INTEGRATED DIGITAL NUCLEAR DESIGN PROGRAMME

Integrated Nuclear Digital Environment

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

Safety Moment

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Why worry about holding the handrail when using stairs?

In the UK there is a fall on stairs every 90 seconds.

During 2015 there were 787 deaths in England and Wales caused by a fall on and from steps or stairs.

Every year there are over 300,000 visits to Accident and Emergency units following falls on stairs.

According to a OnePoll survey in 2017, 33% of people said that they had fallen up or down the stairs in the last 12 months.

Holding the handrail makes sense!

Agenda

John Stairmand (Wood)

Time	Theme
11:00 – 12:00	Presentation
12:00 – 13:30	Lunch + Demos
13:30 – 14:15	Discussion in 4 groups
14:15 – 14:45	Summary statements from discussion and general comments from delegates
14:45 – 15:00	Summary and meeting close

Overview

- **Introduction,** John Stairmand (Wood)
- **Vision and concept,** Ahmed Aslam (Wood) / Mark Bankhead (NNL)
- **Benefits I,** Chris Jackson (Rolls-Royce)
- **Benefits II,** Ionel Nistor (EDF Energy)
- **Opportunities,** Bruno Merk (NNL, University of Liverpool)
- **Progress and Development,** David Bowman (Virtual Engineering Centre)

Vision and concept

Ahmed Aslam (Wood) & Mark Bankhead (NNL)

Vision and Design

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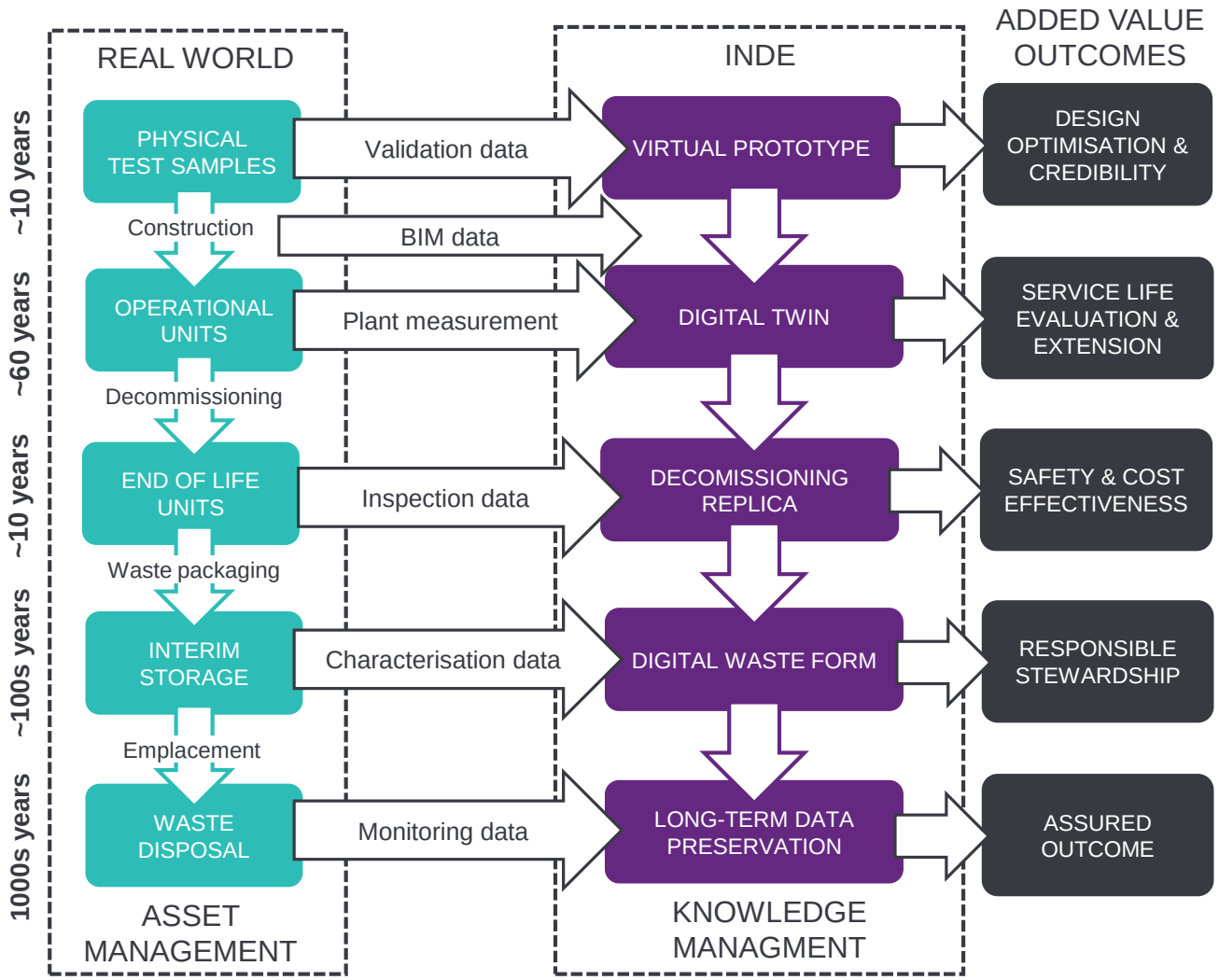
A supported environment set that:

- Enables end users to make informed decisions based on high fidelity information
- Encompasses the whole nuclear lifecycle
- Integrates data and knowledge management
- Allows running complex analysis by broader specialists
- Allows for seamless integration and plug & play
- Enables collaboration within the nuclear sector and internationally
- Promotes the cultural change to enhance innovation
- Adds benefit across the energy sector

Integrated Nuclear Digital Environment – Concept



NEW BUILD:

20% cost savings target

DIGITAL TWIN:

100s Millions cost savings

DECOMMISSIONING:

30% cost savings target

Time / risk reduction

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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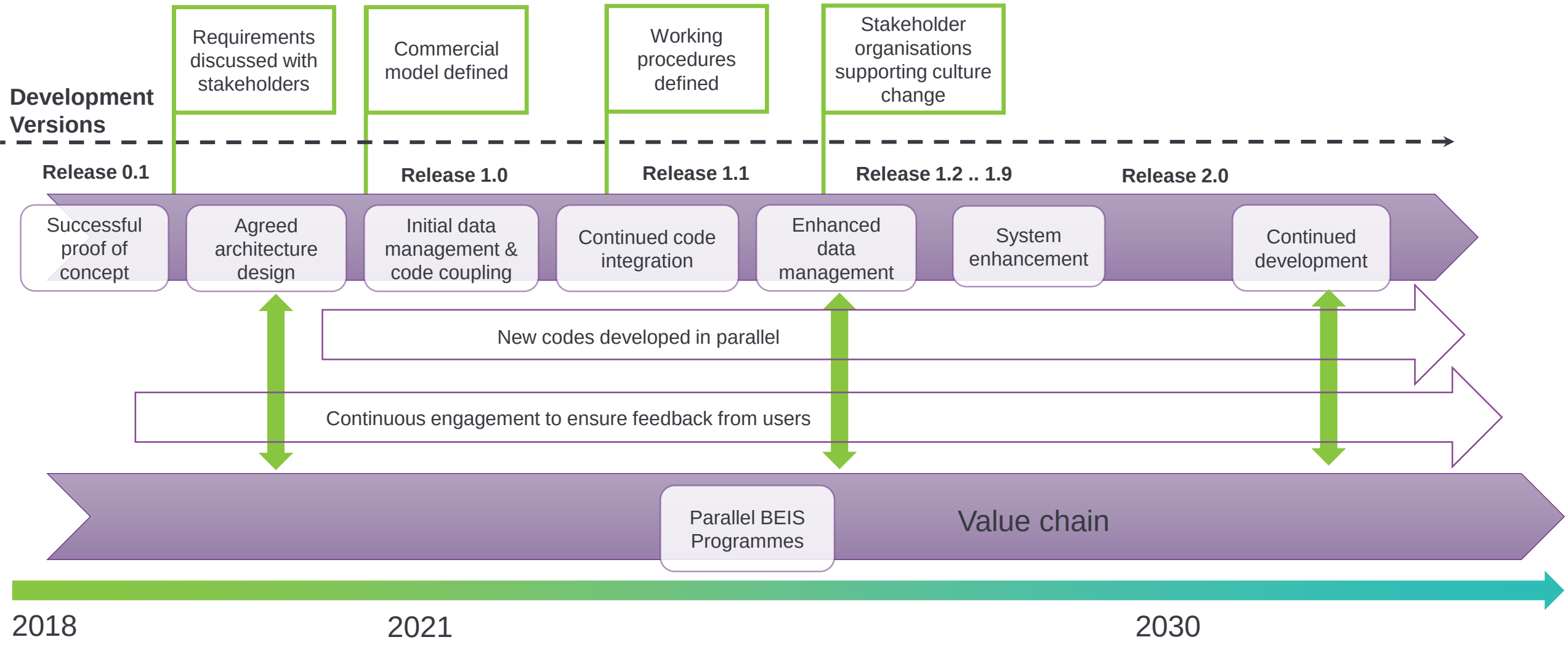
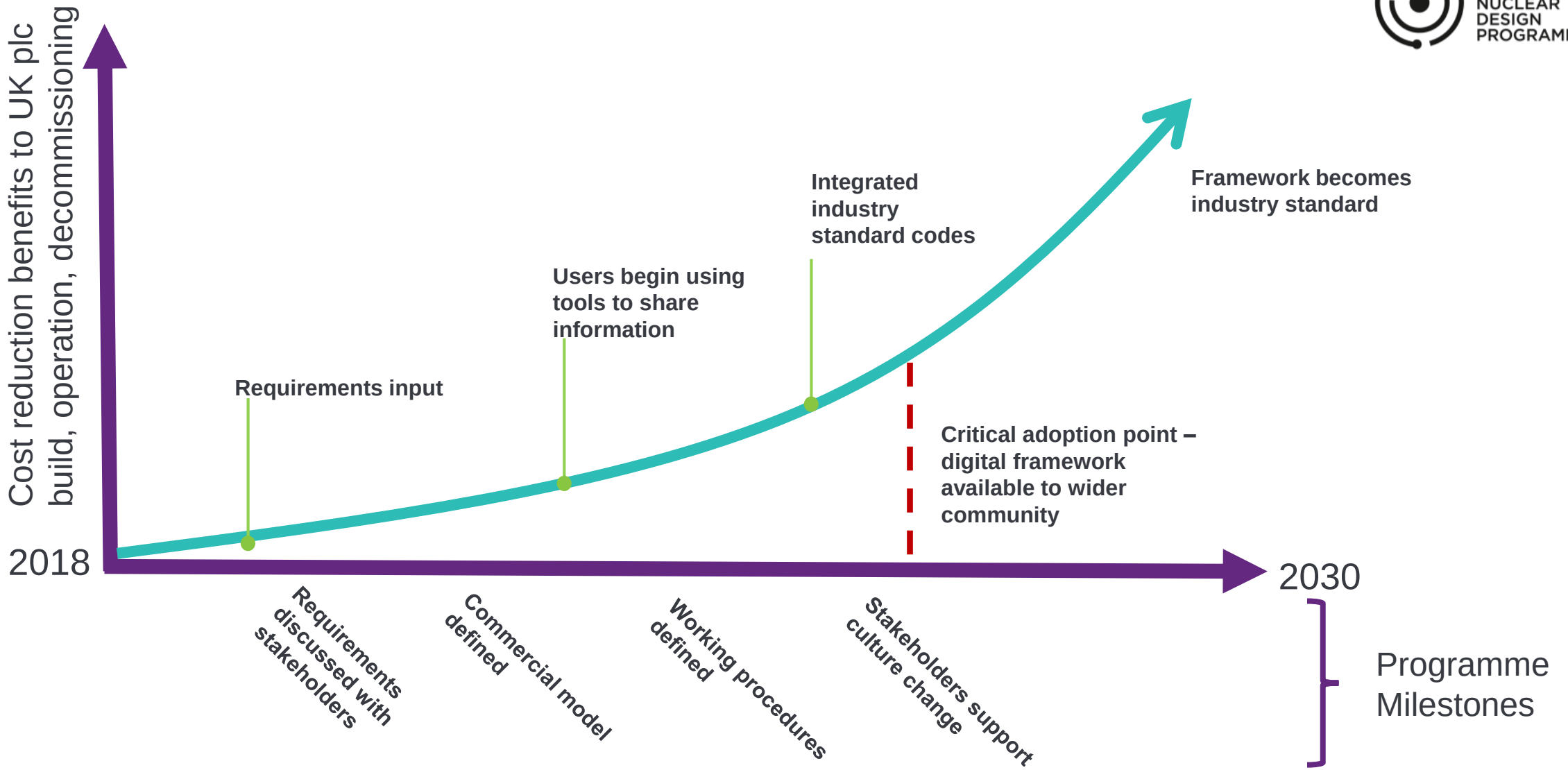
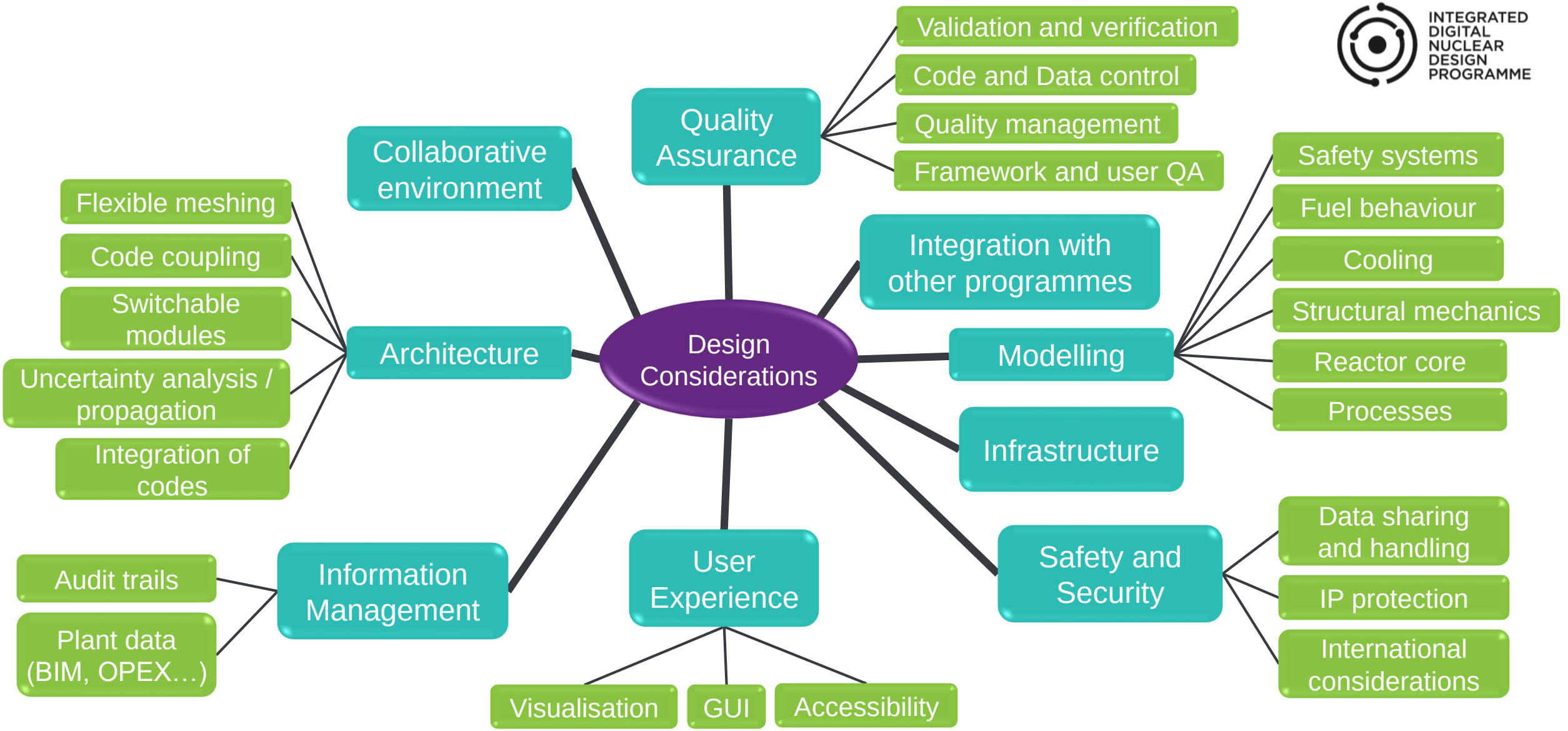
Roadmap

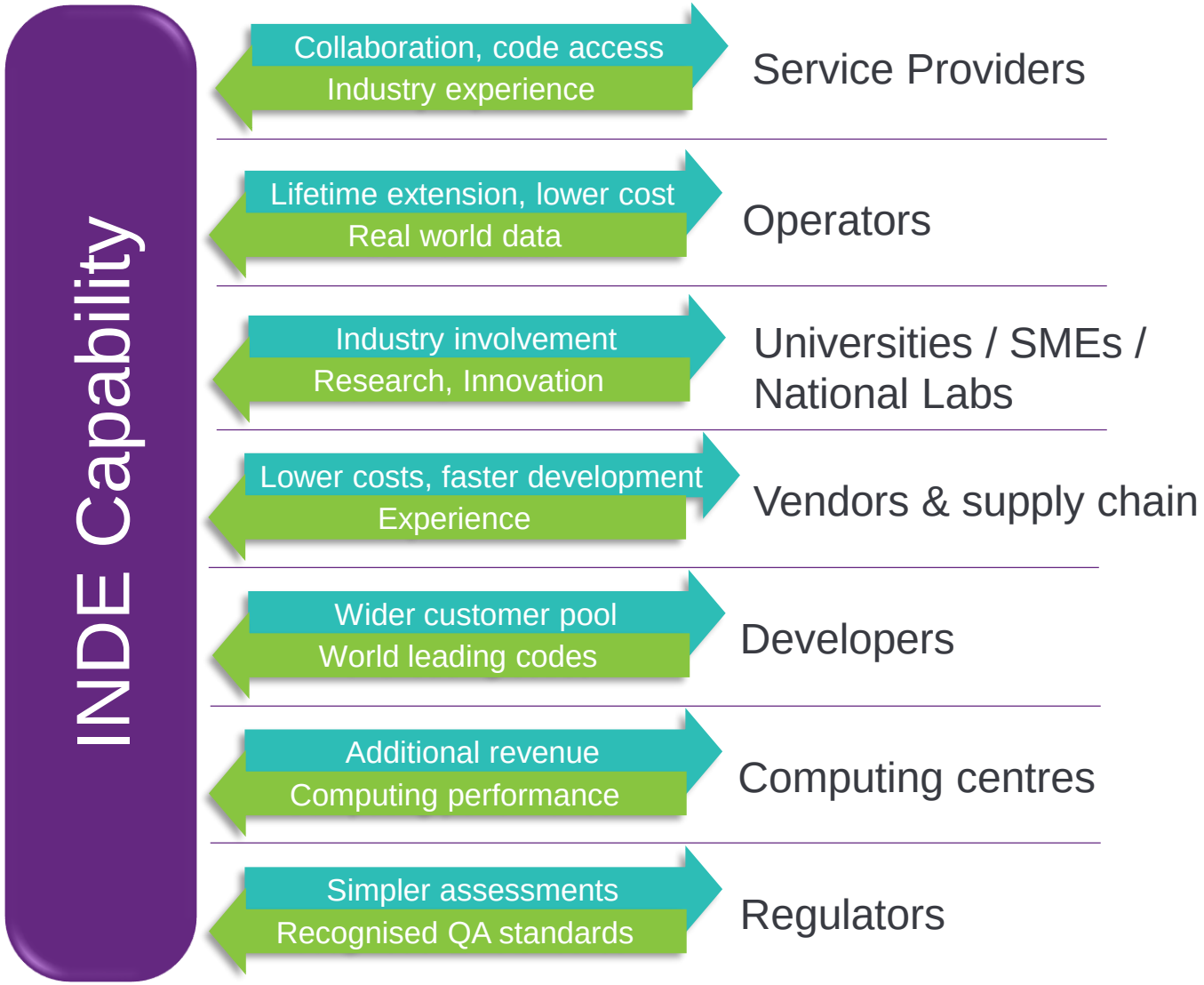

Requirements discussed with stakeholders
Commercial model defined
Working procedures defined
Stakeholder organisations supporting culture change
Development Versions
Release 0.1
Release 1.0
Release 1.1
Release 1.2 .. 1.9
Release 2.0
Successful proof of concept
Agreed architecture design
Initial data management & code coupling
Continued code integration
Enhanced data management
System enhancement
Continued development
New codes developed in parallel
Continuous engagement to ensure feedback from users
Parallel BEIS Programmes
Value chain
2018
2021
2030

Value Roadmap




Design Considerations
Quality Assurance
Validation and verification
Code and Data control
Quality management
Framework and user QA
Collaborative environment
Integration with other programmes
Modelling
Safety systems
Fuel behaviour
Cooling
Structural mechanics
Reactor core
Processes
Infrastructure
Safety and Security
Data sharing and handling
IP protection
International considerations
User Experience
Visualisation
GUI
Accessibility
Information Management
Audit trails
Plant data (BIM, OPEX…)
Architecture
Flexible meshing
Code coupling
Switchable modules
Uncertainty analysis / propagation
Integration of codes

Stakeholders



- Collaboration is key – “UK Plc”.
- Every stakeholder has their own contributions and benefits.
- Interaction with stakeholders to create new ideas.

Key Benefits

- Reduced HMG investment requirements through sector efficiencies
- Reduced cost
- Entire value chain modelling and simulation – digital twin
- Flexible analysis paths - better verification
- Reduced manual intervention – error reduction
- Plug ‘n’ play codes – increased flexibility and design of new tools
- Knowledge capture & management – a single available source for reference
- Easy to use for current and potential sector stakeholders
- Creating belief in Nuclear, creating confidence

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Benefits

Chris Jackson (Rolls-Royce)

Why are Rolls-Royce interested?

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- Small Modular Reactors
- Operational Services
- Submarines

Short Term Benefits

- More accurate predictions → safer plant
  - Integrations support analyses of a greater range of physics at one time
  - Increases the accuracy and confidence in results
- More robust designs → lower through-life costs
  - Automation will better enable design studies and optimisations
  - 1000s of points run automatically to help us understand the overall design space (not just the peak performance)
- Shorter lead times → faster to market
  - Will remove some of the initial slog in setting up analyses
  - Still allow expert users to understand the detail they need

Long Term Benefits

- Rolls-Royce Supply Chain Engagement
  - Many hurdles to overcome to gather outside support (particularly from start-ups/SMEs)
  - A common platform will aid communication and knowledge sharing
- Knowledge Management
  - Expertise currently held by individuals
  - Common platform will help to store this information and teach the next generation
- Learn from Best Practice
  - Different projects often hit the same issues
  - Gives a clear route to implementing lessons

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Benefits

Ionel Nistor (EDF-Energy)

AGR Pod Boiler Spine Digital Twin (EDF Energy)

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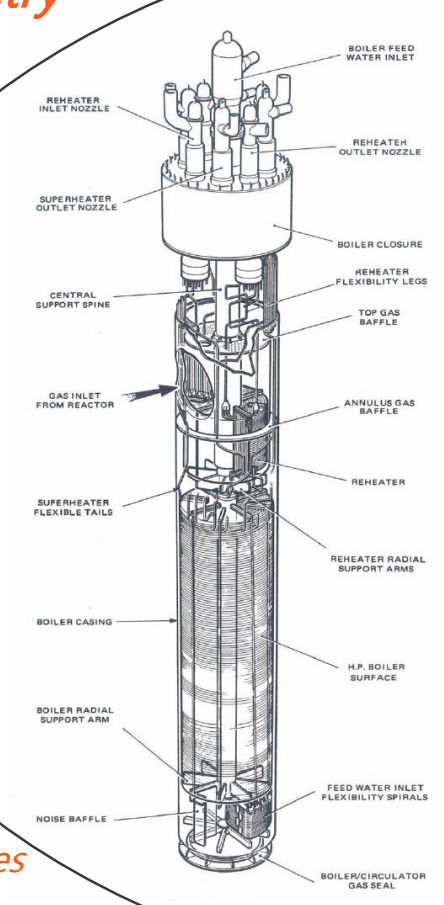
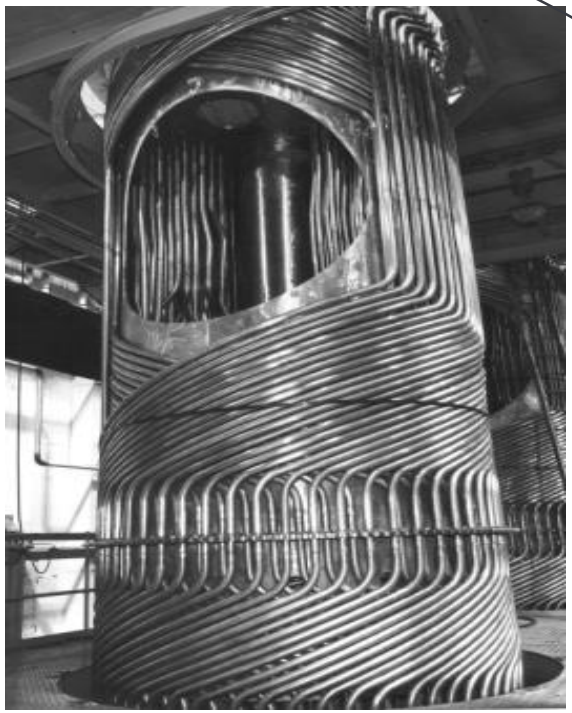
Complex Geometry

- *10m structure*
- *>700 pipes*





Multi-tools

- *Legacy engineering tool (1D)*
- *Advanced CFD tool*
- *Thermal tool*

Multi-scale

e.g. manufacturing imperfections, turbulent boundary layer flow around tubes

Multi-Physics

- *Primary Gas flow*
- *Secondary steam flow*
- *Heat transfer with structures*

Different parameters of interest

- *Temperature at welds (creep, stress corrosion cracking)*
- *Impact of carbon deposition*
- *Impact of tube blanking*

AGR Pod Boiler Spine Digital Twin (EDF Energy)

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Complex Geometry
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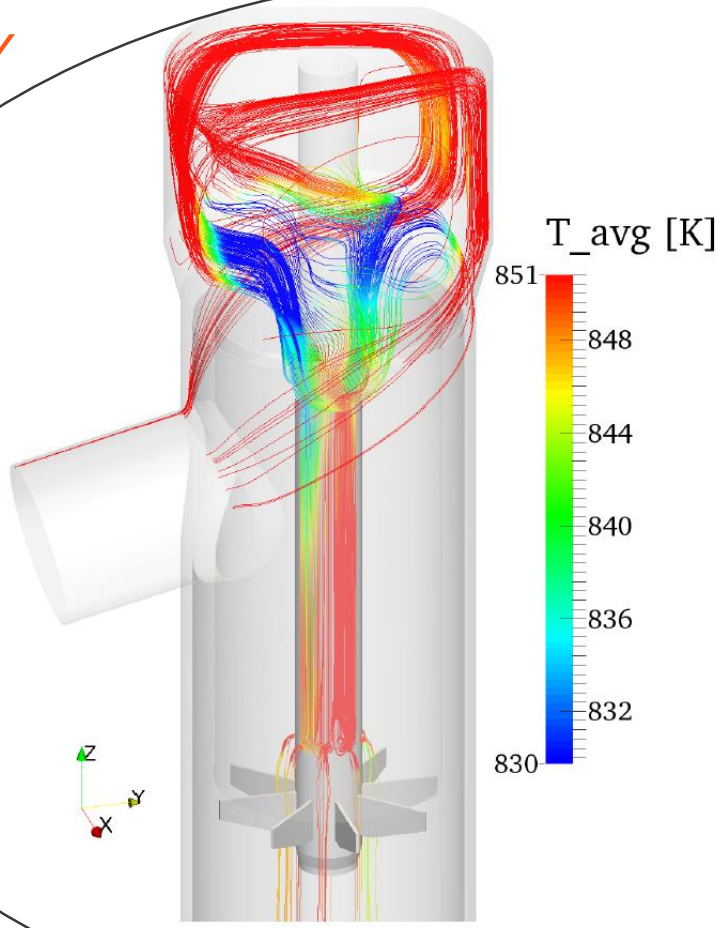

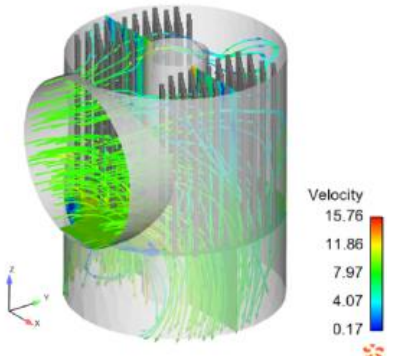

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- Primary Gas flow
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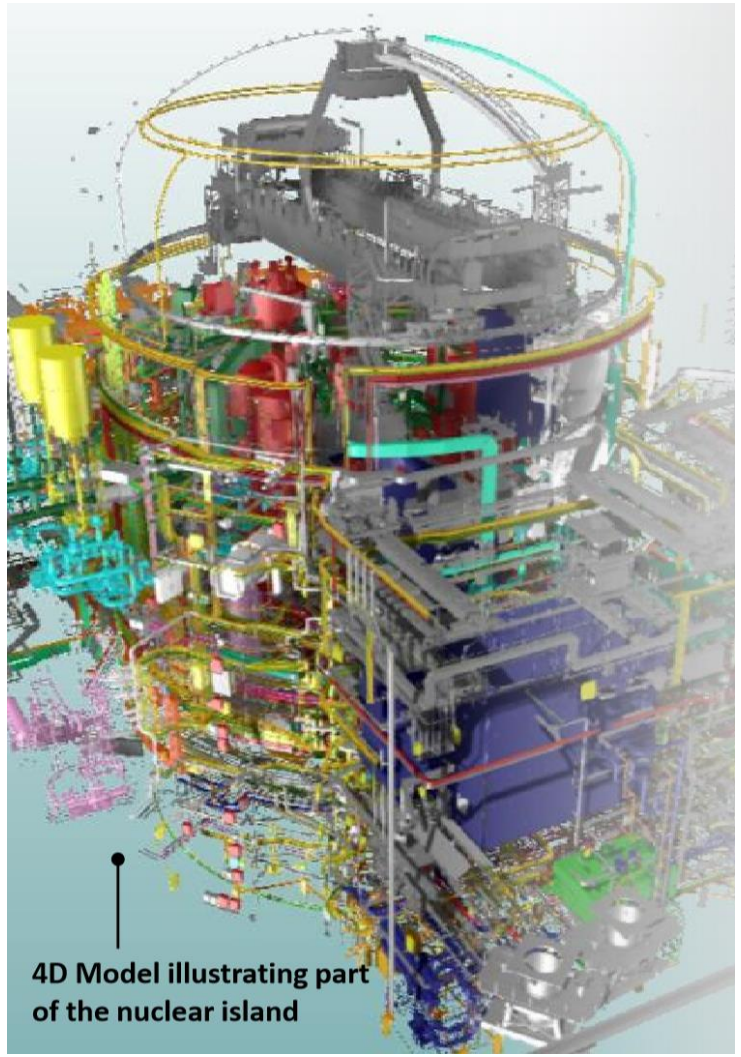
Different parameters of interest
- Temperature at welds (creep, stress corrosion cracking)
- Impact of carbon deposition
- Impact of tube blanking

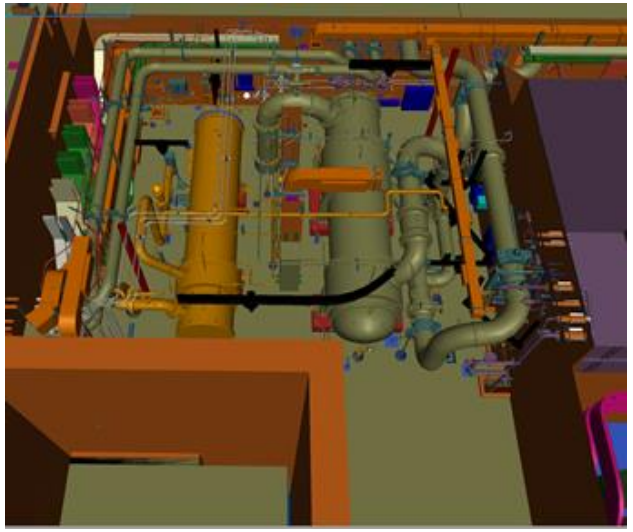
Digital Twin for Components

- Expected benefits from the framework
  - Numerical tools to access to parameters for which one can have experimental data in operation
  - Uncertainty quantification
  - Support to safety cases for life extension
  - Decision tools to avoid replacements when not necessary (justified by reliable prediction)
  - Capitalization of the experimental and numerical data to be valorized later

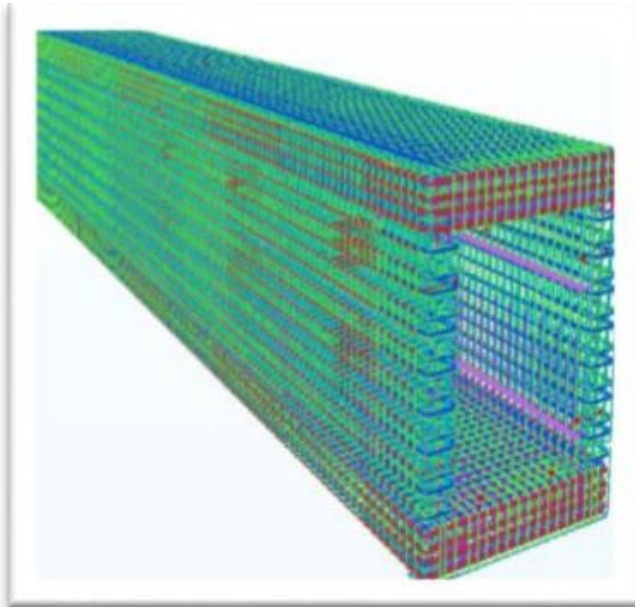
- What is missing / what can be improved
  - Increasing speed to development with an integrated platform rather than ad-hoc approach
  - All the physics present in the numerical model
  - Quality Assurance

Hinkley Point C 3D / 4D Models





Bespoke MEH (Mechanical, Electrical, HVAC) 4D modelling



3D modelling for rebars (design, identification of clash, procurement)

Digital Twin for design, O&M and decommissioning

- Expected benefits from the framework
  - Integrated digital environment allowing for early identification of clash, reduction of the risk in construction/deconstruction
  - Mastering the cost
  - Knowledge management / knowledge transfer tool
  - Easier and faster preparation of the outages
  - Common tools for the Responsible Designer / Licensee / Contractors
  - Communication

- What is missing / what can be improved
  - Extension from CAD / BIM to numerical models
  - Evolving the existing tools/models from as designed to as built and as operated

Opportunities

Bruno Merk (NNL / University of Liverpool)

Opportunities for Development

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Elements

Development of Framework

- Integrating existing codes
- System Integrator
- Cutting edge Multi-scale + multi-physics
- Uncertainty Propagation
- HPC deployment

Information Management

- Quality Assurance
- Data security
- Knowledge capture processes
- Standardising outputs
- Data analytics
- Knowledge preservation and education

Software Development

- Operational use defined
- Networks and data transfer
- Open and flexible commercial model
- Code development
- Standards (Security, Quality, Licensing)

Context

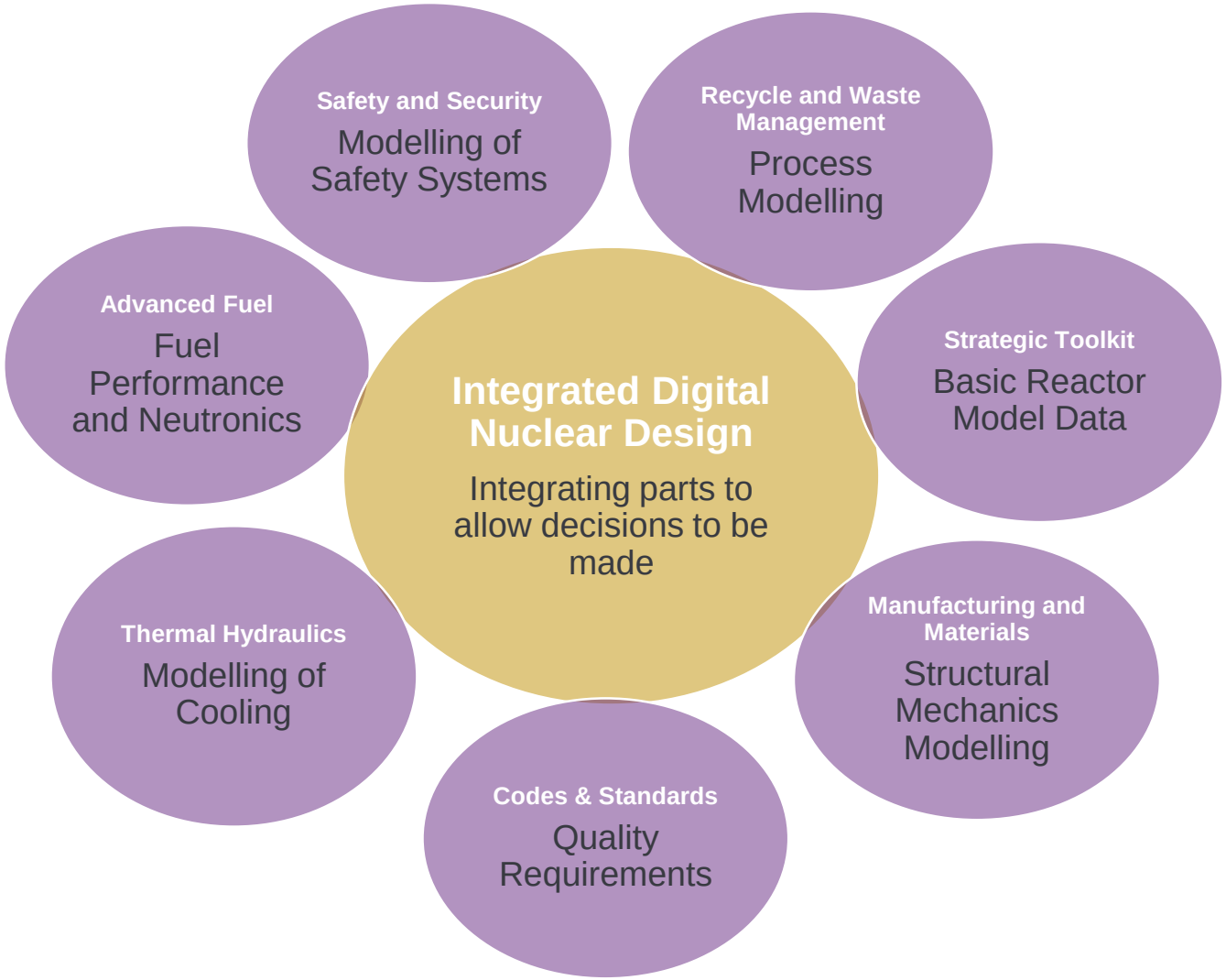
R&D Landscape

- Next generation nuclear design
- Validation data and processes
- Making best use of stakeholder expertise
- Aligning current developments with INDE
- Defining requests for development

Culture Change

- Data sharing across supply chain driving down costs
- Encourage innovation from Universities and SME's
- Open and flexible model
- Integrative working environment

The System Integrator Role



- Enable end users to make informed decisions based on high fidelity information
- Maximising benefits:
  - Learning and linking of individual programmes
  - Managing expectations vs. possible delivery – avoiding duplication
- Common platform for development and knowledge exchange
  - Improving ROI for UK plc

Bruno Merk et al. The UK Nuclear R&D Programme on Digital Nuclear Reactor Design—Modelling, Simulation, and Virtual Engineering, ICAPP2018, International Congress on Advances in Nuclear Power Plants April 8-11, 2018, Charlotte, NC, USA

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Progress and Development

David Bowman (Virtual Engineering Centre)

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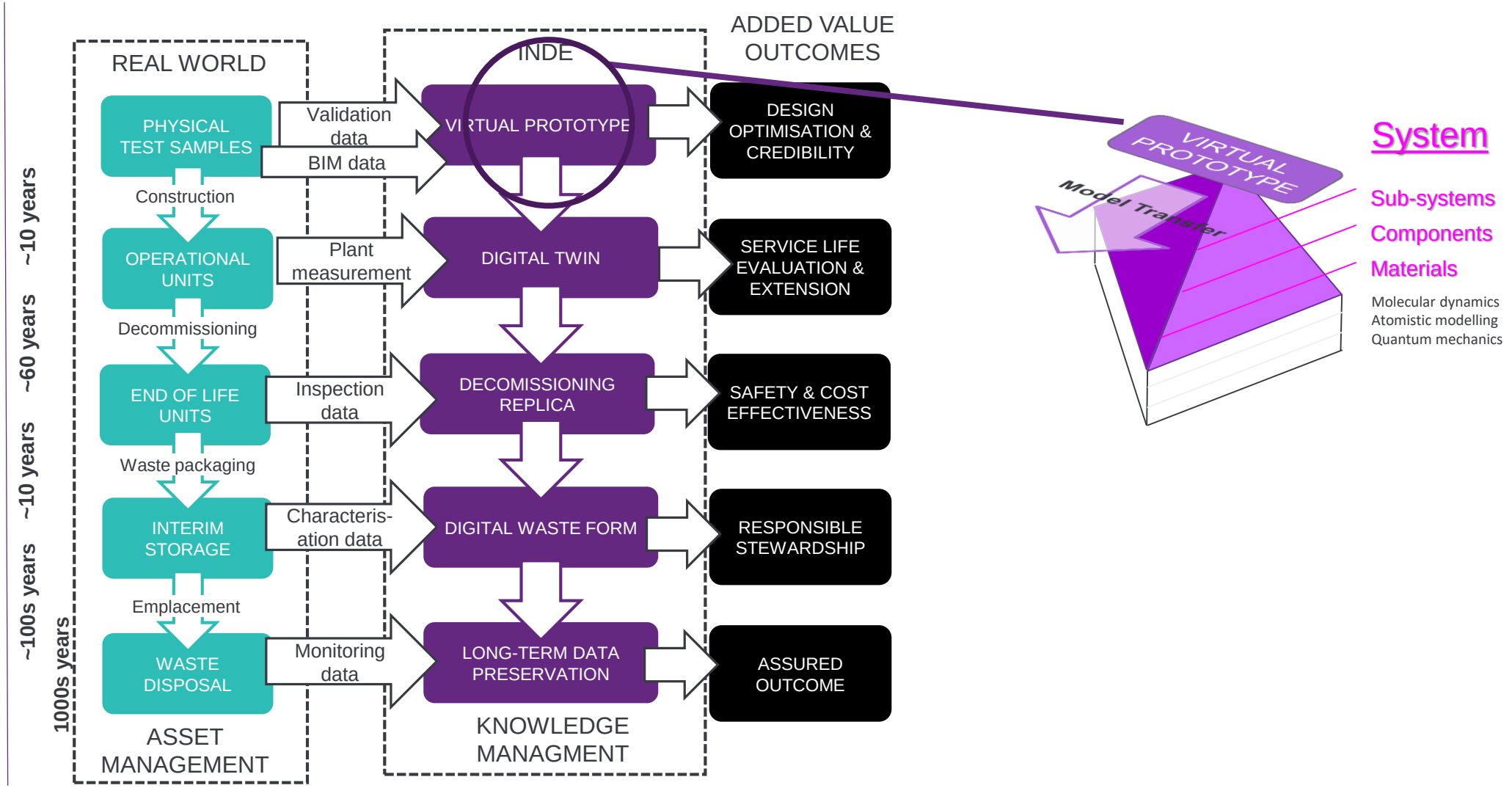

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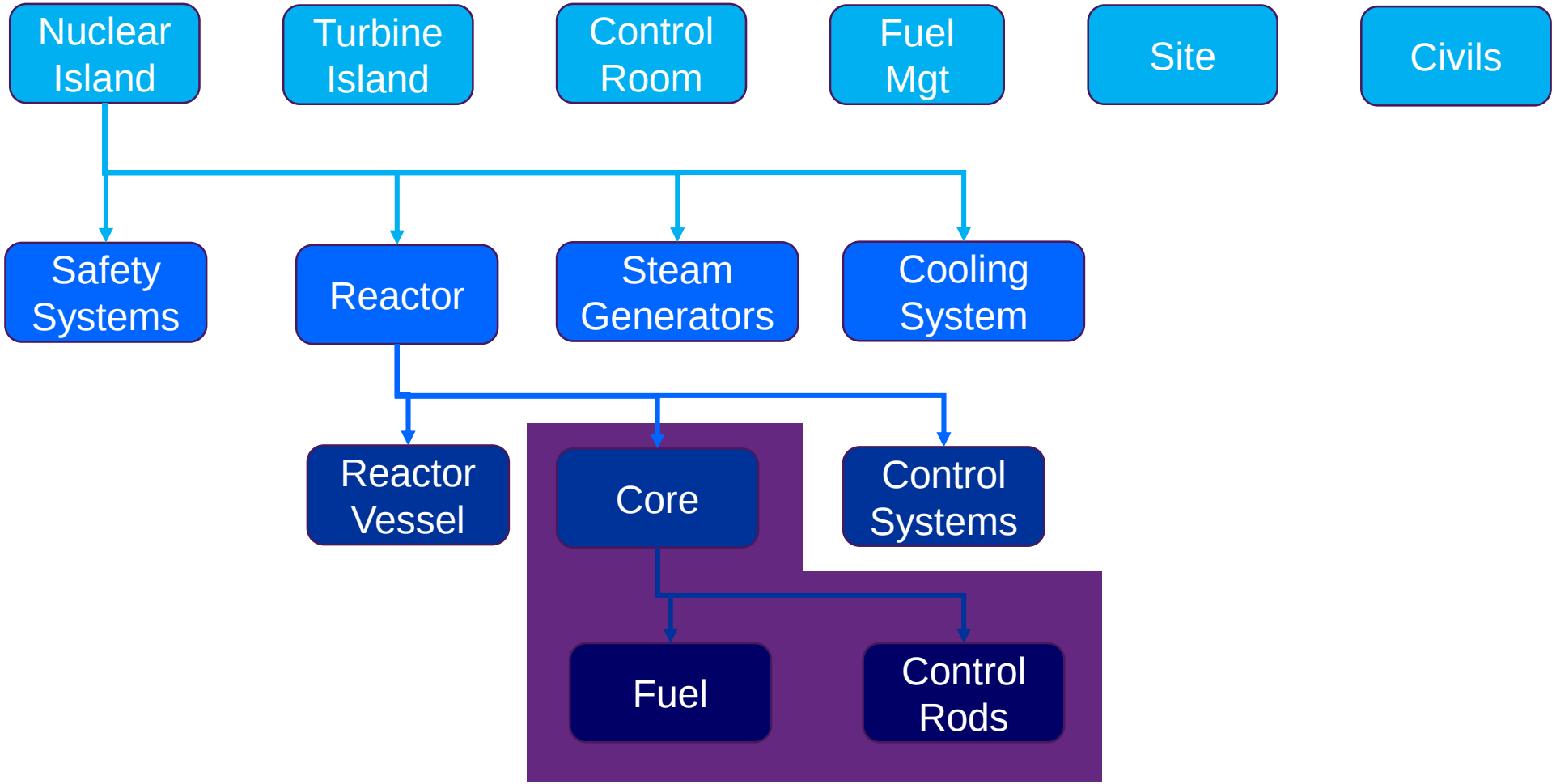
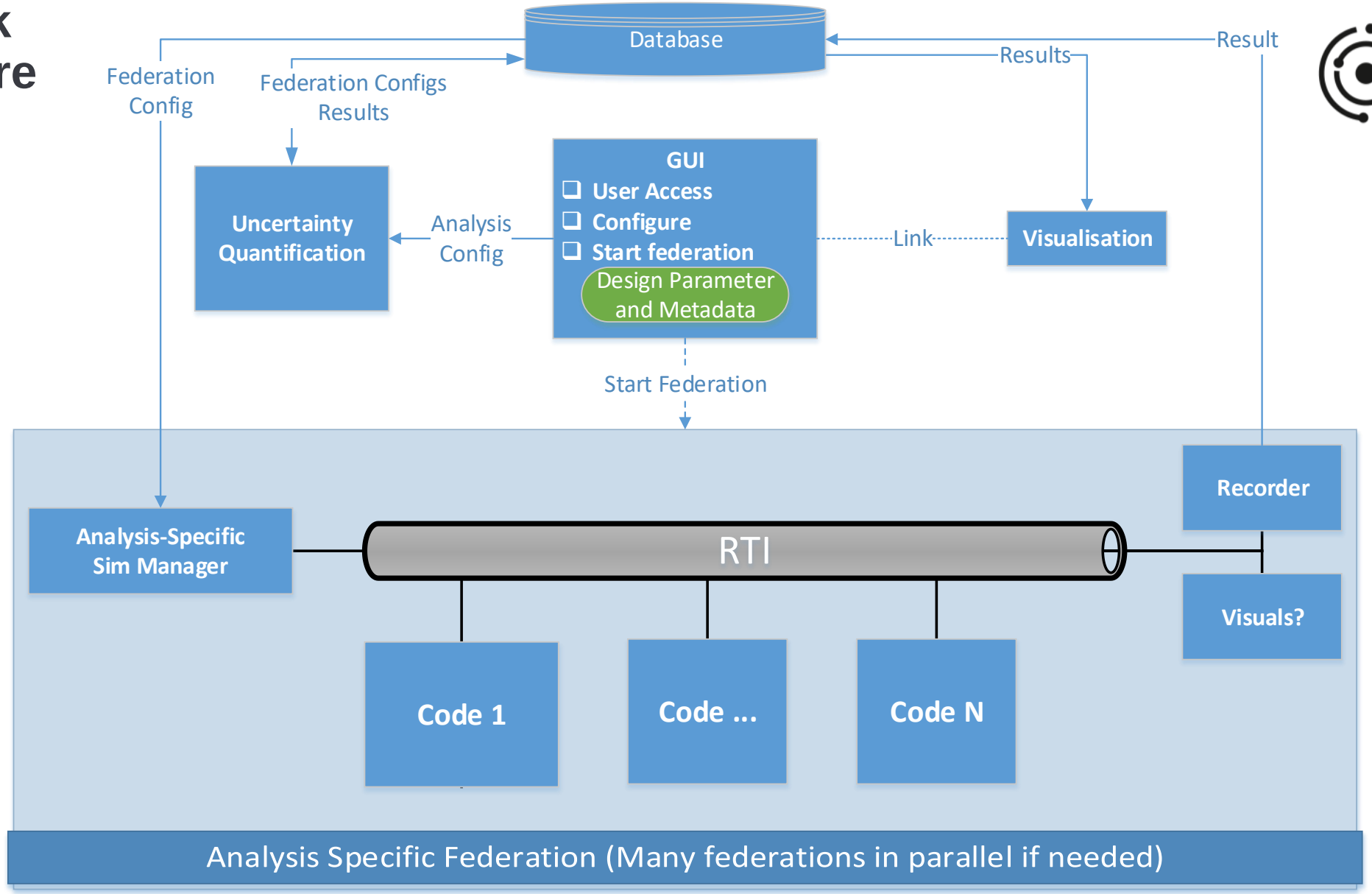
Plant Architecture – System, Sub-System



Framework Architecture



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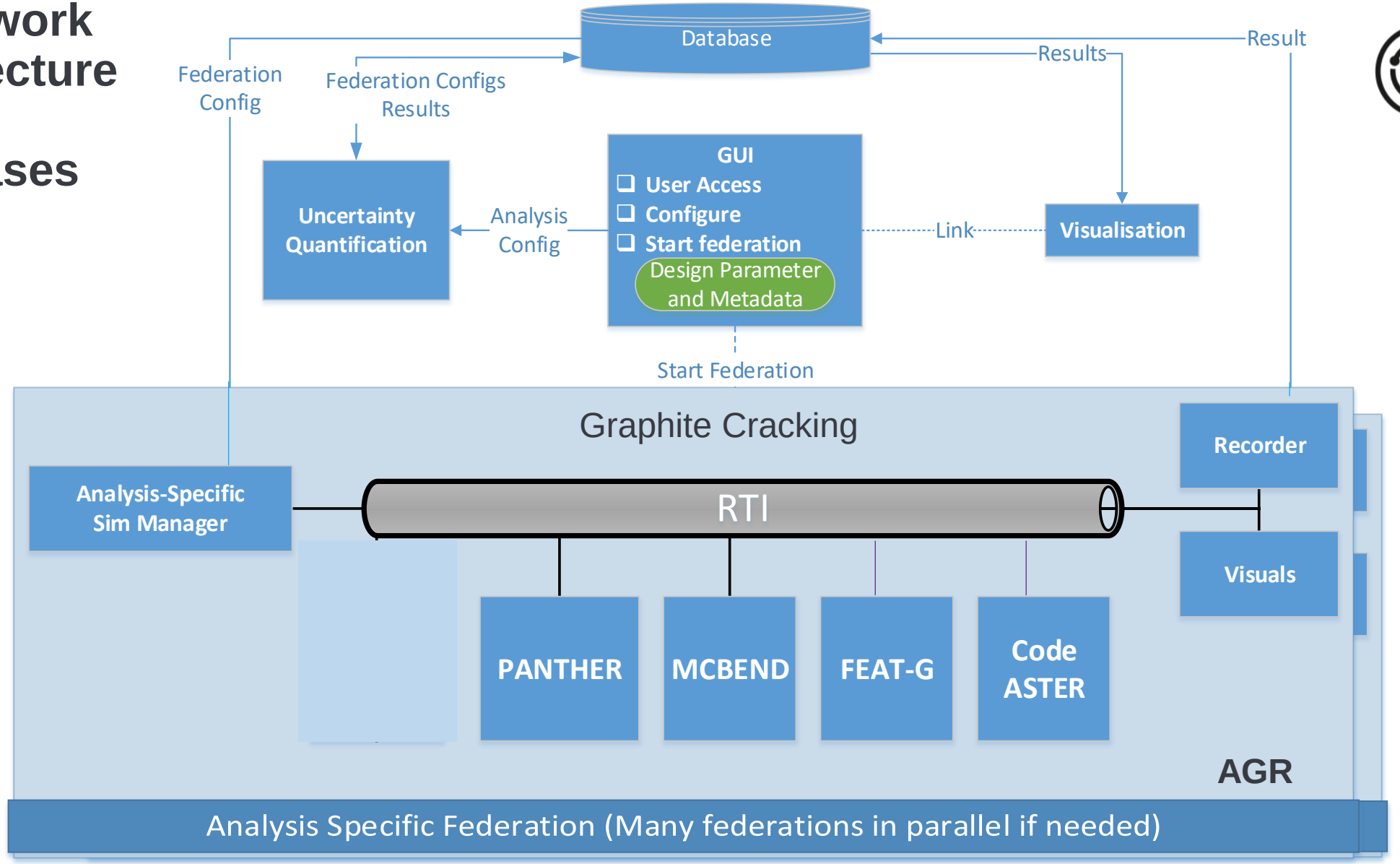
Framework Architecture and Use Cases



Arrangements for Lunch / Demos

	AGR demo	PWR demo	Lunch			
12:00 – 12:20	1	2			3	4
12:20 – 12:40	2	1			3	4
12:40 – 13:00	3	4	1	2		
13:00 – 13:20	4	3	1	2		
13:20 – 13:30	All at lunch					

Group lead
Group 1 – Chris Jackson
Group 2 – Mark Bankhead
Group 3 – Ahmed Aslam
Group 4 – Lynn Dwyer

	Demonstrator
AGR demo	Konstantin Vikhorev
	Albrecht Kyrieleis
PWR demo	Dzianis Litskevich
	Bruno Merk

Give Your Feedback

WiFi Access:

- Select “WiFi Guest” from available hotspots
- Open web browser to access the Cloud WiFi page
- Register or log-on to The Cloud WiFi

Survey:

- Go to: www.digitalnucleardesign.com/events/
- Click the survey link
- Or use the QR code:

Outline of the Afternoon – Planning for the Future

Time	Theme	Facilitator
13:30 – 14:15	Group 1	Chris Jackson
	Group 2	Mark Bankhead
	Group 3	Ahmed Aslam
	Group 4	Lynn Dwyer
14:15 – 14:45	Summary statements by facilitators and general comments from delegates	Chris Jackson, Mark Bankhead, Ahmed Aslam, Lynn Dwyer moderated by John Stairmand
14:45 – 15:00	Summary and meeting close	John Stairmand

Afternoon Discussion Points

- Benefits

  How do you see you organisation benefitting from the project?

- Capabilities

  How do you think you organisation can contribute to the project?

- What future studies and use-cases would you be interested in?
- Who else do you think should be involved?
- Are there any considerations which you think have been missed in developing the project so far.

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Thank you !

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