34th Annual INCOSE international symposium

hybrid event

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One Model to Rule them All … and Through Emergence, Bind Them

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University of Adelaide & Shoal Group

Prof Stephen C. Cook
University of Adelaide & Shoal Group

Dr David Harvey
University of Adelaide

Motivation…

Models have always been central to understanding systems and in the engineering of systems, whether captured in text and/or graphics in a document or digitally, typically labelled MBSE

"4. Model-based systems engineering, integrated with simulation, multi-disciplinary analysis, and immersive visualization environments is standard practice."

INCOSE SE Vision 2035

The future of systems engineering is model-based, leveraging next generation modeling, simulation and visualization environments powered by the global digital transformation, to specify, analyze, design and verify systems (Vision 2035)

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"One ring to rule them all, one ring to find them, one ring to bring them all and in the darkness bind them"

Gandalf, the Fellowship of the Ring (Tolkien, 1991).

Is there "One model to rule them all, one model to find them, one model to frame them all, and through emergence bind them."?

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Motivation…

"Remember, always, that everything you know, and everything everyone knows, is only a model. Get your model out there where it can be viewed. Invite others to challenge your assumptions and add their own."

Donella Meadows : Thinking in Systems

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Structure & Acknowledgement

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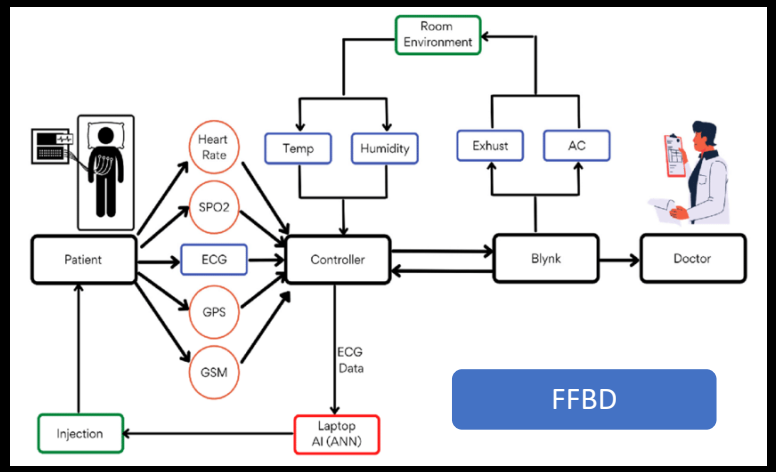
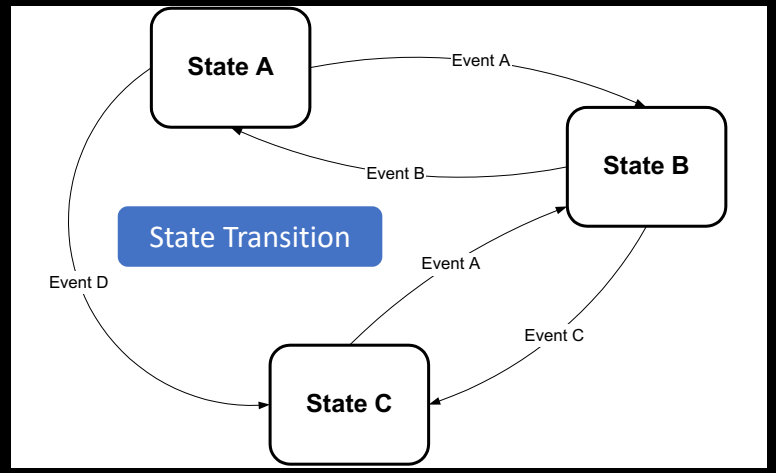
Donella Meadows : Thinking in Systems

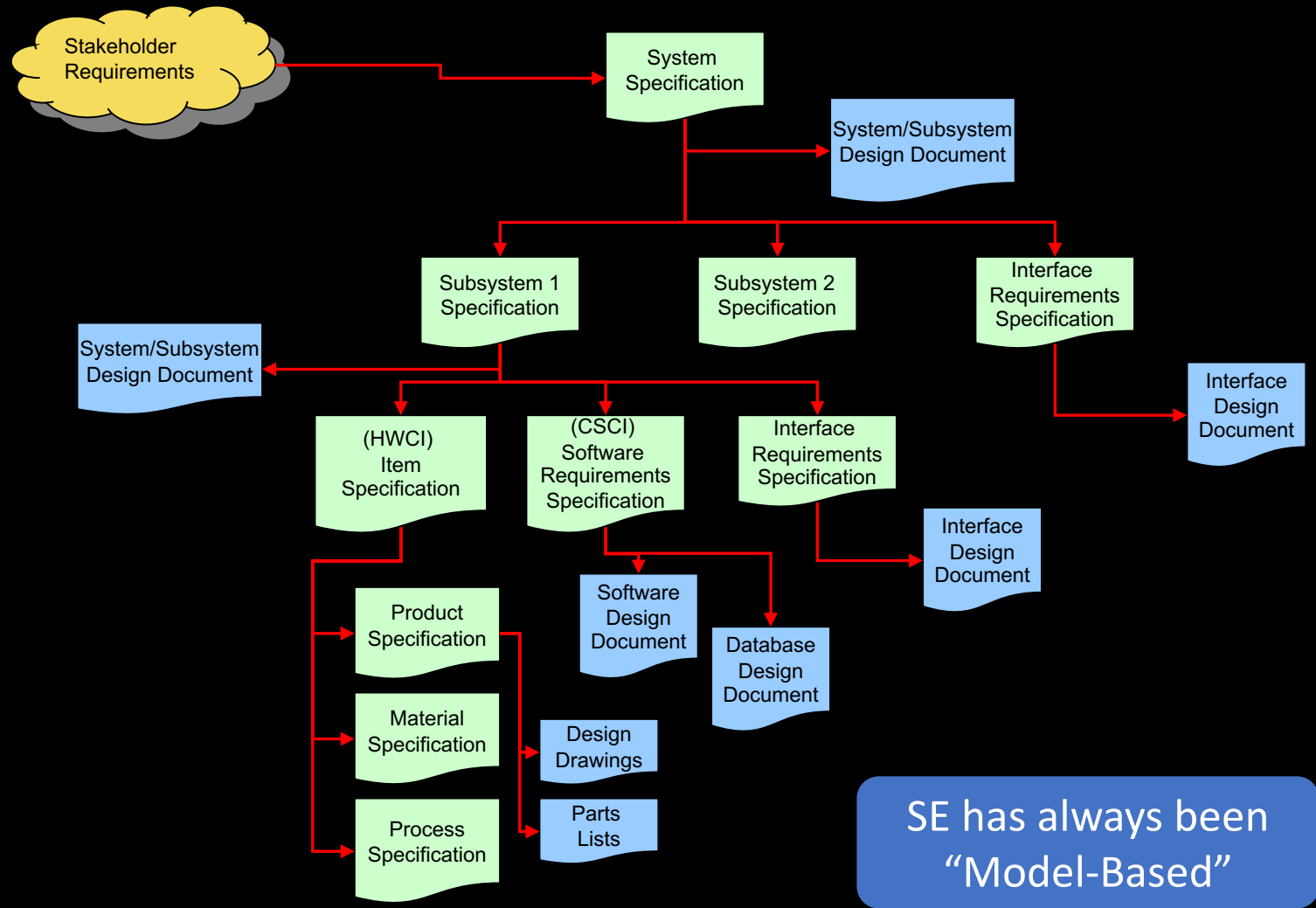
- Models in SE
- Concepts from M&S
- Systems Thinking
- Categorising Systems Models
- A "MoSM" Construct
- Key Points

Is there "One model to rule them all, one model to find them, one model to frame them all, and through emergence bind them."?

This research is supported by an Australian Government Research Training Program (RTP) Scholarship through the University of Adelaide with Shoal Group as the Industry Partner

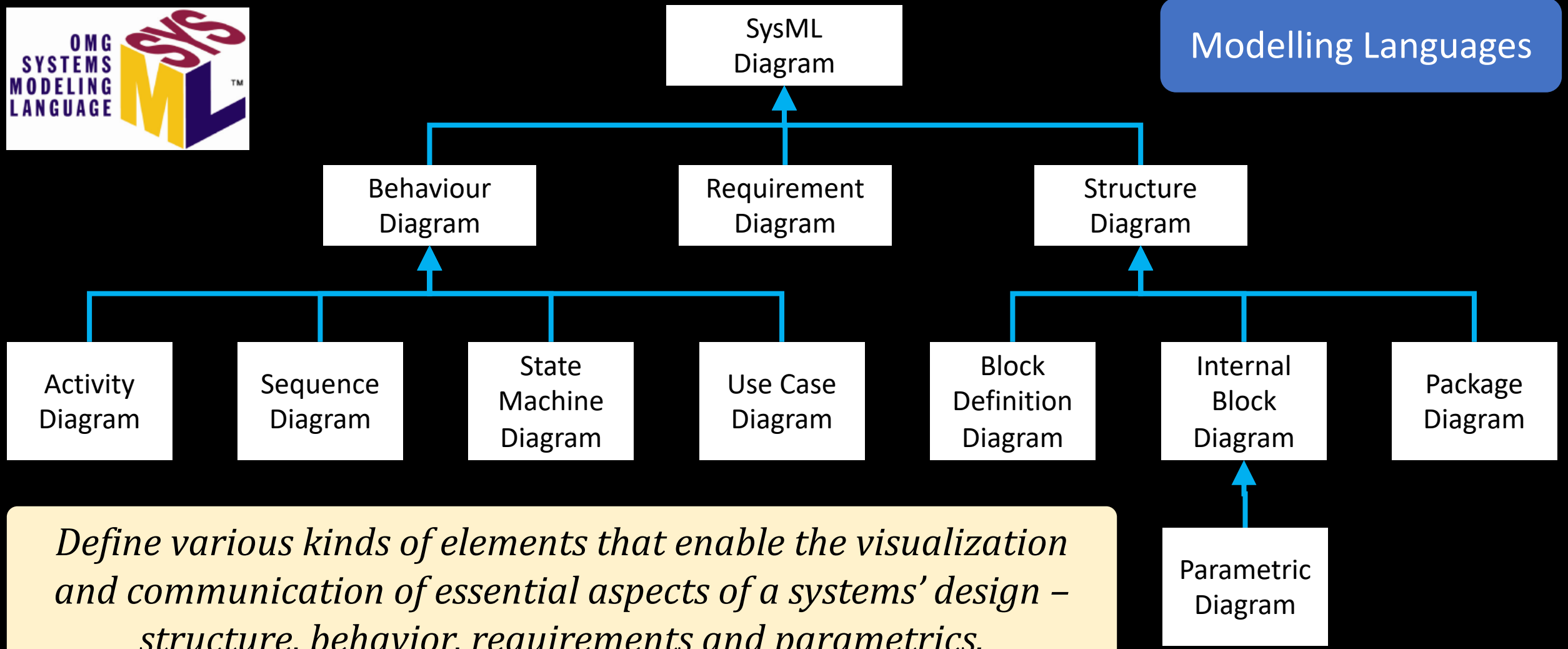




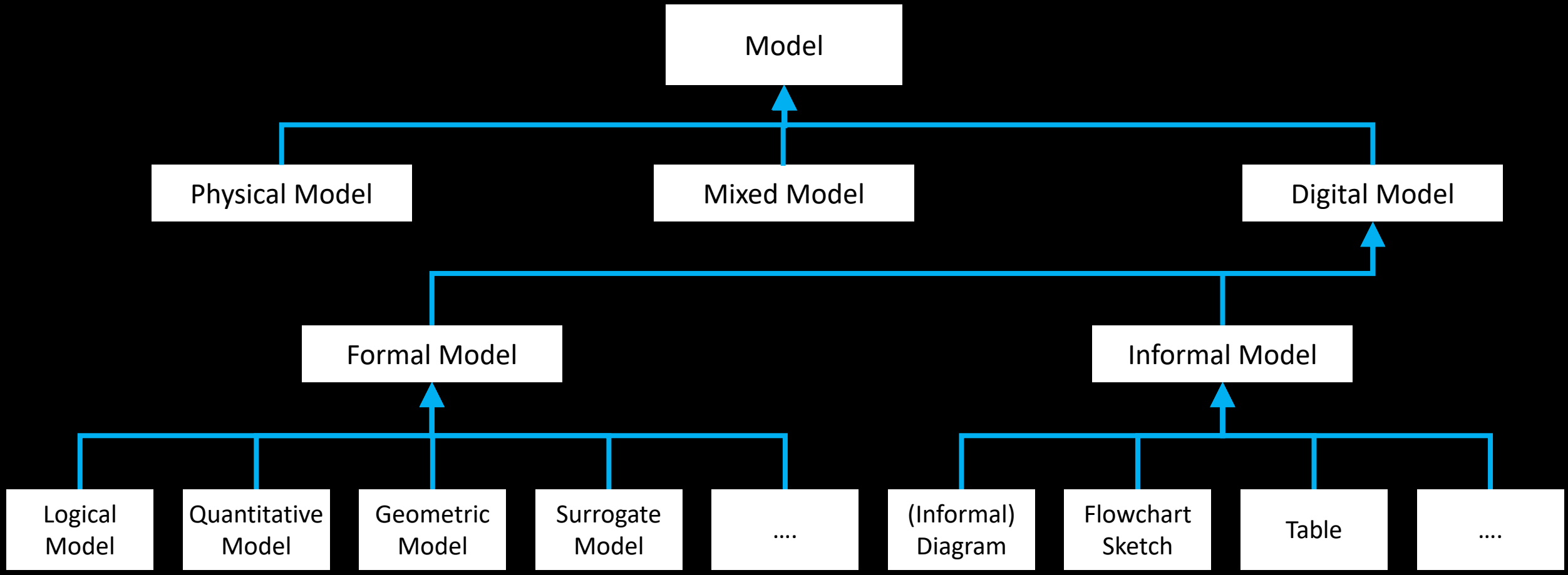


SE has always been "Model-Based"

Modelling Languages



Define various kinds of elements that enable the visualization and communication of essential aspects of a systems' design – structure, behavior, requirements and parametrics.



A Taxonomy of Systems Models – Figure 3.10 "Systems Engineering Handbook" [5th Ed]

What is a Model? What is a Simulation? What is a Simulator?

A Model is a Physical, Mathematical or Logical *abstraction* (of a System, Entity, Phenomenon, Activity or Process) for a *particular purpose* (i.e. a *suitable representation*)

A **Simulation** is an **Enactment** (Method of Implementing) a **Model** over **Time**

Image Credit – Michael Gaida (Pixabay)

A Map (**model**) of Japan

Real-Time GPS navigation (**simulation**) using "map **models**"

Image Credit – giphy.com

A ***Simulator*** ➔ The Tool that **Executes** the **Simulation**

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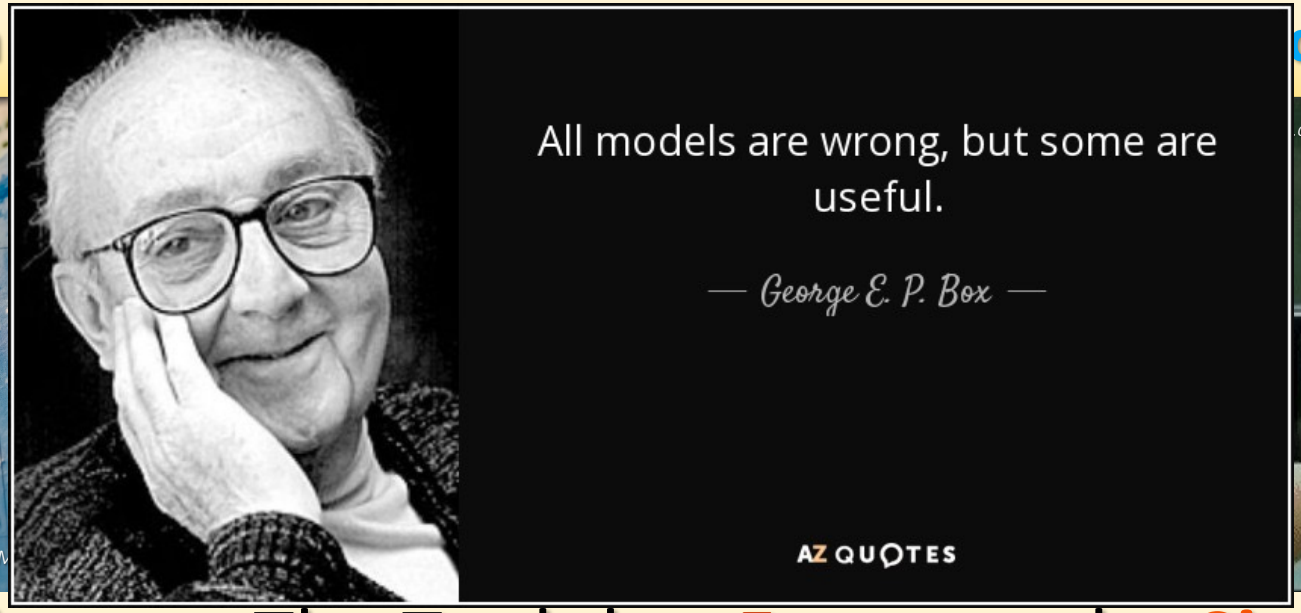
A Simulation



del over Time

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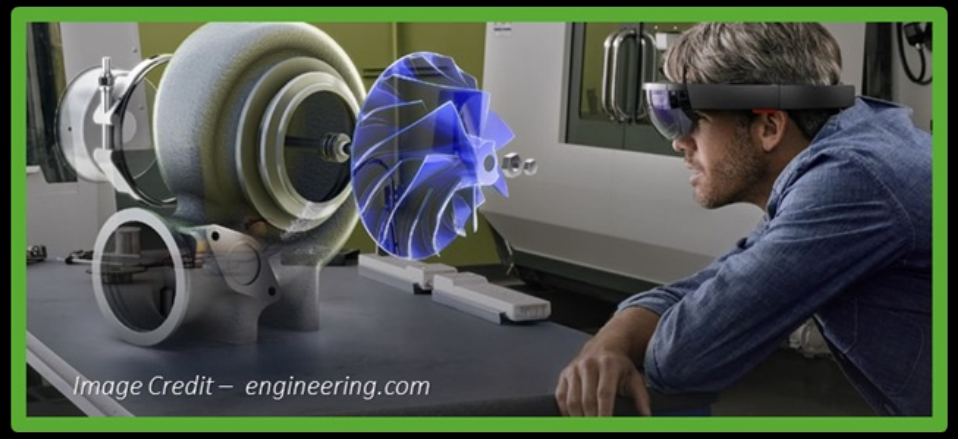


VR (Simulated Environment) ⟷ (Real Environment) AR

A ***Simulator*** ➔ The Tool that Executes the **Simulation**

Categorising Simulations

Scenario Participants

Scenario Environment	Real	Simulated
Real	**LIVE** Real Participants operating in a real-world environment	**REPLICATED** Simulated Participant/s subjected to a real-world environment
Simulated	**VIRTUAL** Real Participants operating in a simulated environment	**CONSTRUCTIVE** Simulated Participants operating in a simulated environment

Categorising Simulations

ABSTRACTION

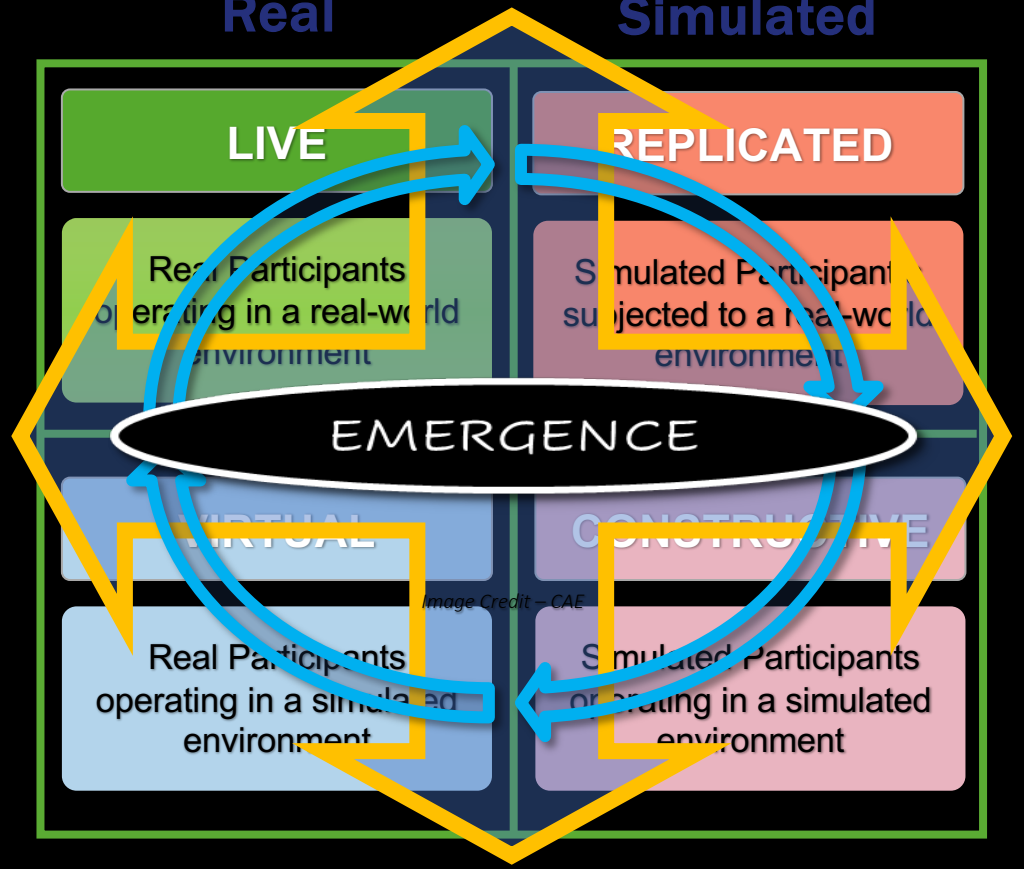
INTEROPERABILITY

Scenario Participants

Scenario Environment

BLENDED/MIXED

Typical Example of VIRTUAL and AUGMENTED REALITY (VR/AR)



JOINT/INTEGRATED

LIVE-VIRTUAL-CONSTRUCTIVE (HUMAN-SIM) or iLVC(R)

Making it "real"…

Sight

Colour

Brightness

Touch

Pressure

Temperature

Pain

Itch

Sound

Frequency

Amplitude

Direction

Smell

Chemicals

Taste

Sweet

Salty

Sour

Bitter

Umami

Image credit todayifoundout.com

ABSTRACTION

EMERGENCE

INTEROPERABILITY

Making it "real"…

- **Sight**
  - Colour
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- **Touch**
  - Pressure
  - Temperature
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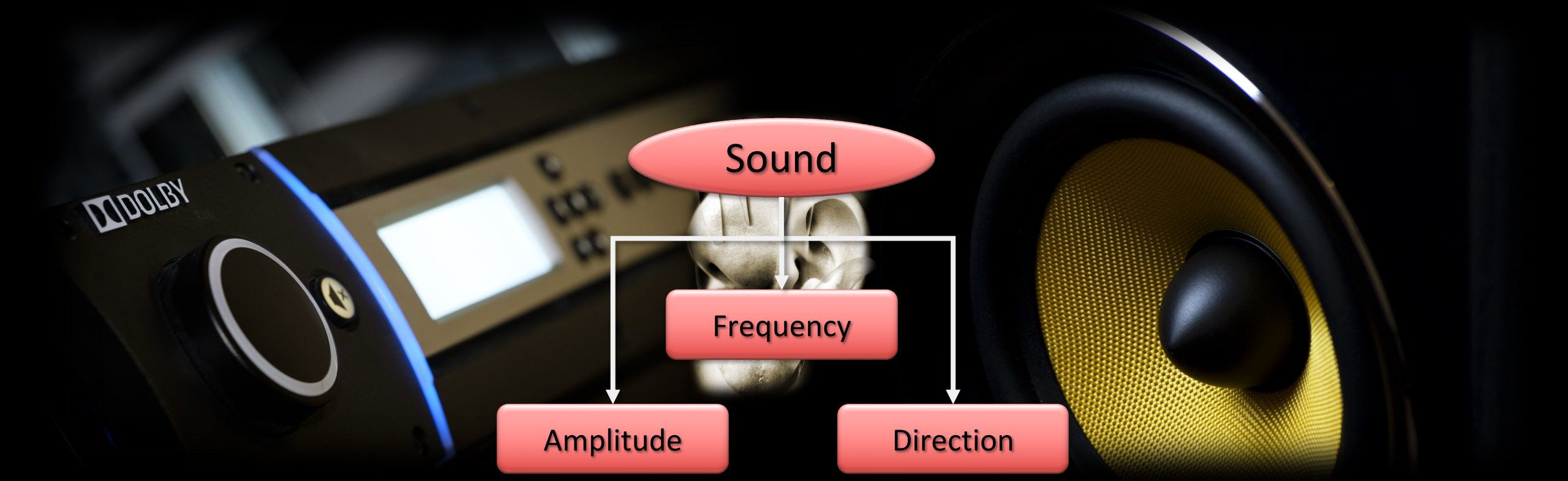
  - Umami

Image credit todayifoundout.com

ABSTRACTION | EMERGENCE | INTEROPERABILITY

Fidelity → Concept of "Goodness" or "Suitability" of a Model



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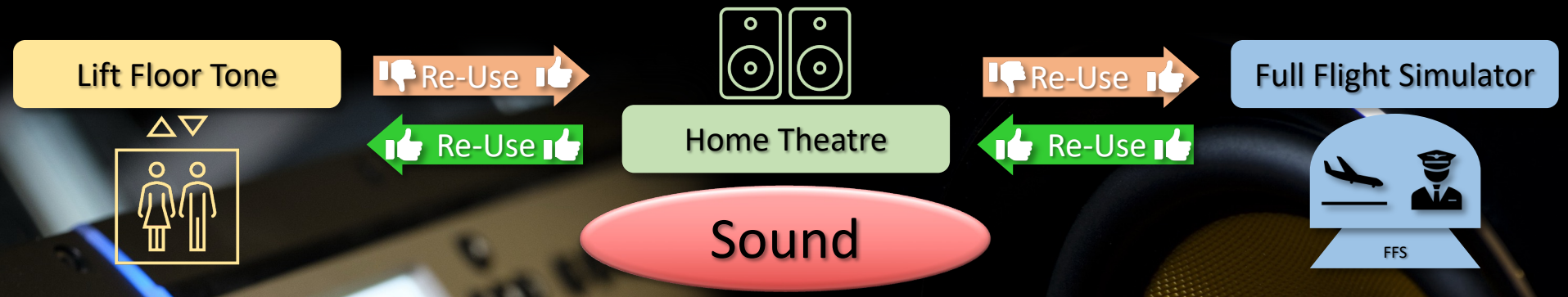
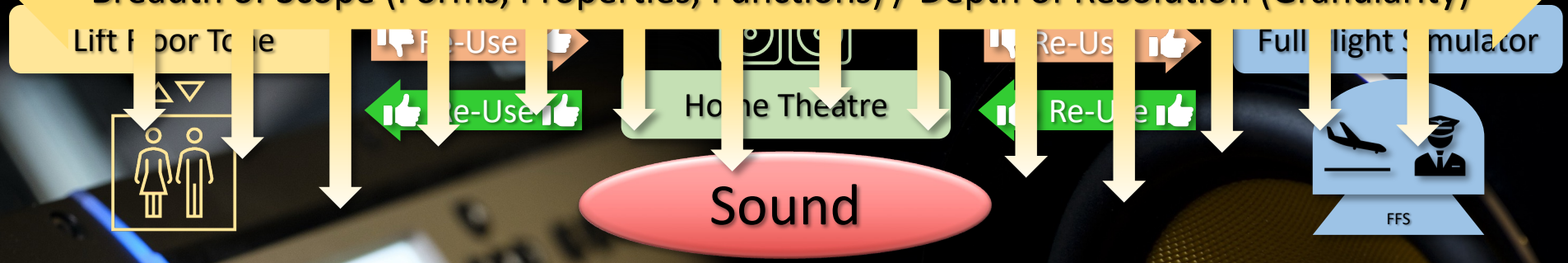


Amplitude	Fixed-On	Fixed-On/Off	Variable Range	Fully Replicated	*Resolution*
Frequency	Fixed-Pitch	Representative	Sensed Range	Fully Replicated	*Resolution*
Direction	Mono-Phonic	Stereo-Phonic	Stereo-Surround	Fully Replicated	*Resolution*

ABSTRACTION | EMERGENCE | INTEROPERABILITY

Fidelity → Concept of "Goodness" or "Suitability" of a Model

Breadth of Scope (Forms, Properties, Functions) / Depth of Resolution (Granularity)



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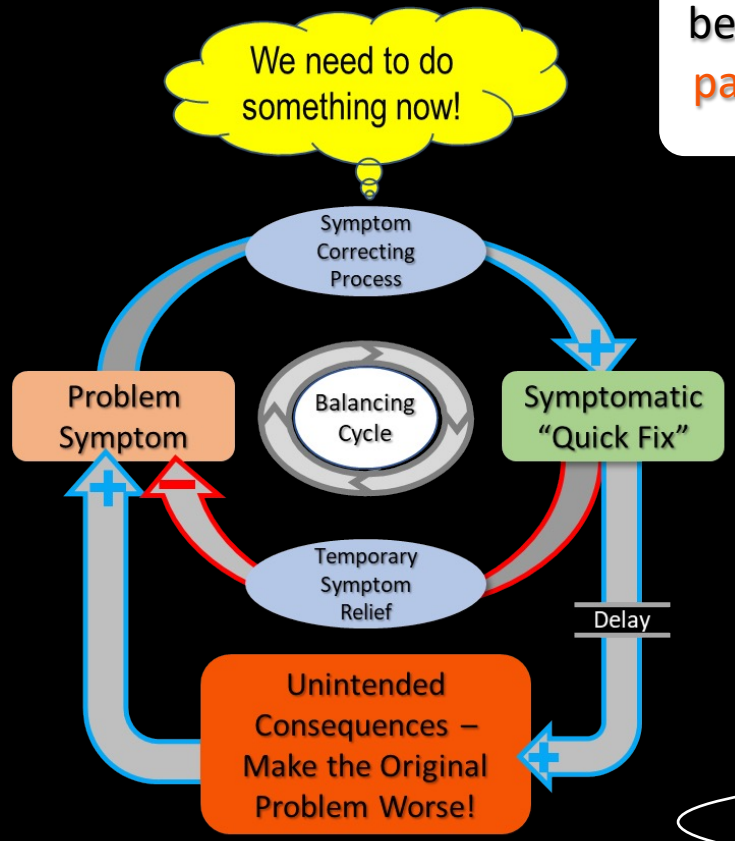
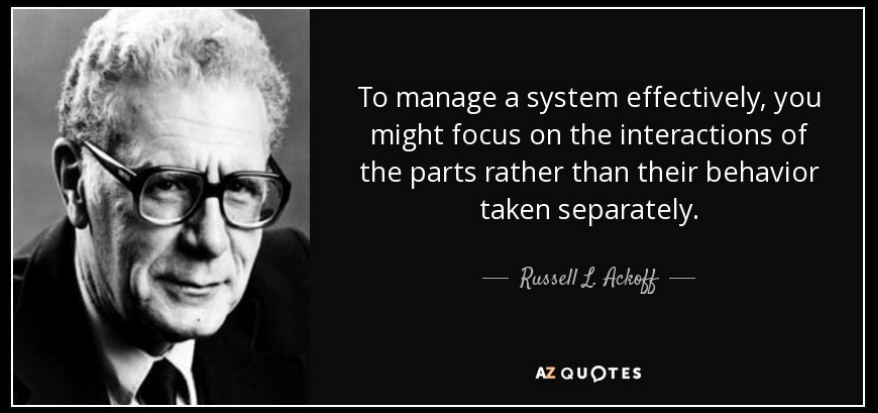
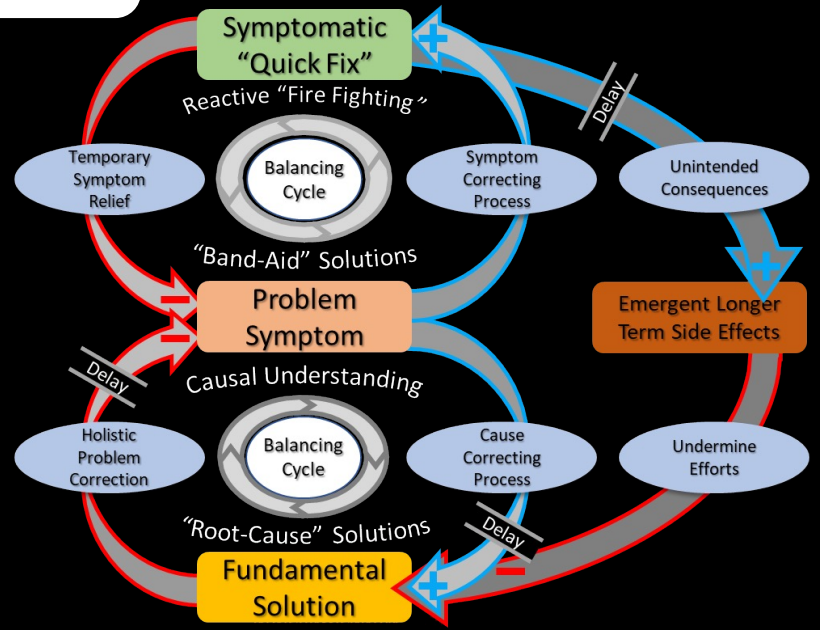
ABSTRACTION | EMERGENCE | INTEROPERABILITY

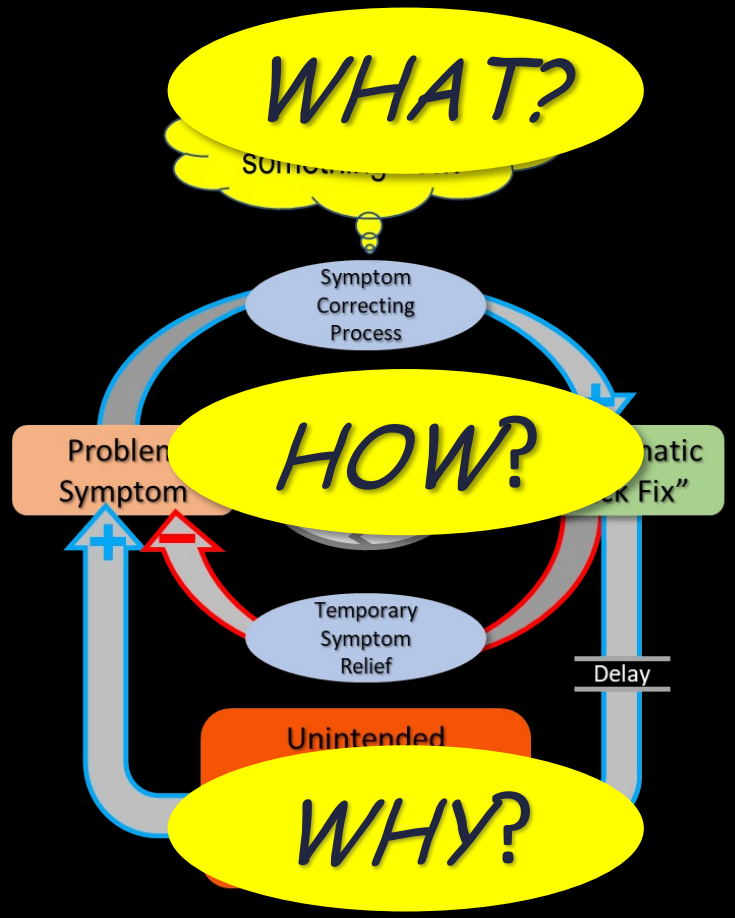
Peter Senge ➔ "Systems Thinking is a *conceptual framework*, a *body of knowledge* and *tools* that have been developed over the past fifty years, to make the full patterns clearer, and to help to change them effectively."







SYSTEMS THINKING



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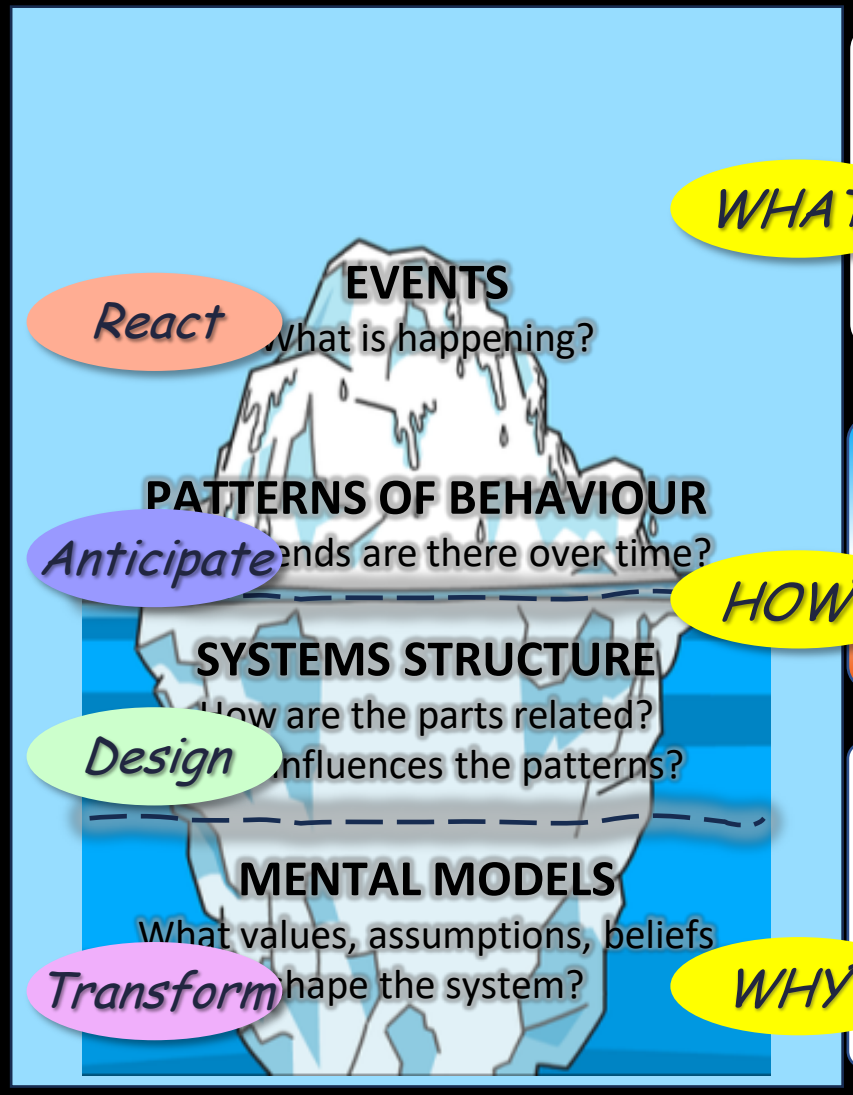
MODELLING

SYSTEMS THINKING

SIMULATION

Personal view ➔ Systems Thinking is a *conceptual framework and methodology* to *understand and make sense* of the world we live in, that helps us deal efficiently and effectively with the *challenges we perceive* and to *create the reality we desire*.



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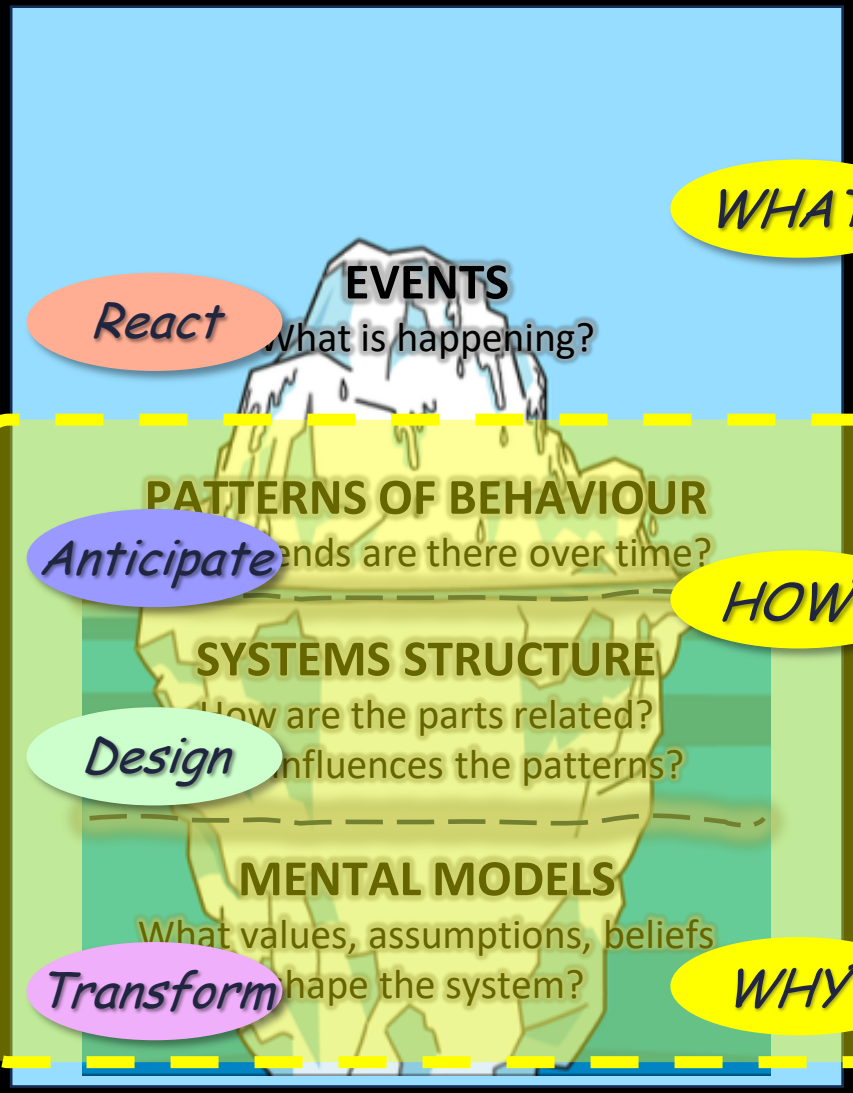


MODELLING

WHAT? ENGINEER SYSTEMS *It's all happening below the surface....*

SIMULATION

HOW?

Behaviour / Dynamics MODELS

Transformative MODELS

Frameworks / Architecture MODELS

Composition (Aggregative) MODELS

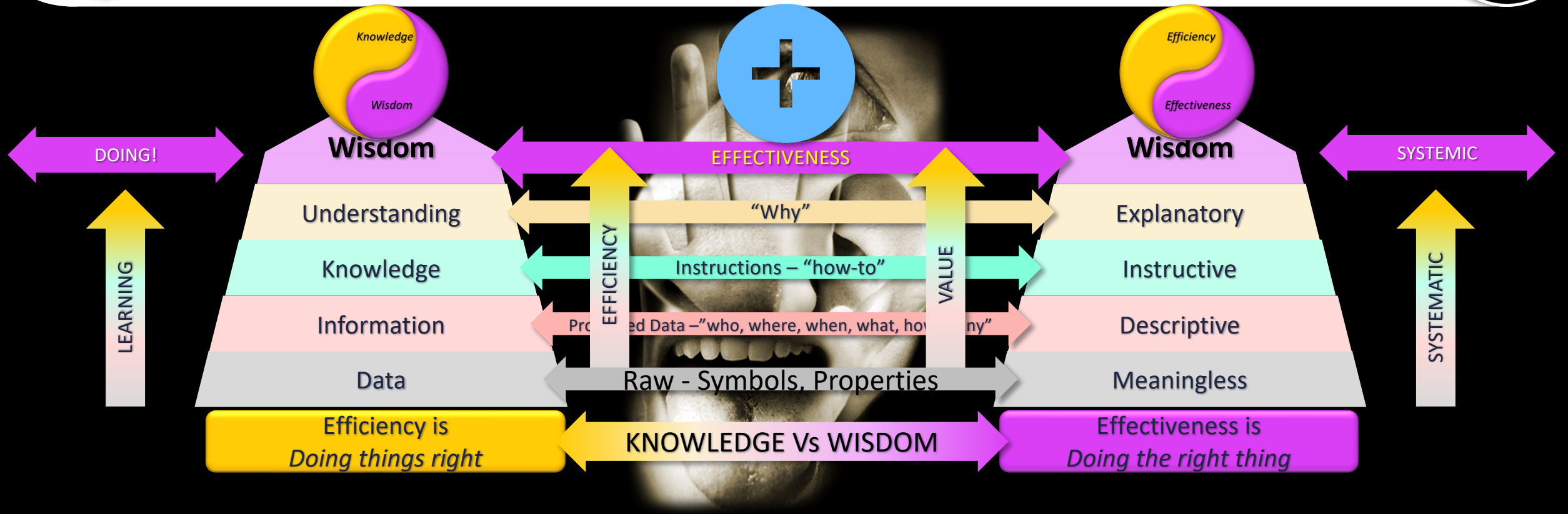
Classification (Hierarchical) MODELS

Communication (Schematic) MODELS

Transformative MODELS

WHY?

Mental / Conceptual MODELS



Mental Models *are deeply ingrained assumptions, generalizations, or even pictures of images that influence how we understand the world and how we take action."- Peter Senge*

Mental / Conceptual MODELS

"Autopoiesis"

DOING!

SYSTEMIC

LEARNING

SYSTEMATIC

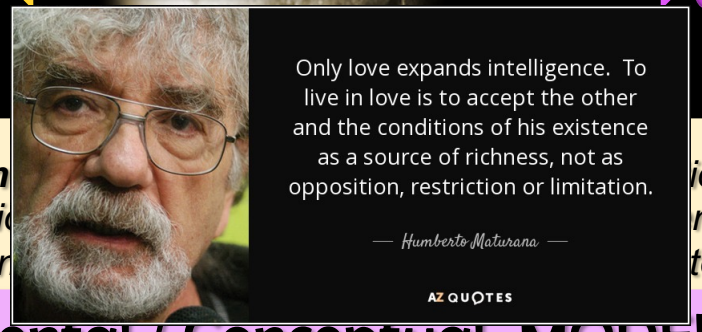
"When one human being tells another human being what is real, they are actually making a demand for obedience" – Humberto Maturana

Efficiency is *Doing things right*

KNOWLEDGE Vs WISDOM

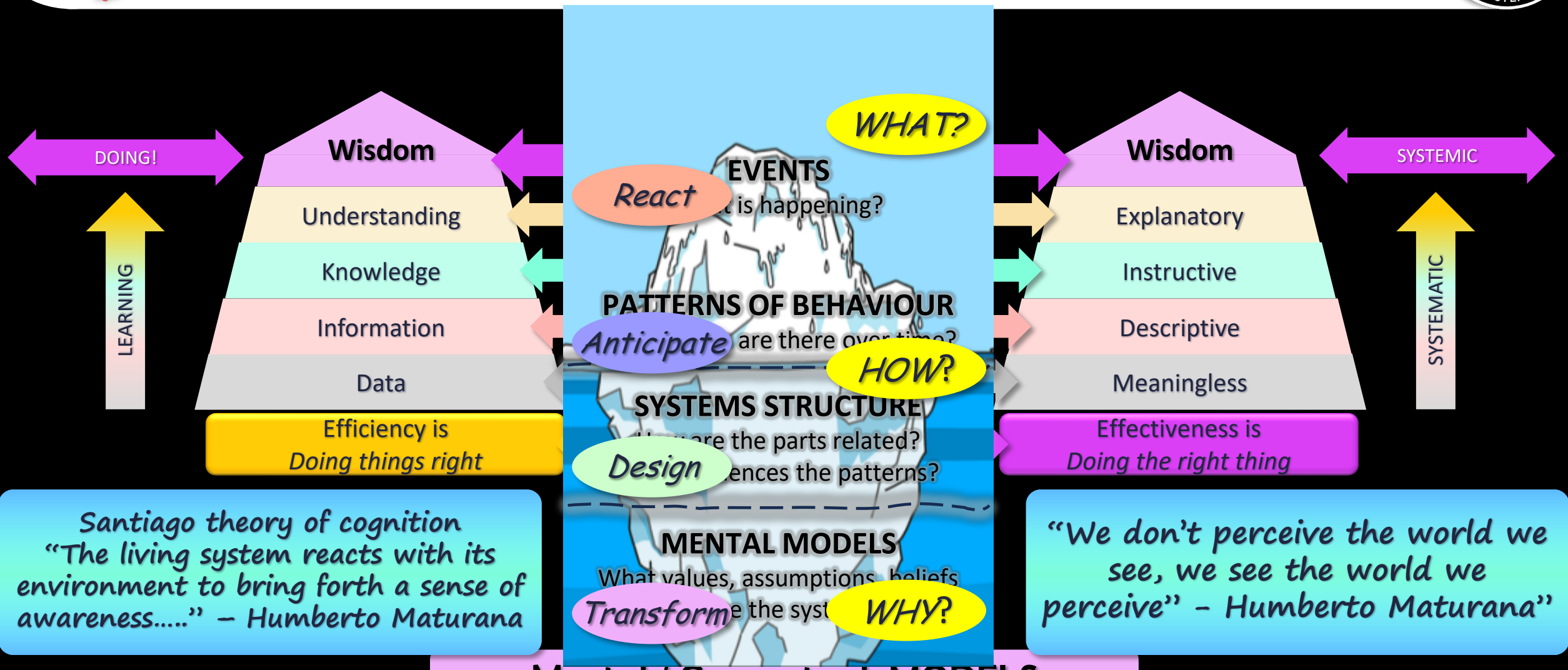
Effectiveness is *Doing the right thing*

Santiago theory of cognition "The living system reacts with its environment to bring forth a sense of awareness....." – Humberto Maturana



"We don't perceive the world we see, we see the world we perceive" – Humberto Maturana"

Mental / Conceptual MODELS



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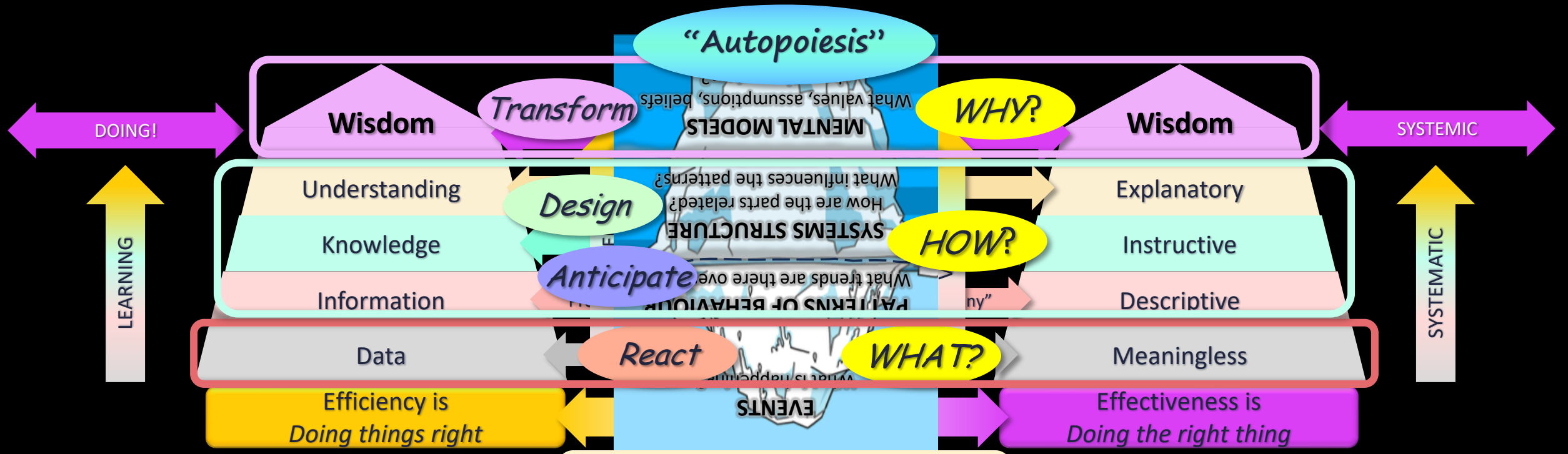

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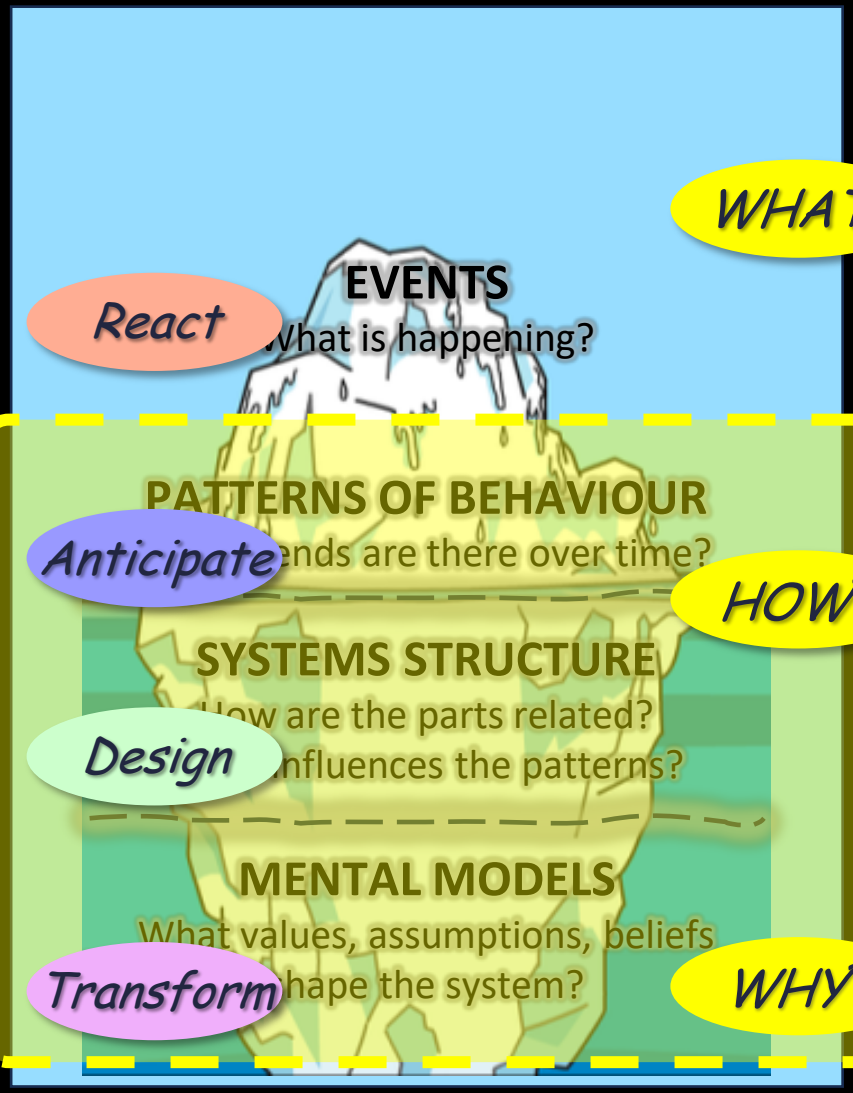
Our Mental Models are our belief systems – of how we perceive and interact with the world around us...

"We don't perceive the world we see, we see the world we perceive" – Humberto Maturana"

Mental / Conceptual MODELS



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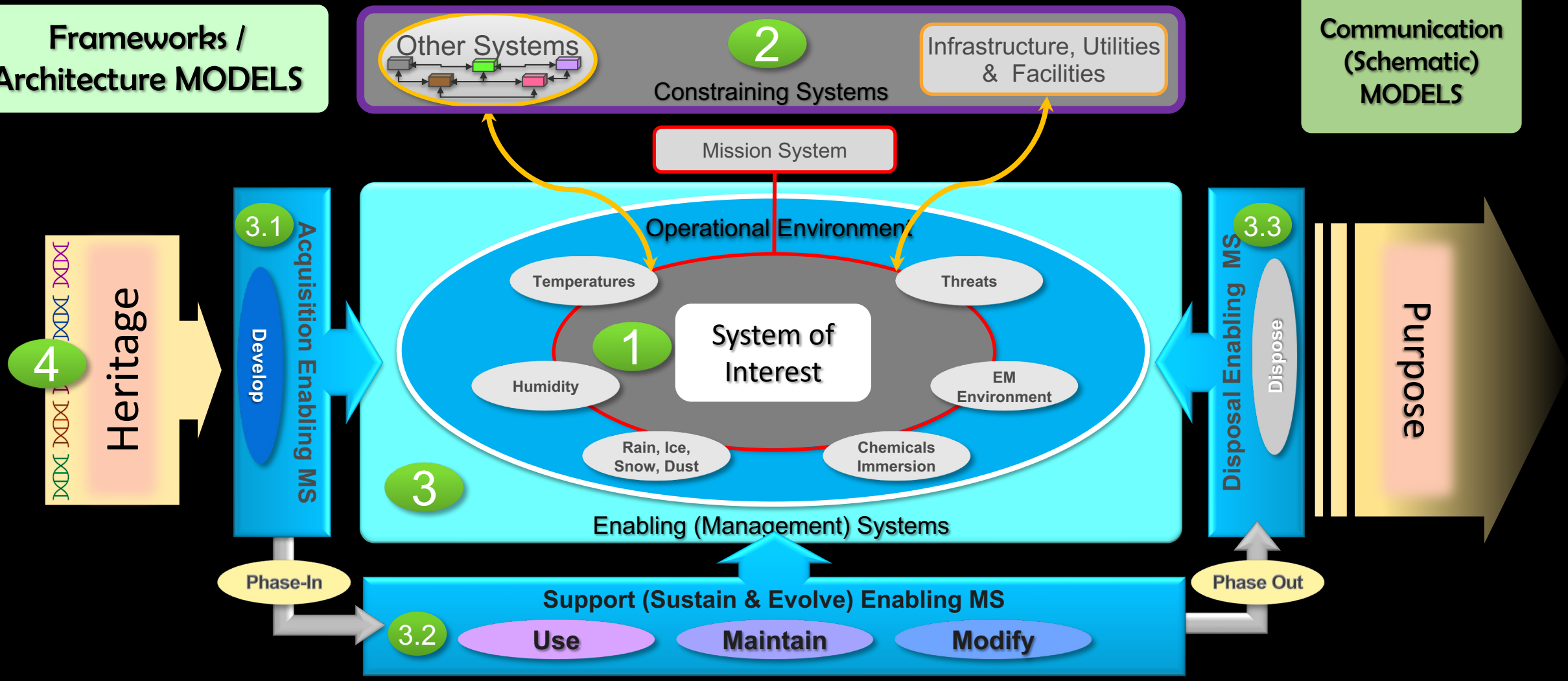

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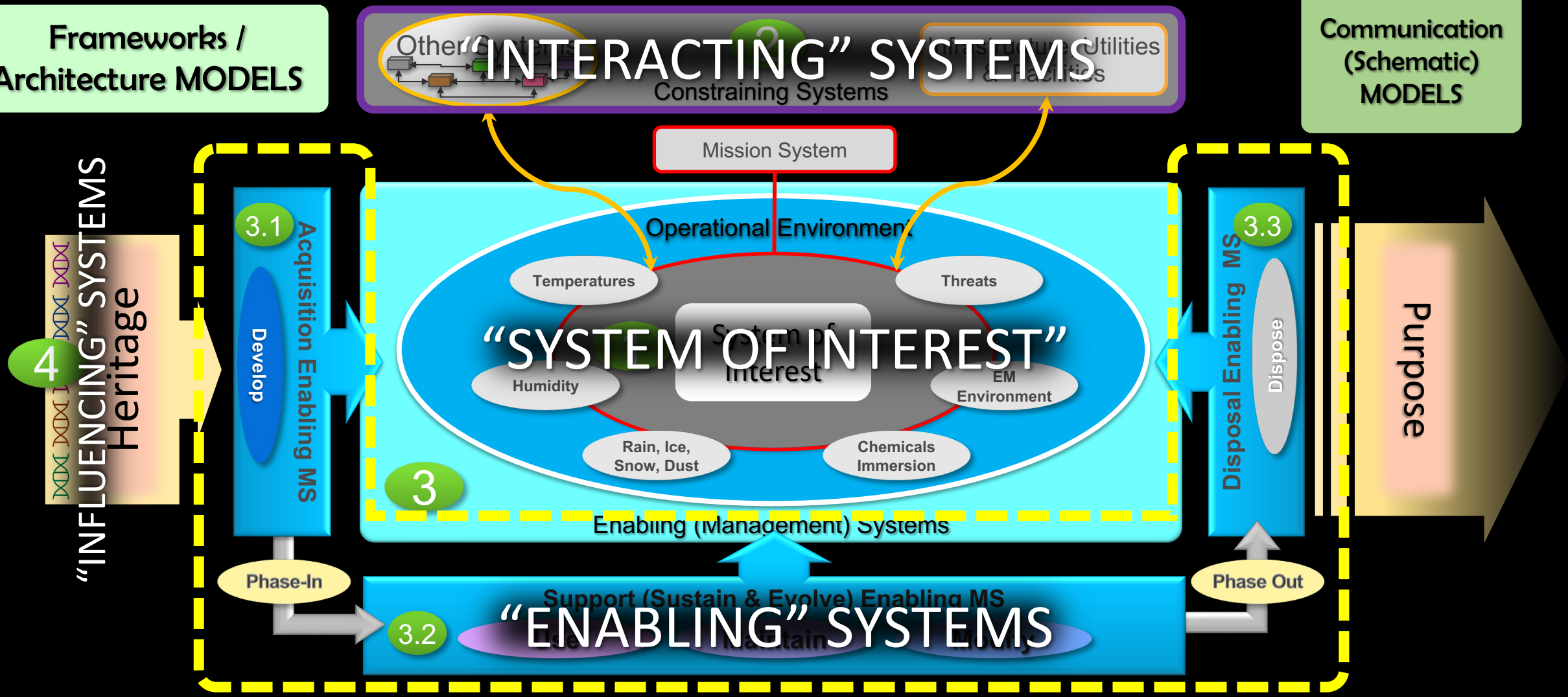


A Compositional (Aggregative) Systems View

Frameworks / Architecture MODELS

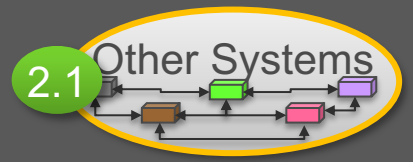
Composition (Aggregative) MODELS

1 System of Interest

1.2 Sub-Systems

"Operating"

2 Constraining Systems



2.2 Infrastructure, Utilities & Facilities

"Interacting"

3 Enabling (Management) Systems

3.1 Acquisition Enabling MS — Develop

3.2 Support (Sustain & Evolve) Enabling MS — Use, Maintain, Modify

"Enabling"

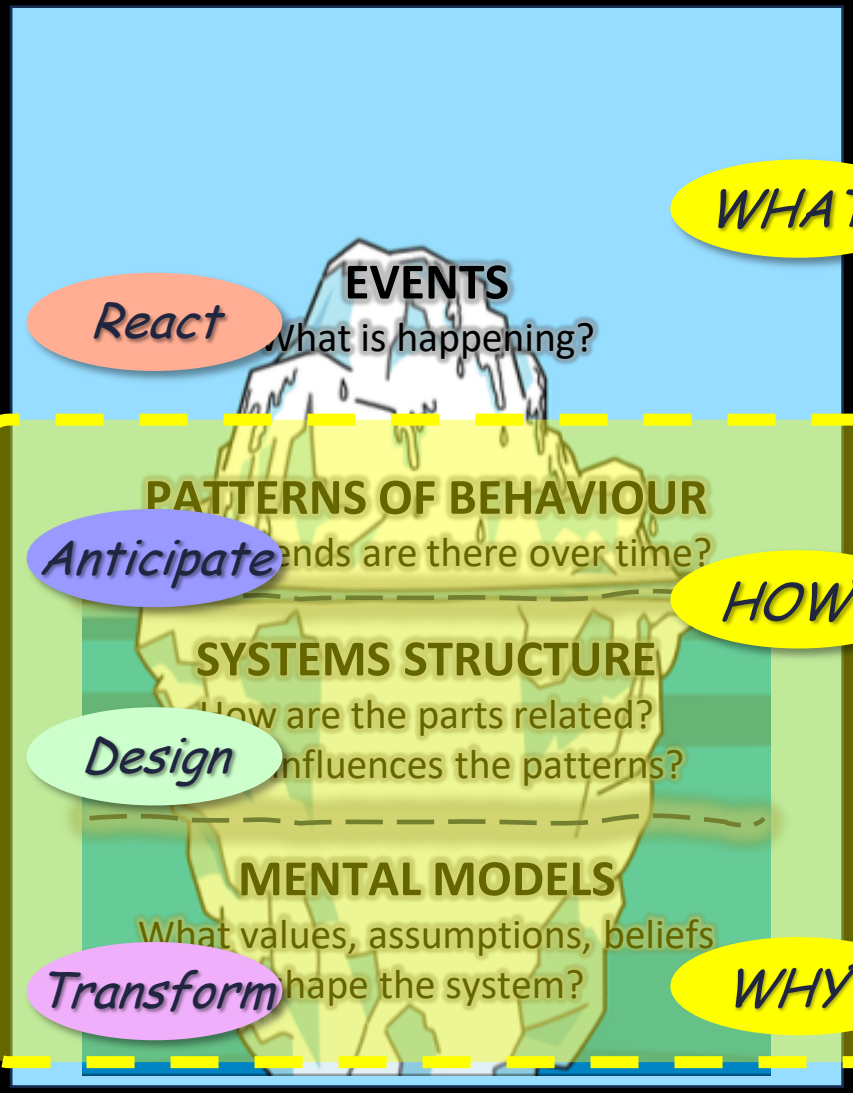
4 Heritage "parent" Systems

Architectures

Technologies

Standards

"Influencing"



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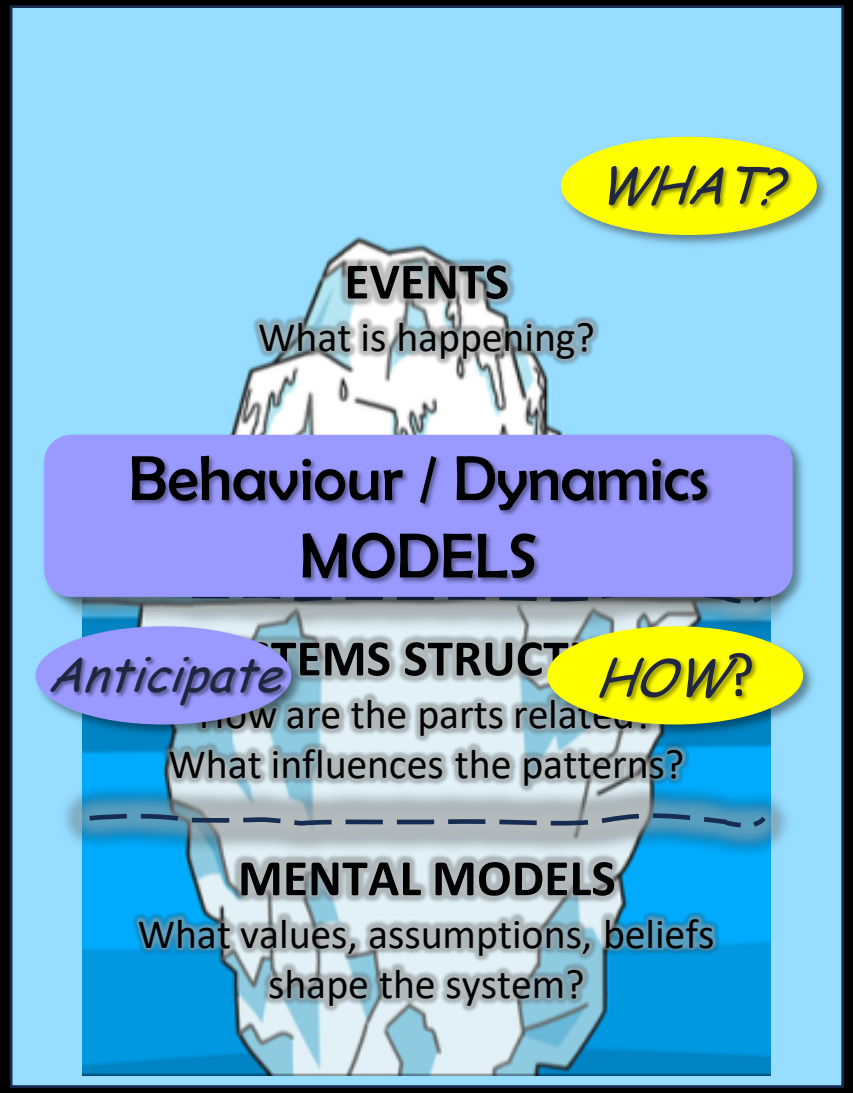
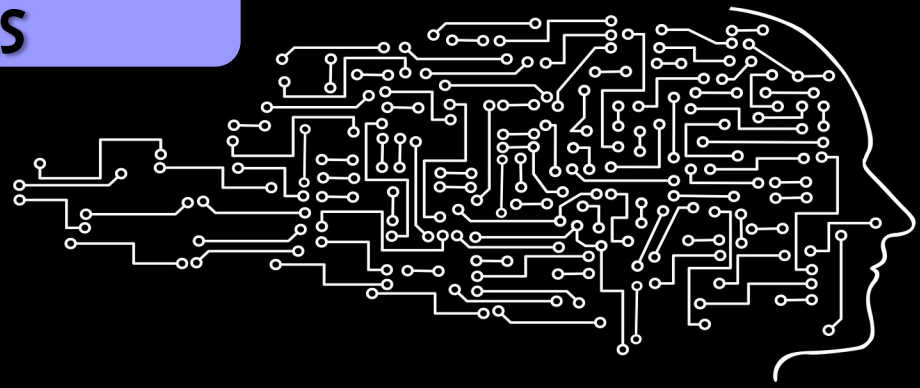
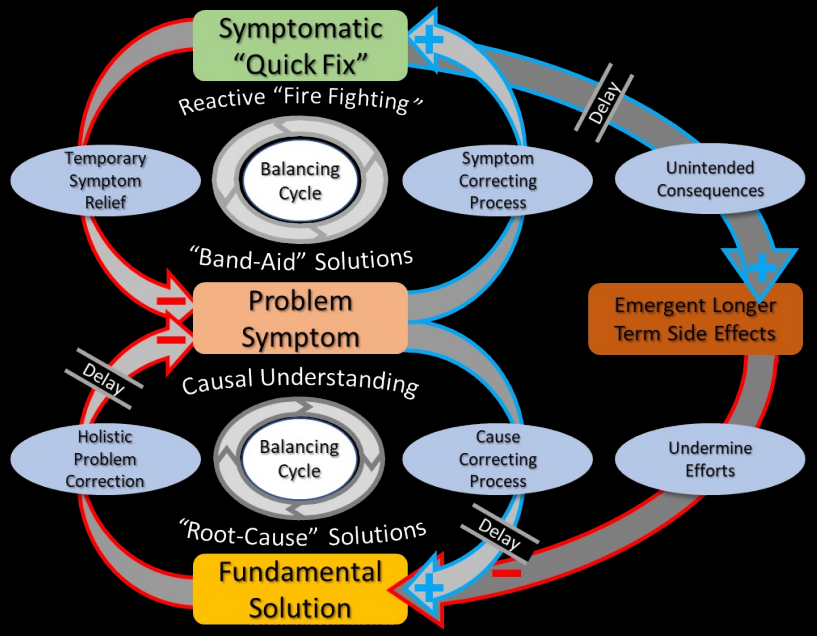


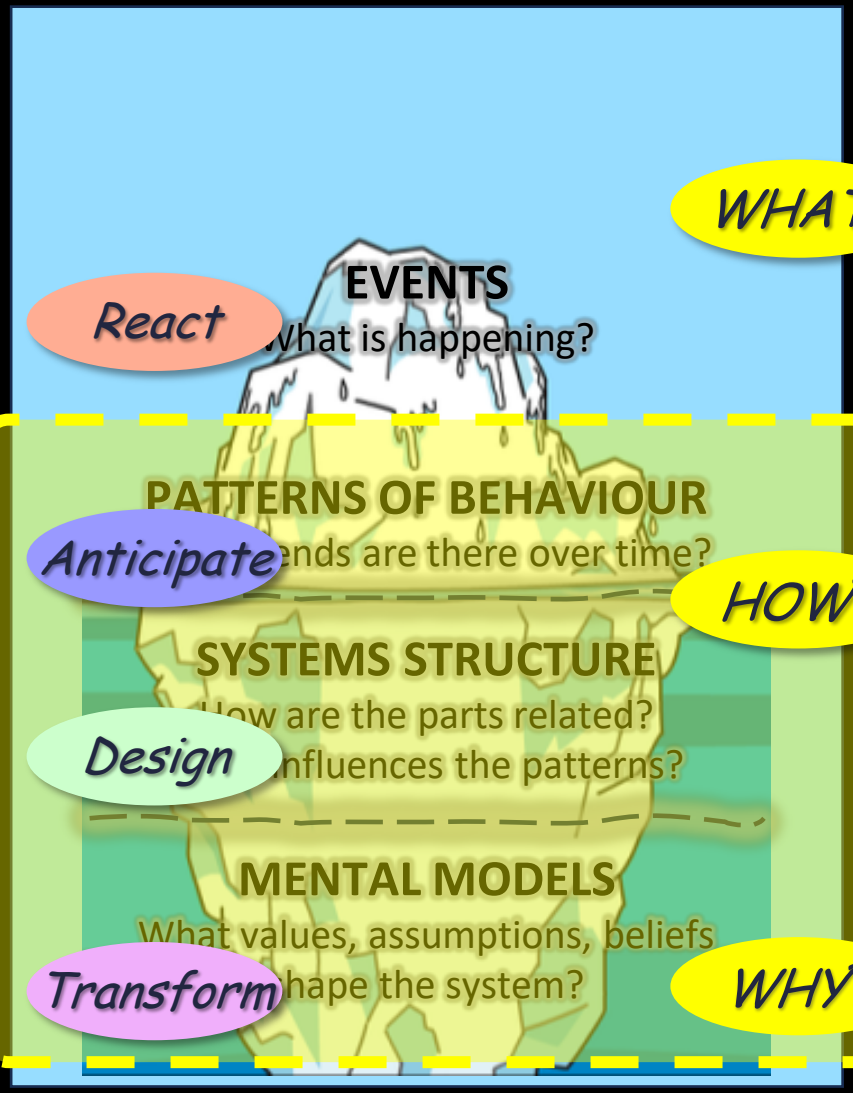
Machine Learning MODELS

Image Credit – Gerd Altmann, Pixabay





Systems Dynamics and Operational Analysis MODELS



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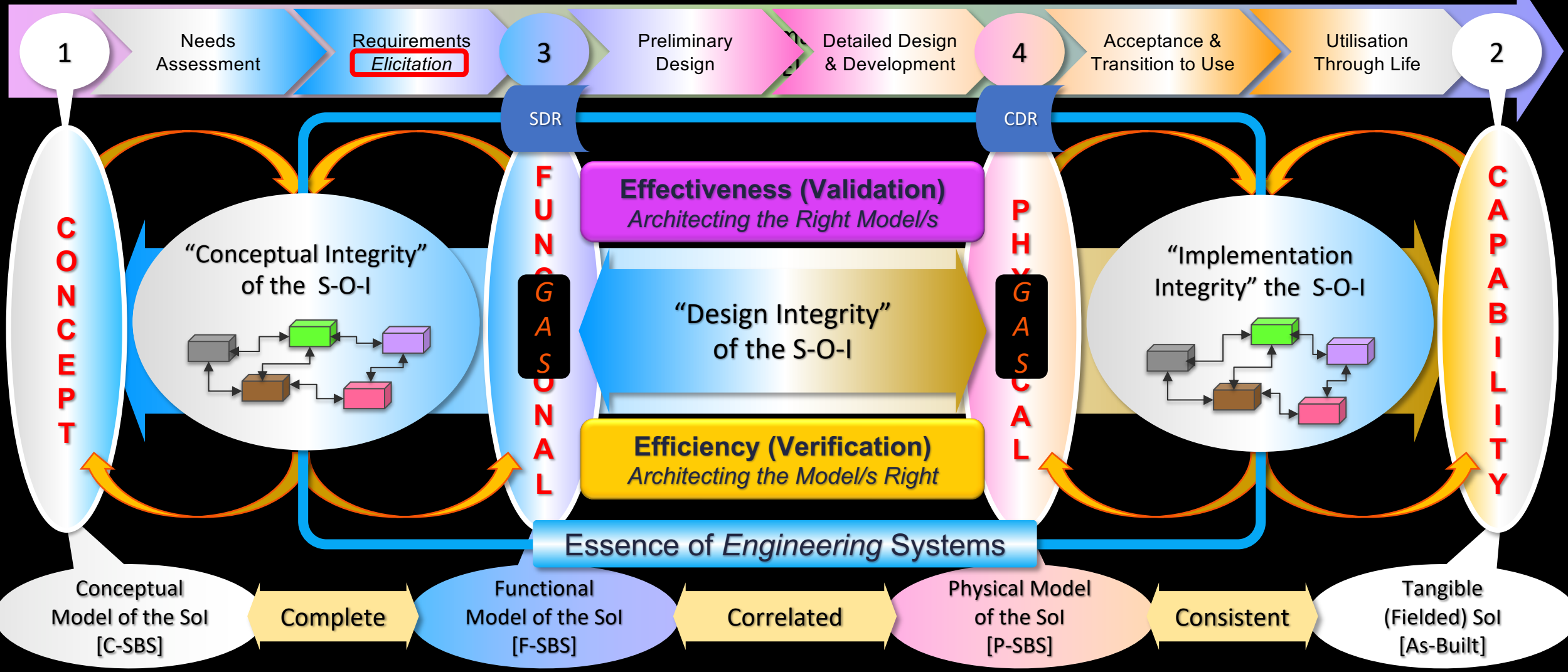

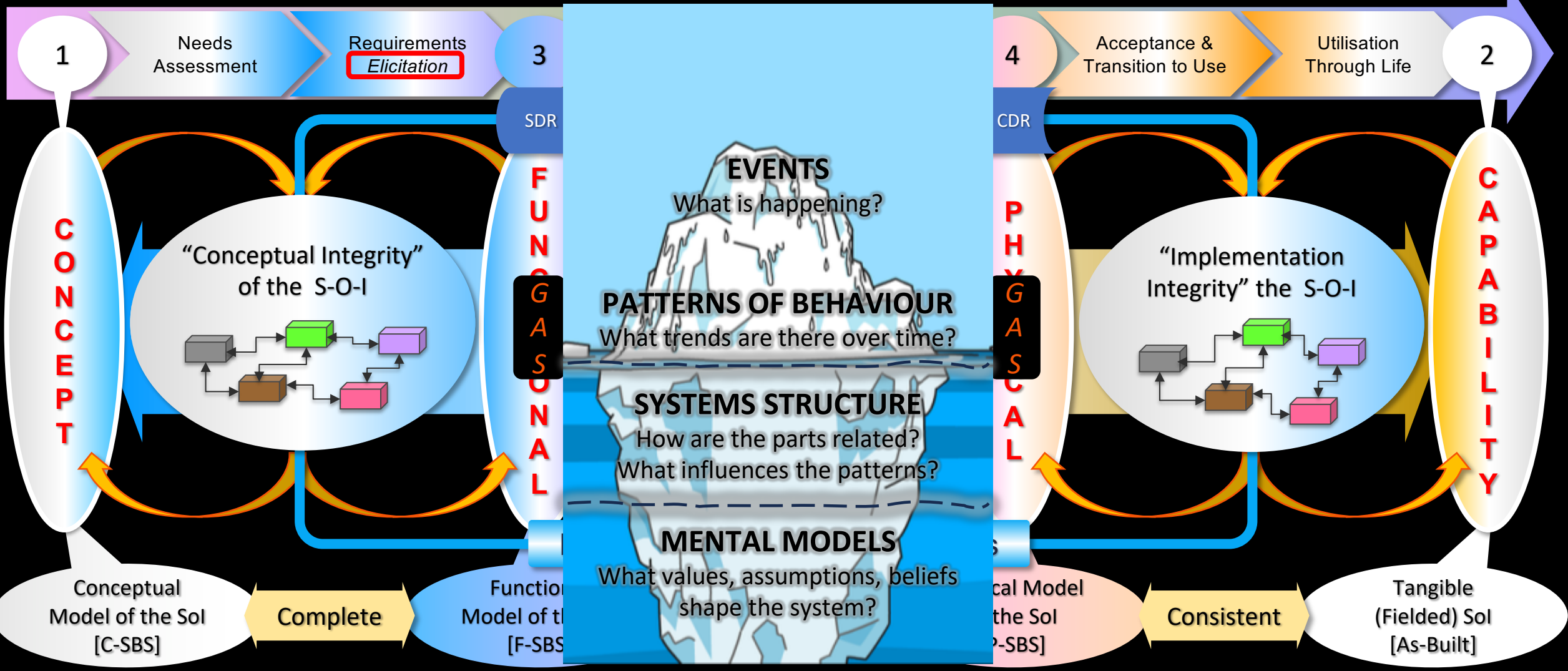

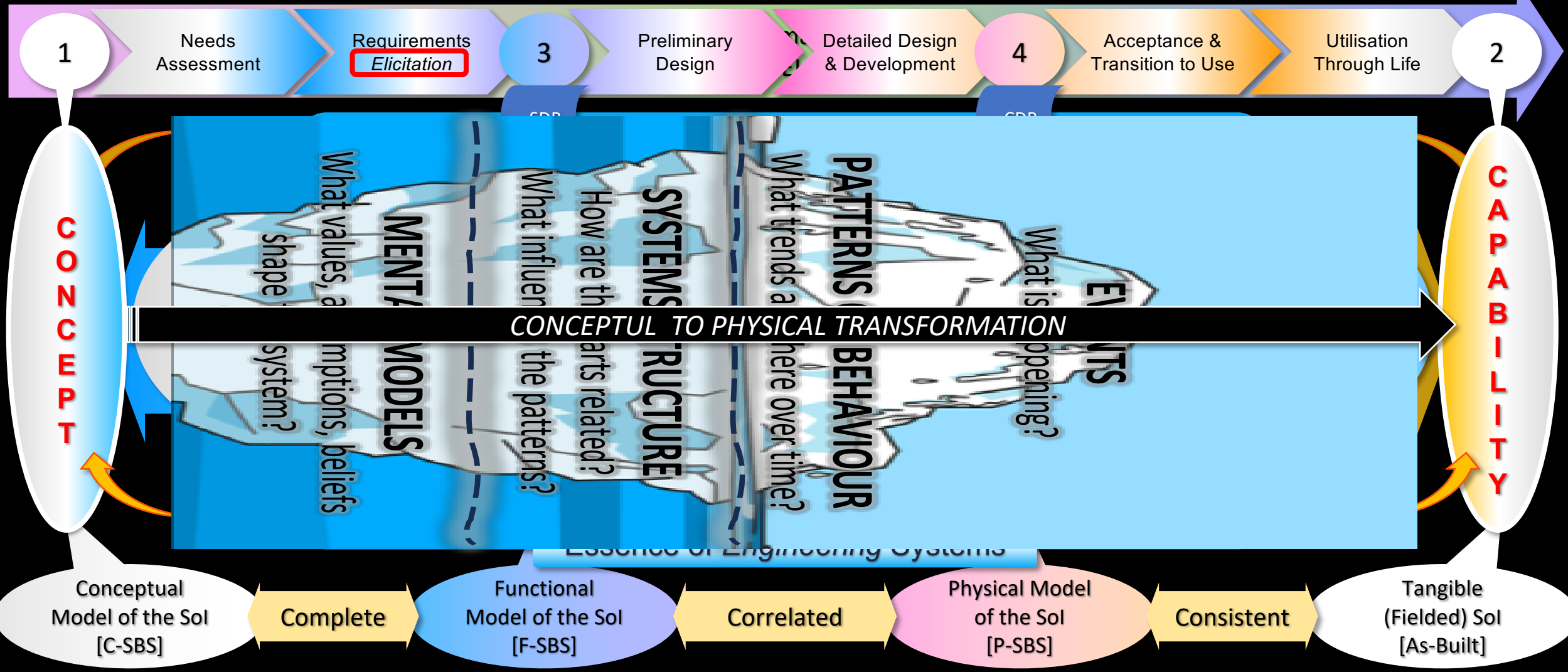

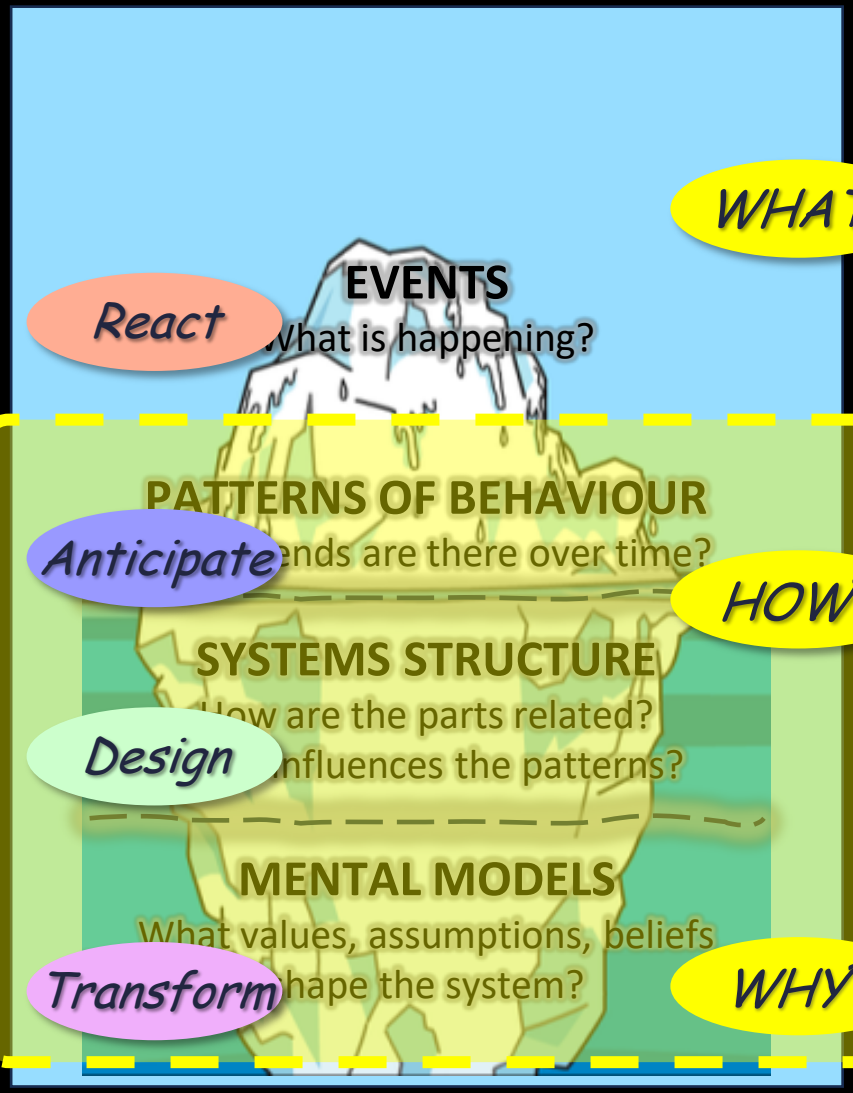

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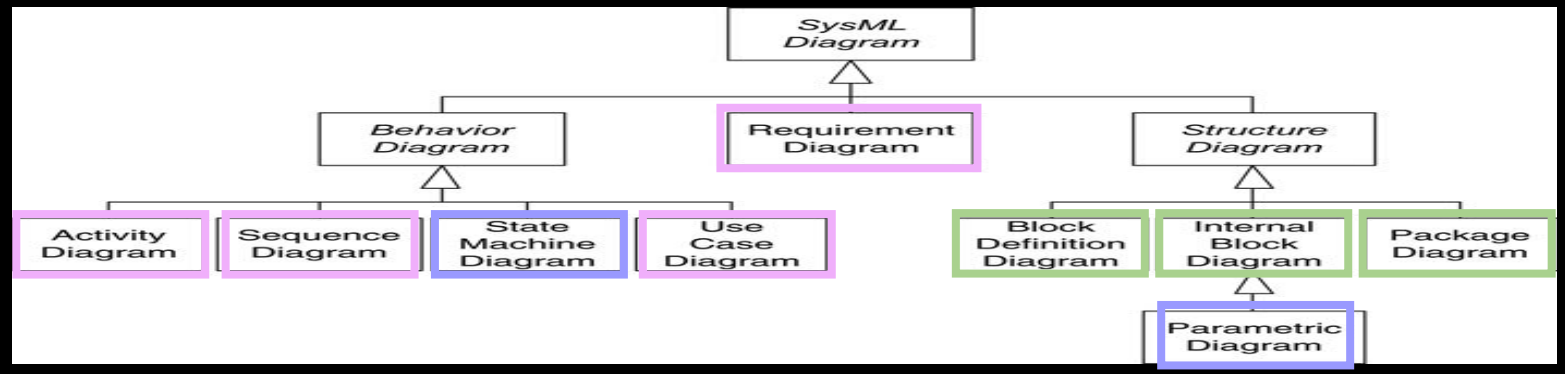
OMG SYSTEMS MODELING LANGUAGE SysML™



Parametric | State-Machine

Structure

BDD | IBD | Package

Sequence | Activity

Use-Case | Requirement

Behaviour / Dynamics MODELS

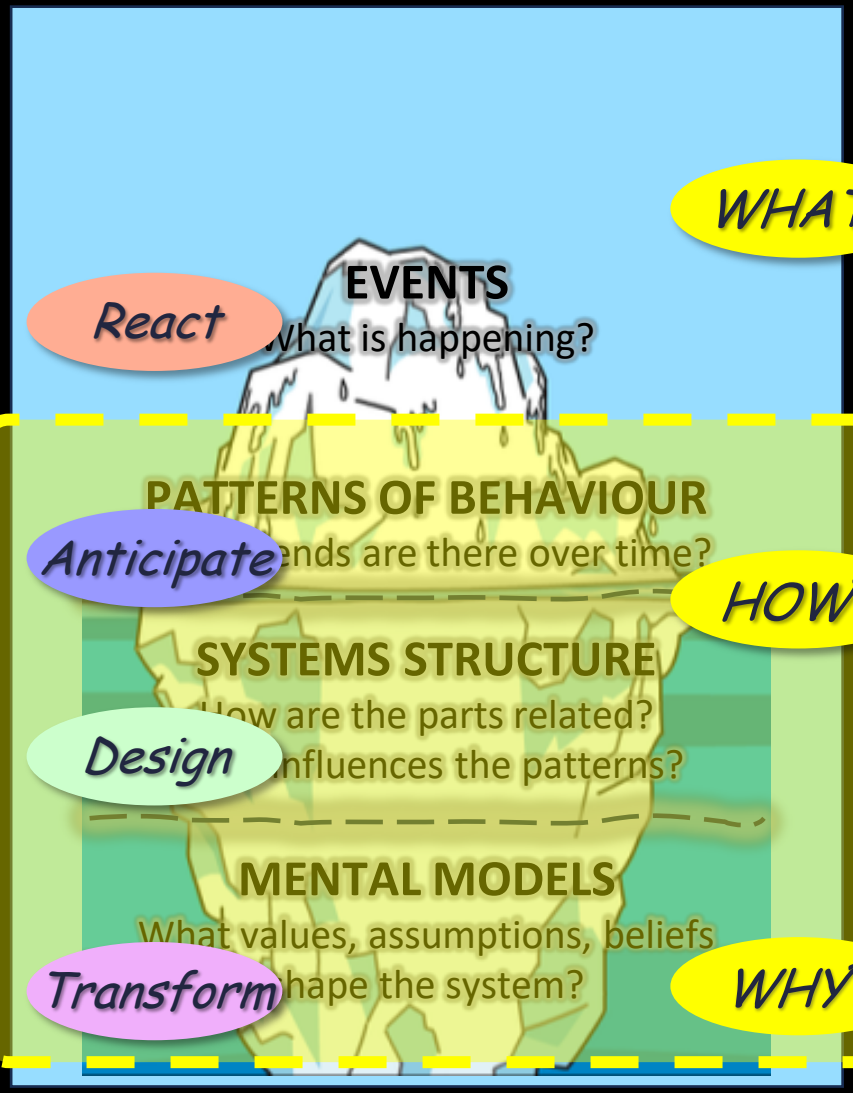
Transformative MODELS

Frameworks / Architecture MODELS

Composition (Aggregative) MODELS | Classification (Hierarchical) MODELS | Communication (Schematic) MODELS

Transformative MODELS

Mental / Conceptual MODELS



MODELLING

WHAT? ENGINEER SYSTEMS *It's all happening below the surface....*

SIMULATION

HOW?

WHY?

Behaviour / Dynamics MODELS

Transformative MODELS

Frameworks / Architecture MODELS

Composition (Aggregative) MODELS

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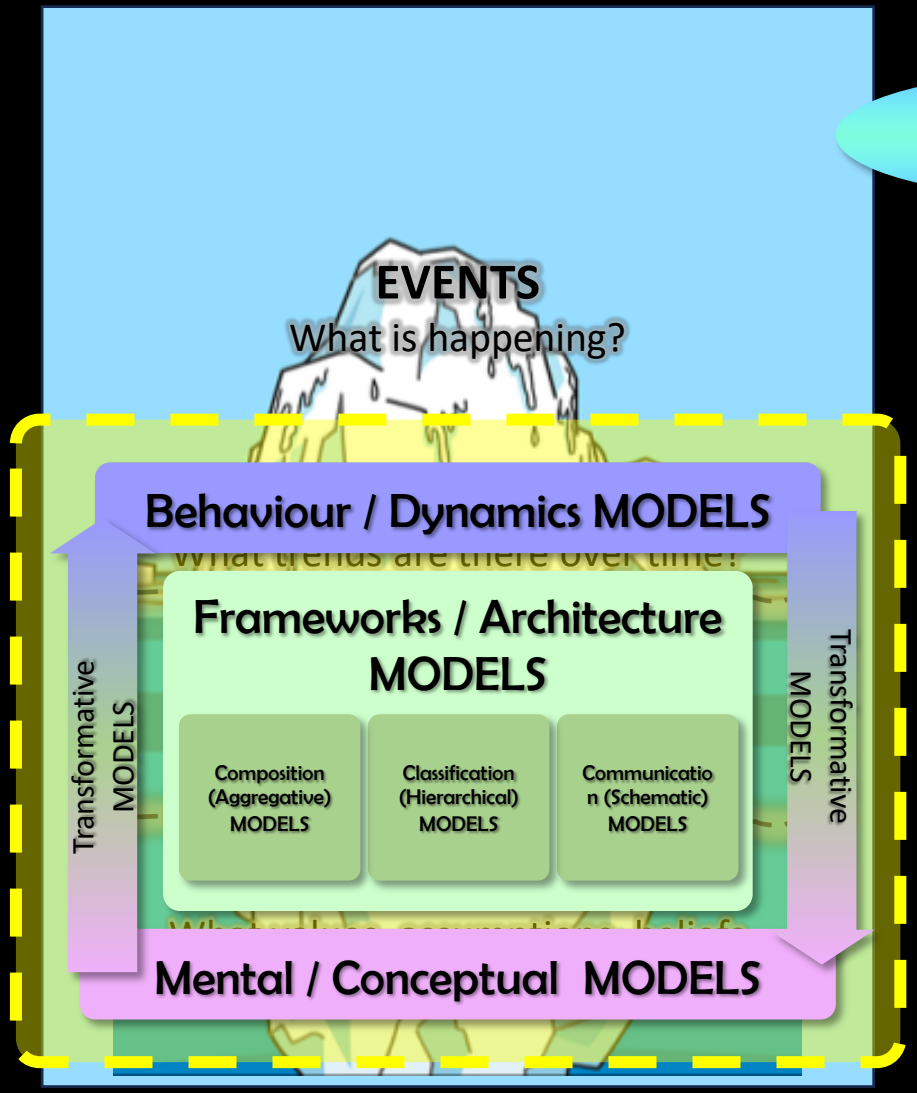


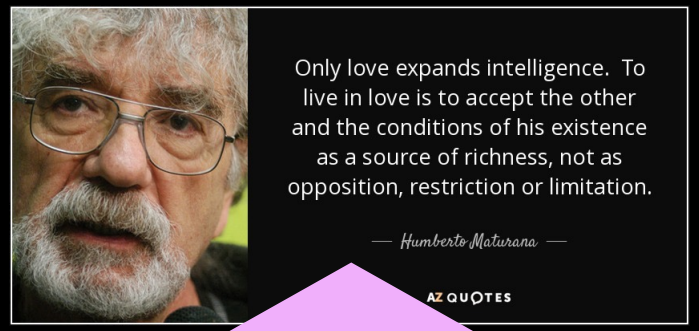
"Autopoiesis"

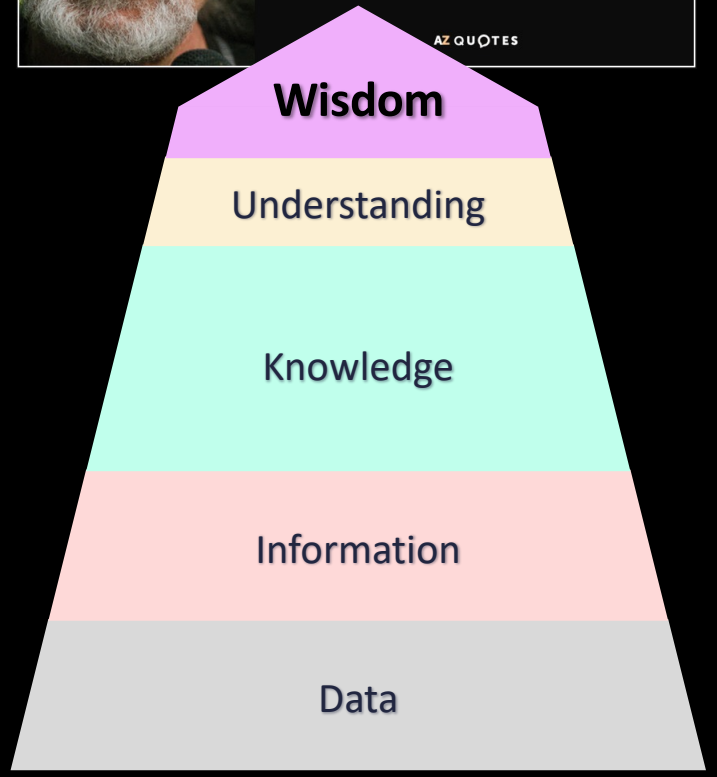
React

Anticipate

Design

Transform





"Autopoiesis"

Only love expands intelligence. To live in love is to accept the other and the conditions of his existence as a source of richness, not as opposition, restriction or limitation.

— Humberto Maturana —

EVENTS
What is happening?

React

Data
Meaningless...

Behaviour / Dynamics MODELS

Frameworks / Architecture MODELS

Transformative MODELS

Composition (Aggregative) MODELS

Classification (Hierarchical) MODELS

Communication (Schematic) MODELS

Transformative MODELS

Anticipate

Information

Design

Knowledge

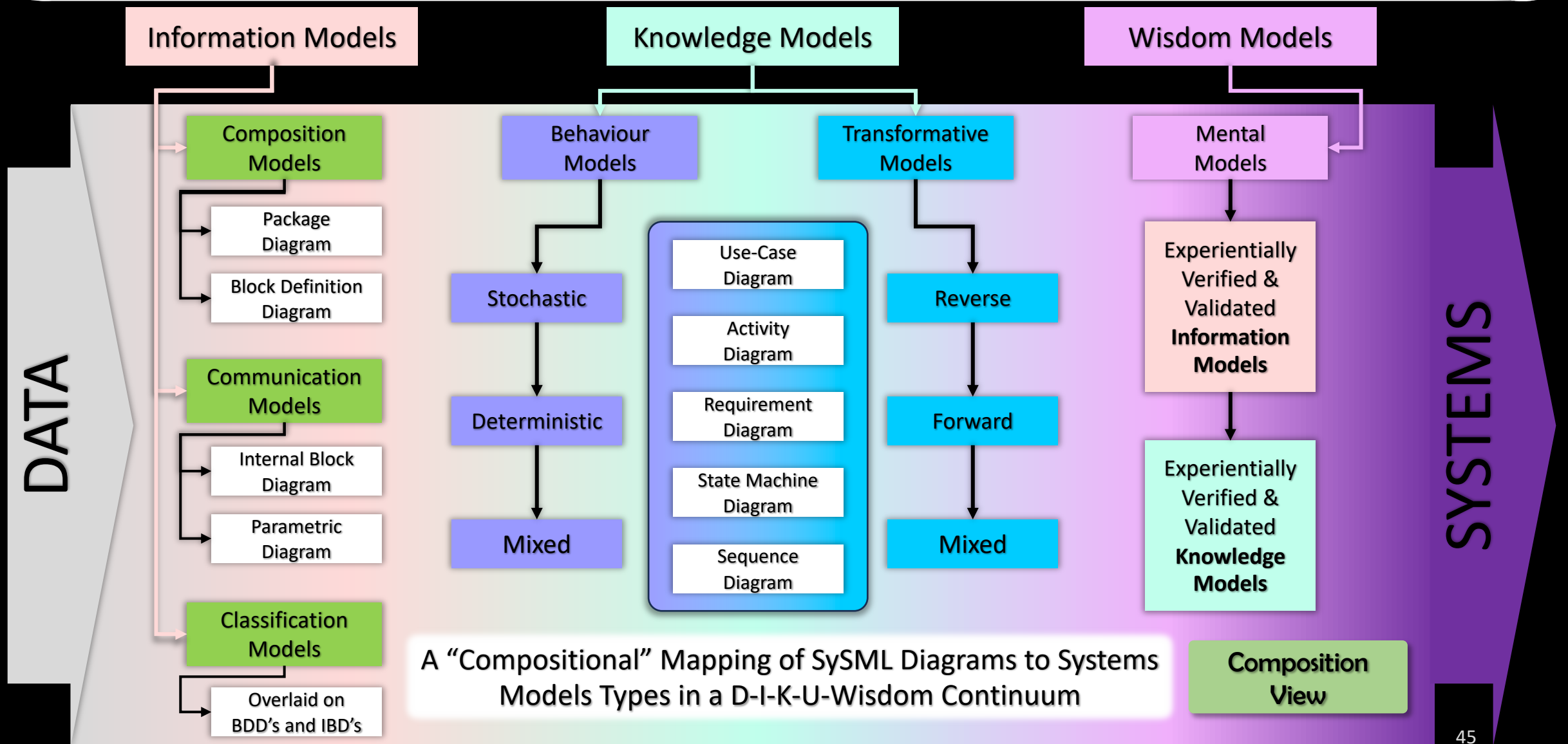
Experiential...

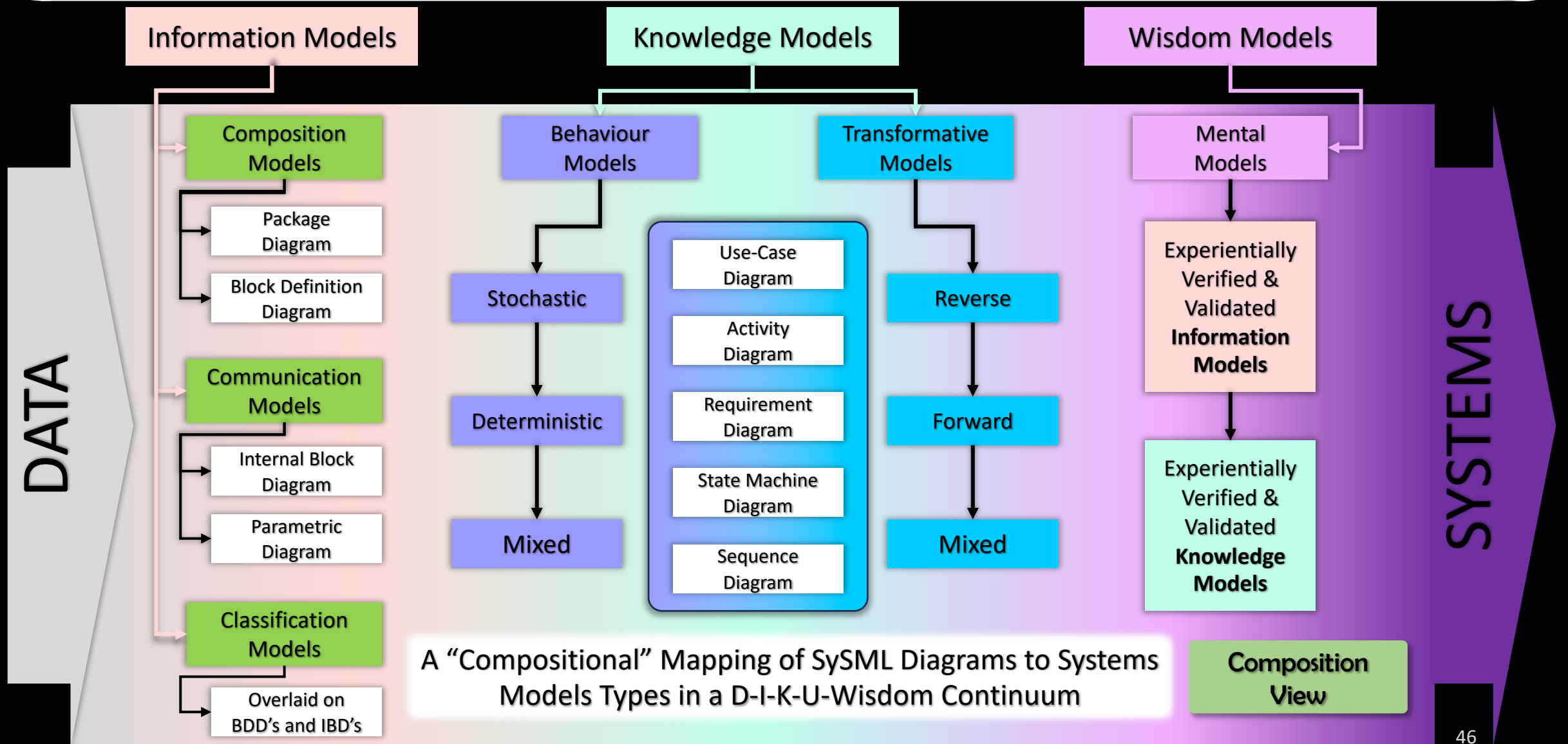
Understanding

Mental / Conceptual MODELS

Transform

Wisdom


Information Models
Knowledge Models
Wisdom Models
DATA
SYSTEMS
Composition Models
Package Diagram
Block Definition Diagram
Communication Models
Internal Block Diagram
Parametric Diagram
Classification Models
Overlaid on BDD's and IBD's
Behaviour Models
Stochastic
Deterministic
Mixed
Use-Case Diagram
Activity Diagram
Requirement Diagram
State Machine Diagram
Sequence Diagram
Transformative Models
Reverse
Forward
Mixed
Mental Models
Experientially Verified & Validated Information Models
Experientially Verified & Validated Knowledge Models
A "Compositional" Mapping of SysML Diagrams to Systems Models Types in a D-I-K-U-Wisdom Continuum
Composition View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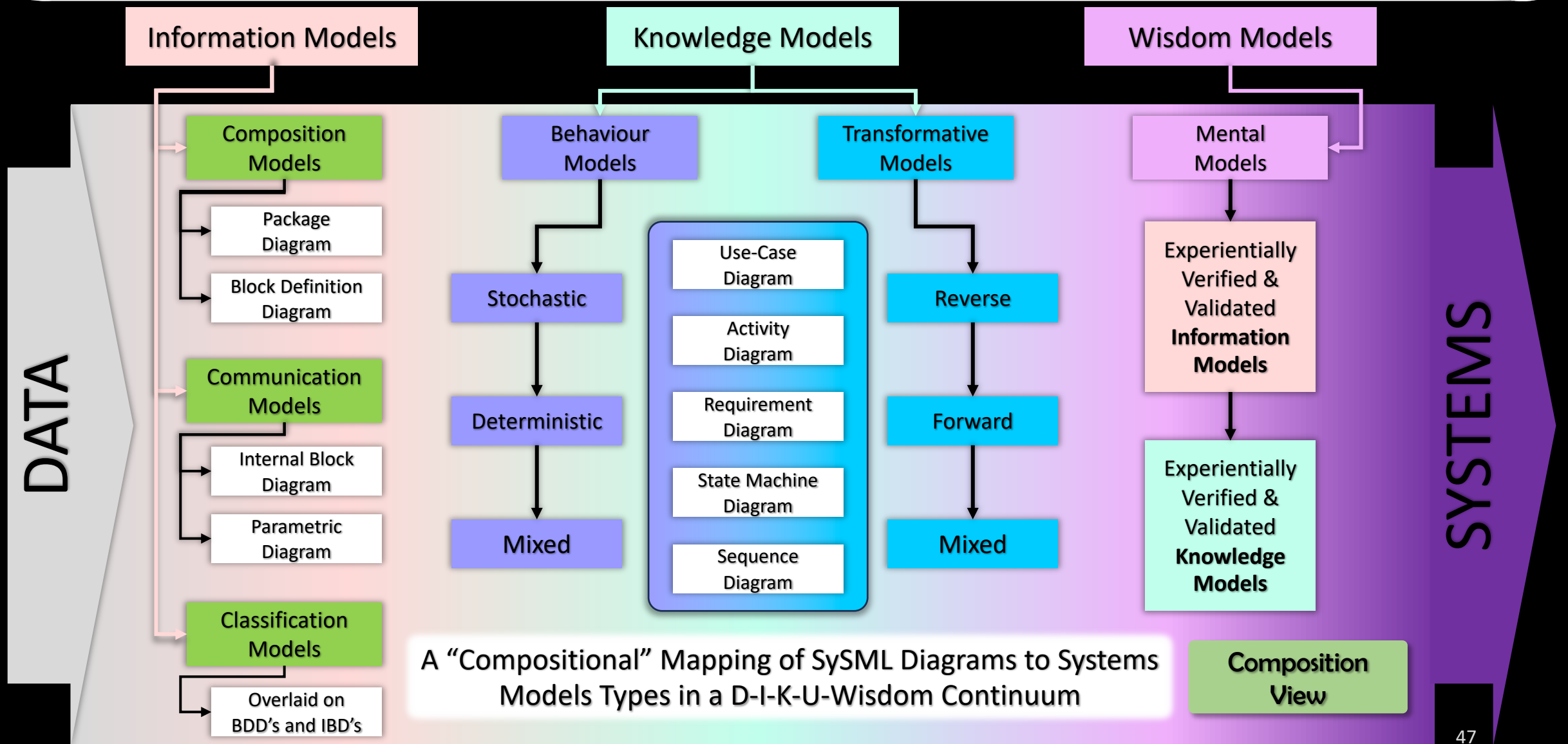
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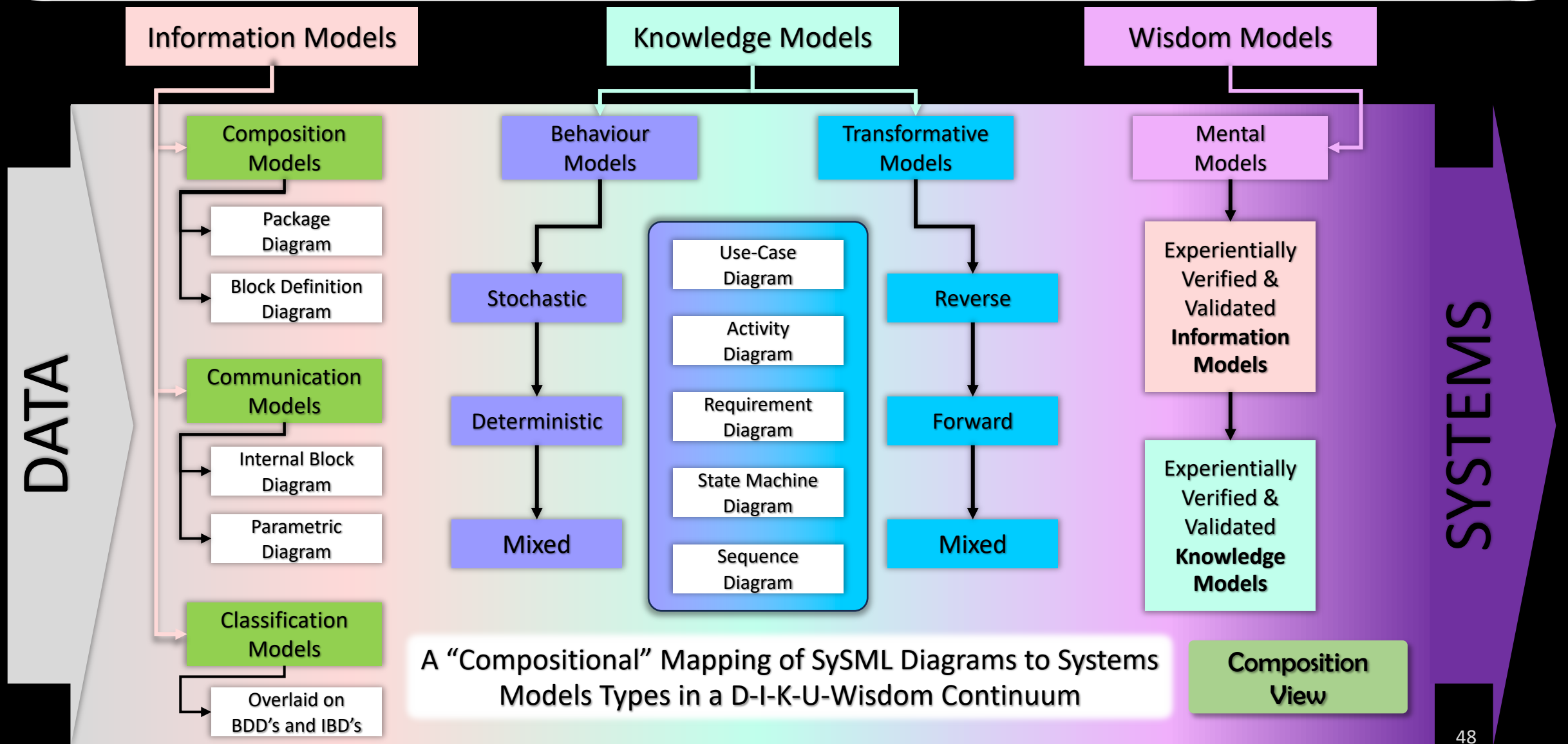
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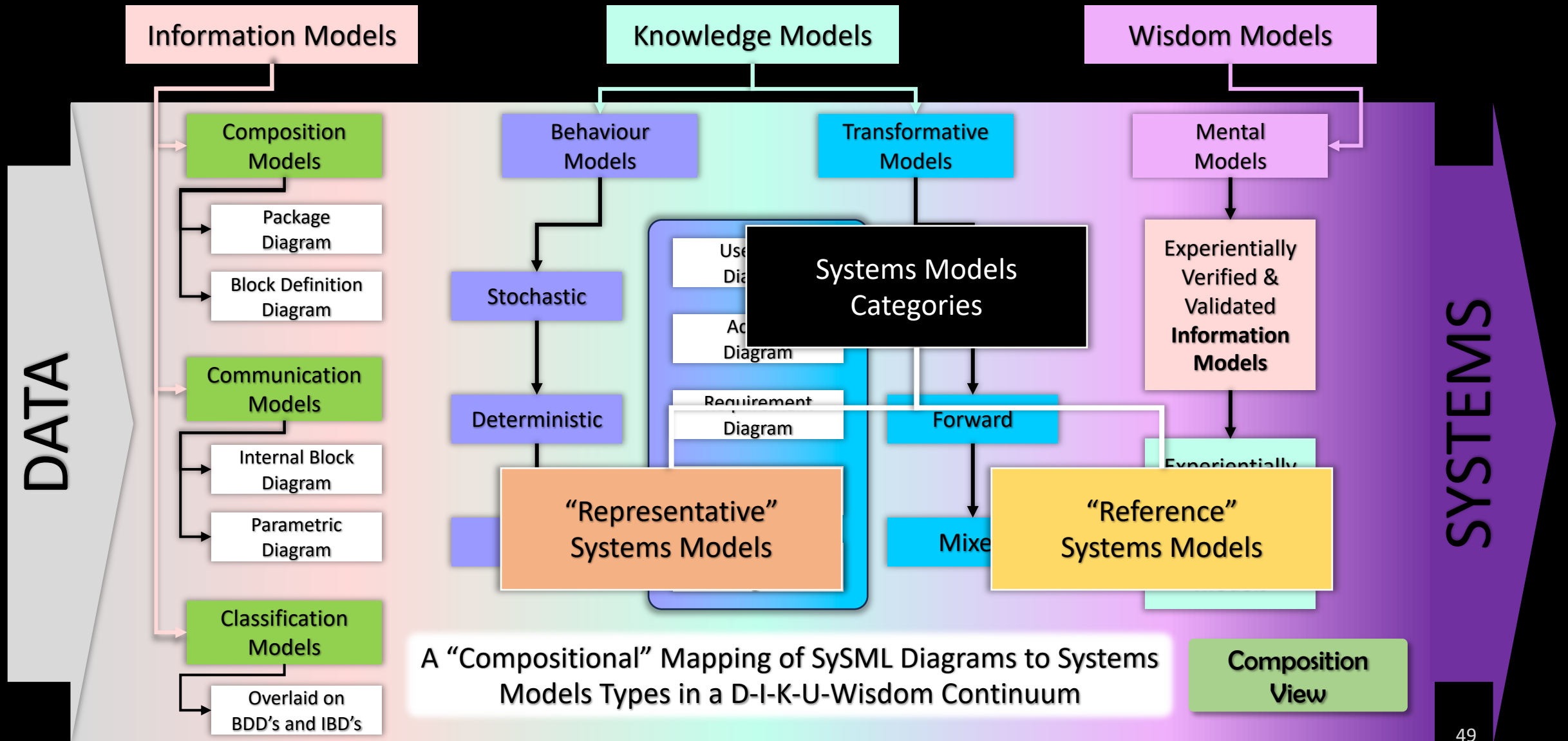
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Systems Models Categories
"Representative" Systems Models
"Reference" Systems Models
A "Compositional" Mapping of SySML Diagrams to Systems Models Types in a D-I-K-U-Wisdom Continuum
Composition View

Applying "Engineering Wisdom" to Engineer Systems

We must then apply this SE Wisdom to architect desired systems through definition and realization, employing personal SE Wisdom and best practice SE information and knowledge systems reference models to deliver efficient and effective fielded, safe, secure and sustainable systems.

Requisite "SE Wisdom"

To Engineer systems, we must first have the requisite "SE Wisdom" (i.e. mental models established through verified and validated experiential learning) to enable understanding and transformation of desired conceptual needs into safe, secure and sustainable systems.

Building "Engineering Wisdom" through Experiential Learning

Applying "Engineering Wisdom" to Engineer Systems

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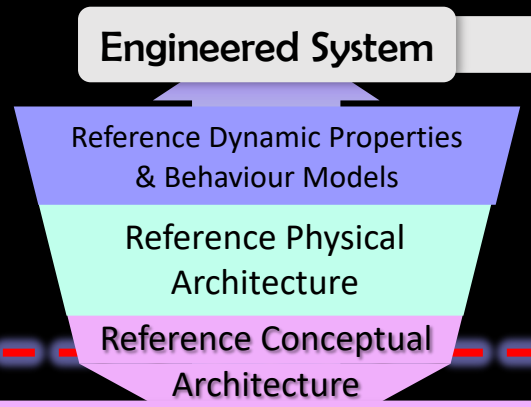


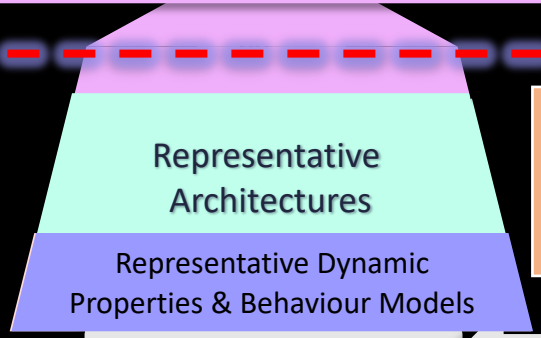
Engineered System

Fielded Systems

Operational Systems

Reference "SE Wisdom" Models

To Engineer systems, we must first have the requisite "SE Wisdom" (i.e. mental models established through verified and validated experiential learning) to enable understanding and transformation of desired conceptual needs into safe, secure and sustainable systems.

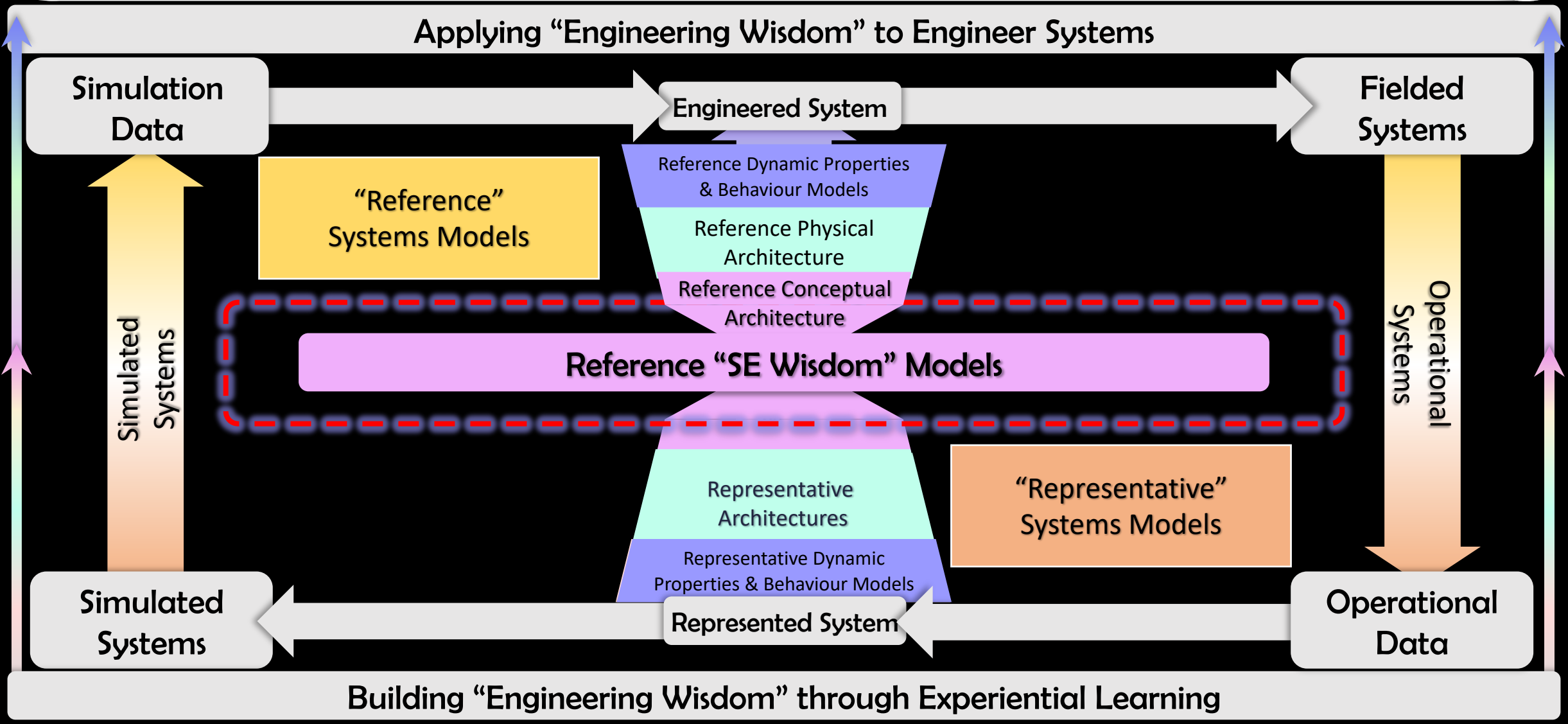


"Representative" Systems Models

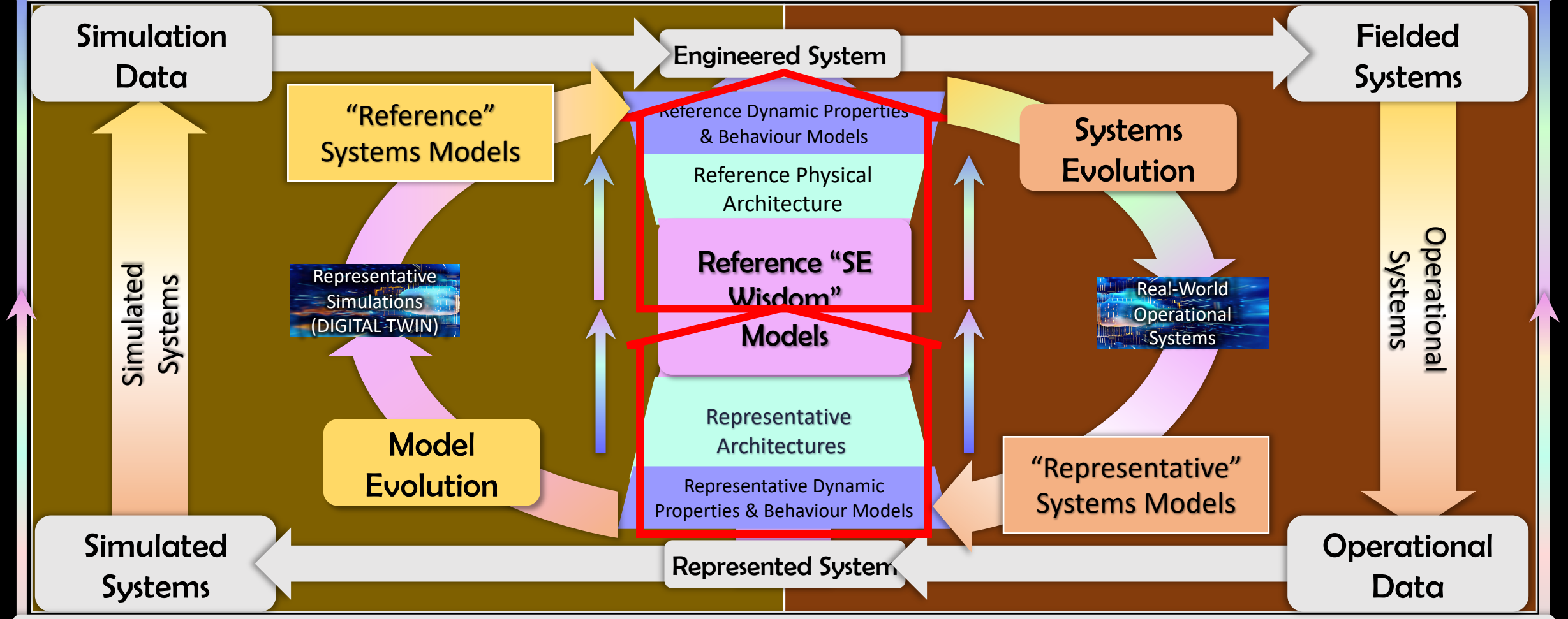
Represented System

Operational Data

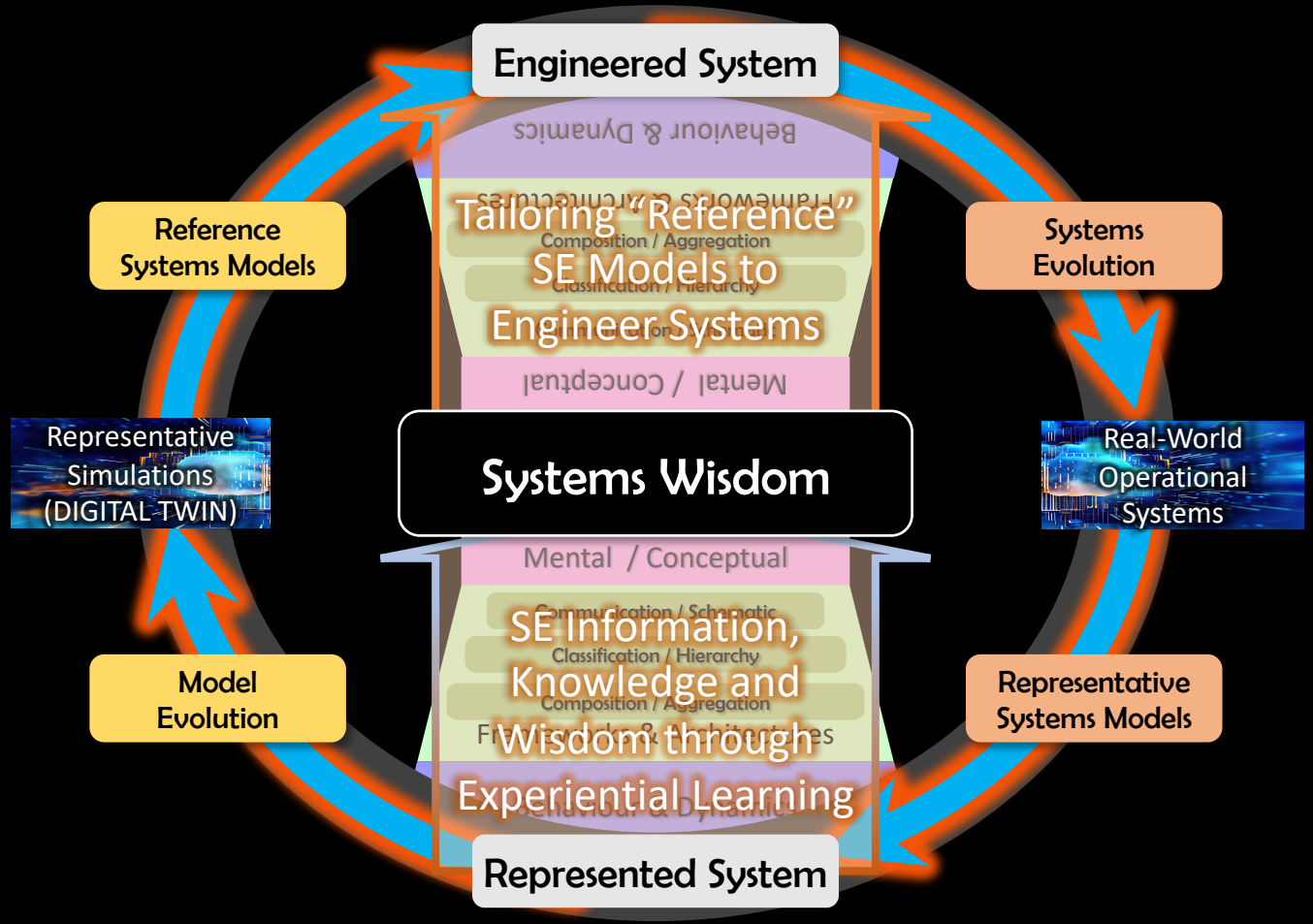
Building "Engineering Wisdom" through Experiential Learning

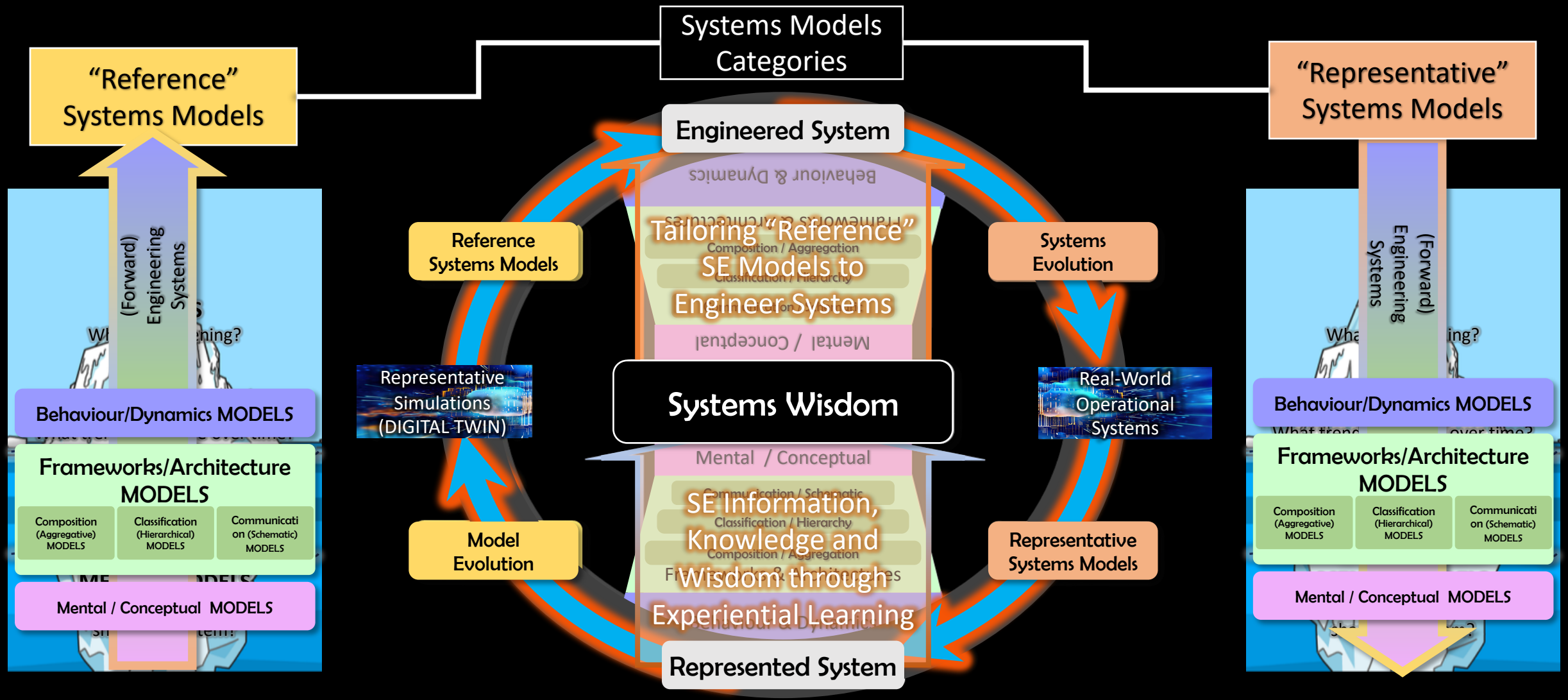


Applying "Engineering Wisdom" to Engineer Systems



Building "Engineering Wisdom" through Experiential Learning





Motivation…

"Remember, always, that everything you know, and everything everyone knows, is only a model. Get your model out there where it can be viewed. Invite others to challenge your assumptions and add their own."

Donella Meadows : Thinking in Systems

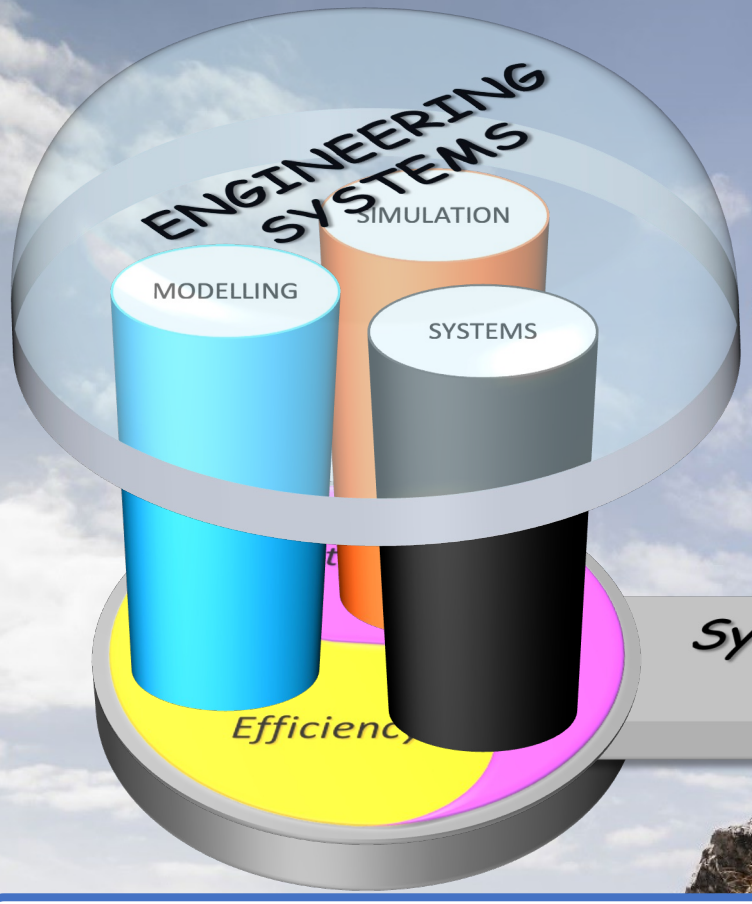
Is there "One model to rule them all, one model to find them, one model to frame them all, and through emergence bind them."?

*Disclaimer – the concepts expressed in this presentation are personal opinions and insights that continue to evolve based on theoretical and experiential learning and should not be taken as suggesting **the** truth nor should any opinions expressed be associated with any organisation that I have been or am affiliated with.*

Systemic *and* Systematic – Doing the Right Job Right!

Motivation….

Elevate the application and understanding of the *Engineering of Systems* and the relative-standing of *Systems Engineers*



Enabled by Systems Thinking (*GAS*)

Systems Engineers enable the efficient and effective realization, sustainment and retirement of complex capabilities!

Complimented by Modelling & Simulation

The ***foundational responsibility of Systems Engineers*** is to ***maximise the right emergence*** while ***minimising the wrong emergence*** and associated unintended outcomes ***in the engineering of systems*** through **Systemic Thinking**, complimented by **Modelling and Simulation**