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Models, Models Everywhere! A practitioners view on the reality of modelling

Duncan Kemp, Chris Hoffman & Meaghan O'Neil

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Authors



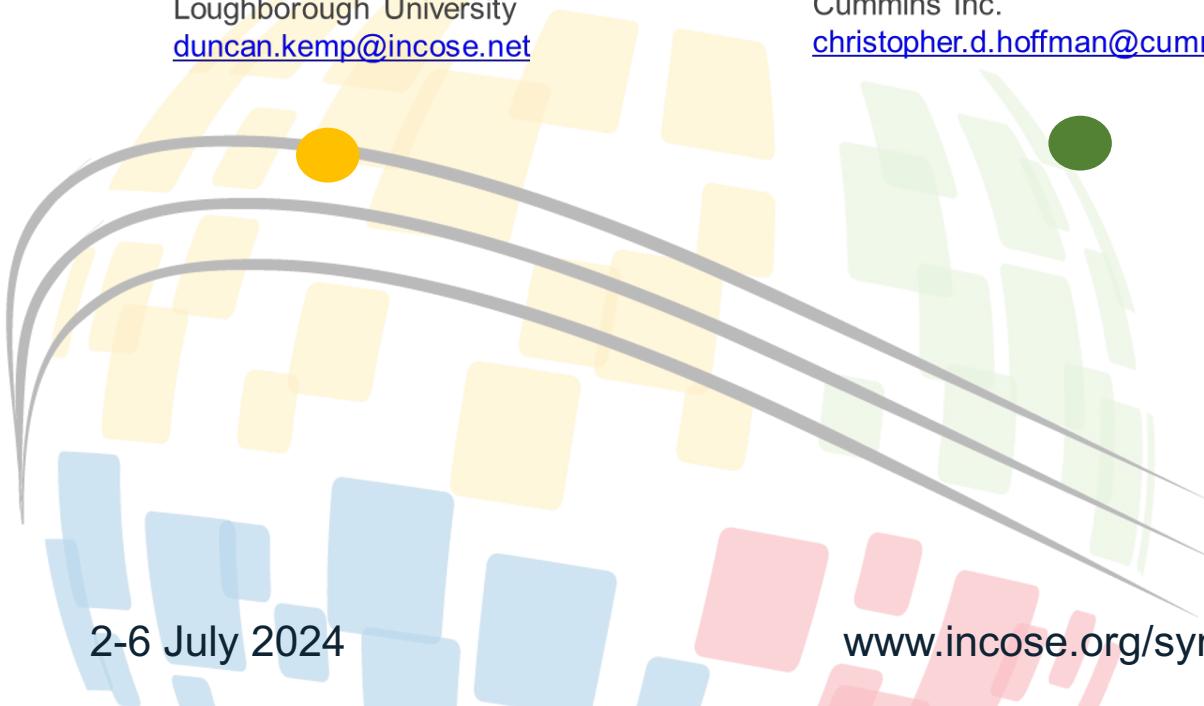
Professor Duncan Kemp
Loughborough University
duncan.kemp@incose.net



Christopher Hoffman
Cummins Inc.
christopher.d.hoffman@cummins.com



Meaghan O'Neil
System Design and Strategy
moneil@systemdesignstrategy.co.uk

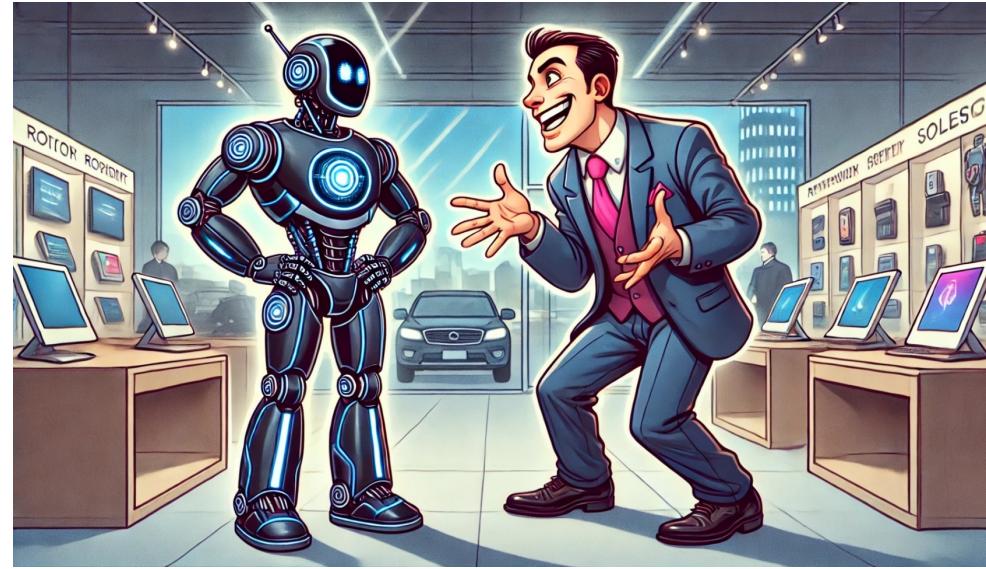


• Overview

- The gap between theory and practice
- Methodology
- Types of models
- Generic Modelling approach
- Real world challenges

Methodology

- Pragmatic research philosophy
- Experienced practitioners with diverse perspectives:
 - Tool developer
 - System developer
 - Asset owner / operator
- Based (in part) on 7-year longitudinal study into state of SE practice



“ ... and version 3.0 of SysEngBot will do exactly what you meant to ask it.”

Mind the gap

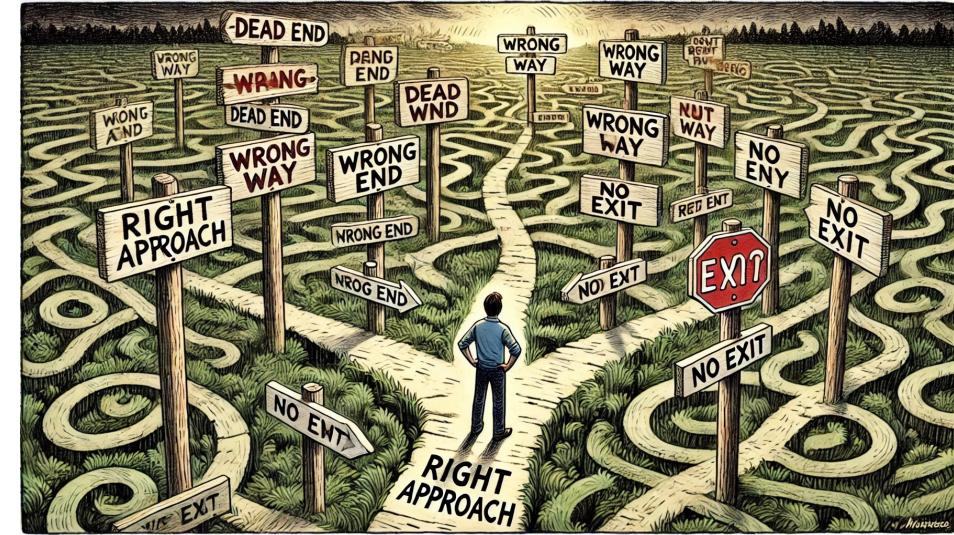
Theory

“... build a SysML model to analyse the end-to-end performance between ...”

“... Programme ‘x’ (previously stated as 100% digital) has just started physical trials.”

“... wow, that is great to see the models being used. Most of our models are produced to get past a stage gate.”

Practice



Types of System Models

Form



Fit

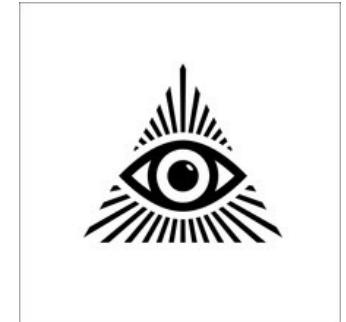


Function

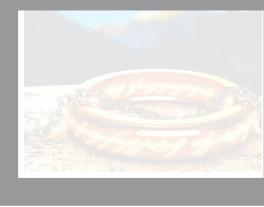


User Needs
Cost
Durability
Weight
Compliance
Serviceability
Is it worth it

...



Understand the Problem

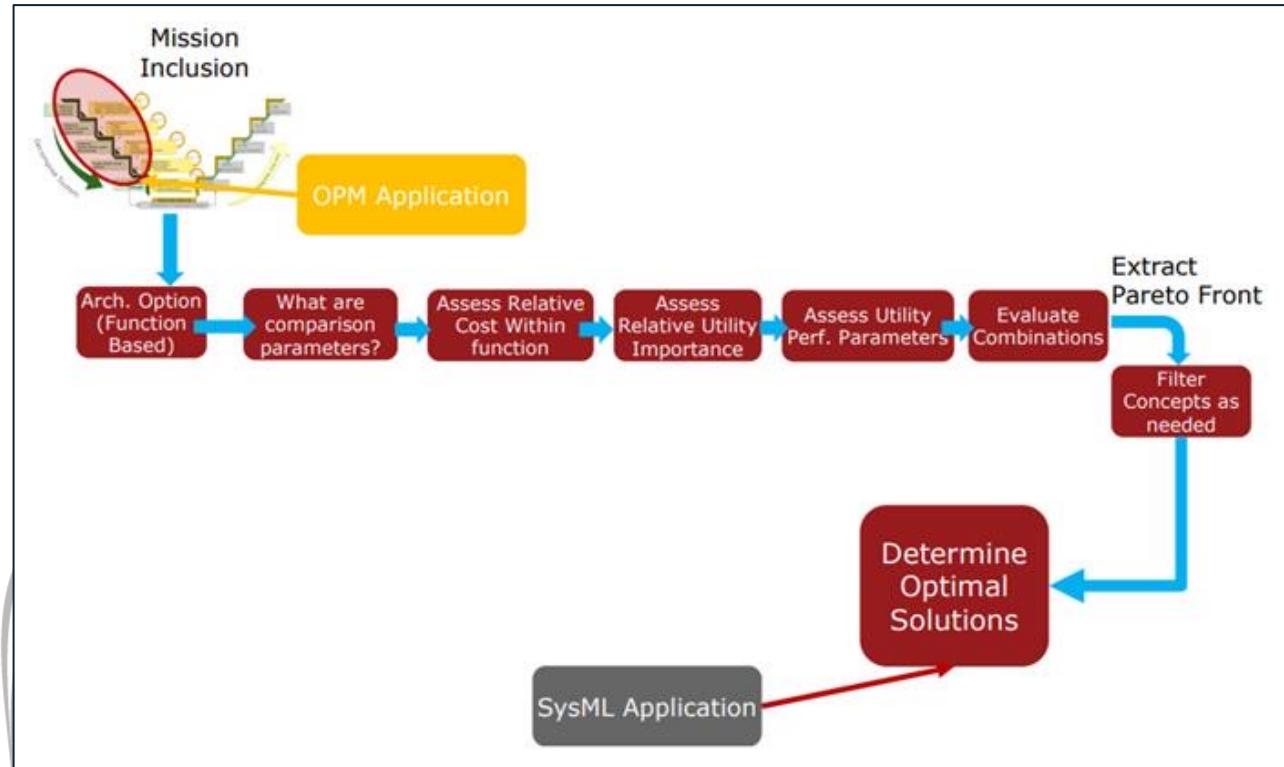


		Pillar			
		Requirements	Behavior	Structure	Parametrics
Layer of Abstraction	Problem	Stakeholder Needs	Use Cases	System Context	Measurements of Effectiveness
	White Box	System Requirements	Functional Analysis	Logical Subsystems Communication	MoEs for Subsystems
	Black Box	Component Requirements	Component Behavior	Component Assembly	Component Parameters

The MBSE Grid Framework (Morkevicius et al., 2017)

- Used to understand the problem or opportunity space, including understanding
 - Potential system purpose
 - Operating environment
 - Other systems that might be collaborating or competing with the system.
- Requires a diverse range of models and model types
 - Systems thinking
 - Operational simulations
 - Enterprise architectures

Define the System



- Elaboration and evaluation of multiple options / solution concepts.
- Support trade studies
- Typically, the models used will include:
 - Static behavioural models, e.g. SySML or OPM
 - End to end performance simulations of key system performance / effectiveness characteristics.
 - Whole system models of system properties such as safety, reliability, and security.

Define System Elements



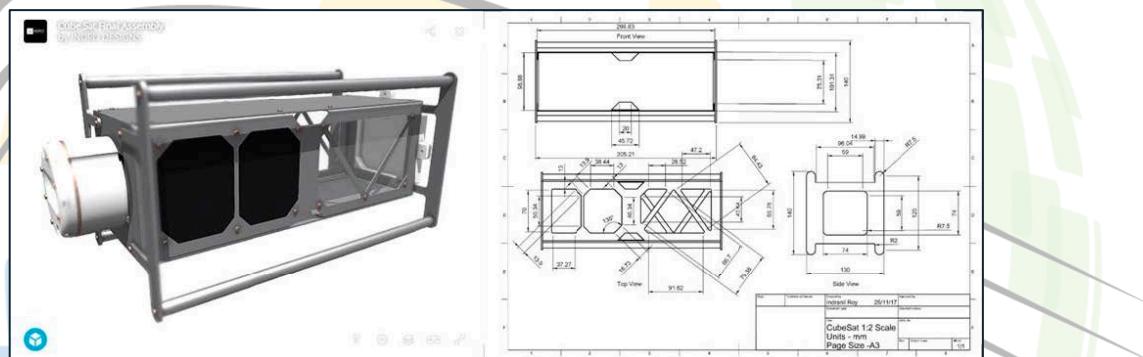
How to “Shop” for the best design (solutions of interest)?

Integrated ADCS

Antenna systems
Attitude actuators
Attitude sensors
Cameras & payloads
Command & data handling
Communication systems
CubeSat kits & buses
CubeSat Structures
Ground stations
Ground support equipment
Integrated ADCS
Launch adapters
Propulsion & pressurisation
Software services
Solar panels & power systems
Training & simulators

<http://www.cubesatshop.com>

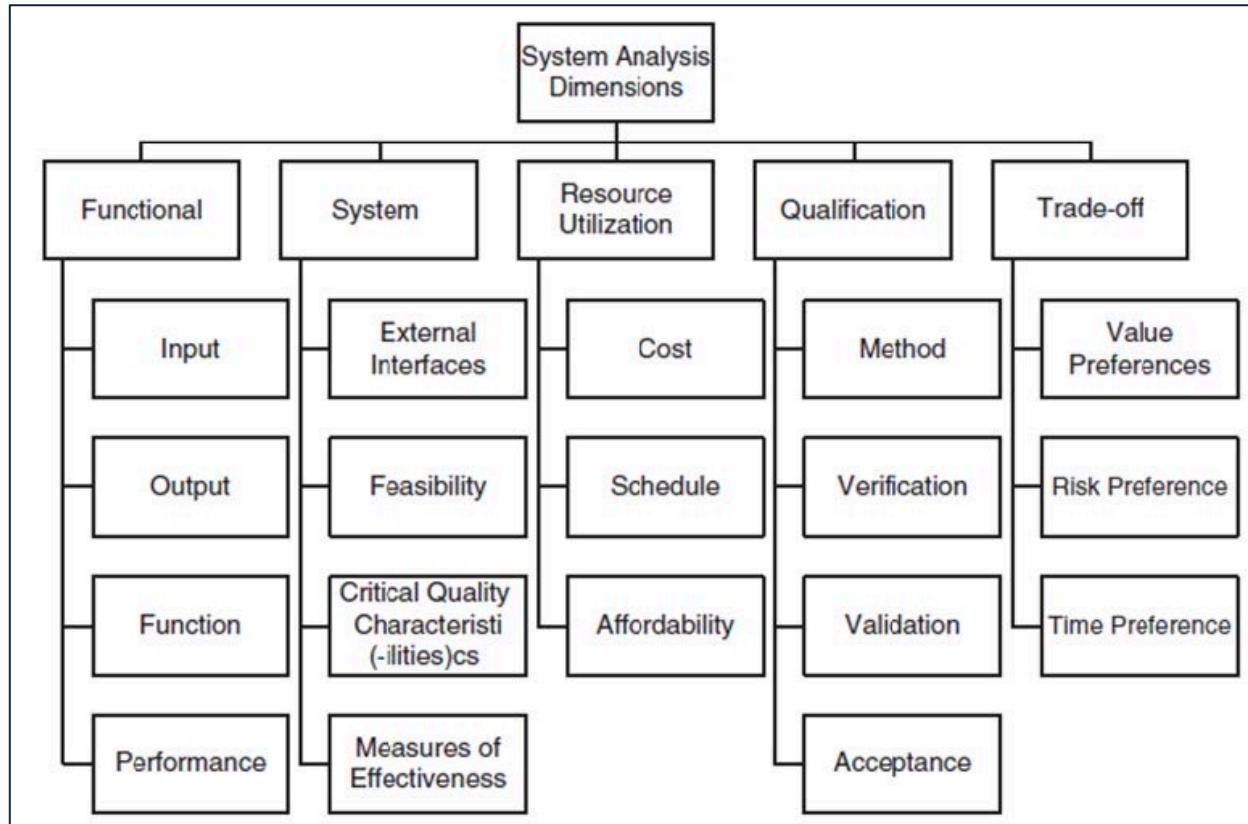
Multiple Design Elements (Qiao et al., 2017)



3D Physical Model with 2D Technical Drawings (Roy, 2023)

- What are they?
- Understand how elements work with
 - Other systems
 - Organizations
 - Product line engineering approaches
 - Wider system of systems
 - Maintenance and support
- Significant elements may be legacy (or future legacy)
- Different organisations will have different concerns and model types

System Analysis



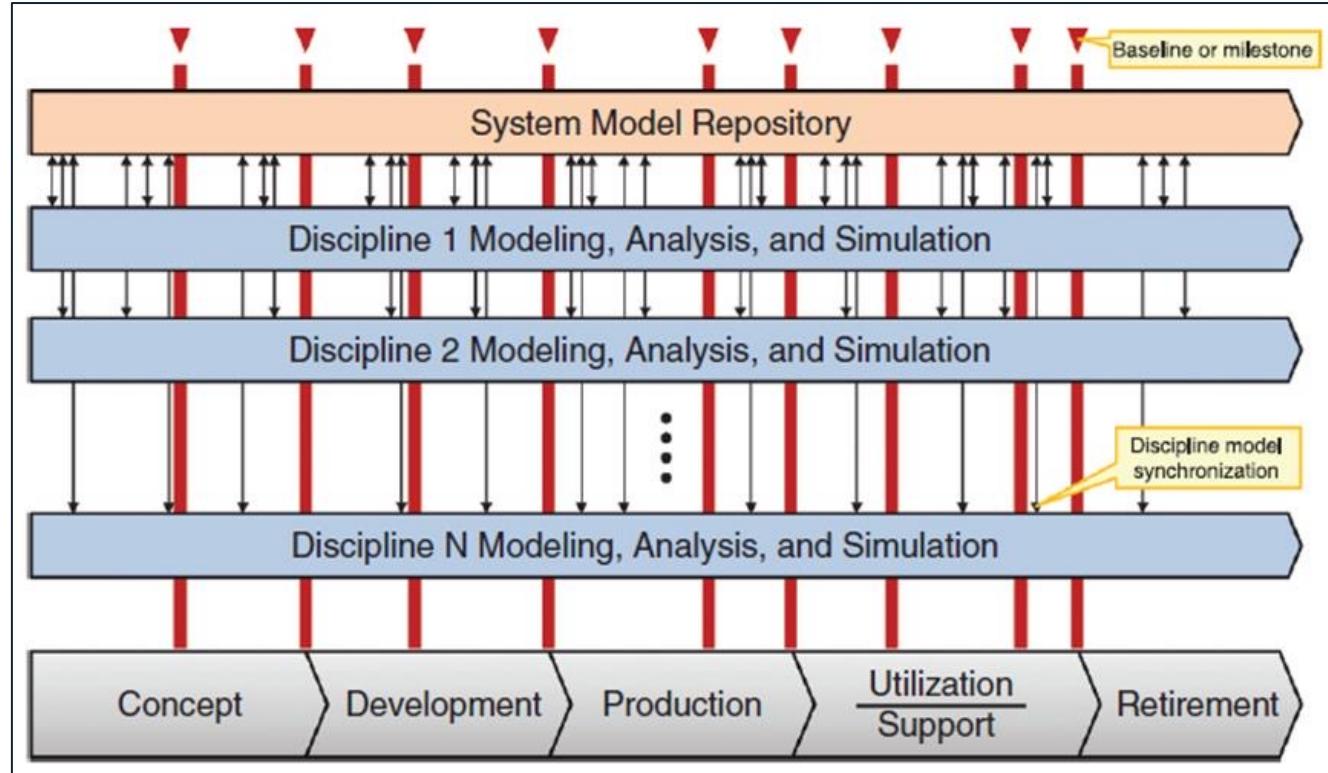
Taxonomy of system analysis dimensions. (Walden et al., 2023, fig. 2.45)

- Verify
 - The defined system will satisfy system requirements
 - The physics of the system
 - Other design and system constraints.
- This could include
 - 0D & 1D system models to simulate behaviours and performance
 - 3D models of the physical items to understand and adjust for material stress/strain, thermal loads, and dimensional fit concerns
 - Multi-domain system models to understand and optimize complex behaviours such as combustion and sealing (e.g., bolted joints with gaskets and multiple parts)
 - ...

Additional Purposes

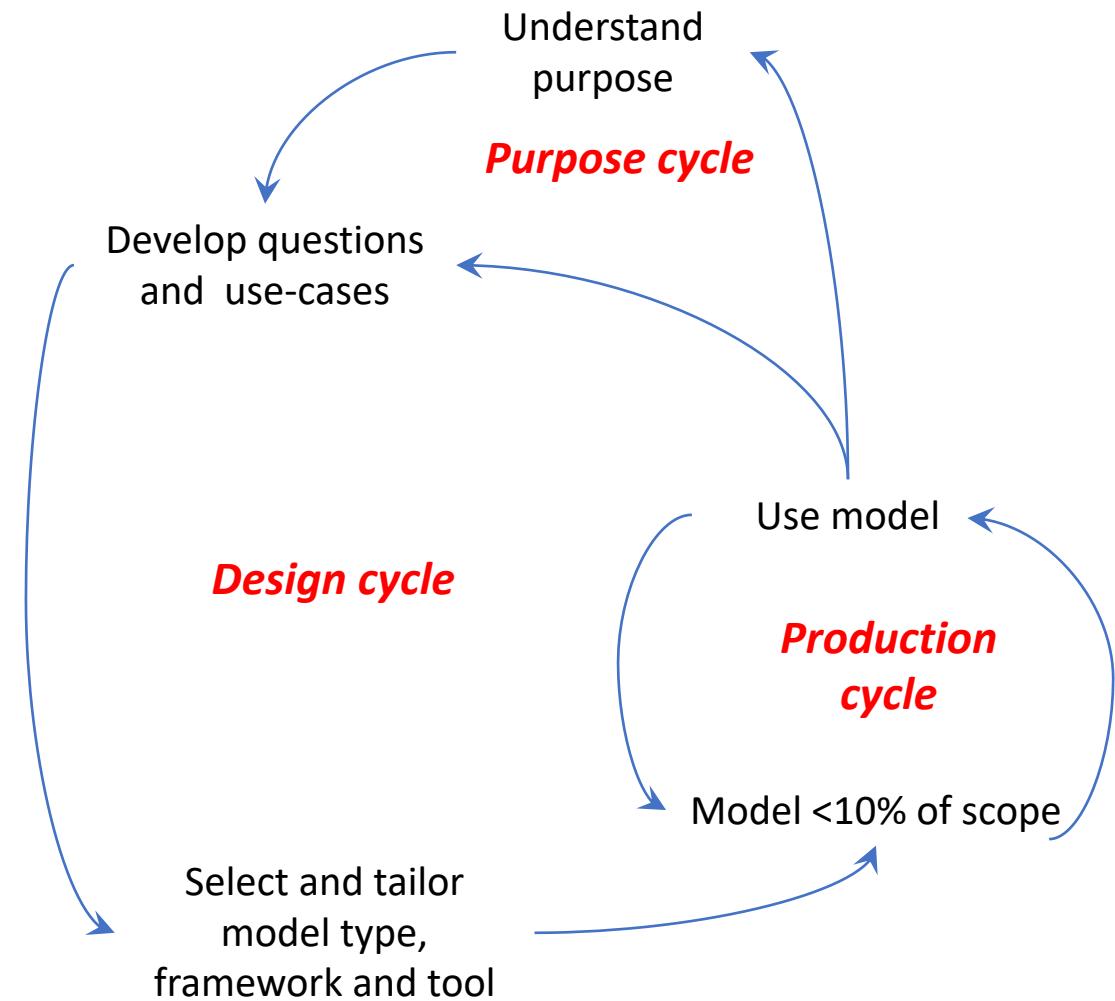
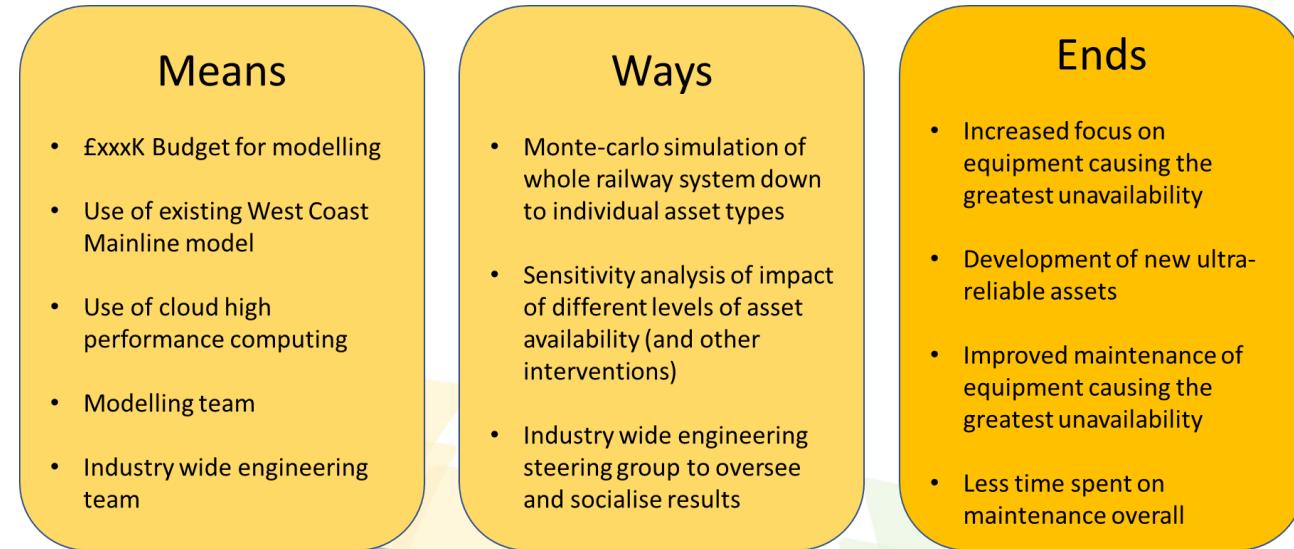


- Wide range of additional uses
 - Common descriptive system representation
 - Increasing the opportunity for the full development team to understand and align on 'the system'.
 - Knowledge management hub
 - The information at the heart of the Safety Management System
 - The information at the heart of the Asset Management System
 - ...

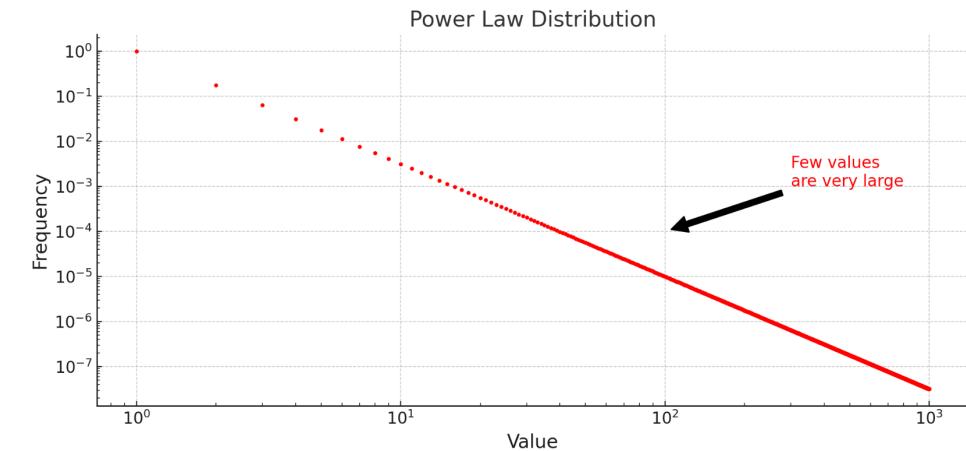
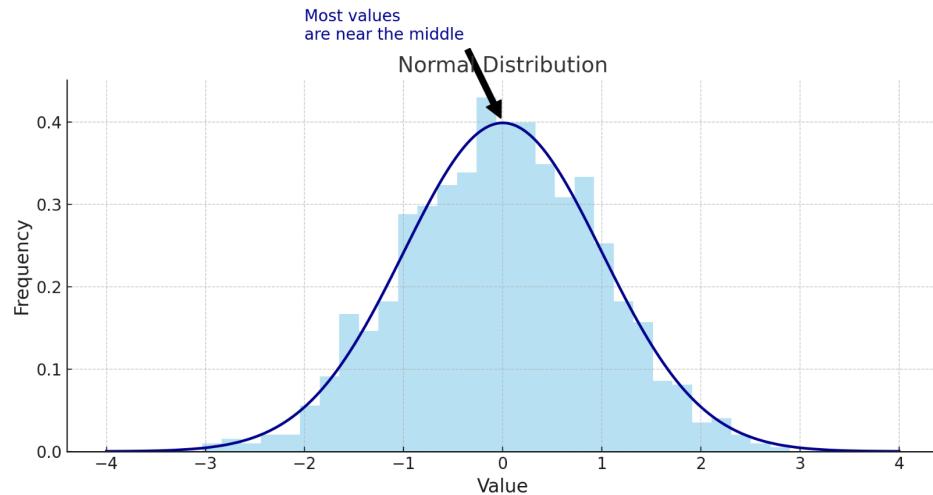


Multidisciplinary Modeling, Analysis, and Simulation coordination
along the life cycle (Walden et al., 2023, fig. 3.12)

Generic modelling approach



Averages, distributions, and simulations



A

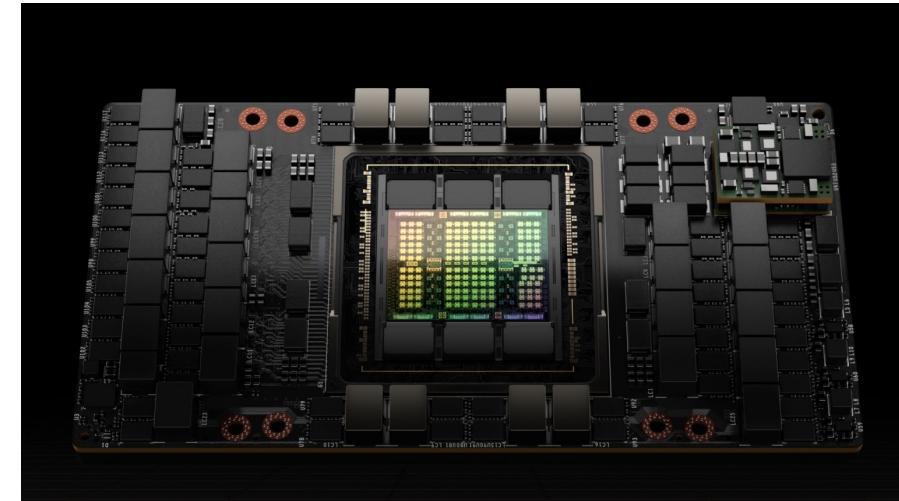
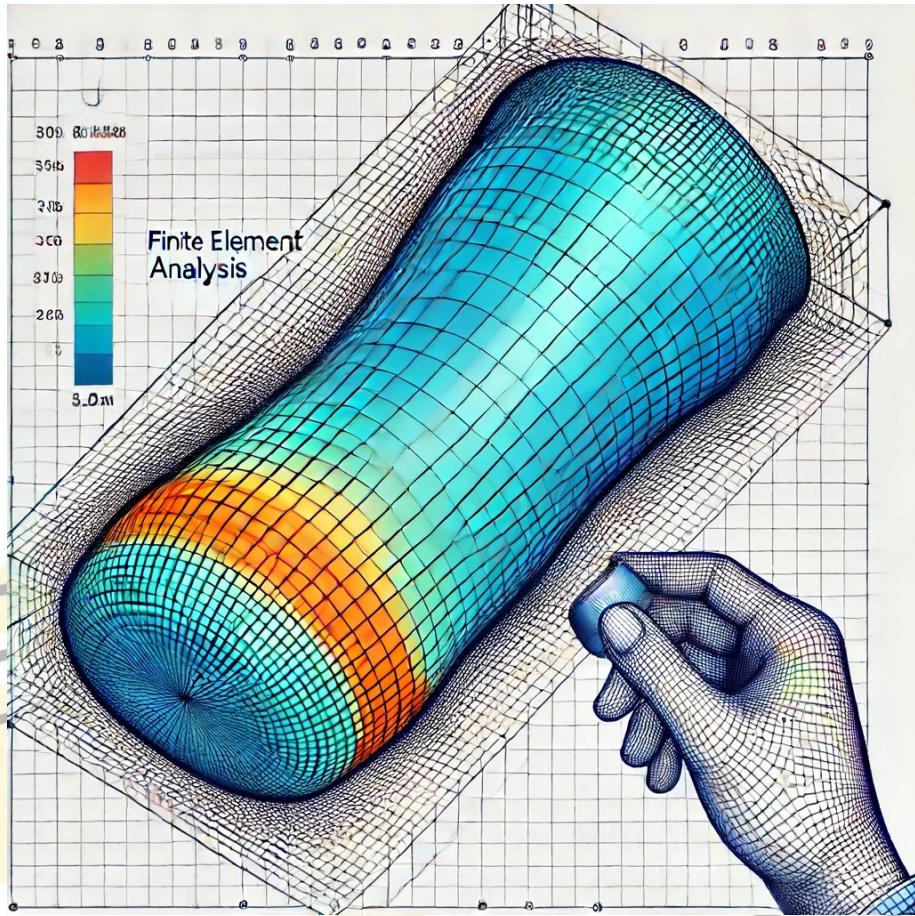
B

C

D

E

Model performance and computer power



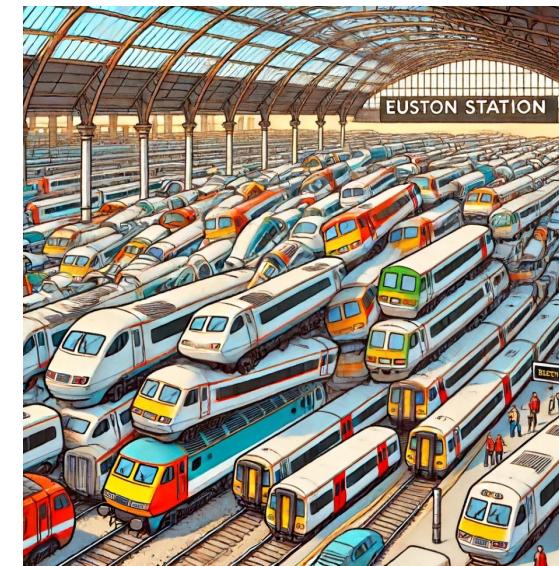
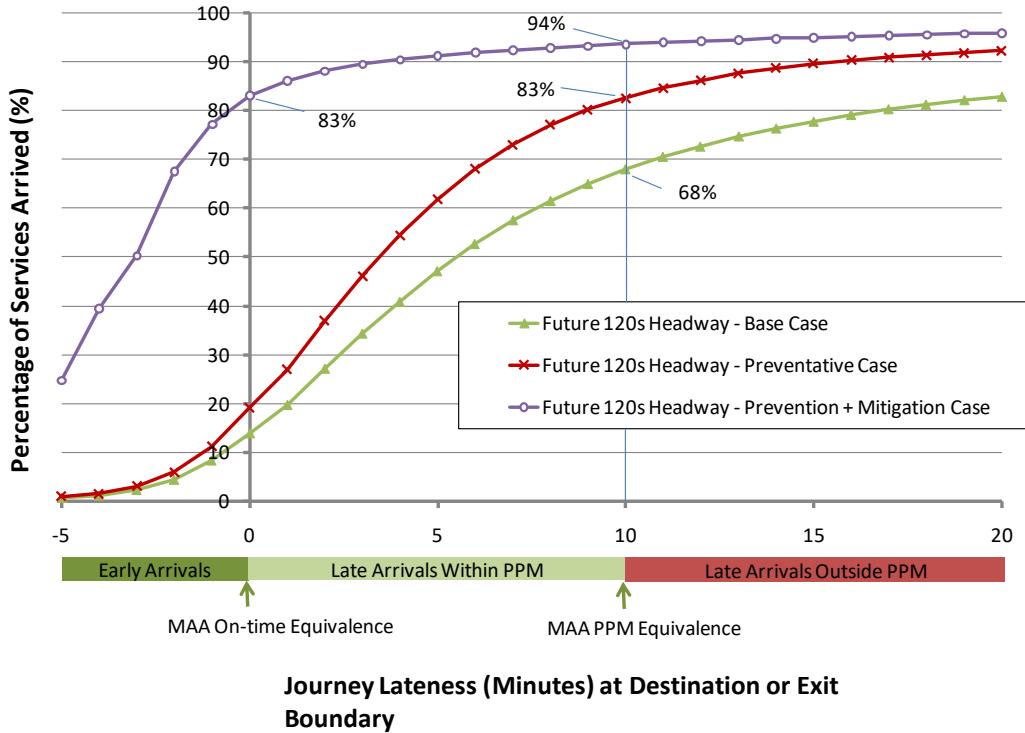
Some images generated by OpenAI's DALL-E.

Model Verification and Validation



"... Network Map, Road Map, what's the difference? They are both maps."

Assumptions and Sensitivity

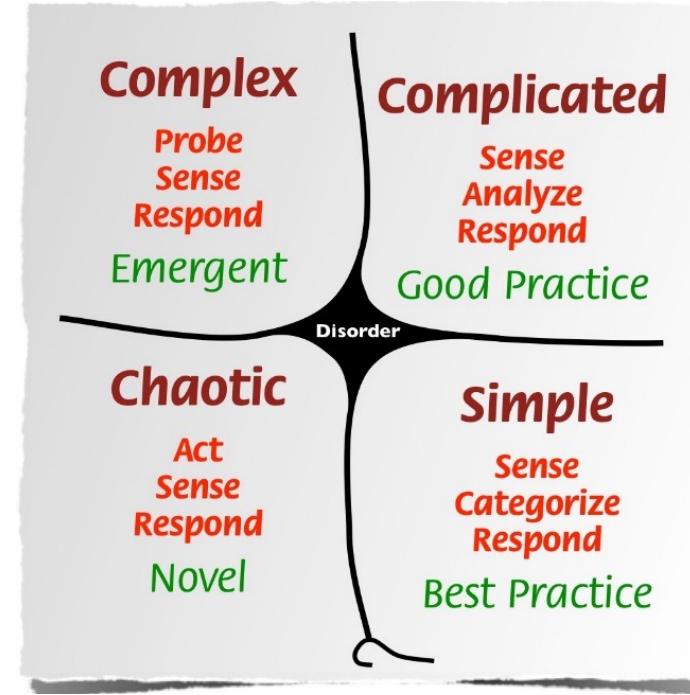


... I know electrical trains require external power, but I told you to just model train reliability"

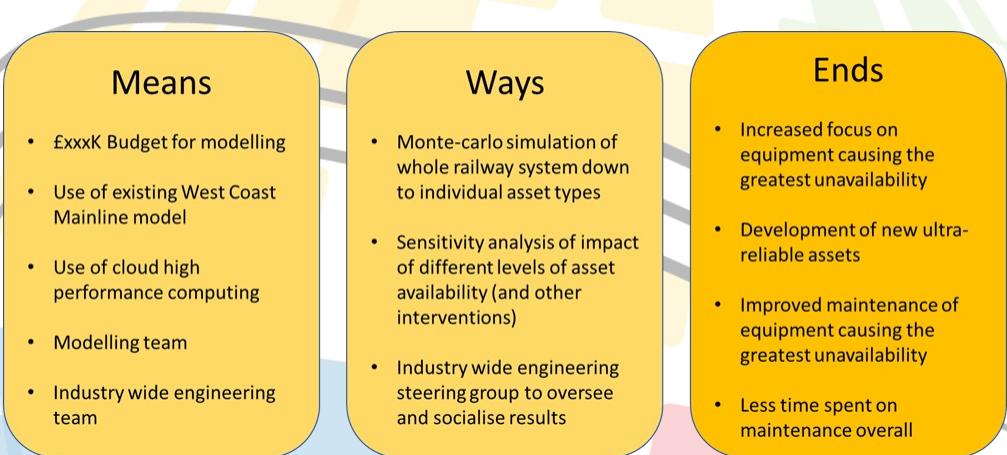
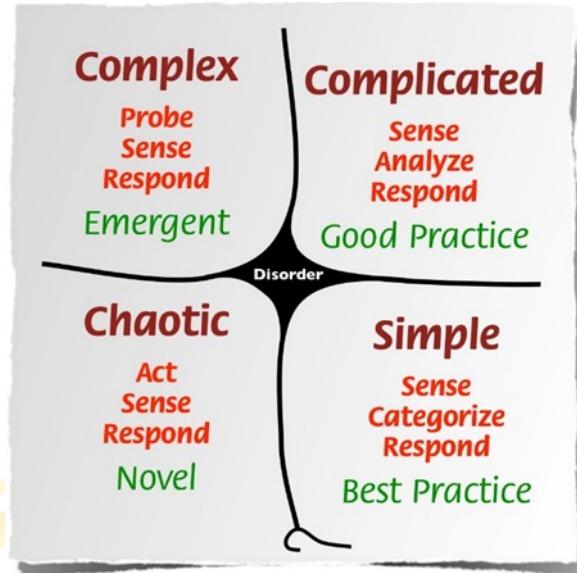
Ensuring stakeholders appropriately trust the results



"I'm sorry Janet, but the client wants to use Brad's simulation for the structural analysis. His outputs just look better."



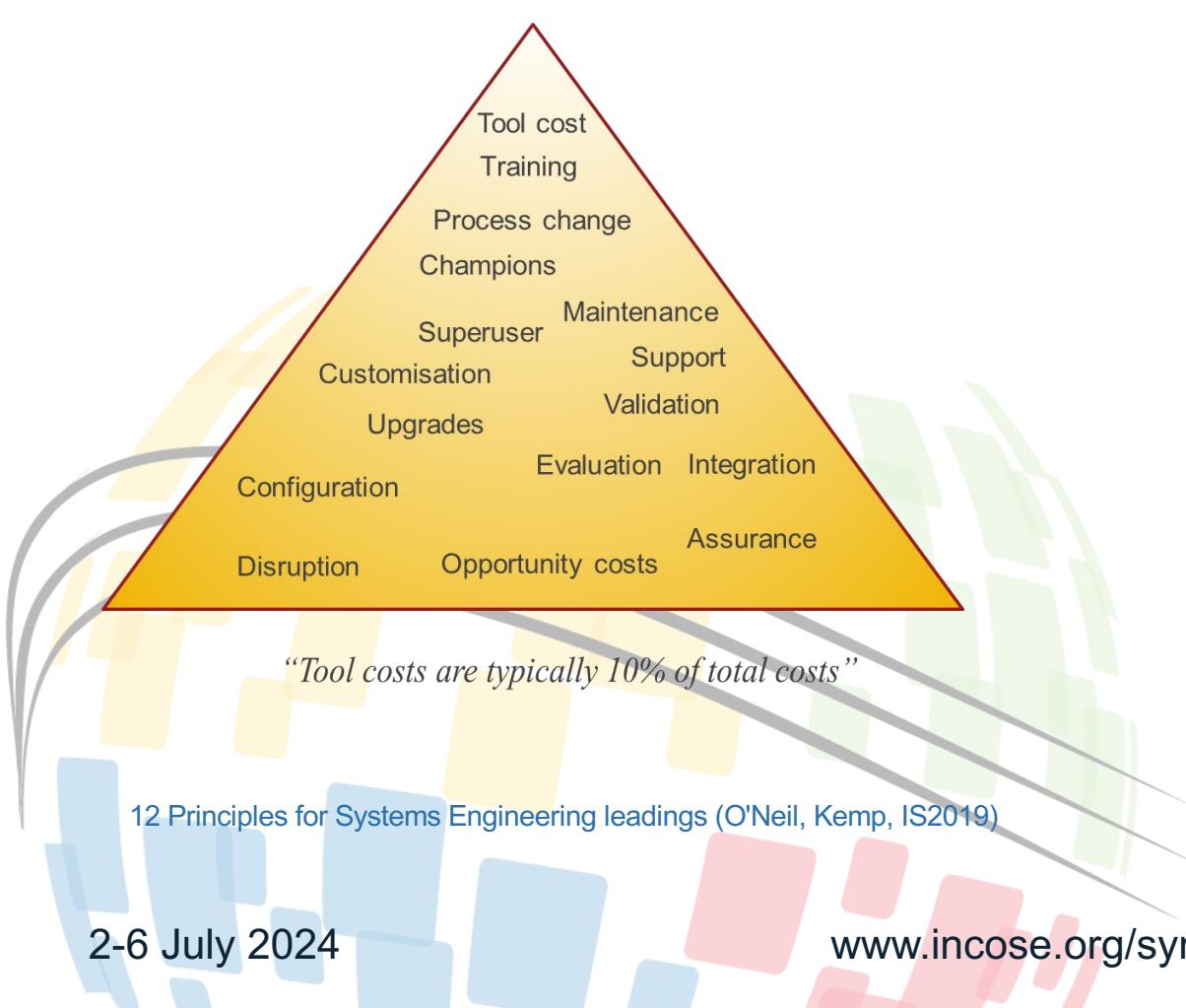
Modelling is a human process



Be wary of confusing good engineering with good modelling



Cost and Economics of modelling and the challenges of reuse



Clarity of model purpose

Don't know what	Making a movie <ul style="list-style-type: none">• Use systems thinking to identify potential purposes• Configure existing modules and develop new ones• Use standard parameters• Build model• Use model	Walk in the fog <ul style="list-style-type: none">• Use systems thinking to identify potential purposes• Try some modelling• If it helps do more• If not try a different approach
Know what	Painting by numbers <ul style="list-style-type: none">• Configure existing moules• Use standard parameters• Get new/modified data• Build model• Use model	Quest <ul style="list-style-type: none">• Understand problem• Understand available data• Select modelling approach• Get new/modified data• Build model• Use model

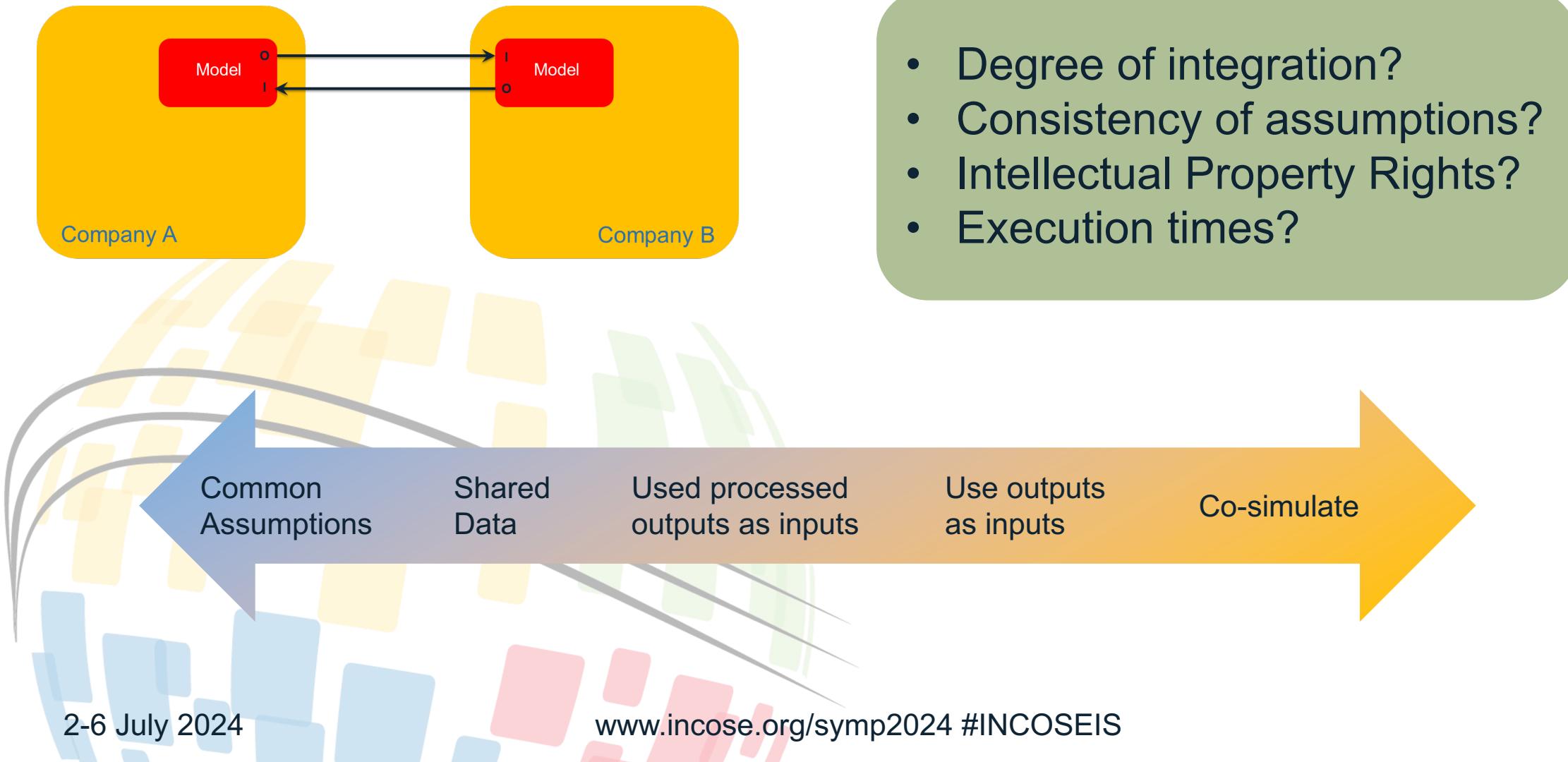
Know how

Don't know how

Clarity of modelling approach

Adapted from Obeng E (1994) The Project Leader's Secret Handbook, Financial Times Prentice Hall

Integrating models and co-simulation



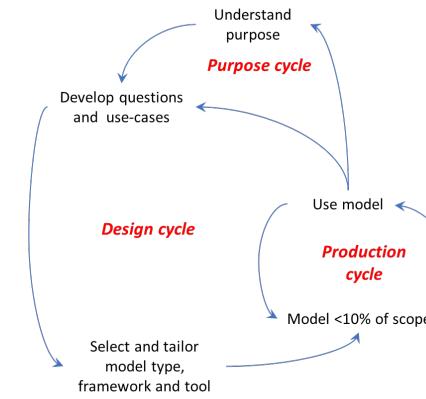
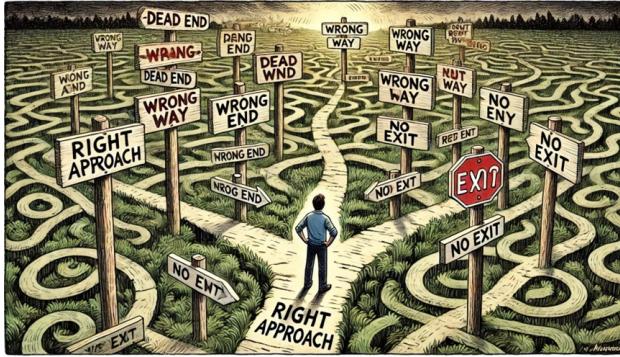
Model Governance



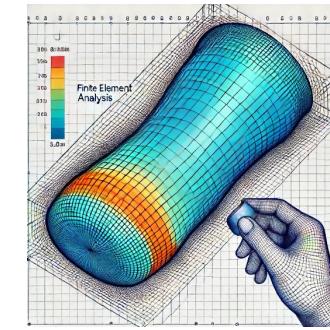
"It worked well when we last used it 10 years ago,
I'm sure that it will be OK now"

- Not all models need to be reused
- Reuse of models requires substantial consideration and effort
- Models are a business-critical asset
- Need sufficient funding, resource and (often) maintenance
- Configuration management of models, assumptions, test scripts and historical outputs
- Ensuring the tool suite is, as far as possible, evergreen where required
- Ensuring that there are enough experienced, and suitably trained modelers
- Ensuring clear and suitable accountability for the effective use and maintenance of models

Summary



Any questions?



Means

- XXXX Budget for modelling
- Use of existing West Coast Mainline model
- Use of cloud high performance computing
- Modelling team
- Industry wide engineering steering group to oversee and socialise results

Ways

- Monte-carlo simulation of whole railway system down to individual asset types
- Sensitivity analysis of impact of different levels of asset availability (and other interventions)
- Improved maintenance of equipment causing the greatest unavailability

Ends

- Increased focus on equipment causing the greatest unavailability
- Development of new ultra-reliable assets
- Improved maintenance of equipment causing the greatest unavailability
- Less time spent on maintenance overall



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