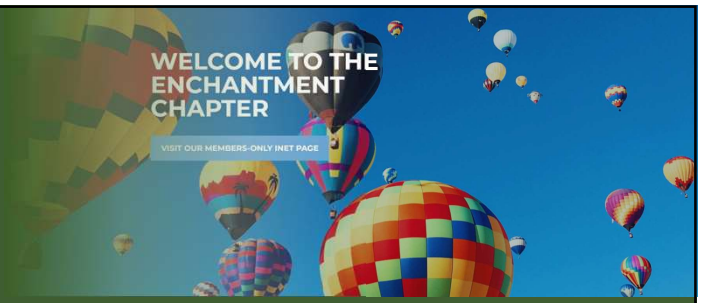
INCOSE Enchantment Chapter Webinar

Wednesday, December 11, 2024 – 4:45pm-6:00pm MT
Thursday, December 12, 2024 – 10:45am-12:00pm AEDT



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

Jawahar Bhalla (JB)
University of Adelaide & Shoal Group

Prof Stephen C. Cook
University of Adelaide & Shoal Group

Dr David Harvey
University of Adelaide

1

34th Annual INCOSE international symposium
hybrid event
Dublin, Ireland
July 2 - 6, 2024

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

Jawahar Bhalla (JB)
University of Adelaide & Shoal Group

Prof Stephen C. Cook
University of Adelaide & Shoal Group

Dr David Harvey
University of Adelaide

2-6 July 2024 www.incose.org/symp2024 #INCOSEIS 2

2

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)

3

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)

4

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)

5

Motivation…

"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, 1954).

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

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)

6

Motivation…

"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."?

*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.*

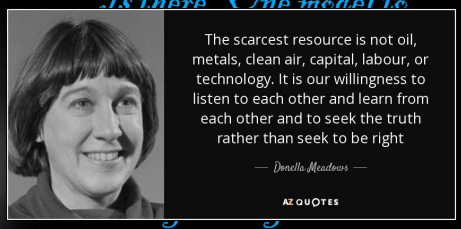
7

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



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.*

8

Structure & Acknowledgement

"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

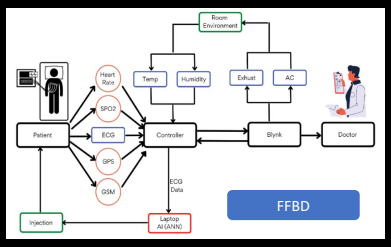
- Models in SE
- Concepts from M&S
- Systems Thinking
- Categorising Systems Models
- A "MoSM" Construct
- Key Points

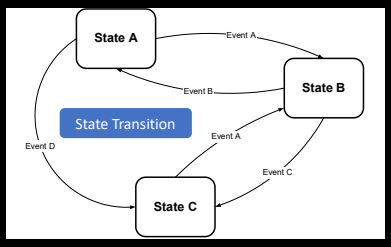
Is there "One model to rule them all, one model to find them, one model to frame them all, and through emergence bind them."?

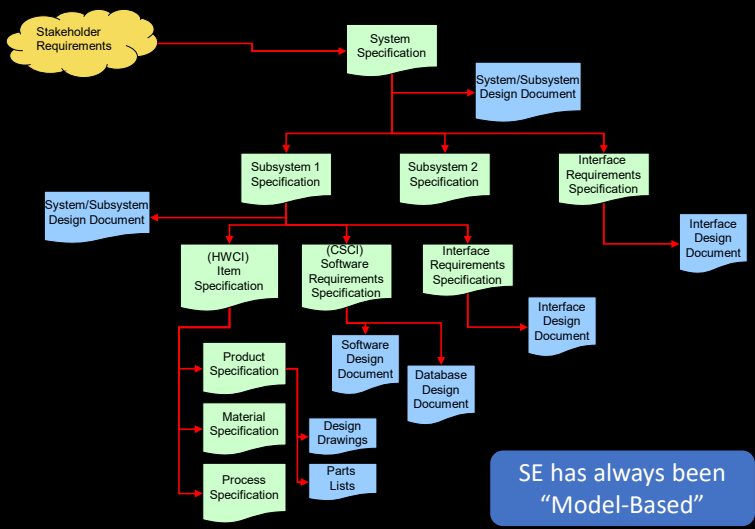
My work is supported by an Australian Government Research Training Program (RTP) Scholarship through the University of Adelaide with Shoal Group as the Industry Partner

9

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

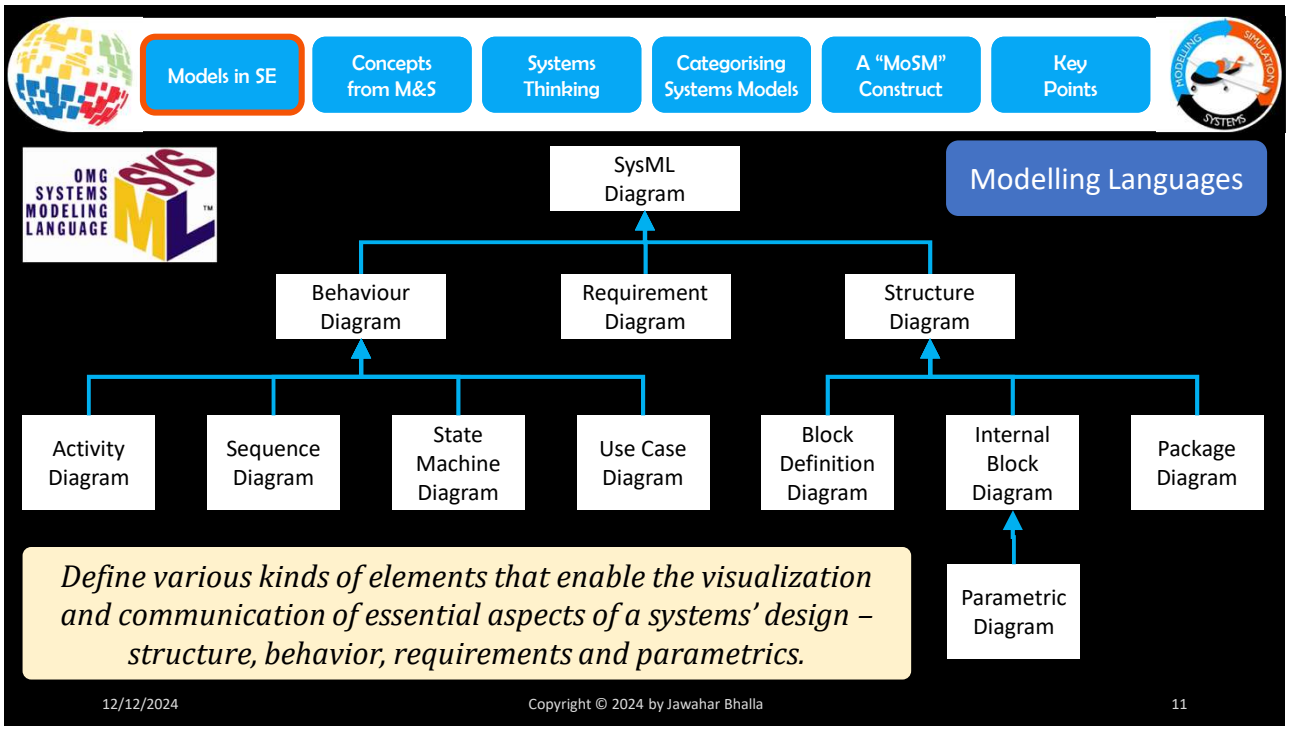




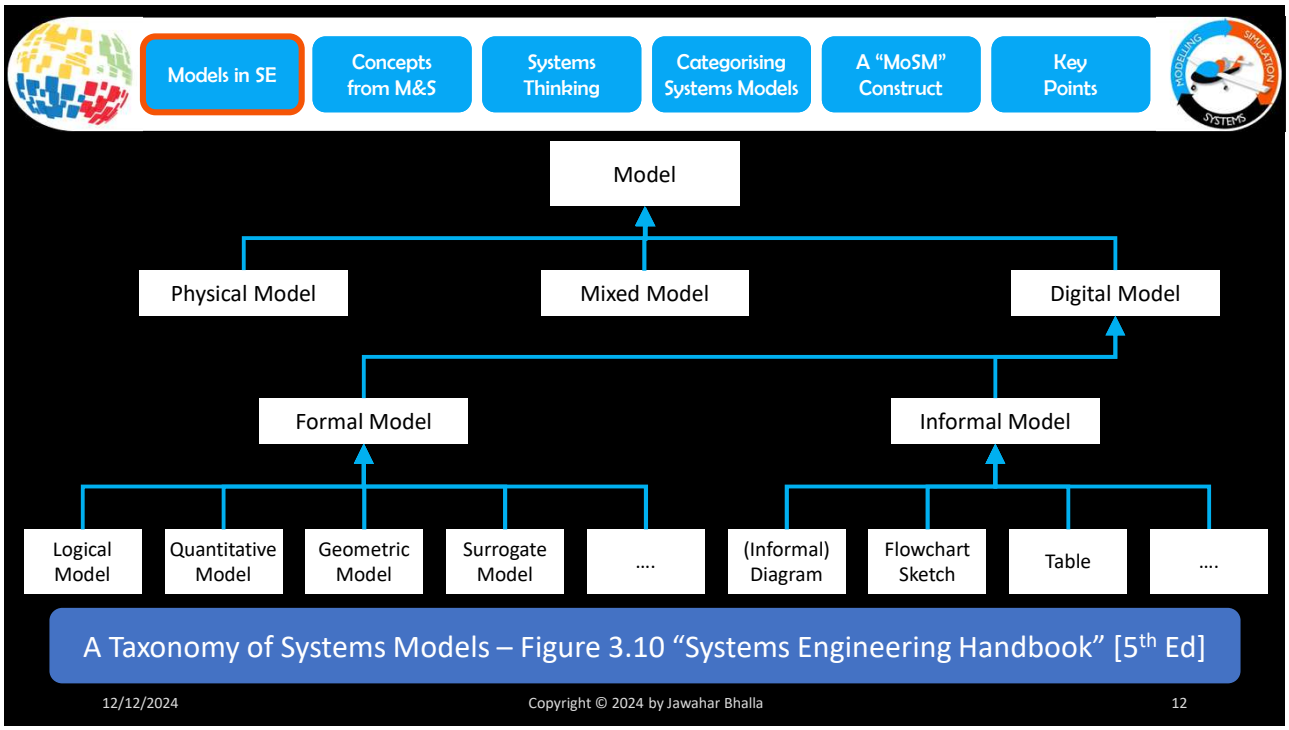


SE has always been "Model-Based"

10


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
OMG SYSTEMS MODELING LANGUAGE
SysML Diagram
Modelling Languages
Behaviour Diagram
Requirement Diagram
Structure Diagram
Activity Diagram
Sequence Diagram
State Machine Diagram
Use Case Diagram
Block Definition Diagram
Internal Block Diagram
Package Diagram
Parametric Diagram
Define various kinds of elements that enable the visualization and communication of essential aspects of a systems' design – structure, behavior, requirements and parametrics.
12/12/2024
Copyright © 2024 by Jawahar Bhalla
11

11

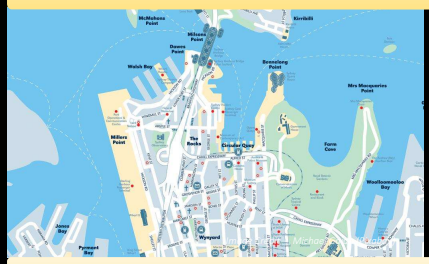

Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Model
Physical Model
Mixed Model
Digital Model
Formal Model
Informal Model
Logical Model
Quantitative Model
Geometric Model
Surrogate Model
....
(Informal) Diagram
Flowchart Sketch
Table
....
A Taxonomy of Systems Models – Figure 3.10 "Systems Engineering Handbook" [5th Ed]
12/12/2024
Copyright © 2024 by Jawahar Bhalla
12

12

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



A Map (**model**) of Sydney

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

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

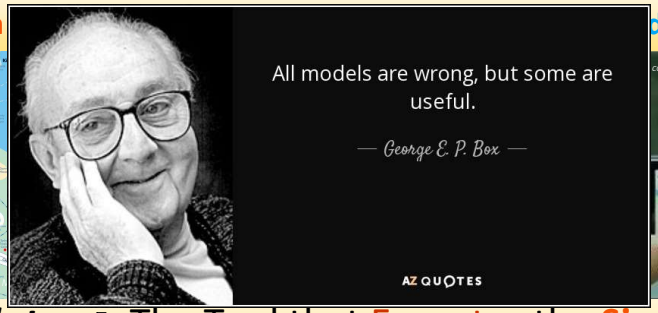
13

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

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** …del over Time



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

14

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*)

VR (Simulated Environment) ⟷ (Real Environment) AR

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

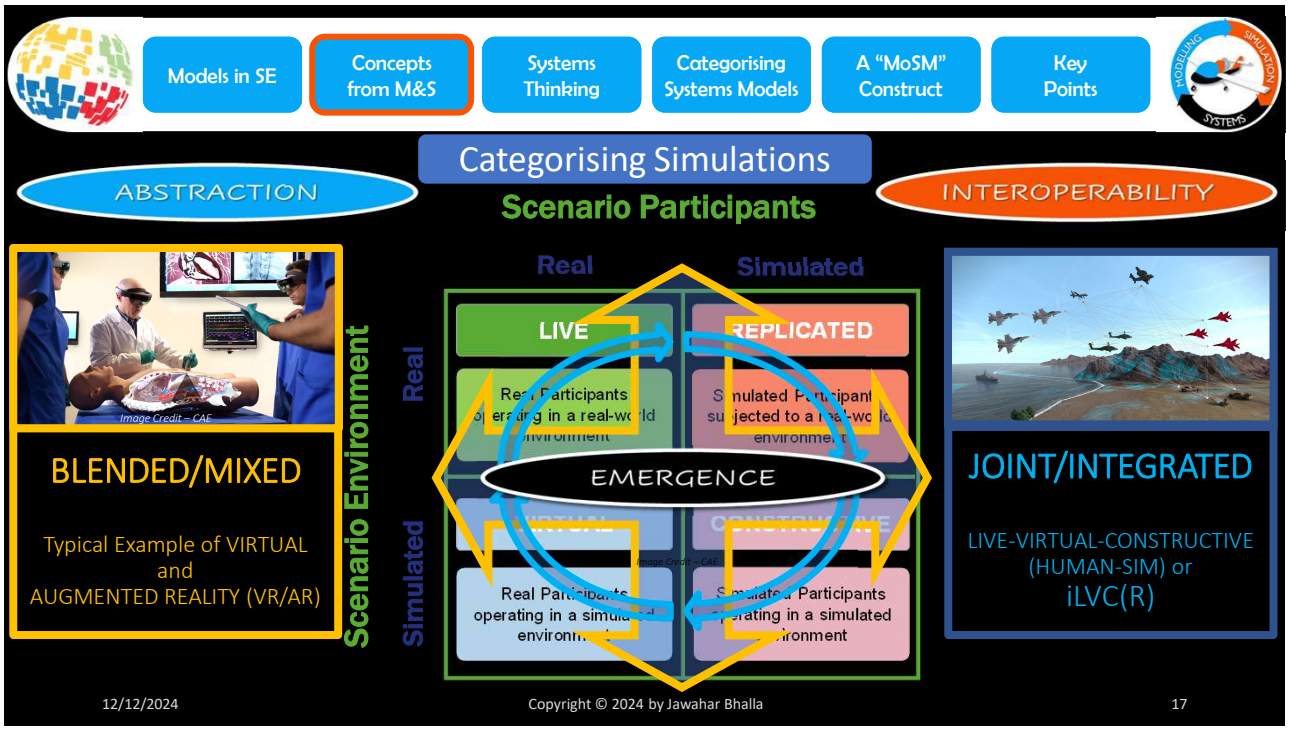
15

Categorising Simulations

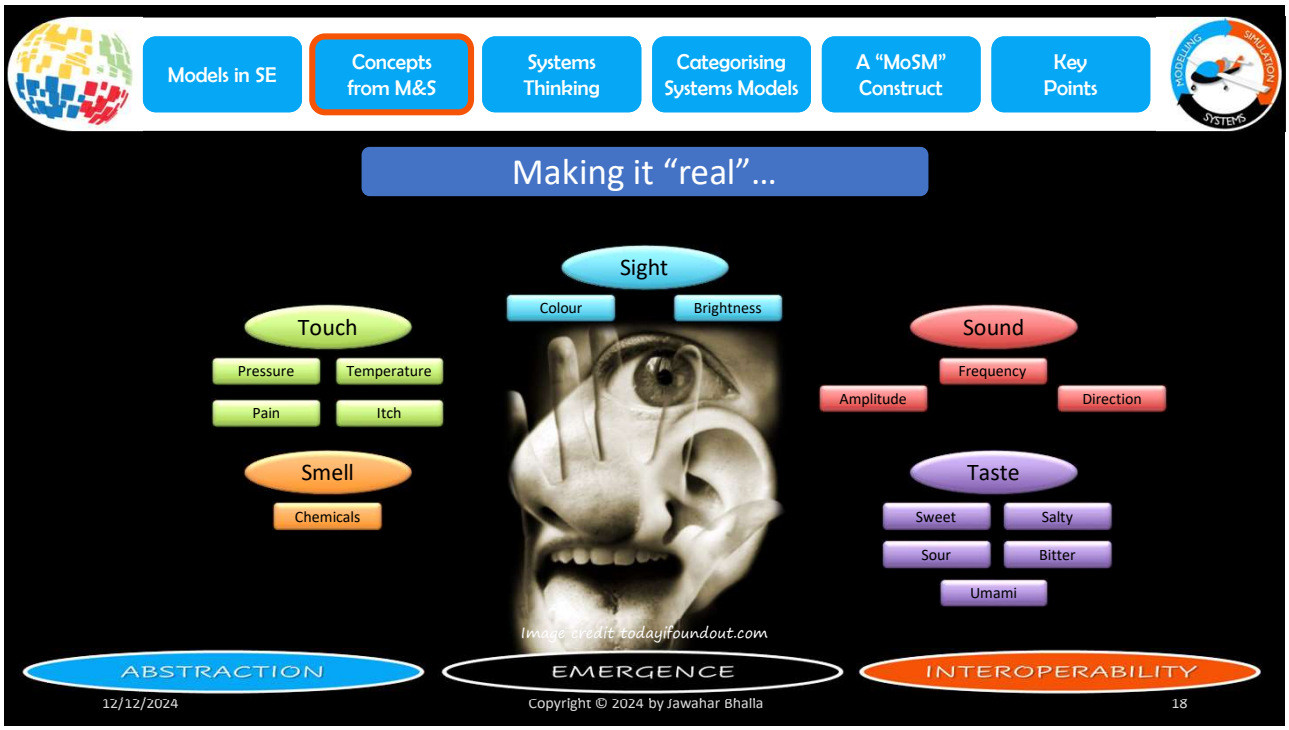
Scenario Participants

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

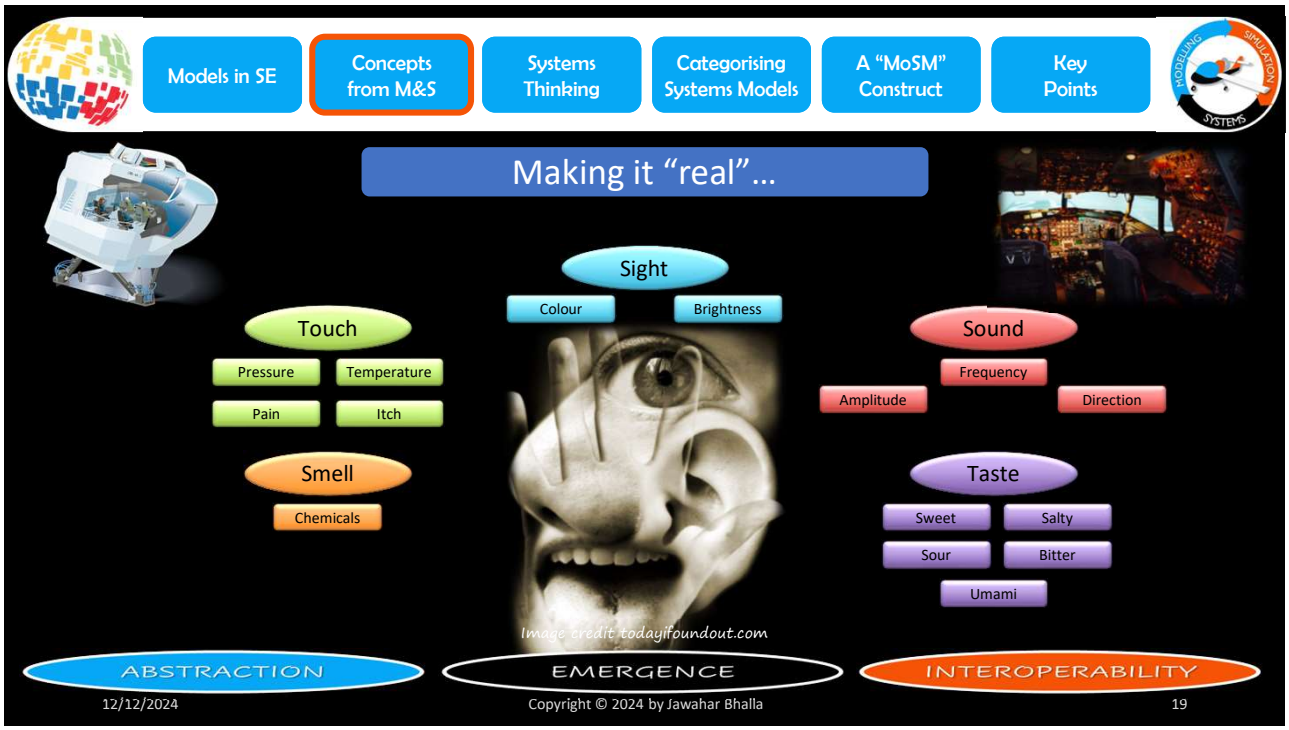
16


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Categorising Simulations
ABSTRACTION
INTEROPERABILITY
Scenario Participants
Real
Simulated
Scenario Environment
Real
Simulated
LIVE
REPLICATED
EMERGENCE
Real Participants operating in a real-world environment
Simulated Participants operating in a simulated environment
Real Participants operating in a simulated environment
Image Credit – CAE
BLENDED/MIXED
Typical Example of VIRTUAL and AUGMENTED REALITY (VR/AR)
JOINT/INTEGRATED
LIVE-VIRTUAL-CONSTRUCTIVE (HUMAN-SIM) or iLVC(R)
12/12/2024
Copyright © 2024 by Jawahar Bhalla
17

17


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Making it "real"…
Sight
Colour
Brightness
Touch
Pressure
Temperature
Pain
Itch
Smell
Chemicals
Sound
Frequency
Amplitude
Direction
Taste
Sweet
Salty
Sour
Bitter
Umami
Image credit todayifoundout.com
ABSTRACTION
EMERGENCE
INTEROPERABILITY
12/12/2024
Copyright © 2024 by Jawahar Bhalla
18

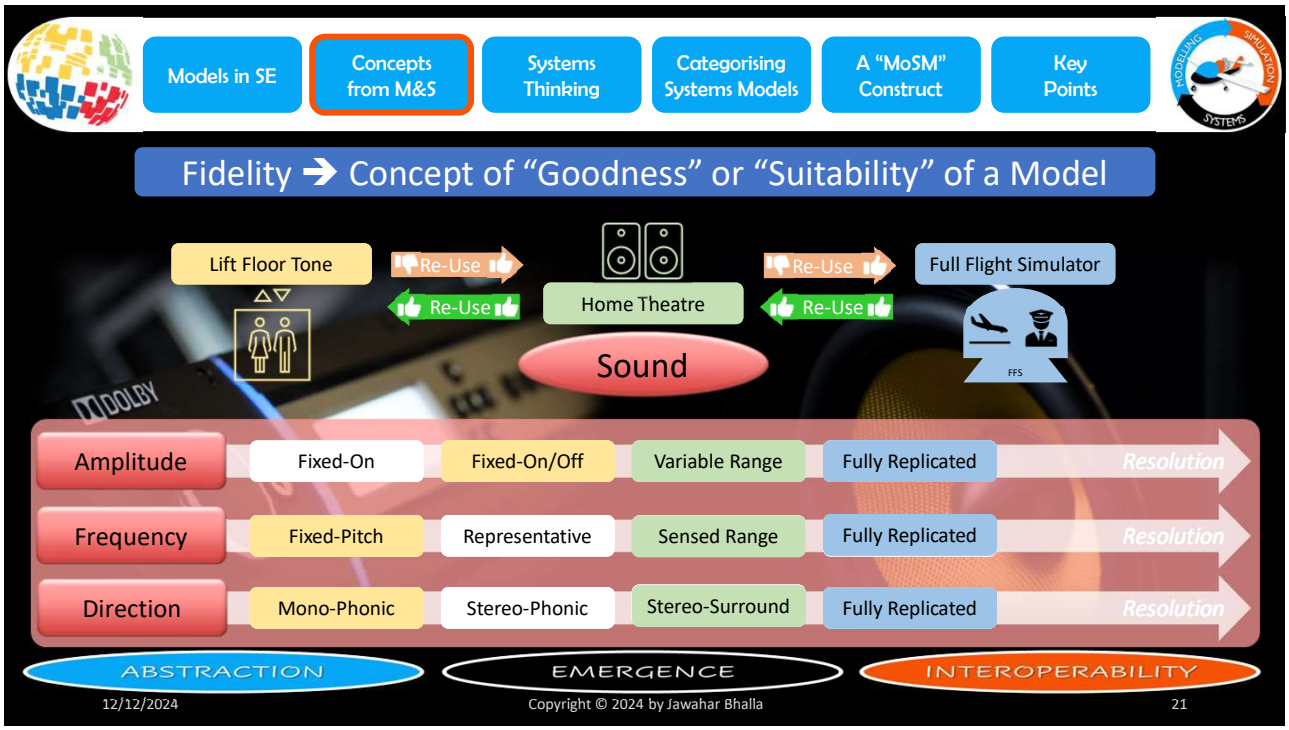
18


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Making it "real"…
Sight
Colour
Brightness
Touch
Pressure
Temperature
Pain
Itch
Smell
Chemicals
Sound
Frequency
Amplitude
Direction
Taste
Sweet
Salty
Sour
Bitter
Umami
Image credit todayifoundout.com
ABSTRACTION
EMERGENCE
INTEROPERABILITY
12/12/2024
Copyright © 2024 by Jawahar Bhalla
19

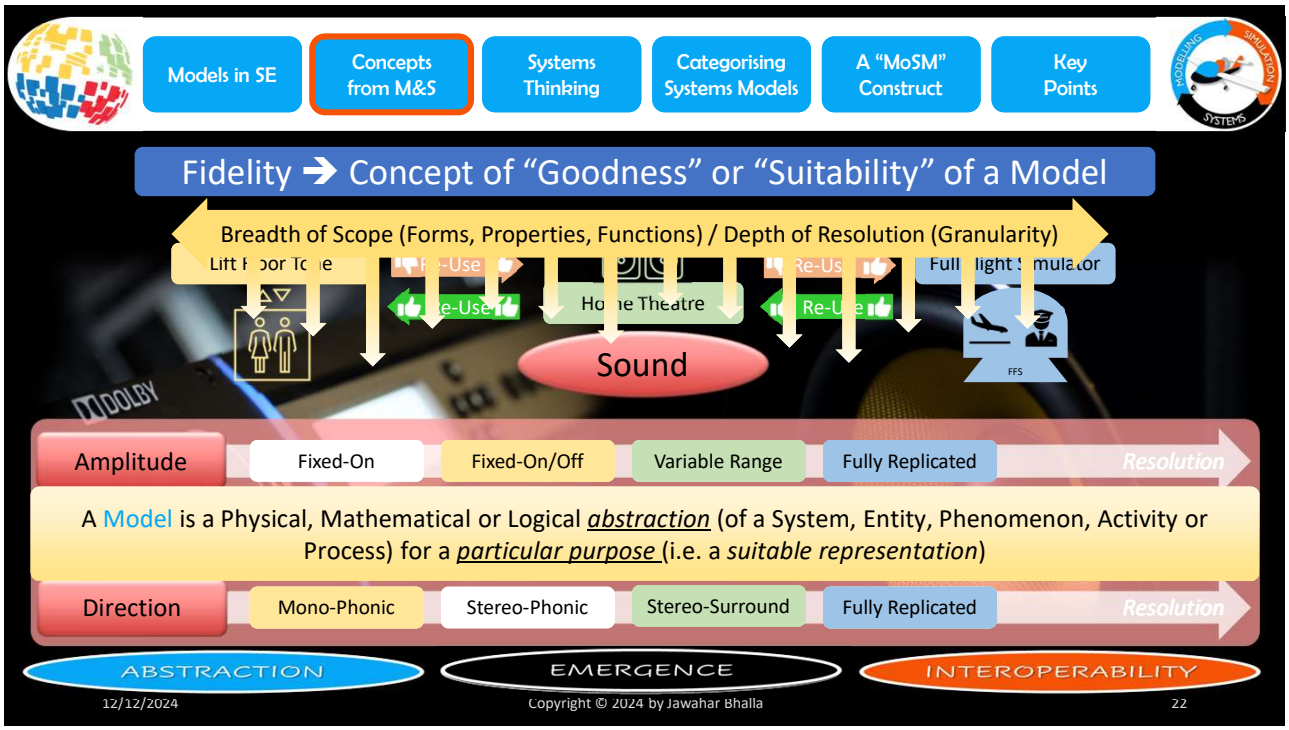
19


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Fidelity ➔ Concept of "Goodness" or "Suitability" of a Model
Sound
Frequency
Amplitude
Direction
ABSTRACTION
EMERGENCE
INTEROPERABILITY
12/12/2024
Copyright © 2024 by Jawahar Bhalla
20

20


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Fidelity ➔ Concept of "Goodness" or "Suitability" of a Model
Lift Floor Tone
Re-Use
Re-Use
Home Theatre
Re-Use
Re-Use
Full Flight Simulator
Sound
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
12/12/2024
Copyright © 2024 by Jawahar Bhalla
21

21

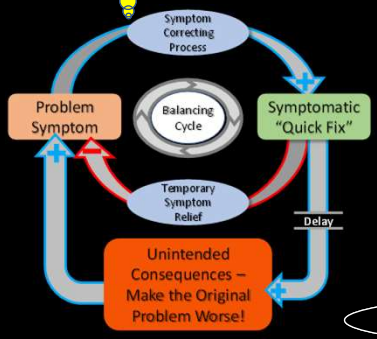

Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Fidelity ➔ Concept of "Goodness" or "Suitability" of a Model
Breadth of Scope (Forms, Properties, Functions) / Depth of Resolution (Granularity)
Sound
Amplitude
Fixed-On
Fixed-On/Off
Variable Range
Fully Replicated
Resolution
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)
Direction
Mono-Phonic
Stereo-Phonic
Stereo-Surround
Fully Replicated
Resolution
ABSTRACTION
EMERGENCE
INTEROPERABILITY
12/12/2024
Copyright © 2024 by Jawahar Bhalla
22

22

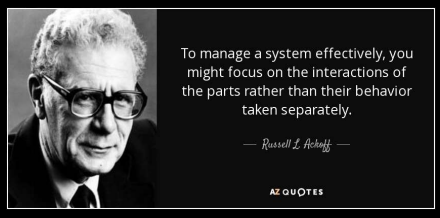
Models in SE | Concepts from M&S | Systems Thinking | Categorising Systems Models | A "MoSM" Construct | Key Points

"Fixes that Backfire"

We need to do something now!

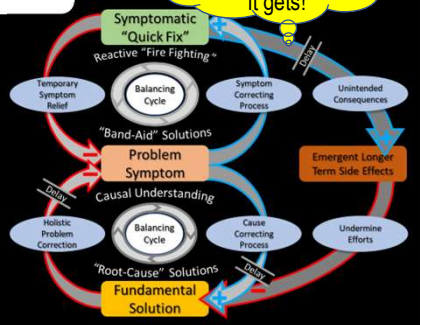


Peter Senge ➔ "Systems Thinking is a *conceptual framework*, a *body of knowledge* and *tools* that have been developed over the past fifty years, to make the full patterns clearer, and to help to change them effectively."



"Shifting the Burden"

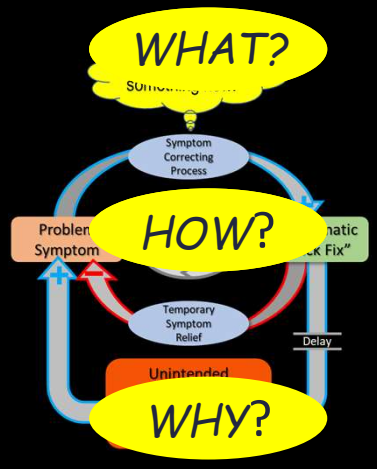
The longer we delay, the harder it gets!



SYSTEMS THINKING

23

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



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*.

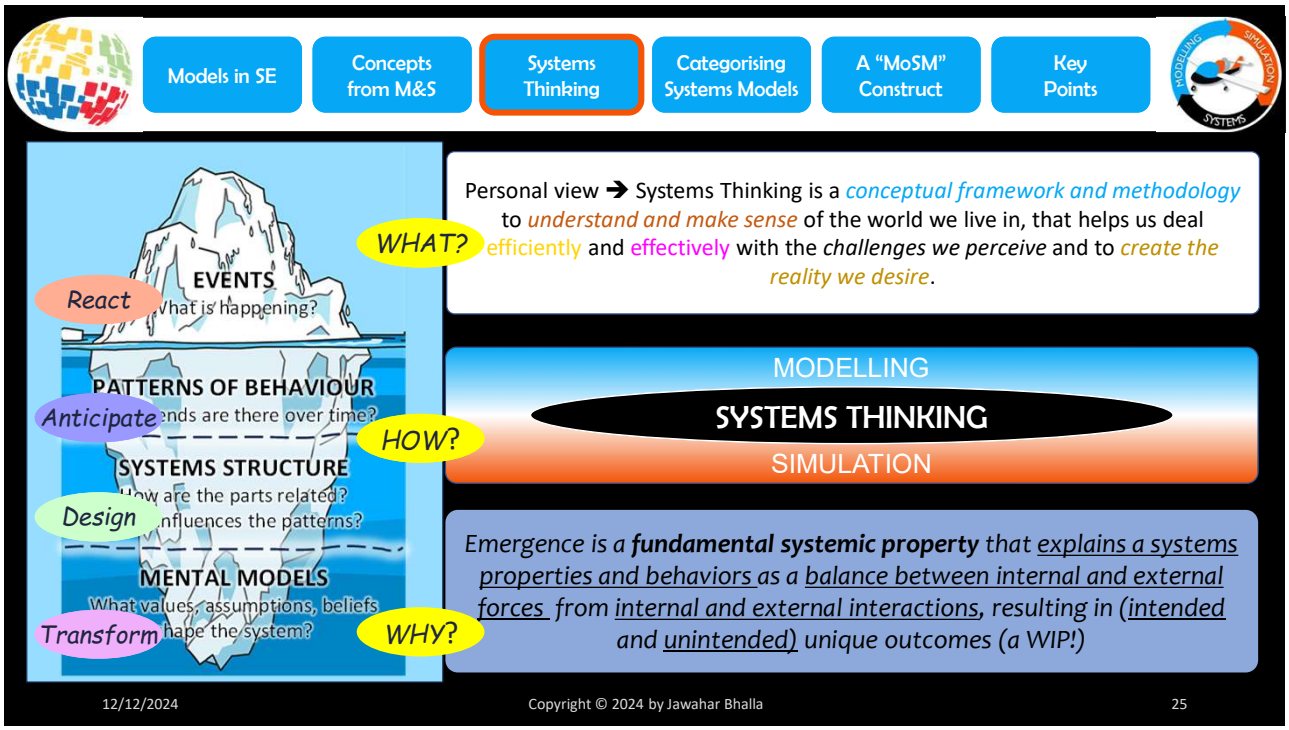
MODELLING

SYSTEMS THINKING

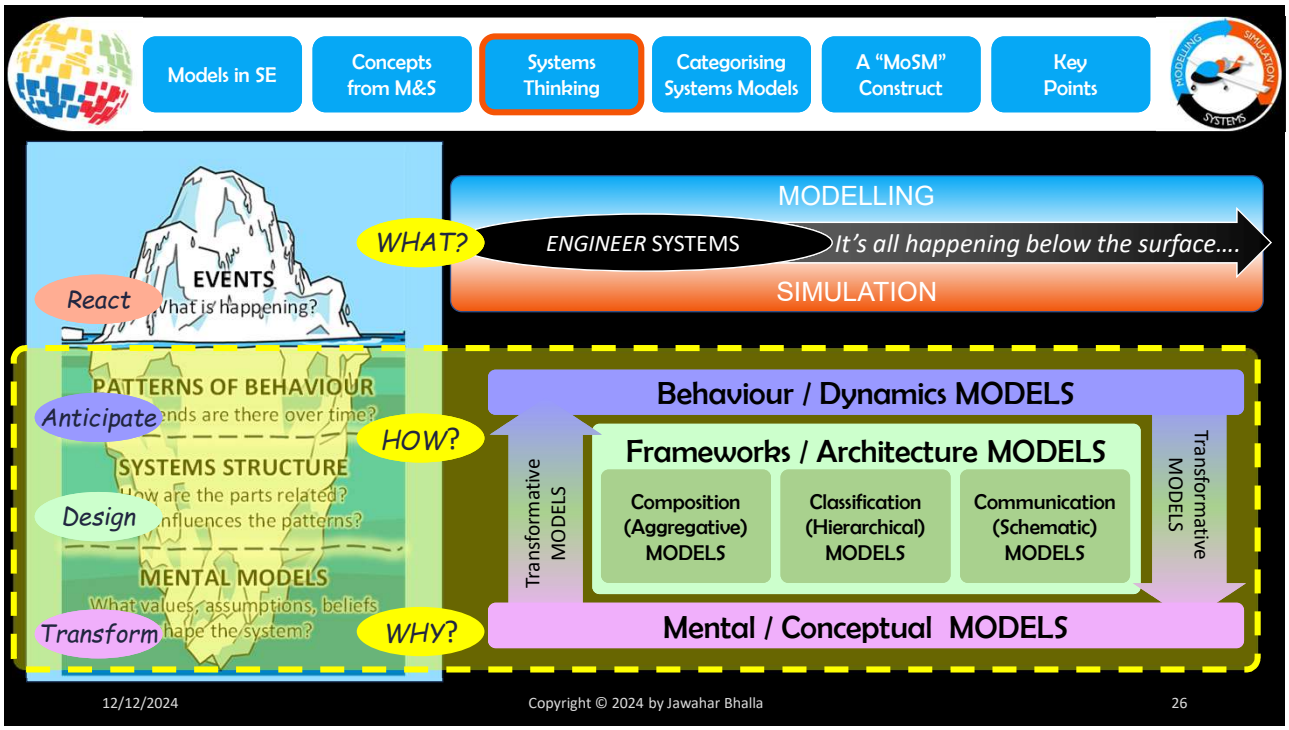
SIMULATION

*Emergence is a **fundamental systemic property** that explains a systems properties and behaviors as a balance between internal and external forces from internal and external interactions, resulting in (intended and unintended) unique outcomes (a WIP!)*

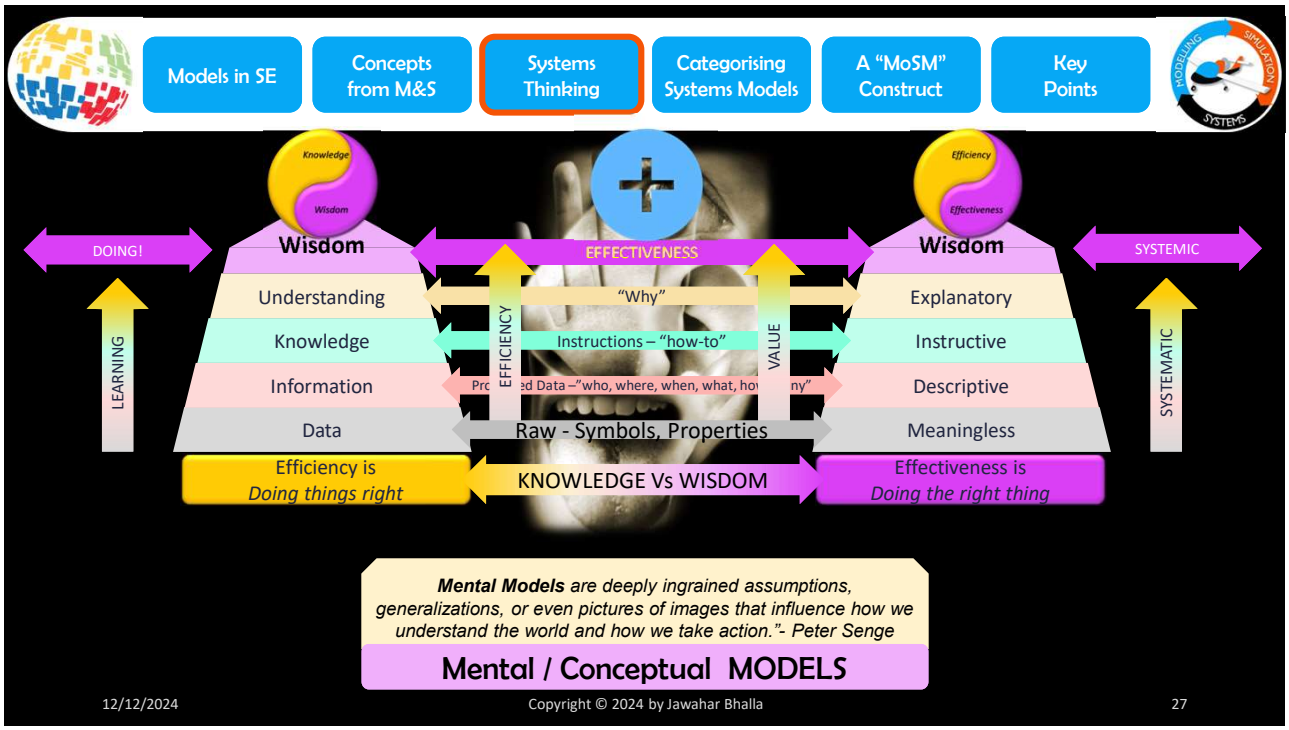
24


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
EVENTS
What is happening?
React
PATTERNS OF BEHAVIOUR
Anticipate
SYSTEMS STRUCTURE
How are the parts related?
Design
MENTAL MODELS
What values, assumptions, beliefs
Transform
WHAT?
HOW?
WHY?
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.
MODELLING
SYSTEMS THINKING
SIMULATION
Emergence is a fundamental systemic property that explains a systems properties and behaviors as a balance between internal and external forces from internal and external interactions, resulting in (intended and unintended) unique outcomes (a WIP!)
12/12/2024
Copyright © 2024 by Jawahar Bhalla
25

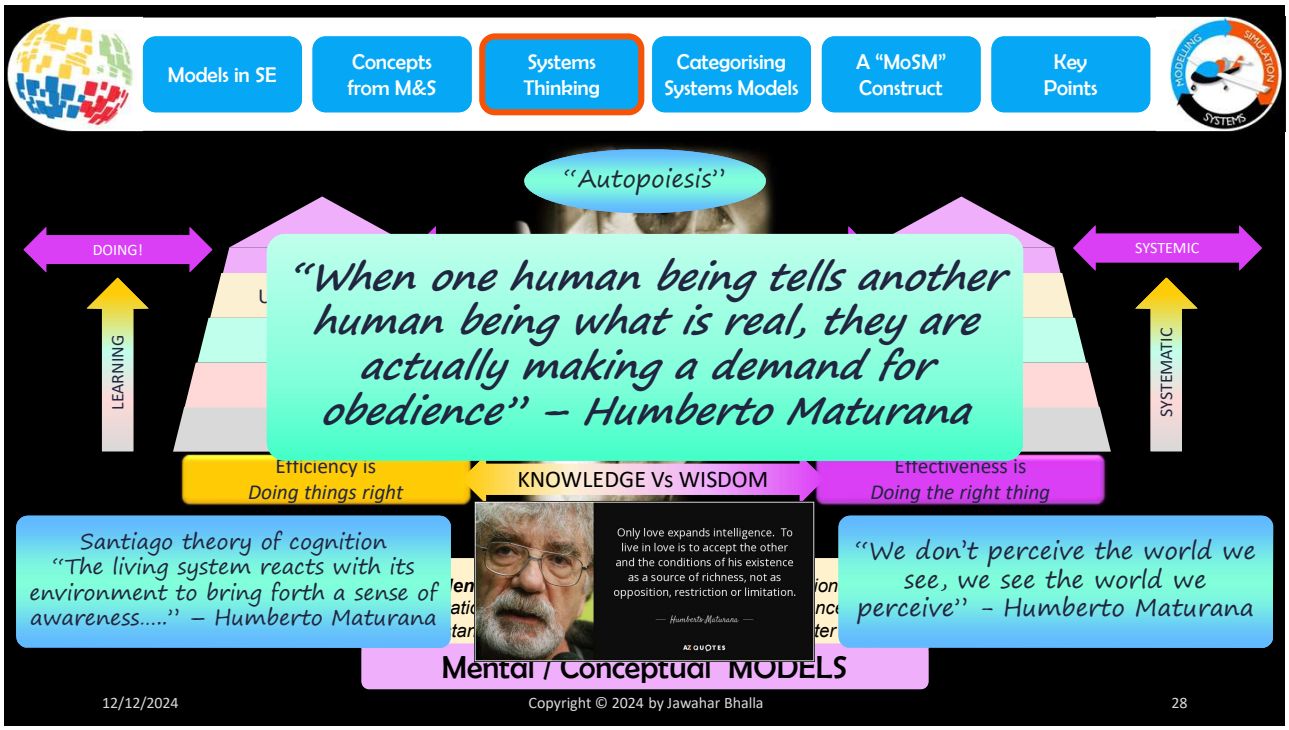
25


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
EVENTS
What is happening?
React
PATTERNS OF BEHAVIOUR
Anticipate
SYSTEMS STRUCTURE
How are the parts related?
Design
MENTAL MODELS
What values, assumptions, beliefs
Transform
WHAT?
HOW?
WHY?
MODELLING
ENGINEER SYSTEMS
It's all happening below the surface....
SIMULATION
Behaviour / Dynamics MODELS
Frameworks / Architecture MODELS
Composition (Aggregative) MODELS
Classification (Hierarchical) MODELS
Communication (Schematic) MODELS
Transformative MODELS
Transformative MODELS
Mental / Conceptual MODELS
12/12/2024
Copyright © 2024 by Jawahar Bhalla
26

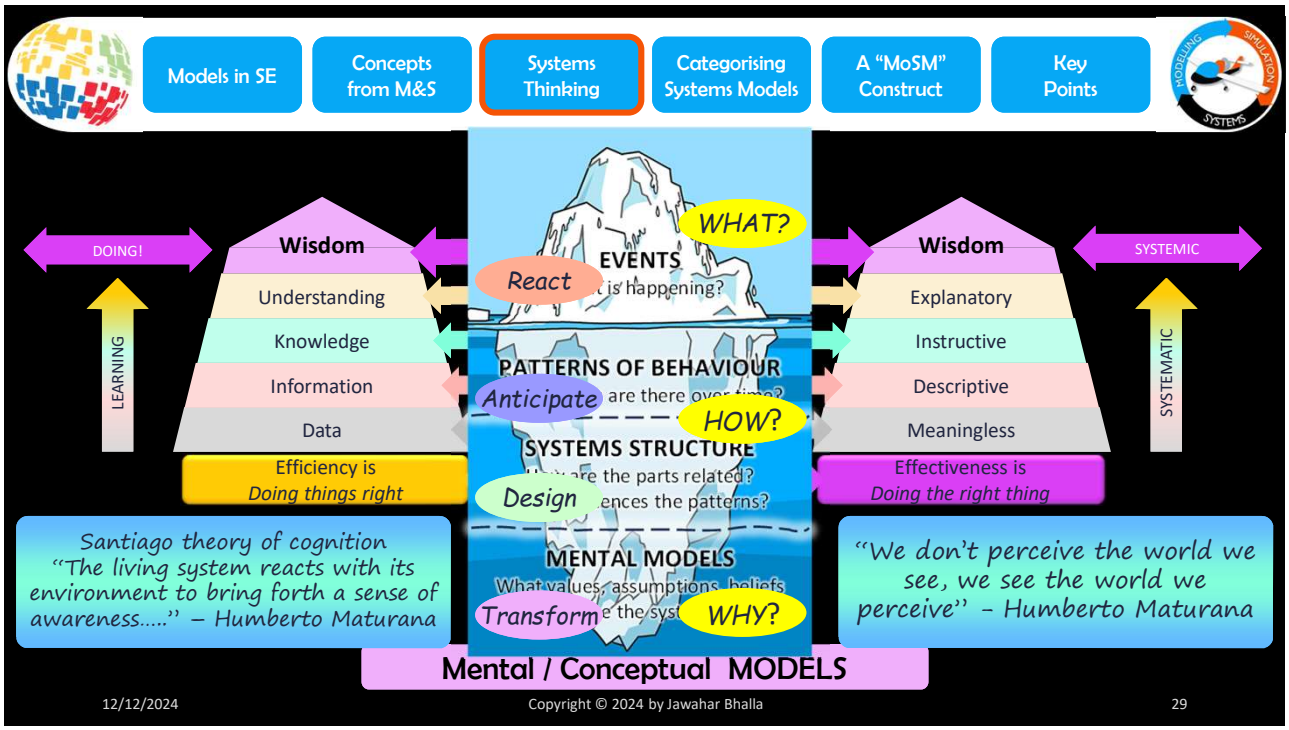
26


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
DOING!
LEARNING
Wisdom
Understanding
Knowledge
Information
Data
EFFECTIVENESS
EFFICIENCY
VALUE
"Why"
Instructions – "how-to"
Raw - Symbols, Properties
Wisdom
Explanatory
Instructive
Descriptive
Meaningless
SYSTEMIC
SYSTEMATIC
Efficiency is Doing things right
KNOWLEDGE Vs WISDOM
Effectiveness is Doing the right thing
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
12/12/2024
Copyright © 2024 by Jawahar Bhalla
27

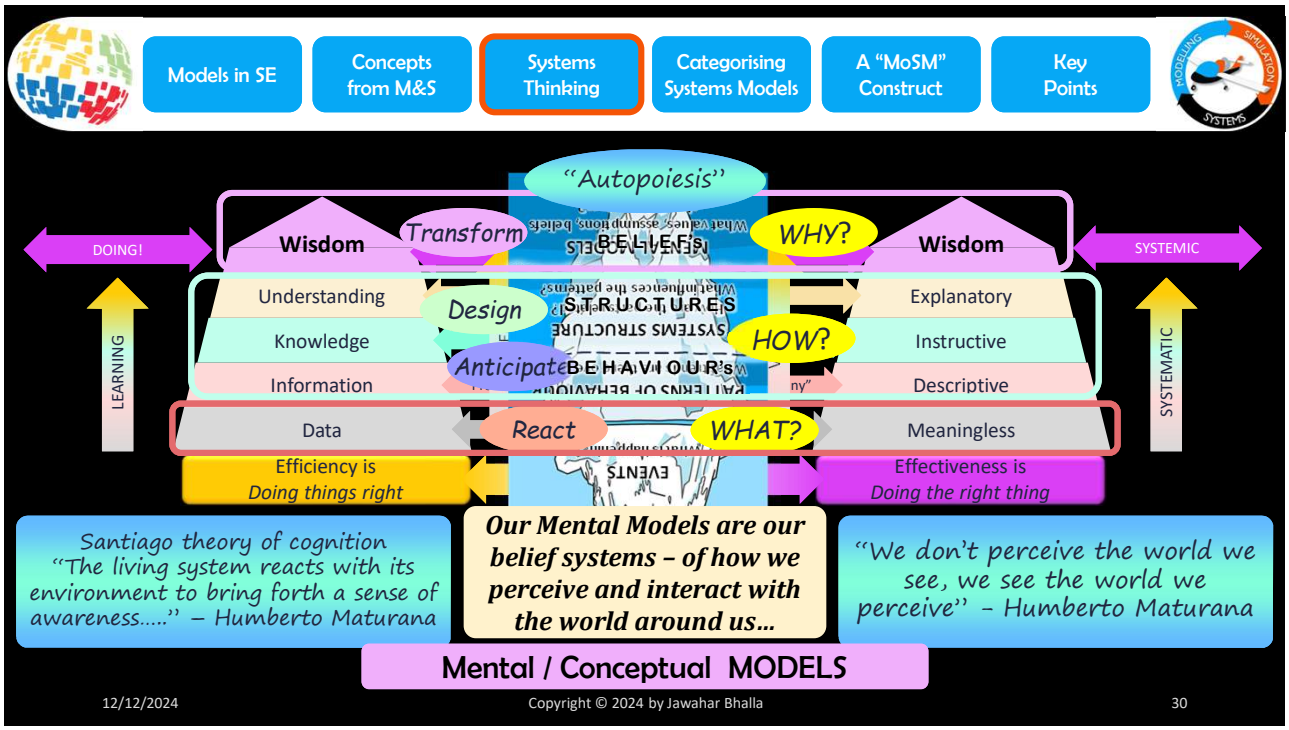
27


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
"Autopoiesis"
DOING!
LEARNING
SYSTEMIC
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
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 —
AZ QUOTES
"We don't perceive the world we see, we see the world we perceive" - Humberto Maturana
Mental / Conceptual MODELS
12/12/2024
Copyright © 2024 by Jawahar Bhalla
28

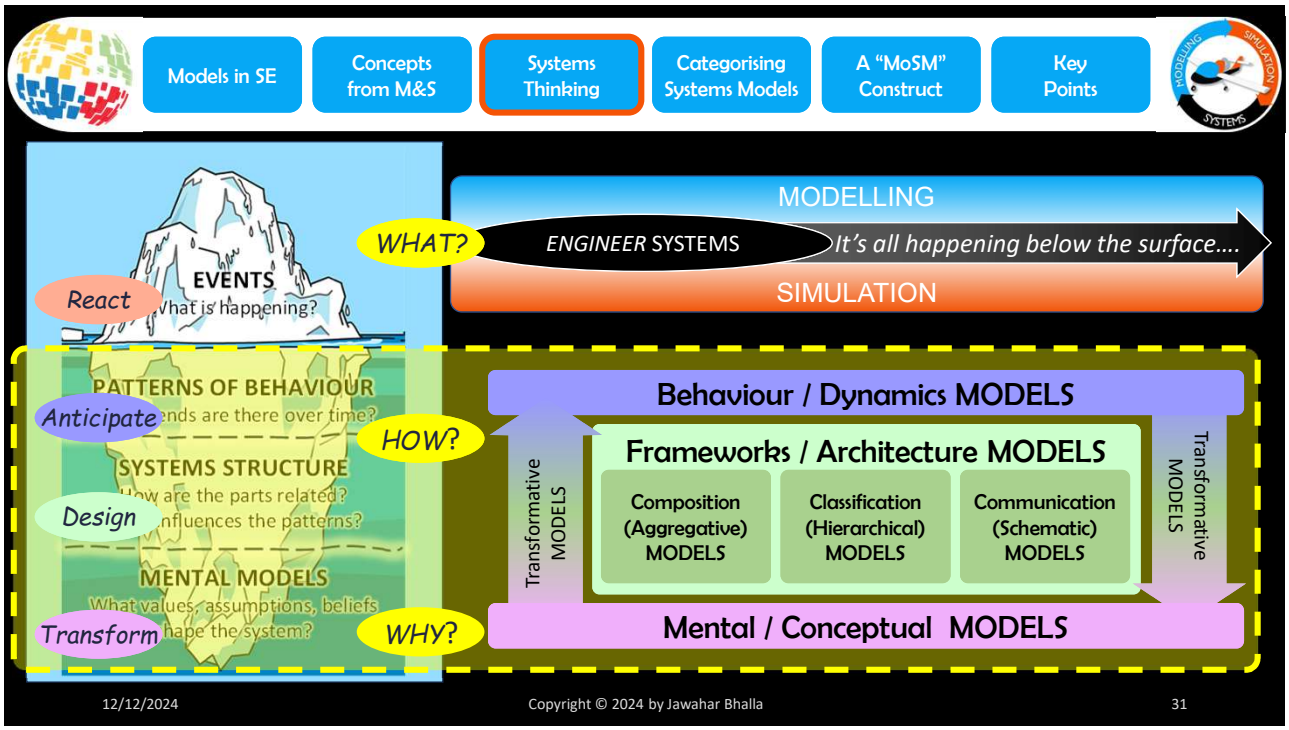
28


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
DOING!
LEARNING
Wisdom
Understanding
Knowledge
Information
Data
Efficiency is Doing things right
WHAT?
EVENTS
React
PATTERNS OF BEHAVIOUR
Anticipate
HOW?
SYSTEMS STRUCTURE
Design
MENTAL MODELS
Transform
WHY?
Wisdom
Explanatory
Instructive
Descriptive
Meaningless
Effectiveness is Doing the right thing
SYSTEMIC
SYSTEMATIC
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
12/12/2024
Copyright © 2024 by Jawahar Bhalla
29

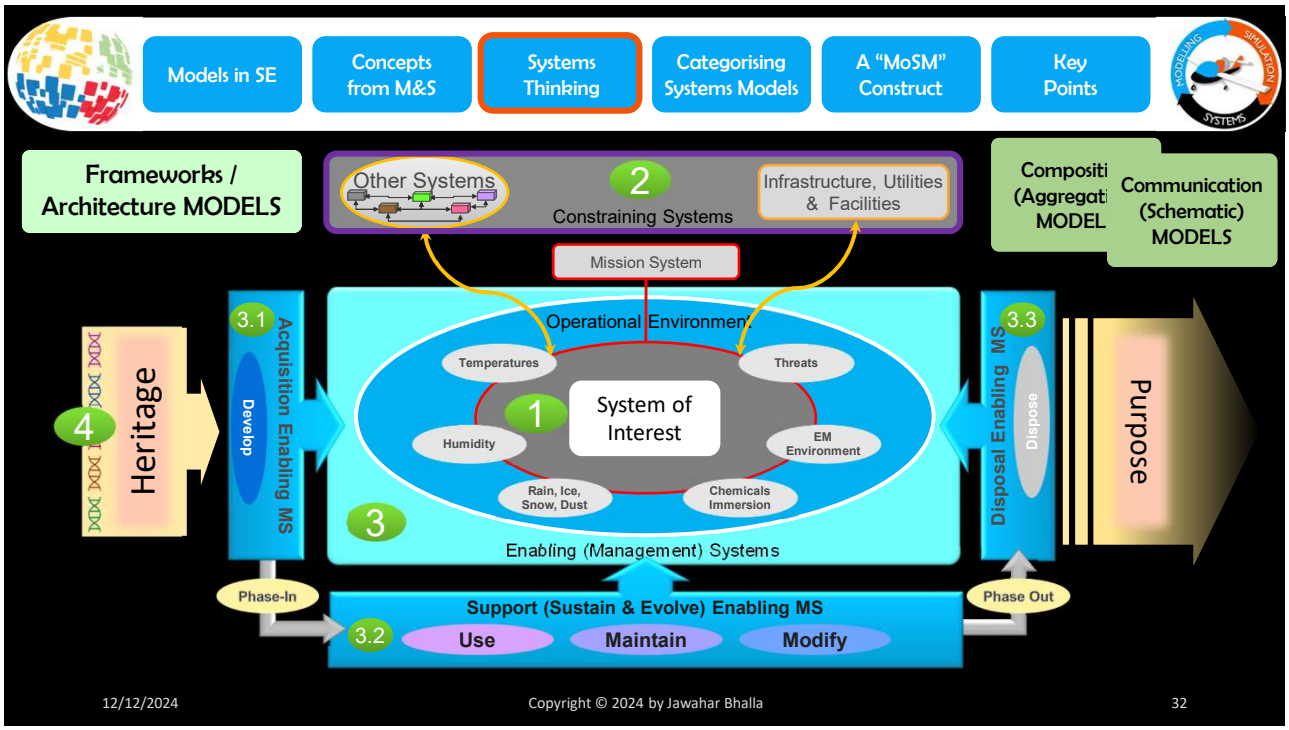
29


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
"Autopoiesis"
DOING!
LEARNING
Wisdom
Understanding
Knowledge
Information
Data
Efficiency is Doing things right
Transform
WHY?
Design
STRUCTURES
HOW?
Anticipate
BEHAVIOUR's
React
WHAT?
EVENTS
Wisdom
Explanatory
Instructive
Descriptive
Meaningless
Effectiveness is Doing the right thing
SYSTEMIC
SYSTEMATIC
Santiago theory of cognition "The living system reacts with its environment to bring forth a sense of awareness....." – Humberto Maturana
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
12/12/2024
Copyright © 2024 by Jawahar Bhalla
30

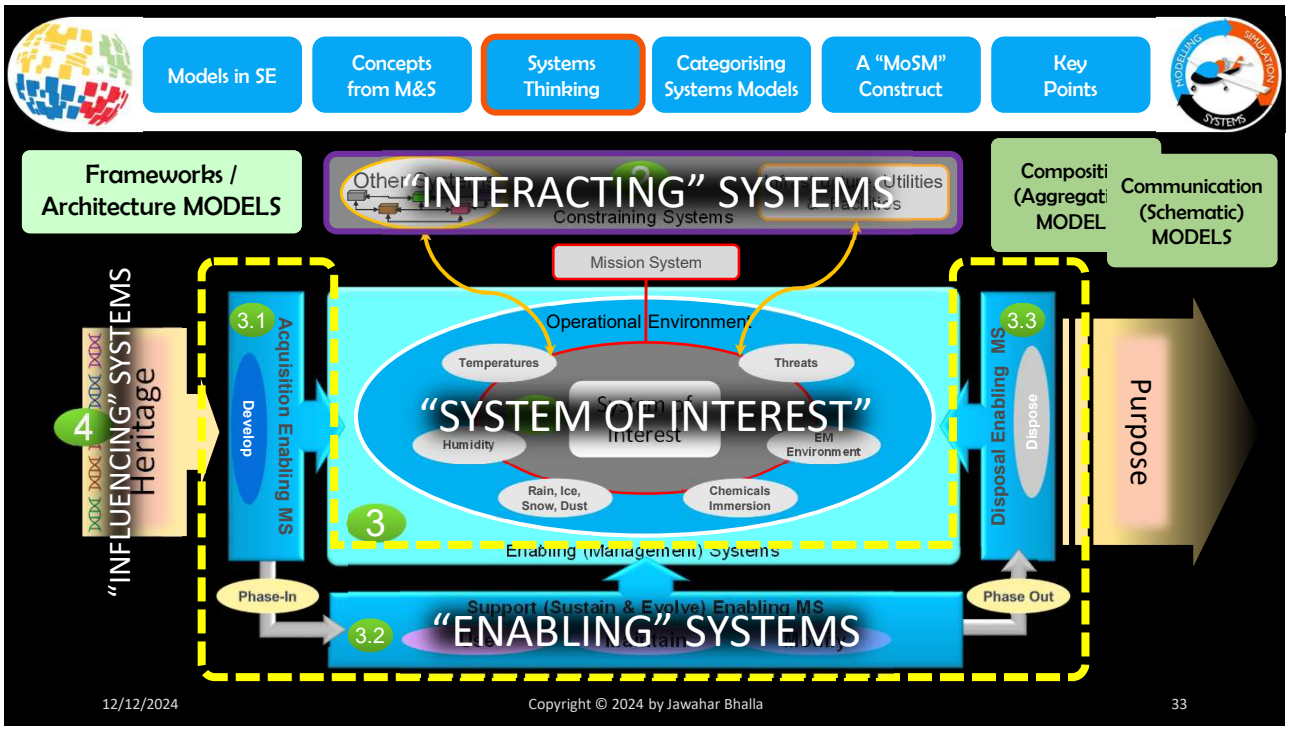
30


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
EVENTS
What is happening?
React
PATTERNS OF BEHAVIOUR
Anticipate
SYSTEMS STRUCTURE
Design
MENTAL MODELS
What values, assumptions, beliefs
Transform
WHAT?
HOW?
WHY?
MODELLING
ENGINEER SYSTEMS
It's all happening below the surface....
SIMULATION
Behaviour / Dynamics MODELS
Frameworks / Architecture MODELS
Composition (Aggregative) MODELS
Classification (Hierarchical) MODELS
Communication (Schematic) MODELS
Transformative MODELS
Transformative MODELS
Mental / Conceptual MODELS
12/12/2024
Copyright © 2024 by Jawahar Bhalla
31

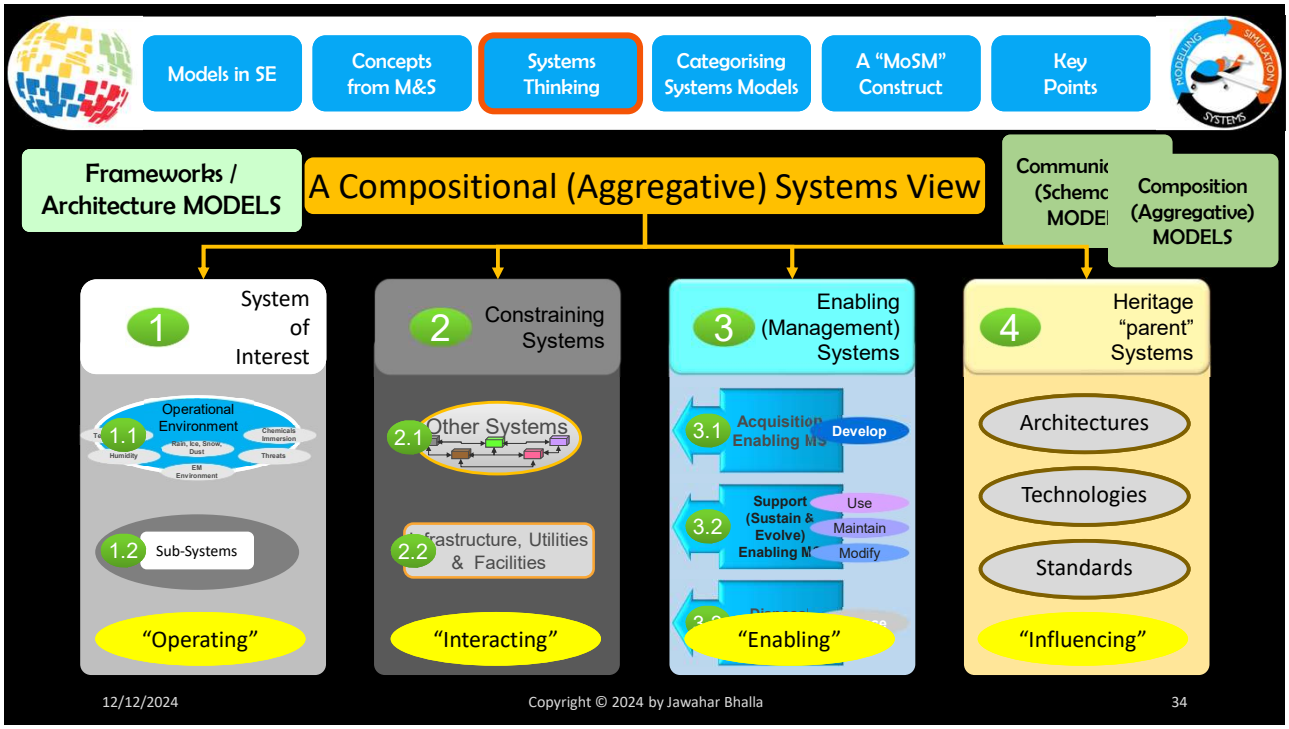
31


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Frameworks / Architecture MODELS
Other Systems
2
Constraining Systems
Infrastructure, Utilities & Facilities
Communication (Schematic) MODELS
Mission System
Operational Environment
Temperatures
Threats
Humidity
EM Environment
Rain, Ice, Snow, Dust
Chemicals Immersion
1
System of Interest
3
Enabling (Management) Systems
4
Heritage
3.1
Acquisition Enabling MS
Develop
3.3
Disposal Enabling MS
Dispose
Purpose
Phase-In
Phase Out
Support (Sustain & Evolve) Enabling MS
3.2
Use
Maintain
Modify
12/12/2024
Copyright © 2024 by Jawahar Bhalla
32

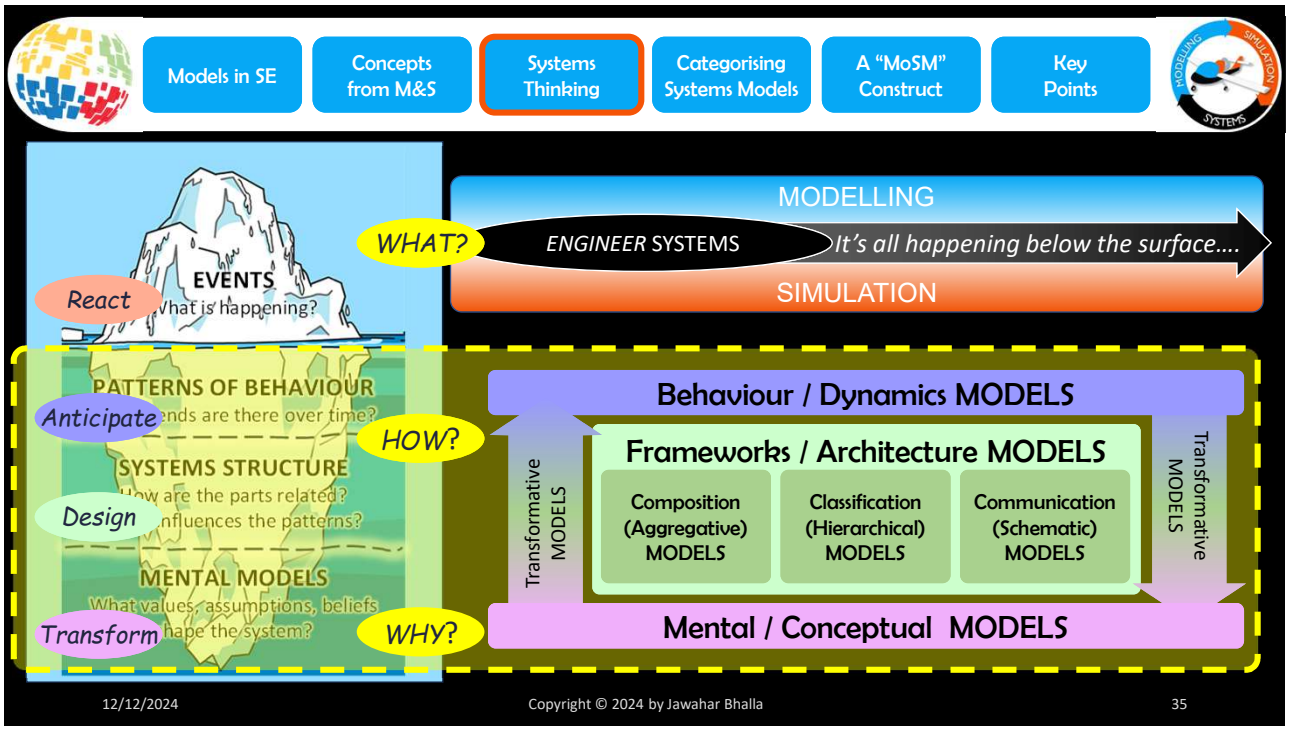
32


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Frameworks / Architecture MODELS
"INTERACTING" SYSTEMS
Constraining Systems
Mission System
Operational Environment
Temperatures
Threats
"SYSTEM OF INTEREST"
Humidity
EM Environment
Rain, Ice, Snow, Dust
Chemicals Immersion
Enabling (Management) Systems
"INFLUENCING" SYSTEMS
Heritage
Acquisition Enabling MS
Develop
Disposal Enabling MS
Dispose
Purpose
Phase-In
Phase Out
Support (Sustain & Evolve) Enabling MS
"ENABLING" SYSTEMS
Communication (Schematic) MODELS
12/12/2024
Copyright © 2024 by Jawahar Bhalla
33

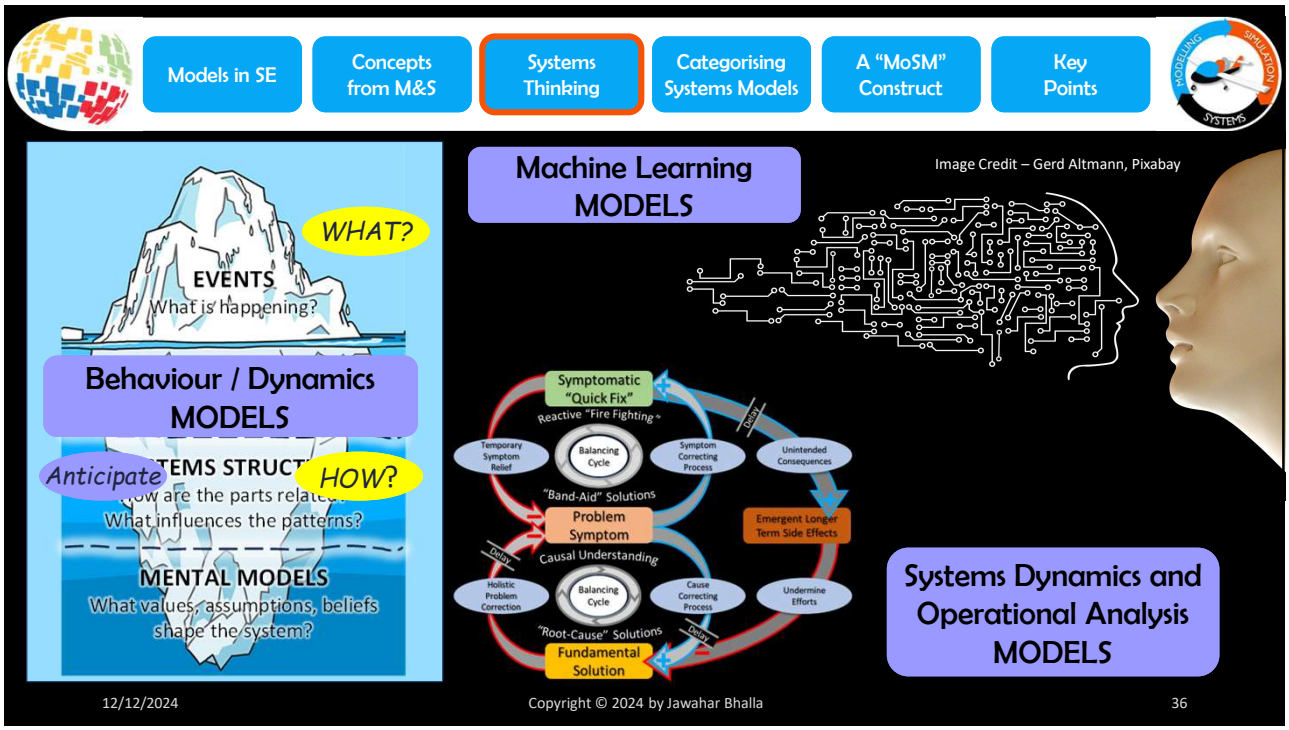
33


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Frameworks / Architecture MODELS
A Compositional (Aggregative) Systems View
Composition (Aggregative) MODELS
1 System of Interest
Operational Environment
1.1
1.2 Sub-Systems
"Operating"
2 Constraining Systems
2.1 Other 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"
12/12/2024
Copyright © 2024 by Jawahar Bhalla
34

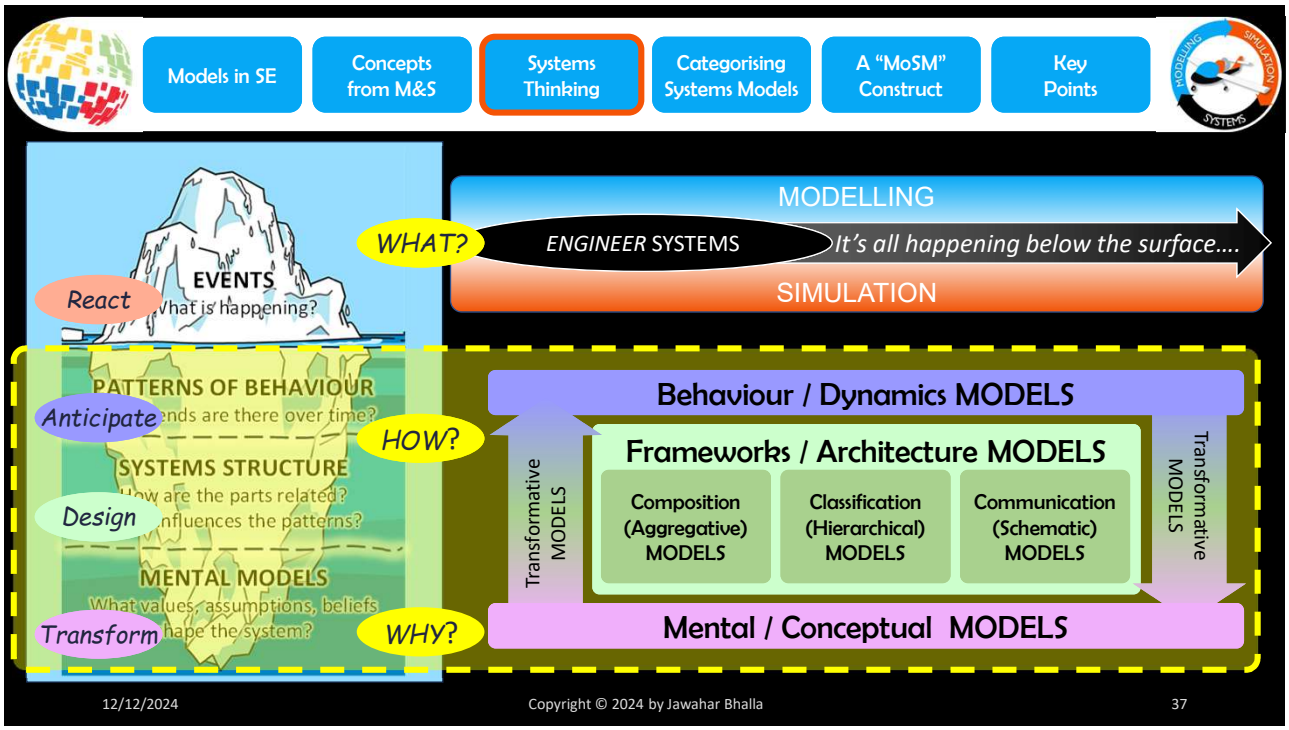
34


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
EVENTS
What is happening?
React
PATTERNS OF BEHAVIOUR
Anticipate
SYSTEMS STRUCTURE
Design
MENTAL MODELS
What values, assumptions, beliefs shape the system?
Transform
WHAT?
HOW?
WHY?
MODELLING
ENGINEER SYSTEMS
It's all happening below the surface....
SIMULATION
Behaviour / Dynamics MODELS
Frameworks / Architecture MODELS
Composition (Aggregative) MODELS
Classification (Hierarchical) MODELS
Communication (Schematic) MODELS
Transformative MODELS
Transformative MODELS
Mental / Conceptual MODELS
12/12/2024
Copyright © 2024 by Jawahar Bhalla
35

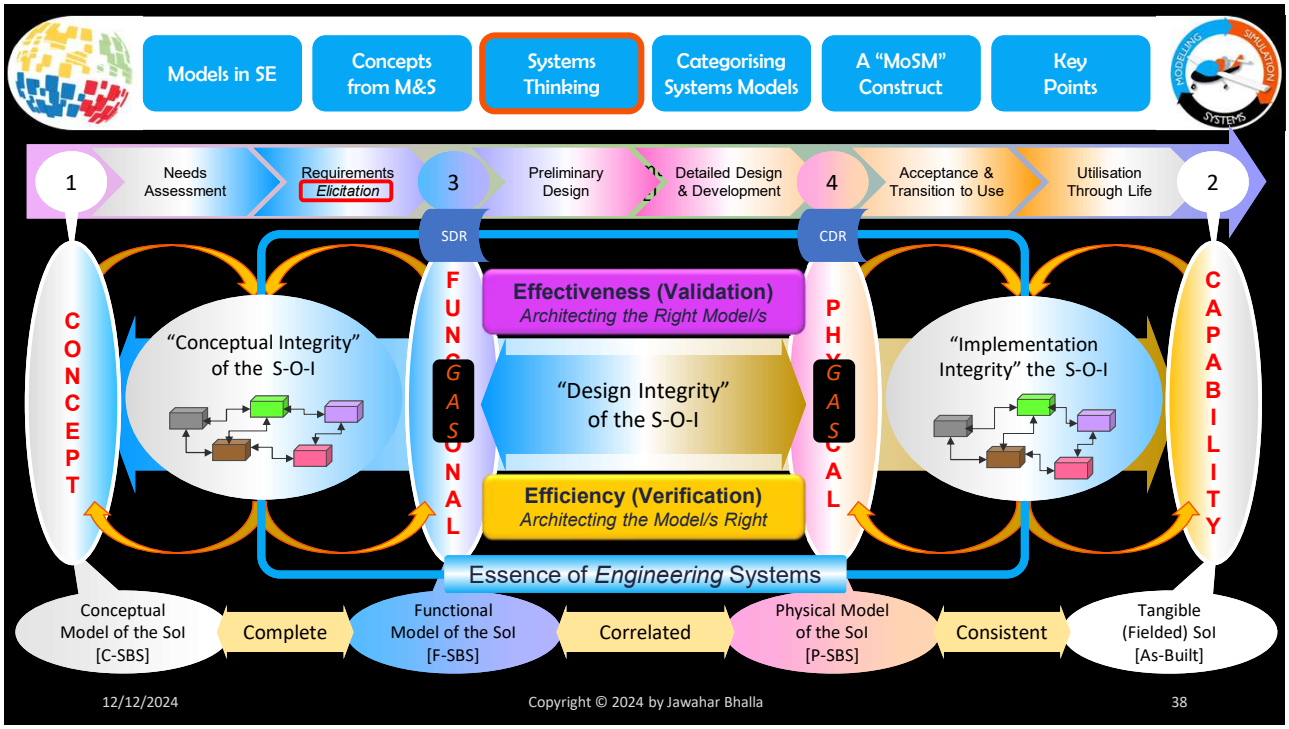
35


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
EVENTS
What is happening?
WHAT?
Behaviour / Dynamics MODELS
Anticipate
What influences the patterns?
HOW?
MENTAL MODELS
What values, assumptions, beliefs shape the system?
Machine Learning MODELS
Image Credit – Gerd Altmann, Pixabay
Symptomatic "Quick Fix"
Reactive "Fire Fighting"
Delay
Temporary Symptom Relief
Balancing Cycle
Symptom Correcting Process
Unintended Consequences
"Band-Aid" Solutions
Problem Symptom
Emergent Longer Term Side Effects
Causal Understanding
Delay
Holistic Problem Correction
Balancing Cycle
Cause Correcting Process
Undermine Efforts
"Root-Cause" Solutions
Delay
Fundamental Solution
Systems Dynamics and Operational Analysis MODELS
12/12/2024
Copyright © 2024 by Jawahar Bhalla
36

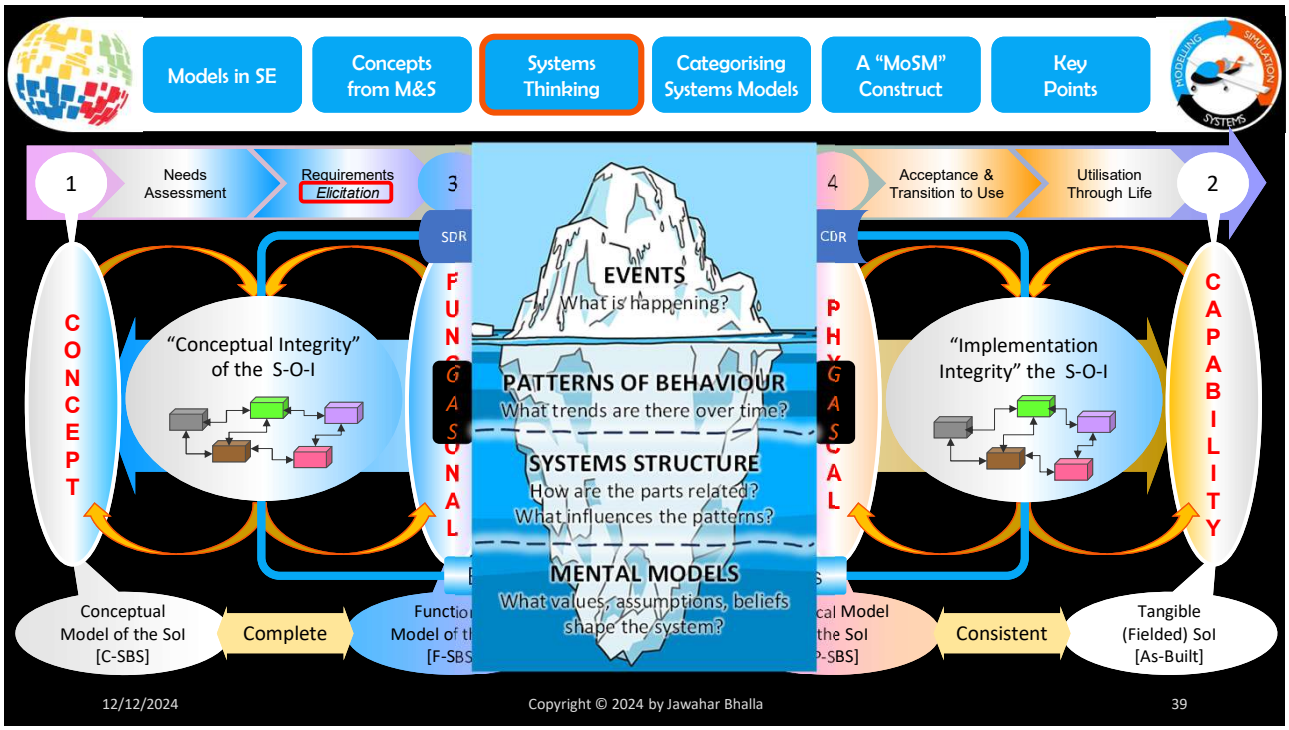
36


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
MODELLING
WHAT?
ENGINEER SYSTEMS
It's all happening below the surface....
SIMULATION
EVENTS
What is happening?
React
PATTERNS OF BEHAVIOUR
Anticipate
SYSTEMS STRUCTURE
Design
MENTAL MODELS
What values, assumptions, beliefs
Transform
HOW?
WHY?
Behaviour / Dynamics MODELS
Transformative MODELS
Frameworks / Architecture MODELS
Composition (Aggregative) MODELS
Classification (Hierarchical) MODELS
Communication (Schematic) MODELS
Transformative MODELS
Mental / Conceptual MODELS
12/12/2024
Copyright © 2024 by Jawahar Bhalla
37

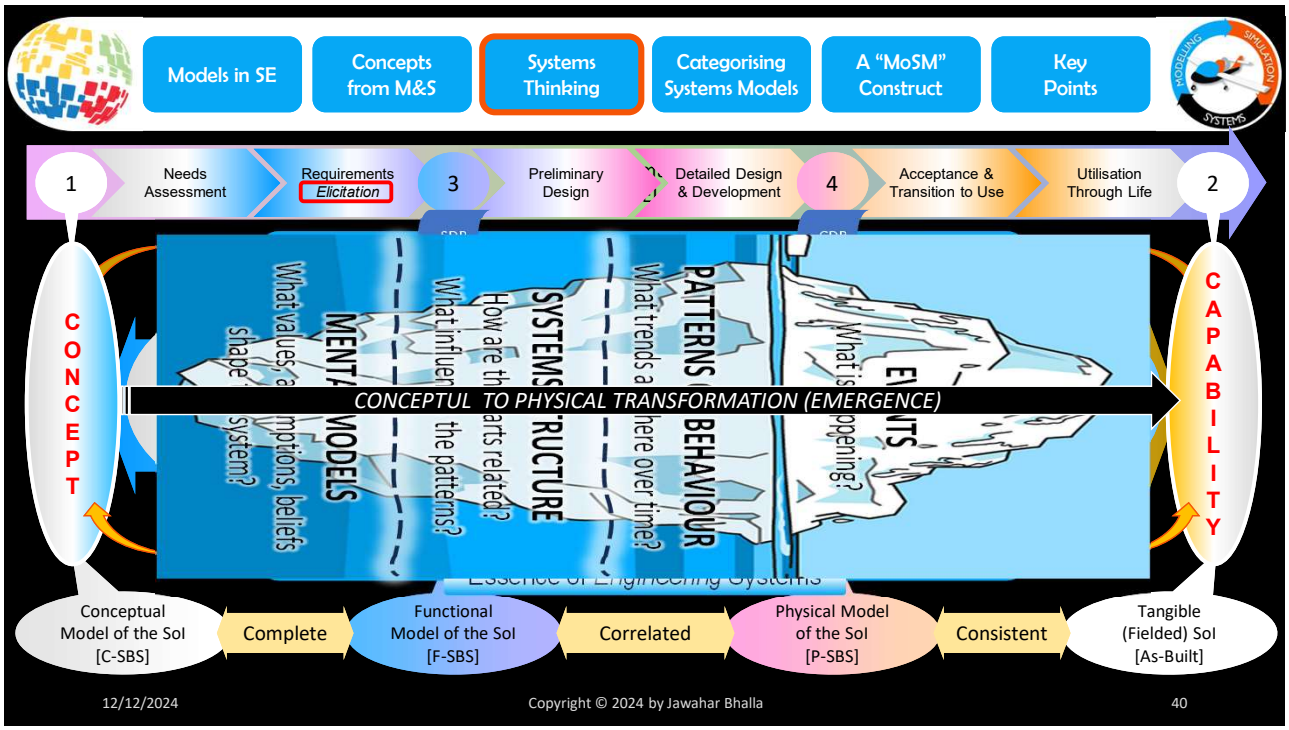
37


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
1
Needs Assessment
Requirements Elicitation
3
Preliminary Design
Detailed Design & Development
4
Acceptance & Transition to Use
Utilisation Through Life
2
SDR
CDR
CONCEPT
"Conceptual Integrity" of the S-O-I
FUNCTIONAL
Effectiveness (Validation)
Architecting the Right Model/s
"Design Integrity" of the S-O-I
Efficiency (Verification)
Architecting the Model/s Right
PHYSICAL
"Implementation Integrity" the S-O-I
CAPABILITY
Essence of Engineering Systems
Conceptual Model of the SoI [C-SBS]
Complete
Functional Model of the SoI [F-SBS]
Correlated
Physical Model of the SoI [P-SBS]
Consistent
Tangible (Fielded) SoI [As-Built]
12/12/2024
Copyright © 2024 by Jawahar Bhalla
38

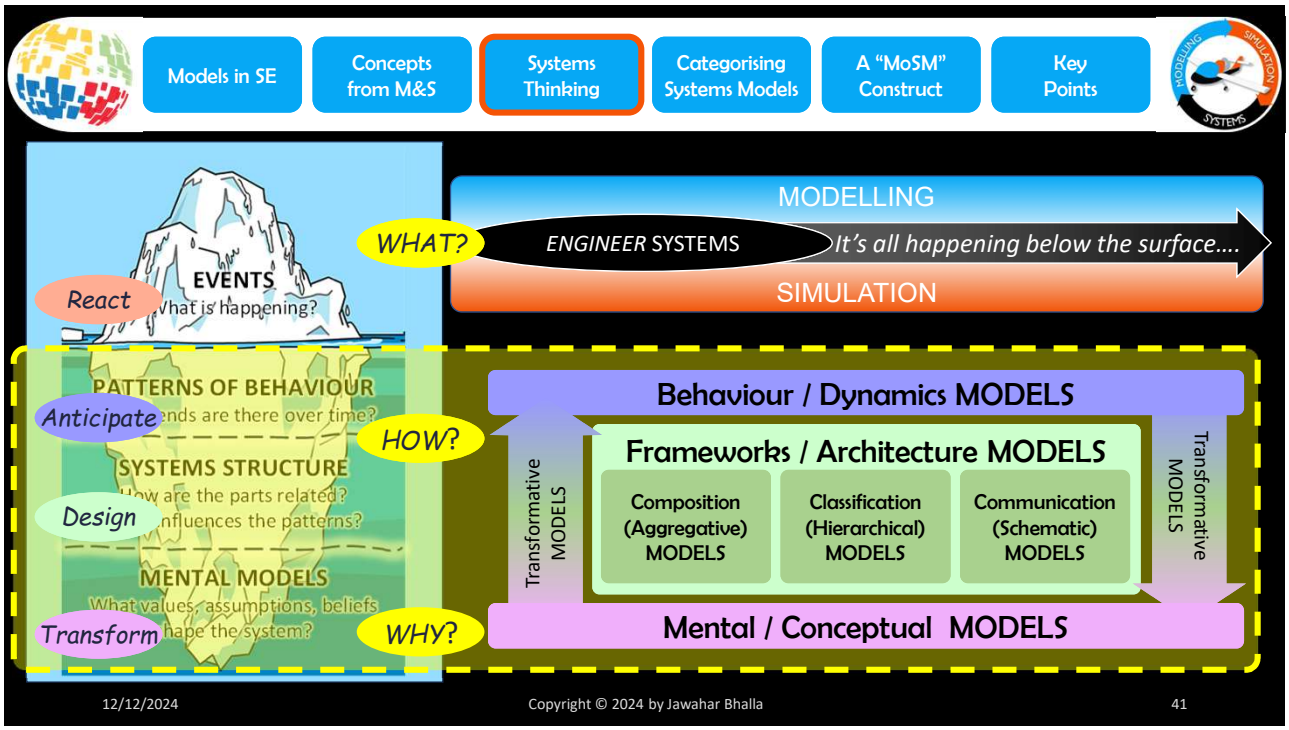
38


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
1
Needs Assessment
Requirements Elicitation
3
Preliminary Design
Detailed Design & Development
4
Acceptance & Transition to Use
Utilisation Through Life
2
SDR
CDR
CONCEPT
FUNCTIONAL
PHYSICAL
CAPABILITY
"Conceptual Integrity" of the S-O-I
"Implementation Integrity" the S-O-I
EVENTS
What is happening?
PATTERNS OF BEHAVIOUR
What trends are there over time?
SYSTEMS STRUCTURE
How are the parts related?
What influences the patterns?
MENTAL MODELS
What values, assumptions, beliefs shape the system?
Conceptual Model of the SoI [C-SBS]
Complete
Functional Model of the SoI [F-SBS]
Correlated
Physical Model of the SoI [P-SBS]
Consistent
Tangible (Fielded) SoI [As-Built]
12/12/2024
Copyright © 2024 by Jawahar Bhalla
39

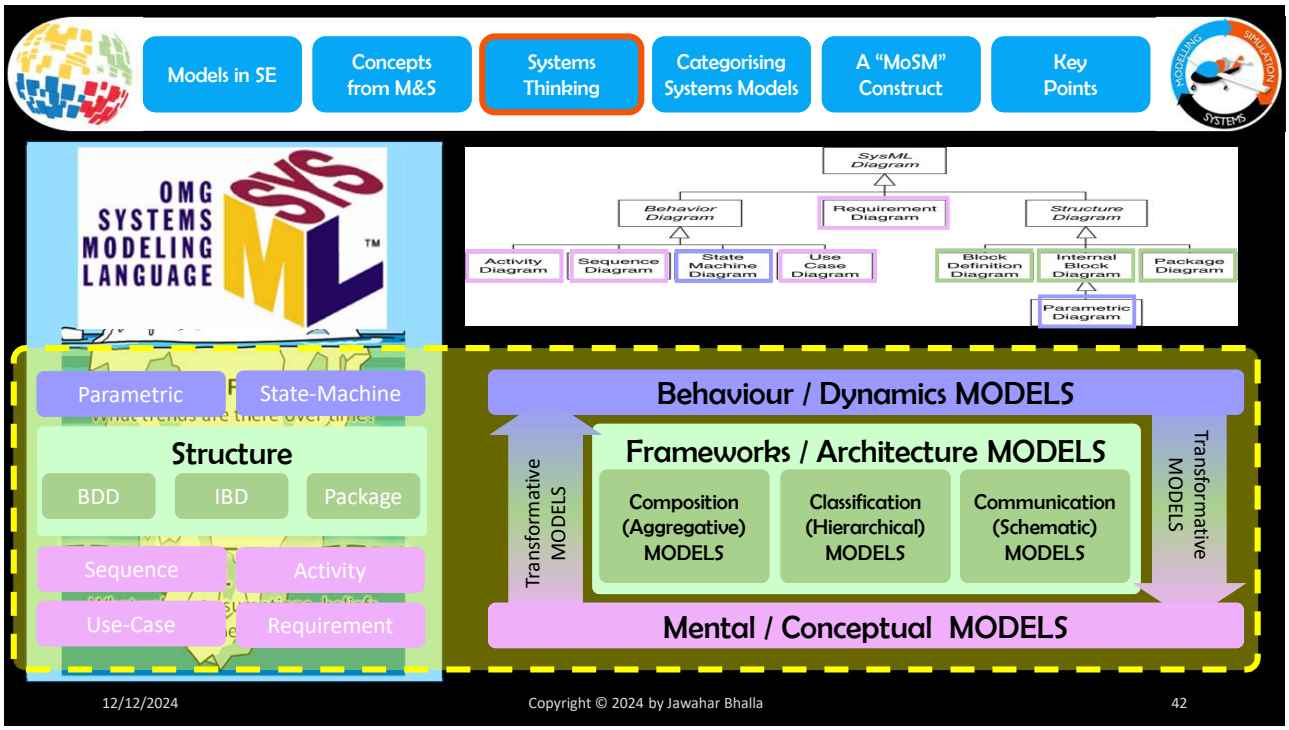
39


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
1
Needs Assessment
Requirements Elicitation
3
Preliminary Design
Detailed Design & Development
4
Acceptance & Transition to Use
Utilisation Through Life
2
CONCEPT
CAPABILITY
CONCEPTUL TO PHYSICAL TRANSFORMATION (EMERGENCE)
Conceptual Model of the SoI [C-SBS]
Complete
Functional Model of the SoI [F-SBS]
Correlated
Physical Model of the SoI [P-SBS]
Consistent
Tangible (Fielded) SoI [As-Built]
12/12/2024
Copyright © 2024 by Jawahar Bhalla
40

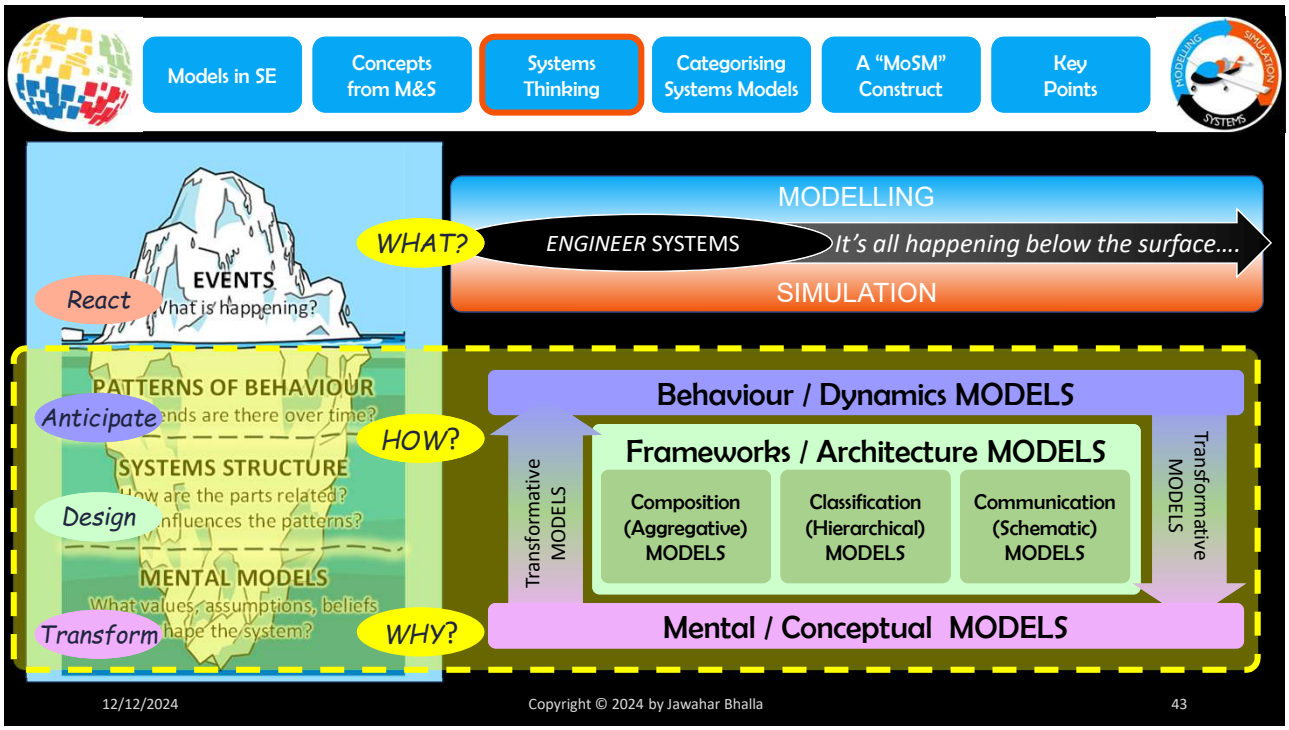
40


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
MODELLING
WHAT?
ENGINEER SYSTEMS
It's all happening below the surface....
SIMULATION
EVENTS
What is happening?
React
PATTERNS OF BEHAVIOUR
Anticipate
HOW?
SYSTEMS STRUCTURE
Design
MENTAL MODELS
What values, assumptions, beliefs
Transform
WHY?
Behaviour / Dynamics MODELS
Frameworks / Architecture MODELS
Transformative MODELS
Composition (Aggregative) MODELS
Classification (Hierarchical) MODELS
Communication (Schematic) MODELS
Mental / Conceptual MODELS
12/12/2024
Copyright © 2024 by Jawahar Bhalla
41

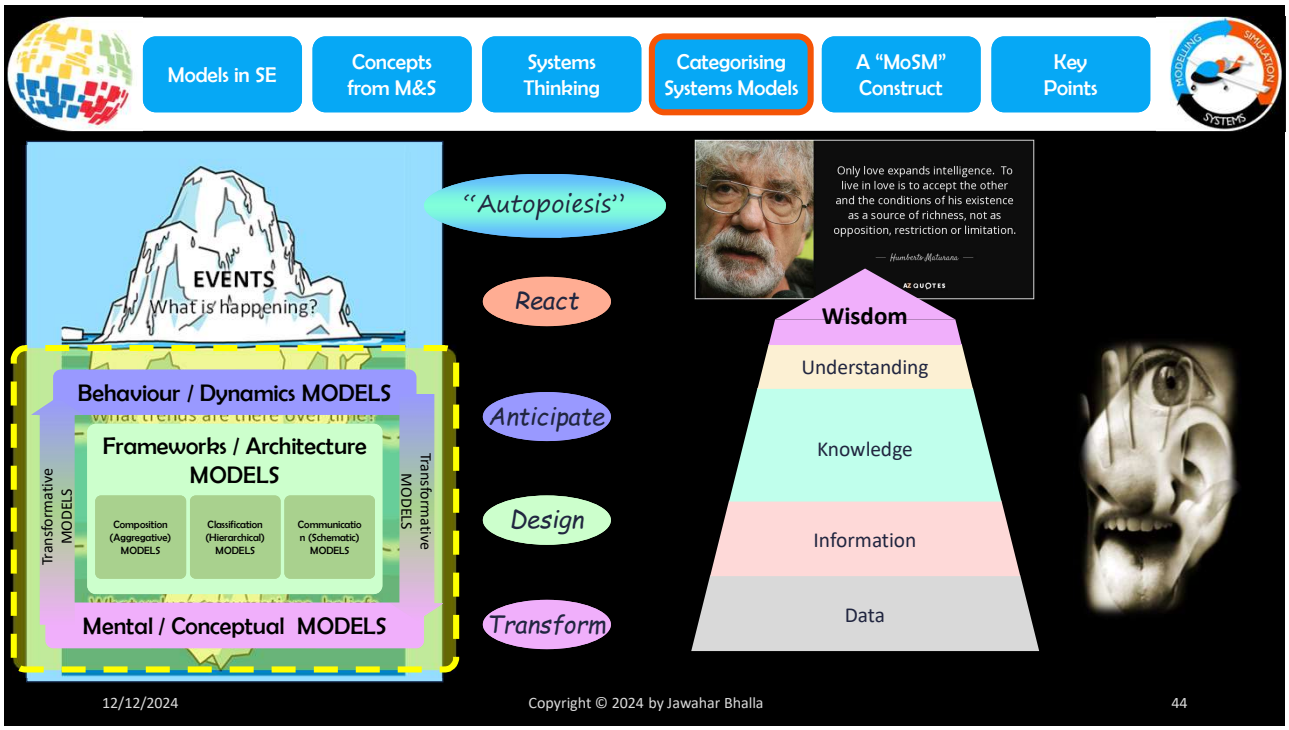
41


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
OMG SYSTEMS MODELING LANGUAGE
SysML Diagram
Behavior Diagram
Requirement Diagram
Structure Diagram
Activity Diagram
Sequence Diagram
State Machine Diagram
Use Case Diagram
Block Definition Diagram
Internal Block Diagram
Package Diagram
Parametric Diagram
Parametric
State-Machine
Structure
BDD
IBD
Package
Sequence
Activity
Use-Case
Requirement
Behaviour / Dynamics MODELS
Frameworks / Architecture MODELS
Transformative MODELS
Composition (Aggregative) MODELS
Classification (Hierarchical) MODELS
Communication (Schematic) MODELS
Mental / Conceptual MODELS
12/12/2024
Copyright © 2024 by Jawahar Bhalla
42

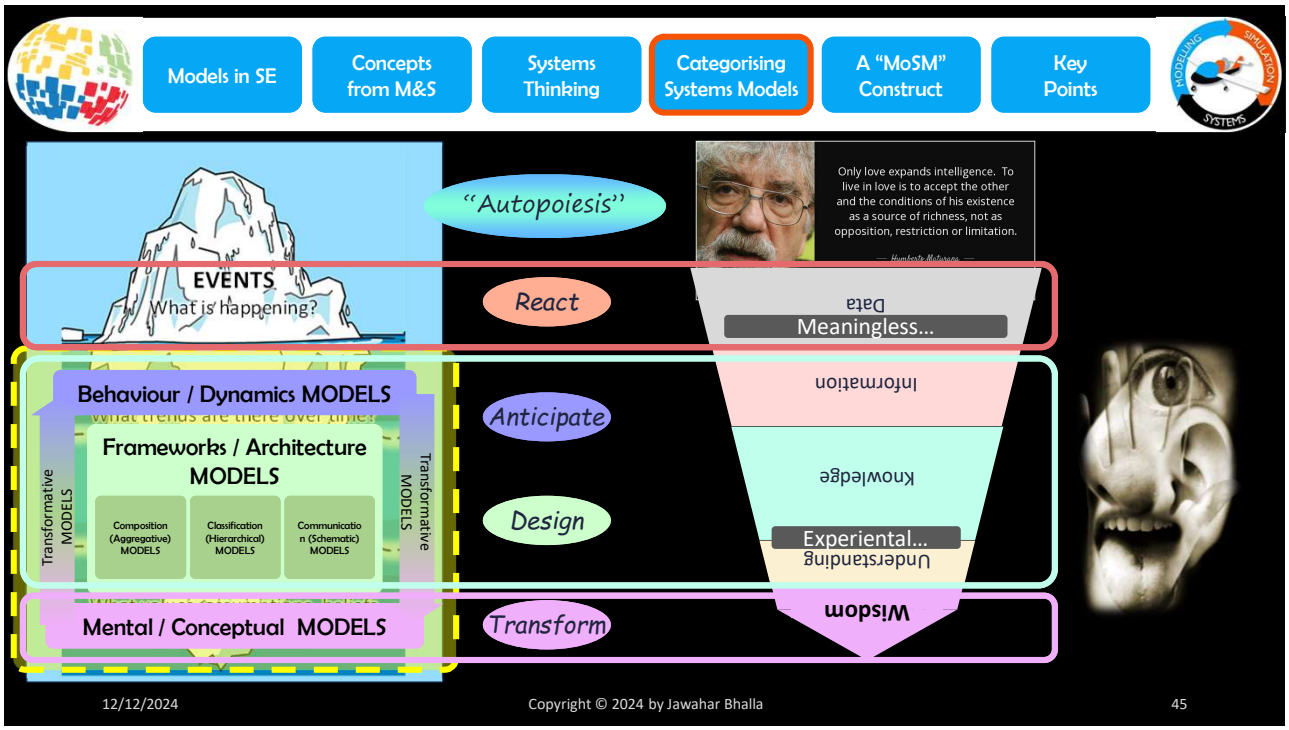
42


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
MODELLING
WHAT?
ENGINEER SYSTEMS
It's all happening below the surface....
SIMULATION
React
EVENTS
What is happening?
PATTERNS OF BEHAVIOUR
Anticipate
HOW?
SYSTEMS STRUCTURE
Design
MENTAL MODELS
Transform
WHY?
Behaviour / Dynamics MODELS
Frameworks / Architecture MODELS
Composition (Aggregative) MODELS
Classification (Hierarchical) MODELS
Communication (Schematic) MODELS
Transformative MODELS
Transformative MODELS
Mental / Conceptual MODELS
12/12/2024
Copyright © 2024 by Jawahar Bhalla
43

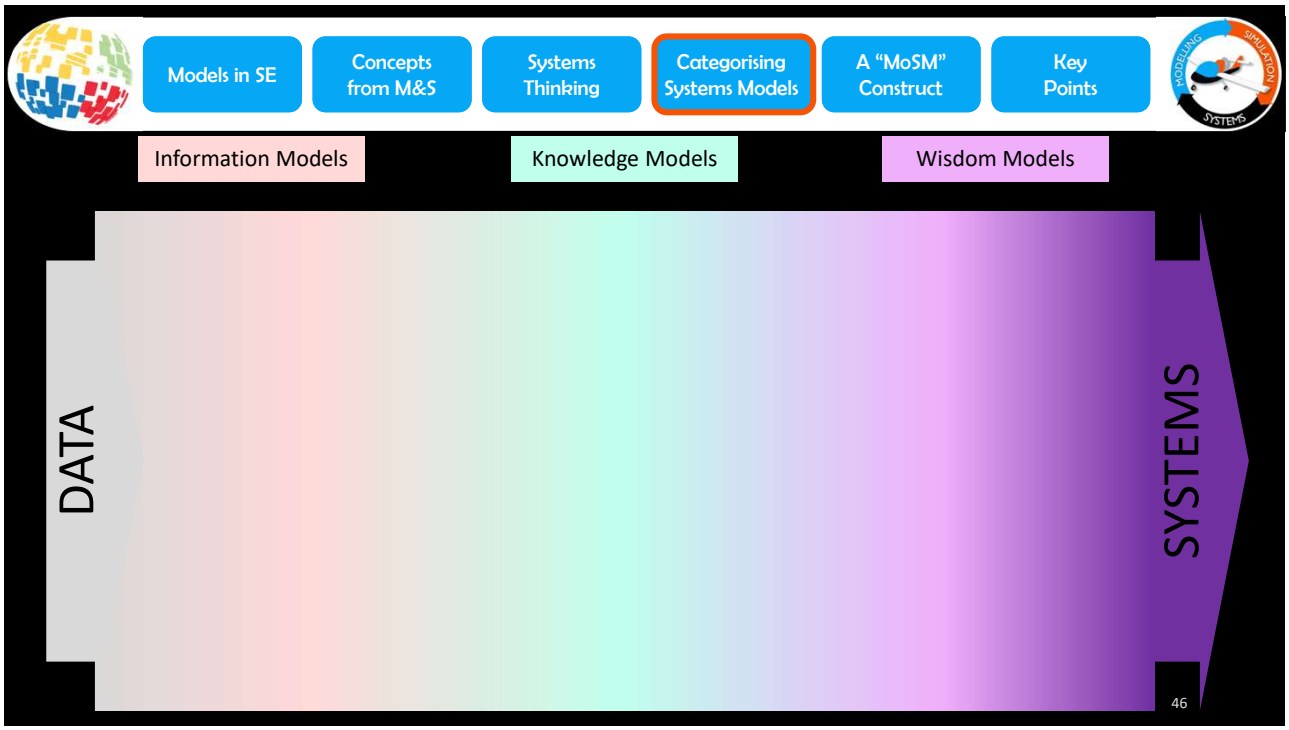
43


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
EVENTS
What is happening?
"Autopoiesis"
React
Anticipate
Design
Transform
Behaviour / Dynamics MODELS
Frameworks / Architecture MODELS
Composition (Aggregative) MODELS
Classification (Hierarchical) MODELS
Communication (Schematic) MODELS
Transformative MODELS
Transformative MODELS
Mental / Conceptual MODELS
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 —
AZ QUOTES
Wisdom
Understanding
Knowledge
Information
Data
12/12/2024
Copyright © 2024 by Jawahar Bhalla
44

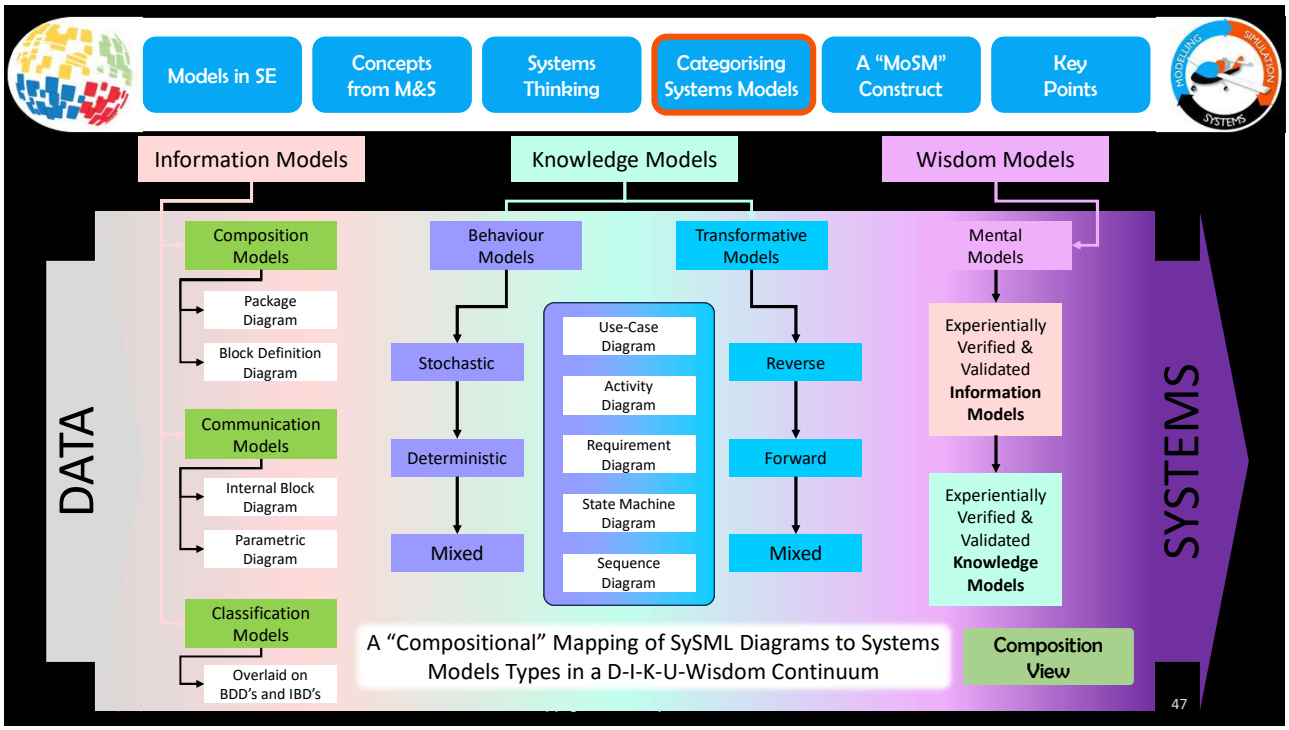
44


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
"Autopoiesis"
EVENTS
What is happening?
React
Anticipate
Design
Transform
Behaviour / Dynamics MODELS
Frameworks / Architecture MODELS
Mental / Conceptual MODELS
Transformative MODELS
Composition (Aggregative) MODELS
Classification (Hierarchical) MODELS
Communication (Schematic) MODELS
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.
Data
Meaningless...
Information
Knowledge
Understanding
Experiental...
Wisdom
12/12/2024
Copyright © 2024 by Jawahar Bhalla
45

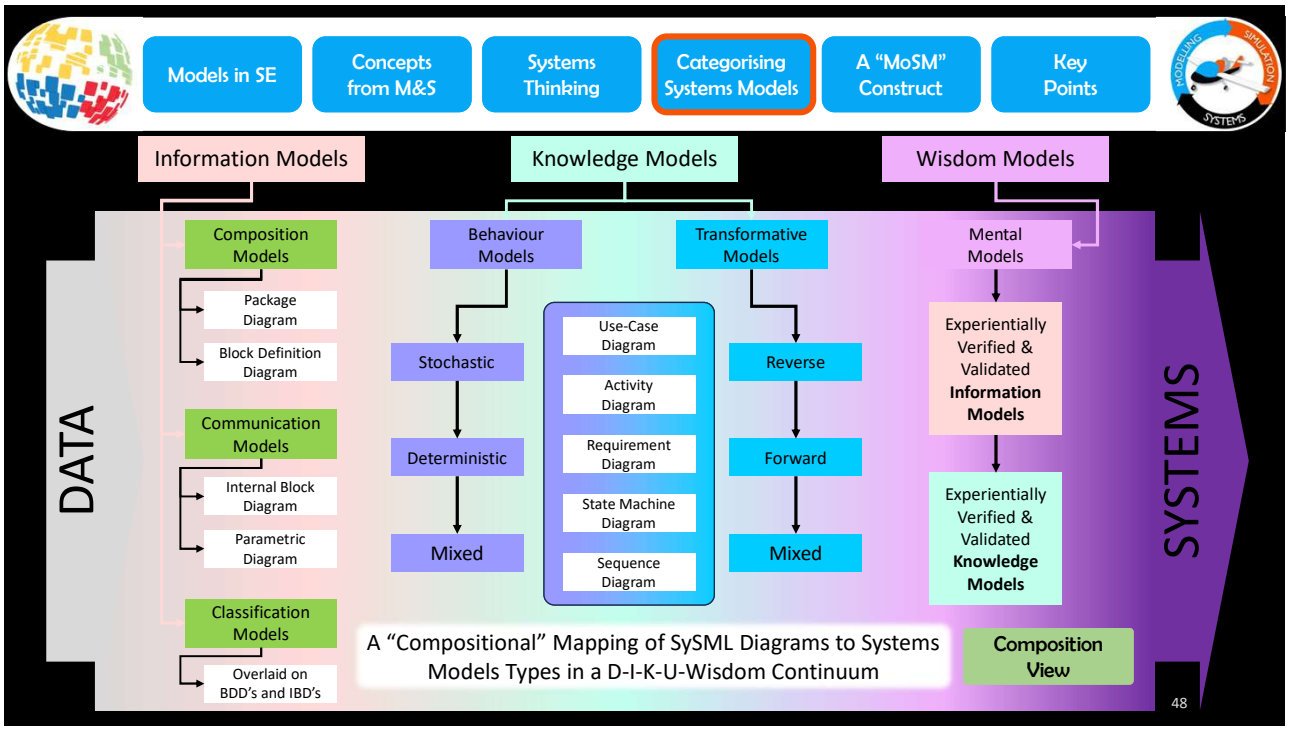
45


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Information Models
Knowledge Models
Wisdom Models
DATA
SYSTEMS
46

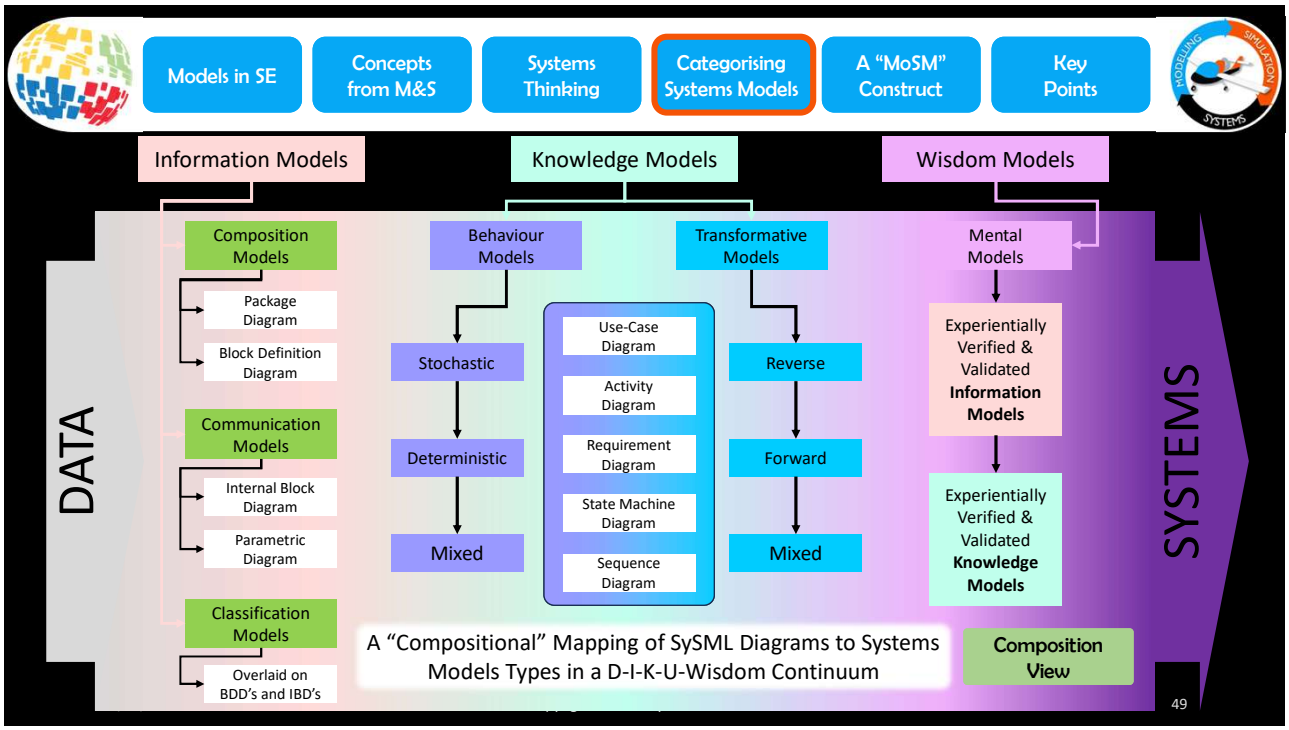
46


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
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
47

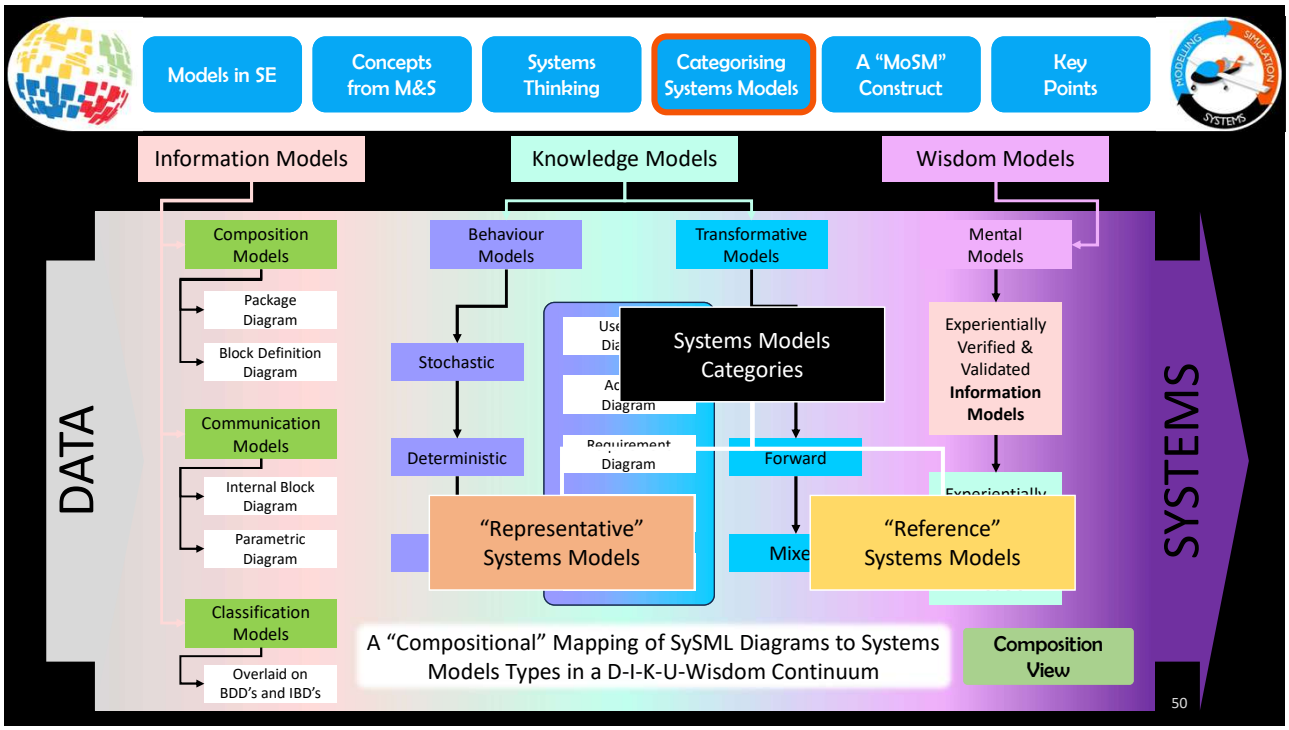
47


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
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
48

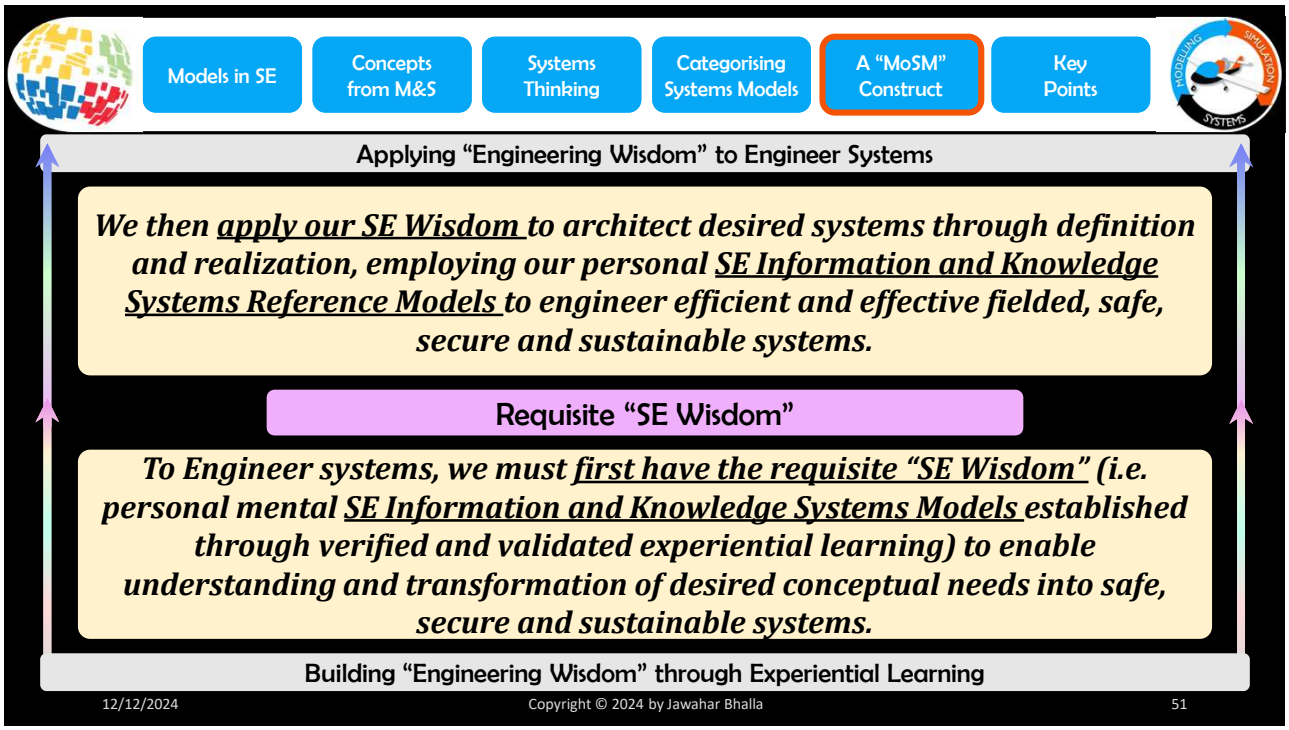
48


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Information Models
Knowledge Models
Wisdom Models
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
DATA
SYSTEMS
A "Compositional" Mapping of SySML Diagrams to Systems Models Types in a D-I-K-U-Wisdom Continuum
Composition View
49

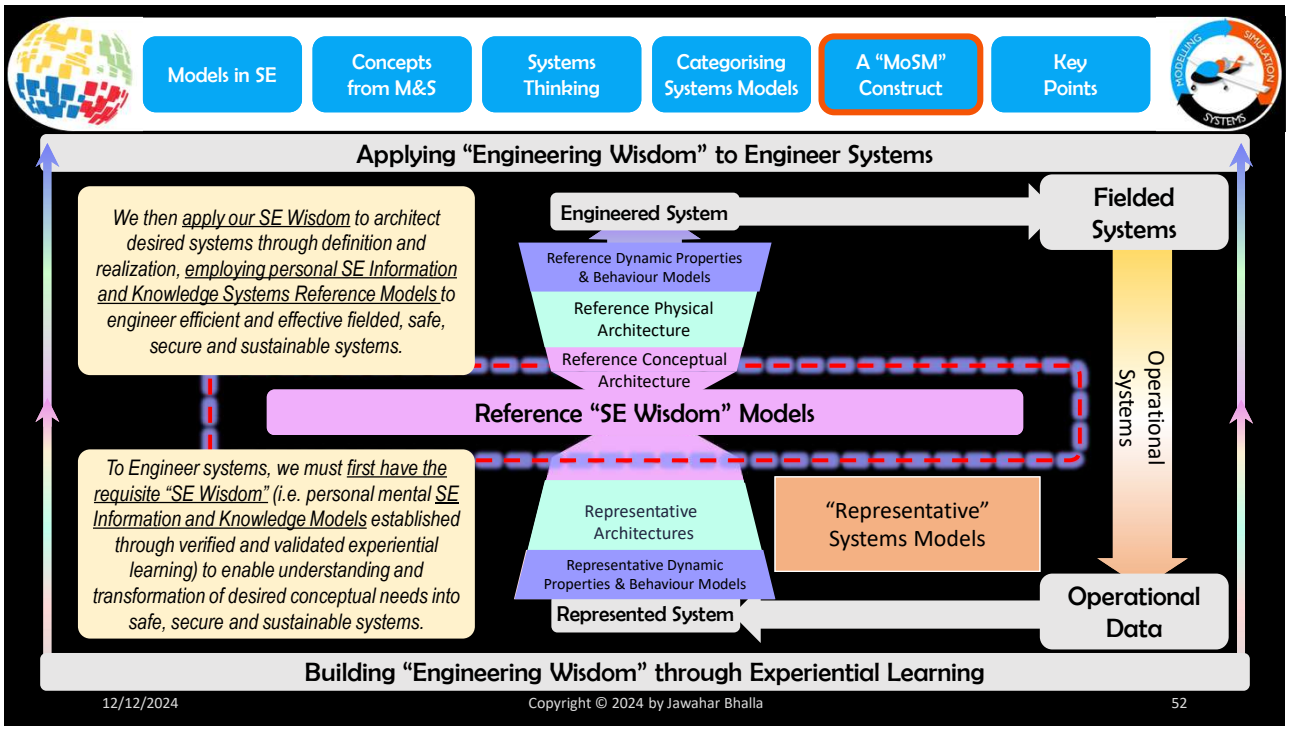
49


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Information Models
Knowledge Models
Wisdom Models
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
Systems Models Categories
Forward
"Representative" Systems Models
"Reference" Systems Models
Mental Models
Experientially Verified & Validated Information Models
DATA
SYSTEMS
A "Compositional" Mapping of SySML Diagrams to Systems Models Types in a D-I-K-U-Wisdom Continuum
Composition View
50

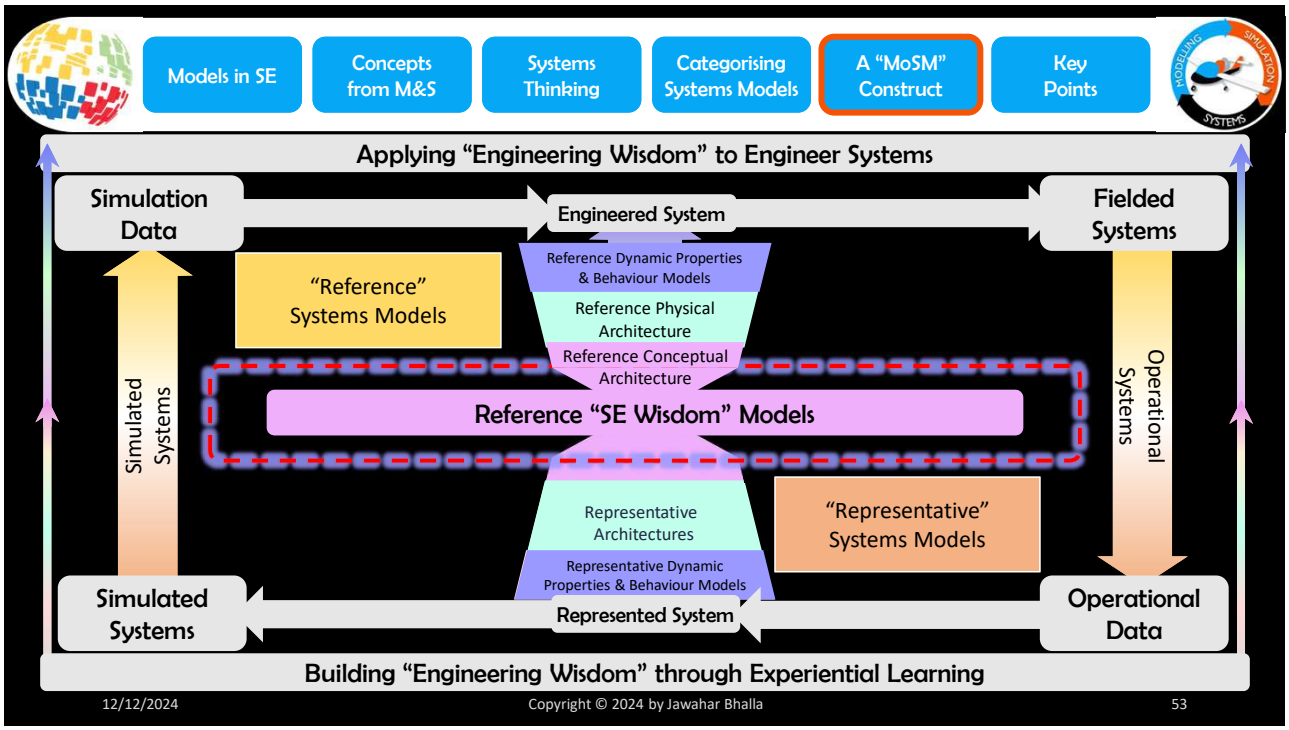
50


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Applying "Engineering Wisdom" to Engineer Systems
We then apply our SE Wisdom to architect desired systems through definition and realization, employing our personal SE Information and Knowledge Systems Reference Models to engineer 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. personal mental SE Information and Knowledge Systems 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
12/12/2024
Copyright © 2024 by Jawahar Bhalla
51

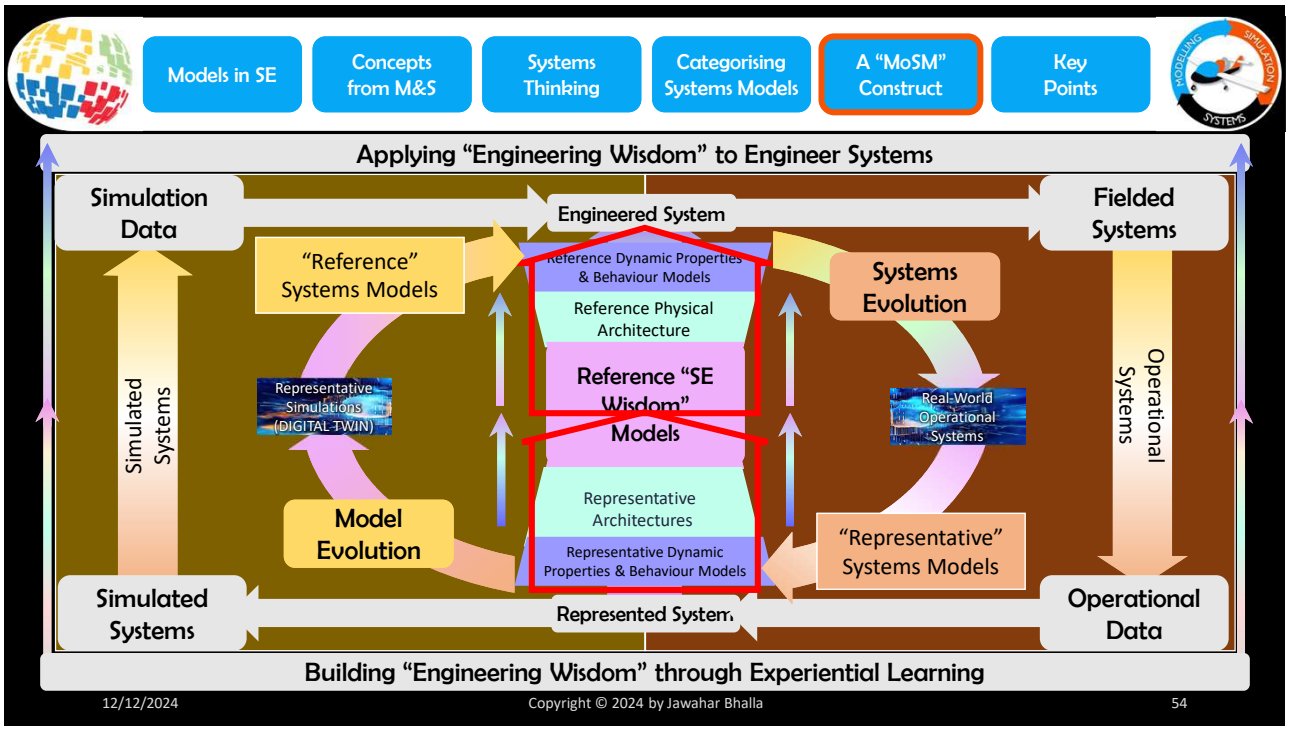
51


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Applying "Engineering Wisdom" to Engineer Systems
We then apply our SE Wisdom to architect desired systems through definition and realization, employing personal SE Information and Knowledge Systems Reference Models to engineer efficient and effective fielded, safe, secure and sustainable systems.
Engineered System
Fielded Systems
Reference Dynamic Properties & Behaviour Models
Reference Physical Architecture
Reference Conceptual Architecture
Reference "SE Wisdom" Models
Operational Systems
To Engineer systems, we must first have the requisite "SE Wisdom" (i.e. personal mental SE Information and Knowledge Models established through verified and validated experiential learning) to enable understanding and transformation of desired conceptual needs into safe, secure and sustainable systems.
Representative Architectures
"Representative" Systems Models
Representative Dynamic Properties & Behaviour Models
Represented System
Operational Data
Building "Engineering Wisdom" through Experiential Learning
12/12/2024
Copyright © 2024 by Jawahar Bhalla
52

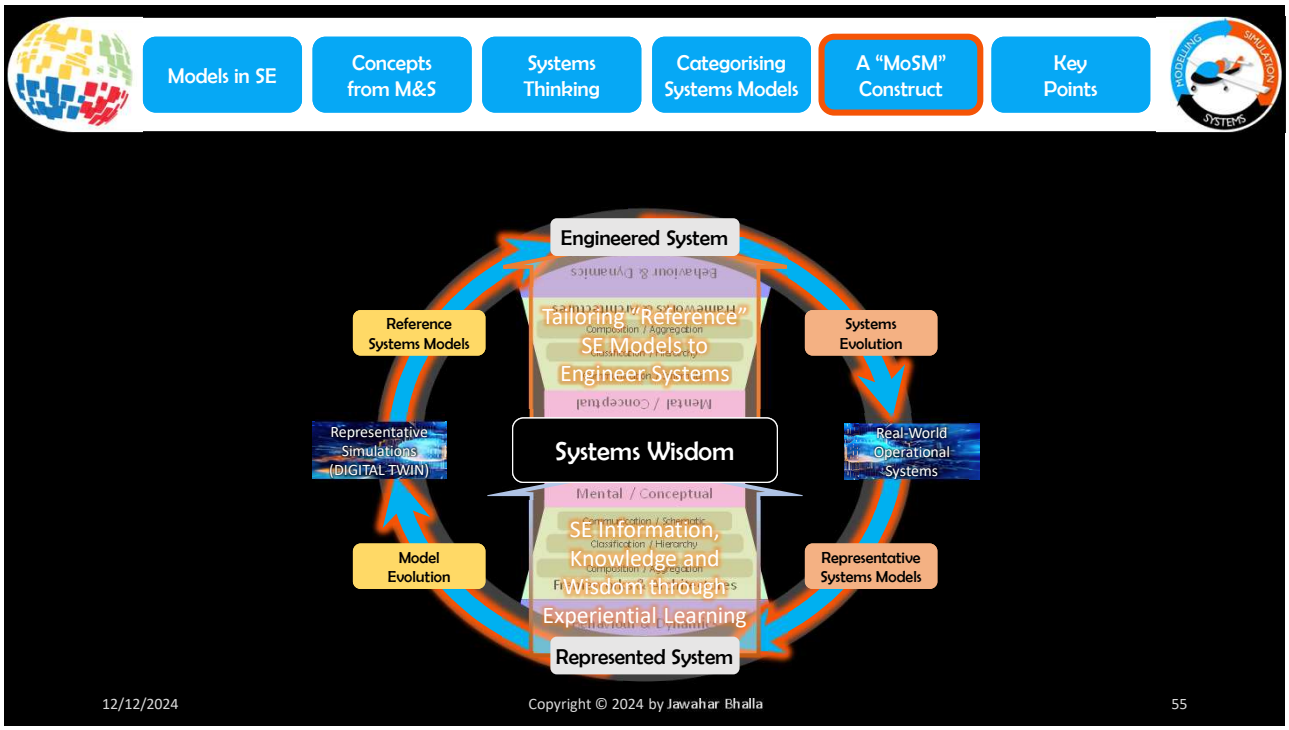
52


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Applying "Engineering Wisdom" to Engineer Systems
Simulation Data
Engineered System
Fielded Systems
"Reference" Systems Models
Reference Dynamic Properties & Behaviour Models
Reference Physical Architecture
Reference Conceptual Architecture
Reference "SE Wisdom" Models
Simulated Systems
Operational Systems
Representative Architectures
Representative Dynamic Properties & Behaviour Models
"Representative" Systems Models
Simulated Systems
Represented System
Operational Data
Building "Engineering Wisdom" through Experiential Learning
12/12/2024
Copyright © 2024 by Jawahar Bhalla
53

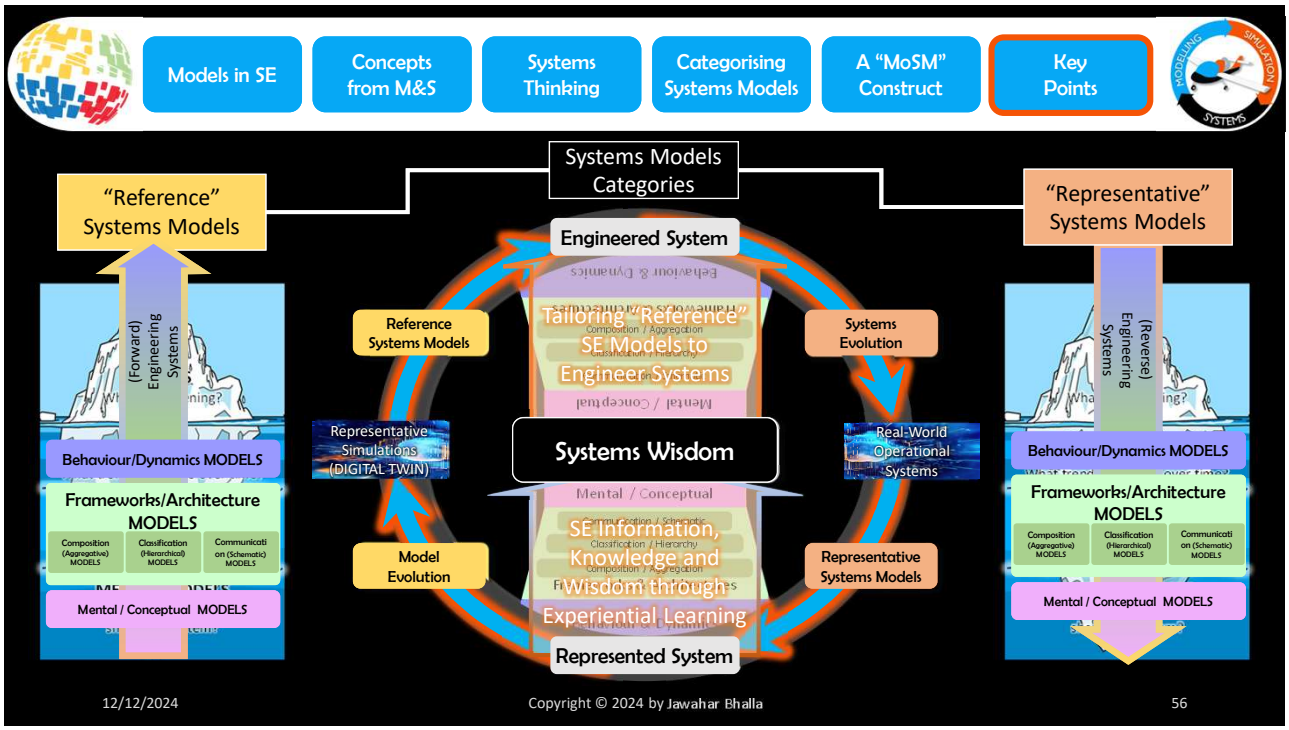
53


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Applying "Engineering Wisdom" to Engineer Systems
Simulation Data
Engineered System
Fielded Systems
"Reference" Systems Models
Reference Dynamic Properties & Behaviour Models
Reference Physical Architecture
Reference "SE Wisdom" Models
Systems Evolution
Simulated Systems
Representative Simulations (DIGITAL TWIN)
Real-World Operational Systems
Operational Systems
Model Evolution
Representative Architectures
Representative Dynamic Properties & Behaviour Models
"Representative" Systems Models
Simulated Systems
Represented System
Operational Data
Building "Engineering Wisdom" through Experiential Learning
12/12/2024
Copyright © 2024 by Jawahar Bhalla
54

54


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Engineered System
Reference Systems Models
Systems Evolution
Tailoring "Reference" SE Models to Engineer Systems
Representative Simulations (DIGITAL TWIN)
Systems Wisdom
Real-World Operational Systems
Model Evolution
SE Information, Knowledge and Wisdom through Experiential Learning
Representative Systems Models
Represented System
12/12/2024
Copyright © 2024 by Jawahar Bhalla
55

55


Models in SE
Concepts from M&S
Systems Thinking
Categorising Systems Models
A "MoSM" Construct
Key Points
Systems Models Categories
"Reference" Systems Models
"Representative" Systems Models
(Forward) Engineering Systems
(Reverse) Engineering Systems
Behaviour/Dynamics MODELS
Frameworks/Architecture MODELS
Mental / Conceptual MODELS
Engineered System
Reference Systems Models
Systems Evolution
Tailoring "Reference" SE Models to Engineer Systems
Representative Simulations (DIGITAL TWIN)
Systems Wisdom
Real-World Operational Systems
Model Evolution
SE Information, Knowledge and Wisdom through Experiential Learning
Representative Systems Models
Represented System
12/12/2024
Copyright © 2024 by Jawahar Bhalla
56

56

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."

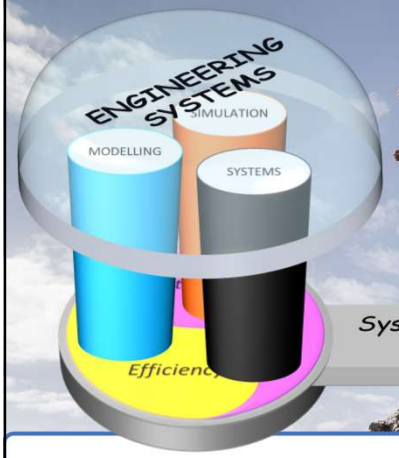
Donella Meadows : Thinking in Systems

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.*

57

Engineering Solutions for a Better World



Custodians of our Past

Creators of our Present

Guardians of our Future

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 safe, secure, sustainable and ethical solutions*** through **Systemic and Systematic Thinking**, complimented by **Modelling and Simulation**

Freedom of Speech, Choice and Expression, not Imposition. No Mandates, Lockdowns or One-size Fits All Solutions.

58