The University of Manchester
Dalton Nuclear Institute

UK Nuclear Academics Meeting
University of Cambridge
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Generation-IV: Opportunities for UK Academics

Tim Abram

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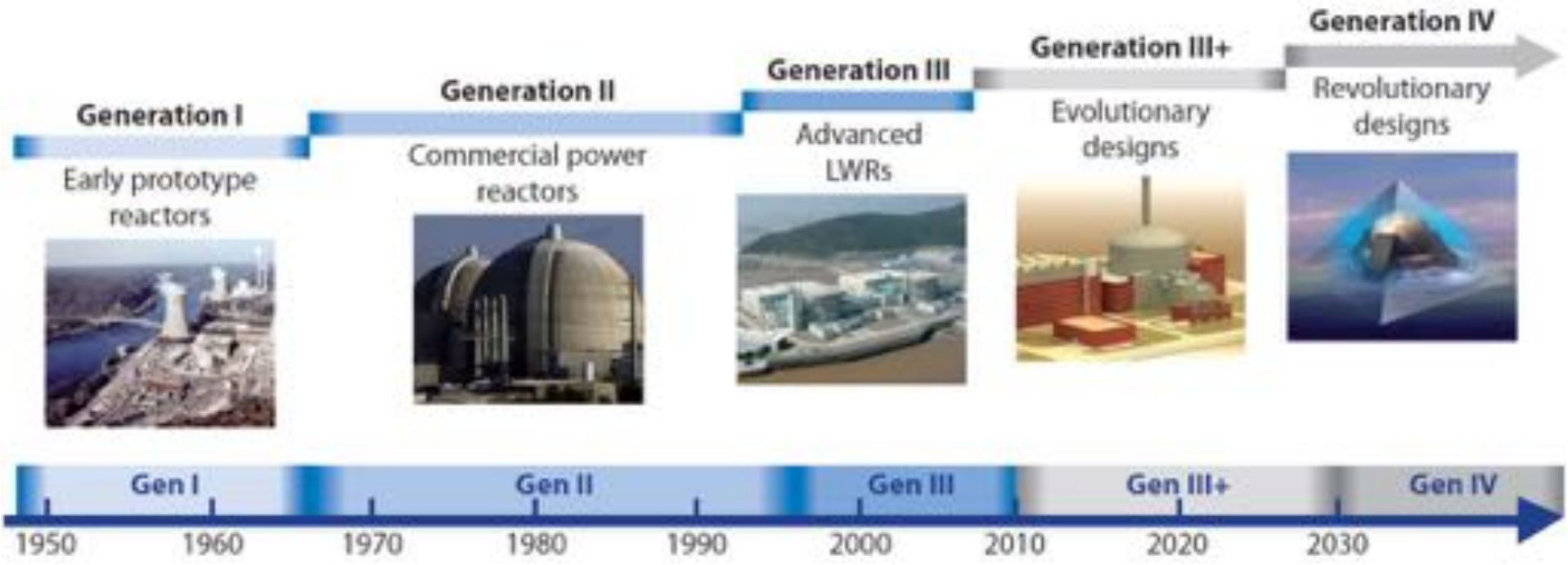
Gen-IV: origins and objectives

- GIF proposed by US DOE in 2000. Originally 9 member states; now 13 plus EU
- Aims to promote the development of the next "generation" of nuclear energy systems, commercially available after 2020 but before 2030
- With significant advances and competitive performance in:

Sustainability / Safety & reliability / Proliferation resistance / Economics

- Flexibility to address different applications: electricity, hydrogen, etc.
- Research is "pre-competitive"



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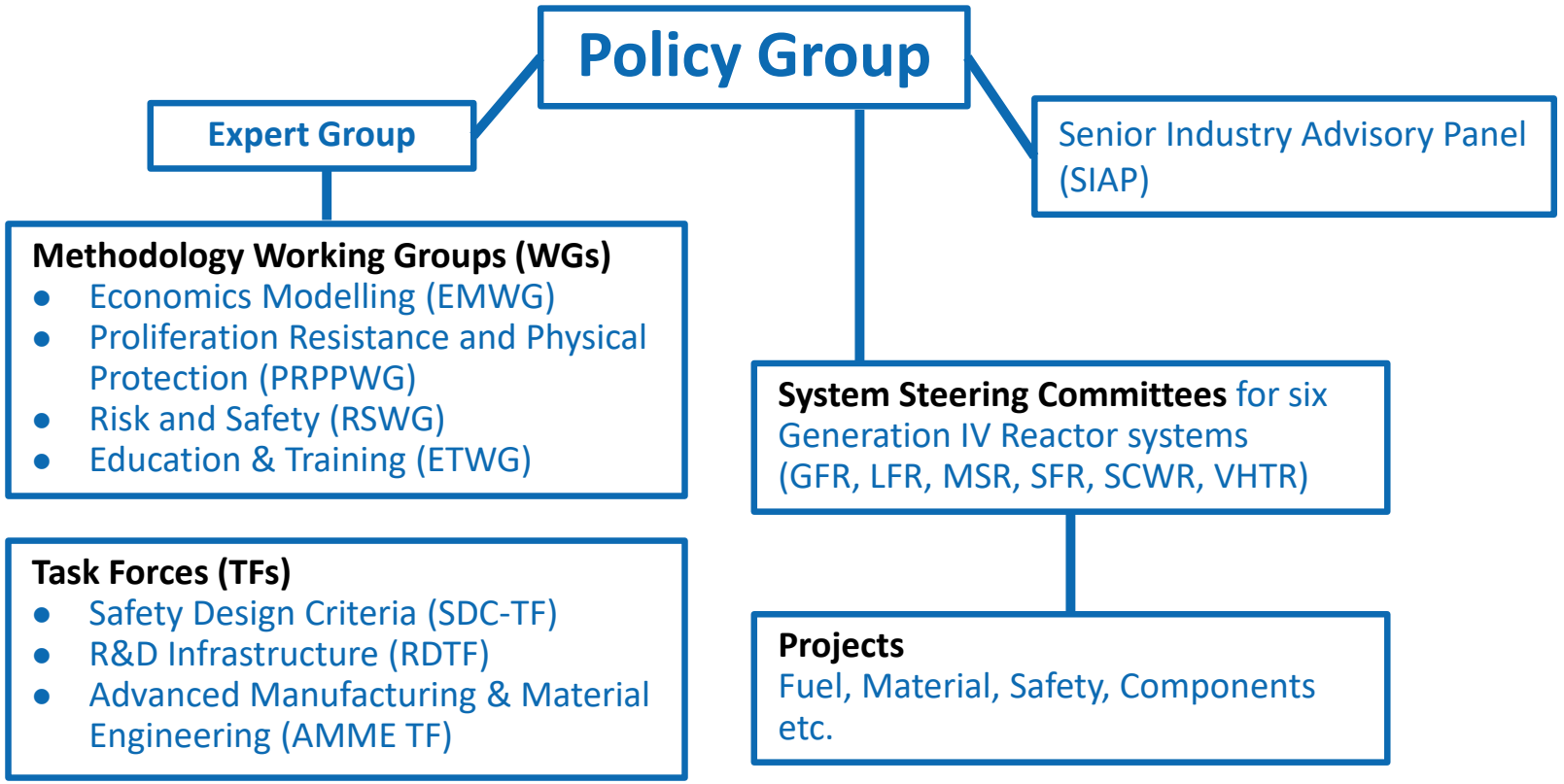
GIF: structure and funding



- No central research fund ☹ All activities are funded by the GIF members
- Members propose contributions that are consistent with the research needs elaborated in the System Research Plans
- Proposed contributions are assessed (and voted on) by the Project Management Boards and System Steering Committees

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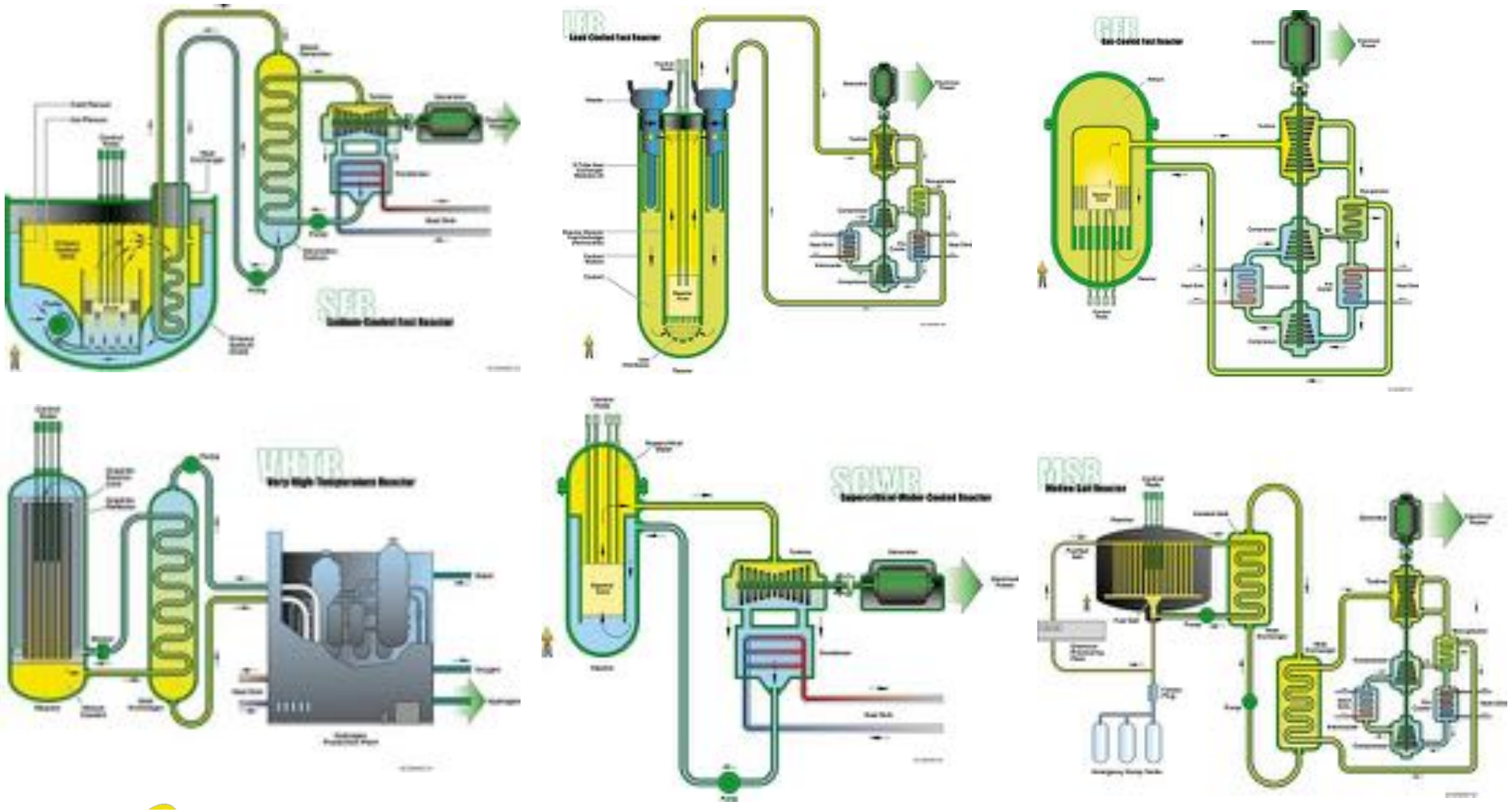
Gen-IV systems

- Originally selected from over 150 candidates in 2000 (not updated since)
- The 6 systems represent ‘families’ of reactors, rather than specific designs



UK priority systems

- UK has identified the **Very High Temperature Reactor (VHTR)** and the **Sodium-cooled Fast Reactor (SFR)** as priority systems.
- UK representatives engaged across almost all VHTR and SFR working groups
- These systems do not represent a single design, but rather a family of technologies.
- Previous UK experience focussed on prismatic core HTRs and pool-type SFRs (although DFR was a loop-type), but remains highly relevant to other designs

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Rationale for selection of UK priority systems

VHTR	SFR
UK has unrivalled experience in the design, licensing, operation, and decommissioning of gas-cooled graphite-moderated reactors.	UK experience in SFR technology remains internationally significant (although operational experience is > 25 years ago).
Significant technical capability within academia, industry, and regulators.	Some residual technical capability within academia, industry, and regulators.
High temperatures provide flexibility to meet a range of energy demands: electricity, industrial heat, co-generation.	Higher temperatures offer better flexibility than LWRs (although less good than (V)HTRs).
Highly resilient fuel enables **inherent** safety, i.e. much reduced (arguably no) requirement for engineered safety systems.	Unrivalled **demonstrated** sustainability: high utilisation of fissile resource and ability to manage actinides. (Not an urgent requirement, but will clearly become important over time.)
Well suited to provide local power (important for process heat).	

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GIF partner priority systems

SFR			●	●	●	●	●			●	●	●
VHTR	●	●	●	●	●	●			●	●	●	●
LFR			●		●	●	●			●		●
SCWR		●	●		●		●					●
GFR				●	●							●
MSR	●	●		●			●		●	●		●

● : signatory of System Arrangement
● : signatory of Project Arrangement
● : signatory of MoU

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Research themes

- GIF research is primarily organised according to reactor type
- For each system, research is co-ordinated by a **System Steering Committee**
- Research themes are led by **Project Management Boards**, that report to the SSC
- The six SSCs report to the **Policy Group**

VHTR SSC (Tim Abram)	**SFR SSC** (Nick Barron)
Materials (Andrew Wisbey) ○ Graphite sub-group (James Marrow) ○ Ceramics sub-group (Ping Xiao) ○ Metals sub-group (Grace Burke)	**System Integration and Assessment** (Zara Hodgson)
Fuel & Fuel Cycle (Robin Grimes)	**Advanced Fuels** (Mark Sarsfield)
Computational Methods (John Lillington)	**Component Design** (John Stairmand)
Hydrogen Production (Aiden Peakman)	**Safety and Operation** (Colette Grundy)

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Working Groups and Task Forces

Several cross-cutting groups have been established within the GIF.
Their purpose is not to undertake research, but to:

- develop common and consistent evaluation methodologies and criteria that can be applied across all systems;
- catalogue R&D infrastructure resources available within the GIF community;
- engage with education and training communities;
- encourage sharing of best practice.

Methodology Working Groups	Task Forces
Economic Modelling (Fiona Reilly)	**Safety and Design Criteria** (Deborah Hill)
Proliferation Resistance & Physical Protection (Kevin Hesketh)	**R&D Infrastructure** (Jon Hyde)
Risk and Safety (Mike Finnerty)	**Education and Training** (Eugene Shwageraus)
	Advanced Manufacturing and Materials Engineering (Andrew Storer)

Examples of proposed UK contributions: VHTR Materials PMB

Proposed UK contributions are largely based on activities funded under the UK Nuclear Innovation Programme (e.g. AFCP), but can include work undertaken in other programmes (e.g. EPSRC projects).

Key requirements are:

- permission from the holder of the IP
- strong likelihood that the research will be funded (or already exists)
- relevance to the research needs identified in the GIF System Research Plans

Graphite (James Marrow and Nassia Tzelepi)

- Fracture behaviour of UK reactor graphite
- Microstructural characterisation of the thermally oxidised fine grained graphite and irradiated graphite
- Macroscale deformation & lattice strain of irradiated graphite
- Codes and standards work
- Modelling of high temperature fracture & constrained thermal expansion of graphite

Examples of proposed UK contributions: VHTR Materials PMB (contd.)

Ceramics (Ping Xiao and Dan Shepherd)

- Report on a thermal conductivity testing method for ion irradiated materials with test results for bulk CVD SiC and SPS SiC, including the effects of sintering aids and initial characterisation.

Metals (Grace Burke, Susan Ortner, and Andy Wisbey)

- Fracture performance of EB welded SA508 steels
- Development of ferritic-martensitic steels by micro-alloying
- Fatigue and tensile behaviour of additively manufactured stainless steel
- High temperature fatigue and creep behaviour of PM/HIP stainless steel
- Fatigue and creep-fatigue of PM/HIP IN-617 nickel base alloy
- Ion/proton irradiation of low alloy steels

Facilities underpinning potential UK VHTR contributions to the Fuel and Fuel Cycle PMB

NNL

- Kg-scale kernel manufacturing rig under commissioning

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- Gram-scale uranium-active CVD coater and compacting press / furnaces being installed
- U-active Hot Isostatic Press under order to investigate alternative compact manufacture and waste-form research

NNUF

- Ion beam irradiation facilities and U-active SEM, FIB, and TEM

Other potential contributions?

All suggestions welcome!

Remember the key requirements:

- permission from the holder of the IP
- strong likelihood that the research will be funded (or already exists)
- relevance to the research needs identified in the GIF System Research Plans

Contributions could be:

- existing research results (although if they're already fully published, their value as a UK contribution may be judged to be negligible)
- access to results from work already in progress or funded
- proposed new research (relevance to GIF may be helpful in justifying the research, but it can't be offered as a contribution unless there is a very strong likelihood of funding)

Suggest contacting the UK representatives from the relevant research theme

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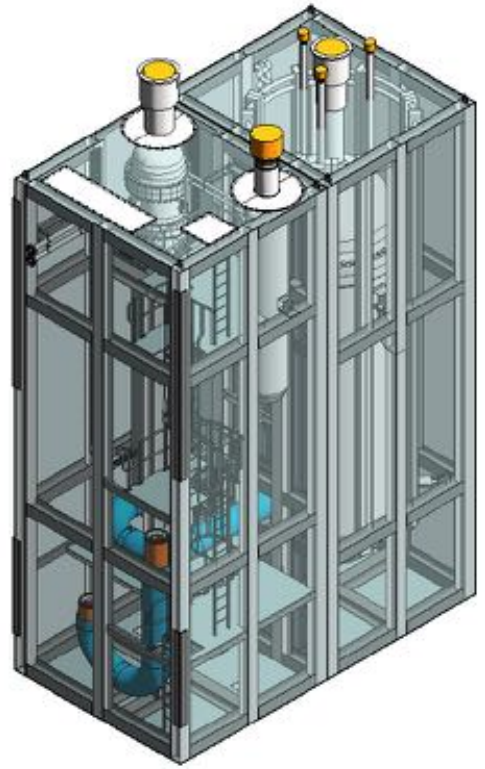
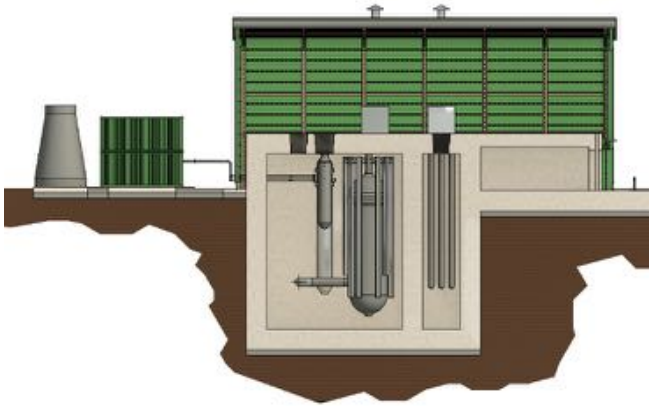
A UK (V)HTR Project – the U-Battery

- U-Battery is a very small prismatic core HTR (10 MWt heat output at 750^{o}C) aimed at supplying off-grid electricity and industrial process heat.
- Very conservative technology envelope, employing current commercial or near-to-market components.
- Secondary N_2 cycle allows use of an aero-derivative power turbine (being developed by Rolls-Royce), and removes the possibility of a steam ingress accident.
- TRISO fuel validated in a large-scale US irradiation and PIE programme
- Being developed by a consortium led by Urenco and involving Jacobs, Cavendish Nuclear, Rolls-Royce, BWXT, NNL, Kinectrics, Costain, Howden, Mammoet, NAMRC, and University of Manchester.





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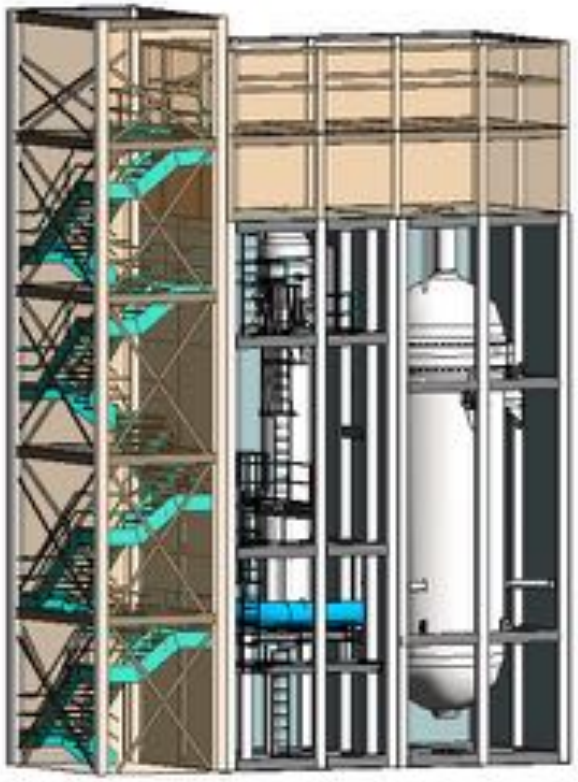
A UK (V)HTR Project – the U-Battery

- The BEIS-funded Advanced Modular Manufacturing and Materials programme is funding a manufacturing trial for mock-ups of the main U-Battery vessels (RPV, IHX, Cross-Vessel Duct).
- Aims are to explore the application of advanced manufacturing technologies at full scales, and to investigate techniques for modular manufacture, transport, and construction.
- All vessels have been fabricated by Manchester Precision Engineering and transported to Cavendish Nuclear at Whetstone
- Full-scale mock-up construction almost complete
- The facility will enable future investigations of operability, for example: maintenance access, refuelling access, etc.



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Thanks for your attention!