INTEGRATED DIGITAL NUCLEAR DESIGN PROGRAMME

Integrated Nuclear Digital Environment

February 2019

wood.	VIRTUAL ENGINEERING CENTRE	NATIONAL NUCLEAR LABORATORY
ROLLS ROYCE	EDF ENERGY	Hartree Centre Science & Technology Facilities Council
UNIVERSITY OF LIVERPOOL	Imperial College London	UNIVERSITY OF CAMBRIDGE

Contents

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

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The Vision

Context

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Purpose → Deliver cultural change across the industry through enhanced collaboration

Provide digital tools on an integrated collaborative platform → Help nuclear industry exploit benefits of Industry 4.0

Provide digital tools on an integrated collaborative platform → Reduce costs throughout the nuclear lifecycle

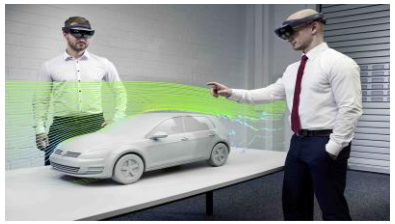
Design Standardisation:
Make UK the hub of the world's nuclear energy markets generating revenue & sustain 30k jobs in the nuclear sector

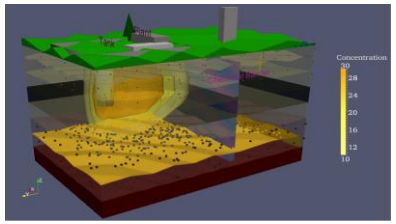
Vision

Nuclear engineering of the future, across the whole nuclear lifecycle:

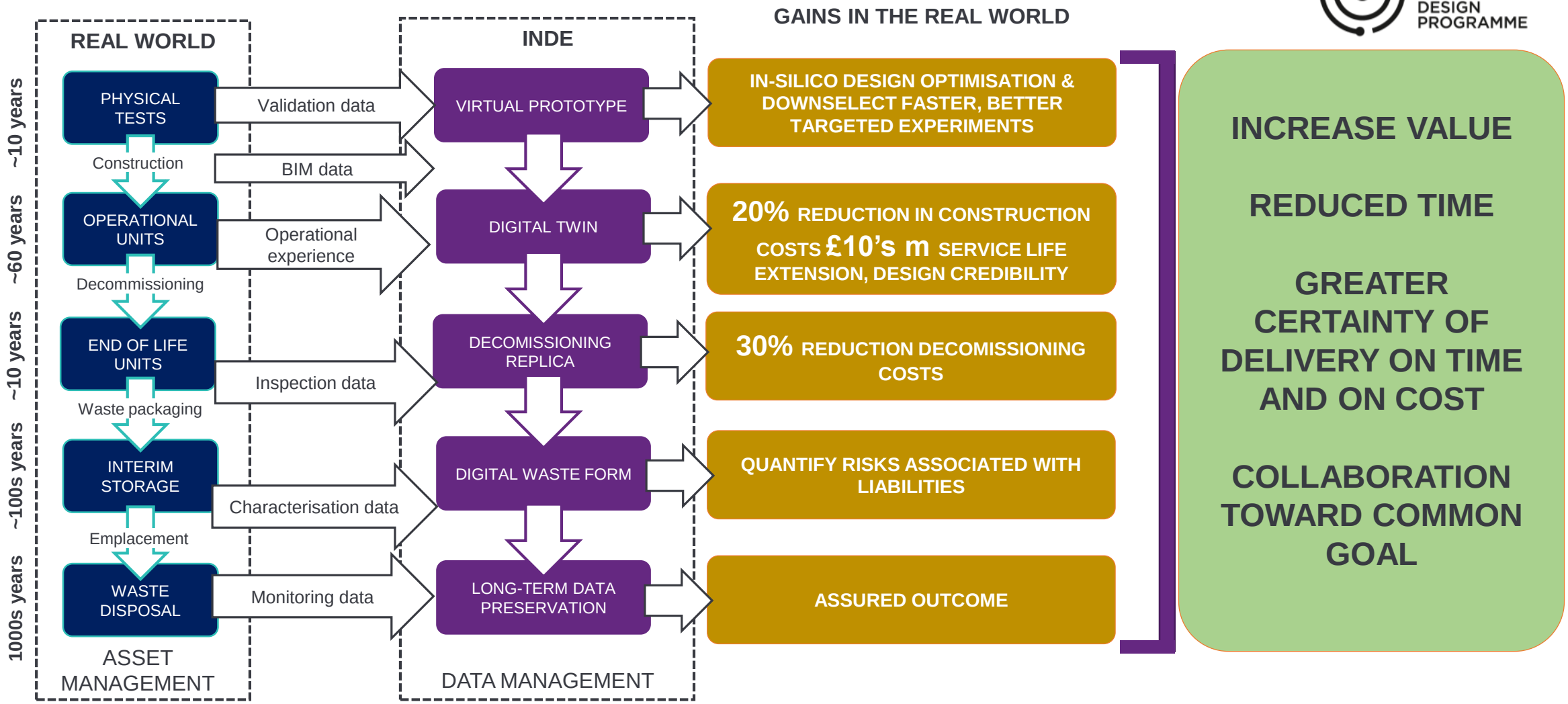
- Integrated simulation
- Trusted in-silico simulation
- Faster / (lower cost) increased value
- Easily auditable decisions
- Appropriate application of VR and AR
- Integrated smart systems
- Real-time monitoring and diagnosis

End-to-end integration for the design licensing of future nuclear plant





Vision – Integrated Nuclear Digital Environment



Patterson EA, Taylor RJ & Bankhead M, A framework for an integrated nuclear digital environment, *Progress in Nuclear Energy*, 87:97-103, 2016

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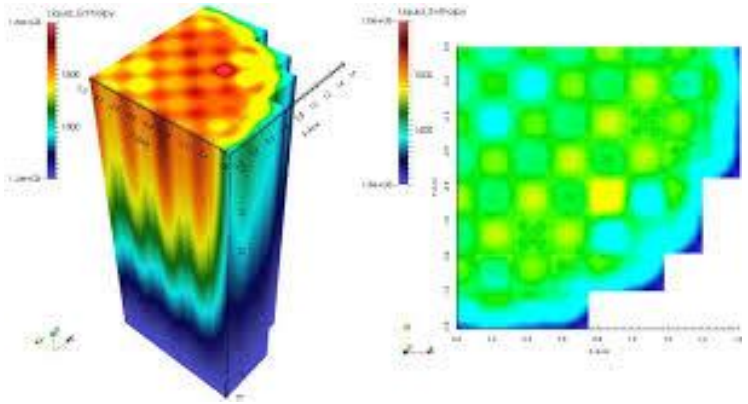
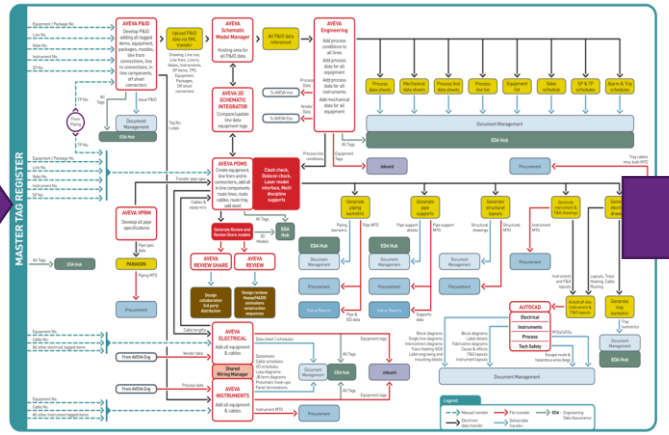
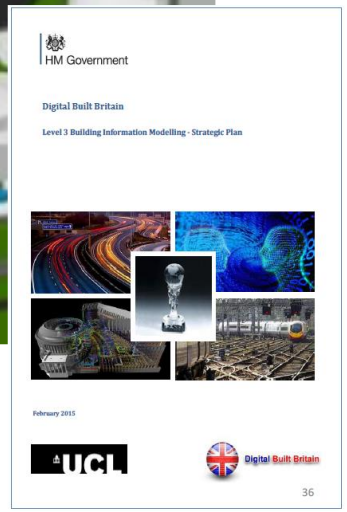
Vision - Joining the Dots…….







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

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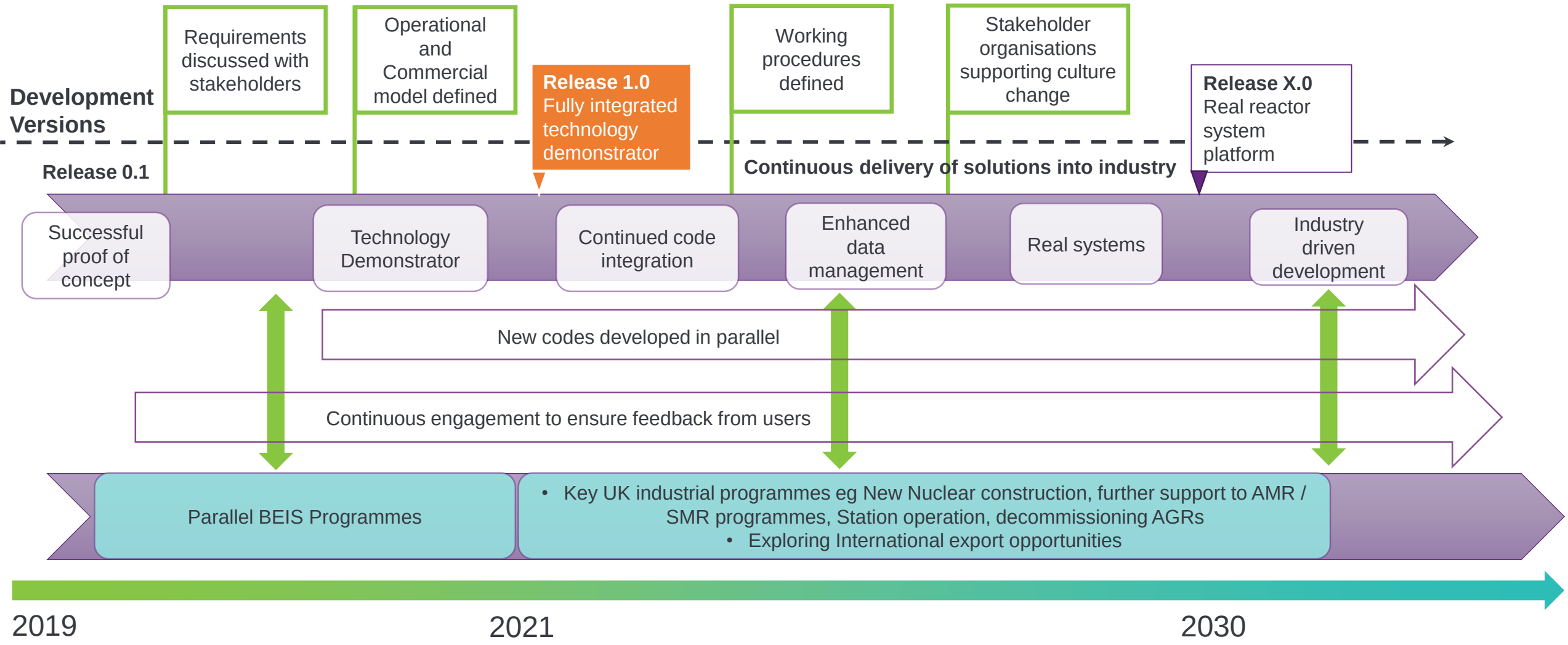
the nuclear institute

Digital Special Interest Group

Innovate UK Knowledge Transfer Network

Digital Built Britain

Roadmap – Now to 2030



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Phase 1

Phase 1 – Highlights

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

Partners


PRIFYSGOL BANGOR UNIVERSITY
MANCHESTER 1824
The University of Manchester
assystem
Brunel University London
UNIVERSITY OF LEEDS
ARUP
NUCLEAR AMRC
CAMMELL LAIRD
ONR Office for Nuclear Regulation
JACOBS
VIRTUAL ENGINEERING CENTRE
ROLLS ROYCE
FRAZER-NASH CONSULTANCY
NDA Nuclear Decommissioning Authority
Hartree Centre
Science & Technology Facilities Council
NATIONAL NUCLEAR LABORATORY
HPC
wood.
UK Atomic Energy Authority
UNIVERSITY OF CAMBRIDGE
EDF ENERGY
EDF
Department for Business, Energy & Industrial Strategy
Imperial College London
UNIVERSITY OF LIVERPOOL
Westinghouse
cavendish nuclear
HORIZON NUCLEAR POWER
NU'GEN
HITACHI
BAE SYSTEMS

Phase 1 – Proof of Concept

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Integrator

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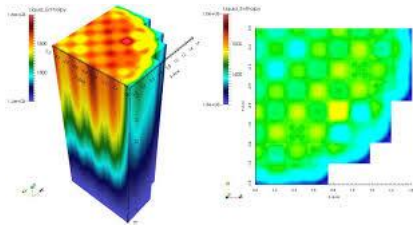
Faster & more reliable → Lower cost solutions

Higher fidelity simulation → Innovation

Evidence for decision making → Lower cost regulation

Sharing software whilst protecting IP → Collaborating to reduce costs



Developer

VIRTUAL ENGINEERING CENTRE

UNIVERSITY OF LIVERPOOL

Hartree Centre
Science & Technology Facilities Council

HPC

Integrated Collaborative Framework

wood.

WIMS, MCBEND

EDF ENERGY

PANTHER

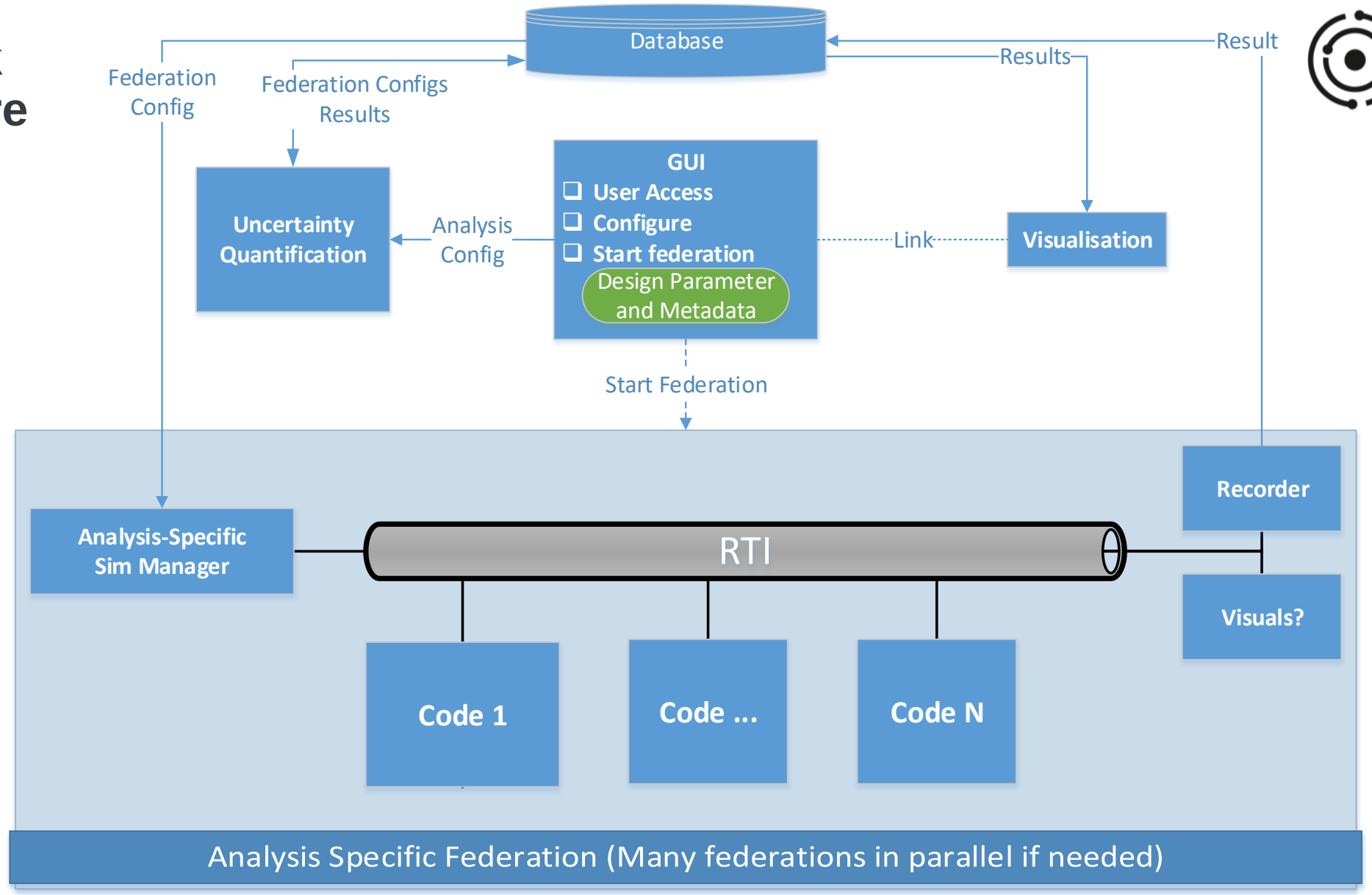
NATIONAL NUCLEAR LABORATORY

ENIGMA

Imperial College London

UNIVERSITY OF CAMBRIDGE

Phase 1 Framework Architecture



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.

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Demos

User Portal of the Framework

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- 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.

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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.

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Click>>[PWR Rod Ejection Accident scenario video]

Example Application 2: AGR Graphite Degradation

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- 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.

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[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