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A truly testing experience – how Model Based Systems Engineering can help to ensure that you build the right product and build the product right

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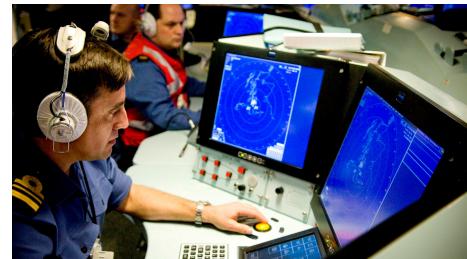
Overview



- The challenges of Verification and Validation (V&V) of complex Naval Platforms and the Joint Force within which they operate
 - Building and Delivering a Complex Naval Platform (System of Interest)
 - The Joint Force as a System of Systems
- Using MBSE to “left shift” the challenges
 - Understanding the User and System requirements and how to progressively build platform assurance
 - Using the Systems Engineering Approach and Methodologies (SEAM) to support the Integrated Test, Evaluation and Acceptance (ITEA) process
 - Assessing and managing interoperability using the System Process for Interoperability Requirements and Implementation Testing (SPIRIT)

Building and Delivering a Complex Naval Platform

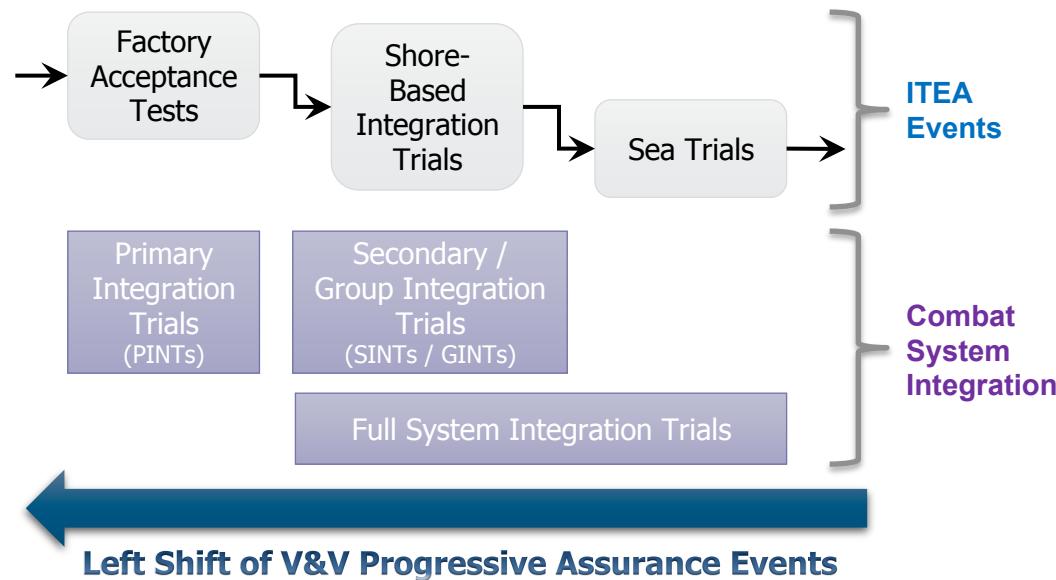
- BAE Systems Naval Ships design, manufacture and deliver warships to navies around the world.
- The Combat Systems group within Naval Ships (NS CS) are engaged in the role of Lead Systems Integrator (LSI) for the combat/mission systems on a variety of platforms including Royal Navy ships such as the Queen Elizabeth Class (QEC) Aircraft Carriers, Type 45 Destroyers and the Type 26 Global Combat Ship.



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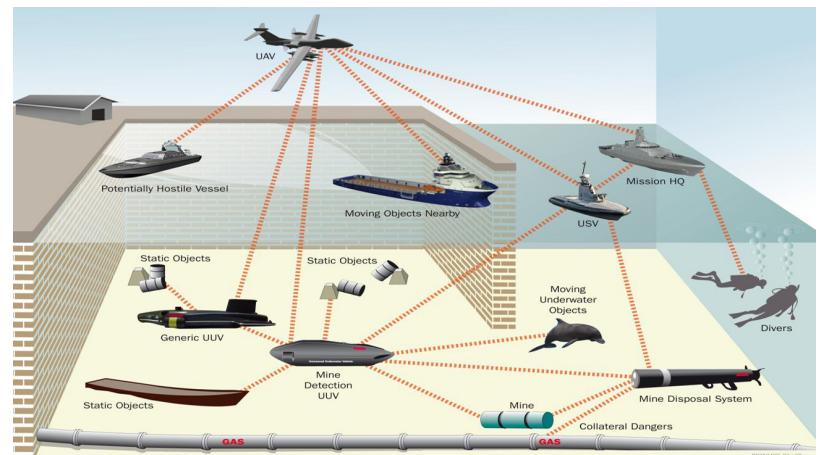
Challenges of V&V: Progressive Assurance

- Waiting until a complex Naval platform is built to verify whether it performs as expected is:
 - **A big gamble**
 - **Prohibitively Expensive**
- We therefore need to develop a programme of progressive assurance, **testing little and often** from as early in the system lifecycle as is practicable.



The Joint Force as a System of Systems (SoS)

- Each Platform System of Interest (SoI) is modelled separately (if at all) and V&V activities focus solely on the Platform itself
- Information exchanges between a variety of Platforms across environments vastly increases complexity by forming a (non-designed) SoS
- Maier (1998) states the following characteristics are useful to determine if an SoI is an SoS:
 - Operational independence of constituent systems
 - Managerial independence of constituent systems
 - Geographical distribution
 - Emergent behaviour
 - Evolutionary development processes
- A Joint Force exhibits all of these characteristics



Modelling of the Force SoS and Interoperability (IO)

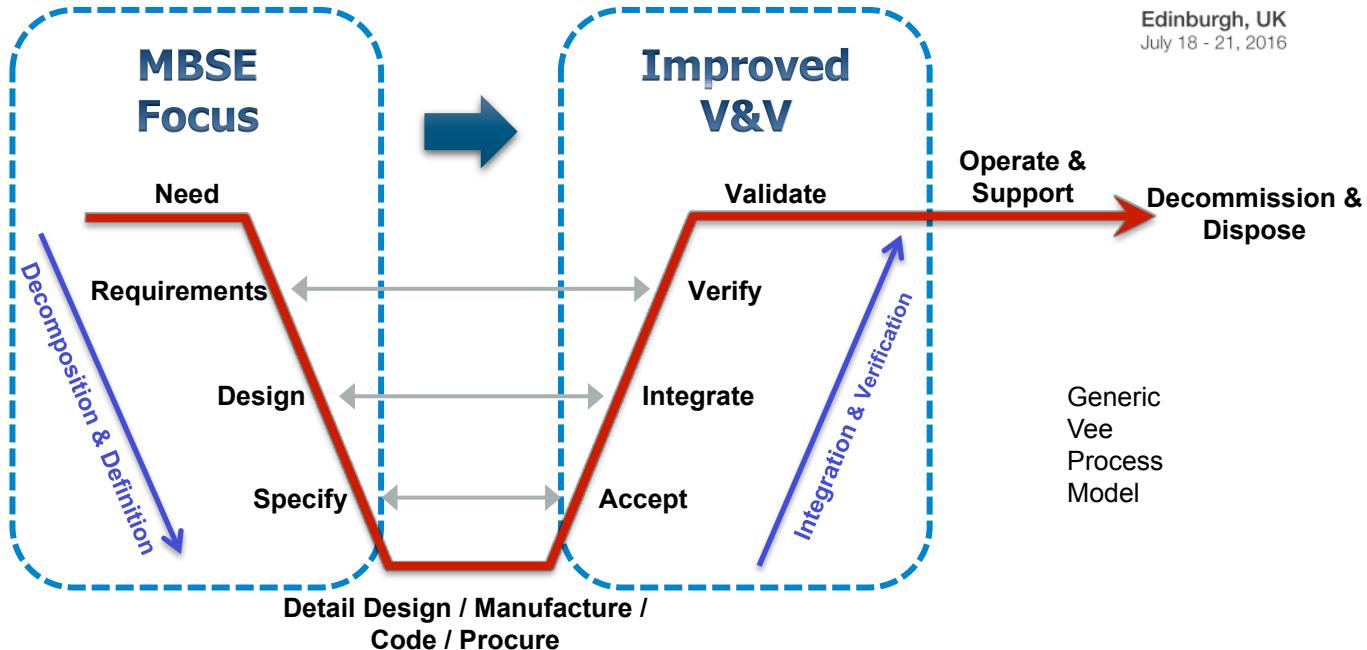


- Methods used to address the V&V of an individual Platform, will not necessarily work at the Force level
- No one attempts to model the SoS or address SoS level V&V (beyond IO testing)
- Since modelling has been proven to work at the Platform level, could it be applied and made to work at the Force level?
- SyntheSys' approach to assessing and managing the IO of Platforms within a System of Systems is the System Process for Interoperability Requirements and Implementation Testing (SPIRIT).



Left Shifting the V&V Challenge

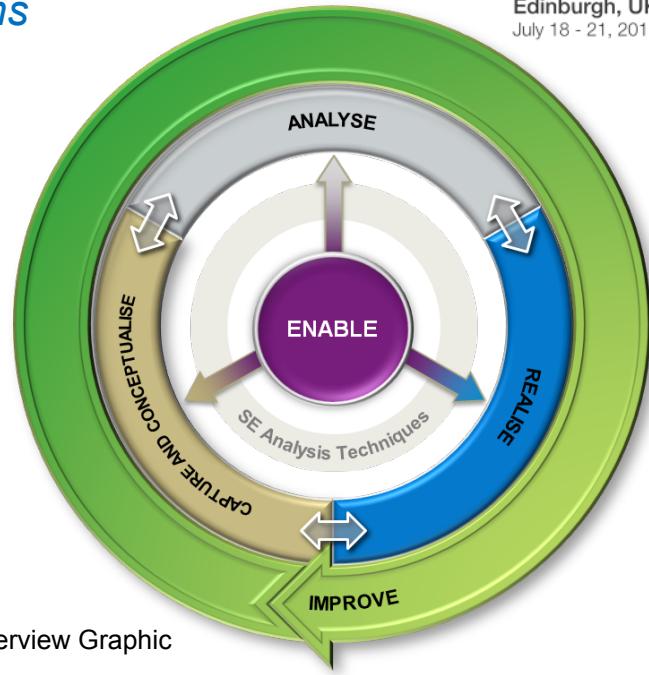
- By adopting an MBSE approach early in the system lifecycle that focusses on progressive assurance we are able to improve our V&V outcomes during latter lifecycle stages.



MBSE Approach in BAE Systems Naval Ships (Combat Systems)

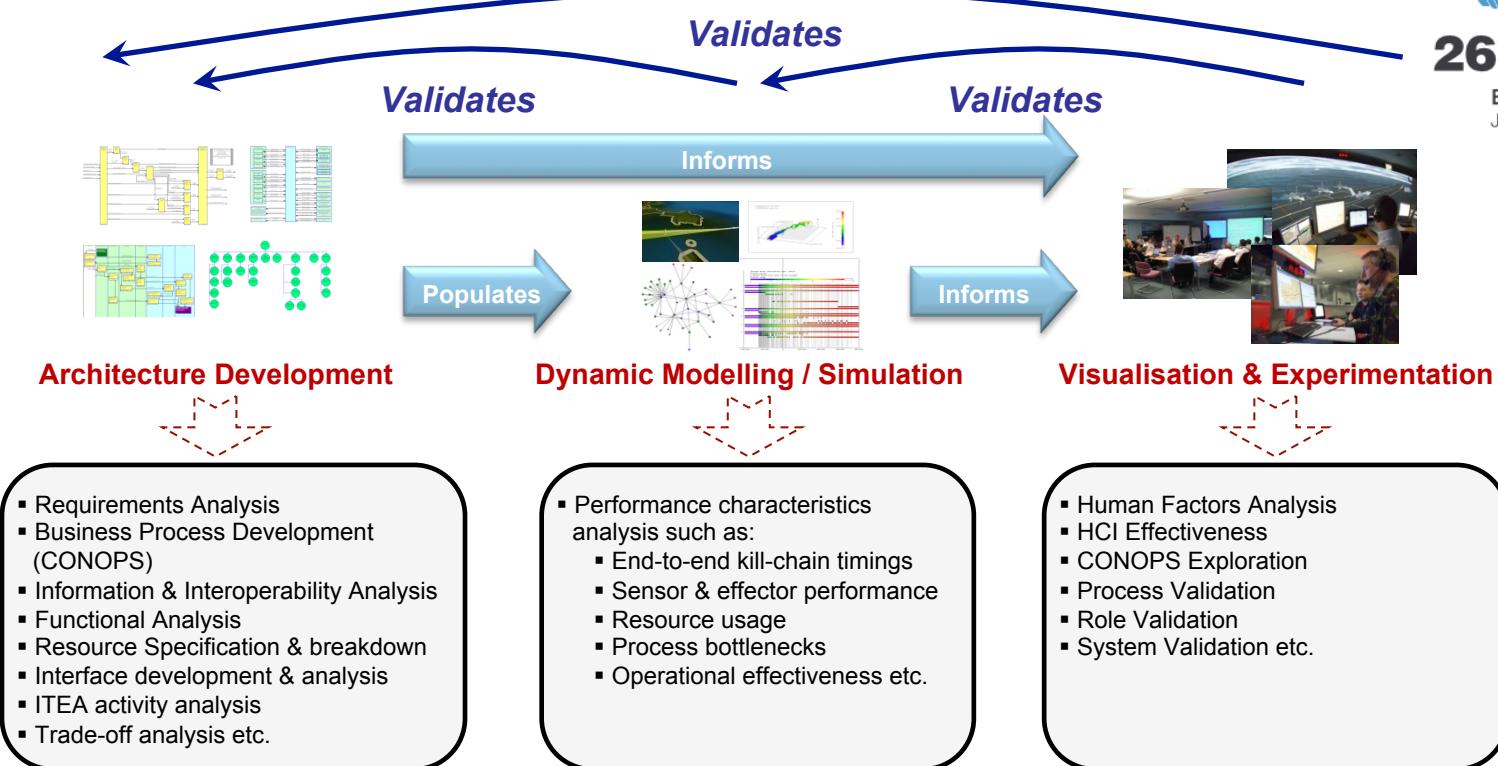


- In NS CS our MBSE approach is underpinned by an architecture framework and is referred to as our *Systems Engineering Approach and Methodologies* (SEAM).
- SEAM consists of:
 - *Five Approach Steps*
 - Enable
 - Capture & Conceptualise
 - Analyse
 - Realise
 - Improve
 - *Three SE Analysis Techniques*
 - Architecting
 - Dynamic Modelling & Simulation
 - Visualisation & Experimentation



SEAM Overview Graphic

Iteratively Building Progressive Assurance Evidence using Interacting SE Analysis Techniques



Requirements Driven V&V

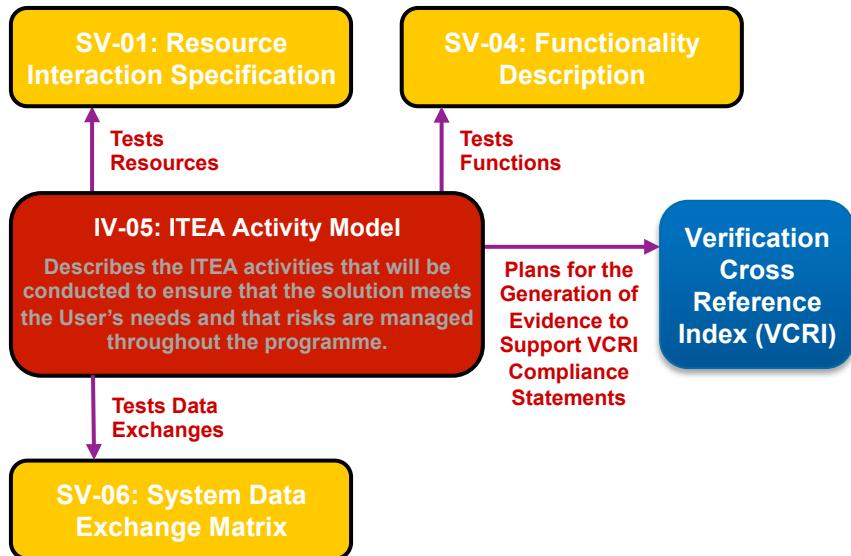
- It is widely understood that when developing requirements it is vital to ensure that they are testable.
- As we develop our understanding of our requirements on the left-hand side of the Vee model we also consider how we are going to conduct V&V on the right-hand side.
- As a LSI if we are unable to demonstrate to our customer that we have met their requirements we will not be able to get the system accepted.
- As a LSI we are often reliant on our sub-system developers / sub-contractors to provide V&V evidence in support of overall system V&V and so we must be able to clearly identify, partition and articulate requirements responsibilities upfront.

The Ministry of Defence ITEA Process

- The MOD define Integrated Test, Evaluation and Acceptance (ITEA) as *“the MOD process for ensuring that a supplied solution meets the User’s needs. ITEA is also the method of identifying and managing technical and operational risks – and hence time and cost – throughout the programme.”* [MOD Acquisition System Guidance]
- The NS CS ITEA approach mirrors the MoD’s ITEA process and includes:
 - Planning the approach to Test and Evaluation, in preparation for Acceptance.
 - Verification of the system requirements at all levels.
 - Assurance of the quality of the manufactured system prior to acceptance through integration testing.
 - Progressive and formal acceptance that the capability has been achieved.
 - Planning and managing the above activities within an ITEA Management Plan.
 - Executing the ITEA process, specifically identifying, planning, resourcing, scheduling, costing, conducting and reporting on the ITEA activities.

Extending MODAF with an ITEA View Model

- In analysing the requirements and maturing our System Design it is important that we are able to clearly identify how V&V evidence is going to be generated to prove compliance.
- In the SEAM we have done this by extending our MODAF-based architectures to include an ITEA View (IV) model.
- The IV model identifies the assurance and acceptance (contractually significant) activities that need to be completed.
- The IV model allows our Integration and Test teams to schedule ITEA events in a coherent, structured way that can then be automatically extracted into an ITEA Plan.



Using the ITEA View Model

- As the schedule of ITEA activities advances it may be that there are delays or issues that result in events needing to be rescheduled or altered.
- Feeding these issues back into the IV model enables re-scheduling that is automatically linked to the rest of the System Design enabling impacts assessments on:
 - Requirements Compliance
 - Delivery Schedule
- Being able to assess these impacts quickly (and visually) allows us to be more responsive to issues arising during V&V and provides us with quantitative progress information that supports better decision making.

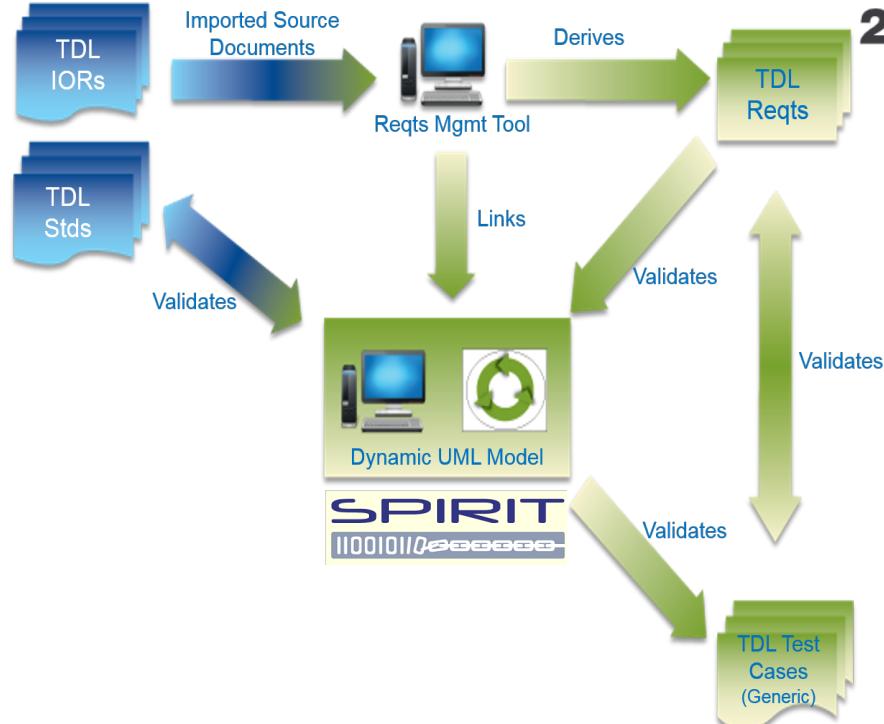
Considering Force V&V beyond the Platform SOI



- Because the Force SoS is not 'designed', the normal definition of V&V can not apply. Against what exactly can you V&V?
- So how can we 'left-shift' testing to demonstrate that a Force will interoperate correctly (or, to be realistic, optimally)?
- The obvious answer is to actually model the Force SoS
 - This is impractical/impossible to do for all possible Platforms and the entire Platform implementation
 - It may be practical/possible if restricted to a national level (e.g. UK Platforms) and to information exchanges over Tactical Data Links (TDL)
 - SPIRIT offers a step towards modelling the Force by modelling the TDL interfaces between Platforms and the standards that govern them

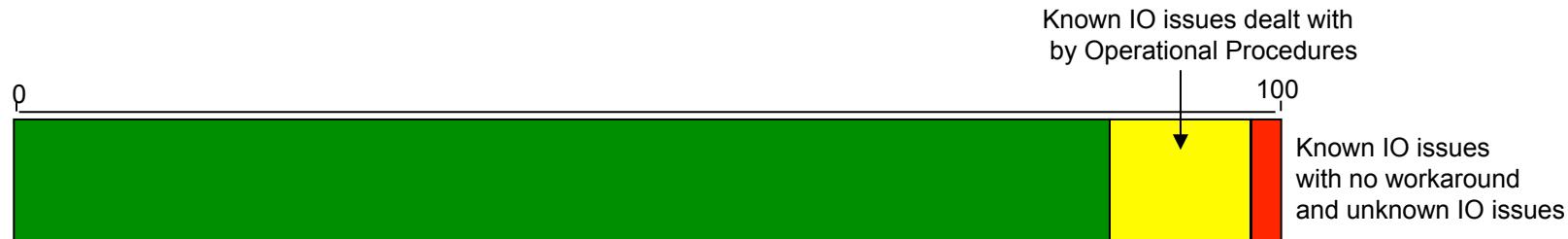
Left Shifting IO testing via Modelling (SPIRIT)

- Full transactional modelling of interface standards for 'what-if' analysis and visualisation of process flow within the standards
- SPIRIT process and toolset supports multiple standards and multiple platform implementations
- SPIRIT process and toolset supports Model Based Testing and the automatic generation of IO tests downstream
- Toolset built on IBM Rational COTS software



IO Benefits of applying MBSE to SoS

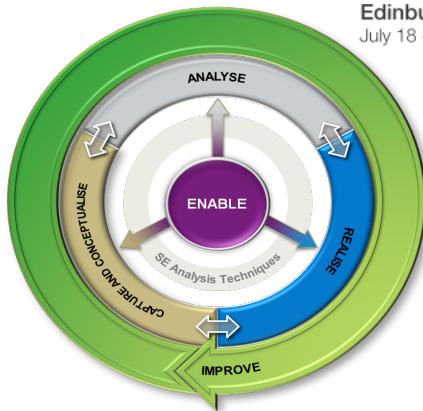
- Within a model, consistency checking is used to identify interface 'errors'. For a Force SoS, it could be used to identify potential IO issues between Platforms within the SoS
- There is often no 'right answer' - changing an interface at one Platform to enable better IO with another may simply create IO problems between that Platform and one or many others
- The aim thus is to achieve optimal IO rather than 100% IO



Conclusions



- MBSE can greatly assist with building and delivering highly complex systems
- By adopting an MBSE approach early in the Platform system lifecycle that focusses on progressive assurance we can improve the V&V outcomes during latter lifecycle stages
- Applying a MBSE-like approach to the Force SoS by early modelling of the TDL interfaces between Platforms and the standards that govern them can reduce the risk of interoperability issues for Platforms on entry into service
- Extending MBSE into the Force domain by actually modelling the Force and providing a means whereby each Platform model could be integrated into the overarching Force model would offer significant benefits if it could be achieved



SPIRIT

Questions



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