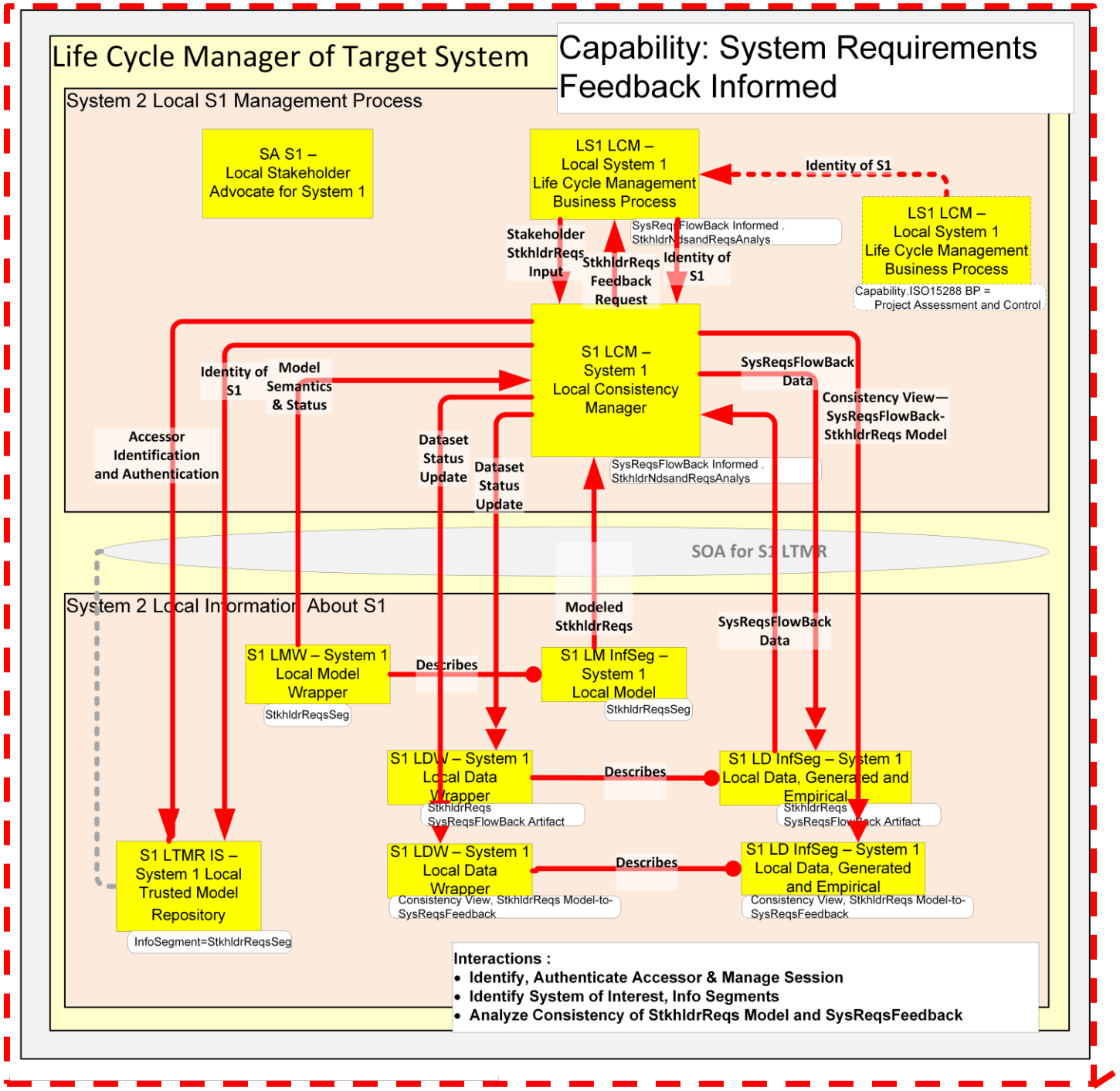

- This Capability includes three interactions of Process roles and Information roles.
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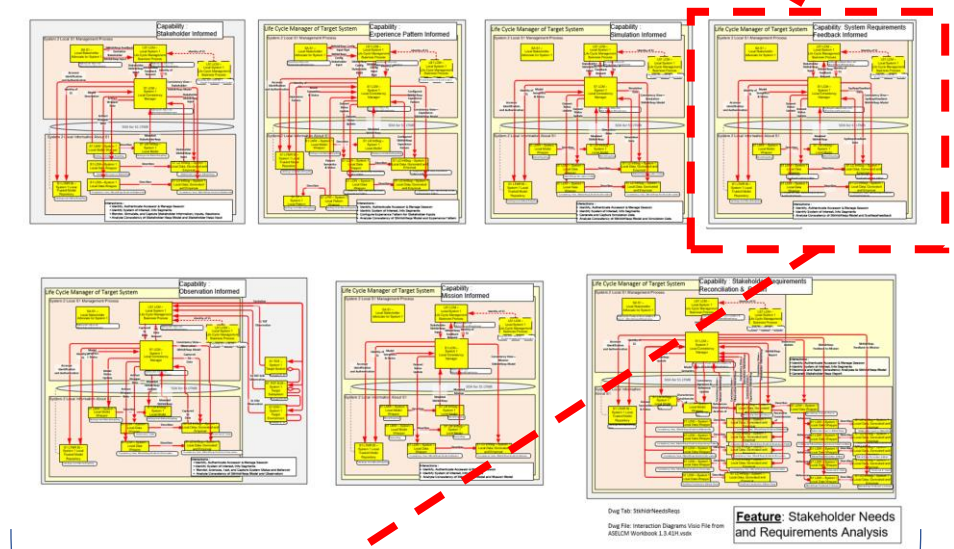

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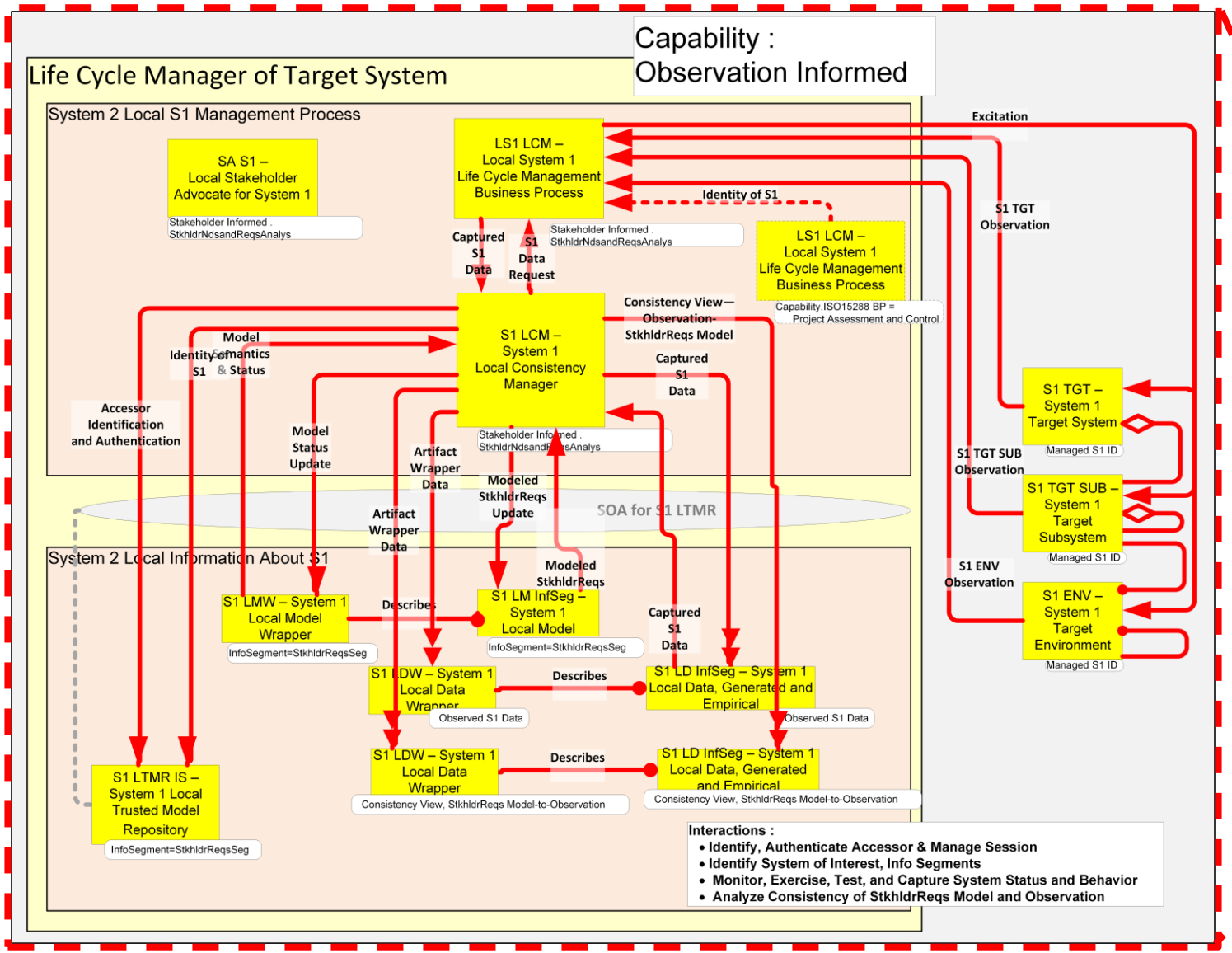

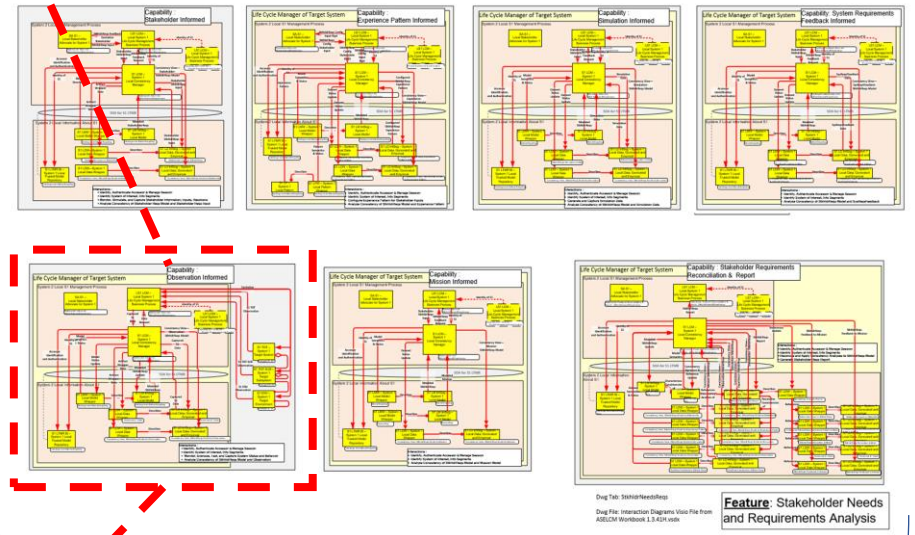

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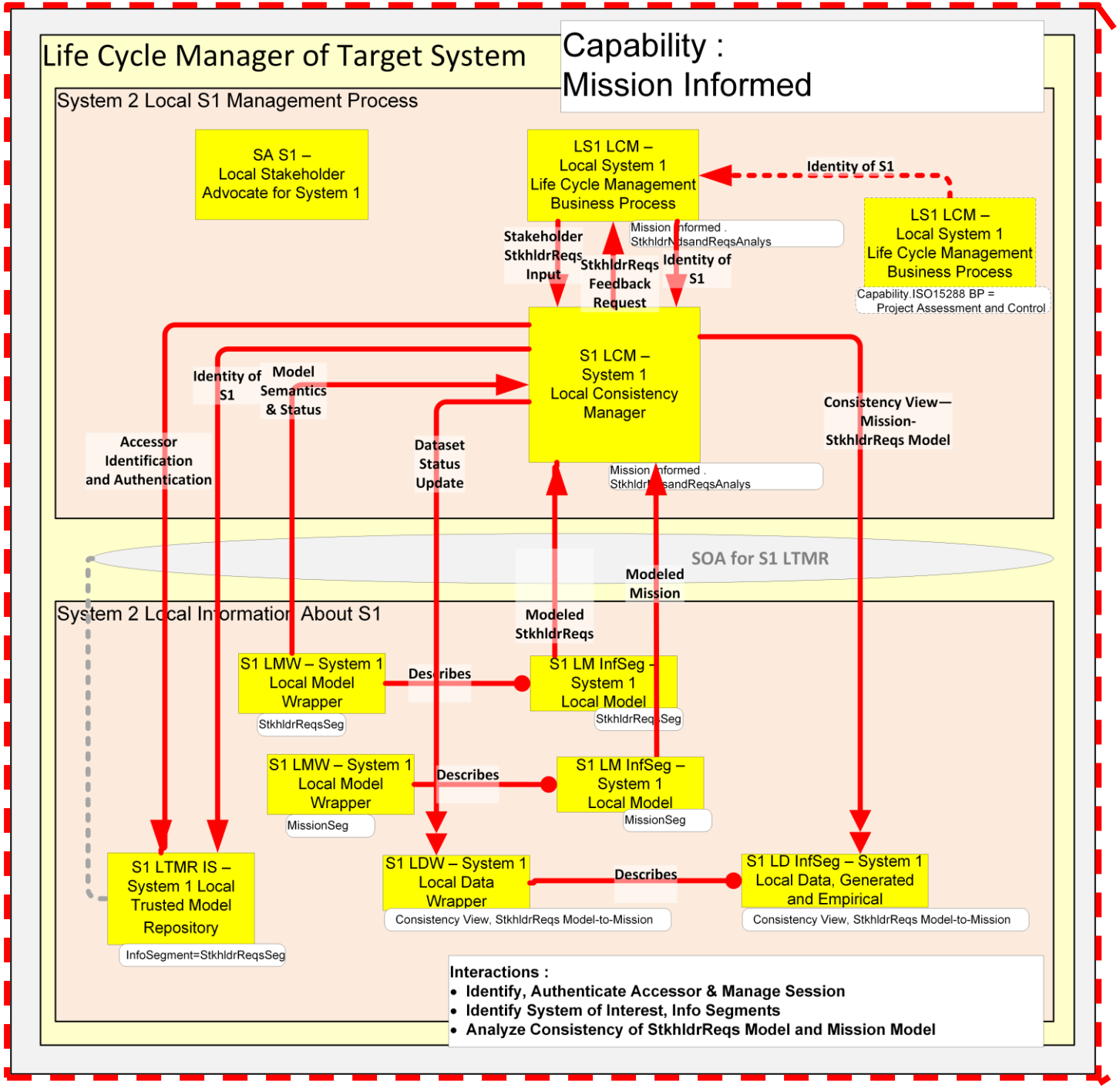

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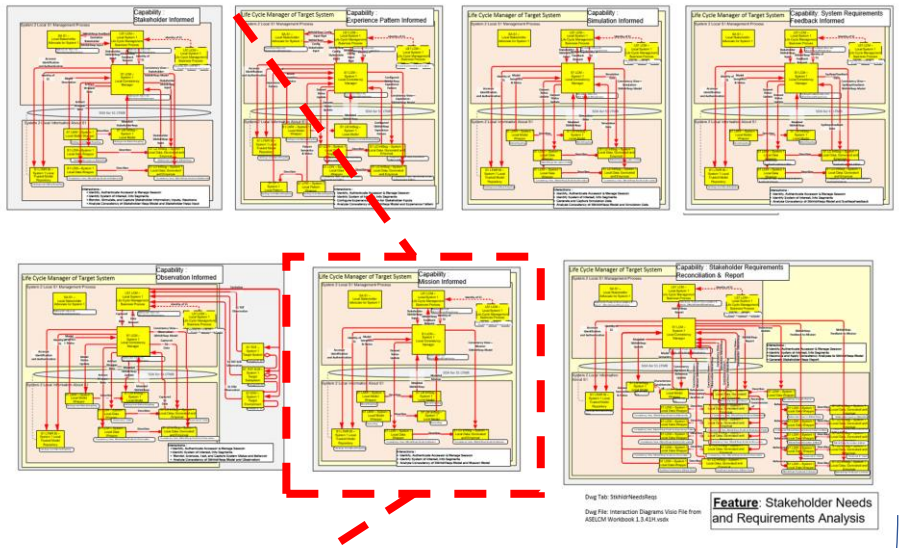

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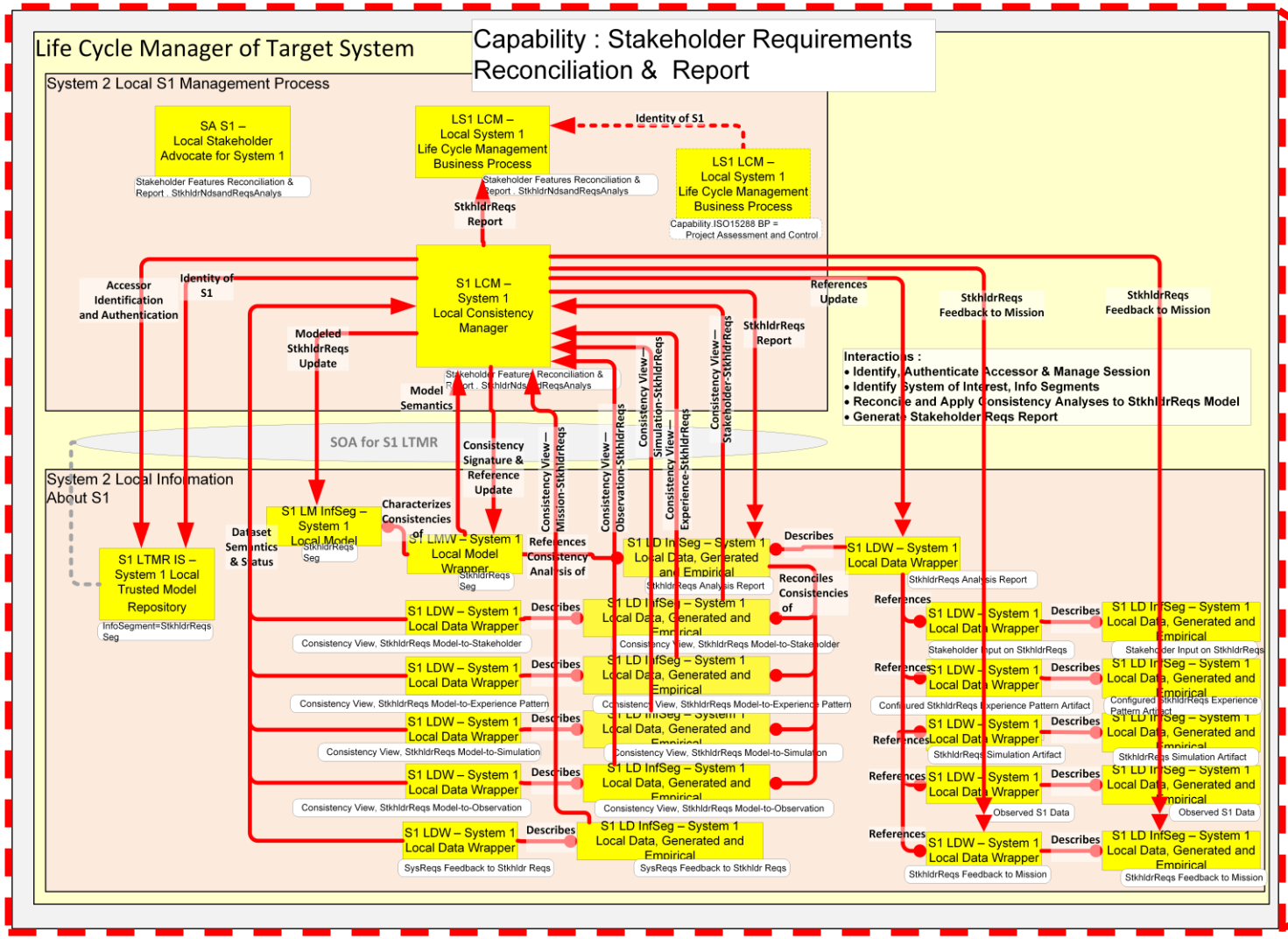
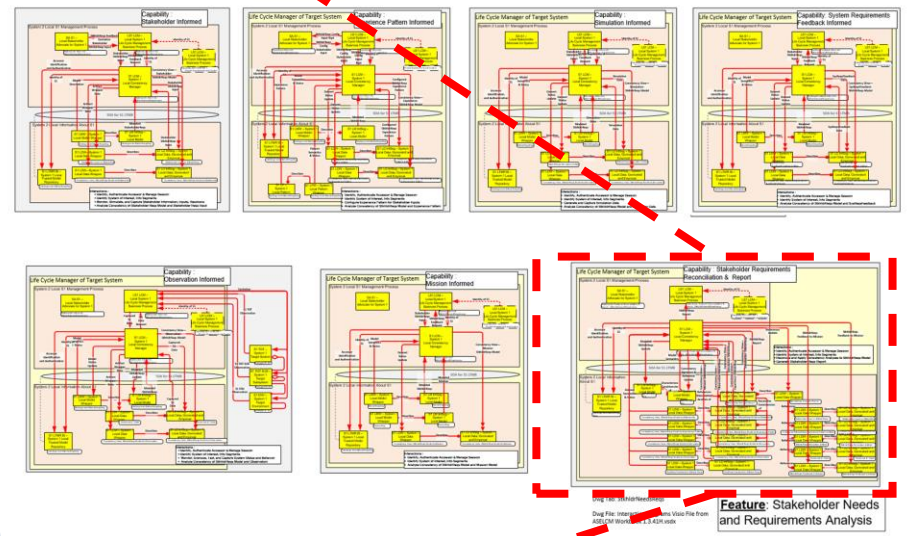
- This Capability includes four interactions of Process roles and Information roles.
- It reconciles the comparisons made by the other Capabilities, to generate a single update to the Stakeholder Requirements model and a single Stakeholder Requirements Report as a Dataset artifact, with wrappers.





Overall ASELCM ISO 15288 Feature: Stake-holder Needs and Requirements Definition, with seven configurable Capabilities.

Attachment 2: Additional aspects worth considering

1. What can we learn from the giants on decision-making?
2. What can we learn from ISO 15288? from the INCOSE SE Handbook?
3. Scope of decisions domain of interest
4. Consistency management paradigm for ISO 15288-oriented decision focus
5. “Deciding” versus coupled adjacent activities
6. Level and uniformity of abstraction level
7. The “Bayesian HUD” paradigm: Decision-essential information, uncertainty, risk, time urgency
8. Learning; the role of recurring patterns; System 1 versus System 2 patterns
9. Negative incentives and non-rational agents
10. The value selection phenomenon, non-linearity and Pareto
11. Information not shared, and other non-cooperative games

1. What can we learn from the giants on decision-making?

- Even though the systems engineer might argue that "Hey, I am just trying to optimize along a numerical value curve, not understand psychology" . . .
- It is hard to imagine a person more associated with the study of decision-making in the commercial world than **Herbert A. Simon** (1916-2001), who won the 1978 Nobel Price in Economic Sciences for his work in **Bounded Rationality**. His subsequent pioneering work in the use of computers and AI at CMU likewise puts him strongly in the space of interest to this work.
- Building on that work in more recent times, **Daniel Kahneman** (1934-) also won the 2002 Nobel Prize in Economic Sciences for his work on related real human behavior, with Amos Tversky. Kahneman's even more recent (2021) publication on "**Noise**" in formalized decision-making provides striking evidence that *we may still misunderstand what is going on, even in formalized decision-making,* and ought to proceed carefully with that in mind.
- It is also hard to imagine a name more associated with understanding these matters in the presence of **uncertainty** than **Thomas Bayes** (1702-1761), who illuminated the path later followed by **Rudolf Kalman** (1930-2016) in explaining how to "perform" best in the presence of uncertainty.
- For a small subset of life cycle decisions (e.g., competitive strategies), we also argue that **game theory** from **John von Neumann** (1903-1957) brings useful perspective.
- So, if we aim to make models of practical decision-analysis / decision-making, it should be with some awareness of the patterns implied by the work of these giants.

2. What can we learn from ISO 15288? From the INCOSE SE Handbook?

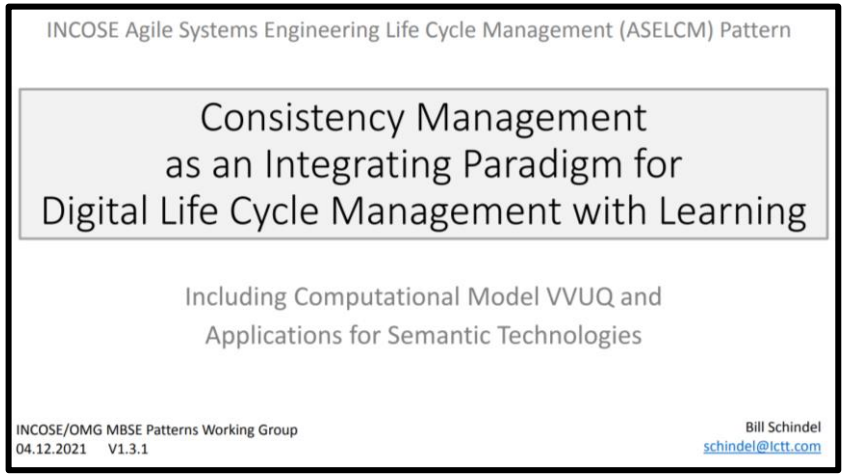
- ISO 15288 (and the companion INCOSE SE Handbook) provide guidance about the Decision Analysis Process, as well as its coupling with other life cycle management processes.
- For this INCOSE effort, it would appear important to pay close attention to what ISO 15288 and the SE Handbook have to say about the subject, . . . even if we disagree with some aspect.

3. Scope of decisions domain of interest

- Given that this work is by and for the INCOSE systems engineering community, it can be argued that the scope of decisions of interest to this work should be that set of decisions which are made *about and across the life cycle of systems*:
  - We risk making the problem too hard if we assume it should be about "making decisions in general". (Should I accept this job offer? Should I move to Atlanta? Get married? . . .)
  - We risk providing INCOSE membership with insufficient value if we assume it should only be about a tiny subset of that life cycle range of decisions—such as only decisions about design. Just as important are earlier and later aspects of life cycle management—for example, in manufacturing, use of field data, understanding the customer, etc.
  - By selecting exactly the set of decisions that occur about and across the life cycle of systems, we have the best opportunity to characterize just what those systems are, the patterns into which they fall, etc. . . . And aligning with ISO 15288, the INCOSE Handbook, and the INCOSE systems community.

4. Consistency management paradigm for ISO 15288-oriented decision focus

- The Consistency Management Paradigm of the Ecosystem Pattern shows us how to view all the traditional processes across the entire system life cycle as instances of managing “consistencies” between information segments.
- From this perspective, all the related decisions across that life cycle fit into the “consistency management” framework, and become decisions about consistency--referred to as “reconciliations”.
- This strongly suggests the underlying pattern for decisions across the life cycle.



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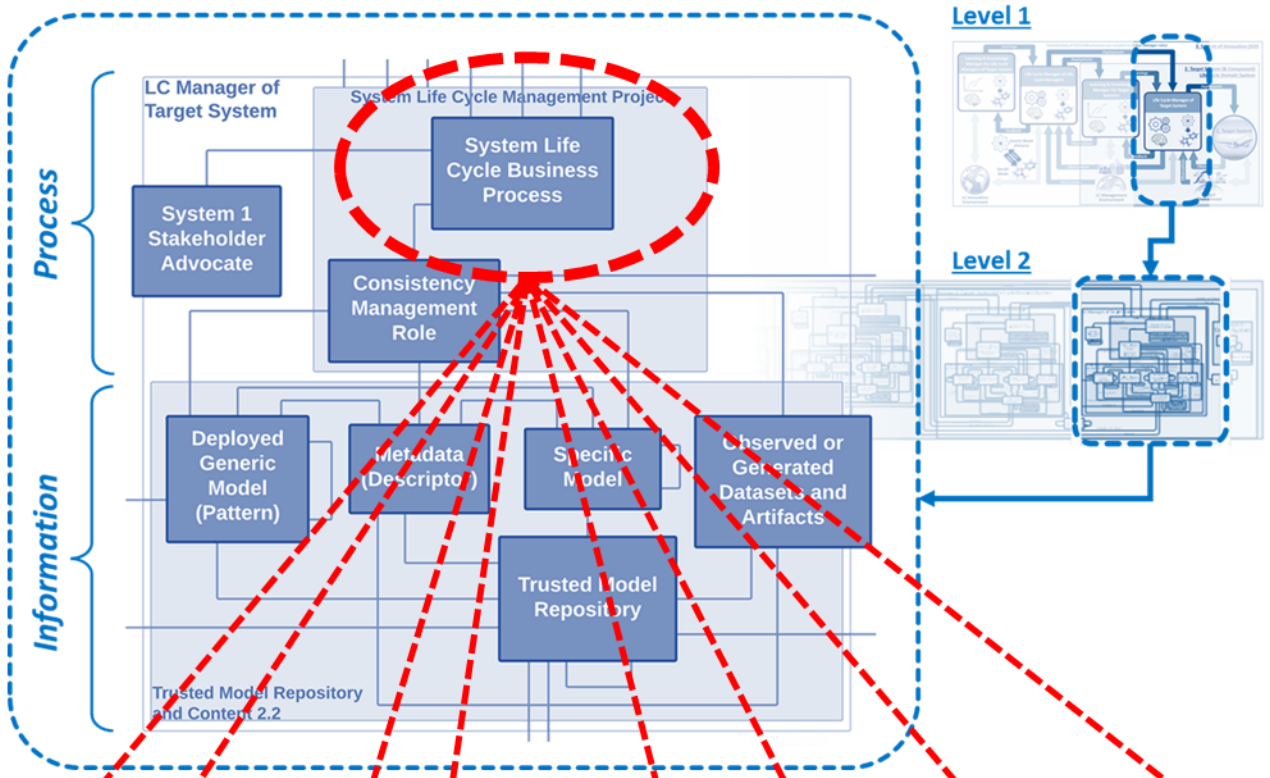
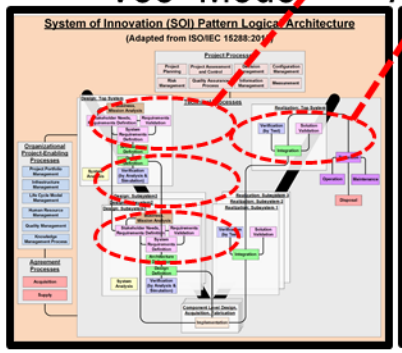
From the ASELCM Innovation Ecosystem Pattern



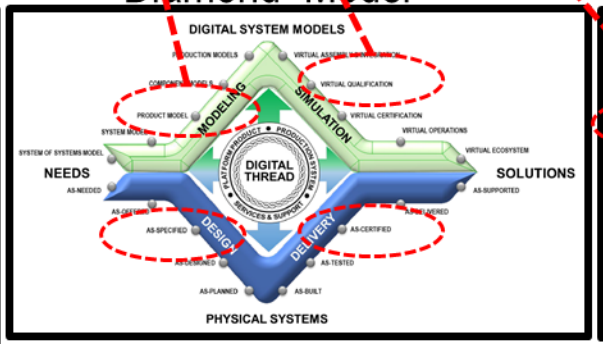
Configurable to specific life cycle management models---

ISO15288 Life Cycle "Vee" Model[1]

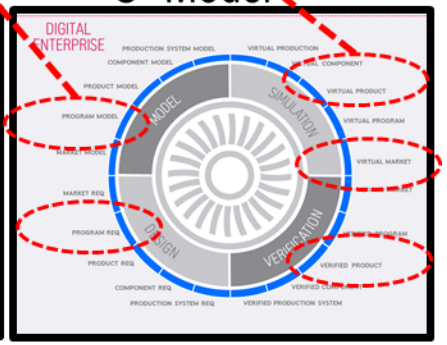


DoD 5000 Defense Acquisition Life Cycle Model[2]

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

5. “Deciding” versus coupled adjacent activities

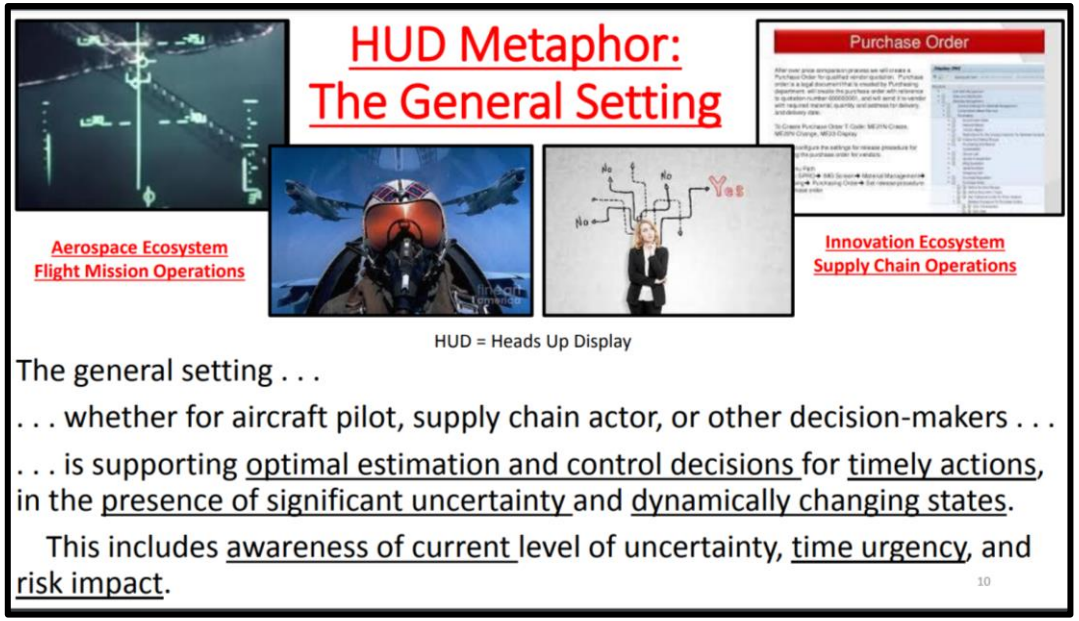
- Some of the “decision *management*” aspects of ISO15288, the SE Handbook, etc., are not about making decisions, but instead about managing the assembly of needed decisions, information required, effectively communicating decisions to those who must implement or accept them, etc.
- This is especially because those other activities “adjacent” to the making of the decision itself can fail in the real world, with the result that good decisions are nevertheless compromised.
- So, it is important to understand what the scope of the “decision” pattern will be, concerning those related activities.
- And, even if the choice is to be very narrow, it will still be necessary to describe how the part being focused on is to be effectively coupled to the adjacent parts.

6. Level and uniformity of abstraction level

- If a pattern or patterns are created for support of decision-making across some range of domains, there is benefit in keeping the level of abstraction relatively uniform across that range.
- For example, if the pattern includes a data model for use across all the life cycle domains, but the data model appears to be specific to design-related decision data, then we don’t really have the asset we thought we had.
- The same idea applies to patterns describing process.
- See also (4) Consistency Management Paradigm, above.

7. The "Bayesian HUD" paradigm: Decision-essential information, uncertainty, risk, and time urgency

- Not only is certain "essential information" required for each such decision, but it is very common for there to be related uncertainty about that information, risk of the impacts of wrong decisions, and time urgency to make a decision.
- These ingredients have been shown to fit together in the pattern of the "Bayesian HUD" (Heads Up Display), in the context of life cycle management:



https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:team_top_gun_idn_presentation_06.09.2021_v2.1.1.pdf

The HUD concept appears in military aircraft—1960's-70's

- The first operational American combat aircraft to get a fully instrumented Heads Up Display (HUD) as it is conceptually understood today was the A7 Corsair.
- The author served as an A7 systems engineer for the team integrating the computer algorithms (nav and weapons, incorporating Kalman filter Bayesian estimation) and HUD on that program, in the late 1960's – early 1970's.
- The general HUD concept was to allow the pilot to keep attention on the external environment, providing timely, dynamic information overlays upon, of limited information focused on current and projected (using models, estimators) situation. (Today would be called Augmented Reality.)
- The following lists key aspects of the purpose, nature, and characteristic of the HUD concept in a (potentially) analogous manufacturing digital thread setting.

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

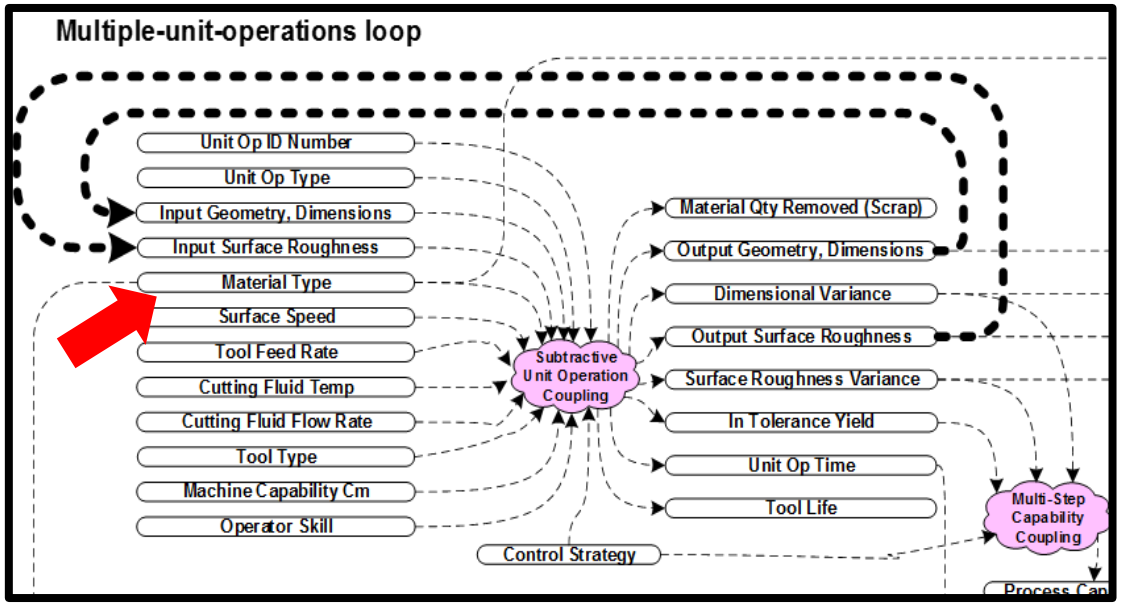
TASK	PROGRESS	START	END
Gate 2	100%		
Gage / Fixture Design Review	100%	2/23/2021	2/23/2021
Release Gage / Fixture Design	100%	2/24/2021	2/24/2021
Review Material Quotes	100%	2/19/2021	2/22/2021
Order Sample Material	100%	2/22/2021	3/5/2021
Order Gage Material Stock List	100%	2/22/2021	3/5/2021
Gage / 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

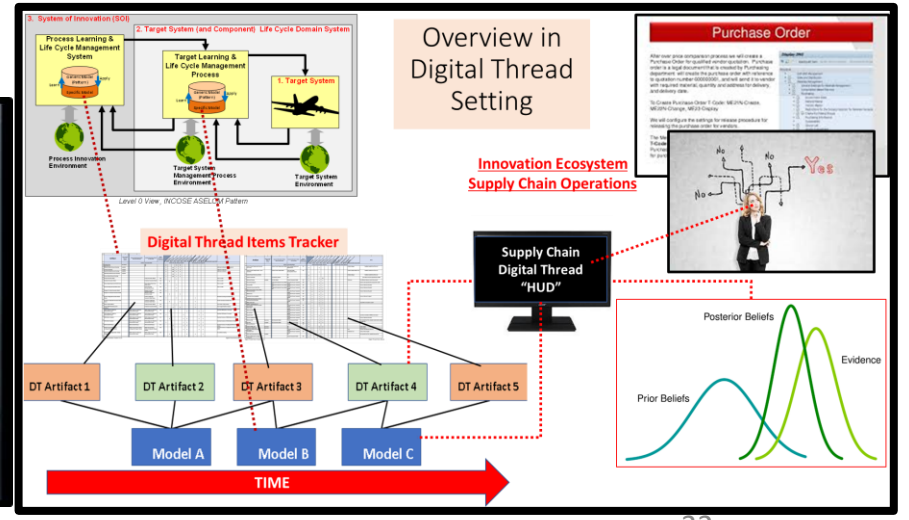
Feb 8, 2021 | Feb 15, 2021 | Feb 22, 2021 | Mar 1, 2021 | Mar 8, 2021

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			



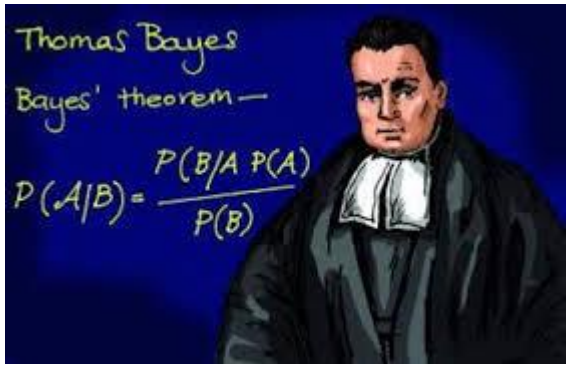


Relating the two analogous situations

Concept	Aircraft HUD Case	Supply Chain Manufacturing Digital Thread Case
Supported mission	Navigation to / execution of weapon delivery	Collaboration of multi-enterprise supply chain, to engineer, qualify, and manufacture system products and components
Persons, roles	Aircraft pilot (also navigator in some cases)	Project manager in each enterprise
Multi-party	Not typical, until advent of AWACS et al	OEM, SMM, separate overlapping digital threads
Overlaid background	Partial visible situation, as terrain, terrain objects, terrain actors, sky, sky actors, as visual or radar	Current project state, as PERT / GANTT / CPM (probably PERT in most complex case, else GANTT)
Information overlay	Attention flags, predicted weapons aiming or release point, uncertainties vs ‘lock”, current attitude and course vs. desired	Attention flags, predicted decision and action steps, what is missing (e.g., information) to enable them, conditional uncertainty interval widths; addition of supply chain partner information.
Time frame / scale	Seconds, minutes, hours (mission)	Days, weeks, months (project)
Update rate	Sub-second	Hourly, daily, or slower (opportunity here for improvement over current performance)
Prediction	Bayesian conditional estimation (Kalman Filter) of nav and weapon delivery	Bayesian conditional estimation (KF, BNN, or other suitable)

The Math, Tools, and People

R. E. Kalman, 1930-2016,
winner of IEEE Medal of Honor,
US National Medal of Science



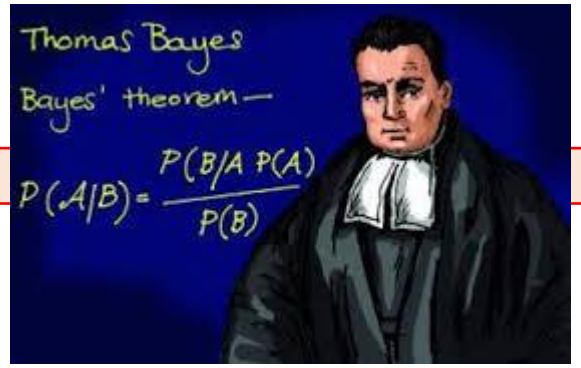
Rev. Thomas Bayes, 1701-1761,
Bayes Theorem,
Conditional Probability

Judea Pearl, 1936-present,
winner of the Turing Prize in
Computer Science

- This general problem has been very successfully attacked, leading to some of the 20th Century's greatest applied engineering triumphs, including navigation to & landing on the Moon in 1969, and a wide variety of modern communication systems including cell phones and deep space exploration.
- The general mathematical setting is Bayesian Estimation, concerned with prediction/estimation in the presence of uncertainty and noisy information.

The Math, Tools & People

Kalman Filters



Bayesian Networks

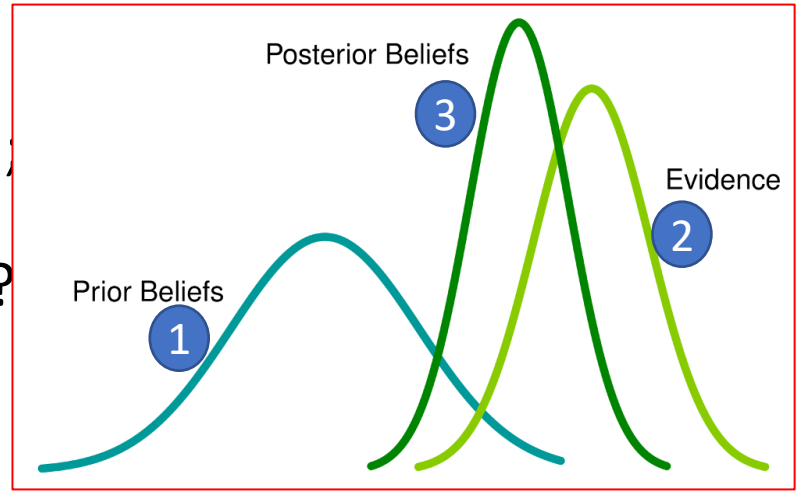
R. E. Kalman, 1930-2016, winner of IEEE Medal of Honor, US National Medal of Science

Rev. Thomas Bayes, 1701-1761, Bayes Theorem, Conditional Probability

Judea Pearl, 1936-present, winner of the Turing Prize in Computer Science

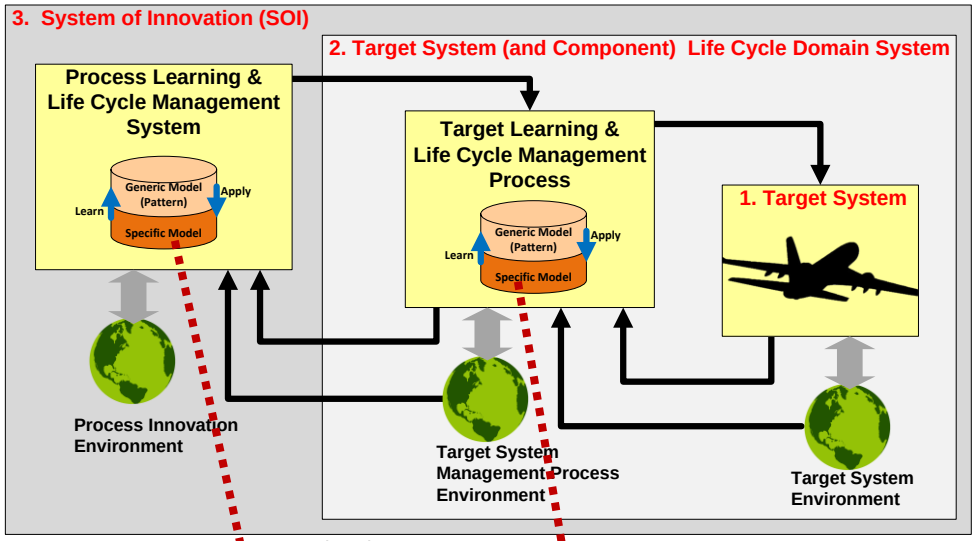
That general setting is the following problem:

1. I have a previous, uncertain estimate of my (changing) situation;
2. I acquire new information about that situation, also uncertain;
3. How to best combine information to obtain improved estimate?
4. What is the uncertainty of that new estimate?
5. Can this be expressed in a learning algorithm?



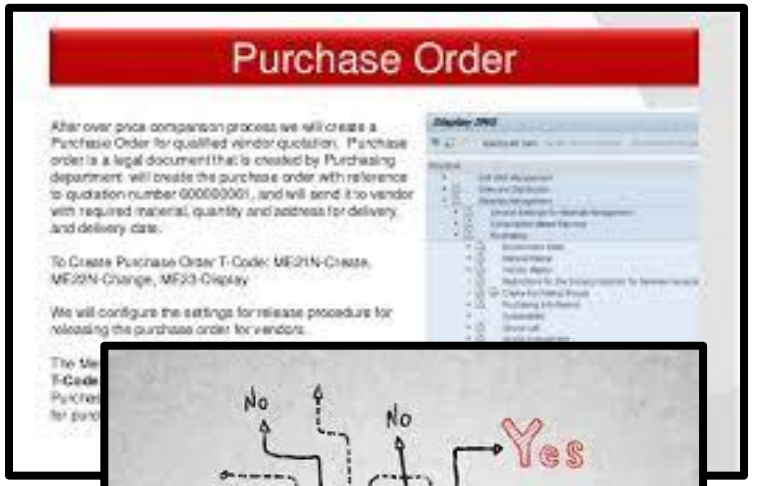
The more specific tools arising out of it include Kalman Filters and Bayesian Networks, among others.

Overview in Digital Thread Setting

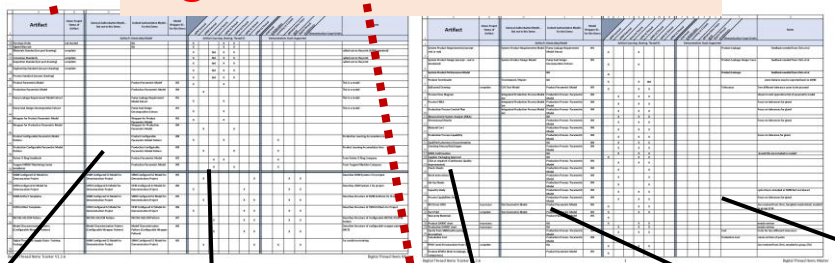


Level 0 View, INCOSE ASELCM Pattern

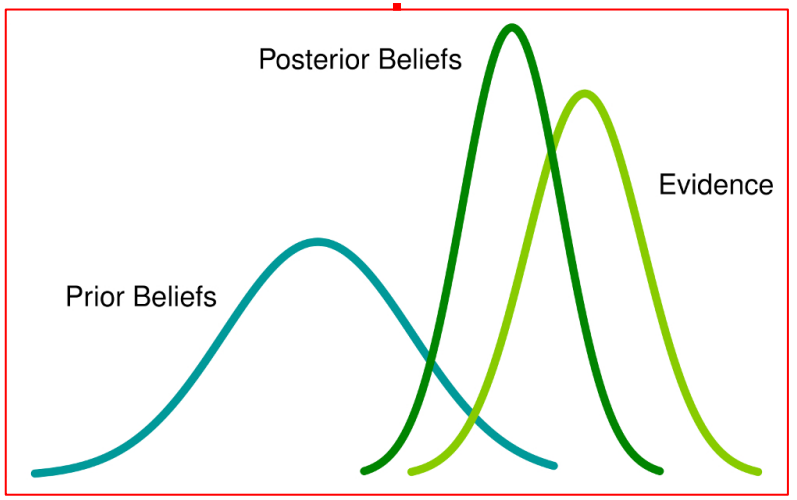
Innovation Ecosystem
Supply Chain Operations



Digital Thread Items Tracker



Supply Chain Digital Thread "HUD"

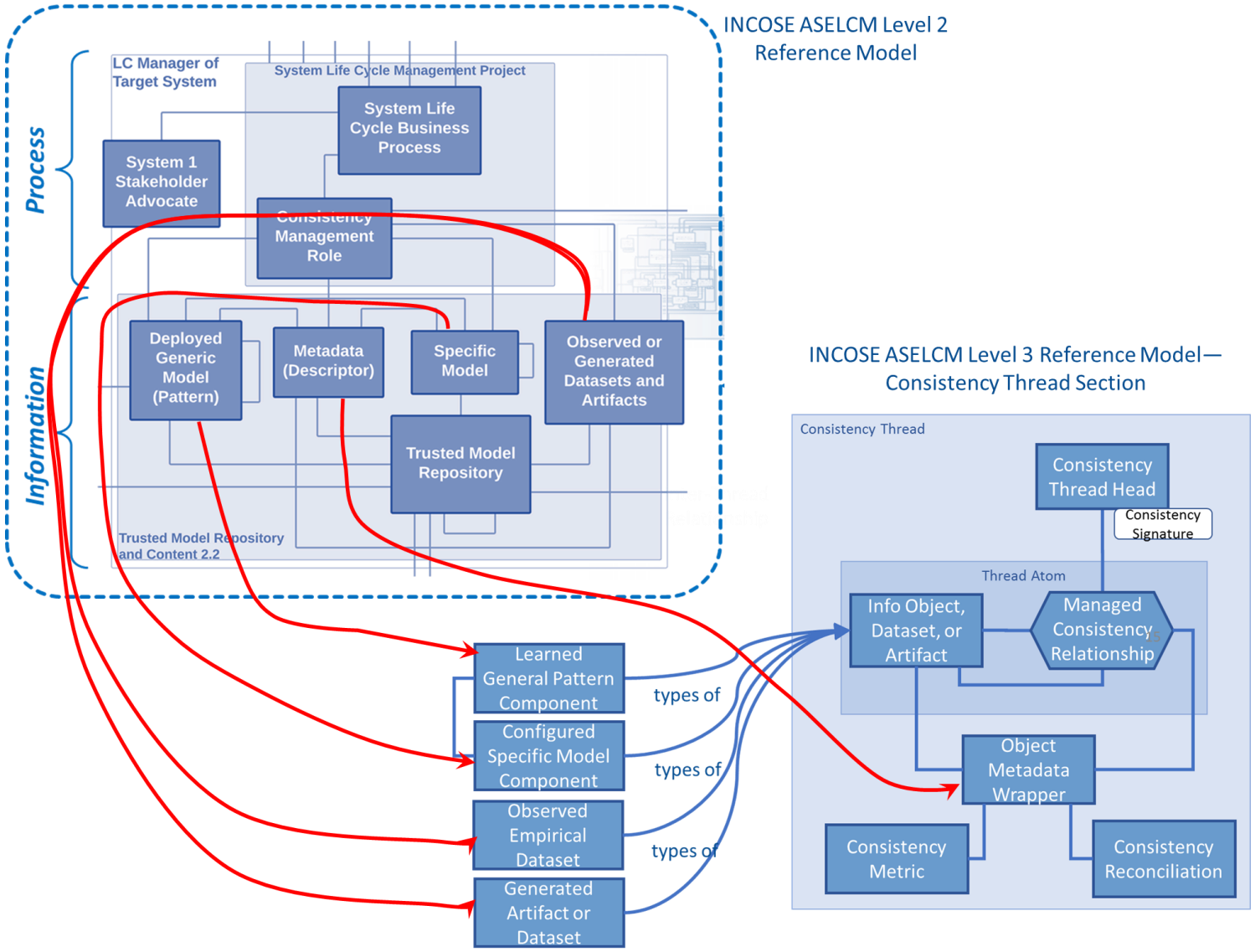


DT Artifact 1 | DT Artifact 2 | DT Artifact 3 | DT Artifact 4 | DT Artifact 5

Model A | Model B | Model C

TIME

8. Learning; the role of recurring patterns; System 1 versus System 2 patterns



- The general ecosystem reference pattern for Consistency Threads includes the use of learned experience patterns in the resulting Digital Threads.
- For Digital Threads within System 2, this describes learned patterns about System 1, the Engineered System, and its environment.
- For Digital Threads within System 3, this describes learned patterns about System 2, *including its decision-making processes.*

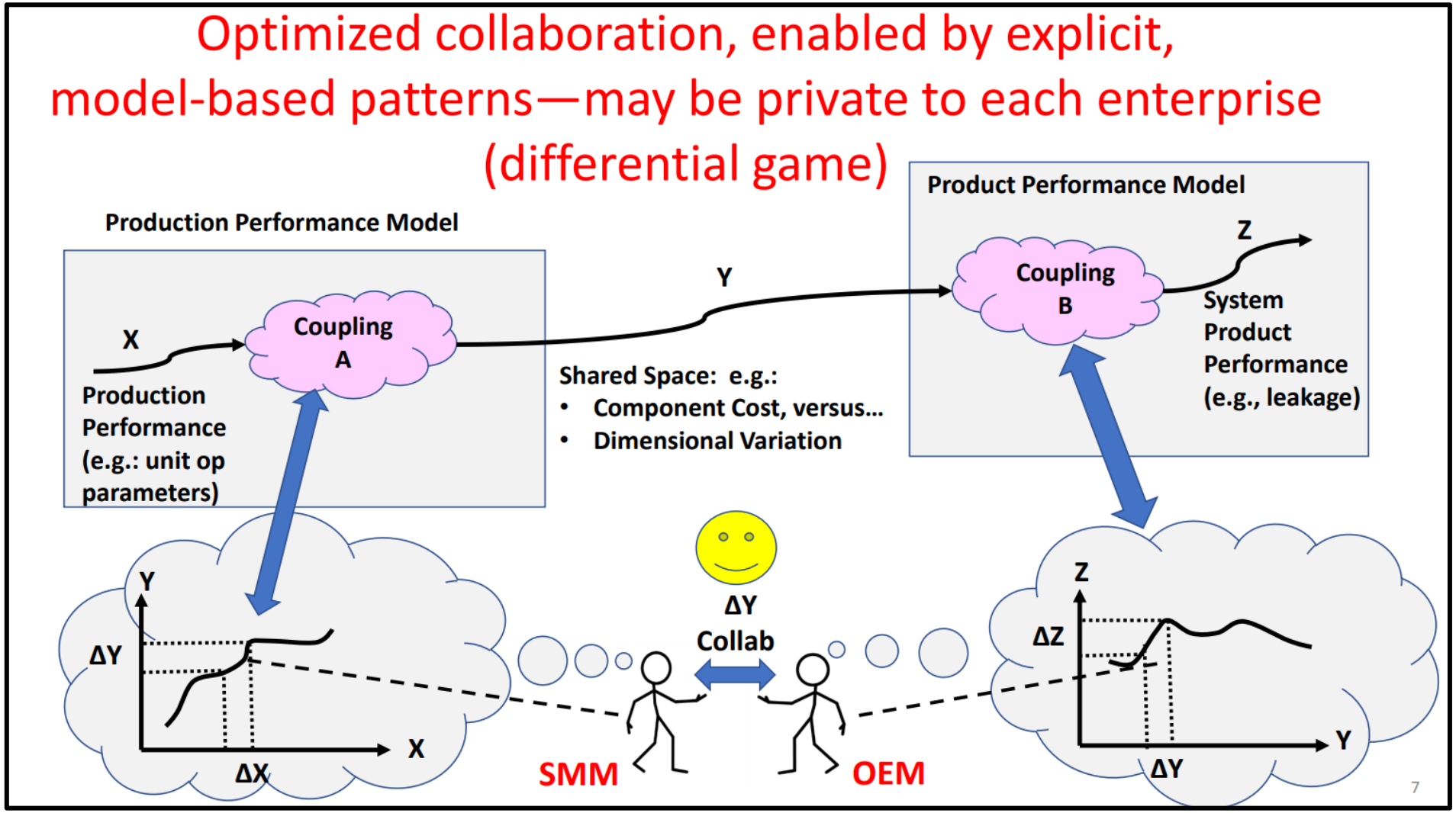
9. Negative incentives and non-rational agents

- Participants in an innovation ecosystem are subject to incentives that are not always in the interest of the other innovation stakeholders.
- These can include commercial interests of enterprises, defensive postures of individuals not supporting the need for transparent decision histories, use of recorded models and decisions as a “cover” for poor outcomes or underlying motives, etc.
- These behaviors include unconscious aspects as well as conscious aspects, such as well-studied in work by Kahneman and Tversky and others.
- The use of explicit models in decision analysis suggests a vision of escape from the effects of these incentives.
- However, selection and use of models brings its own set of framing errors, biases, and other factors known to the model credibility community.
- This suggests the use of explicit safeguards addressing these issues.

10. The value selection phenomenon, non-linearity and Pareto

- Decision analysis implies inclusion of “objective functions” associated with value to stakeholders, and selection of alternatives scored by such functions.
- In real-world applications, determining what stakeholders and objective functions apply can itself be difficult, subject to framing errors, etc.
- Use of “weighting” of factors may imply notions of linearity which is not really present over decision ranges.
- Use of Pareto frontiers to describe selection phenomena can be helpful to include these considerations.
- It may also be useful to reverse the typical view: Instead of viewing selection as driven by value, consider value as defined to be the gradient of selection:
  - See the Value Selection Phenomenon, in 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

11. Information not shared, and other non-cooperative games



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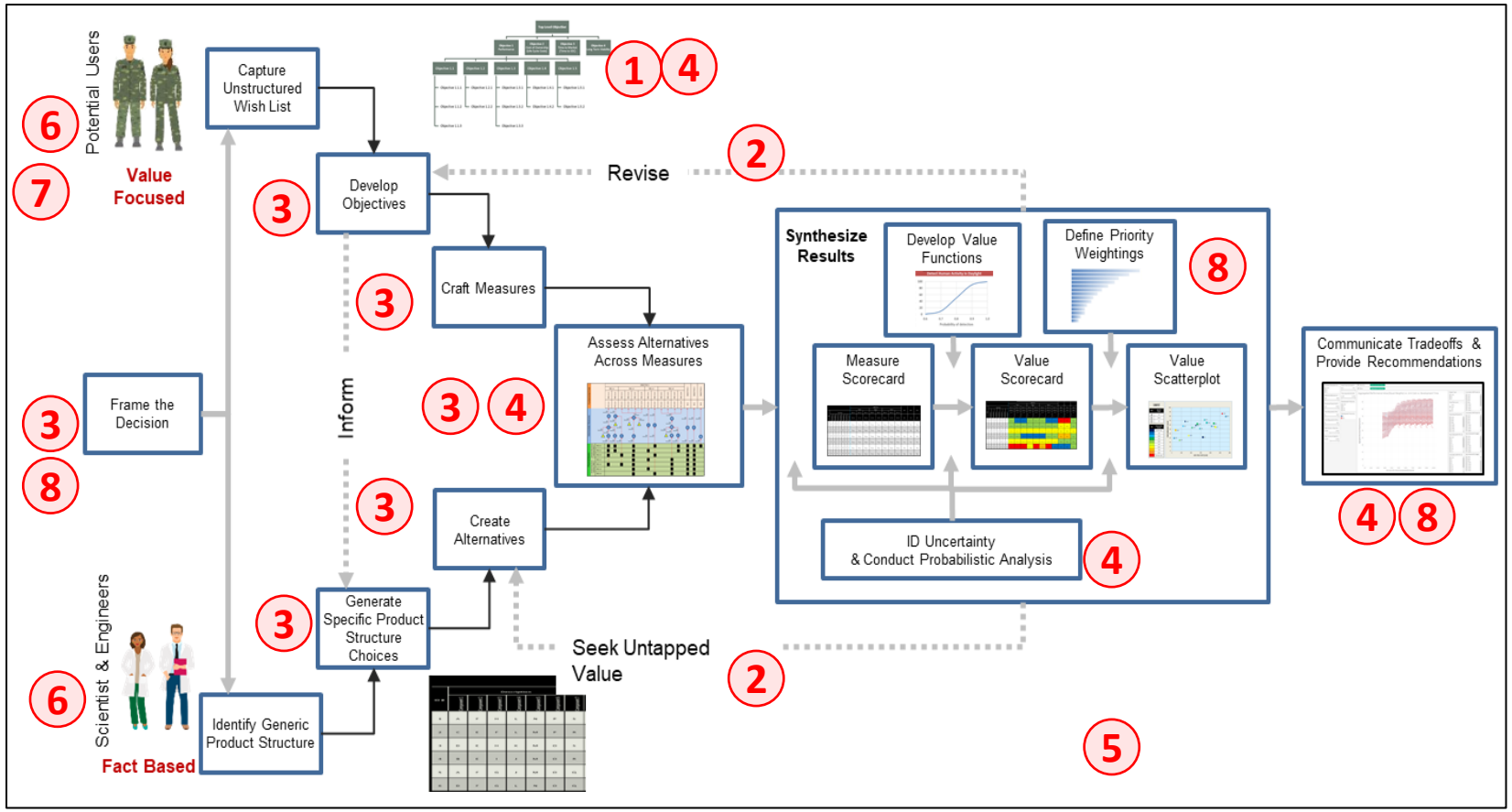
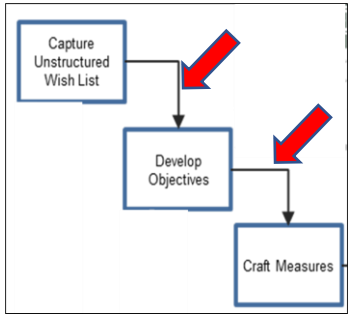
Attachment 3: Observations on the Trade Study Example that Help Us Understand the More General Ecosystem Pattern

1. Process vs. Information; Information Segments
2. Iteration, Process Loops, Dynamic Trajectory, Time Urgency
3. Overlapping Multiple Processes
4. Uncertainty
5. Learning: Tapping Experience Patterns and Contributing to Them
6. Stakeholder Value versus Technical Description
7. Range of Stakeholders
8. Framing the Decision as Selection, Scored in Stakeholder Space

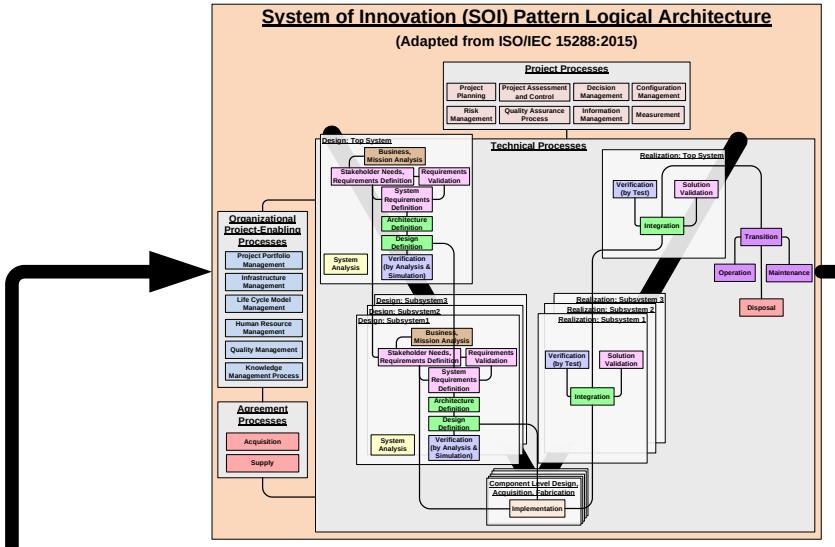


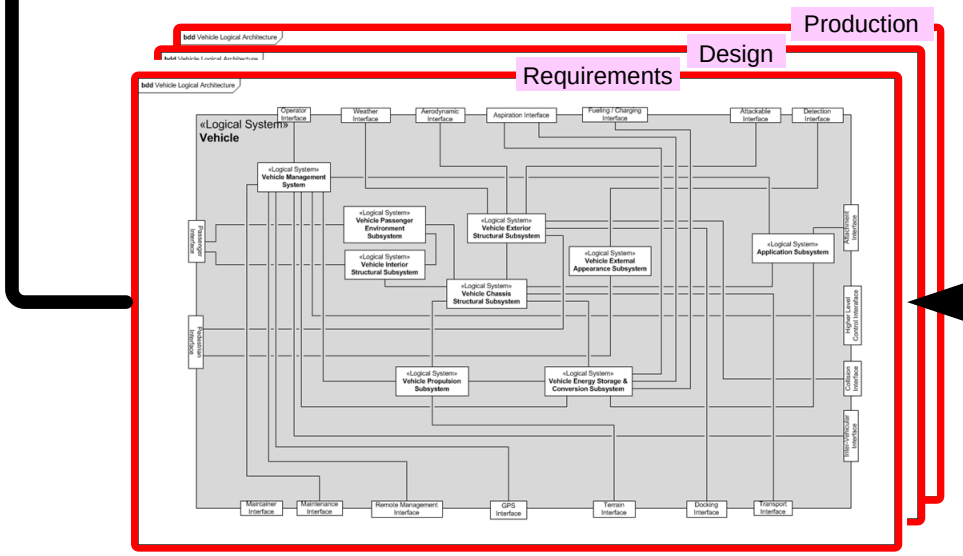
1. Process vs. Information; Information Segments



- Begins with recognizing and formalizing distinction of Process versus the Information it consumes and produces.
- That information can be seen as “segmented” in the sense that it is about different subjects, often produced by separate sub-processes:
  - For example, Requirements information versus Design information.
  - Even when part of an integrated model.
  - (Option: For capture in Digital Thread.)
- This discussion is concerned with the “consistency” of the content of those different information segments with each other.

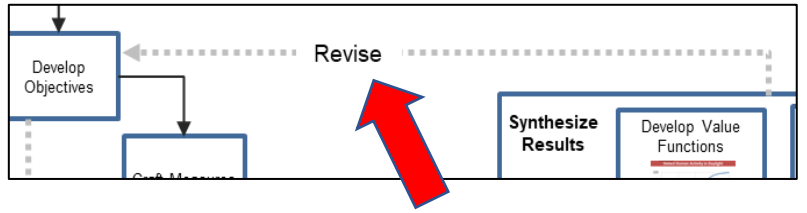
Processes
(Consume and Produce Information Segments)



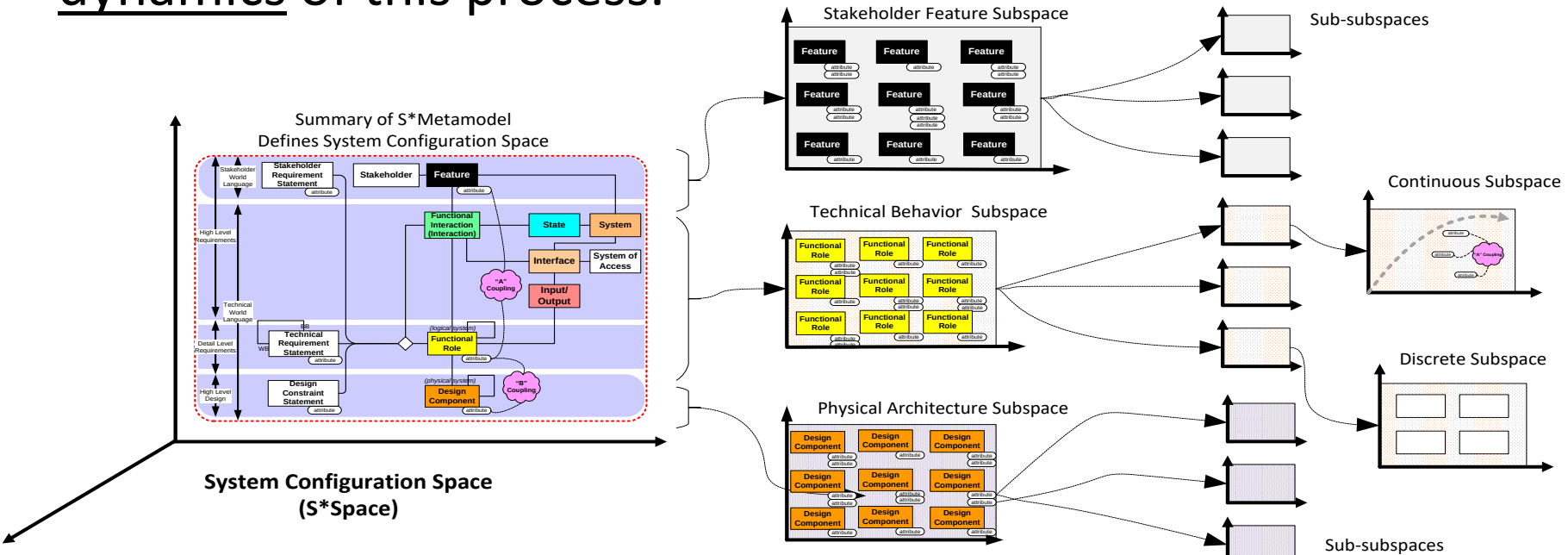


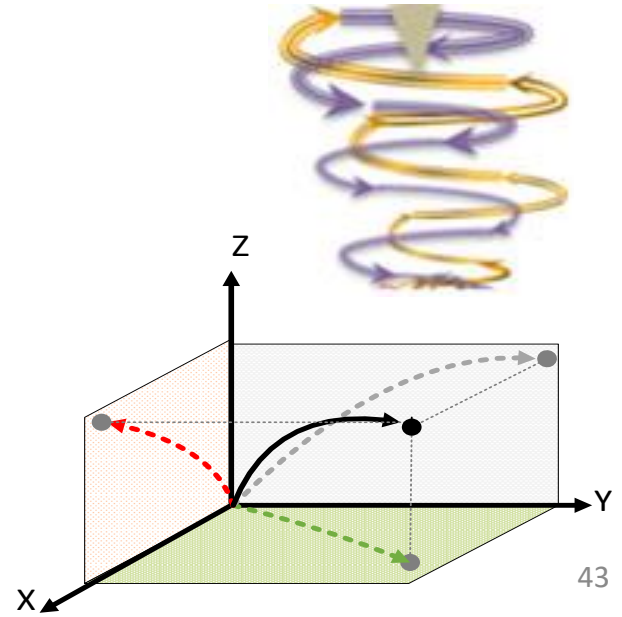
Information Segments
(Produced and Consumed by Processes)

2. Iteration, Process Loops, Dynamic Trajectory, Time Urgency



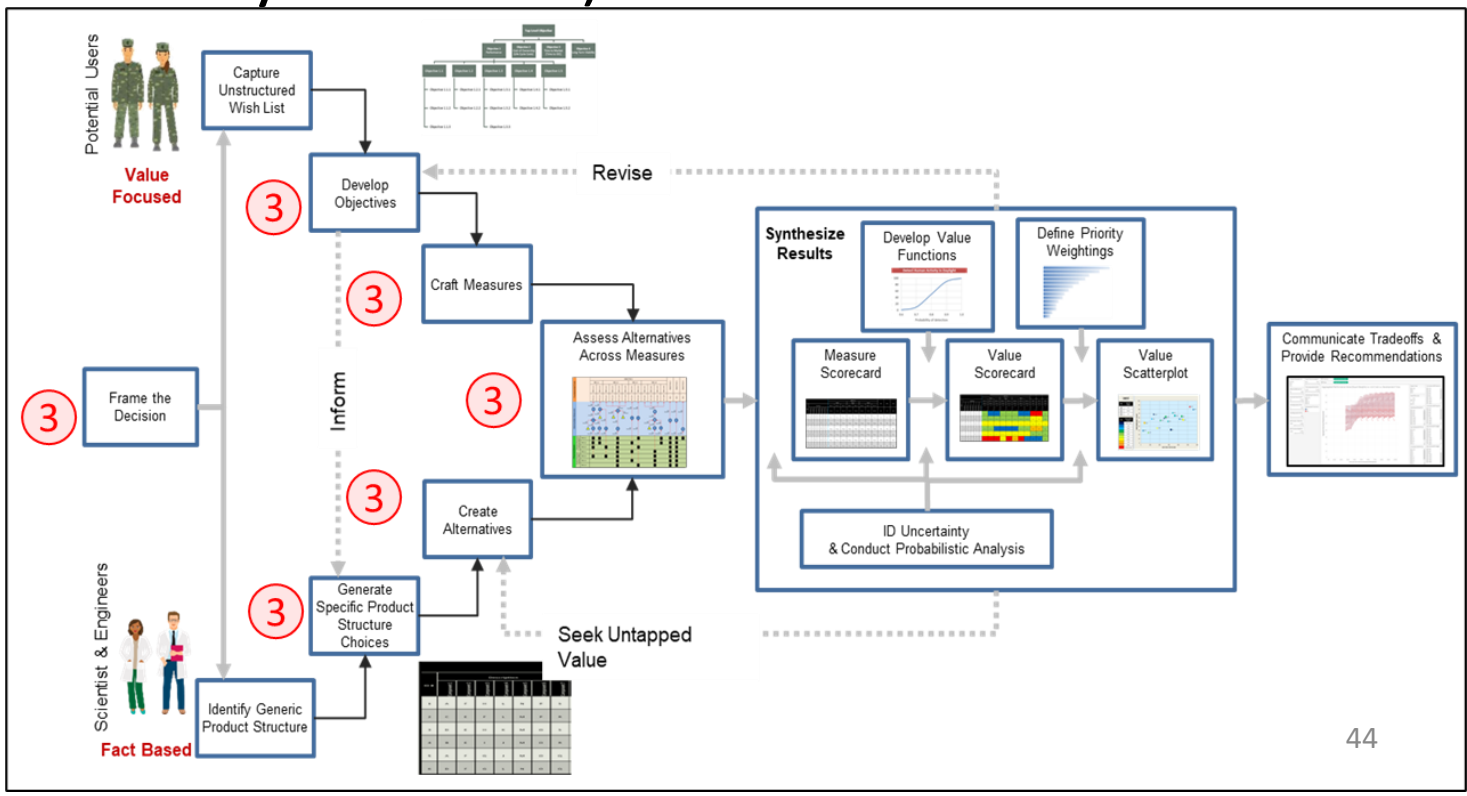
- Processes iterate (repeat, in “loops”), to adjust information segment contents (model configuration state) toward desired combinations that are “consistent”:
  - Generally don’t think of processes as “linear” or “one and done”.
  - It is not the process that becomes “done”—it is the information.
- So, think of dynamic state trajectories through information configuration space—not checklists of completed processes.
- Decisions are often required with time urgent deadlines—another constraint on dynamics of this process.





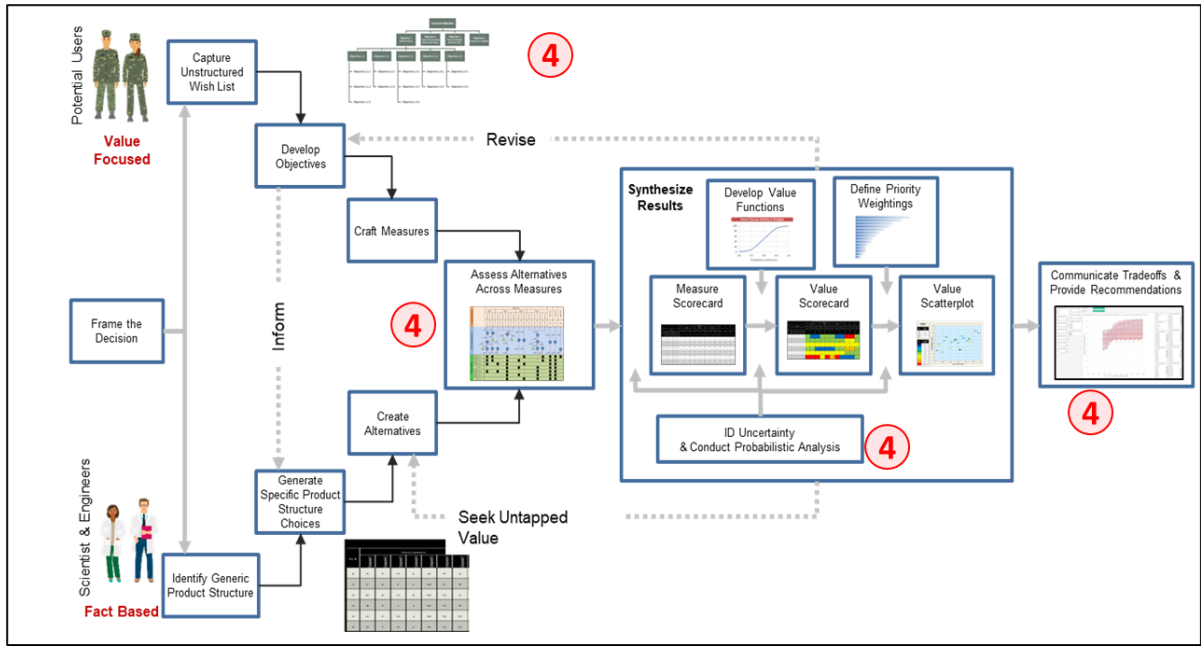
3. Overlapping Multiple Processes

- Notice that the Trade Study Example effectively involves several of the traditional / ISO15288 life cycle processes: Stakeholder Requirements, System Requirements, Design, etc.
- Another way to say this: Decision Analysis appears multiple times across multiple life cycle processes (ISO15288 says as much).
- Related to Digital Thread vision.
- The General Pattern we will see shows the mapping to all those processes, and their enterprise-specific cases.
- Also related to the vision for the Digital Thread.



4. Uncertainty

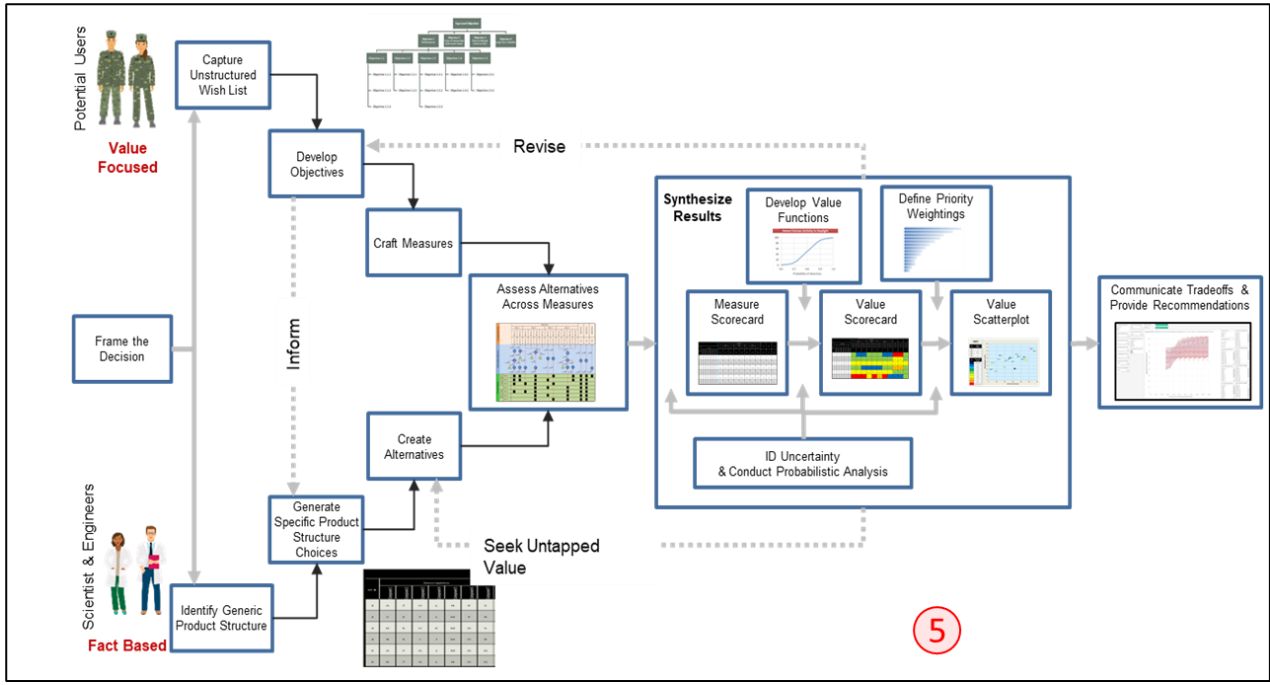
- There is uncertainty in the inputs to the decision: Requirements, Design, Measurements, etc.—those inputs should carry an indication of the degree of uncertainty, such as using MCP Metadata Wrapper in the General Pattern.
- The decision itself can add to uncertainty.
- Thus, the process propagates uncertainty.
- So, the output (decision recommendation) should include indication of degree of its uncertainty.
- The decision that follows should include consideration of risks that uncertainty.



- The risks associated with the recommendation include issues of the severity of impact of a wrong or sub-optimal decision, the degree to which the decision will depend upon the recommendation versus other inputs, etc.

5. Learning: Tapping Experience Patterns and Contributing to Them

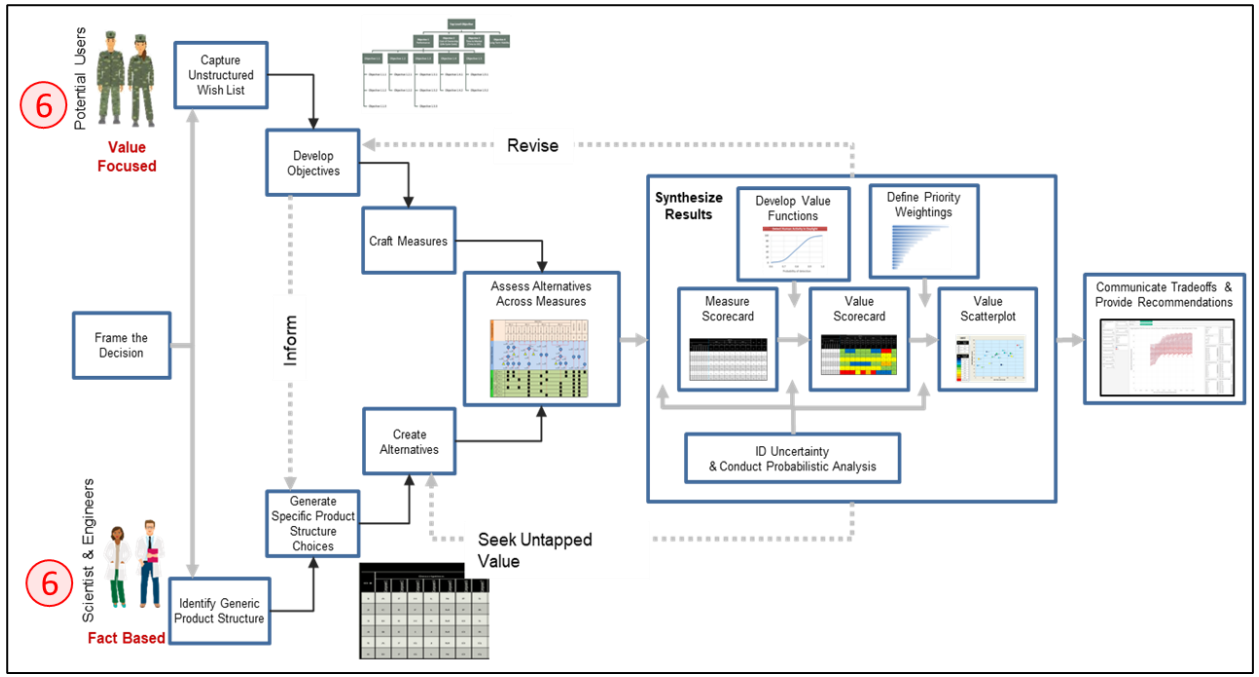
- Virtually every aspect of the example would be expected to draw on the knowledge of the participants—not just the explicit "inputs" shown:
  - Knowledge of the specific domain.
  - Knowledge of the processes/methods.
- Explicit "inputs" shown could be considered to locally configure the (not shown) implicit knowledge of participants.



- The overall process and retrospective on its impacts should also update learning and is integrated with uncertainty management through learning curves.
- In the General Pattern that will follow, we will make that implicit knowledge explicit, in the form of patterns:
  - Pattern of the specific domain.
  - Pattern of the processes/methods.
- This will be seen to be a Digital Thread with Learning.

6. Stakeholder Value versus Technical Description

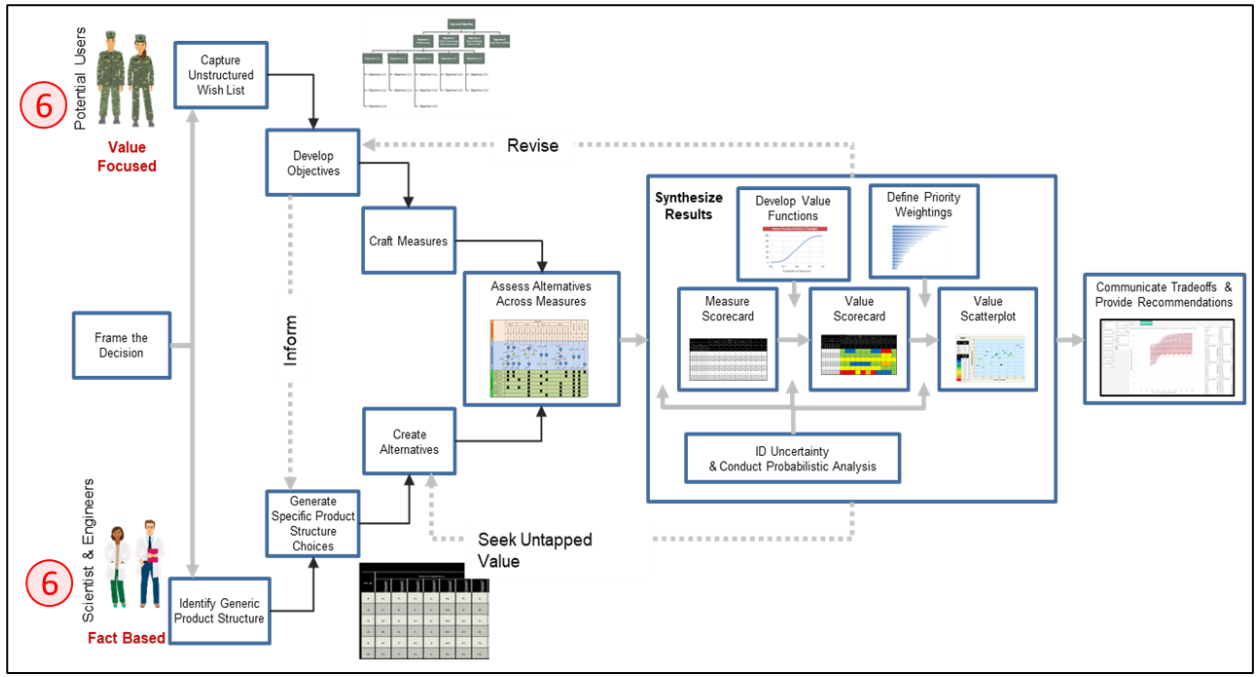
- The Trade Study example reminds us to recognize the roles of both stakeholder representation and more technical representation.
- This includes the difference between stakeholder view of required system capabilities/behaviors, as well as more technical / objective representation of that required behavior.



- And, that is in addition to also including information about the design(s) to produce that required behavior.
- In the general pattern, we will see all those and other types of information segments, depending on the decision type.
- But, it is the stakeholder information which provides the “scoreboard” for all the decision types across the life cycle—if our view of stakeholders is broad . . .

7. Range of Stakeholders

- While the "potential users" shown in the Trade Study example are an important subset of the Stakeholders, the General Pattern will remind us to think more broadly about the other classes of Stakeholders that are critical to these decisions and their scoring—even for Trade Studies:



  - For example: Maintainers, Supplier Shareholders, Production Operators, Distribution Operators, Local and Global Communities.
  - Stakeholder Features exist for all these and other Stakeholders.

8. Framing the Decision as a Reconciliation Selection, Scored in Stakeholder Space

- Multiple, conflicting interests: The name "Trade Study" reminds us that many important decisions involve "trade-offs", in which one interest may sacrifice to a degree for the good of another interest.
- Multiple directions: The bottom-up, top-down, and iteration parts of the diagram remind us that "back propagation" may occur, in which "downstream" (e.g., Design) aspects may influence "upstream" (e.g., Requirements) aspects.
- Reconciliations: For these and other reasons, the general pattern will remind us that these decisions are in the most general case "reconciliations" of conflicts, gaps, collisions, and interests, selected from the subset which is the Pareto Frontier.