Successfully Integrating Complex Systems for Submarine Programmes

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Modern submarines…

Complex

Integrated

Increasing use of platform wide software

Systems engineering can help, but how?

So what is systems engineering?

Systems Engineering is a way of designing and managing complex systems to make sure they work well and meet their intended goals. It involves looking at the big picture and understanding how different parts of a system fit together and interact

Think of it like building a puzzle. Systems engineers help figure out what the puzzle should look like, how the pieces should fit together, and how they should function as a whole

So what is systems engineering?

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Systems Engineers consider various factors…

- Cost
- Reliability
- Safety
- User Needs
- Performance

…and many more

It's about taking a systematic approach to problem-solving and ensuring that all the pieces of a system come together smoothly to achieve the desired outcome

The complexity and scale challenge…

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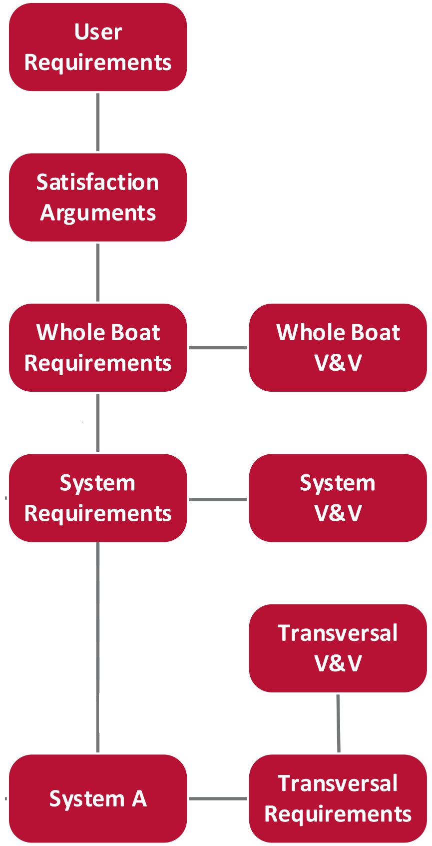
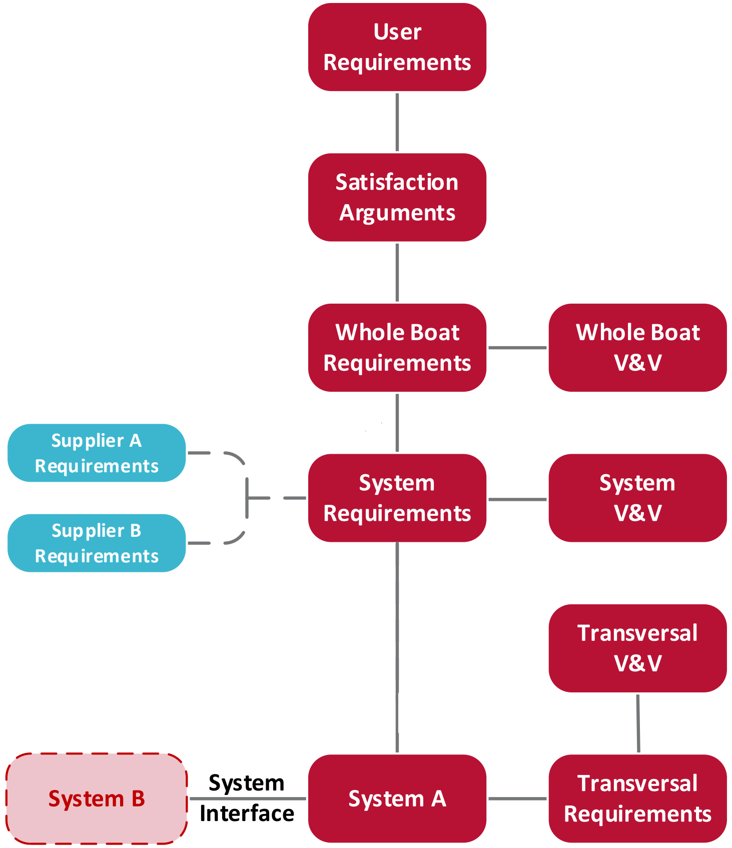
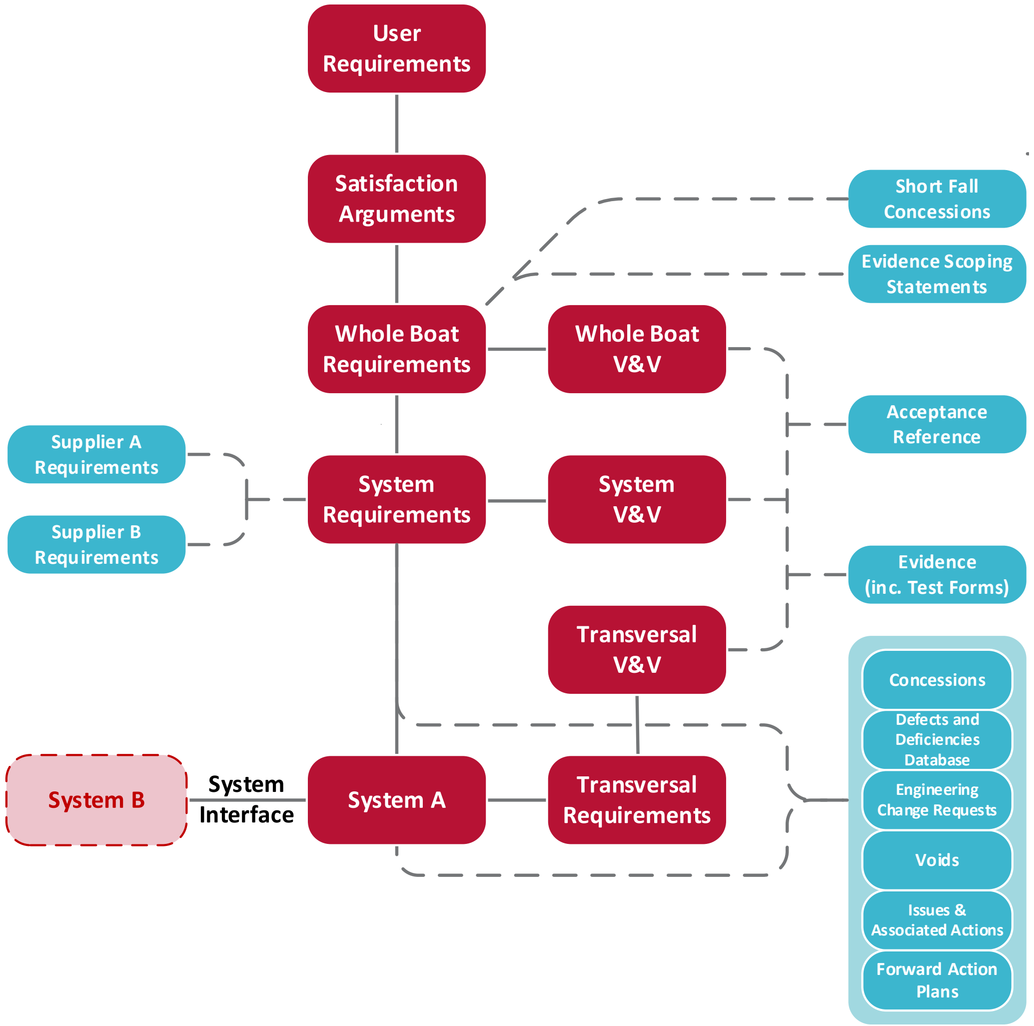
The information space



The information space



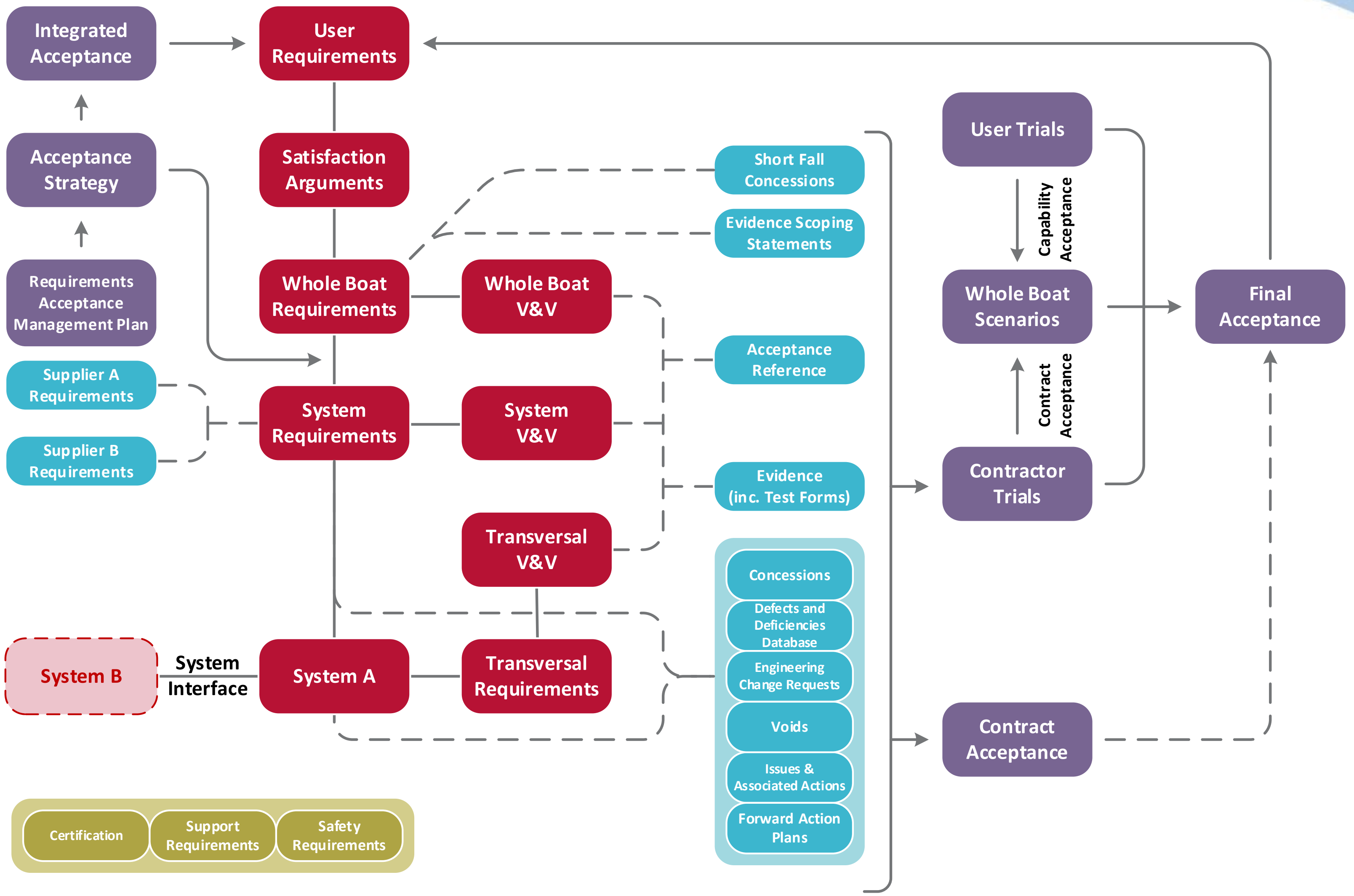
The information space



The information space

The sheer quantity of information and data is vast

And that's just part of the the equipment DLOD



The pan-DLOD issue

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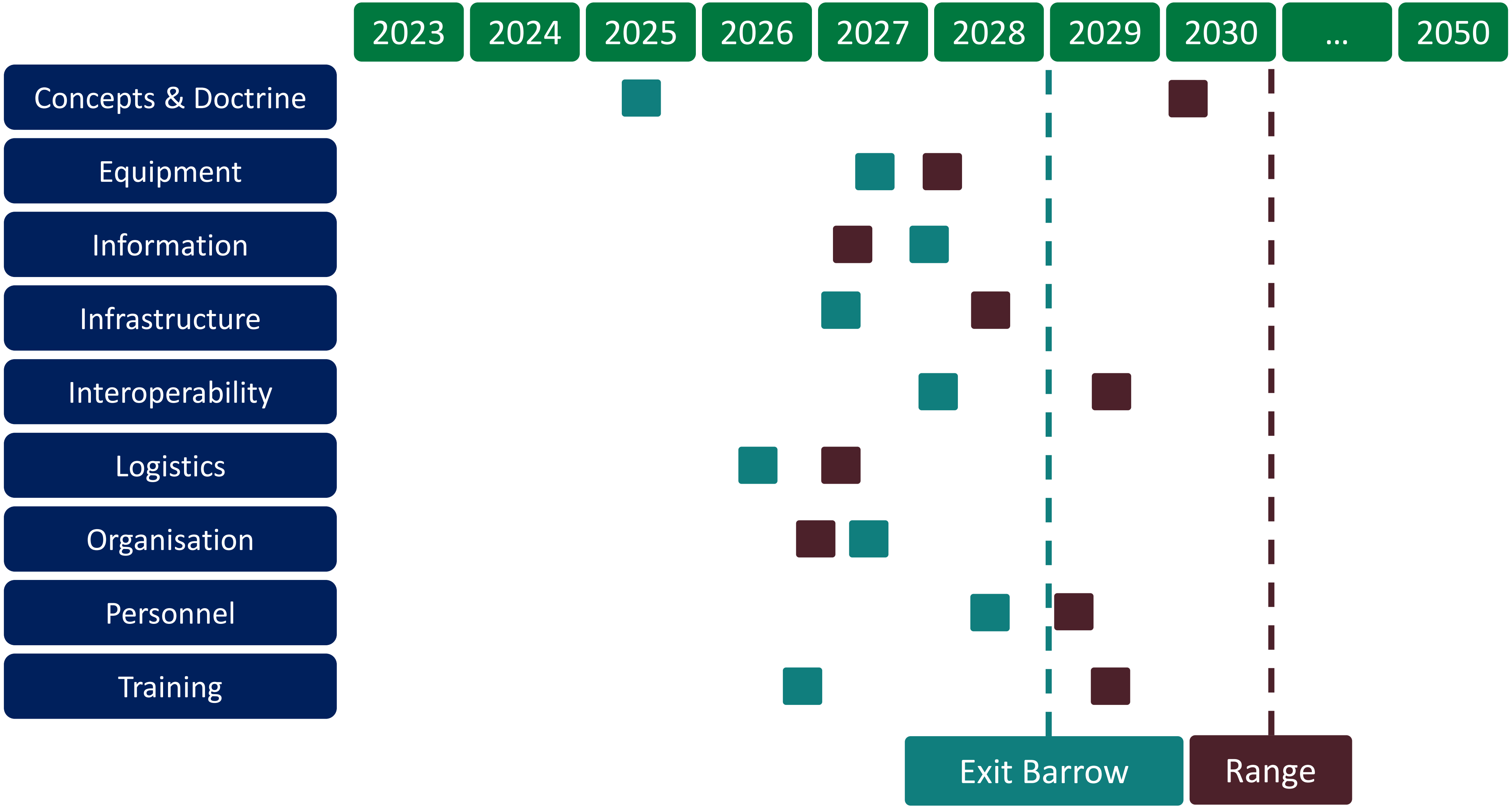
Timing is everything



What do we do about it?

Some modern methods explained

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Model Based Systems Engineering	A formalised, coherent and consistent toolset to clarify the requirements, structure, behaviour and parameters of a system
Model Based Design	Formalised method during the design lifecycle most commonly applied to control systems
Digital Twins	Digital representation of a system which accurately mimics a physical system

Model Based Systems Engineering

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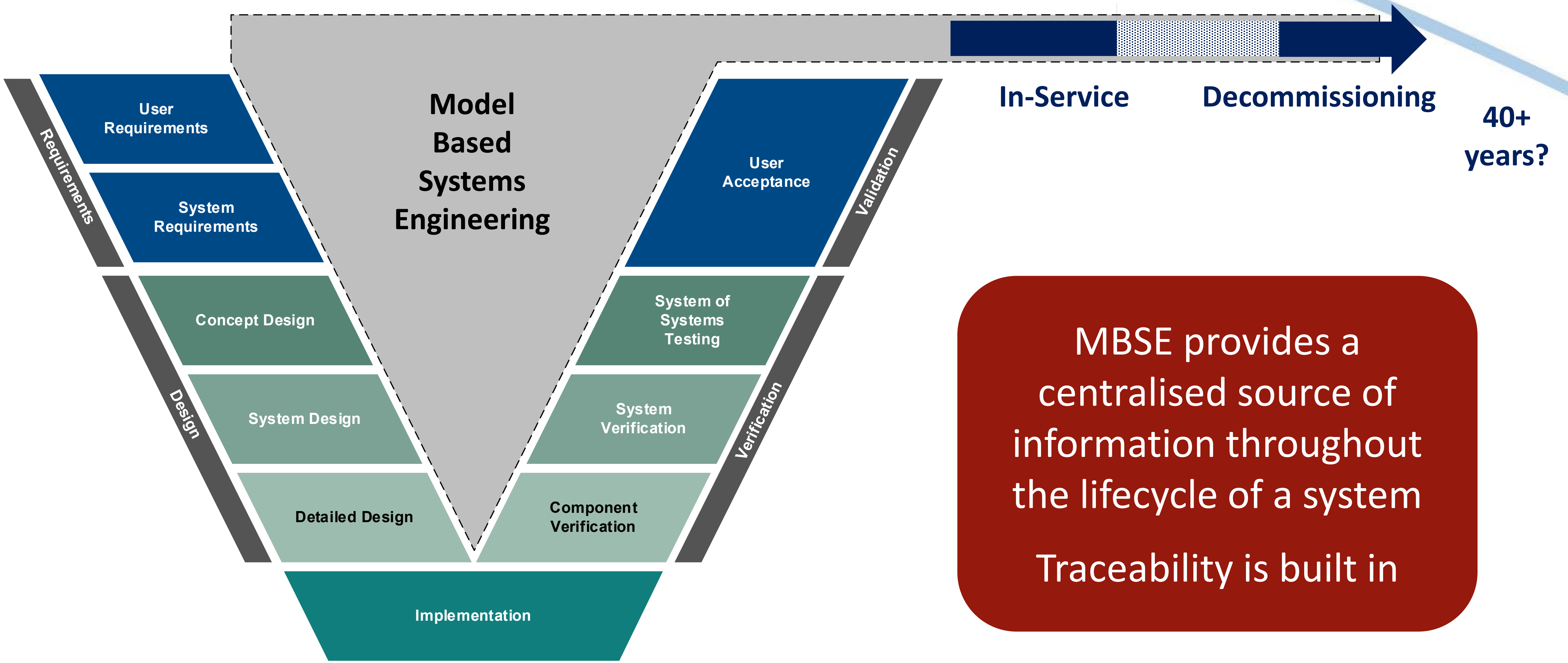
Model Based Systems Engineering



MBSE provides a centralised source of information throughout the lifecycle of a system

Traceability is built in

MBSE – Defence Example

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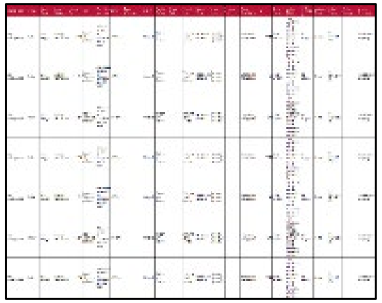
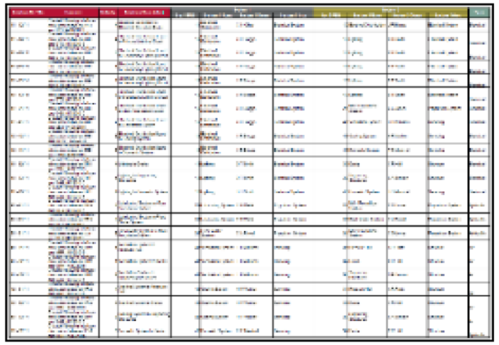
Requirements (DOORS)

Type	System Level	Title	Number	Status
Heading	Level 0	WHOLE SYSTEM	00	Current
Heading	Level 1	ELECTRICAL SYSTEM	1	Current
System	Level 2	Electrical Generation	11	Current
System	Level 2	Electrical Distribution	12	Current
System	Level 2	Lighting	13	Current
Heading	Level 1	PROPULSION SYSTEM	2	Current
System	Level 2	Main Propulsion System	21	Current
System	Level 2	Lubricating System	22	Current
System	Level 2	Feed Water System	23	Current
Heading	Level 1	STRUCTURE	3	Current
System	Level 2	Pressure Hull	31	Current
System	Level 2	Decks	32	Current
System	Level 2	Supporting Structures	33	Current
Heading	Level 1	SERVICING	4	Current
System	Level 2	Ventilation System	41	Current
System	Level 2	Cooling System	42	Current
System	Level 2	Domestic System	43	Current

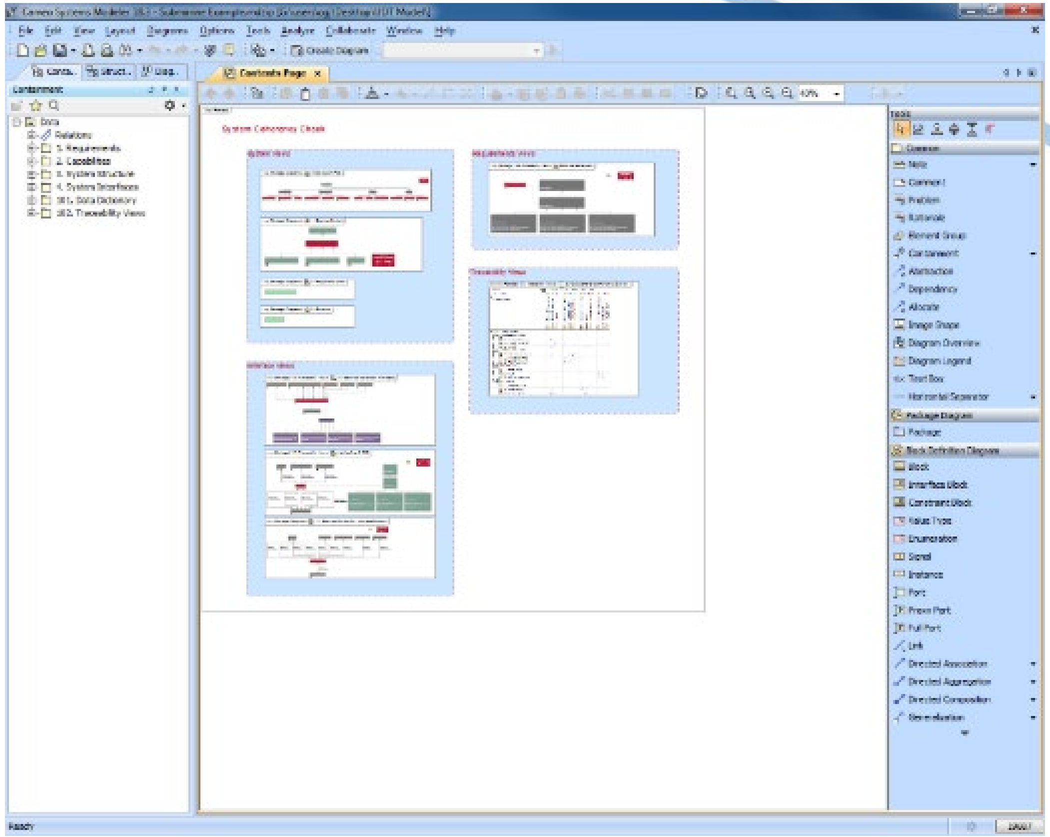
System List (Excel)



Design Issues List (Access Database)

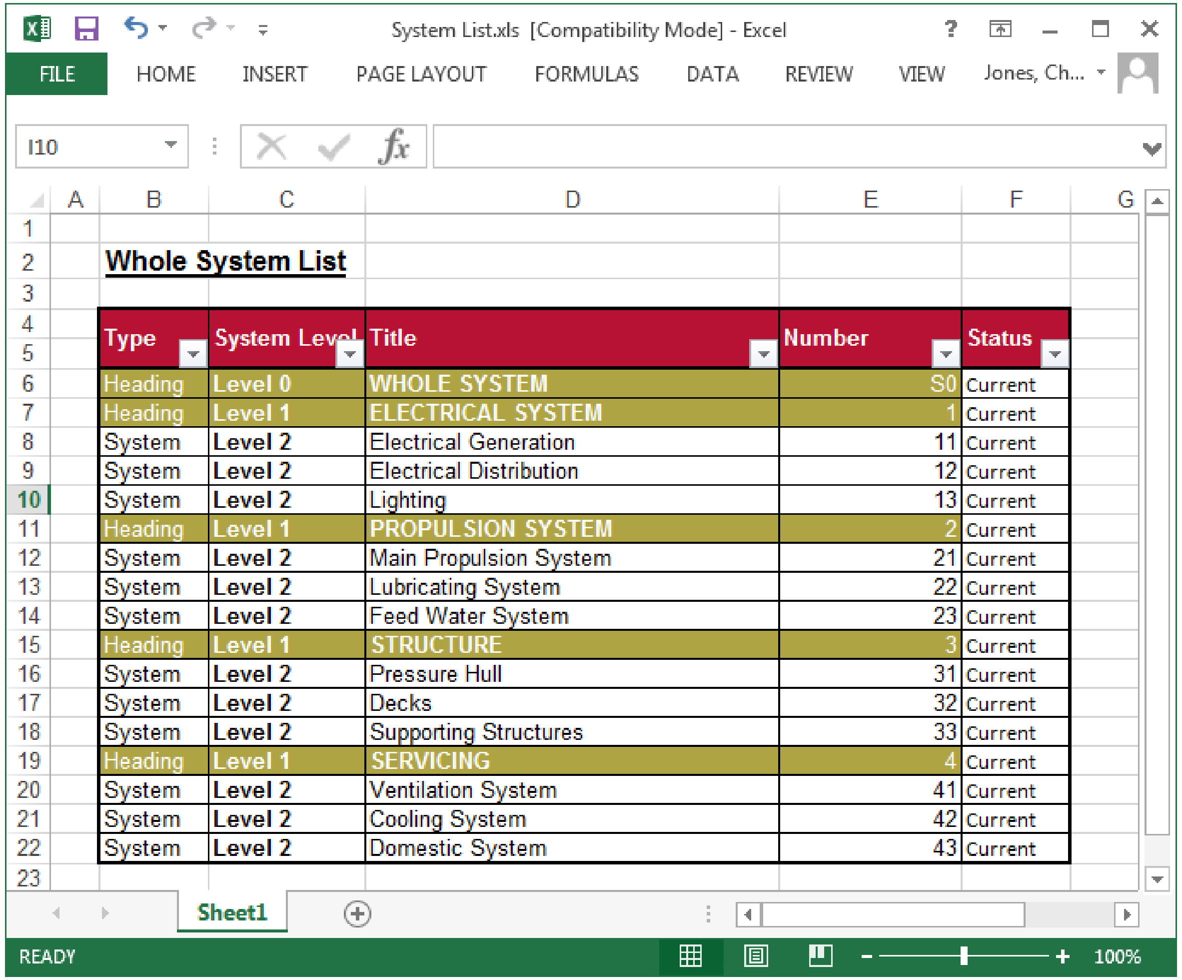


System Interface List (Excel)



The MBSE Environment

MBSE – Defence Example



System List.xls [Compatibility Mode] - Excel

Whole System List

Type	System Level	Title	Number	Status
Heading	Level 0	WHOLE SYSTEM	S0	Current
Heading	Level 1	ELECTRICAL SYSTEM	1	Current
System	Level 2	Electrical Generation	11	Current
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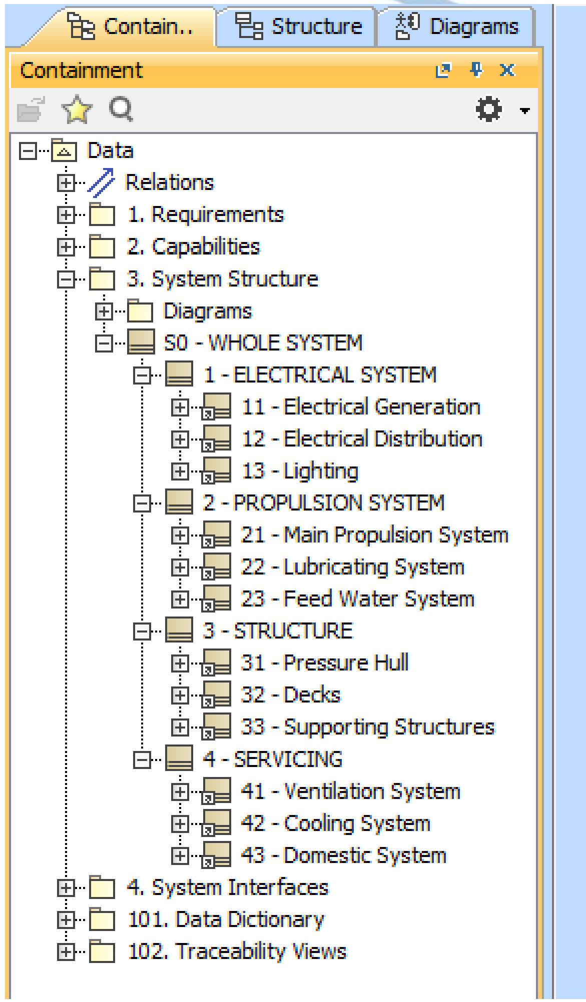
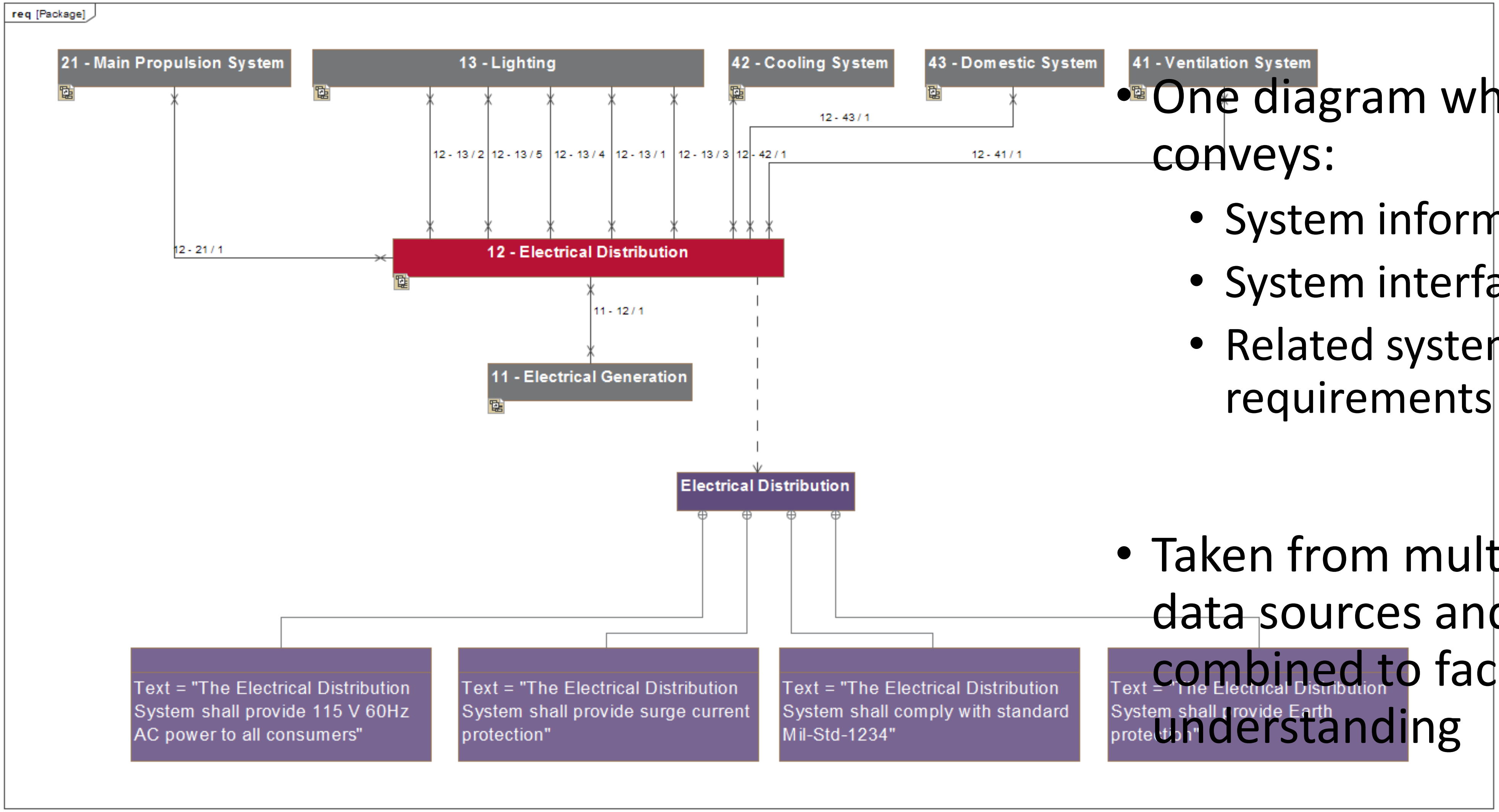


MBSE – Defence Example



- One diagram which conveys:
  - System information
  - System interfaces
  - Related system requirements
- Taken from multiple data sources and combined to facilitate understanding

MBSE – Defence Example

- The benefits:
  - Better understanding of the totality of information
  - Understand design maturity
  - Self-generate analysis documentation
  - Understand where key system integration risks may lie and the potential severity
  - Increase awareness of likely issues and actions which could impact build and testing schedules

Model Based Design

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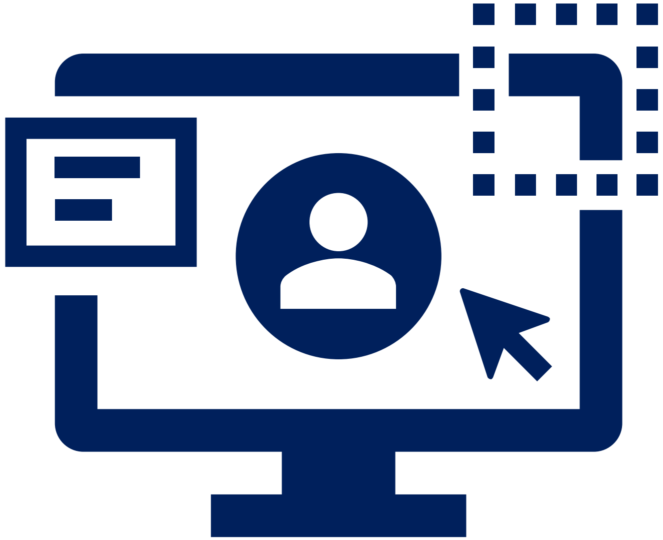
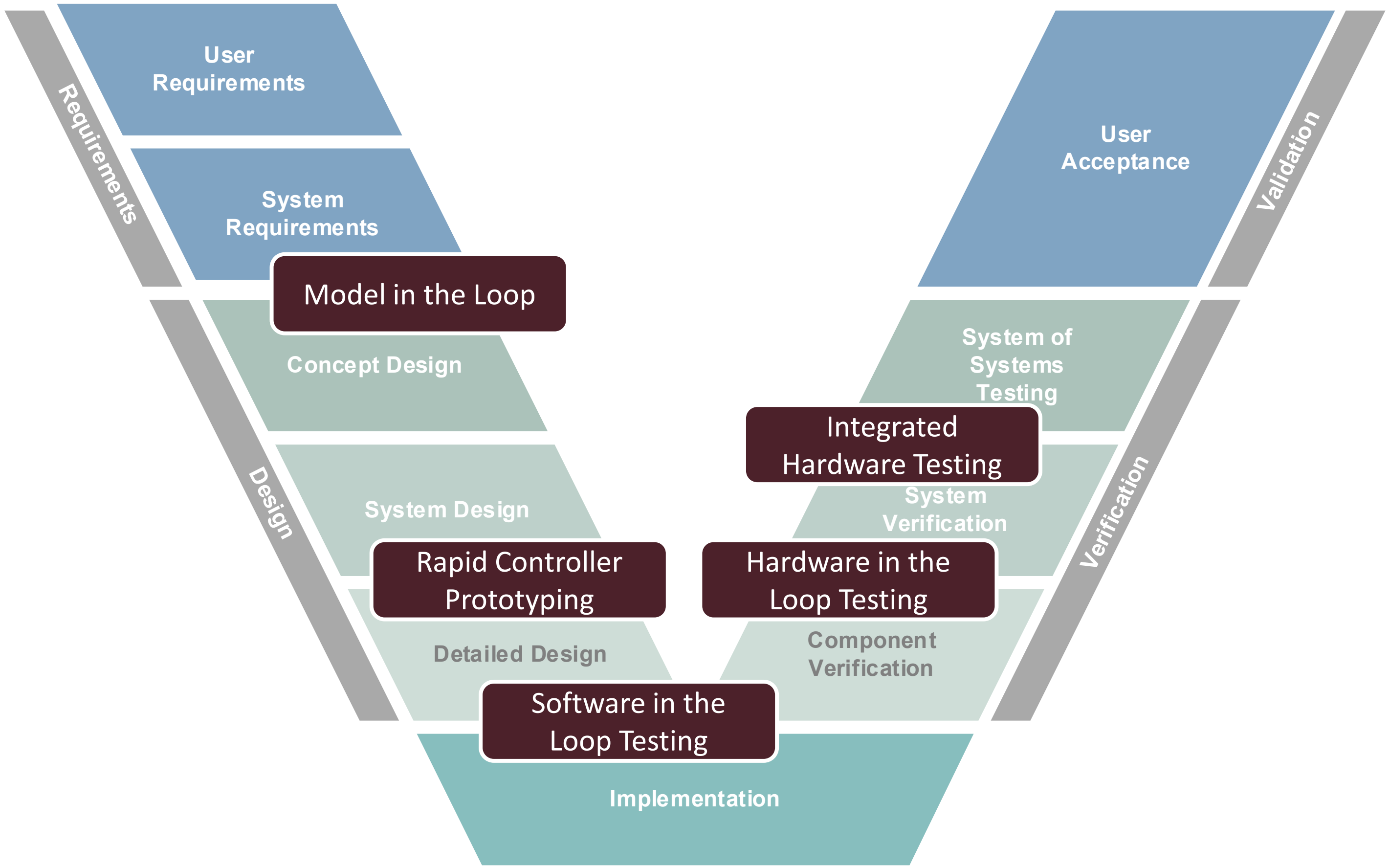
Model Based Design

- Overall aim is risk and cost reduction for:
  - Requirements
  - Functions
  - Architecture
  - Performance
  - Integration
  - Simulation



Develop models early and use often for successful development of complex systems as rectification of errors in the requirements is increasingly costly throughout the system life cycle

Model Based Design

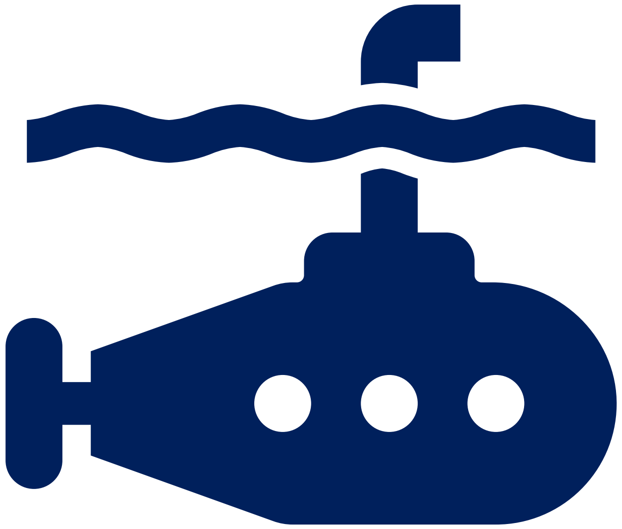


Develop models early and use often

Fixing errors in the requirements is increasingly costly

MBD – Modelling a Generic Submarine

- Example development path:
  - Plant model
    - Hydrostatic
    - Hydrodynamic
  - Controller development
    - Manual and automatic controls
    - Beginnings of fault insertion
  - Model validation & limitations



Digital Twins

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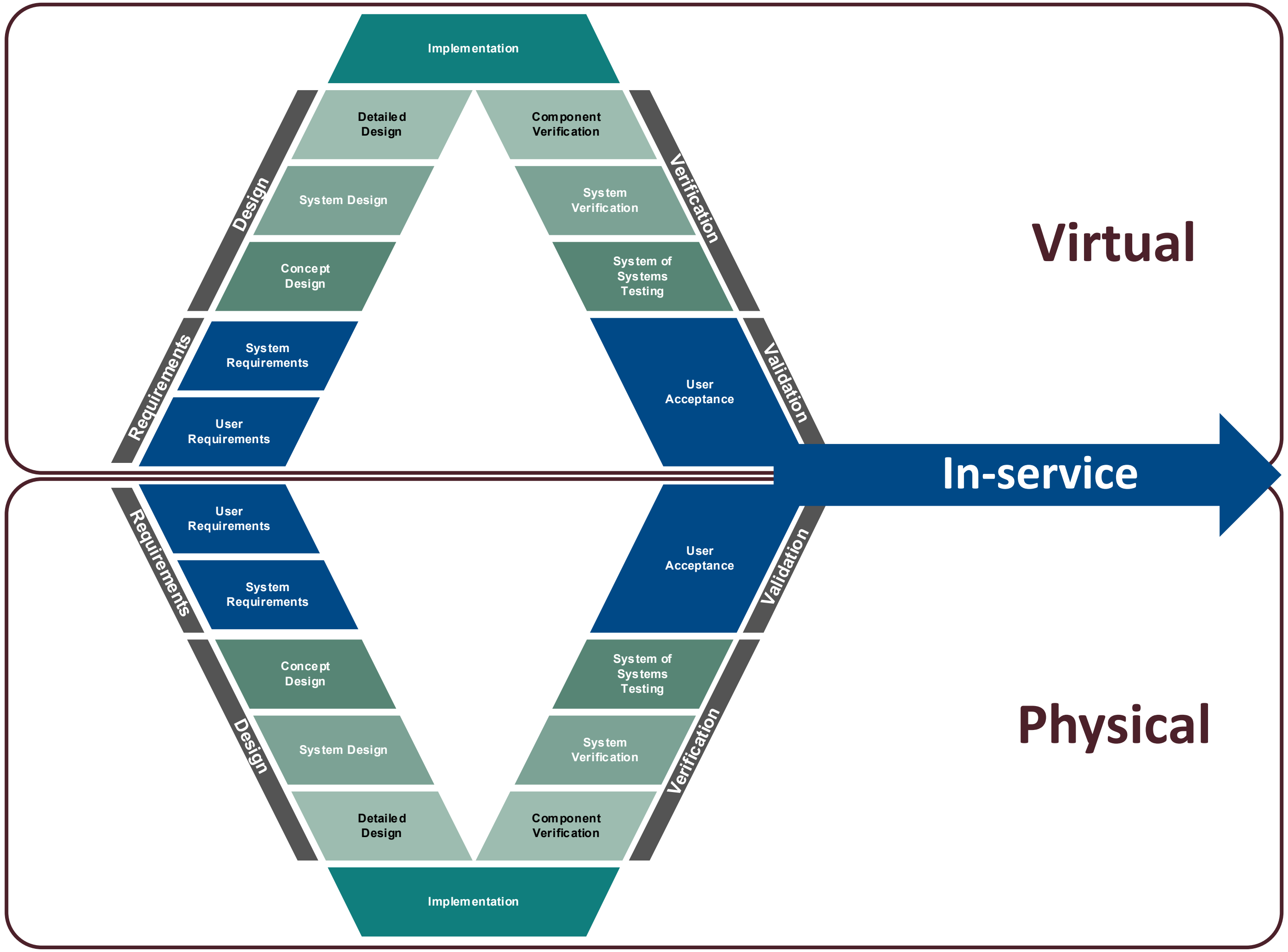
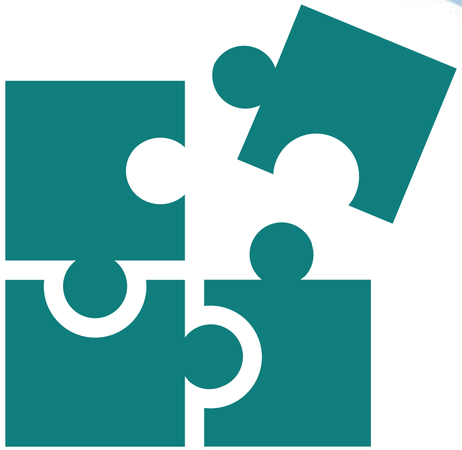
Digital Twins



Co-development of a system (or system of systems) throughout the development lifecycle

Summary

We can solve our puzzle but we need to have confidence from the outset in the Systems Engineering processes being adopted



The virtual world is an asset from the outset, not just once a design is established

Virtual + Reality (*not Virtual Reality*) is a key enabler to delivering success

Thank you

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