Health and Pathology in Systems of Innovation

Bill Schindel, ICTT System Sciences
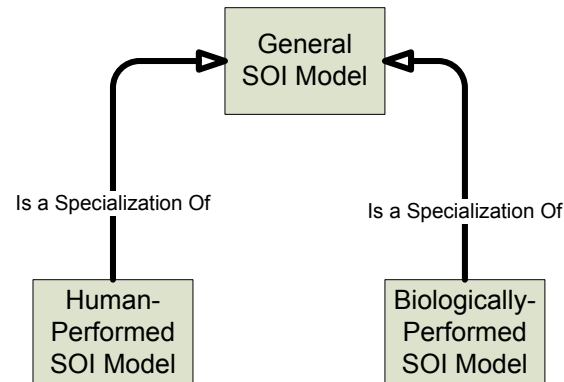Bruce Beihoff, SYSDYNETIX

Systems of Innovation Project

- **Project Lead**: Bill Schindel and Bruce Beihoff

- **Planned Deliverables:** Model of abstract General System of Innovation, including its health and pathologies, and its specialization to (1) Human-Performed System of Innovation and (2) Biologically-Performed System of Innovation.

- **Related Projects, Schedule, and Events:** This project (initiated at IW2011 by Bill Schindel and Bruce Beihoff) is stimulated by the broader System Processes and Systems Pathologies Projects (also initiated at IW2011 by Len Troncale). Based on initial work, an IS2012 paper was generated, and subsequent related model review sessions occurred at the IW2012 SSWG and IS2012 SOI Workshop meetings. This project continues during 2012.

In a nutshell . . .

- Innovation is critical to viability in changing environments.
- Innovation may itself be described as a system--the System of Innovation.
- Modeling of health and pathology improves understanding of systems.
- This project is concerned with modeling health and pathology in Systems of Innovation.
- Our (3) modeled patterns span innovation in (A) Nature and (B) Human-Performed Innovation:

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                    ┌──────────────┐
                    │   General    │
             ┌─────►│  SOI Model   │◄─────┐
             │      └──────────────┘      │
             │                            │
    Is a Specialization Of        Is a Specialization Of
             │                            │
    ┌────────┴─────┐            ┌─────────┴──────┐
    │    Human-    │            │  Biologically- │
    │  Performed   │            │   Performed    │
    │  SOI Model   │            │   SOI Model    │
    └──────────────┘            └────────────────┘
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- We believe that by including the scope of the System of Innovation in this pattern, we have engaged several important historical concerns with complex systems--this is being tested as our project proceeds, including this workshop.
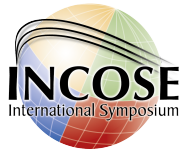
Model-based Approach Used Here

- Modeled system concepts we discuss are drawn from the S* Metamodel:
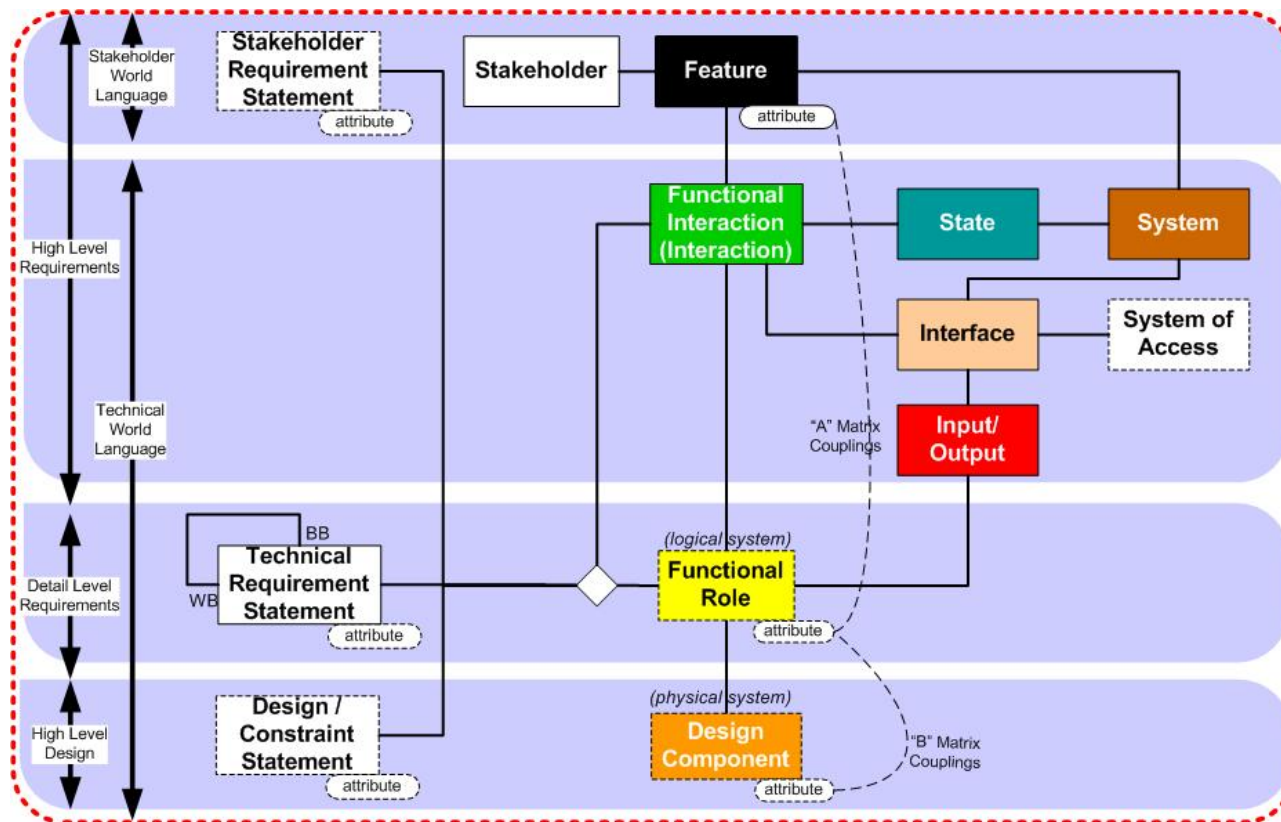

Summary of S* Metamodel

Working definition of innovation

- For this project, we define "innovation" as the _realization of significantly enhanced stakeholder benefit_:

    - Distinguishes Innovation from Invention, Novelty, Ideation, Creativity, which become possible parts of, but not all of, Innovation.

    - Our definition needs to be as effective for the natural world of biological systems as it is in the commercial world of engineered systems.

    - Some resulting abstractions (e.g., "stakeholder") may be unfamiliar to biologists or engineers, but we believe add insight in both domains.

    - This level of abstraction is not without precedent (Rosen, 1991; Kineman, 2011)

The Context of the System of Innovation (SOI)

- Shows relationship between three <u>logical</u> systems:
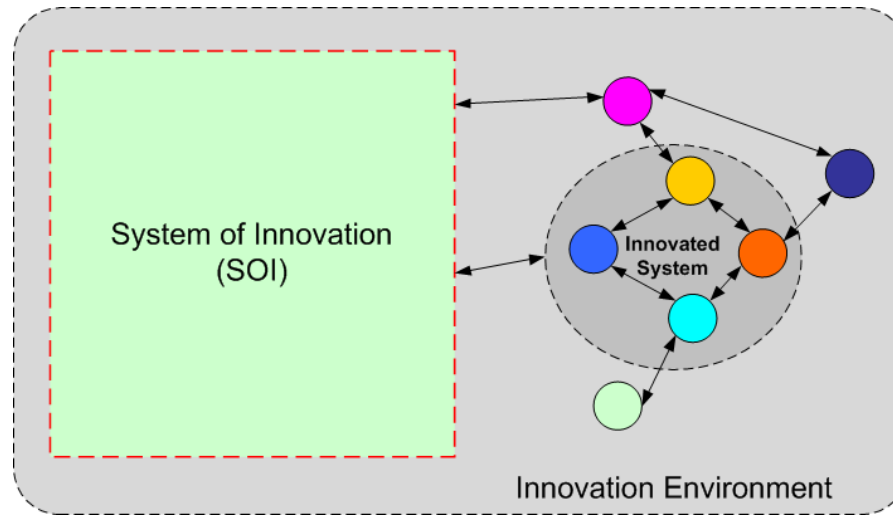
<u>The Innovated System</u>: The system which results from innovation. Also called the "Target System", because it is the target of the innovation process.

<u>The Innovation Environment</u>: The system within which the Innovated System and System of Innovation will reside, including other actors.

<u>The System of Innovation (SOI)</u>: The logical system that, interacting with the other two systems, accomplishes the innovation process.

# The Context of the System of Innovation (SOI)

These are <u>Logical</u> Systems (roles)—not physical allocations:
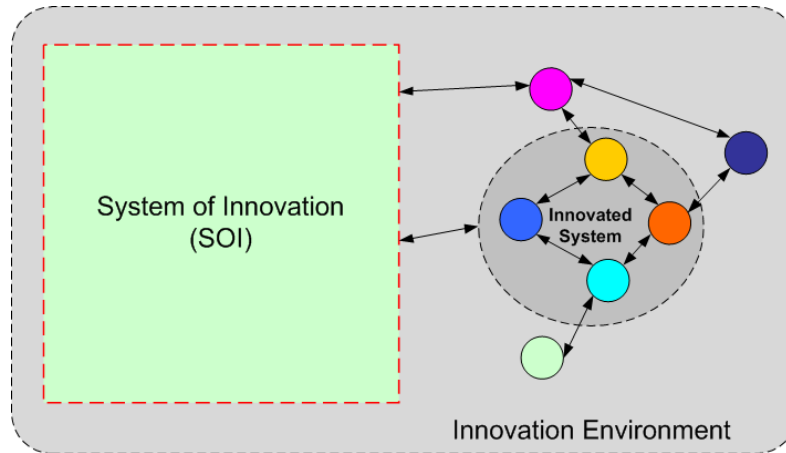
- Innovated System

- Innovation Environment

- System of Innovation (SOI)

- These are **<u>behaviors</u>**, visible through external interactions, and not boundaries of physical systems:

  - Aspects of the SOI and Innovated System can occur in ("Be allocated to") a single physical system;

 - As in, for example, a biological cell

Specialized Innovation Domains
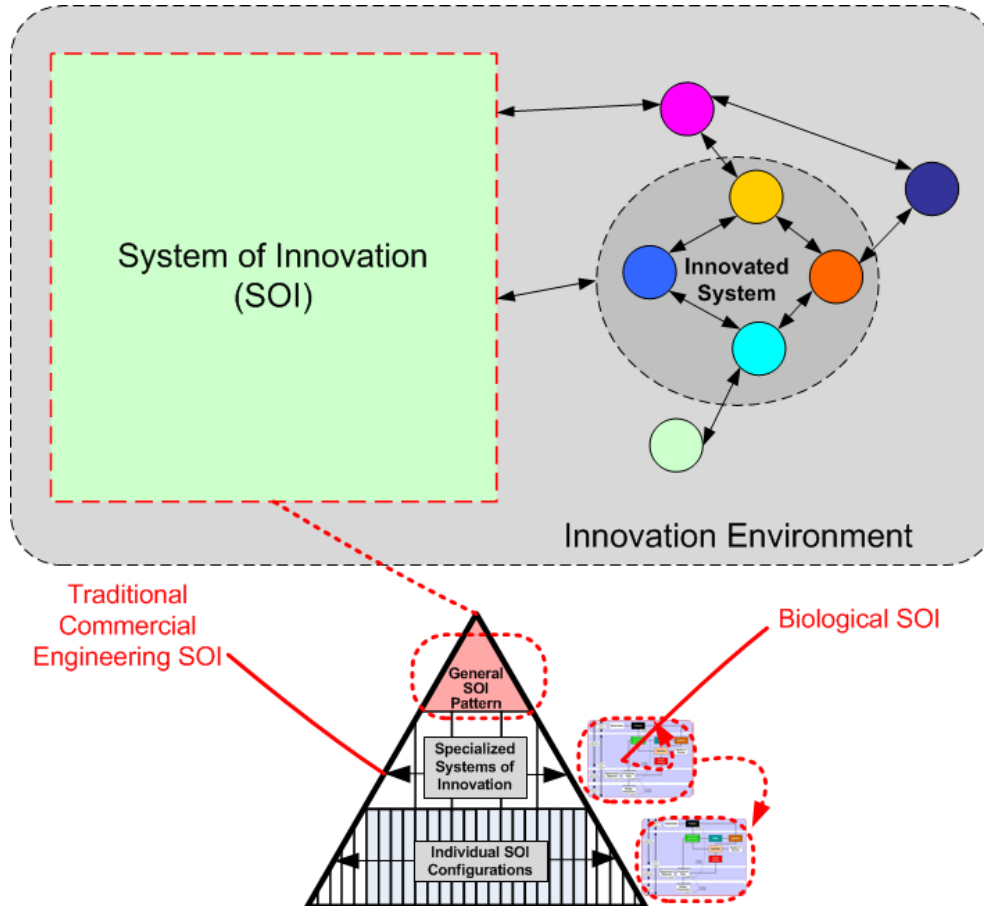
- We want this model to apply across a diverse range of natural world and human-engineered world systems.
- Because of the differences in how these domains embody innovation, the constructs of our SOI model will be more abstract than either.
- We are interested in what we can learn from the general model that can be specialized to fit the different domains.
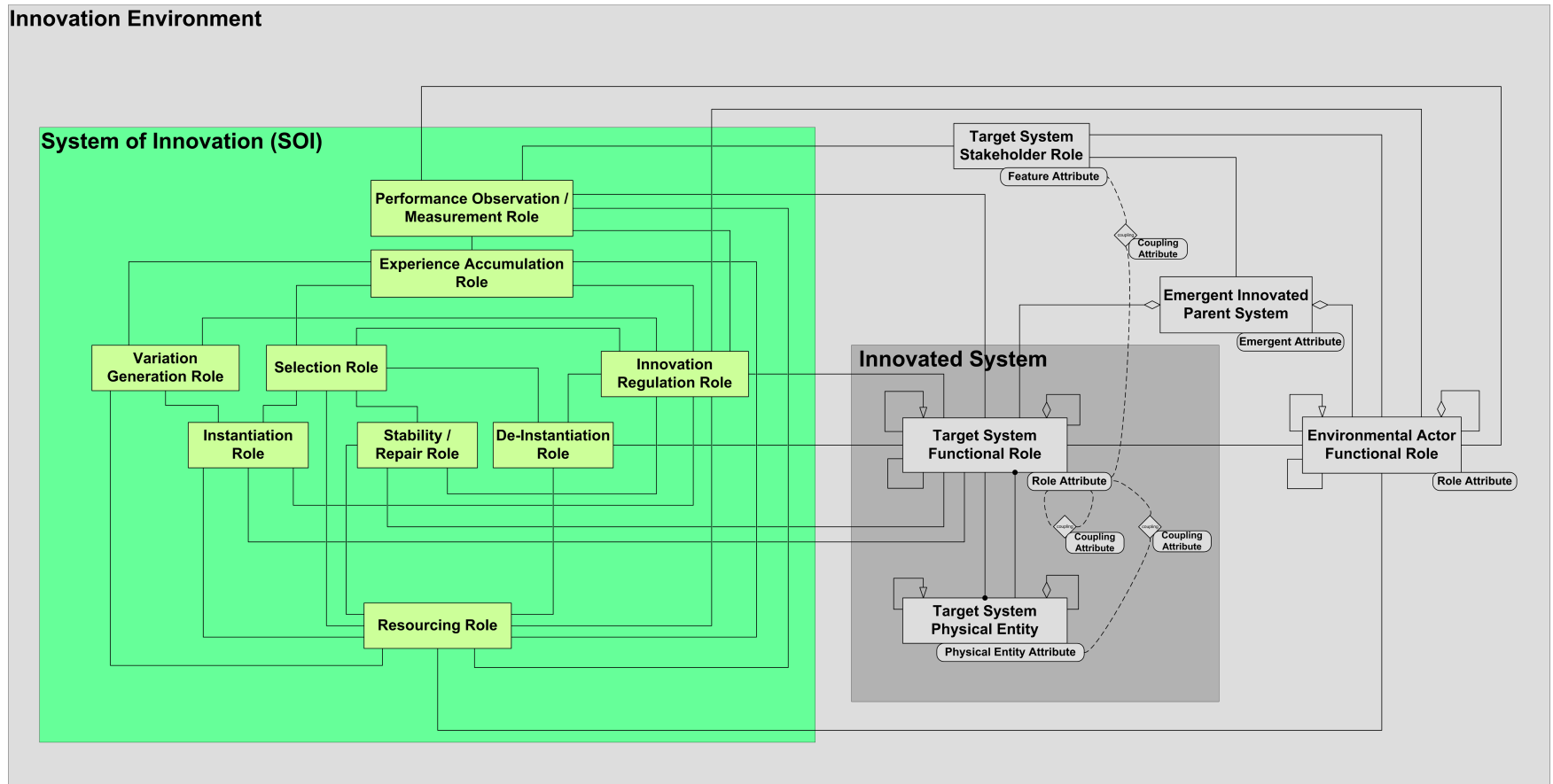
Logical Architecture of the SOI

- We partitioned the SOI "black box" into a logical architecture:
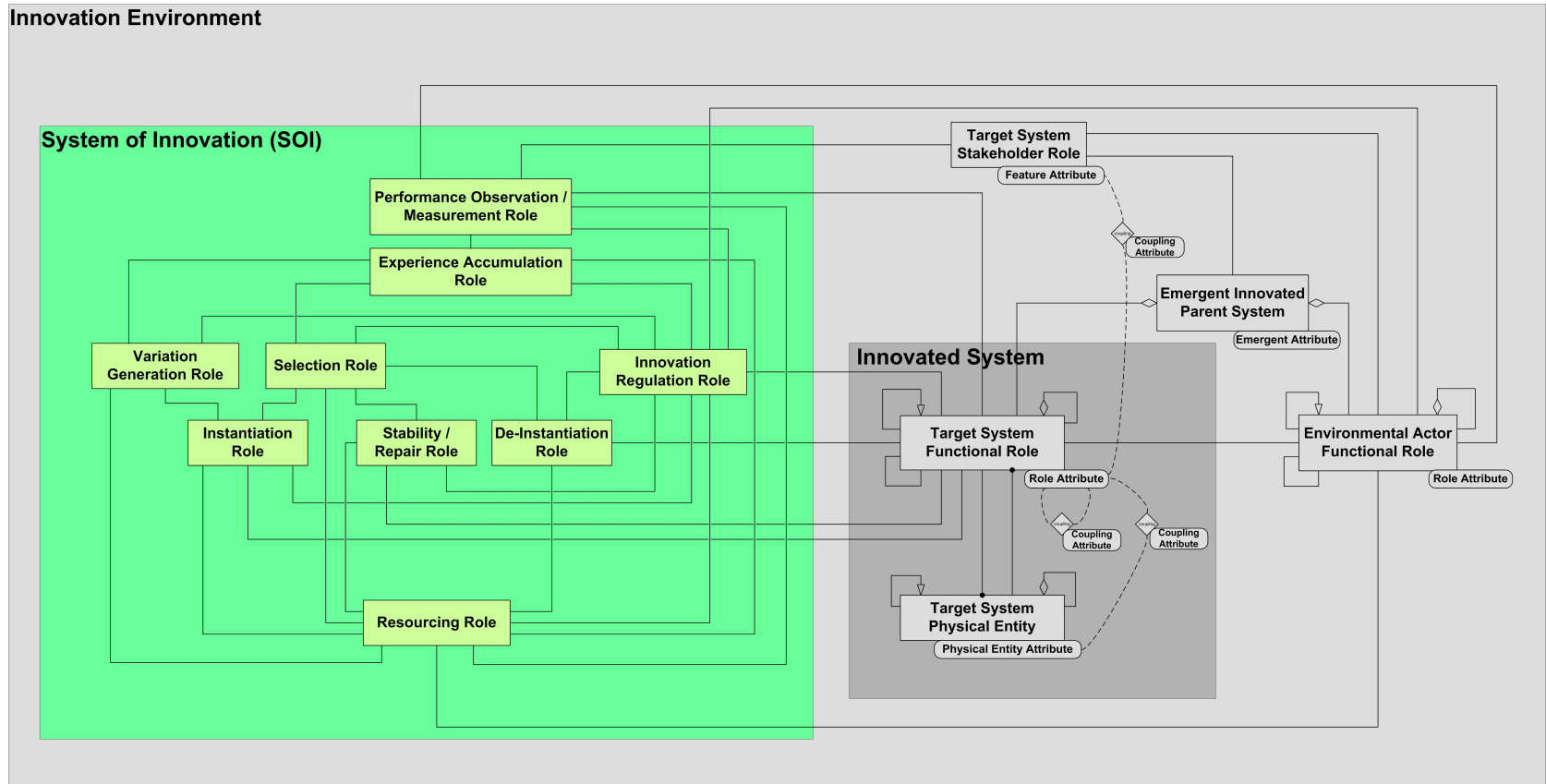
The lines represent interaction relationships, along which I/Os are exchanged: Energy, Force, Mass, Information.
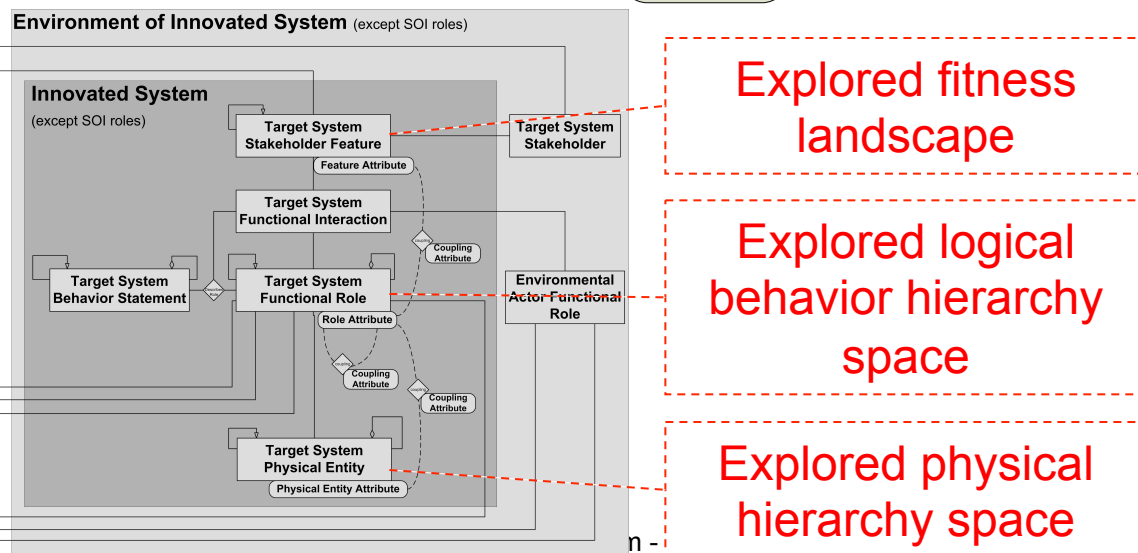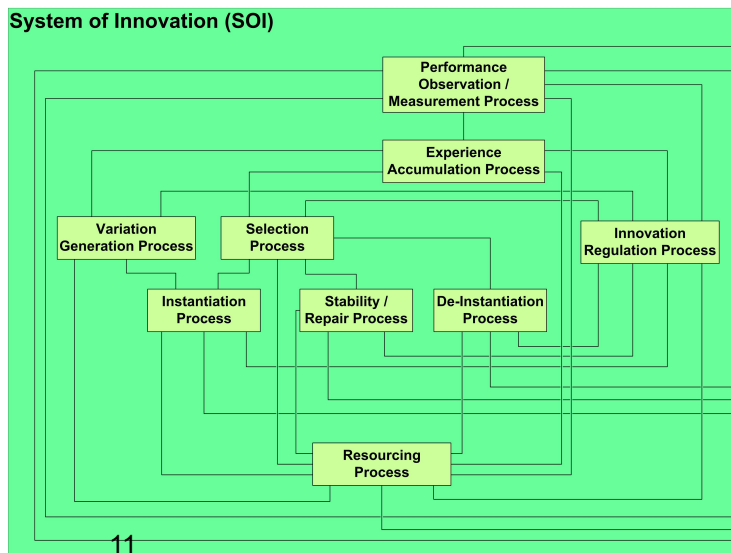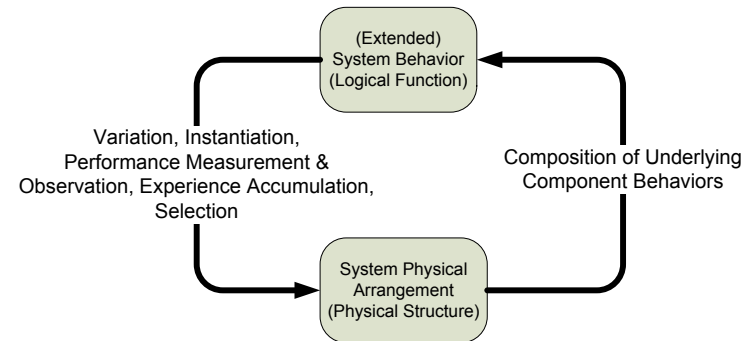
Logical Architecture Definitions

- Each logical role is a partitioning of SOI behavior.
- Each role (block) is defined in the Attachments

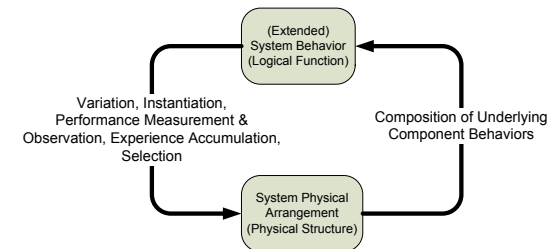# Exploring configuration spaces for logical and physical systems

- Innovation explores configuration space—both logical (behavior) and physical entities—at multiple hierarchical levels.

- Trying different physical entities leads to their behaviors, which in turn are observed and selected, in turn impacting on physical configurations again, in a continuing cycle.
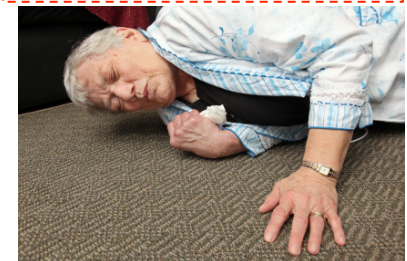

(Extended) System Behavior (Logical Function)

Variation, Instantiation, Performance Measurement & Observation, Experience Accumulation, Selection

Composition of Underlying Component Behaviors

System Physical Arrangement (Physical Structure)

System of Innovation (SOI)

Performance Observation / Measurement Process

Experience Accumulation Process

Variation Generation Process

Selection Process

Innovation Regulation Process

Instantiation Process

Stability / Repair Process

De-Instantiation Process

Resourcing Process

Environment of Innovated System (except SOI roles)

Innovated System (except SOI roles)

Target System Stakeholder Feature

Feature Attribute

Target System Stakeholder

Target System Functional Interaction

Target System Behavior Statement

Target System Functional Role

Coupling Attribute

Role Attribute

Environmental Actor Functional Role

Coupling Attribute

Coupling Attribute

Target System Physical Entity

Physical Entity Attribute

Explored fitness landscape

Explored logical behavior hierarchy space

Explored physical hierarchy space

11

Exploring configuration spaces for logical and physical systems

Humorous example (Rogow, 2011) of <u>exaptation</u>:

– Rubber mats were installed on a sidewalk in front of a Sydney bar, to reduce the delivery noise of arriving beer carts.

– Led to later observation that when rowdy patrons fell on the (covered) sidewalk, they had fewer injuries.

– So, scores of Sydney bars added rubber mats to their sidewalks and interiors.

– Illustrates scope & importance of "observation" as innovation Discovery Skill (Schindel et al, ASEE 2011)
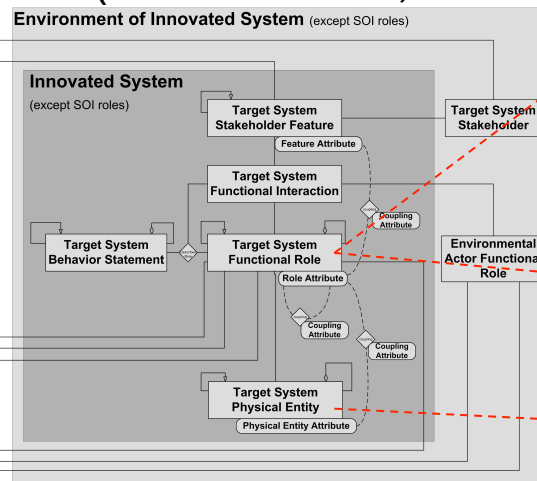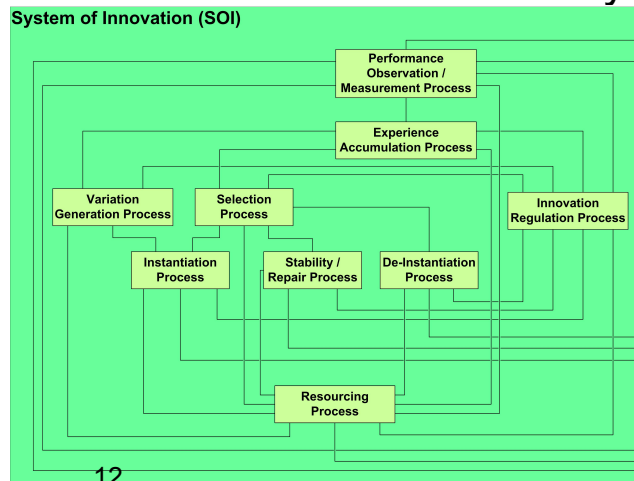

(Extended) System Behavior (Logical Function)

Variation, Instantiation, Performance Measurement & Observation, Experience Accumulation, Selection

Composition of Underlying Component Behaviors

System Physical Arrangement (Physical Structure)

Behavior: Noise Reduction

Behavior: Injury Reduction

Physical Component: Rubber Mat

System of Innovation (SOI)

Performance Observation / Measurement Process

Experience Accumulation Process

Variation Generation Process

Selection Process

Innovation Regulation Process

Instantiation Process

Stability / Repair Process

De-Instantiation Process

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Environment of Innovated System (except SOI roles)

Innovated System (except SOI roles)

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Target System Functional Role

Role Attribute

Environmental Actor Functional Role

Coupling Attribute

Coupling Attribute

Target System Physical Entity
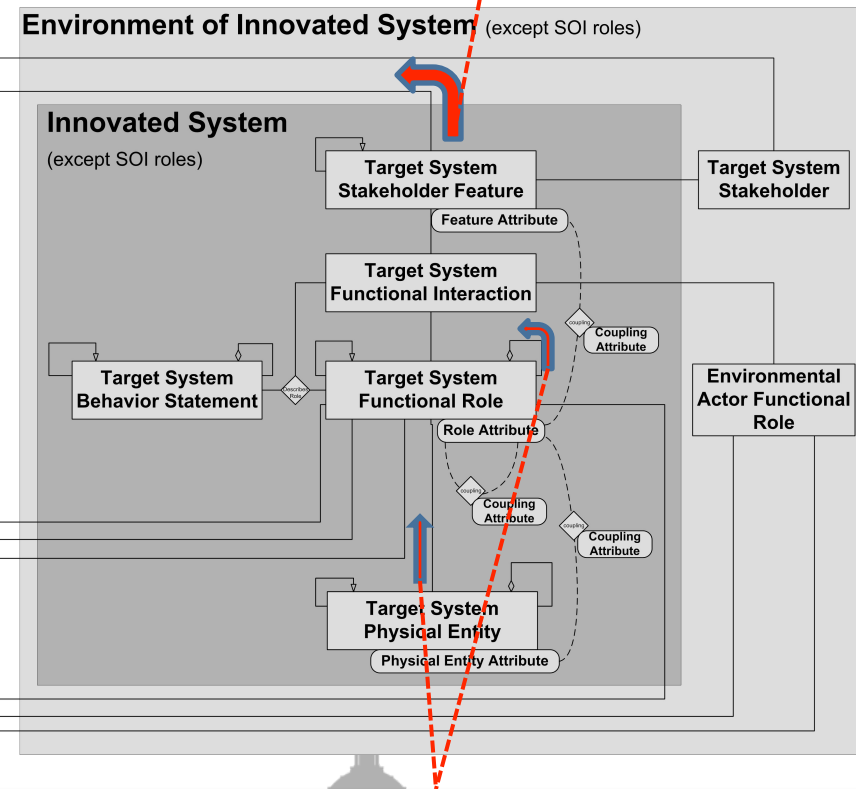
Physical Entity Attribute

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Mapping of Aristotelian Cause Classes to the Systems of Innovation Framework

Formal Cause: The pattern (form) describing the system

Final Cause: The advantage for which selection has occurred
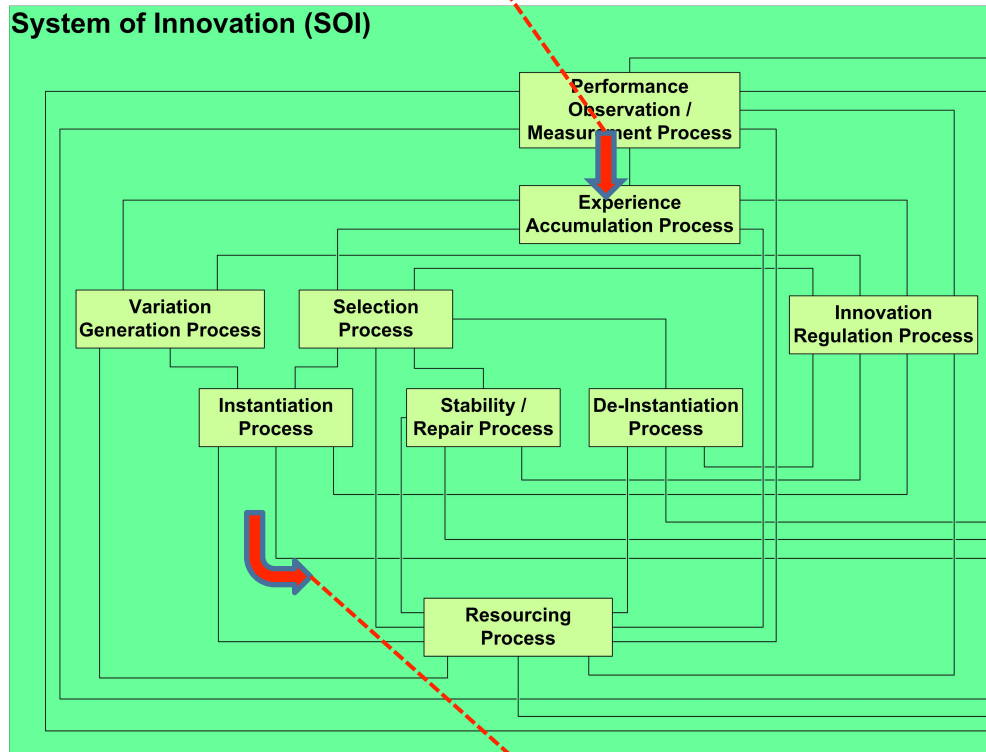
**Efficient Cause**: That which creates a system instance

Material Cause: The interacting behaviors or physical allocations from which behavior arose

13

Conceptual Patterns Emerge at Different Abstraction Levels

(SOI is complete enough to be closed under efficient cause, per R Rosen)

SOI Pattern
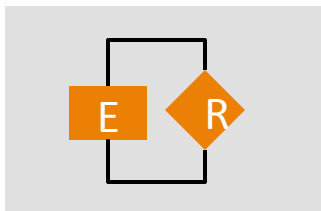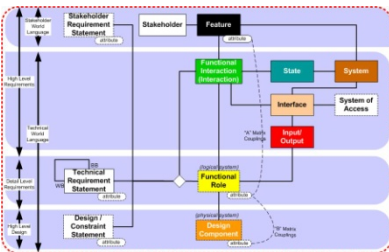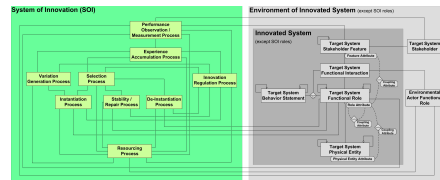
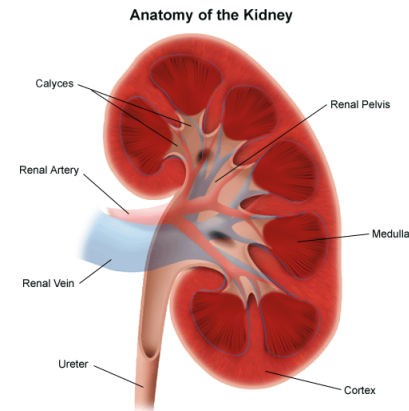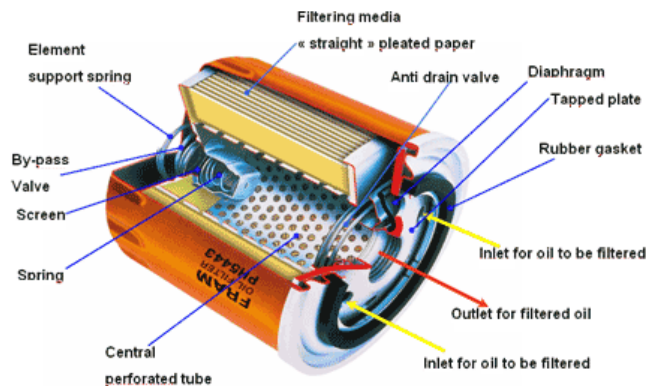Final Cause
Formal Cause
Efficient Cause

Used to Construct

S* Metamodel
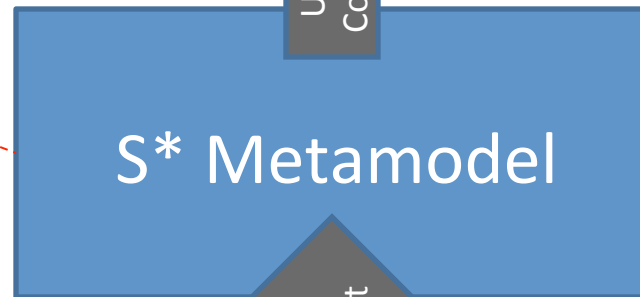
Material Cause

Used to Construct

Entity-Relationship Paradigm

Working definition of system pathology


- For our purposes, we define a <u>pathology</u> of a system as:
  - *any failure of the system to perform (externally or internally) in the manner typical of other systems of the same type in like external circumstances.*
  - This includes performing within a family statistical envelope.
- Thus, the typical locomotion rate of a tortoise is not a pathology, even though it is slower than a hare.
- Conversely, the failure of a filter caused by a break in its filtration media (permitting contaminants to flow through) is (or causes) a pathology.

SOI: Feature Overview Diagram
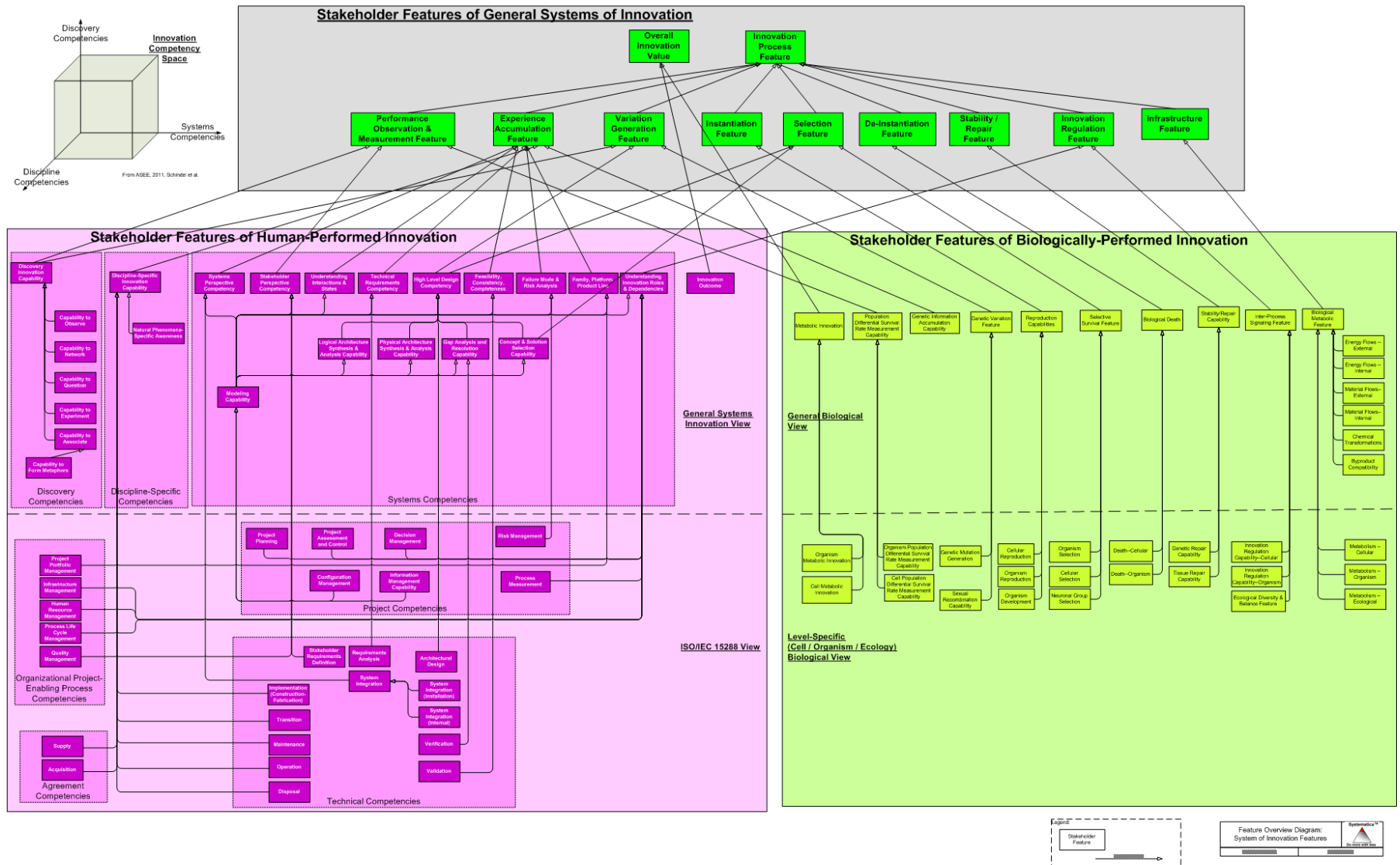
SOI: Feature Overview Diagram
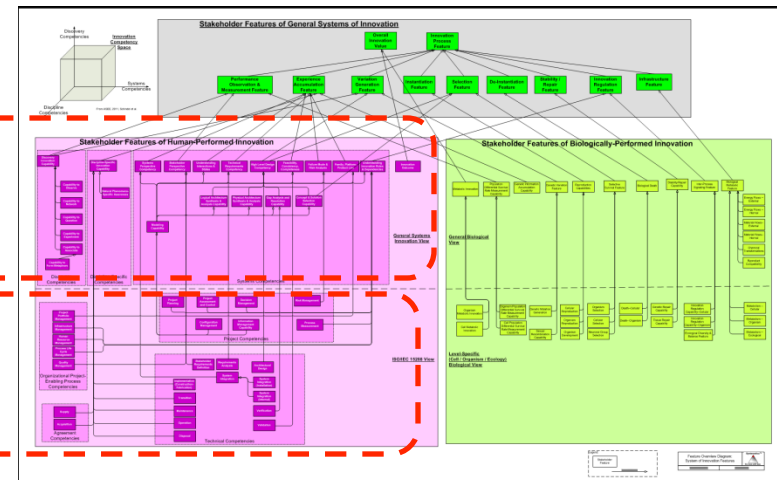
Features of General SOI
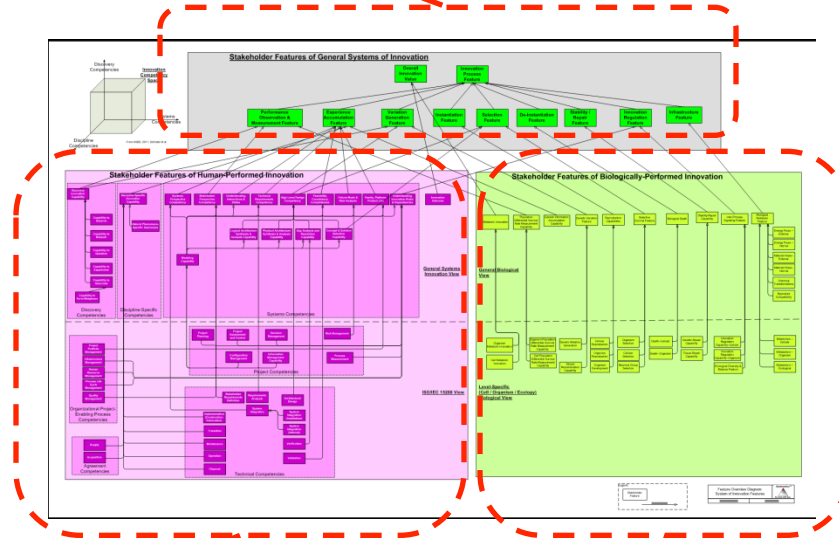
Features of Human-Performed Innovation

Features of Biologically-Performed Innovation
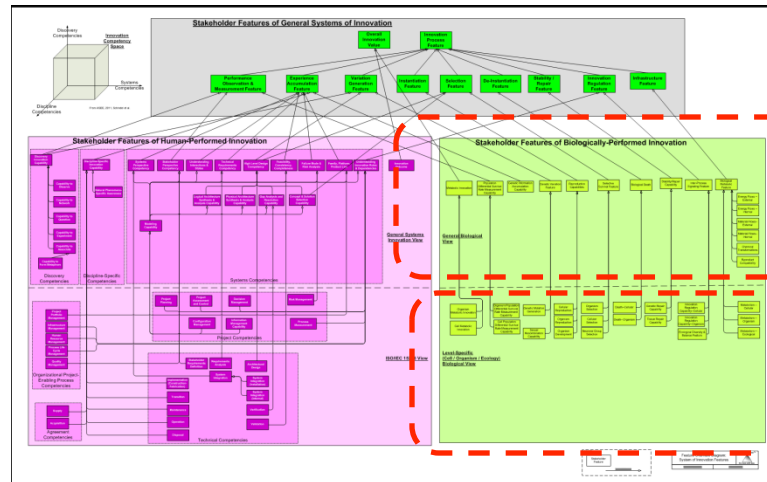
SOI: Feature Overview Diagram

Features of General Human-Performed Innovation

Features Specialized to ISO / IEC 15288
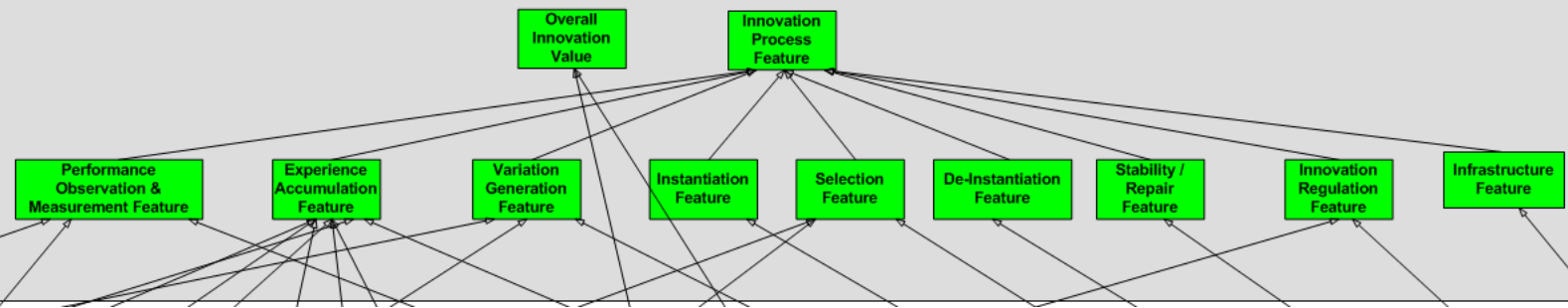
SOI: Feature Overview Diagram

Features of General Biologically-Performed Innovation

Features Specialized Specific Biological Hierarchy Levels

Feature Definitions for General System of Innovation

Each Feature of the General System of Innovation is defined in the Attachments.
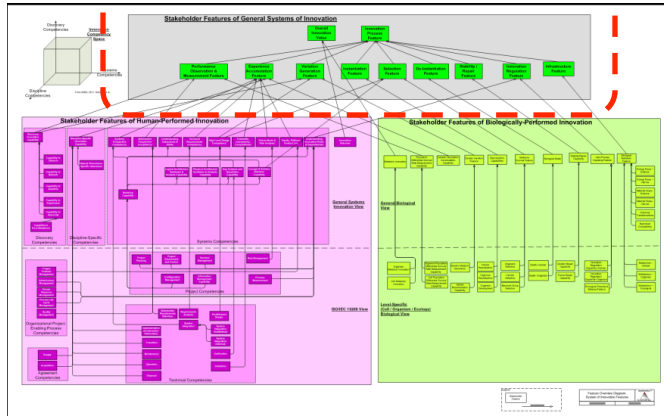
An Initial Catalog of SOI Pathologies
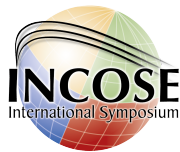
- For each pathology, we want to model:
  - Its behavioral description
  - Its impact or potential impact on innovation (including prognosis)
  - Potential causes of the pathology
  - Means of detection of the pathology (diagnosis)
  - Potential treatments for the pathology

# Initial Catalog of SOI Pathologies
(Human Performed Innovation Case)

Pathologies of Feedback and Observation	
	Distortion
	Interruption
	Accuracy and Drift
	False Lags and Leads
Pathologies of Environmental Boundary Dynamics	
	Policies of Government
	Policies of Industries
	Intellectual Property Policies
Pathologies of Knowledge Management and Flows	
	Lost data and Information
	Distortion of Interpretation
	Interruption of Interpretation and Flows
	Accuracy Drift of Information as Processed
	False leads and lags
Pathologies of Decision Making and Flows	
	Distortion of Reasoning
	Prejudice
	Distortion of Risk Model
	False Lags and Leads
Pathologies of Inventing and Innovation Development	
	Distortion of Validation and Verification
	Poor Modelling Practice
	Poor Experimental Practice
	Poor Design Practice
	Accuracy and Drift

A Particle Dynamics Model Approach Lubricant Filtration Example – Scientific Non-Linear Causal
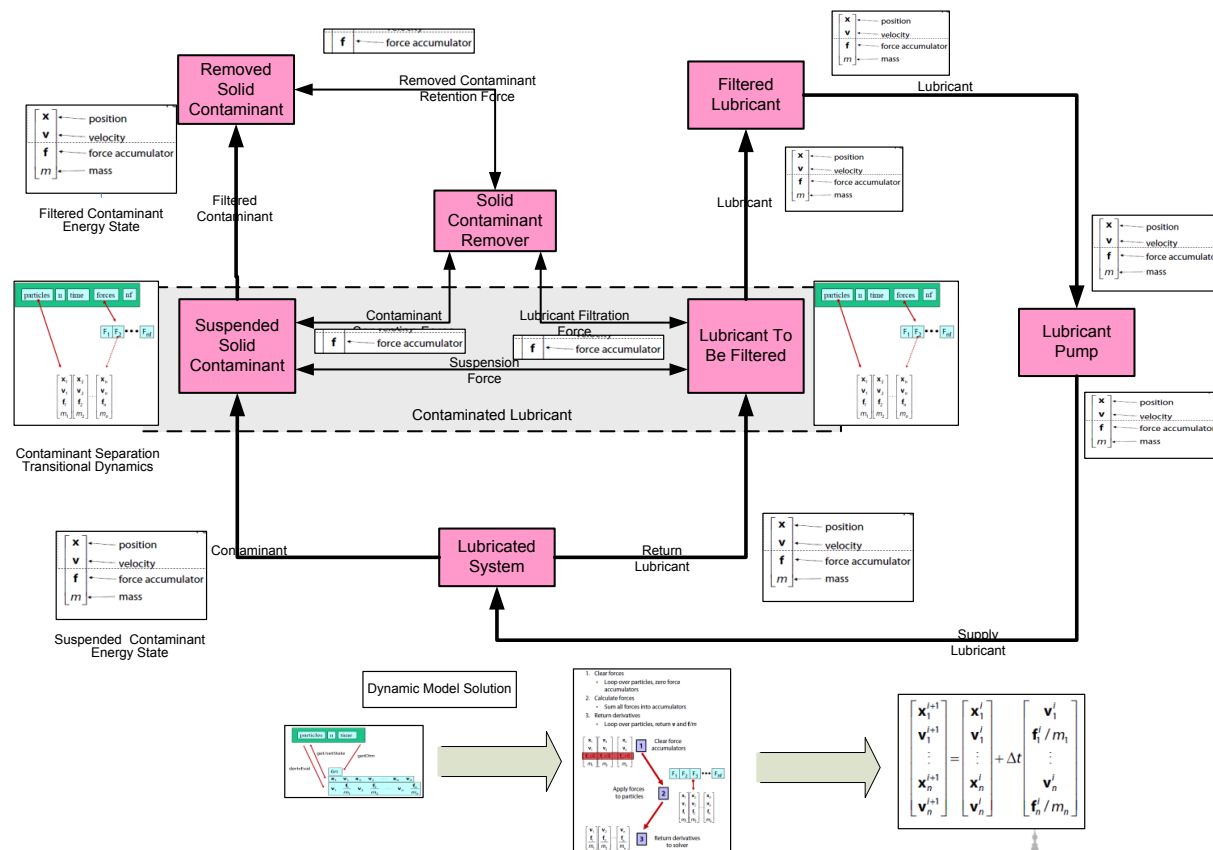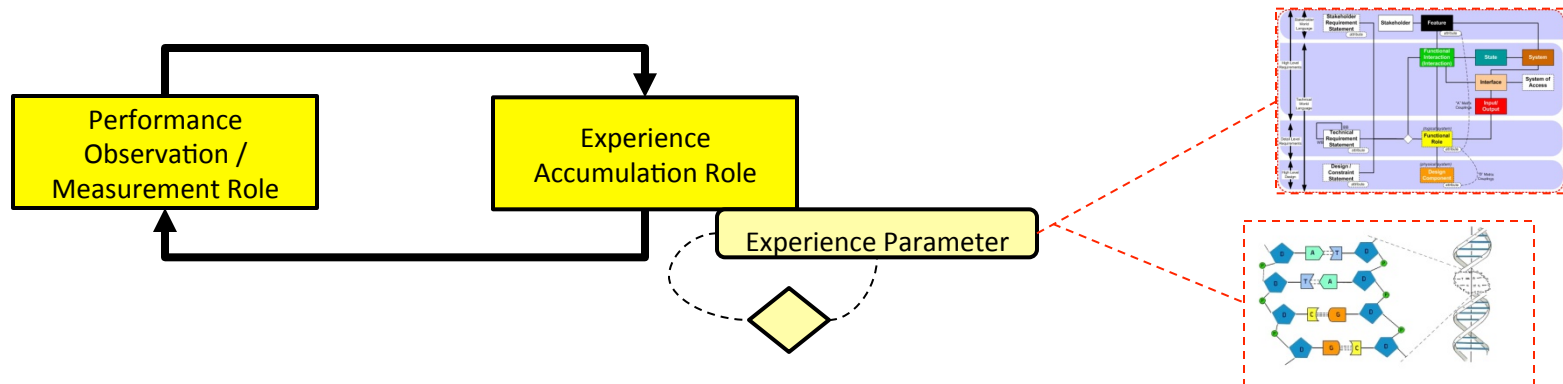
SOI Interactions Model

| Interaction Name	Definition	Performance Observation / Measurement Role	Experience Accumulation Role	Variation Generation Role	Selection Role	Instantiation Role	Stability / Repair Role	De-Instantiation Role	Innovation Regulation Role	Resourcing Role	Target System Stakeholder Role	Target System Functional Role	Environmental Actor Functional Role	Emergent Innovated Parent System
Perform Target System Interactions	The interaction of the Innovated System with its Environment, for which its behavior has been selected.											X	X	X
Experience Stakeholder Outcome	The interaction through which the Target System Stakeholder Role experiences behaviors having stakeholder utility or value.										X		X	X
Observe and Measure Performance	The interaction through which the System of Innovation observes and measures the real or projected performance of the Innovated System, as valued by the Target System Stakeholder.	X							X	X	X		X	
Analyze and Accumulate Experience	The interaction through which the System of Innovation analyzes the real or projected target system performance measured or observed, and analyzes or otherwise accumulates that performance as experience for future reference.	X	X						X	X				
Generate Variation	The interaction through which the System of Innovation generates variant configurations of the real or modeled Innovated System.		X	X		X			X	X				
Perform Selection	The interaction through which the System of Innovation selects real or modeled instances of the target system, as future instantiation (or de-instantiation) candidates.		X		X	X			X	X				
Instantiate System	The interaction through which the System of Innovation creates real or modeled instances of the target system.					X			X	X		X		X
Maintain System	The interaction through which the System of Innovation maintains stable instances of the target system, including prevention or correction (repair) of faults.						X		X	X		X		X
De-Instantiate System	The interaction through which the System of Innovation de-instantiates real or modeled instances of the target system.							X	X	X		X		X
Distribute Innovation Resources	The interaction through which the System of Innovation allocates and distributes resources (e.g., flow of energy, mass, financial, or other types) to the innovation roles that consume them. This can include collection of by-products (waste materials, energy, etc.) from those roles.	X	X	X	X	X	X	X	X	X				
Regulate Innovation	The interaction through which the System of Innovation maintains the stability of the innovation process.	X	X	X	X	X	X	X	X	X				

Interaction: Analyze and Accumulate Experience

Definition:	The interaction through which the System of Innovation analyzes the real or projected target system performance measured or observed, and analyzes or otherwise accumulates that performance as experience for future reference.
Attributes	
Attribute Couplings	
Other	Note feedback loop of prediction versus observation.

Role Allocation Configurations

Generic Role		Biological Genetic Configuration	Unrecorded Human Knowledge	Human Prose Recording	S*MBSE Configuration	S*PBSE Configuration
<<Experience Parameter>>		DNA			S*Metamodel	Configurable S*Metamodel

Assembled SOI Interaction Loops

Modeling System World

Modeled System World
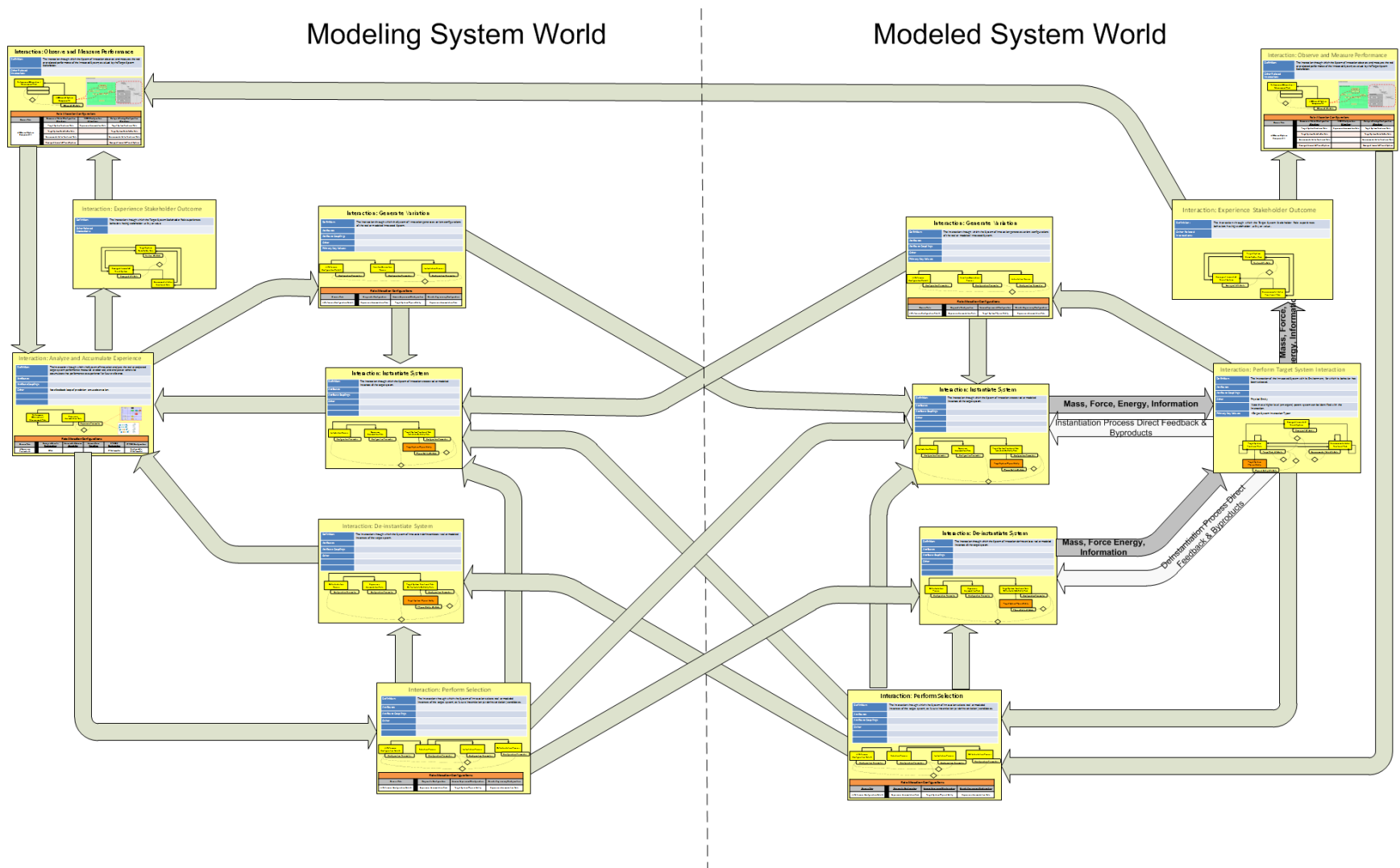
Conclusions and Future Work

1. We have started the Systems of Innovation (SOI) Logical Architecture Model, Features Model, and Interactions Model, including related examples and insights. This work continues in 2012.

2. We have begun accumulating the catalogue of SOI Pathologies, and this work continues in the related SSWG sub-project, improving understanding of SOI effectiveness. This is important for assessing and improving of SOI effectiveness, including preventing or "treating" SOI Pathologies.

3. For human-performed innovation, there are needs to improve historical functional modelling approaches by developing further science and related models. This includes integration of science-based models of system interactions, phenomena, and mechanisms.