Nuclear Innovation Programme – Nuclear Structural Materials

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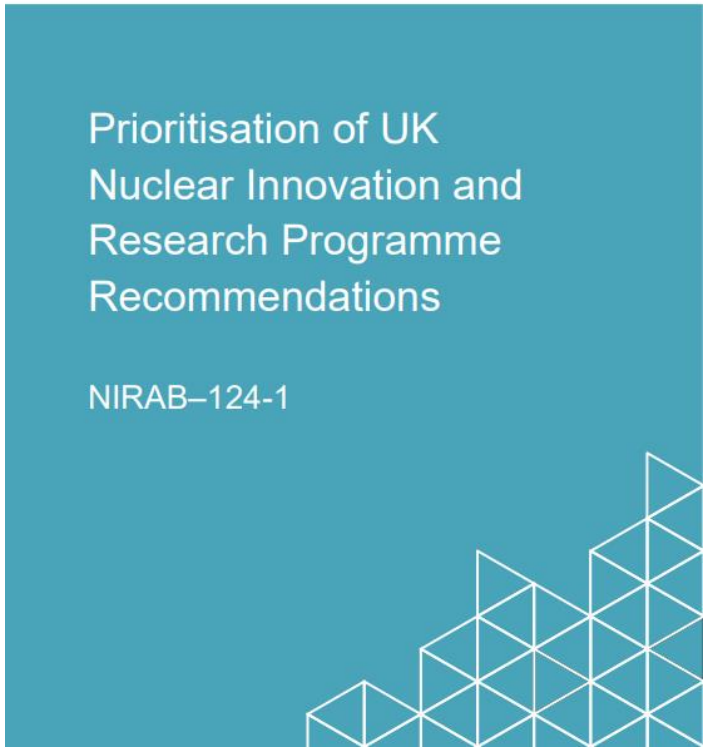
Nuclear Innovation UK Conference – 2nd & 3rd July 2019

SYSTEMS AND ENGINEERING TECHNOLOGY

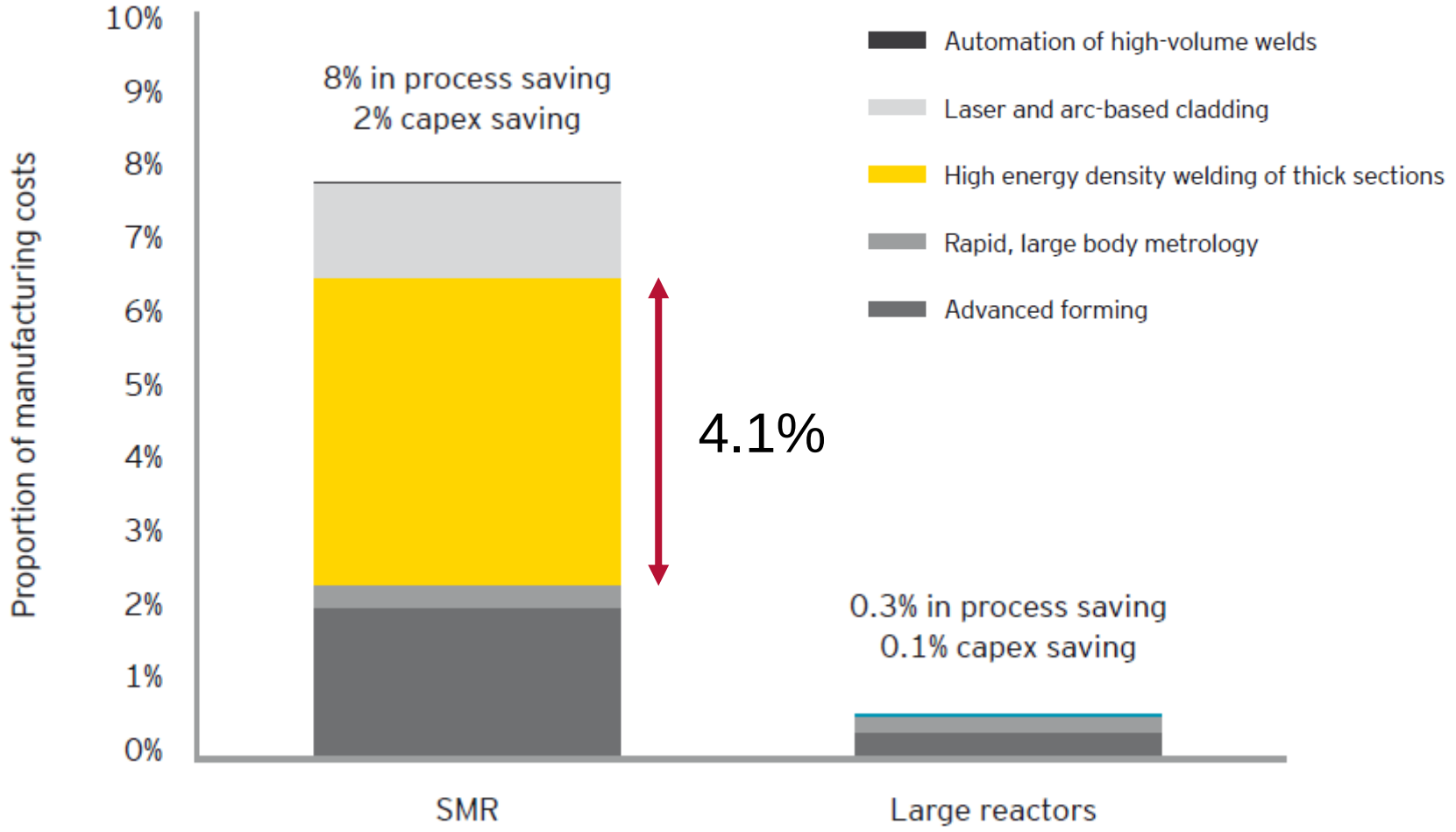
FRAZER-NASH CONSULTANCY

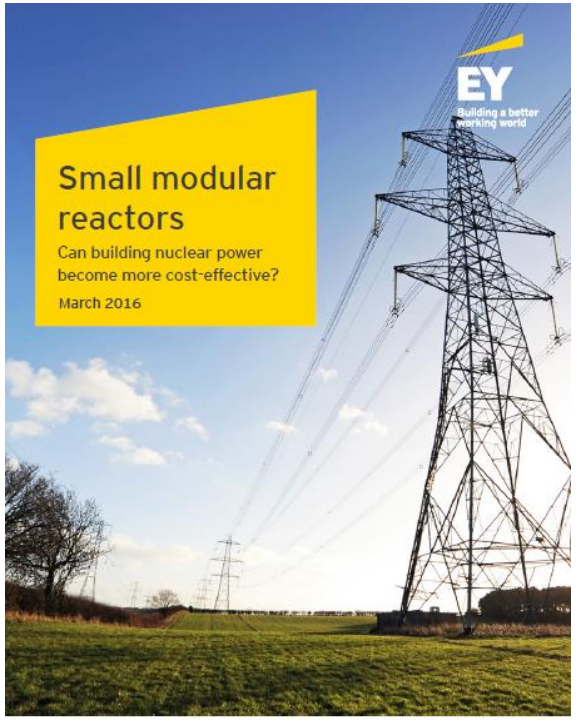
Introduction



- Advanced manufacturing processes and materials offer significant cost savings
- A number of manufacturing processes could be implemented in nuclear new build
- Focus on SMRs / AMRs and Gen IV
- We have undertaken research that supports OEM, operators and the regulator

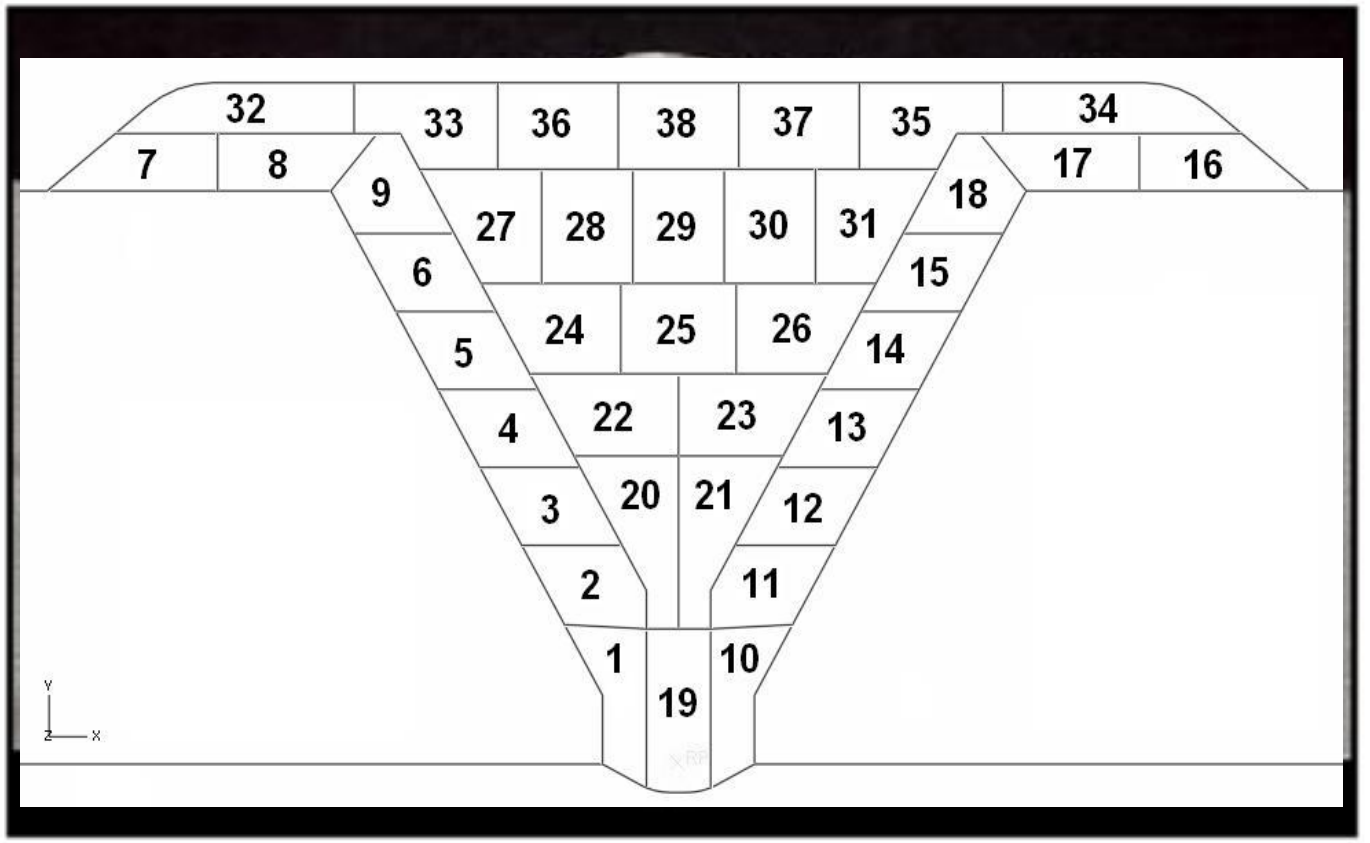
The benefit of advanced manufacturing techniques



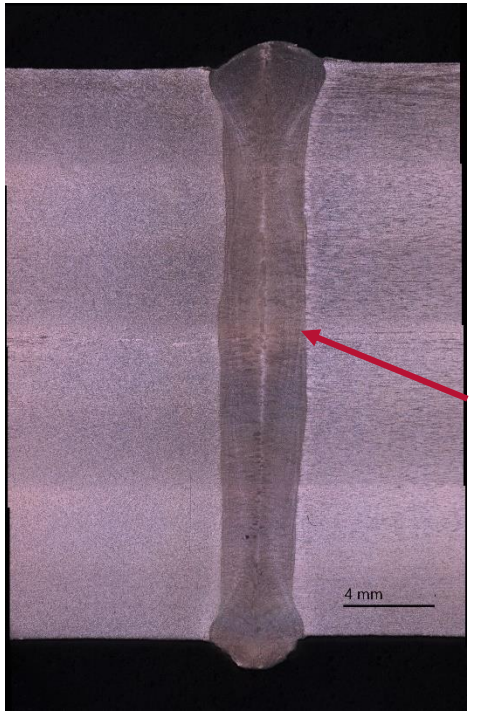


Power beam welding

Conventional arc weld



Electron beam weld



Single pass

Power beam welding

Pros

- Time and therefore cost saving
  - Single pass
  - Reduced NDT
- Simpler microstructures
  - No weld filler metal
  - Smaller weld influence zone
- High TRL
  - Used in other industries

Cons

- Technical challenges
  - Vacuum versus partial vacuum for EB welds
  - Thicker sections for LB weld
  - Dissimilar metal weld
- Further evidence required for codes
  - Code cases e.g. ASME
  - Structural integrity assessment codes

“Improved understanding of advanced joining methods with a view to enhancing the procedures in structural assessment codes”

Project team

Delivery Team

Project Partners

Facilities

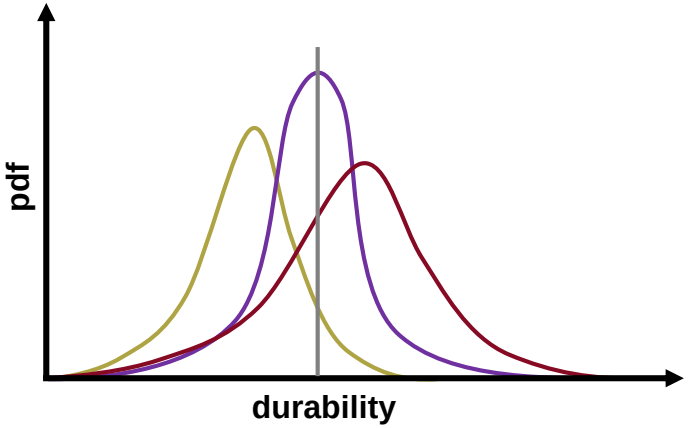
Work packages

Weld Residual Stress

Characterising EB and LB weldments and developing modelling approach to predict weld residual stresses accurately and efficiently

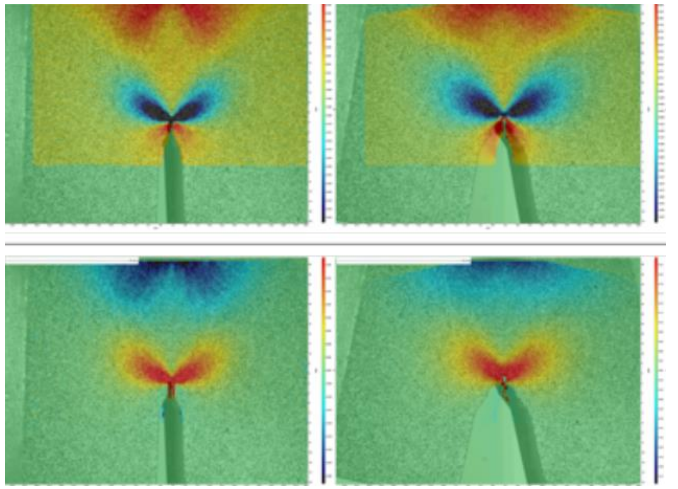
Probabilistic Methods

Development of a probabilistic framework incorporating the variation in material properties and welding residual stresses in structural integrity assessments



Fracture Modelling

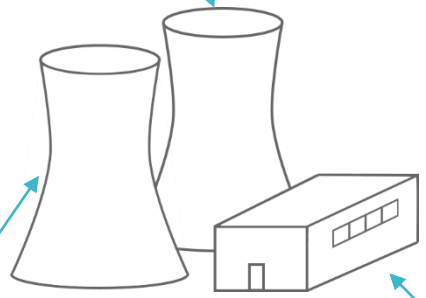
Prediction of the fracture behaviour of power beam welds in the presence of residual stresses, and the effects of thermal ageing



Weld Residual Stress

Benefits

Regulators
Gain confidence from a wide body of evidence that the processes are well understood and controlled



OEMs
Automated and repeatable, faster process time, simplify design e.g. dissimilar metal welds

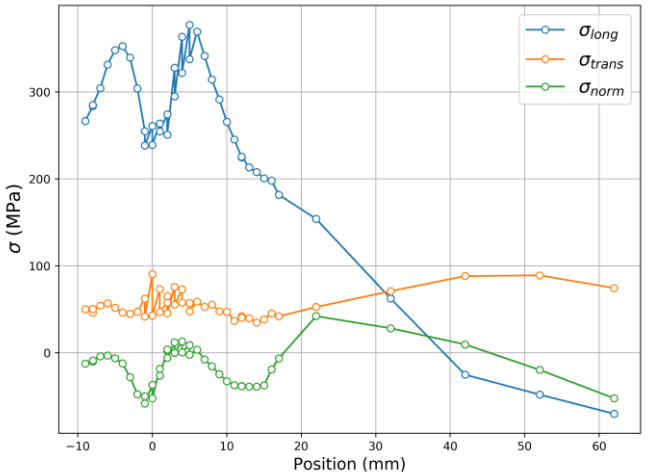
Operators
Favourable conditions for structural integrity assessments, ambition to “remove the weld”.

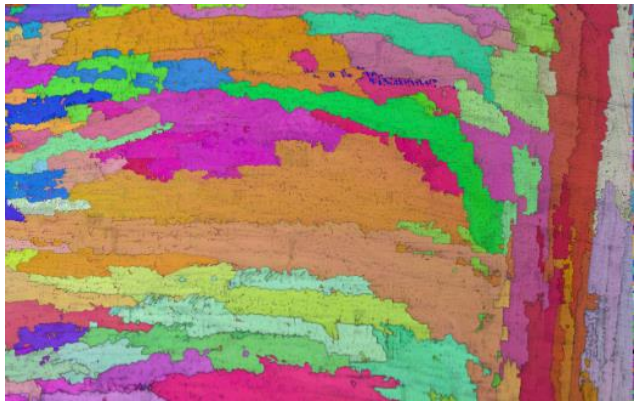
Key Project Outcomes

Manufactured a range of **EB** and **LB** welds

Weld and parent material **characterised**

Crystal plasticity modelling developed for welds





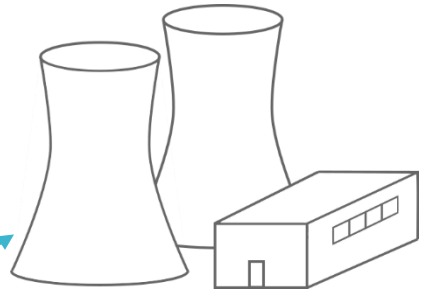
Developed a **modelling approach** for predicting residual stresses

Developed parameterised **residual stress profiles** for EB welds

Probabilistic methods

Benefits

Regulators
Gain confidence in degree of margin and conservatism present



OEMs
Intelligent conservatism for safer, more cost effective plants

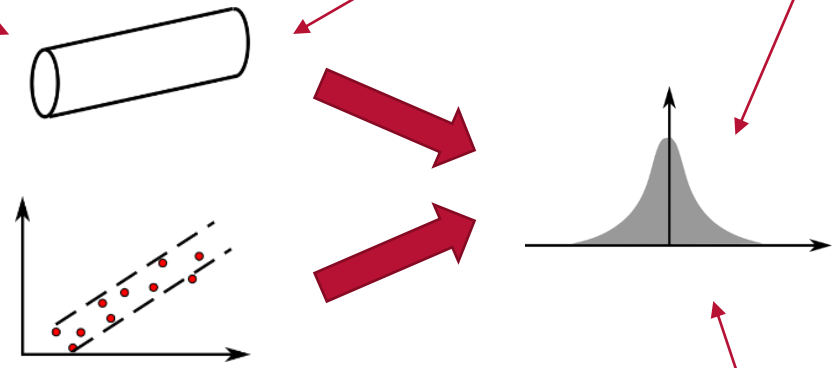
Operators
Identify critical influences on plant reliability

Key Project Outcomes

Measurements of variability in **Weld Residual Stress**

Guidance on design of **Response Surfaces**

Tools to specify **Scale of Monte Carlo** analysis



Models of **Material Variation**

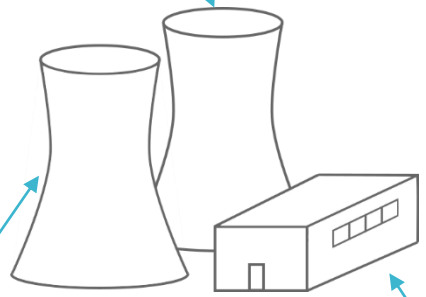
Means to account for **Limited Data**

Framework applied to **Structural Integrity Case Study**

Fracture modelling

Benefits

Regulators
Gain confidence from a wide body of evidence that the failure mechanisms are well understood and controlled



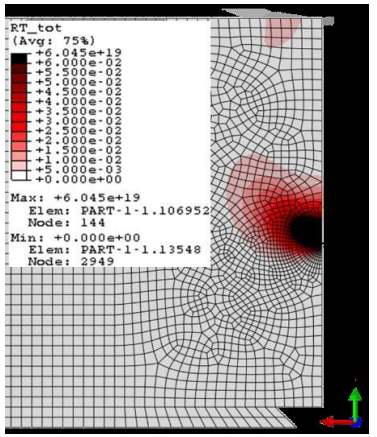
OEMs
Reduce the cost of manufacture by simplifying assessments and the thickness of components

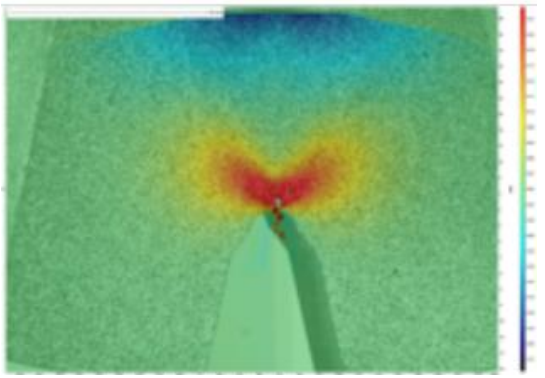
Operators
Reducing known conservatisms in assessment procedures

Key Project Outcomes

Investigated effect of **thermal exposure** on fracture toughness

Mechanistic **understanding** of 316L weld failure





Developed a **modelling approach** incorporating novel damage models

Automation of modelling process for improved efficiency

Characterised **fracture** in 316L weldments

The impact

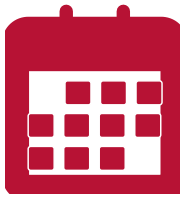
Research focussed on reducing the blockers for the wide-scale use of power beam welding techniques in the nuclear industry. The adoption of power beam welding by the nuclear industry could significantly cut manufacturing costs.

24 Engineers

Upskilling the UK workforce across industry and academia in new reactor technologies with wider dissemination to UK community

2 years

Coordinated research topics informed by an initial scoping investigation



Collaborations

ATLAS+, FESI working group on probabilistics, R5 & R6 panels, NIPCG, NNUMAN Community

10 conference papers

Covering both national and international conferences

Summary and future research requirements

- Greater **flexibility** in design – the right technique for the right application
- **Reduced risk** in power beam welded components due to greater understanding
- Enhanced **structural integrity** assessment codes – make them fit for nuclear new build
  - Fracture methods
  - Weld residual stress profiles
  - Probabilistic approach

- Portfolio of evidence to support and develop design & assessment codes
- Link design and operation more closely to minimise through-life costs
- Increase the MRL of electron and laser beam welding in nuclear
- Demonstrate capability

Don’t want to ask your question now? Come and find out more about our research and how you can be involved at stand 11, in the exhibition room.

www.innovationfornuclear.co.uk

Thermal hydraulics

Securing skills and developing models through Nuclear Thermal Hydraulics research and innovation in the UK for SMR and AMR technologies.

Advanced Manufacturing Materials

Developing understanding in advanced joining techniques for nuclear applications. Helping to unlock the blockers for the adoption of new technologies in nuclear new build.

Safety & Security

Researching new techniques and methods that provide engineers with a greater insight into their reactor technology’s safety and security performance, empowering them to make risk informed decisions that drive cost reduction.