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Questions that open doors . . .

Patterns Storybook

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Nicolaus Copernicus

Door #1: Models

Isaac Newton

What is the smallest model of a system?

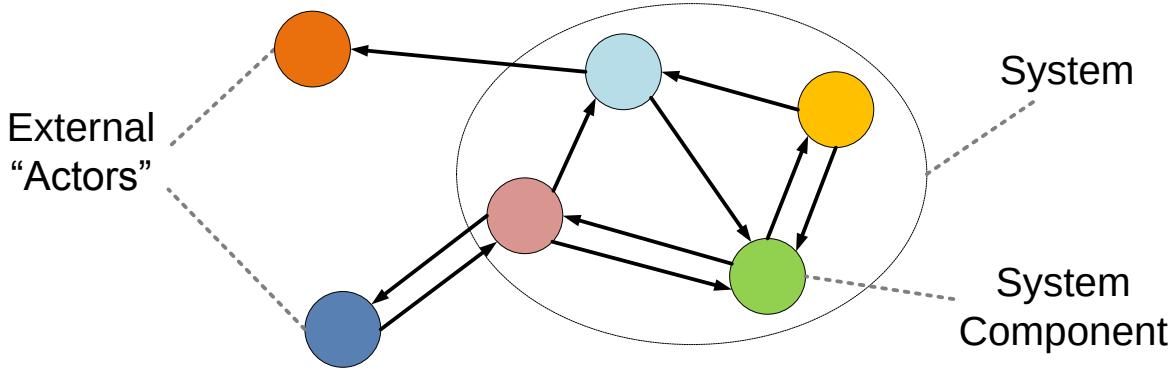
The *size of the smallest model* of a system (for purposes of science and engineering over the system's life cycle) is important for both practical and theoretic reasons:

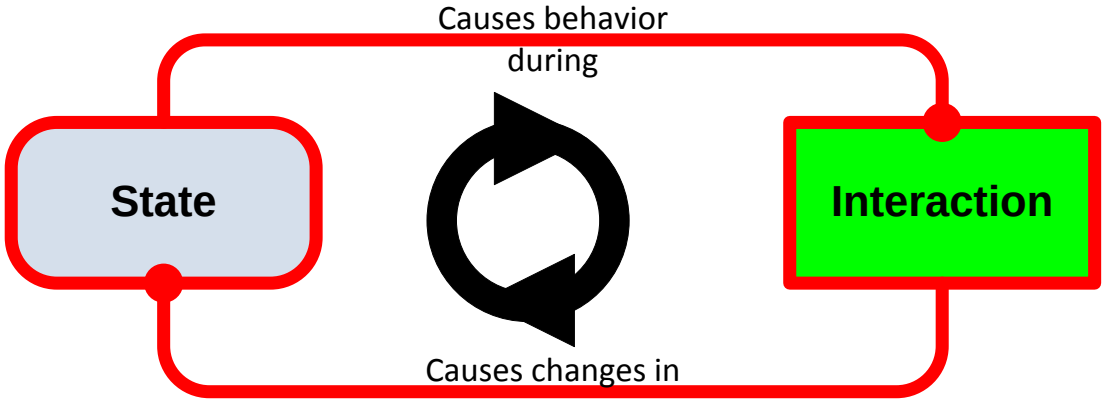
1. **Practice**: Redundant, incomplete, inconsistent, and overwhelming information in engineering is increasingly a concern.
2. **Theory:**
   - The size of the smallest model required to represent a given system is one of the mathematical definitions of complexity of the system.
   - Physical science has often applied Occam's Razor to find the simplest underlying explanation of phenomena.

Seeking the smallest system model has led to some surprising conclusions, in comparison to "SE conventional wisdom" . . .

System Behavior: One part of the smallest model

- *In the perspective described here*, by System we mean a collection of interacting components:





- By "interacting" we mean the exchange of energy, force, material, or information (input-outputs) between system components, . . .
- . . . through which one component impacts the state of another component.
- By "state" we mean a property of a component that impacts its input-output behavior during interactions.
- So, a component's "behavior model" describes input-output-state relationships during interaction—*there is no "naked behavior" in the absence of interaction*.
- The behavior of a system as a whole involves emergent states of the system as a whole.

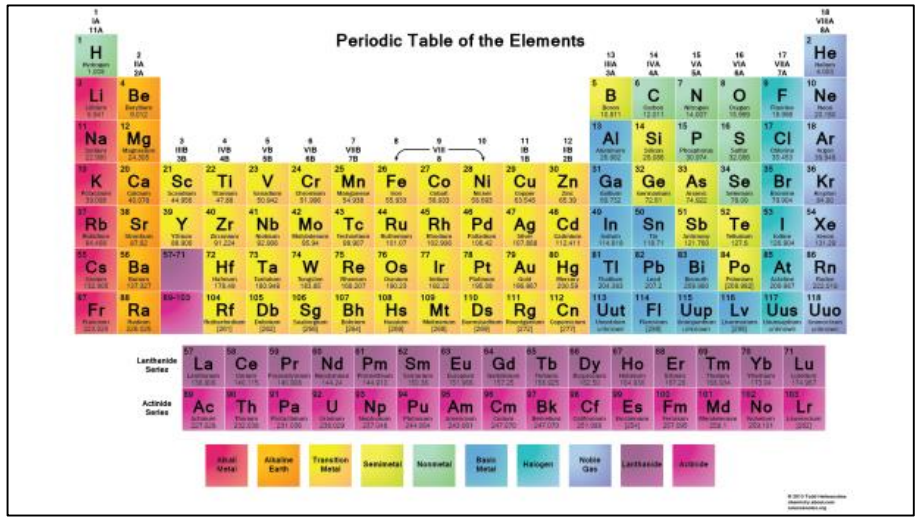
The search for a "system phenomenon"

- Specialists in individual engineering disciplines (ME, EE, CE, ChE, etc.) sometimes argue that their fields are based on:
  - "real physical phenomena",
  - physical laws based in the "hard sciences", and first principles,
- sometimes claiming that Systems Engineering lacks the equivalent phenomena-based theoretical foundation.

$$\nabla \cdot \mathbf{D} = \rho$$
$$\nabla \cdot \mathbf{B} = 0$$
$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$
$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$$

$$\frac{N_b}{N_a} = (\frac{g_b}{g_a})(e^{-(E_b - E_a)/kT})$$

$$H(t)|\psi(t)\rangle = i\hbar\frac{\partial}{\partial t}|\psi(t)\rangle$$

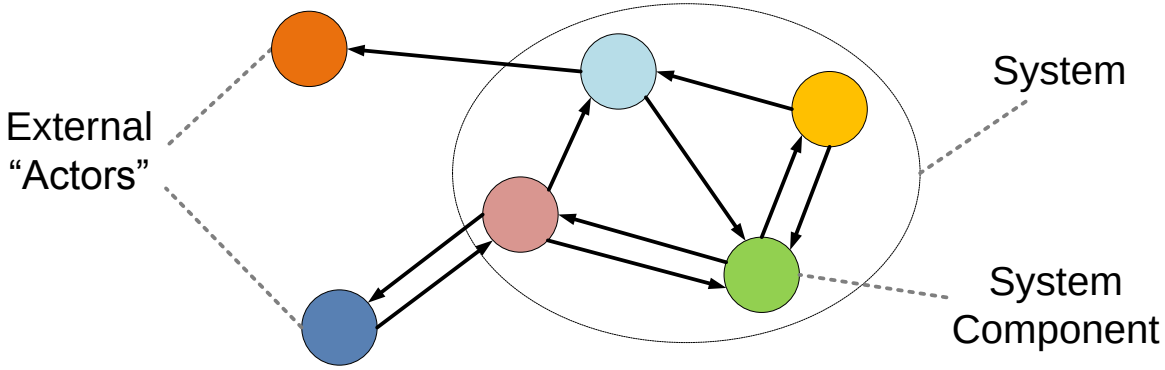


- Instead, Systems Engineering is sometimes viewed as:
  - Emphasizing process and procedure
  - Critical thinking and good writing skills
  - Organizing and accounting for information
- But not based on an underlying "hard science"

The System Phenomenon

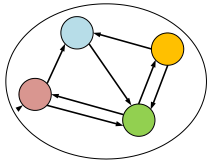
- Phenomena of the hard sciences (Newton, Maxwell, et al) are in each case instances of the following "System Phenomenon":
  - *behavior emergent from the interaction of behaviors (phenomena themselves) a level of decomposition lower.*
- In each such case, the emergent interaction-based behavior of the larger system is a *stationary path of the action integral*:

$$\mathcal{S} = \int_{t_1}^{t_2} L(x, \dot{x}, t)\, dt$$



(Hamilton's Principle)

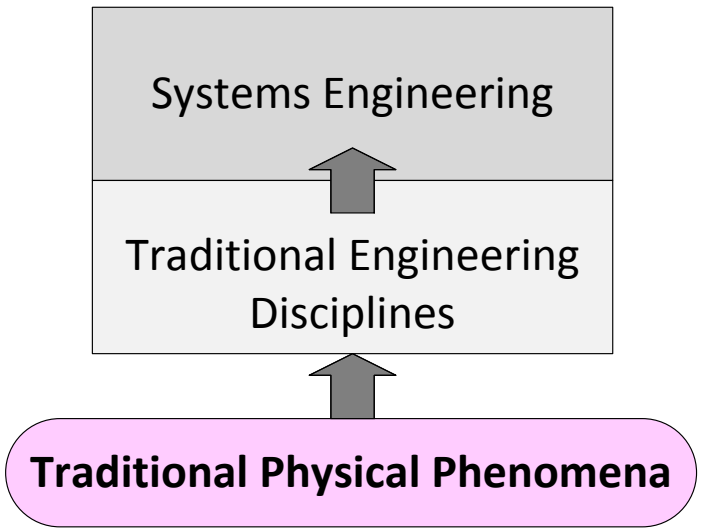
- Reduced to simplest forms, the resulting equations of motion (or if not solvable, empirically observed paths) provide "physical laws" subject to scientific verification.



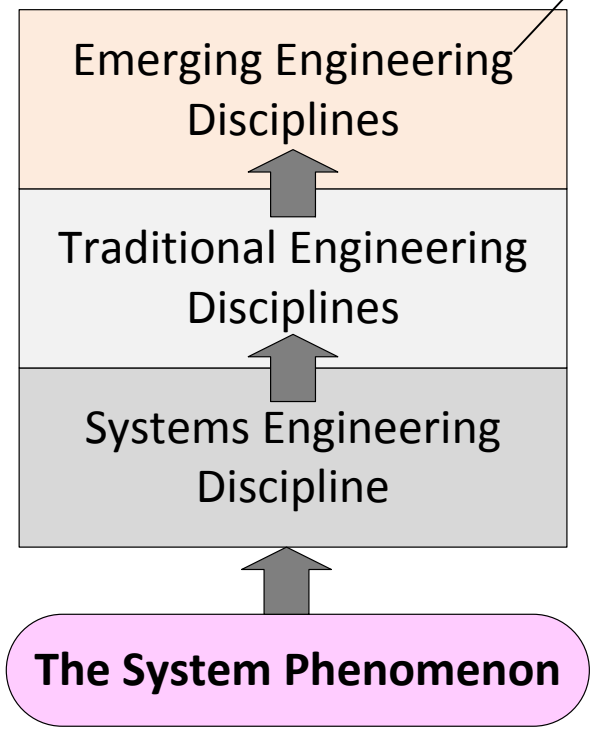
The System Phenomenon

It is not Systems Engineering that lacks its own foundation—instead, it has been providing the foundation for all the other “hard” disciplines!

A traditional view:



Our view:



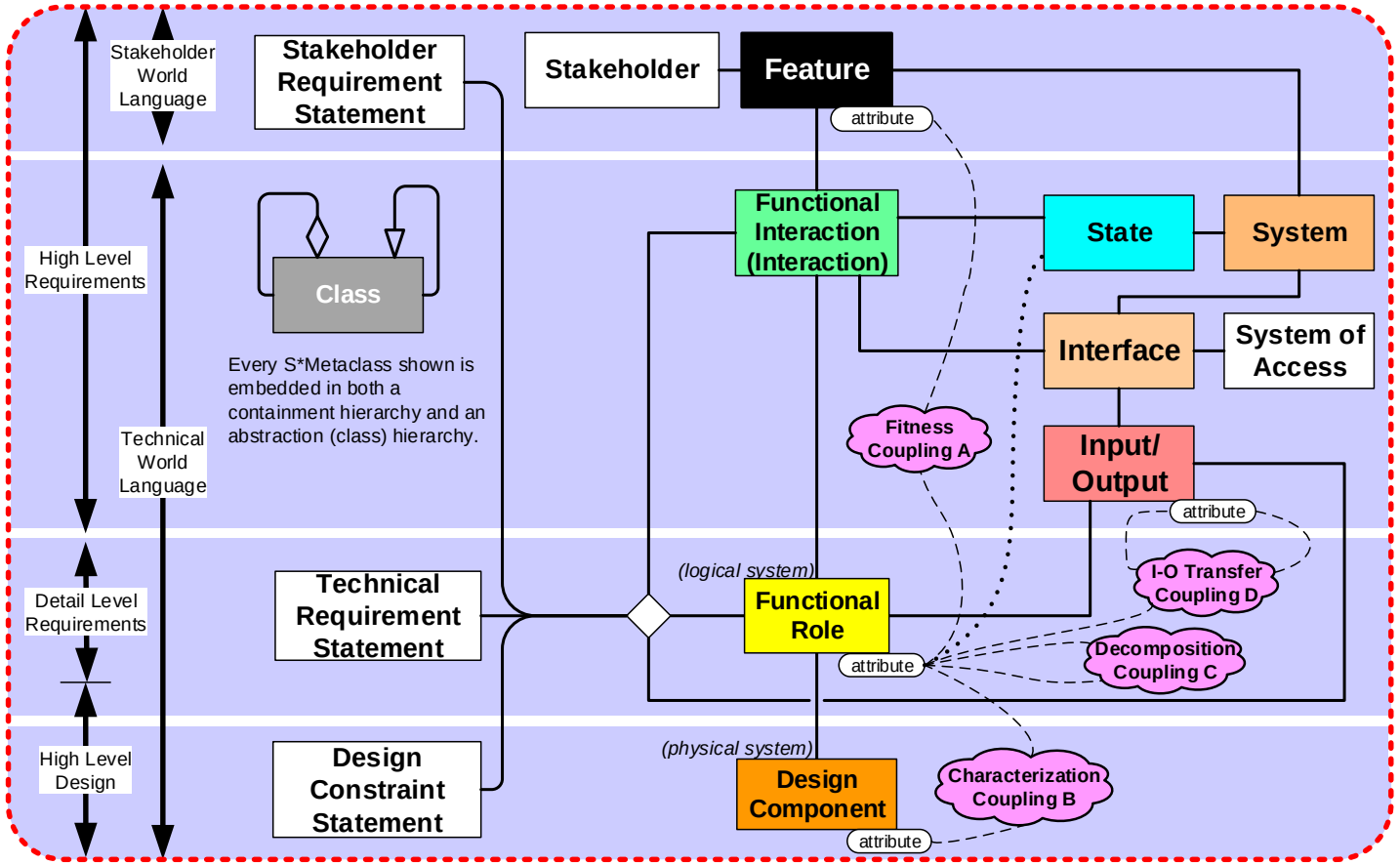
Future

- Distribution networks
- Biological organisms, ecologies
- Market systems and economies
- Health care delivery
- Systems of conflict
- Systems of innovation

Recent

- Ground Vehicles
- Aircraft
- Marine Vessels
- Biological Regulatory Networks

- A “metamodel” is a model of other models—describing the framework (concepts, relationships) used to express those models.
- **S*Models** are any models that conform to the **S*Metamodel**, a 25 year-old answer to “what is the smallest model necessary to represent systems for purposes of engineering & science, over system life cycles?”



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

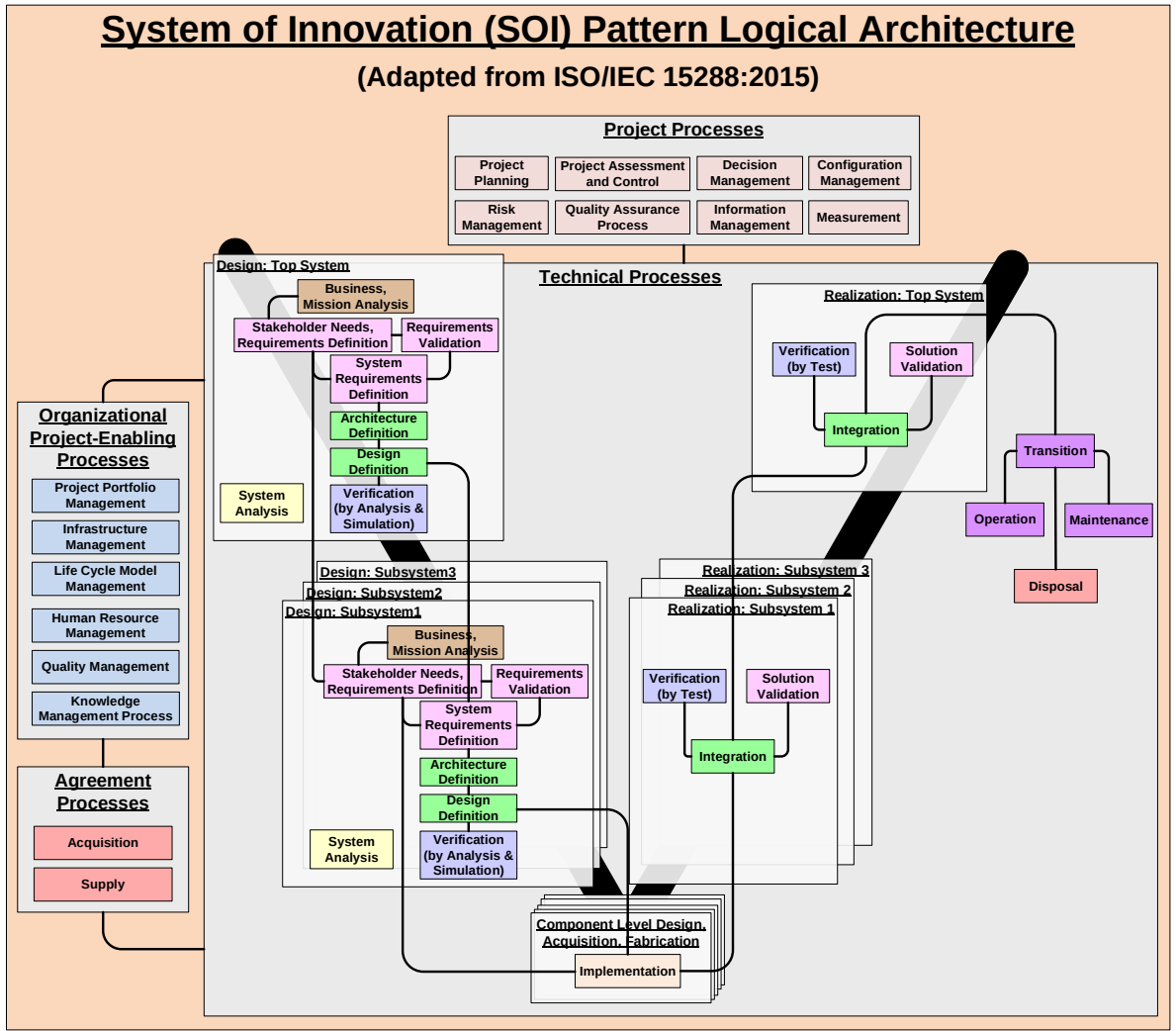
- INCOSE Patterns Working Group applies the S*Metamodel for MBSE Patterns.
- Independent/neutral of any specific modeling language of tools—has been mapped to many COTS tools, SysML®, other languages, information systems.

William Hamilton

Door #2: Patterns

Emmy Noether

Must we repeat others' learnings (and mistakes)?



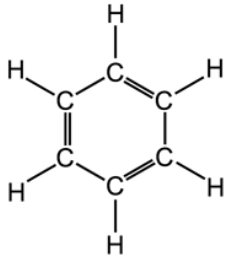
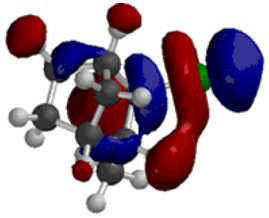
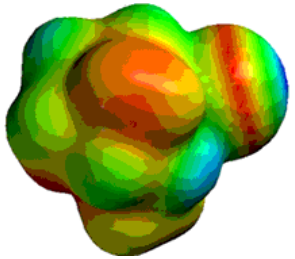
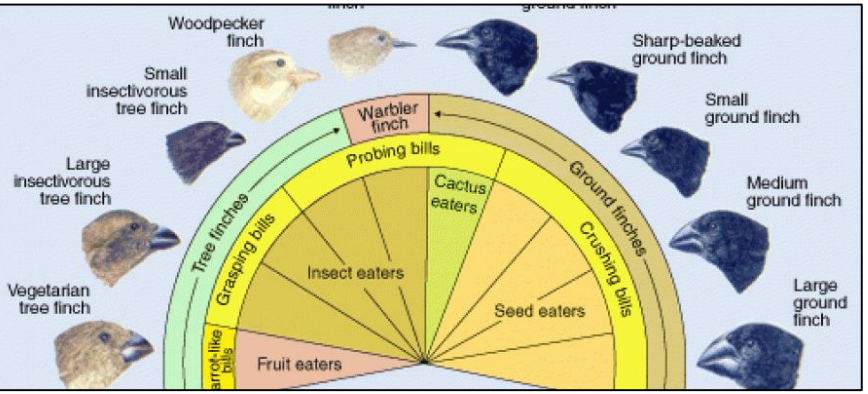
- SE guidance, procedures, standards tell us all the things we would need to do if we didn't already know anything about the system and domain in which we are engineering:
  - But how best to identify and use all that we already know?
  - Do we really need to keep repeating the past learning (and mistakes) of others?

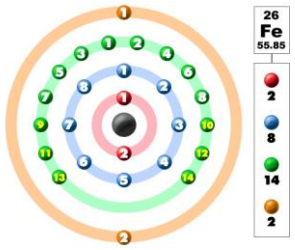


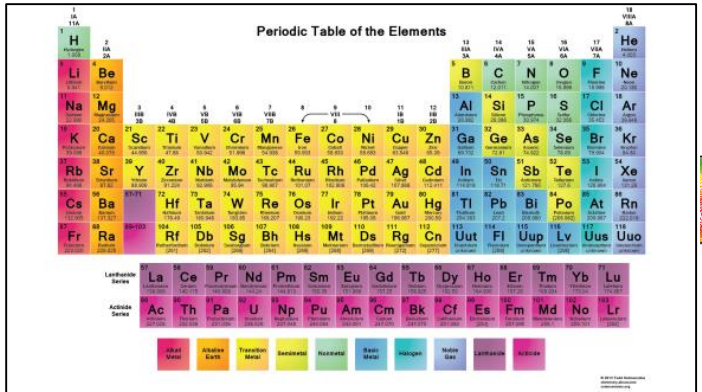


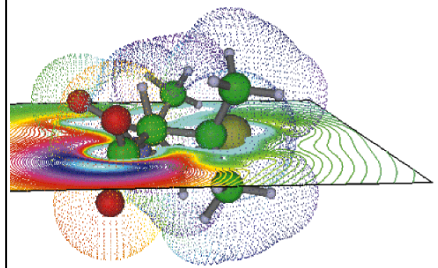

Patterns

- All “patterns” are recurrences, having both fixed and variable aspects.
- The heart of physical science’s life-changing 300 year success in prediction and explanation lies in recognition, representation, exploitation of recurring patterns.
- Noether’s Theorem & Hamilton’s Principle: Math basis for all the physical laws: Newton, Maxwell, Mendeleev, Schrödinger, . . .

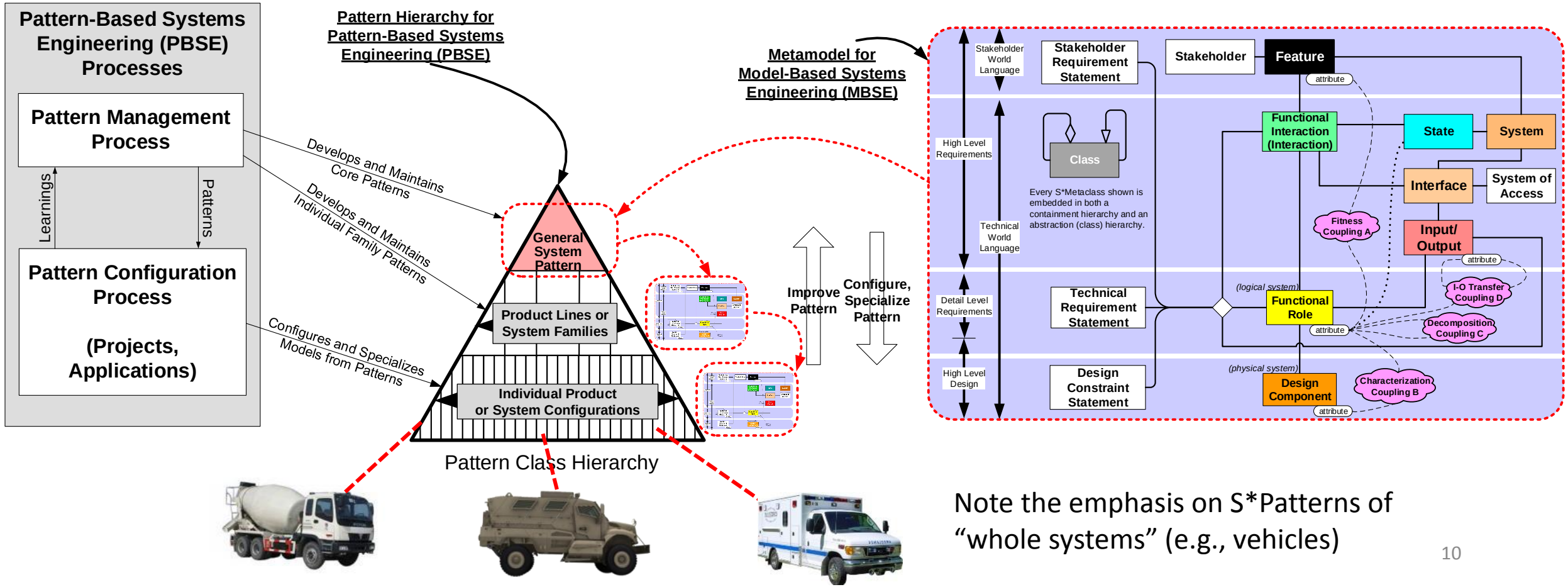






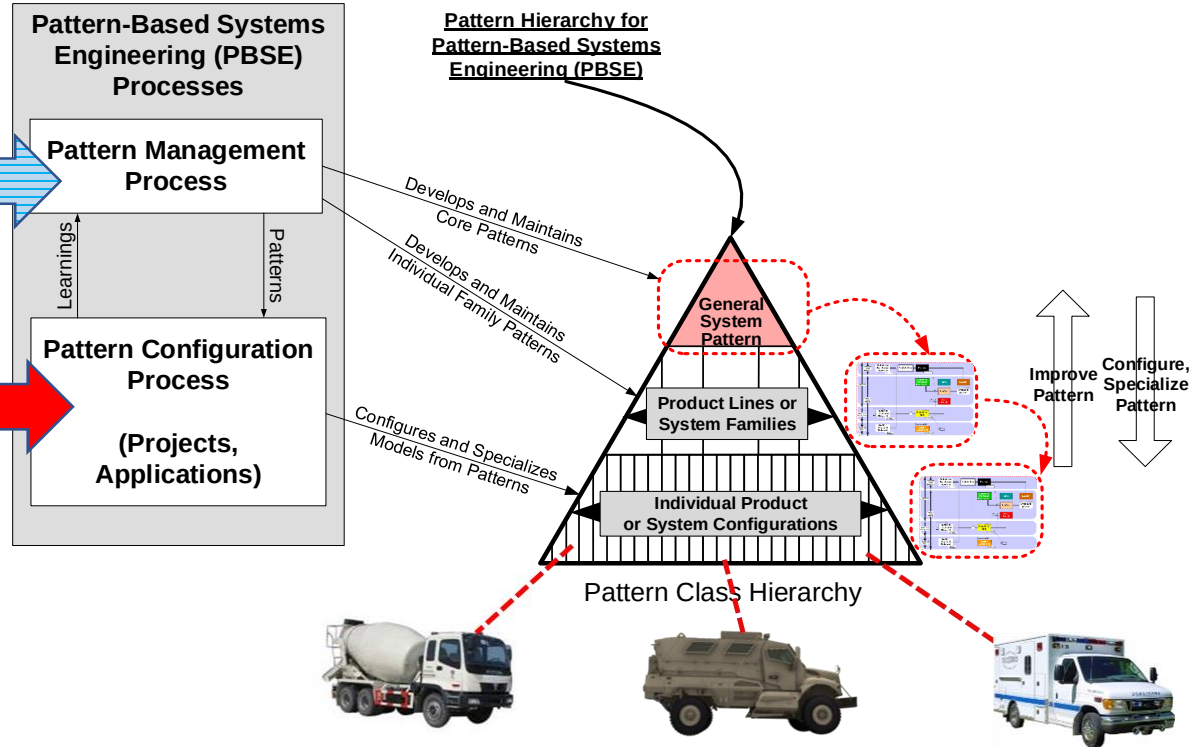
S*Patterns

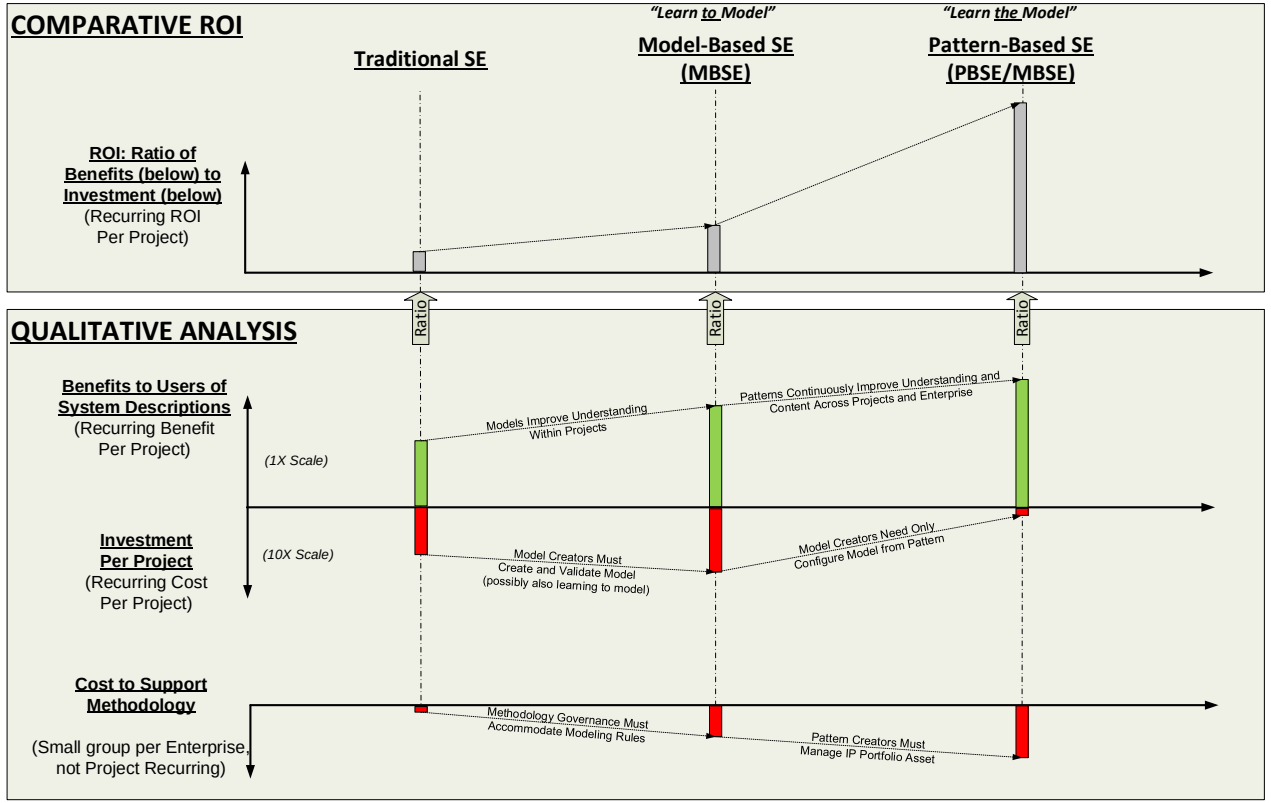
- An **S*Model** is any model conforming to the S*Metamodel,
- An **S*Pattern** is any re-usable, configurable S*Model that can be configured to individual model cases for different applications, species, products, etc.



Note the emphasis on S*Patterns of "whole systems" (e.g., vehicles)

Payoff: Rapidly Configuring Specific S*Models from S*Patterns





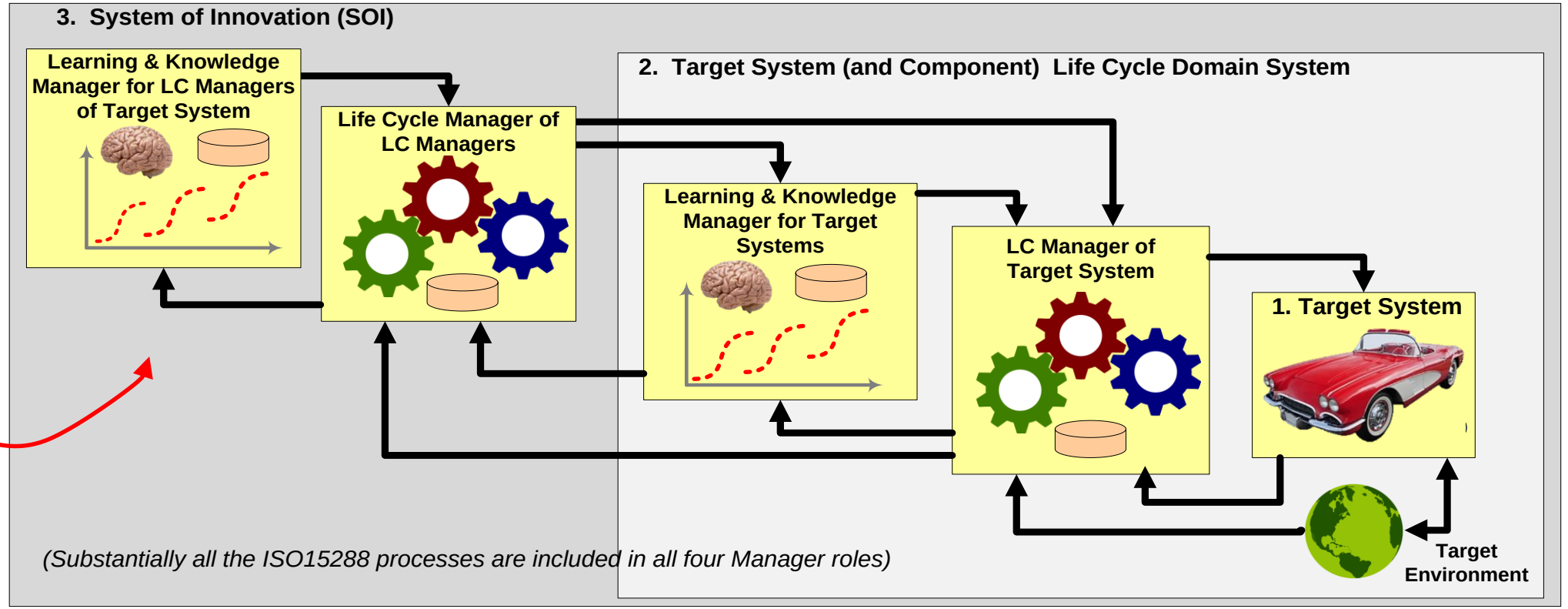
- Generates high quality first draft models from patterns in 10% of the time and effort to generate "traditional" models of lower quality and completeness.
- Most planned S*Patterns take less than 90 days to generate to point of first use, via "Uncover the Pattern" (UTP) Project
- Thereafter, S*Pattern becomes the point of accumulation of future group learning-- the "muscle memory" that is automatically consulted in each future project.

Cultural challenges

- Everyone / every project wants to build their own models:
  - Condemned to learning the same lessons, making the same mistakes, low-grade learning curves
  - Innovation with the brakes on
- Incommensurability of personal or local paradigms:
  - T. Kuhn on incommensurable frameworks in technical communities
  - Reference frameworks, ontologies, beliefs, world views
  - My way or our way?

System of Innovation Pattern

(Used in INCOSE Agile SE Life Cycle Model Discovery Project, descriptive, not prescriptive.)



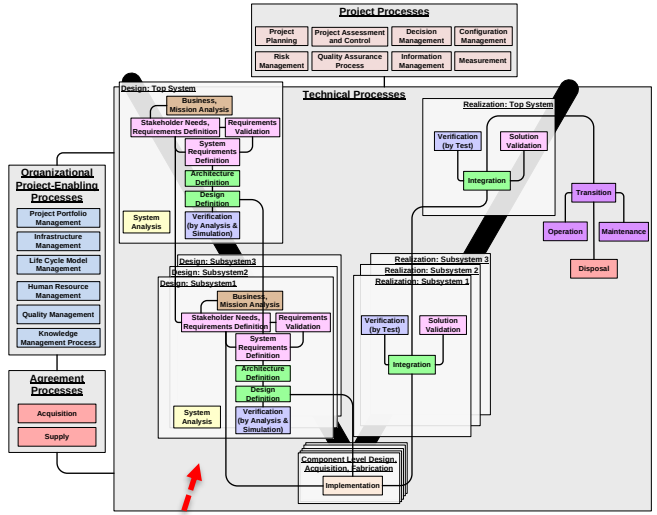
- System 1: Target system of interest, to be engineered or improved.
- System 2: The environment of (interacting with) S1, including all the life cycle management systems of S1 (engineering, production …, including learning about S1.
- System 3: The life cycle management systems for S2, including learning about S2.

Simon Ramo

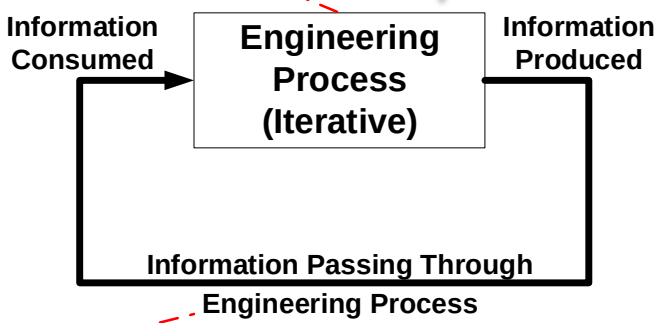
Door #3: Future

Reconceptualizing Systems Engineering

Process & Procedure

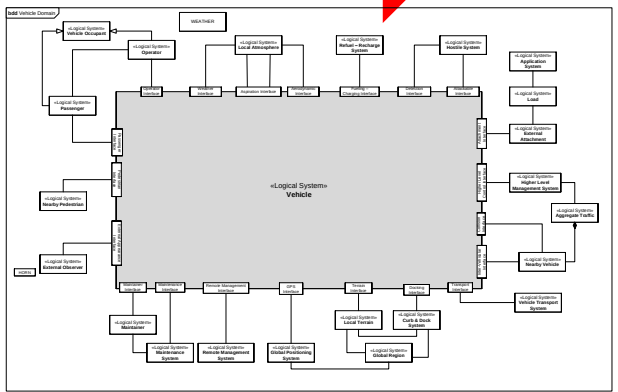


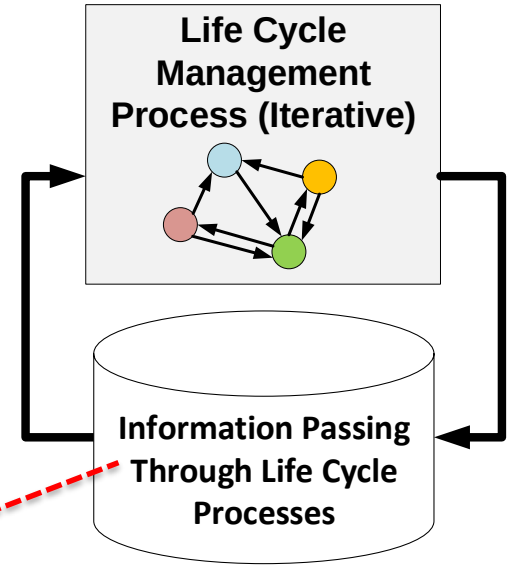
Traditional SE Emphasizes ***Process***



PBSE Increases Relative Emphasis on ***Information***

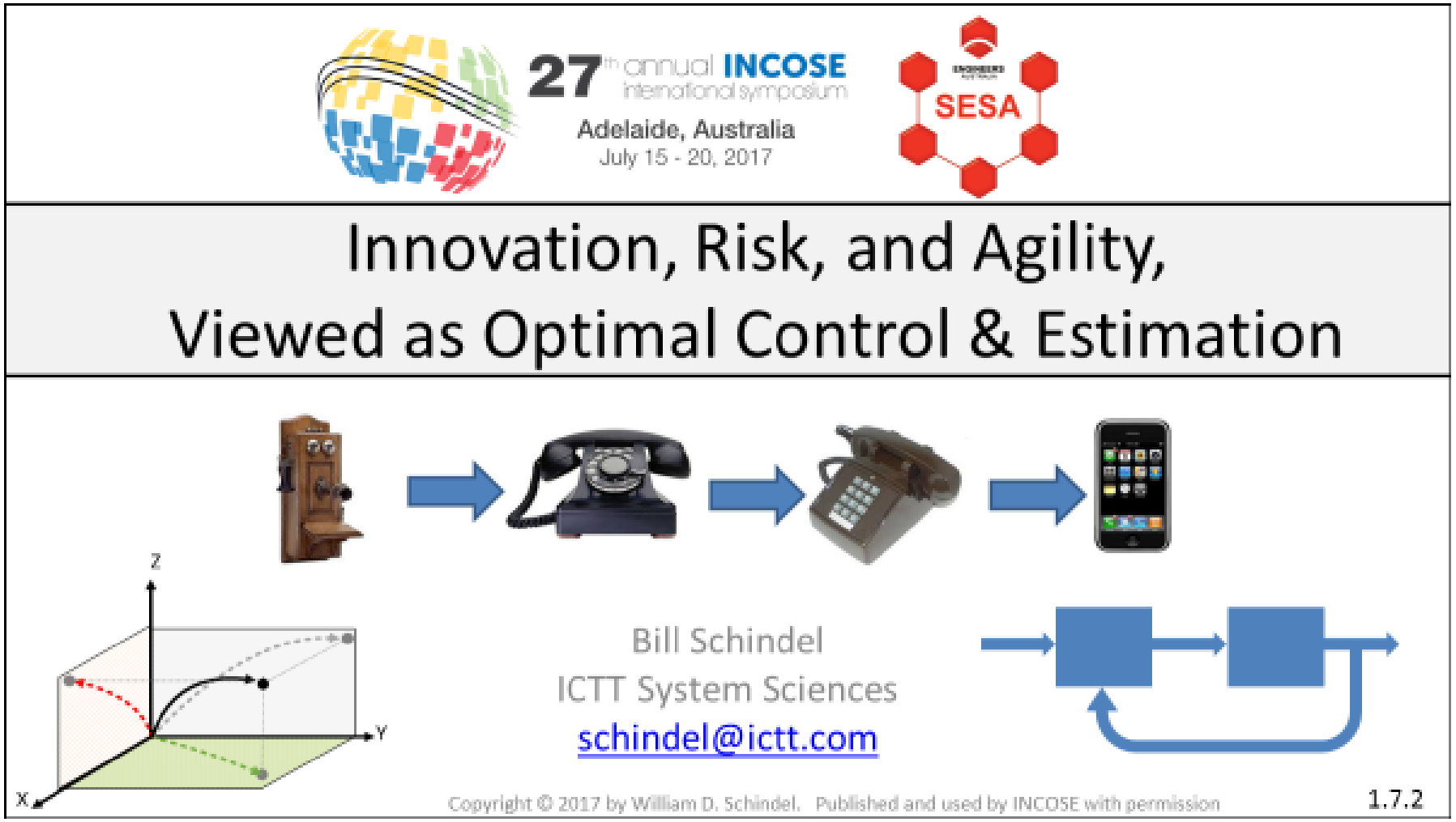
Transformation

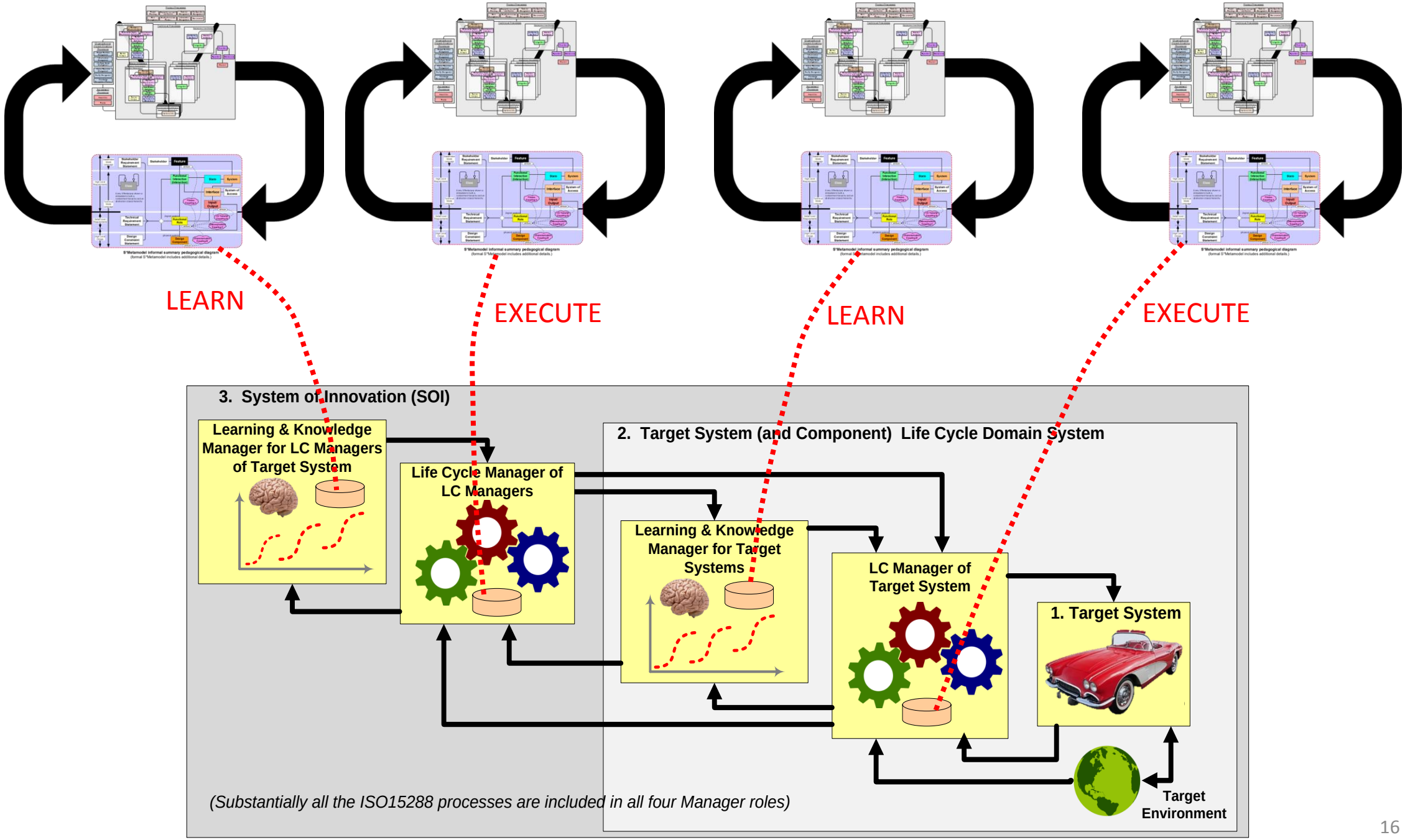




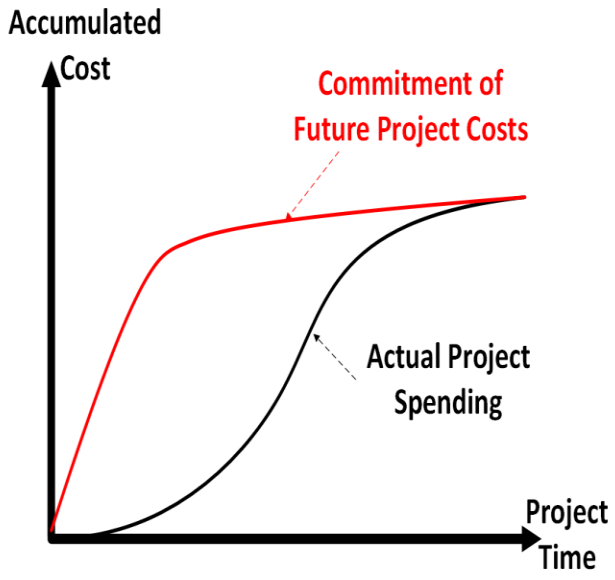
Information

Increased Focus on the Dynamics of Trajectory in Configured Model Space

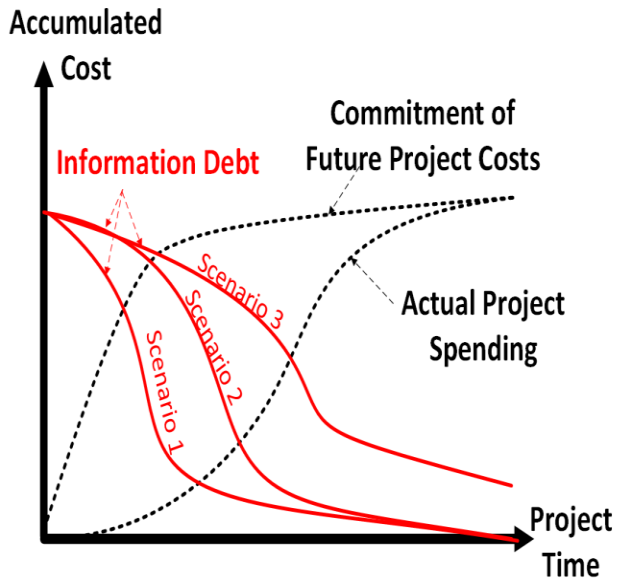



LEARN
EXECUTE
LEARN
EXECUTE
3. System of Innovation (SOI)
Learning & Knowledge Manager for LC Managers of Target System
Life Cycle Manager of LC Managers
2. Target System (and Component) Life Cycle Domain System
Learning & Knowledge Manager for Target Systems
LC Manager of Target System
1. Target System
Target Environment
(Substantially all the ISO15288 processes are included in all four Manager roles)

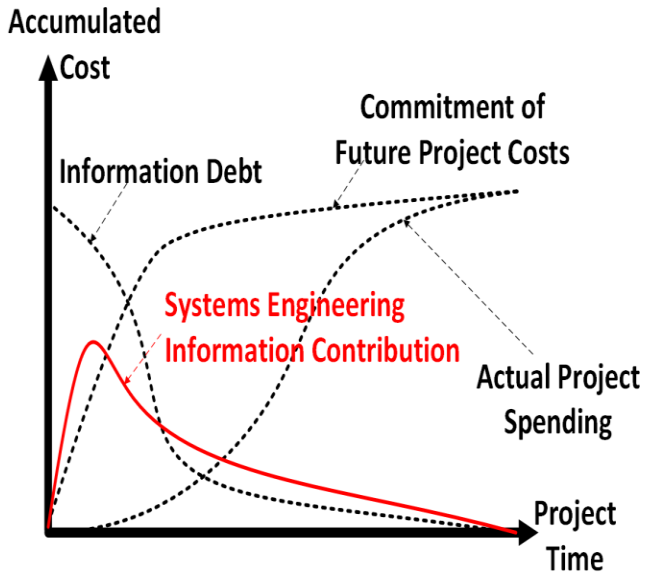
- Pattern data as IP:
  - Information Debt, not just Technical Debt, as a foundation of agile innovation
  - Patterns can be capitalized as financial assets under FASB
- "Patterns as capital" changes the financial logic of project level SE "expense"



(a) When Project Costs Are Committed versus Incurred



(b) Information Debt is Reduced Over the Course of Project



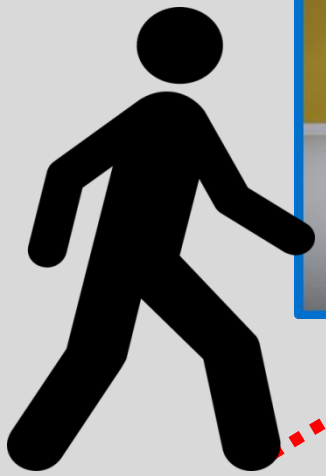
(c) Systems Engineering Information Is Generated to Reduce Information Debt

Reconceptualizing SE: Will you step through Door #3?

Door 1: What is the smallest model of a system?

Door 2: Must we repeat learning and mistakes?

Door 3: Re-conceptualizing Systems Engineering



Join the MBSE Patterns Working Group!

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

Search for:
"MBE Patterns Storybook"

References

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