Putting the "Systemic" (back) into the Engineering of Systems

Jawahar Bhalla (JB)

JB@EngineeringSystems.com.au

www.linkedin.com/in/JawaharBhalla

Technical Director – Systems Engineering Society of Australia (SESA)

SME Industry Co-Chair – Defence Synthetic Environment Working Group (SEWG)

Session Number: 5.1
Session Title: Systems of Systems Engineering
Date: Tuesday, 21st July 2020
Time: 12:30-13:10 UTC+2

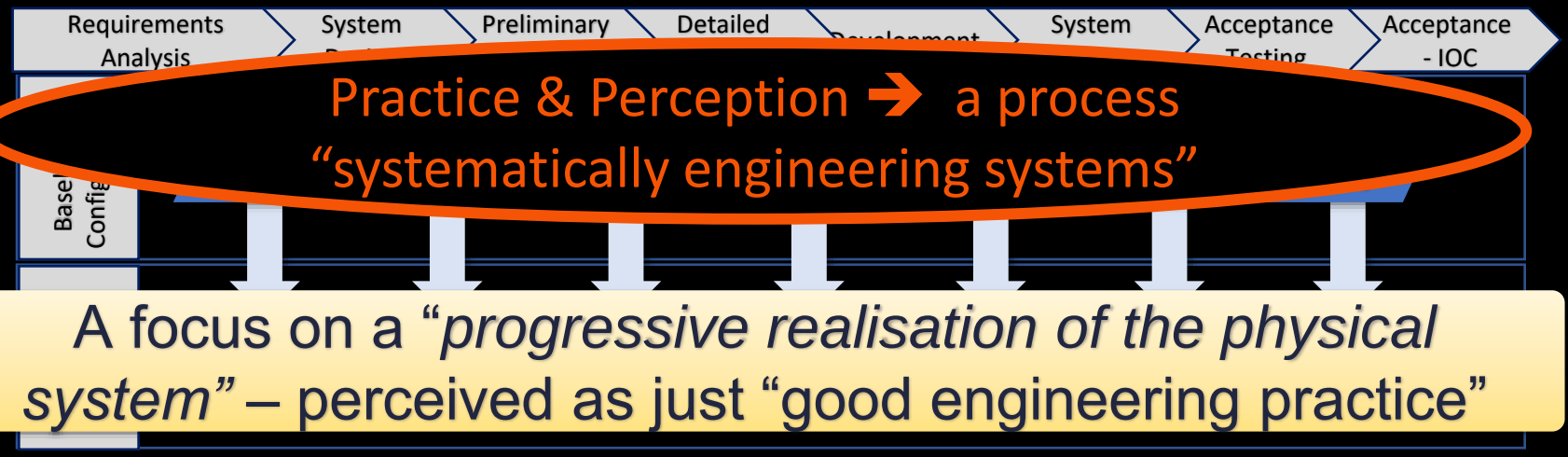
Systems Engineering – Practice & Perceptions

INCOSE Definition (pre mid-2019) – "What is Systems Engineering"

An *engineering discipline* whose responsibility is *creating and executing an interdisciplinary process* to ensure that the customer and stakeholder's needs are satisfied in a *high quality*, *trustworthy*, *cost efficient* and *schedule compliant* manner throughout a system's *entire life cycle*.
(http://www.incose.org/AboutSE/WhatIsSE)

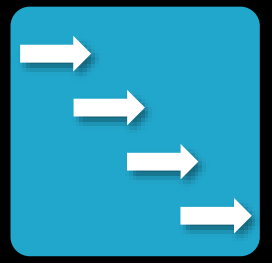
Technically Focused

Financial Milestones



A focus on a "*progressive realisation of the physical system*" – perceived as just "good engineering practice"

Process Overhead



Just another "speciality"

INCOSE Definition (2019) – "What is Systems Engineering"

Systems Engineering is a ***transdisciplinary*** and ***integrative*** approach to enable the successful realization, use, and retirement of ***engineered systems***, using ***systems principles*** and ***concepts***, and scientific, technological, and management methods.
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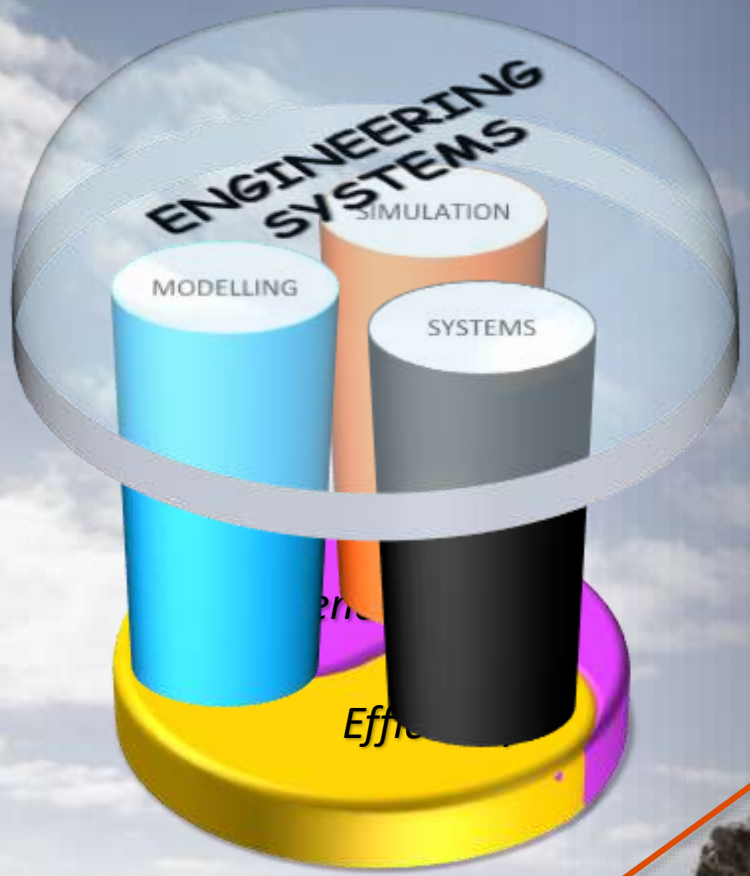
Putting the "*Systemic*" (back) into the *Engineering of Systems*



Motivation…..

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

Paper / Presentation Focus

INCOSE Definition (2019) – "What is Systems Engineering"

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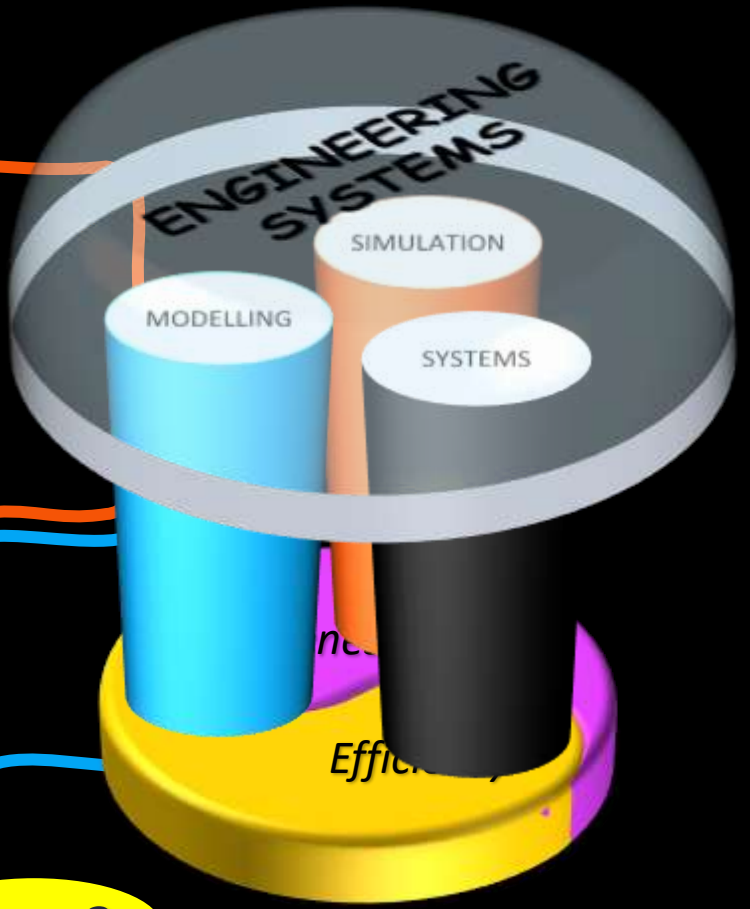
Presentation Structure

Principles & Concepts

- Systems Thinking
- Modelling & Simulation
- The Content of our Minds

- The Engineering of Systems
- Key Points & Recommendations

Application & Conclusions



WHY? *WHAT?* *HOW?*

Problems, Symptoms & Root Causes

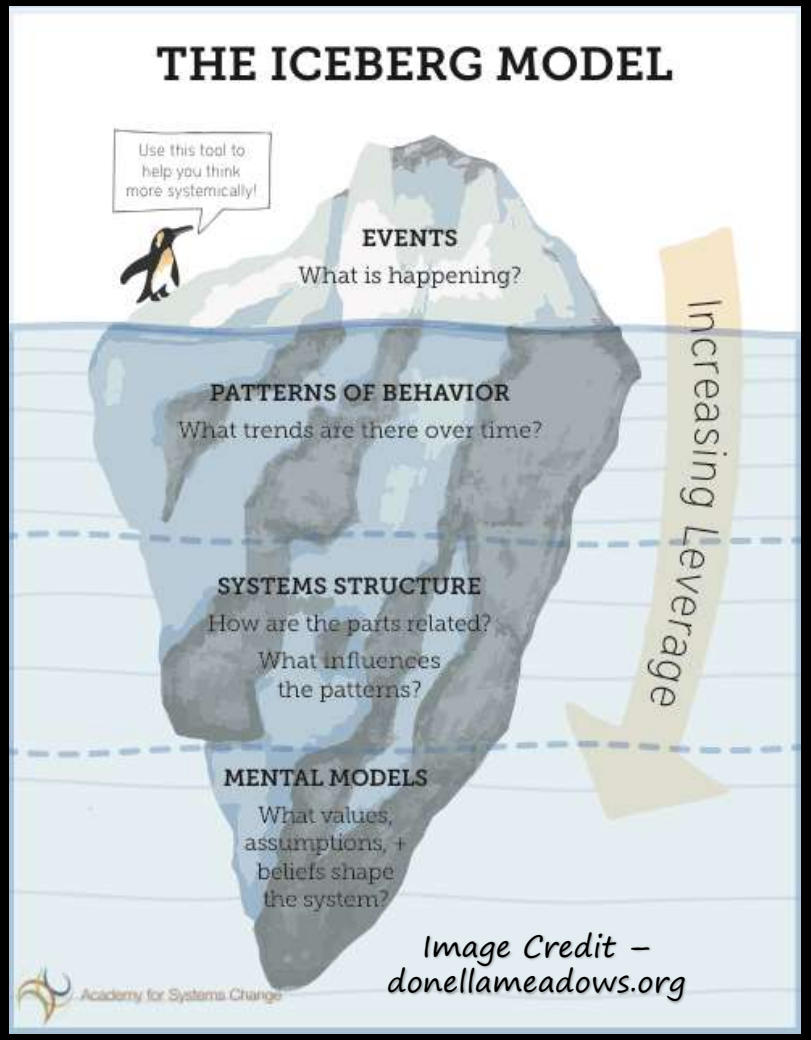
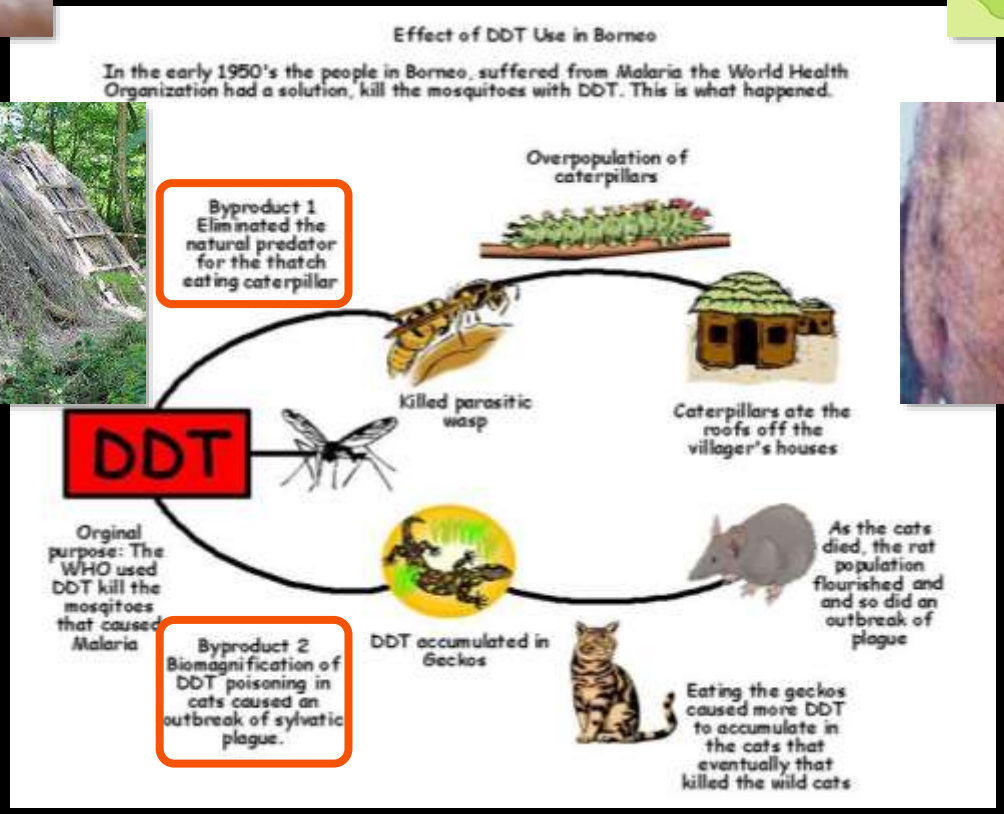


Image Credit – donellameadows.org

A major outbreak of malaria amongst the Dayak people in Sarawak, Borneo

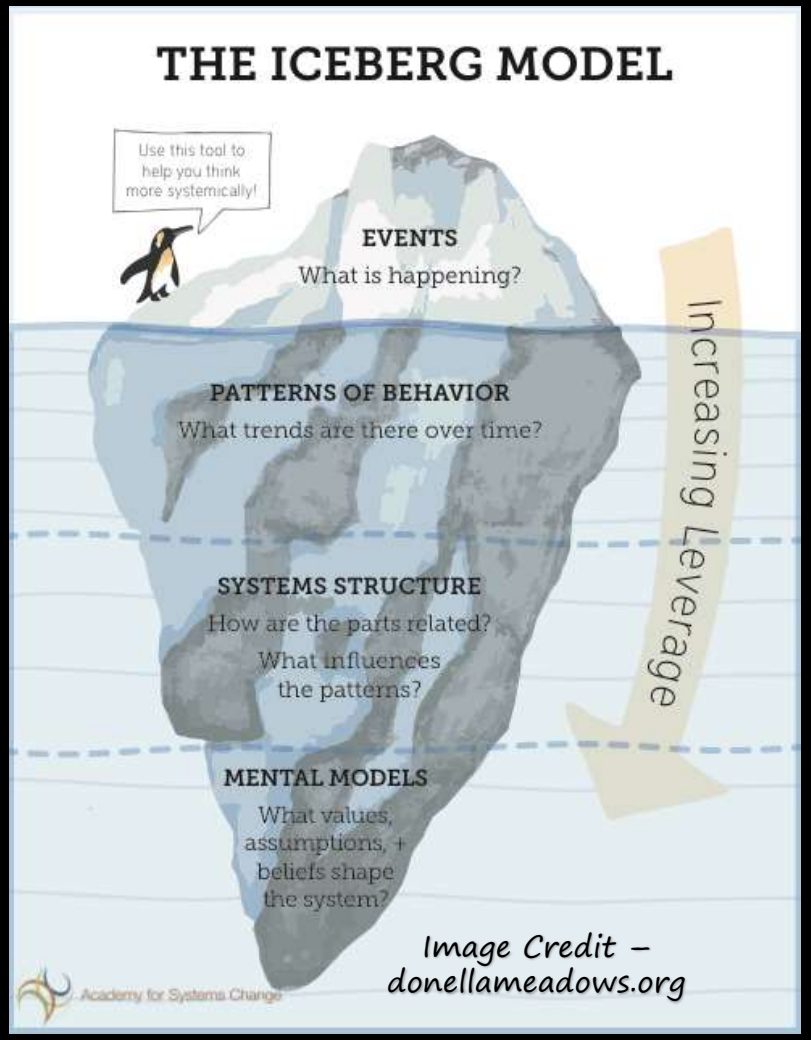
The WHO Responded – Sprayed DDT



Good Intentions

Unintended Consequences!

Problems, Symptoms & Root Causes



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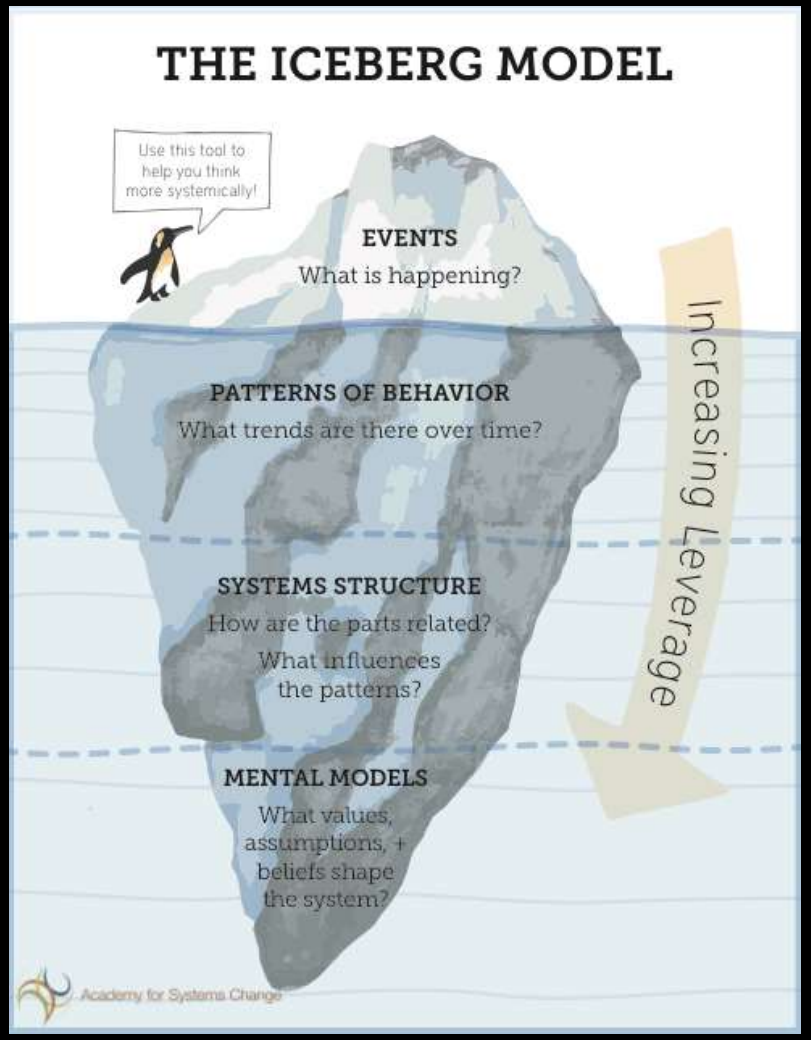
What is Systems Thinking?



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*."

Personal view → *Systems Thinking is a framework to make sense of the world we live in, to deal efficiently and effectively with the challenges we perceive and to create the reality we desire, while minimizing the chances of unintended consequences*.

Complimented by Modelling & Simulation

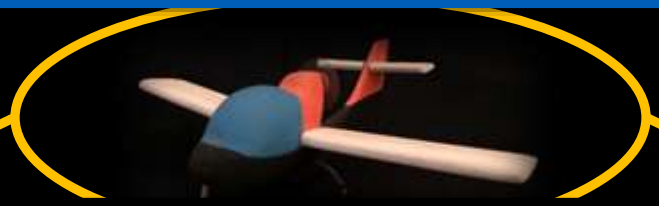
How do we understand a System?

A System

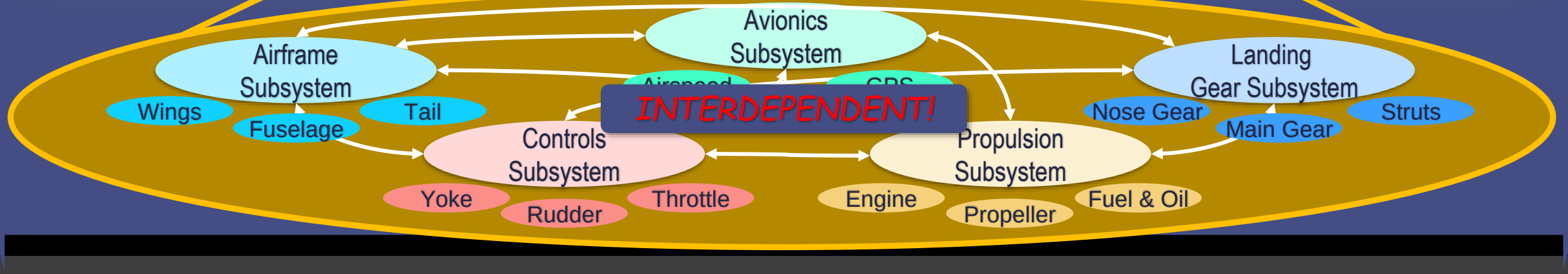
A *whole* that consists of *interdependent parts* each of which can affect its *behaviours* or its *properties*
(Russell Ackoff)

Think About it?

Analyse it?



The "DUJU"
Ultralight Aircraft for Station Inspection



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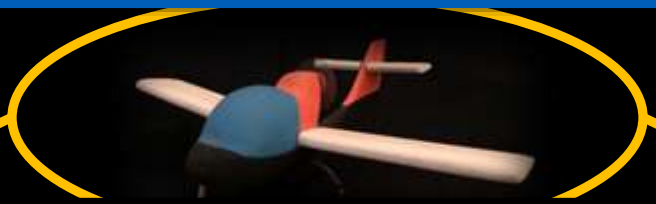
HOW?
ANALYSIS
STRUCTURE
(Organisational Interdependence)

ANALYSIS



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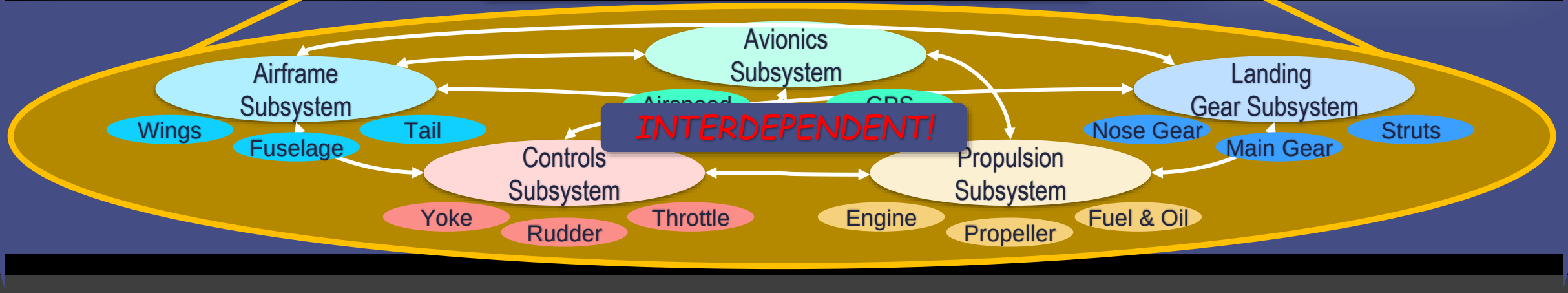
Analyse it?



How do we understand a System?

Predominant determinism

A System

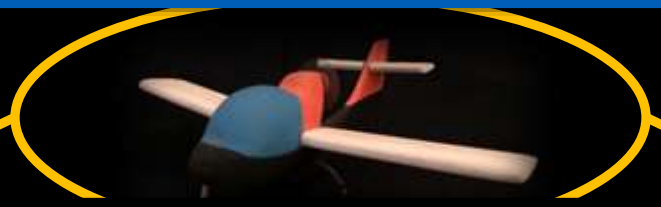
Is an *arrangement* of *parts* or *elements* that *together* exhibit *behaviour* or *meaning* that the individual constituents do not (INCOSE-2019)

HOW?

ANALYSIS

STRUCTURE
(Organisational Interdependence)

ANALYSIS



The "DUJU"
Ultralight Aircraft for Station Inspection

WHAT?
it?

Avionics

Airframe Subsystem

Wings

Fuselage

Landing ar Subsystem

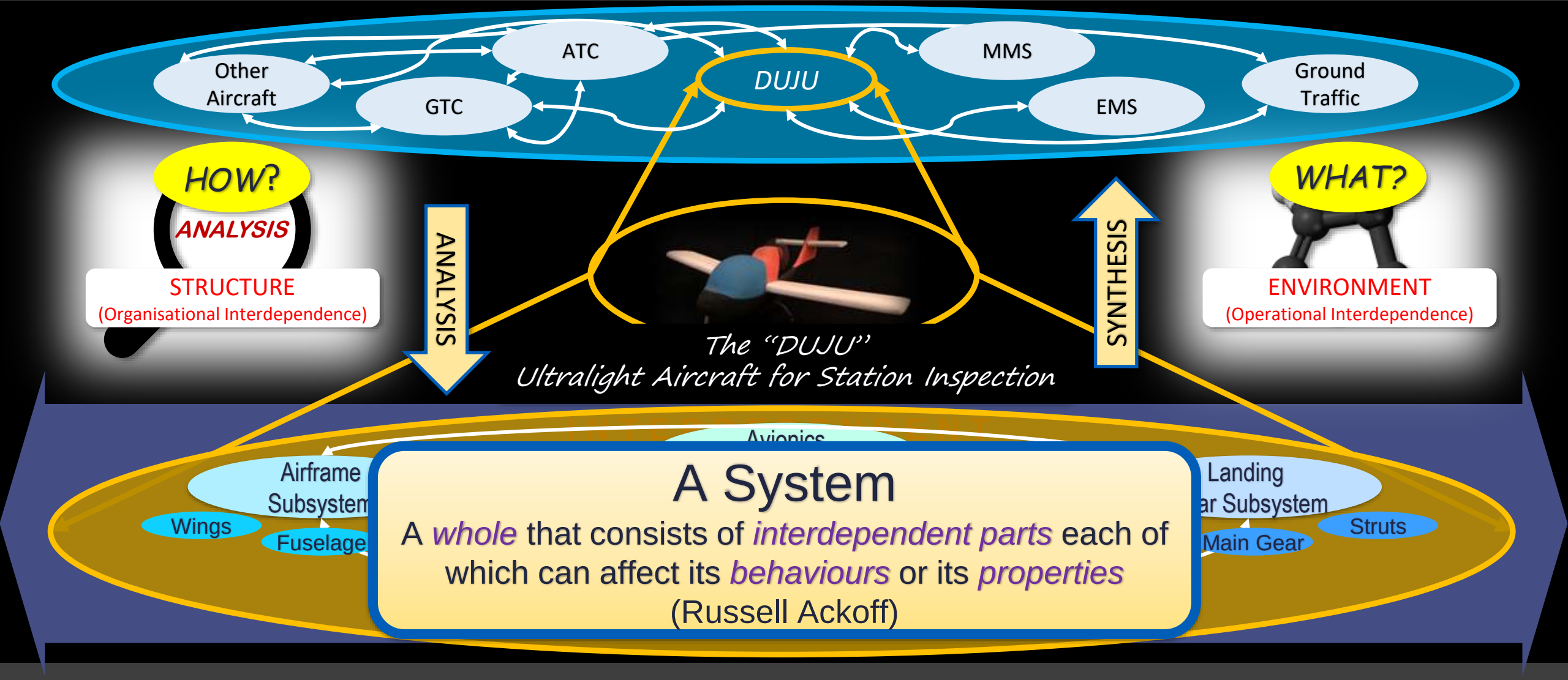
Struts

Main Gear

A System

A *whole* that consists of *interdependent parts* each of which can affect its *behaviours* or its *properties* (Russell Ackoff)

How do we understand a System?



How do we understand a System?

A System

A *whole* that is defined by its *essential functions* within a larger System of which it is a part
(Russell Ackoff)

Other Aircraft

Ground Traffic

HOW?

ANALYSIS

STRUCTURE
(Organisational Interdependence)

WHAT?

ENVIRONMENT
(Operational Interdependence)

ANALYSIS

SYNTHESIS

The "DUJU"
Ultralight Aircraft for Station Inspection

Avionics

Airframe Subsystem

Wings

Fuselage

Landing Gear Subsystem

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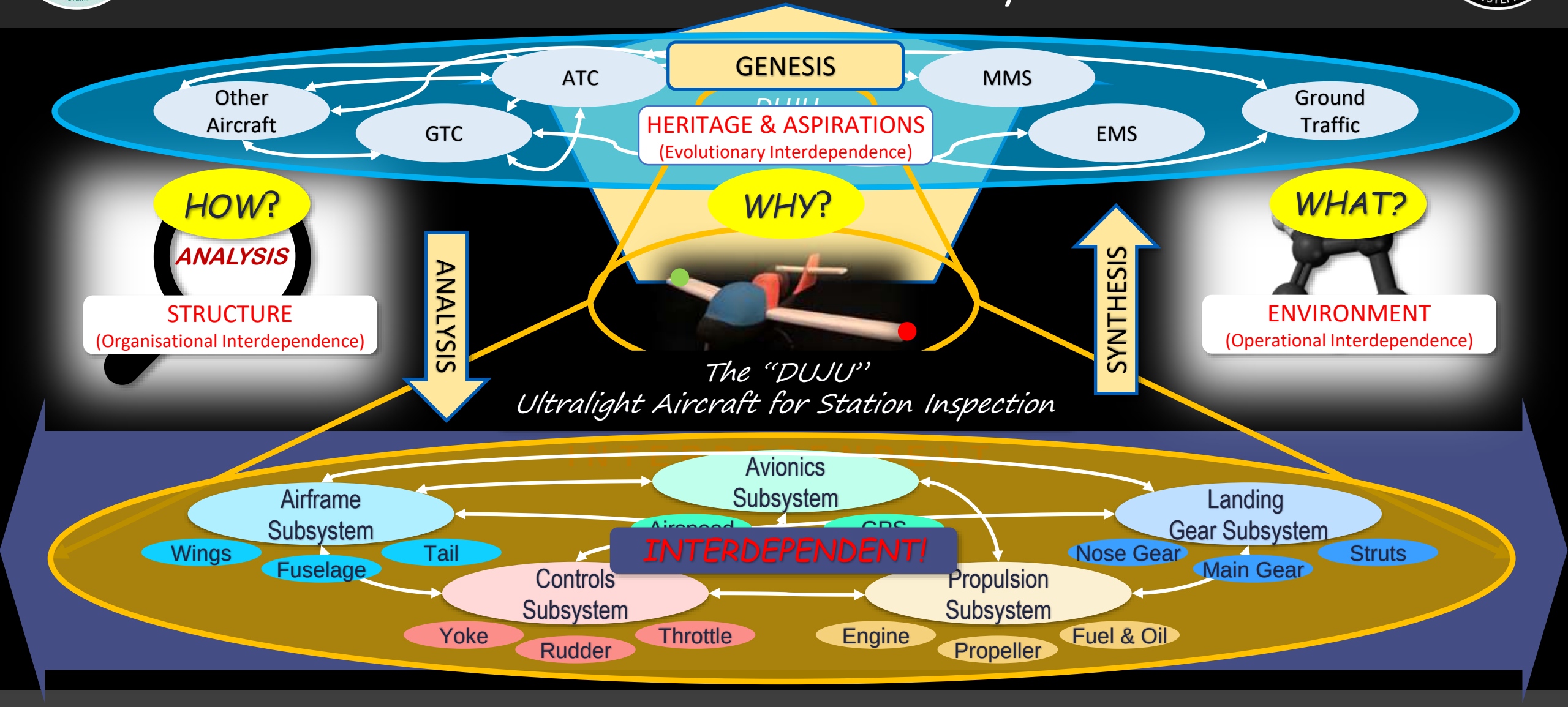


Understanding Systems…with "*GAS*"

A System

A *whole* that consists of *interdependent parts* each of which can affect its *behaviours* or its *properties* (Russell Ackoff)

HOW?

ANALYSIS

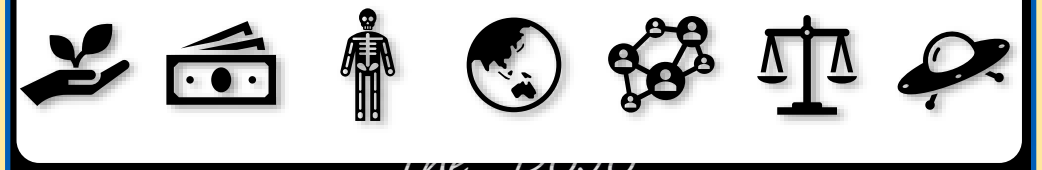
STRUCTURE
(Organisational Interdependence)

GENESIS

HERITAGE & ASPIRATIONS
(Evolutionary Interdependence)

WHY?

ANALYSIS



SYNTHESIS

A System

A *whole* that is defined by its *essential functions* within a larger System of which it is a part (Russell Ackoff)

WHAT?

ENVIRONMENT
(Operational Interdependence)

The "DOVE"
Ultralight Aircraft for Station Inspection

A System

A *whole* who's *behaviours* are a result of its *evolving Structural* **and** *Environmental Heritage & Aspirations* (Personal Refinement)

Analysis answers "**HOW**" questions to provide "Knowledge" focused *Inside* the System to understand "*HOW the System works*" and "*WHAT the System does*"

Genesis Answers the "**WHY**" questions by "understanding" the *heritage & aspirations* of the System and *explains its behaviours* as a result of its *evolving Structure* ***and*** *Environment*

Synthesis Answers the "WHAT *the System should do*" question by "understanding" the *operational context within which the System exists*

Presentation Structure

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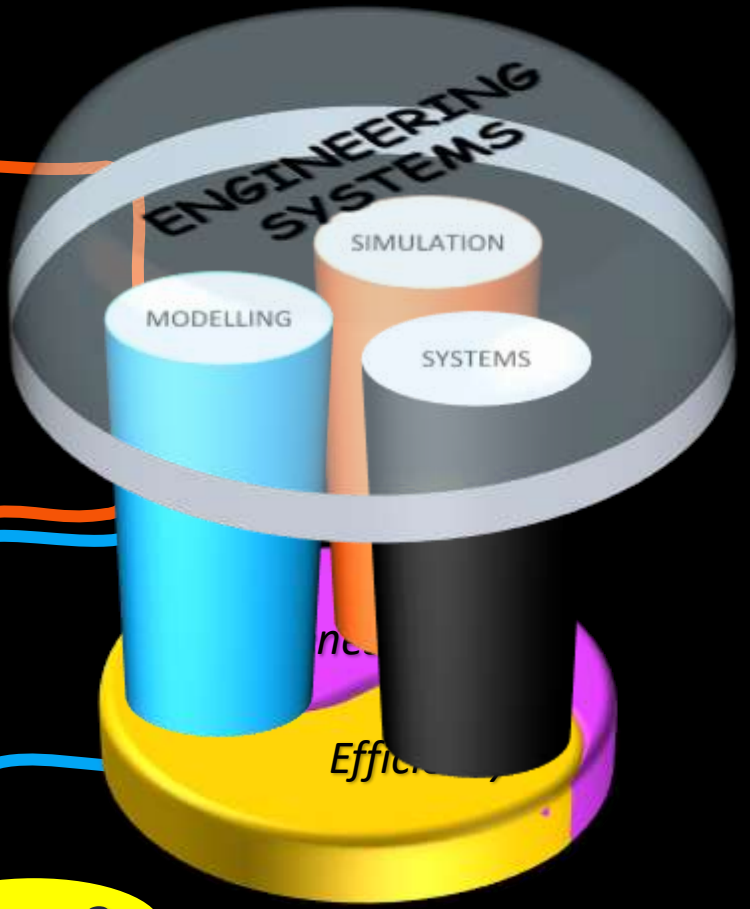
Application & Conclusions



WHY? *WHAT?* *HOW?*

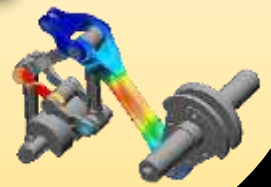
Motivation – Why?

M&S is "all-pervasive"

Compliments "Systems Thinking"

Predict
Decide
Explore
Rehearse
Experiment
Train
Innovate
Learn
Communicate
Play
Entertain
Safety
Manage
Security
Resources
Savings
Time

Modelling & Simulation



Definitions – What?

Simulation = Model + Execution

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

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

Examples of **Simulations**

A **model** of a vehicle that moves across a **model** of terrain over time

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

Definitions – What?

Fidelity ➔ Breadth of Scope (forms, properties, functions) and Associated Resolution (granularity/detail)

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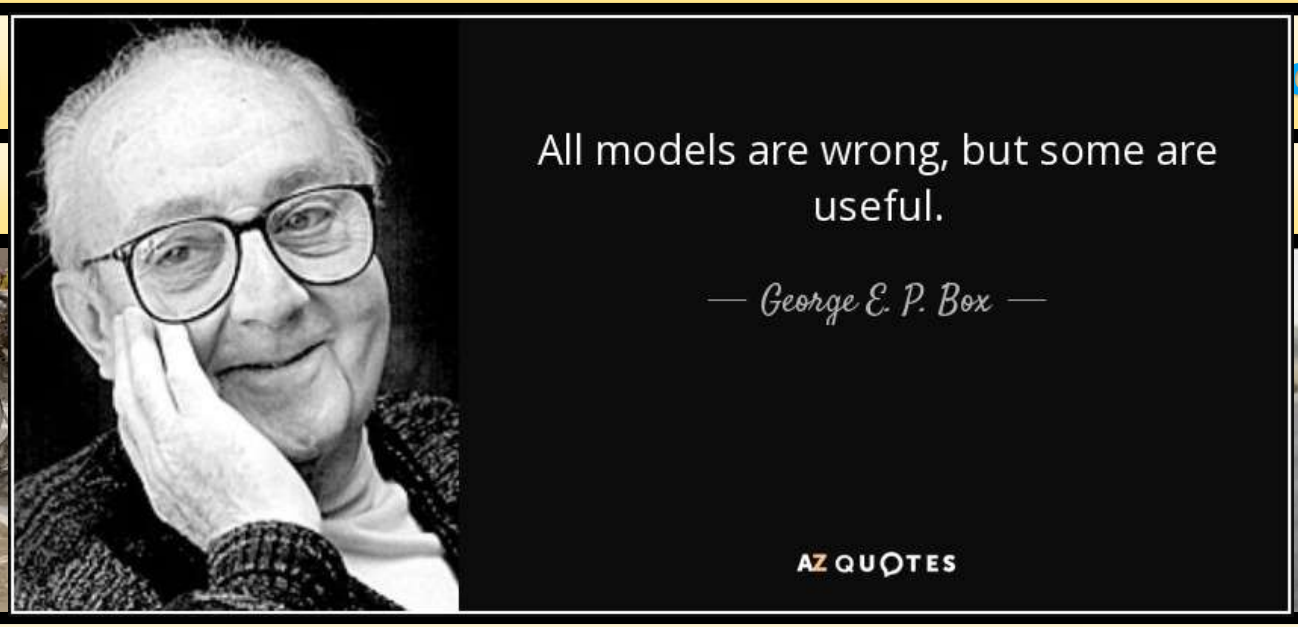
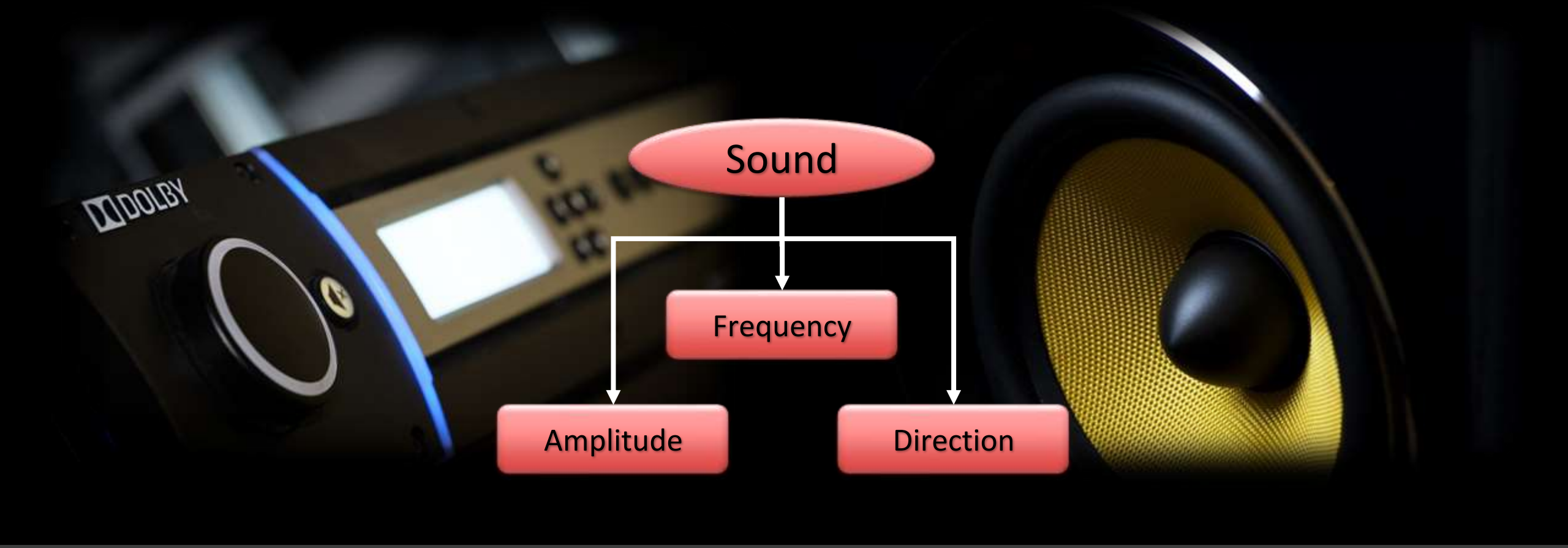
A **Simulation** del over Time



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

Definitions – Fidelity (How?)

Fidelity ➔ Breadth of Scope (forms, properties, functions) and Associated Resolution (granularity/detail)



Definitions – Fidelity (How?)

Fidelity ➔ Breadth of Scope (forms, properties, functions) and Associated Resolution (granularity/detail)

Varying Formats

Lift Floor Tone

Re-Use

Re-Use

Home Theatre

Re-Use

Re-Use

Full Flight Simulator

FFS

IP Protection

Sound

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

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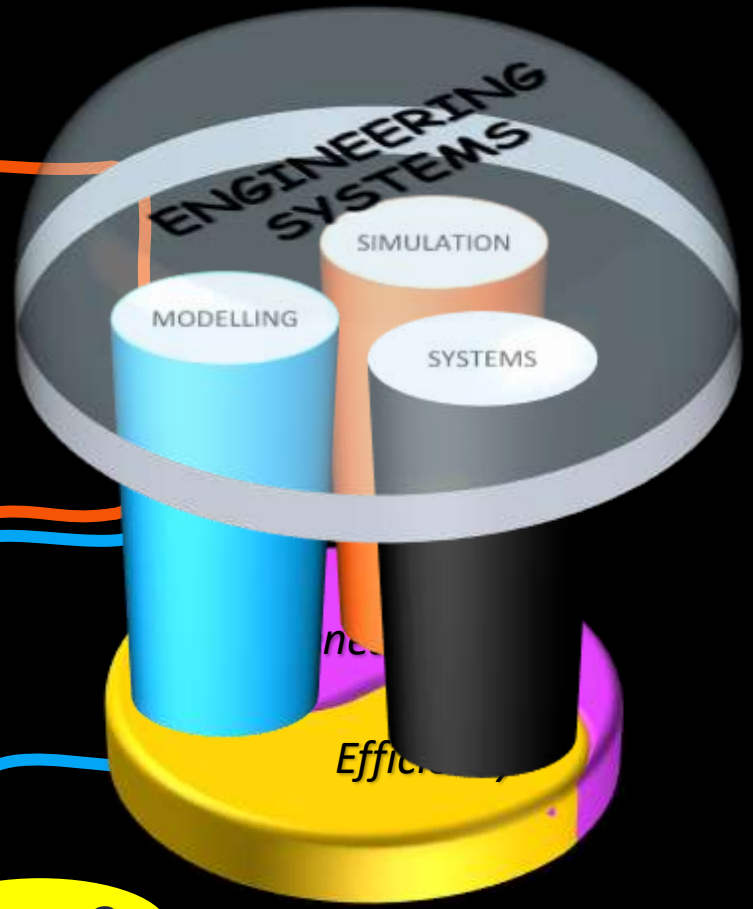
WHY? *WHAT?* *HOW?*



Why do we see things differently?

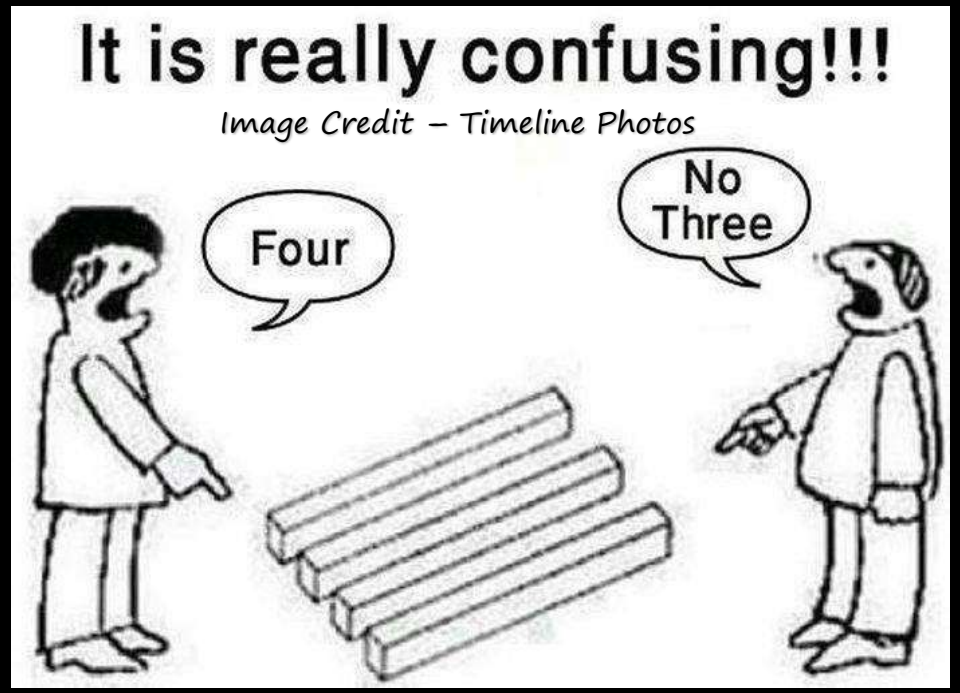


Image credit todayifoundout.com

How do we Understand / Create our Reality?

Knowledge can be taught / Wisdom must be learned ("doing" in an "environment"!)

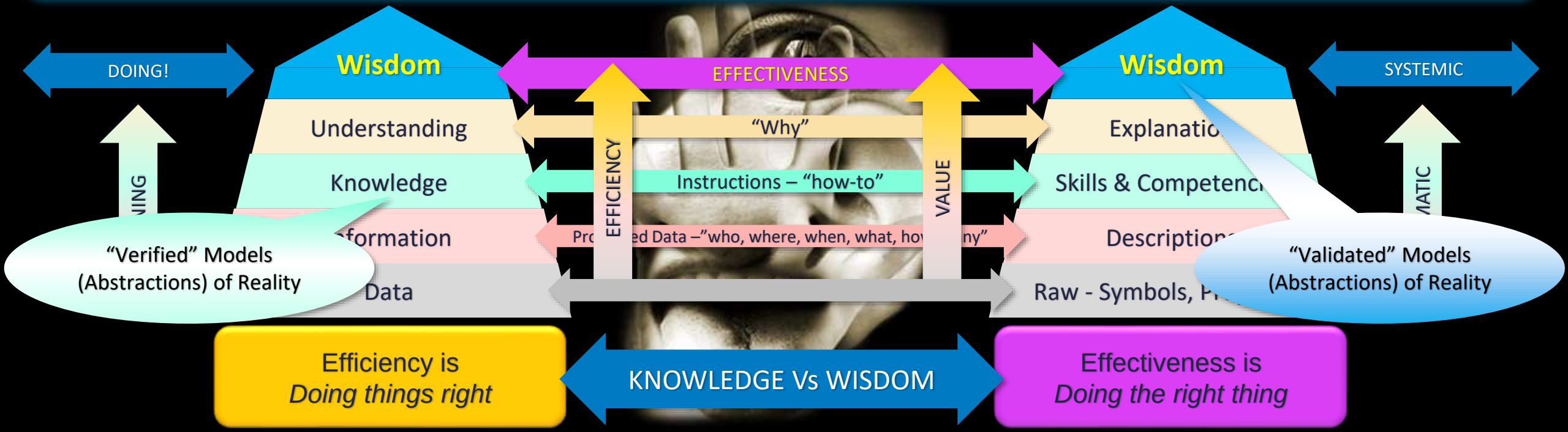


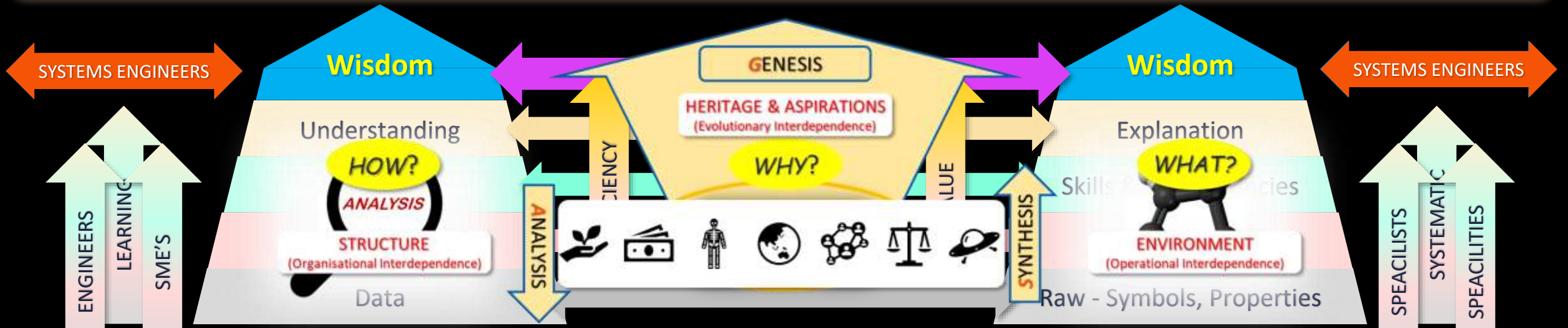
Image credit todayifoundout.com

Efficiency improves when we "*know-how*" things are to be done ➔ "depth of knowledge"

Effectiveness improves when we "*know-why*" things are to be done ➔ "breadth of understanding"

How we Understand / Create our Reality…

"A *transdisciplinary* and *integrative approach* building on *systemic principles* and *concepts*…"



Efficiency is *Doing things right*

ENGINEER SYSTEMS

Effectiveness is *Doing the right thing*

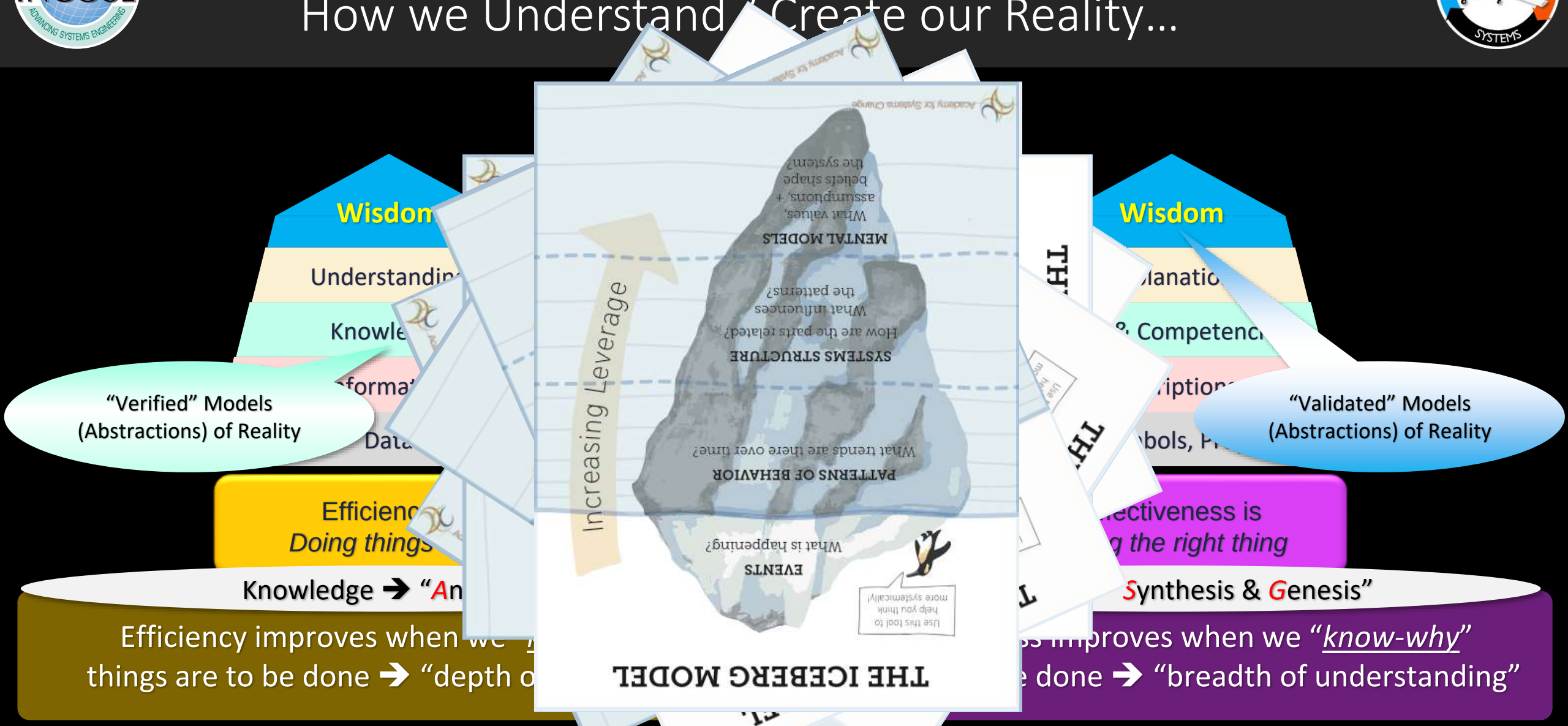
Knowledge ➔ "*A*nalysis"

Efficiency improves when we "*know-how*" things are to be done ➔ "depth of knowledge"

Wisdom ➔ "*S*ynthesis & *G*enesis"

Effectiveness improves when we "*know-why*" things are to be done ➔ "breadth of understanding"

How we Understand / Create our Reality…



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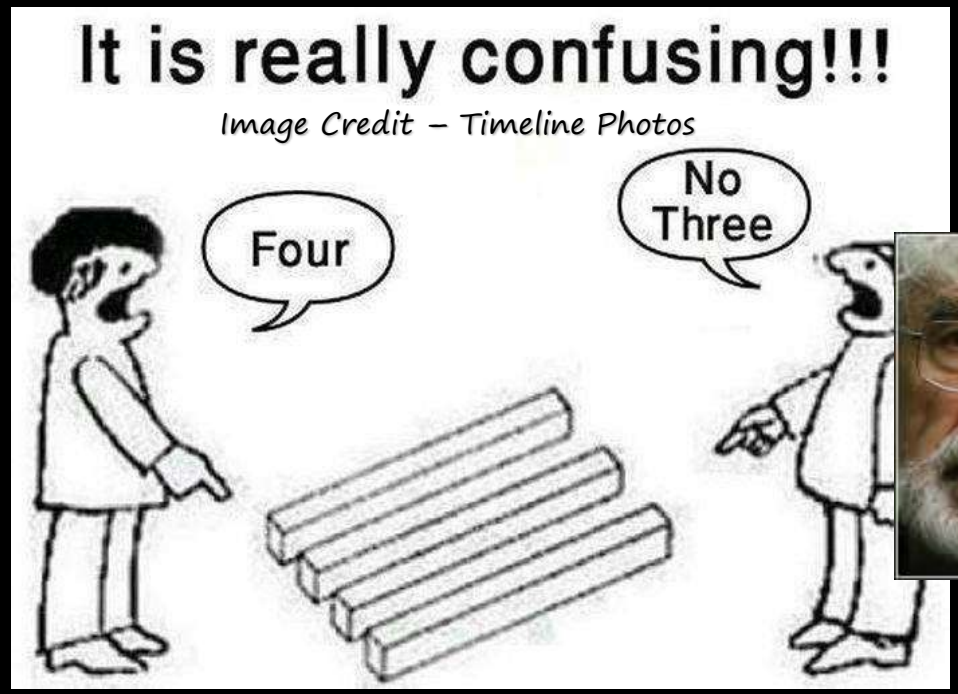

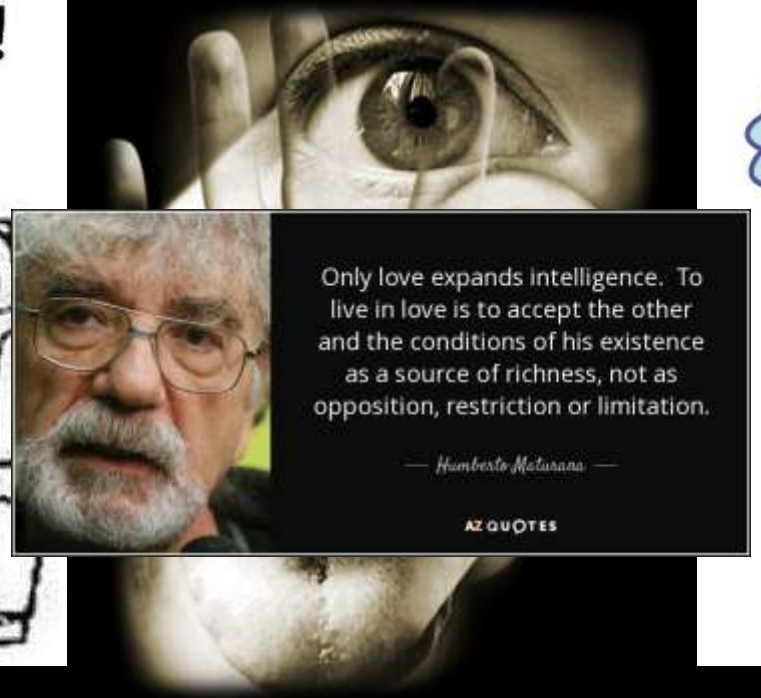

Image credit todayifoundout.com

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

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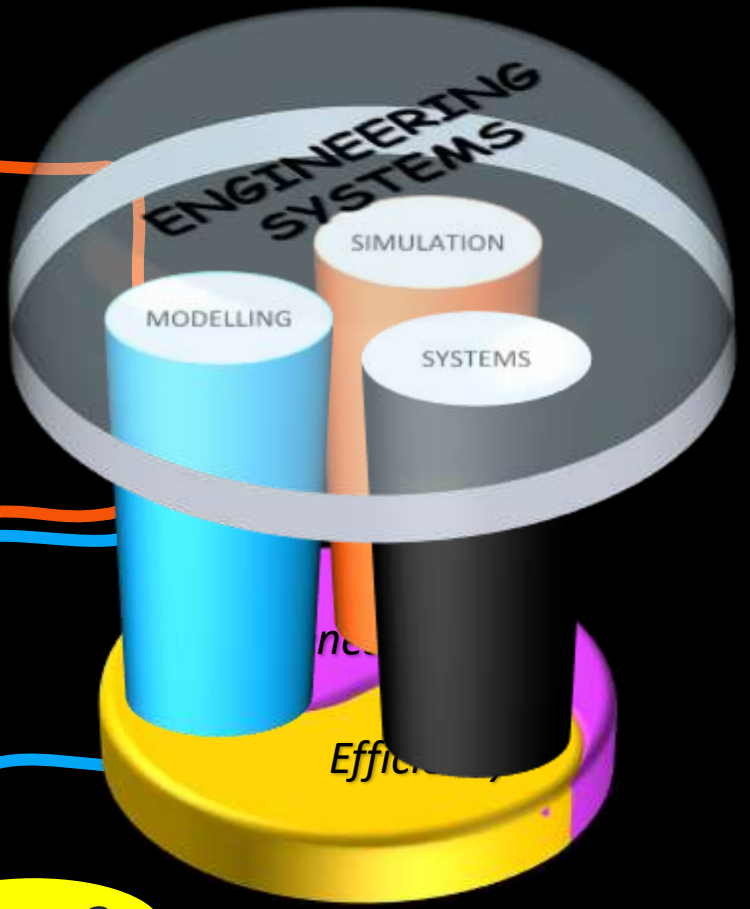
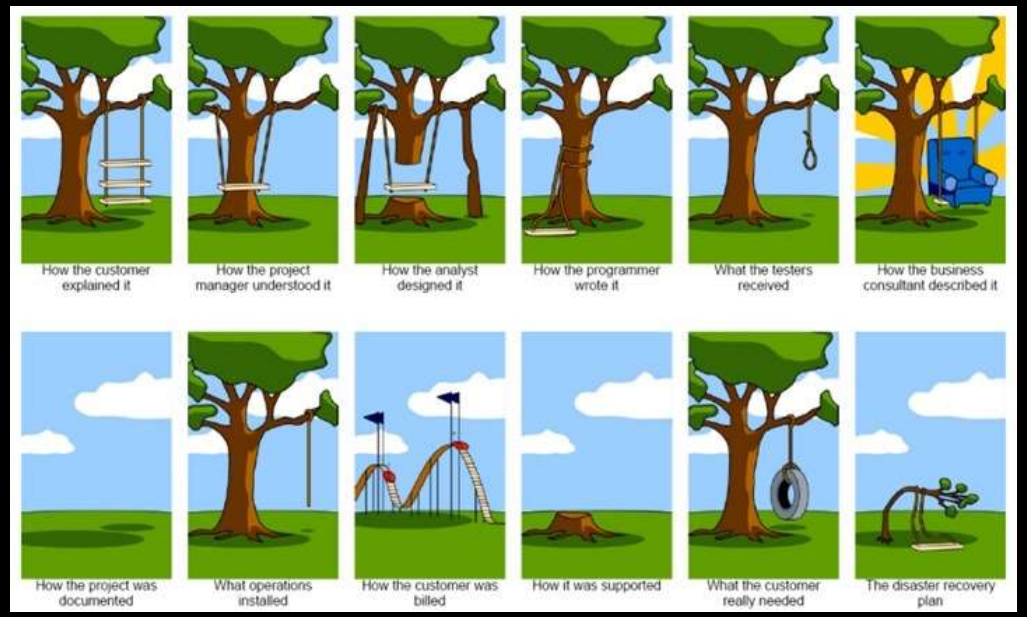


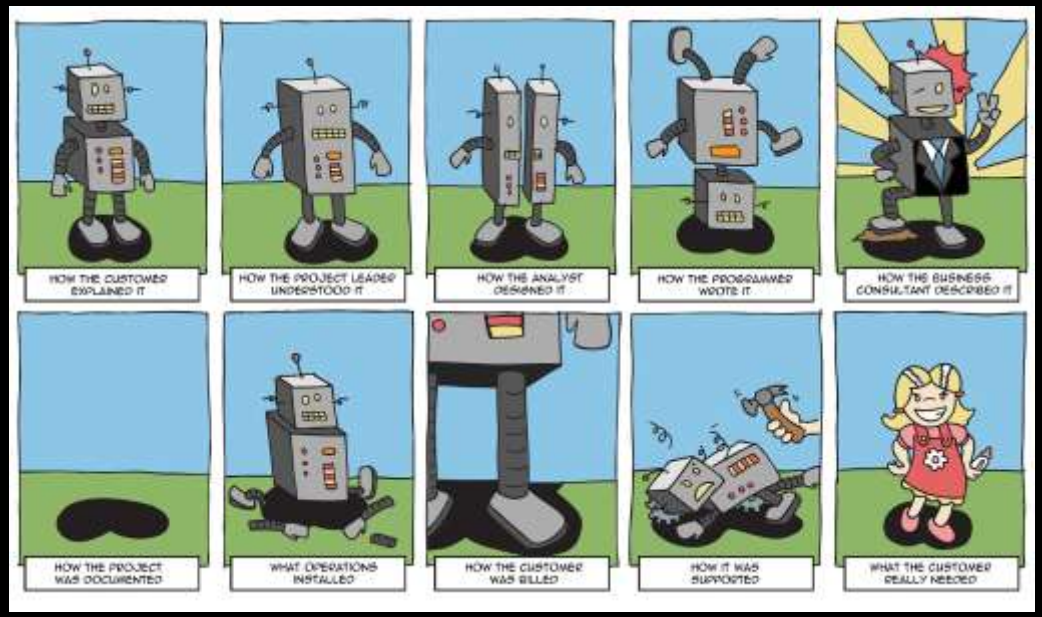
WHY? *WHAT?* *HOW?*

Motivation for Systems Engineering

- A framework to deal with complexity and risk
- Provides a bridging between user needs and the solution that best delivers these needs across stakeholders
- Maximises the chances of the delivered solution meeting the intended need

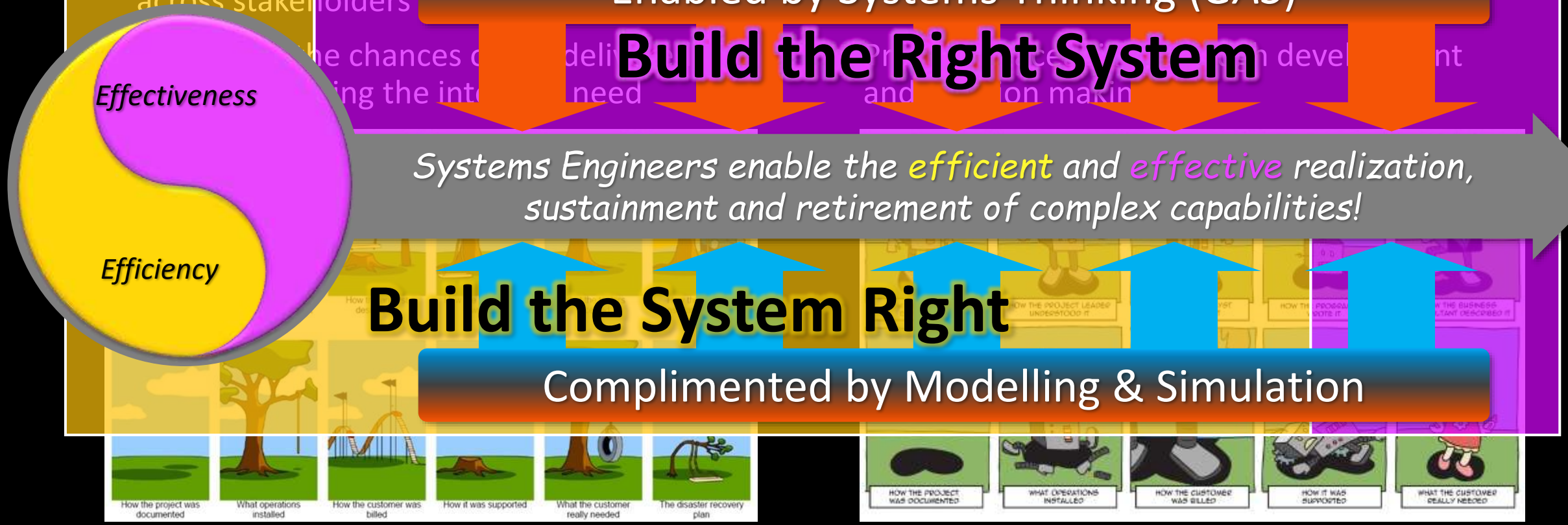


- Builds in the quality, saves money and reduces risk
- Provides a framework for measuring progress through project phases
- Provides traceability through development and decision making



The Essence of "*Engineering Systems*"

- A framework to deal with complexity and risk
- Provides a bridging between user needs and the solution that bes… across stakeholders
- Builds in the quality, saves money and reduces risk



What is our Underlying Intent ?

Requirements Analysis | System Design | System Integration | Acceptance Testing | Acceptance - IOC

Baselines & Configurations: Draft FBL | PBL | Config | Test Config | Final PBL

RTM | System Definition | System Realisation | PCA

Real World: Operational | System-Of-Interest | Environment

Efficient & *Effective*

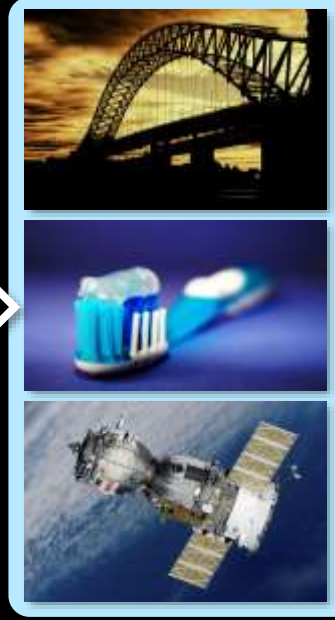
SOLUTIONS

Needs to Solutions

Verification & Validation: VCRM | Verification | Validation | FCA

Mandated Systems Reviews: SRR | TRR | FQR

ocus on a … of the physical system … g practice”



CAPABILITY

Always (at least) Two Creations…

1

C O N C E P T

Operational

System-Of-Interest

Environment

Conceptual Model of the SoI [C-SBS]

Requirements Analysis | System Design | System Integration | Acceptance Testing | Acceptance - IOC

Baselines & Configurations: Draft FBL | PBL | Config | Test Config | Final PBL

RTM | PCA

Efficient & … to Solutions

Actually we create 4 models – 2 of these being SE constructs….

Verification & Validation: VCRM | Verification and Validation | FCA

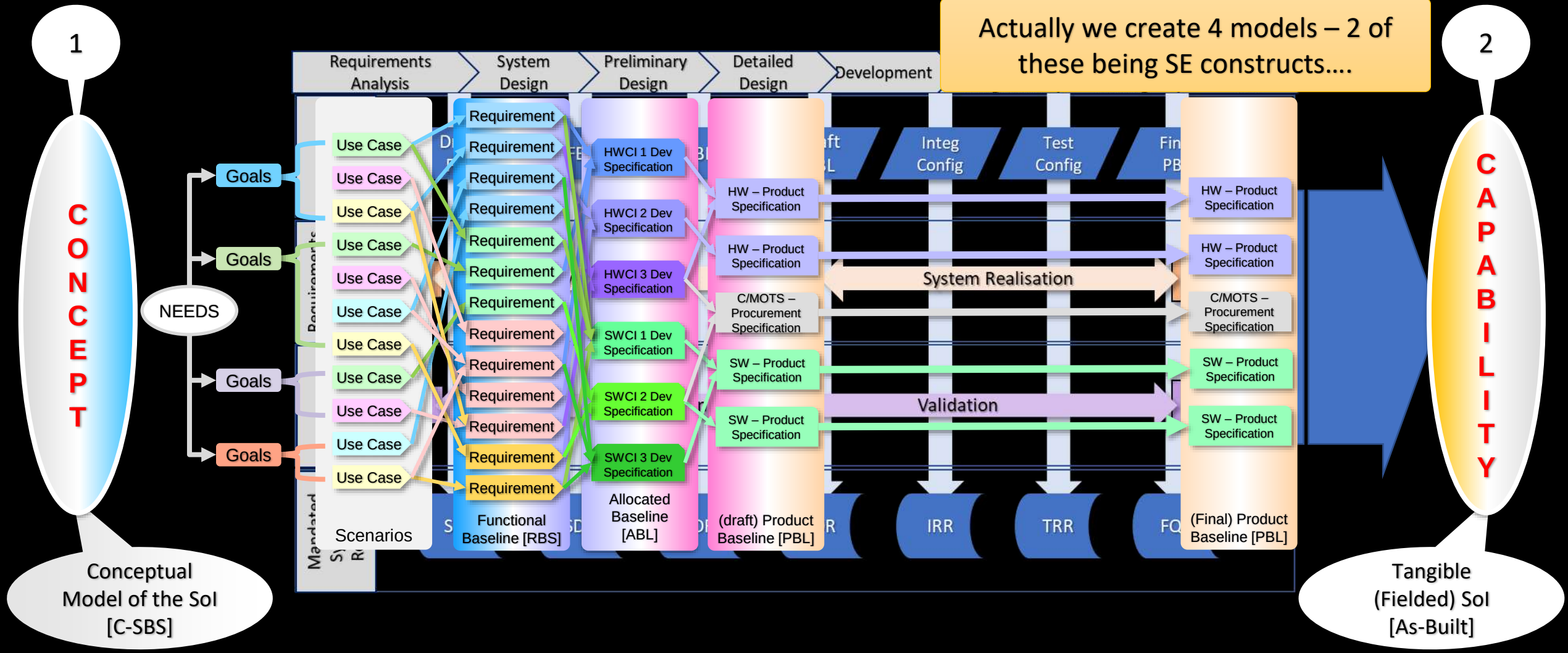
Mandated Systems Reviews: SRR | TRR | FQR

2

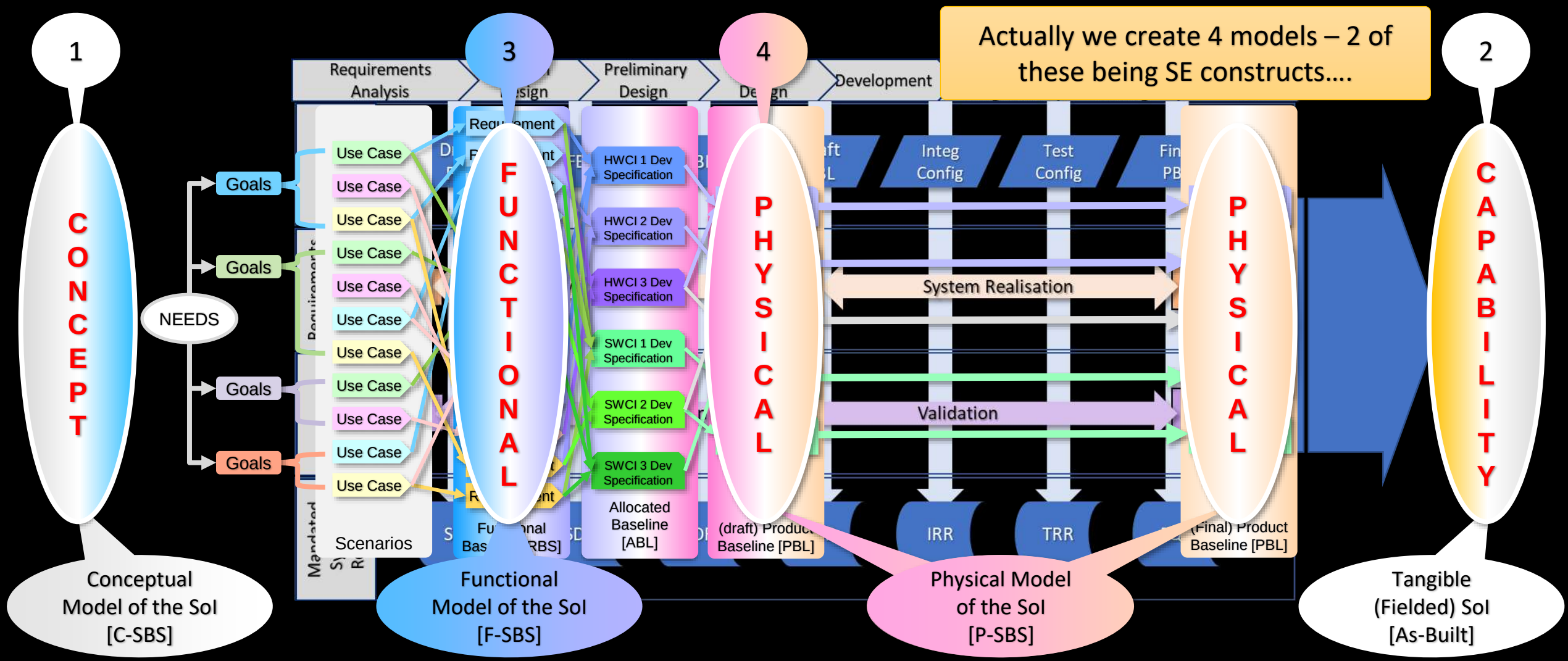
C A P A B I L I T Y

Tangible (Fielded) SoI [As-Built]

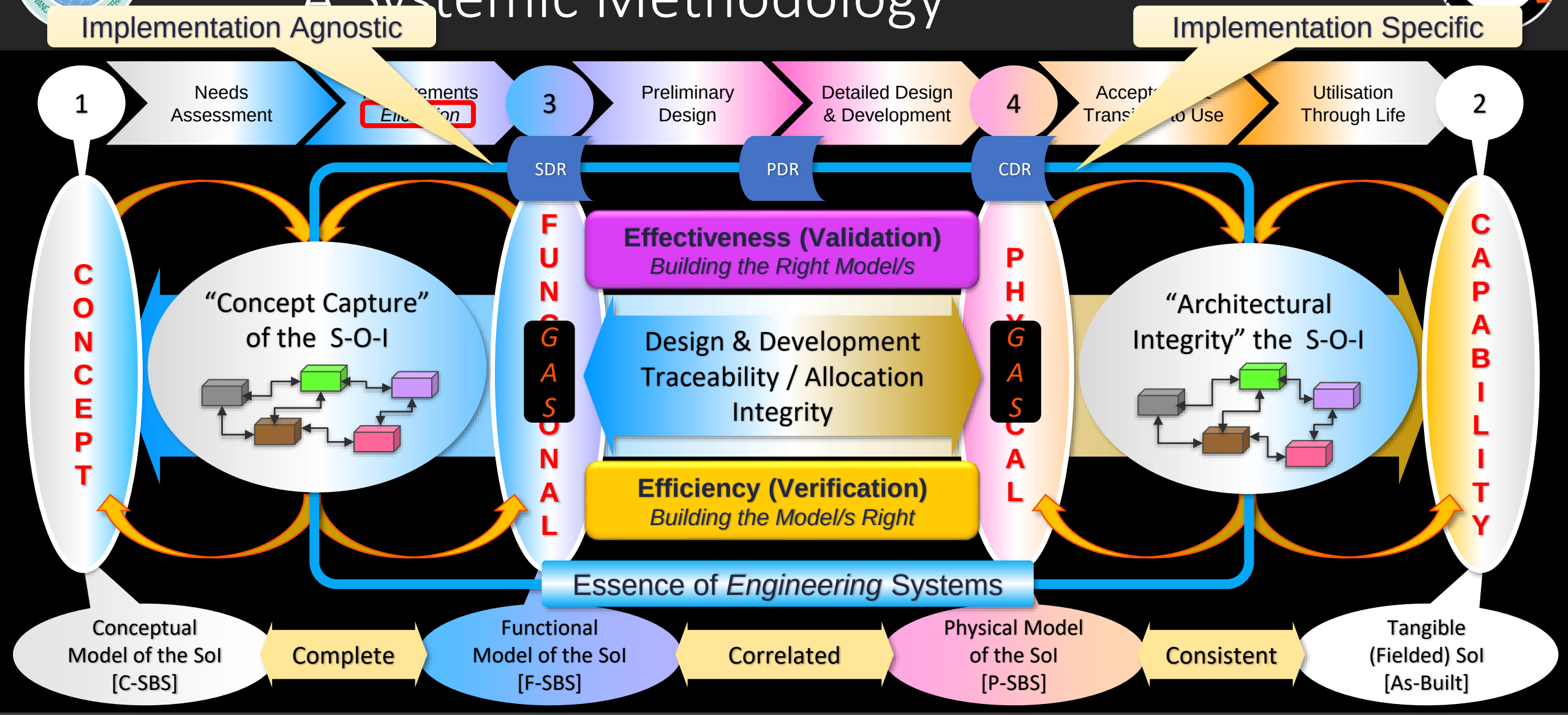
Baselines / Configurations



Four Models of each System Created



A Systemic Methodology



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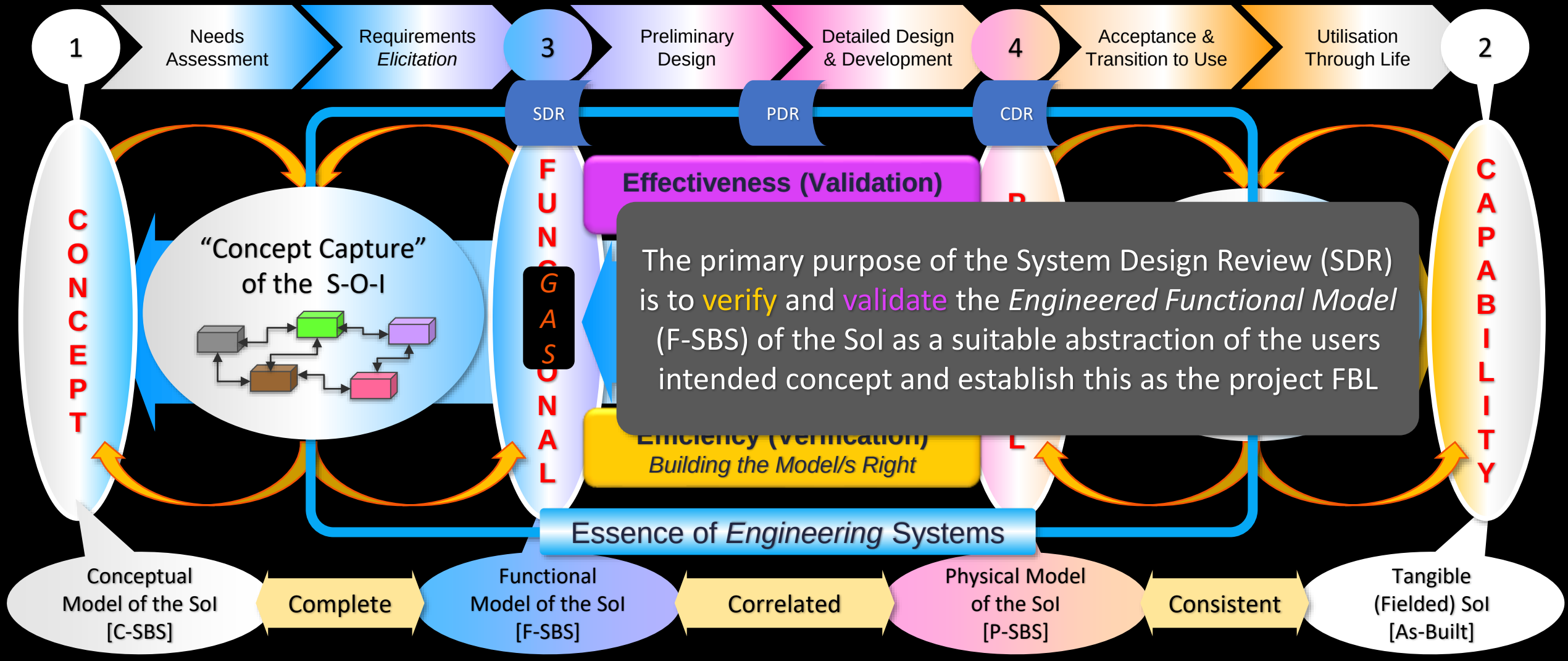

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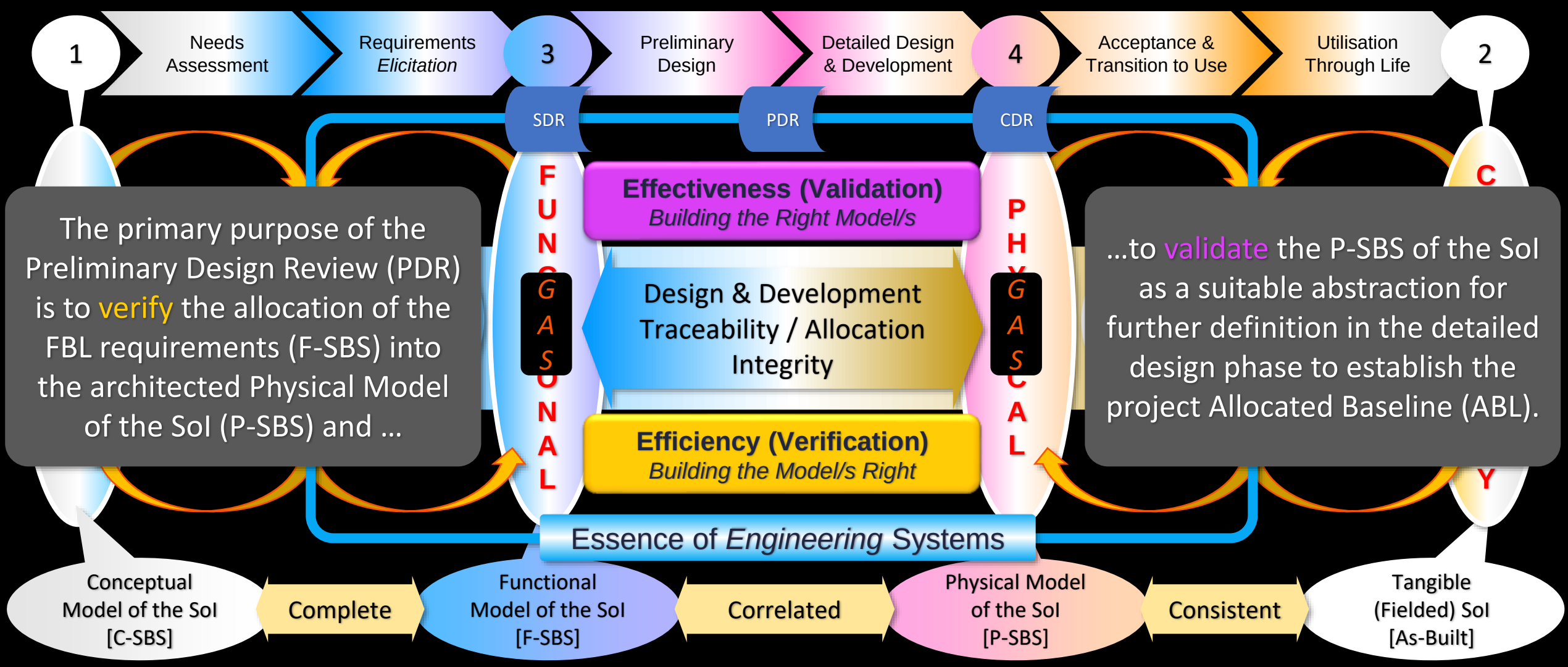
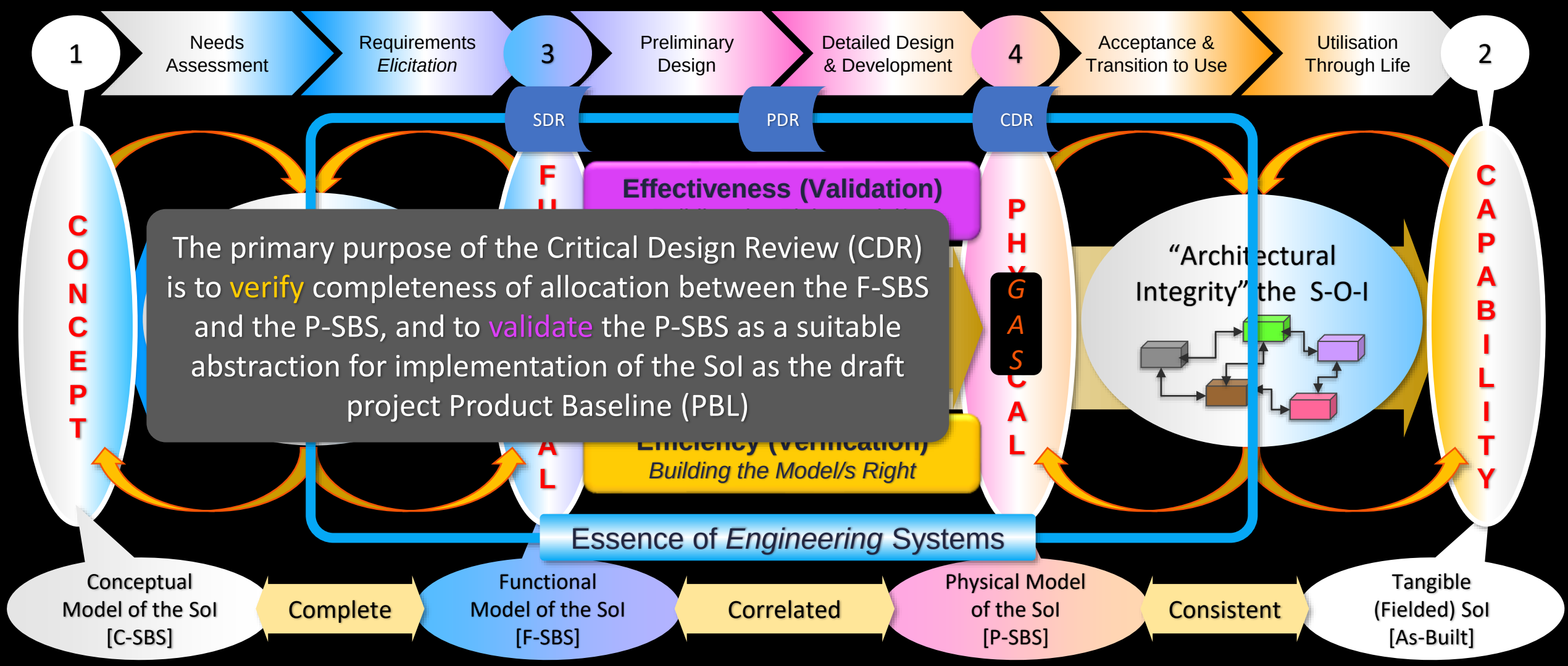
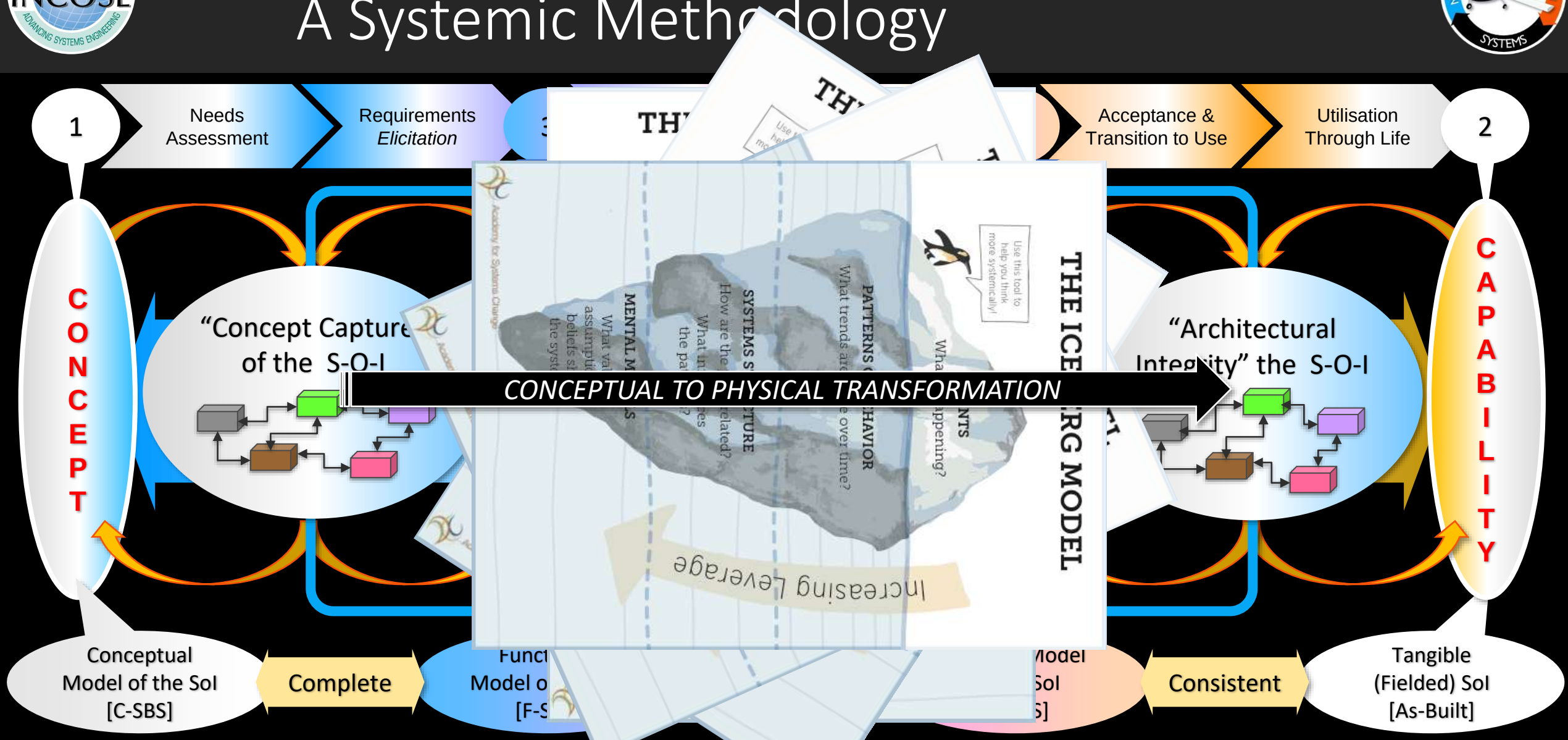


A Systemic Methodology



A Systemic Methodology



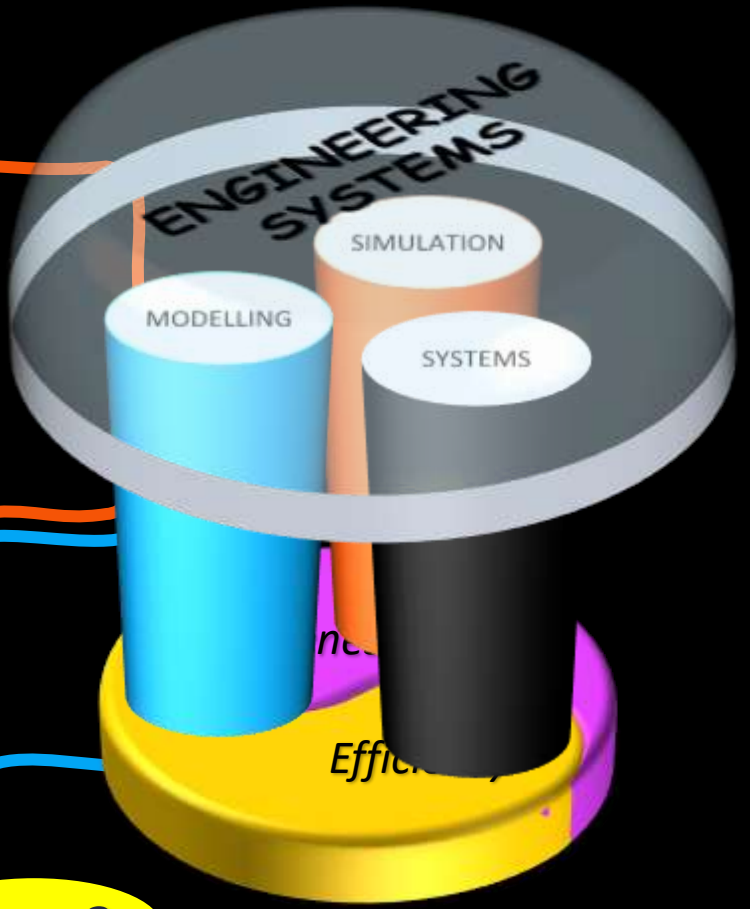
Presentation Structure

Principles & Concepts

- Systems Thinking
- Modelling & Simulation
- The Content of our Minds

- The Engineering of Systems
- *Key Points & Recommendations*

Application & Conclusions



WHY? *WHAT?* *HOW?*

Summary of Key Points

Systems **Thinking**

"Systems Principles"

2 1 3 and 4 5

"Concepts"

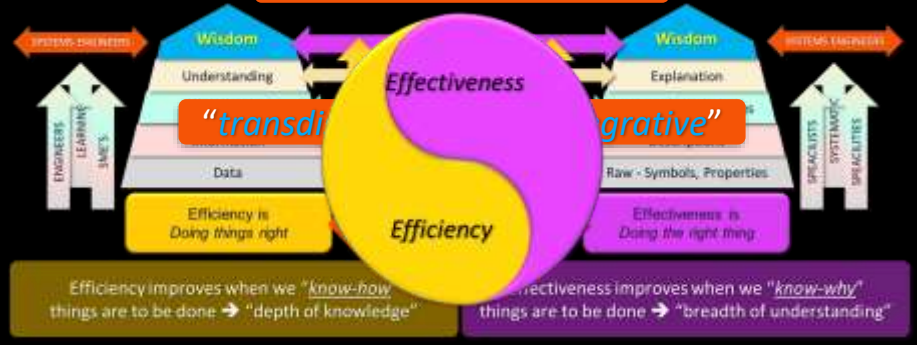
Modelling & Simulation

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

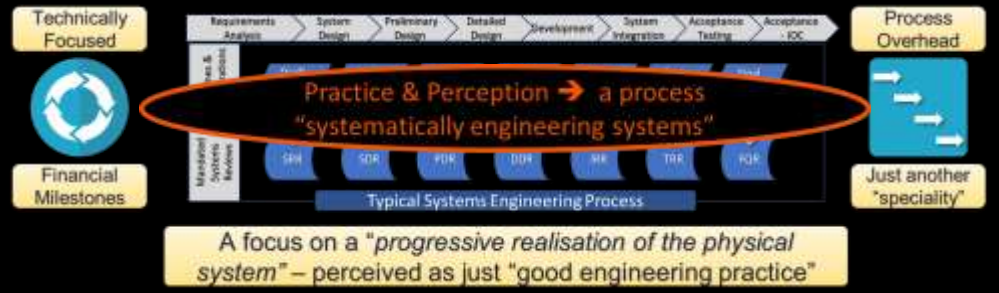
A Simulation is an Enactment (Method of Implementing) a Model over Time

Fidelity ➔ Breadth of Abstracted Scope + Associated Resolution

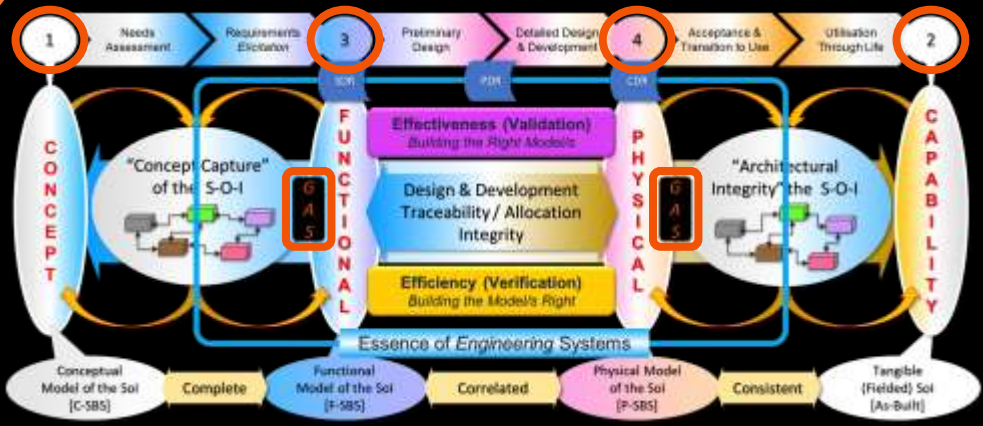
Content of the Mind



Systematic Process



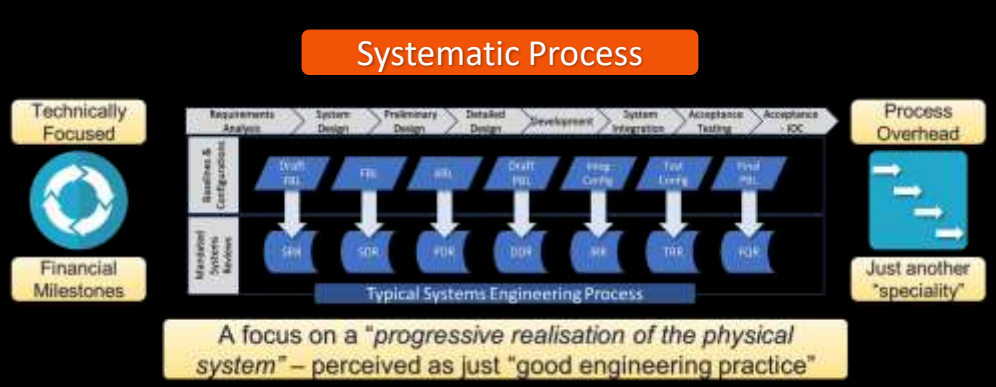
Systemic Methodology

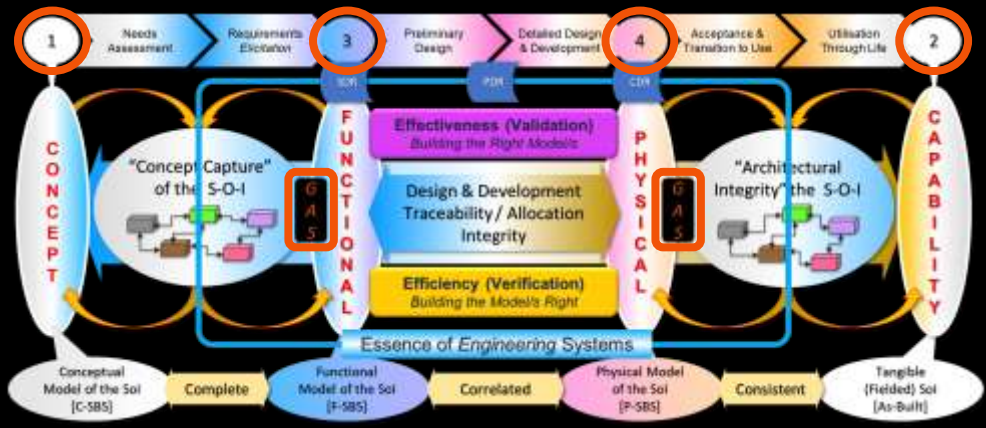


Summary of Key Points

A Personal Definition on the "How" of *Engineering Systems*

The application of ***systemic principles and concepts*** (ST-GAS, M&S) in a ***systematic whole-of-life framework*** that facilitates an ***efficient*** and ***effective*** definition and realisation of Systems, their delivery into service, ensures their ongoing utility through life, their transition out of service and their eventual disposal.





INCOSE Definition (2019) – "What is Systems Engineering"

Systems Engineering is a ***transdisciplinary*** and ***integrative*** approach to enable the successful realization, use, and retirement of engineered systems, using ***systems principles*** ***and*** ***concepts***, and scientific, technological, and management methods.
(http://www.incose.org/AboutSE/WhatIsSE)

Recommendations

A Personal Definition on the "How" of *Engineering Systems*

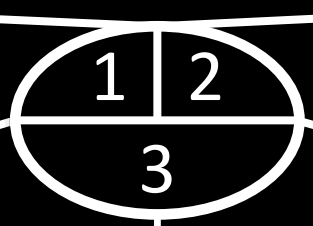
The application of ***systemic principles and concepts*** (ST-GAS, M&S) in a ***systematic whole-of-life framework*** that facilitates an ***efficient*** and ***effective*** definition and realisation of Systems, their delivery into service, ensures their ongoing utility through life, their transition out of service and their eventual disposal.

SE-BOK

Systems Thinking, Modelling and Simulation recognised as foundational SE competencies

Reference Architecture Models

Definition (and evolution) of Reference (Functional and Physical) Architectures (models) - a mandate for INCOSE WG's



DIGITAL

TRANSFORMATION

a) establishment of open modelling formats (form/fit) enabling scope and detail enhancement and sharing

Formats Standards (Form/Fit)

b) establishment of open modelling dynamic behavior (function) enabling sharing/consistency of performance

Behaviour Standards

c) Adoption of standards for sharing model state information where IP constraints limit model content sharing

Standards for Sharing Properties

d) SE Tools that comply with adopted Modelling Standards enabling sharing of models and their state-information

Standards Compliant SE Tools

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