Integrated Nuclear Digital Environment

February 2019
Contents

• Introduction
• Vision
• Achievements in phase 1
• Demos from phase 1
• Outlook
• Conclusion
Introduction

- In 2016: Wood won funding from BEIS for phase 1 of Digital Reactor Design project

- Partnership of 9 organisations (Wood as lead) was formed and finalised work in 2019

- As part of the project a vision for a UK Integrated Nuclear Digital Environment (INDE) was developed

- A proof-of-concept software framework and user portal was developed and operated
The Vision
Context

Purpose

Provide digital tools on an integrated collaborative platform

Deliver cultural change across the industry through enhanced collaboration

Help nuclear industry exploit benefits of Industry 4.0

Reduce costs throughout the nuclear lifecycle

Design Standardisation:
Make UK the hub of the world’s nuclear energy markets generating revenue & sustain 30k jobs in the nuclear sector
Vision

Nuclear engineering of the future, across the whole nuclear lifecycle:
- Integrated simulation
- Trusted in-silico simulation
- Faster / (lower cost) increased value
- Easily auditable decisions
- Appropriate application of VR and AR
- Integrated smart systems
- Real-time monitoring and diagnosis

End-to-end integration for the design licensing of future nuclear plant
Vision – Integrated Nuclear Digital Environment

GAINS IN THE REAL WORLD

IN-SILICO DESIGN OPTIMISATION & DOWNSELECT FASTER, BETTER TARGETED EXPERIMENTS

20% REDUCTION IN CONSTRUCTION COSTS £10’s m SERVICE LIFE EXTENSION, DESIGN CREDIBILITY

30% REDUCTION DECOMMISSIONING COSTS

QUANTIFY RISKS ASSOCIATED WITH LIABILITIES

ASSURED OUTCOME

INCREASE VALUE
REDUCED TIME
GREATER CERTAINTY OF DELIVERY ON TIME AND ON COST
COLLABORATION TOWARD COMMON GOAL

Vision - Joining the Dots

Integrated Reactor Simulation
- Nucleonics
- Thermal Hydraulics
- Structural

Data Centric Engineering
- Mechanical
- Civil
- Instrumentation & Control

Digital Twin
- BIM Level 3 compliant
- 4D Construction planning
- E-working

Digital Special Interest Group
Roadmap – Now to 2030

Development Versions

Release 0.1
- Requirements discussed with stakeholders
- Operational and Commercial model defined

Release 1.0
- Fully integrated technology demonstrator
- Working procedures defined
- Stakeholder organisations supporting culture change

Release X.0
- Real reactor system platform

Continuous delivery of solutions into industry

2019
- Successful proof of concept

2021
- Technology Demonstrator
- Continued code integration
- Enhanced data management
- Real systems

Continuous engagement to ensure feedback from users

New codes developed in parallel

Parallel BEIS Programmes
- Key UK industrial programmes eg New Nuclear construction, further support to AMR / SMR programmes, Station operation, decommissioning AGRs
- Exploring International export opportunities

2030
- Industry driven development

Continuous delivery of solutions into industry
Phase 1
# Phase 1 – Highlights

<table>
<thead>
<tr>
<th><strong>Objective</strong></th>
<th><strong>Delivered</strong></th>
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<tbody>
<tr>
<td>Develop engagement plan</td>
<td>Maximised engagement and understood state-of-the-art</td>
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<td>Capture of industry requirements for digital environment</td>
<td>Clarified end-user requirements</td>
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<td>Develop test cases to prove concept</td>
<td>Real life AGR and PWR test cases run through framework</td>
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<td>Develop software framework architecture</td>
<td>Successful proof of concept</td>
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<td>Integrate simulation codes into framework</td>
<td>Simulation codes support test cases but also integrated for future use</td>
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<td>Prove INDE concept via test cases</td>
<td>Demonstrated code coupling and seamless data sharing across five organisations</td>
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<td>Provide HPC linkage</td>
<td>Successful demonstration of HPC linkage for test cases</td>
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<td>Develop Safety and Security roadmap</td>
<td>Covers IP concerns, data and information security, as well as policy/guidance</td>
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Phase 1 – Proof of Concept

Integrated Collaborative Framework

Faster & more reliable → Lower cost solutions
Higher fidelity simulation → Innovation
Evidence for decision making → Lower cost regulation
Sharing software whilst protecting IP → Collaborating to reduce costs
Phase 1
Framework Architecture

Uncertainty Quantification

GUI
- User Access
- Configure
- Start federation
- Design Parameter and Metadata

Analysis Config

Start Federation

Database

Results

Analysis-Specific Sim Manager

Code 1
Code ...
Code N

RTI

Recorder

Visuals?

Analysis Specific Federation (Many federations in parallel if needed)
Example Applications

The proof-of-concept framework developed has been used for 2 example applications:

1. Simulation of a rod-ejection scenario for a PWR reactor
2. Simulation of graphite degradation for life-time of an AGR reactor

These cases demonstrate key capabilities of the framework, such as e.g. code coupling, data transfer, code synchronisation, visualisation.

The following demos showcase the operation of the framework and the example applications 1 and 2.
Demos
User Portal of the Framework

• This portal provides central access to key functionality:
  • Login to user account
  • Setup of a coupled multi-physics simulation calculation
  • Execution and control of simulation
  • Operation of a data-base storing all simulations, retrieval and replay of past simulations

• Web-based, the front end can be accessed from anywhere simply through a web browser.
Click>>[Web Portal User Interface Video]
Example Application 1: PWR Accident Scenario

• A rod ejection accident at a Pressurised Water Reactor is simulated, using three coupled codes.

• The portal allows choosing codes and setting key design parameters of the model. In future, other codes can be added as ‘plug-and-play’.

• The multi-physics visualisation module enables:
  • Side-by-side analysis of different quantities and various interactions with the data.
  • Visualisation of results in real-time, various data manipulation options.

• Multi-physics visualisation can improve decision-making and thereby enhance safety.
Click>> [PWR Rod Ejection Accident scenario video]
Example Application 2: AGR Graphite Degradation

• The through-life graphite degradation in an Advanced Gas Reactor has been simulated, using 4 coupled codes.
• The simulation is set up in an analogous way to the PWR application above. The extension to a broad range of application is planned for the future.
• The coupling of codes through the framework significantly reduces effort / time to carry out analyses and provide QA.
• The visualisation module enables the display of results on different meshes - a key capability of multi-scale simulations.
Click>>[AGR Graphite Degradation Analysis scenario video]
Outlook

- The developed software framework and portal represent a proof-of-concept and will inform future developments.
- Emerging future technologies will be integrated with these developments to deliver incremental improvements to the sector.
- Along with the framework itself, a commercial model will need to be developed to fund the development of the INDE.
Conclusion

• Vision for INDE is ambitious and aims to bring cross-sector learning

• INDE would
  i. Lower costs across the whole nuclear lifecycle
  ii. Facilitate lower cost of regulation
  iii. Support increased innovation and facilitate cultural change
  iv. Align to Industry 4.0

• Our approach targets early industrial uptake

• Phase 1 has delivered a proven concept and defined the key factors for subsequent phases

• INDE is part of the development of an innovative UK Nuclear Virtual Engineering Capability