

UK Nuclear Thermal Hydraulics Test Facility and Modelling Research

Richard Underhill, Carolyn Howlett, Jordan McIntosh

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Our nuclear industry experience

- ▶ Frazer-Nash support to the nuclear industry spans over 30 years
- ▶ Approximately **35%** of our work **has a nuclear application**
- ▶ Our capability extends to over **400 people with nuclear experience**
- ▶ Our skills are relevant and widely applied to the nuclear lifecycle from **research and development**, through reactor design, safety substantiation (GDA), commissioning, operation and decommissioning to green field
- ▶ **We hold major contracts** with the UK regulator, operators, new build developers, reactor vendors, decommissioning companies and Tier 1 supply chain companies
- ▶ We provide support, professional engineering and technical services to **nuclear new build programmes**
- ▶ Safety is our number one priority and we nurture a company culture that promotes open challenge. All staff understand their responsibility to nuclear safety





Thermal Hydraulics – The Team

- ▶ Led by Frazer-Nash, the team comprises 6 core members:



The
University
Of
Sheffield.



Science & Technology
Facilities Council





UK Government funded research programs

- ▶ The UK Government's 2013 Nuclear Industrial Strategy proposed a series of shared commitments between Government and industry to grow the UK's industrial capability and enable a future where nuclear energy is a key pillar of the UK's 2050 energy mix.
- ▶ The UK Nuclear Innovation and Research Advisory Board (NIRAB) developed a series of research recommendations, and so far over £28 million of funding has been awarded:
 - ▶ Safety and security methodologies in nuclear design justification (Frazer-Nash – Project FOCUS)
 - ▶ Nuclear materials, advanced manufacturing and modular build (Frazer-Nash – Project FORCE)
 - ▶ Digital Reactor Design – Thermal Hydraulics (Frazer-Nash – Project FORTE)
 - ▶ Digital Reactor Design – Virtual engineering
 - ▶ Advanced nuclear fuels and recycling
 - ▶ Materials and manufacturing
- ▶ In addition, the UK government has awarded funding to support advanced reactor technologies through a two-stage advanced modular reactor programme (£4 million in Stage 1)

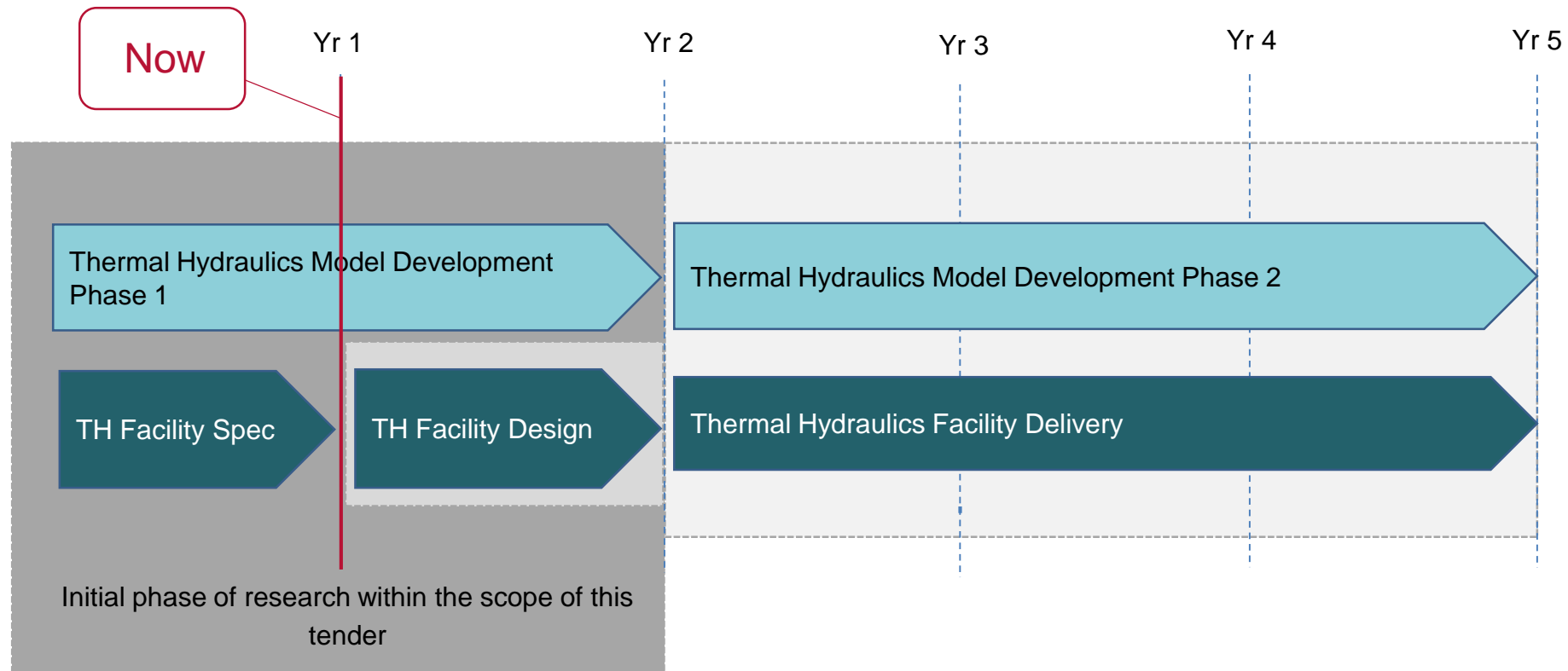


Vision for UK thermal hydraulics

- ▶ Thermal hydraulics is key to the overall system integration and design of reactor plants and it is important to build this capability now to position the UK to take advantage of nuclear new build, SMR deployment and Gen-IV reactor development.
- ▶ Specific requirements to support a strong thermal hydraulics capability in the UK are:
 - ▶ UK National Nuclear Thermal Hydraulic Facility - Delivering a national thermal hydraulic experimental facility to develop and validate new thermal hydraulic models. An experimental facility will be critical in underpinning the safety case for new reactor designs and validating models.
 - ▶ Model Development and Validation Programmes - Devising and implementing new thermal hydraulics models, able to accurately predict passive flows and regimes associated with SMRs and Gen-IV reactors will aid the design, development and evaluation of future reactor designs.
- ▶ Our vision is to develop an **integrated experimental and modelling capability** in nuclear thermal hydraulics across **industry and academia** in order to enable the UK to be a significant partner in the global deployment of advanced reactor technologies

Thermal Hydraulics R&D plan

- ▶ 5 year Integrated Programme of Research and Development for Reactor Thermal Hydraulics





Thermal Hydraulics - First Phase Objectives

- ▶ **Thermal Hydraulic Test Facility (1 year)**
 - ▶ A Critical Review of the State-of-the-Art in thermal hydraulic test facilities worldwide
 - ▶ A Specification for a UK thermal hydraulics test facility
 - ▶ Identification of opportunities to use the facility to benefit other 'NIRAB' programmes

- ▶ **Thermal Hydraulic Modelling (2 years)**
 - ▶ A Critical Review of the State-of-the-Art in thermal hydraulic prediction capability
 - ▶ A Specification for an innovative thermal hydraulics modelling capability
 - ▶ Initial Innovative Models



Test Facility Specification

- ▶ The test facility is anticipated to be **completed in 2022** and will provide a much needed resource to support the UK nuclear industry
- ▶ As part of the specification process, Frazer-Nash has
 - ▶ Reviewed existing thermal hydraulic test facilities around the world
 - ▶ Engaged with industry and academia to identify user requirements
 - ▶ Engaged with other test facilities around the world
 - ▶ Developed a high level specification for the overall facility
 - ▶ Identified options for the initial test rig
- ▶ The test facility is expected to be flexible in order to support Gen-IV reactor technologies in the future
- ▶ This will promote a greater UK involvement in international programmes and support the world-wide nuclear industry

Thermal hydraulic modelling and initial development

- ▶ Critical review of state of the art in thermal hydraulic modelling completed
- ▶ Industry, academia and software vendors contacted via questionnaire to understand requirements for model development.
- ▶ Workshop held on 10 April 2018 with over 30 members of UK thermal hydraulics community, which focussed on 8 core areas for modelling development:
 - ▶ **Multi-fidelity** - The use of modelling methods across the full range of fidelities and scales
 - ▶ **Best Practice and Uncertainty Evaluation** - Improving the confidence in and quality of model predictions
 - ▶ **Boiling and condensation** - The application of and improvement to mechanistic modelling predictions
 - ▶ **Large-scale multi-phase flows** - The prediction of the effects of complex, transient, multi-phase flows
 - ▶ **Advanced fluids** - The additional challenges of molten metals, molten salts and supercritical water
 - ▶ **Multi-physics** - The coupling of thermal hydraulics modelling with neutronics and chemistry
 - ▶ **Turbulent flow** - The prediction of pressure drops, mixing and buoyancy driven circulation
 - ▶ **Turbulent heat transfer** - The prediction of heat transfer and buoyancy influenced convection

Smart component model

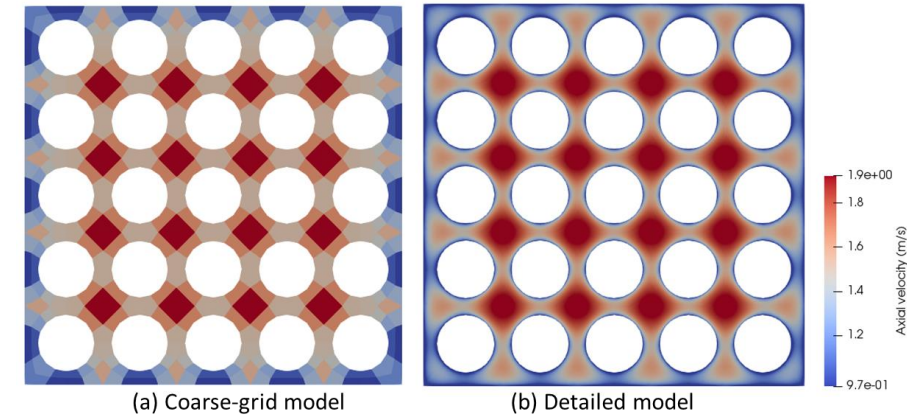
▶ Objective

- ▶ Methodology development, validation and application of a coarse-mesh model for Pressurized Water Reactor (PWR) fuel channels
- ▶ Advanced turbulence modeling & numerical methods using high fidelity model

▶ Innovations

- ▶ Using sub-channel correlations to account for the frictional resistance in an innovative coarse-grid CFD approach for PWR fuel channels
- ▶ Embedding the coarse mesh fuel channel model with detailed subdomain models through code coupling technique
- ▶ Developing and demonstrating a new method to improve CFD simulations in conditions that are frequently encountered in fuel channels

Coarse grid model of fuel bundle



IAEA CRP on Understanding and Prediction of Thermal-Hydraulics Phenomena Relevant to SCWRs



Innovative methods to model single-phase and two-phase flow

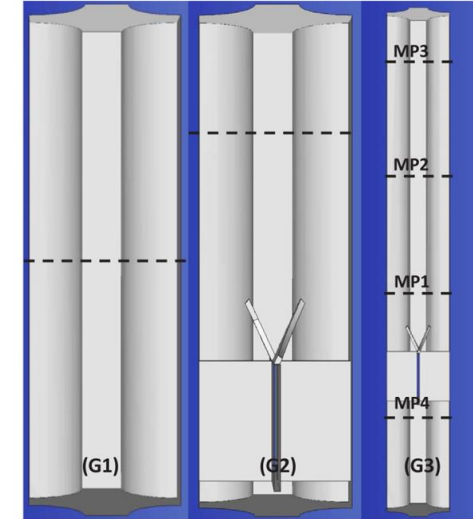
▶ Objective

- ▶ Development of robust, innovative turbulence and thermal models
- ▶ These models can then be implemented in Smart Models, system simulators, or used to study local flow phenomena and improve physical understanding relevant to all nuclear technologies
- ▶ Flow phenomena considered include:
 - ▶ Internal shear flows
 - ▶ Natural circulation

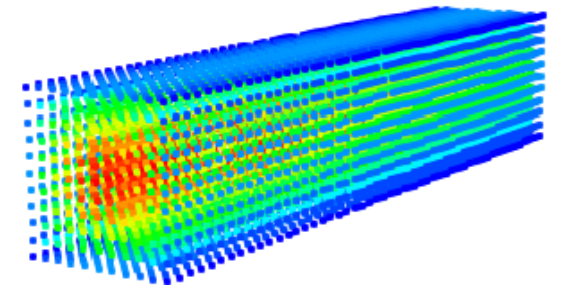
▶ Innovations

- ▶ Use of Finite Volume (FV) methods with advanced wall functions, non-linear eddy-viscosity, stress transport models, temperature variance transport models and models for the turbulent heat fluxes
- ▶ Development of Smoothed Particle Hydrodynamics (SPH) methods to single-phase and two-phase, turbulent heat transfer applications

Argonne DNS fuel bundle test case



Iterative shifting of SPH particles



Different media

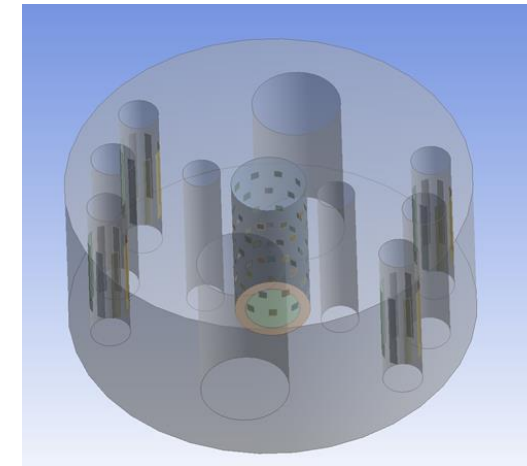
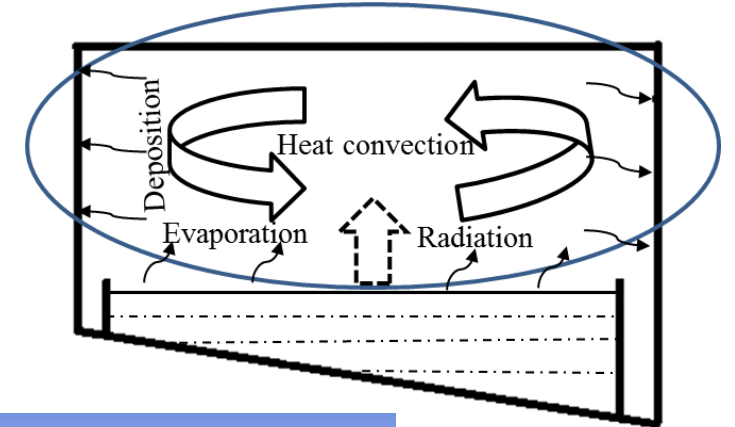
▶ Objective

- ▶ Retrieval of experimental research carried out by University of Manchester during 1980-90s
- ▶ Development of smart model for aerosol dynamics and heat transfer in the cover gas region for a Sodium-cooled Fast Reactor (SFR)
- ▶ Modelling of liquid metal heat transfer in SFRs and numerical study of mixed convection of liquid metal

▶ Innovations

- ▶ Aerosol dynamics and heat transfer in the cover gas region of Sodium-cooled Fast Reactors
- ▶ Research of fluids with unconventional properties in liquid metal reactors, and the development of numerical model for pool thermal hydraulics

Manchester experimental rig



Upper plenum of E-SCAPE test facility 13



Summary

- ▶ Frazer-Nash is leading a UK government initiative to:
 - ▶ Specify a UK National Nuclear **Thermal Hydraulic Test Facility**
 - ▶ Specify **innovative model developments** to support future reactor design
- ▶ Initial research is underway, future research projects have been identified and the facility is anticipated to be **completed in 2022**
- ▶ Our vision is to develop an **integrated experimental and modelling capability** in nuclear thermal hydraulics across **industry and academia** in order to enable the UK to be a significant partner in the global deployment of advanced reactor technologies
- ▶ We want to increase UK collaboration in world-wide nuclear thermal hydraulics research

HOW CAN WE COLLABORATE WITH YOU



Richard Underhill, Technical Manager

Email: r.underhill@fnc.co.uk

www.fnc.co.uk