United Kingdom
National Nuclear
Laboratory

HENRY ROYCE INSTITUTE

UK FISSION MATERIALS ROADMAP

INTERIM REPORT

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FOREWORDS

Prof. Dave Knowles CBE FREng
CEO, Henry Royce Institute

The United Kingdom stands at a pivotal moment in renewing its nuclear capability, driven by the need for secure, low-carbon energy and a clear ambition for a new era of deployment.

At the heart of this renaissance is materials science. From structural components to fuels and wasteforms, materials determine the safety, performance and lifetime of nuclear systems. The choices made today will shape the UK's energy system for decades.

This interim Fission Materials Roadmap is both timely and important. It reflects a coordinated national effort, aligning with the UK Industrial Strategy and the Royce National Materials Innovation Strategy to translate research excellence into economic impact and strengthen sovereign capability.

Energy security is central to this agenda. A strong domestic materials capability underpins resilient nuclear deployment, reduces supply chain dependence and supports the full reactor lifecycle.

Delivery also depends on people. Building a skilled workforce, from apprentices to technical leaders, is essential to realising the UK's nuclear ambitions.

This interim report captures the community's collective insight and sets the direction for the full roadmap, inviting continued engagement to ensure the UK leads in materials innovation for a safe and secure nuclear future.

Dr Gareth Headdock
Chief Science and Technology Officer and Deputy CEO, UKNNL

This is a genuinely exciting moment for nuclear in the UK.

With new build underway, a new generation of reactors in development and a government committed to making Britain a clean energy superpower, the decisions we make now about materials science will shape our future nuclear capability.

As the UK government's lead civil laboratory for nuclear fission, UKNNL has a clear mandate to enable and deliver nuclear outcomes for government and support the growth of the nuclear sector. This Fission Materials Roadmap is a direct expression of our role.

Working with colleagues at the Henry Royce Institute, we have collated expertise from industry, academia, national laboratories and government around shared challenges. This interim report captures the key themes and priorities emerging from our work and sets the direction for the full roadmap to be published later this year.

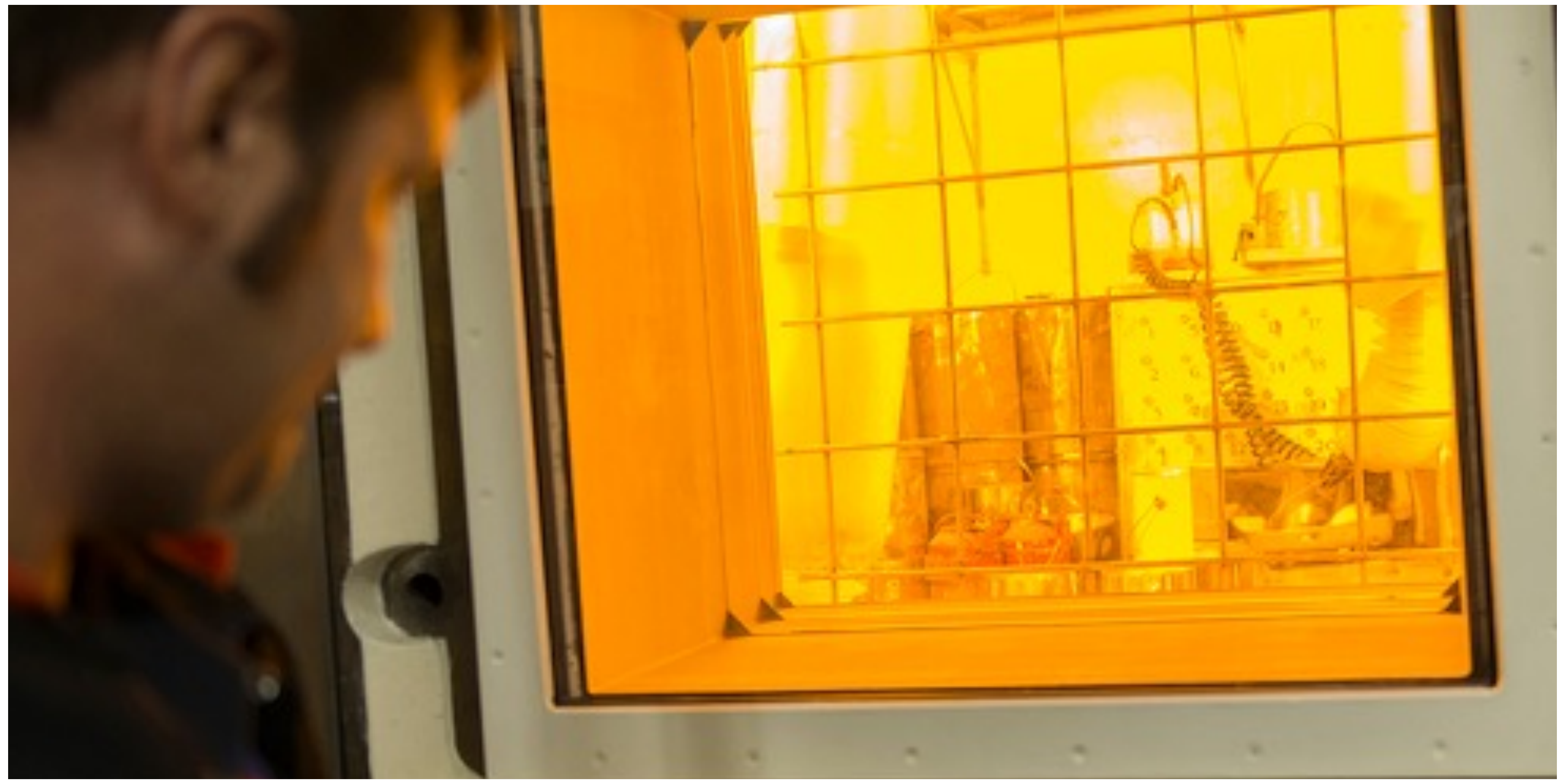
No organisation can deliver on our nation's nuclear ambitions alone. This interim report represents the sector speaking with one voice about its priorities, with a commitment to turning our collective insight into action.

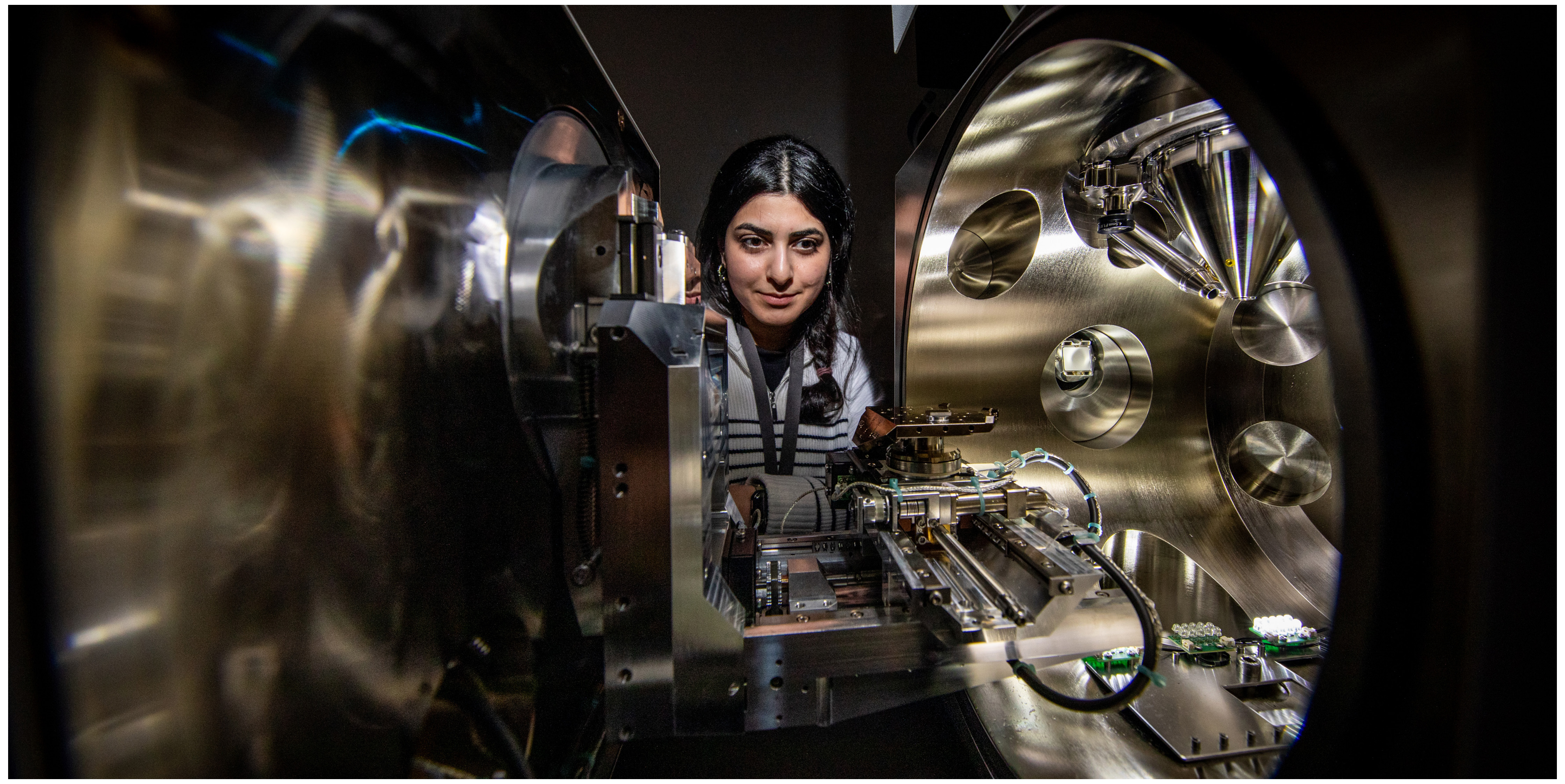
INTRODUCTION

The UK government's ambition to provide clean, secure energy by delivering a 'golden age of nuclear' means it is necessary to ensure nuclear reactors can be designed, operated, monitored and subsequently decommissioned safely, effectively and efficiently.

This requires a detailed understanding of the materials used to build and run reactors, how they behave during service and what innovations could be made to extend their lifetime or performance to meet the demands of next-generation technologies.

That is why over 100 key representatives from across industry, academia, research councils, national laboratories and government have come together to develop the UK Fission Materials Roadmap.





UK FISSION MATERIALS ROADMAP

The roadmap is timely because:

- The UK is building new nuclear capacity for the first time in decades, with Hinkley Point C under construction, Sizewell C planned and a new generation of Small Modular Reactors to be developed at Wylfa.

- The decisions we take today will shape reactors for decades. Many of the materials used in older reactors are approaching, or beyond, their original design lifetimes. The newer reactor designs being developed today, such as High-Temperature Gas-Cooled Reactors, require materials that push the boundaries of current understanding. The research needed to qualify these materials and demonstrate they are safe can take many years, so decisions and investments are needed now to build future reactors.

- From the steels that hold reactors together to the fuels that power them, and the safe, long-term treatment and disposal of waste, the roadmap will set out what is needed and, crucially, when decisions must be made.

- Convening experts to discuss the challenges and opportunities ahead (e.g. skills needs and regulatory reform) and using collective knowledge to make key recommendations will provide crucial direction for the sector to proceed with confidence.

This interim report sets out the scope of the upcoming roadmap and provides an overview of the key themes and challenges identified during expert group workshops. Our aim is to generate wider discussions and draw maximum further input for the final roadmap planned for later in 2026 by providing a high-level first insight of the key focus areas and activities to date.


STRUCTURAL MATERIALS
IRRADIATION DAMAGE
FUELS AND CLADDING
DISPOSABILITY OF MATERIALS

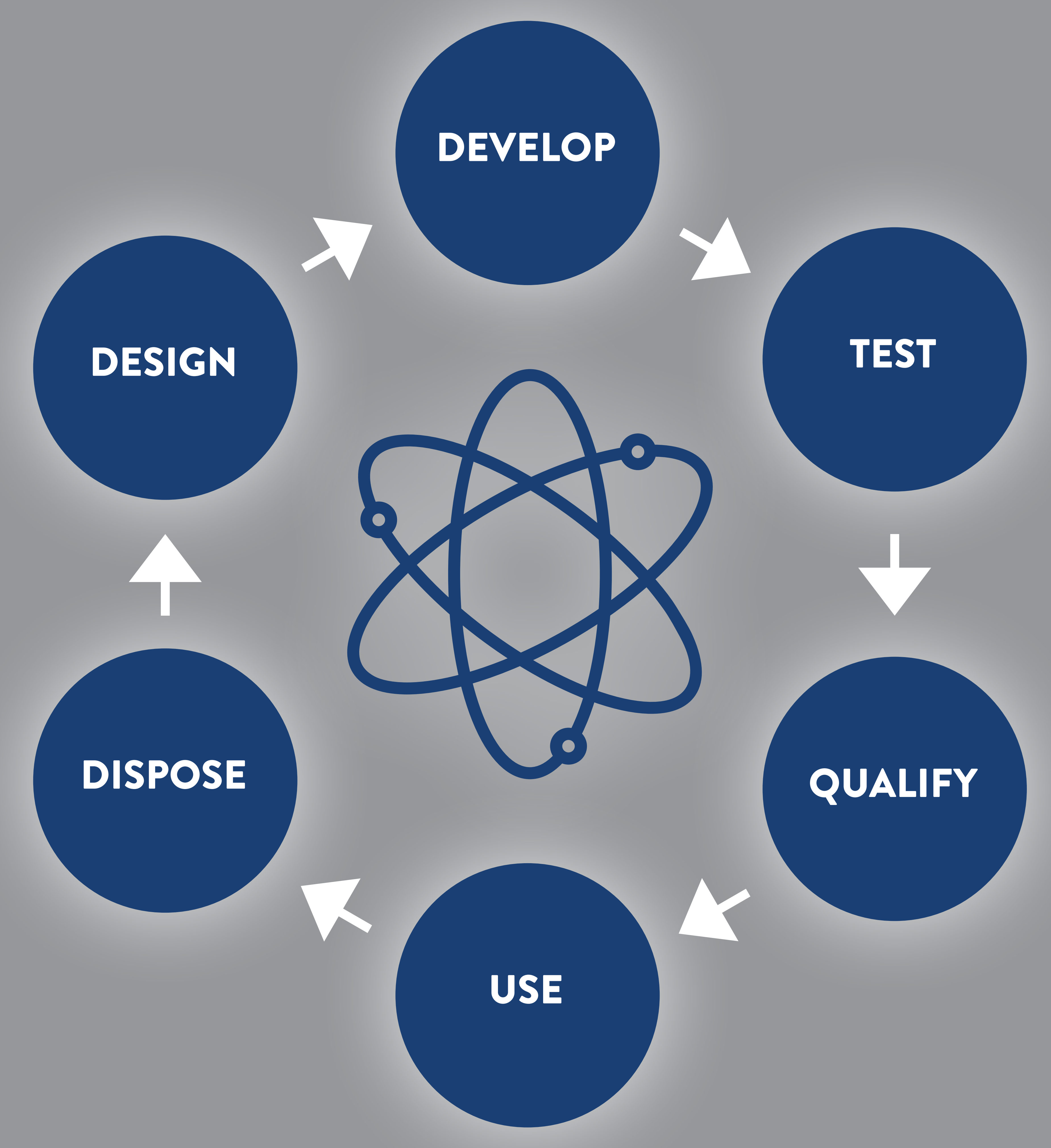
PURPOSE

The Fission Materials Roadmap will set out a coherent, strategic framework to guide UK fission materials research and development (R&D).

It is designed to clarify what actions are required, and by when. It aims to highlight the various opportunities for driving new activity and investment across the sector.

Ahead of the full roadmap's publication in late 2026, this interim report outlines the key themes, cross-cutting priorities and essential enablers that will underpin the final strategy.

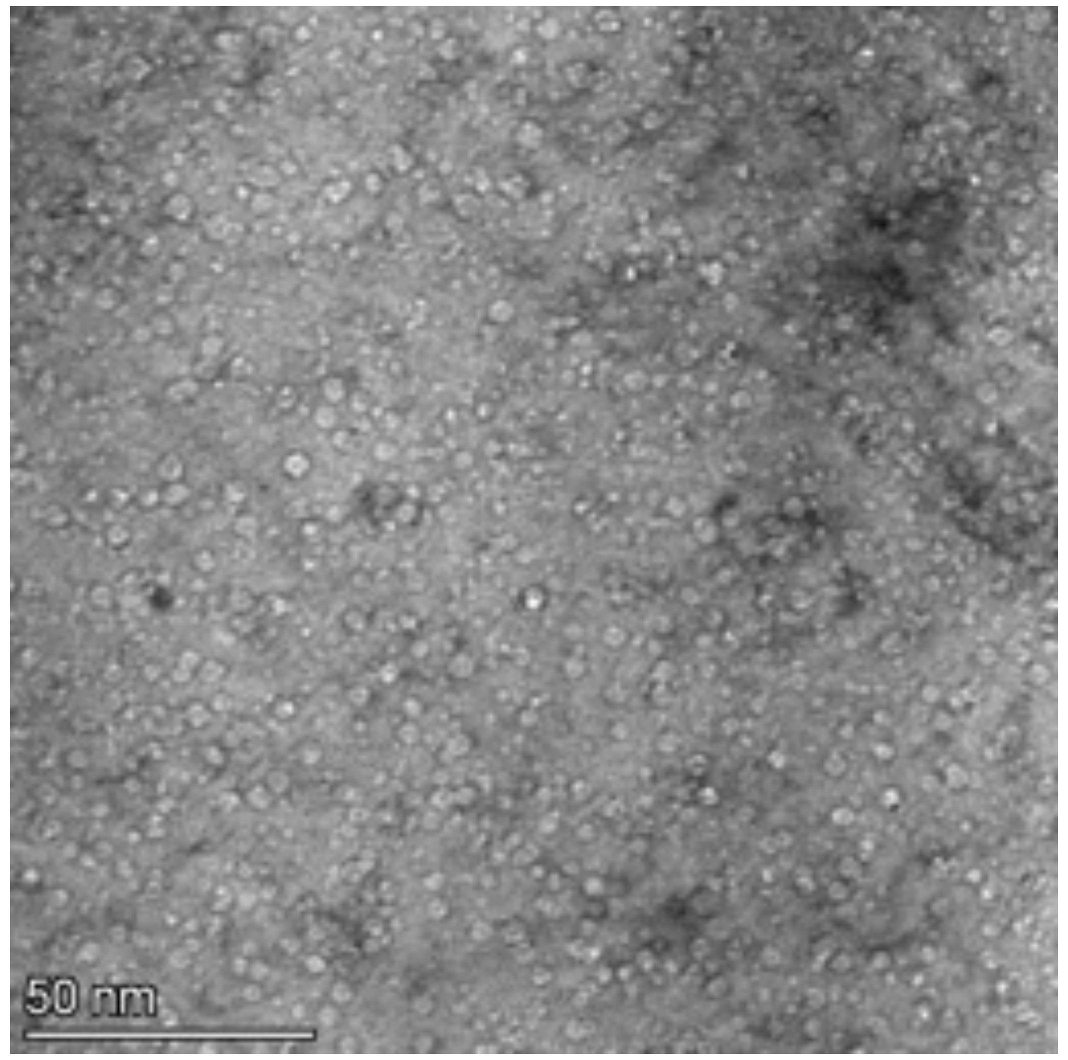
MATERIALS FOR NUCLEAR FISSION APPLICATIONS

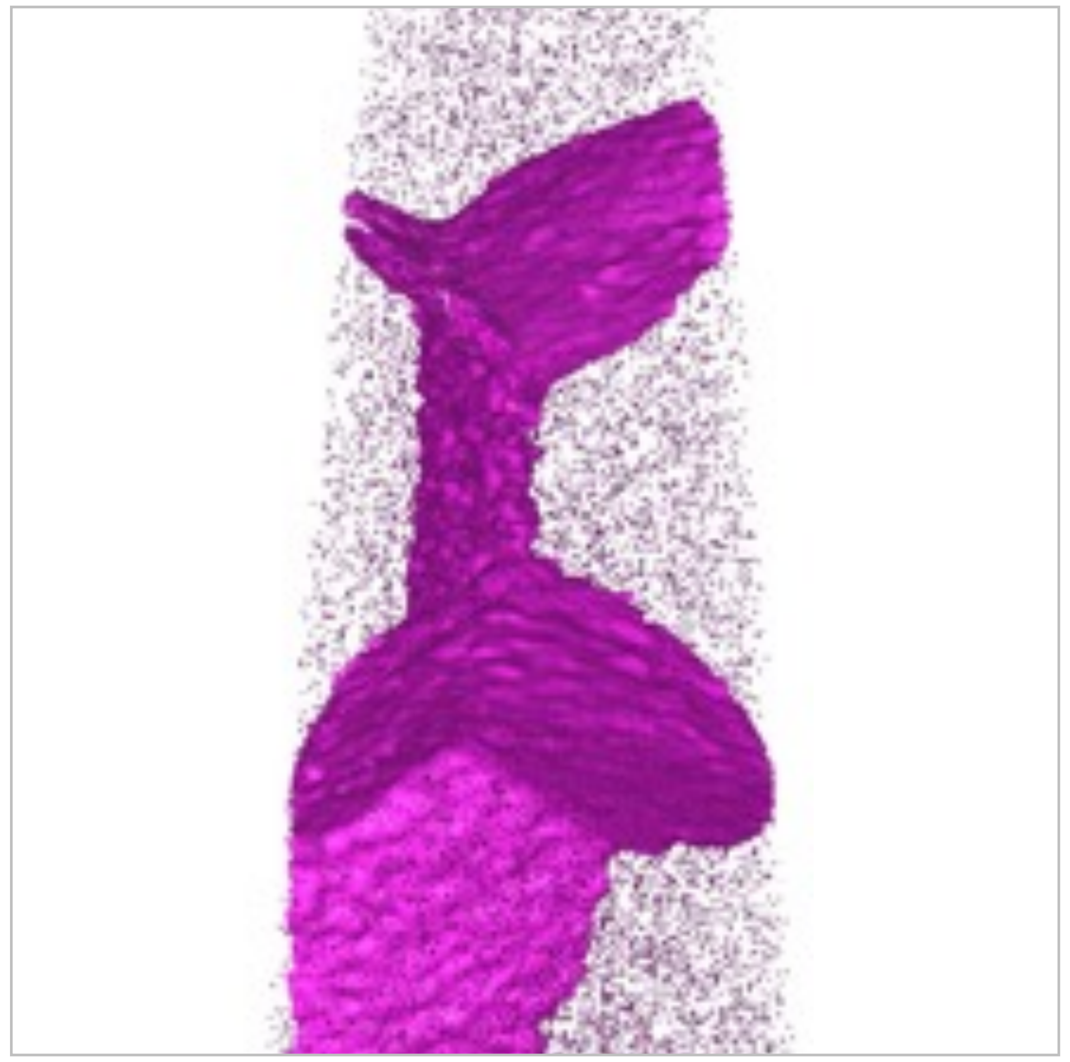
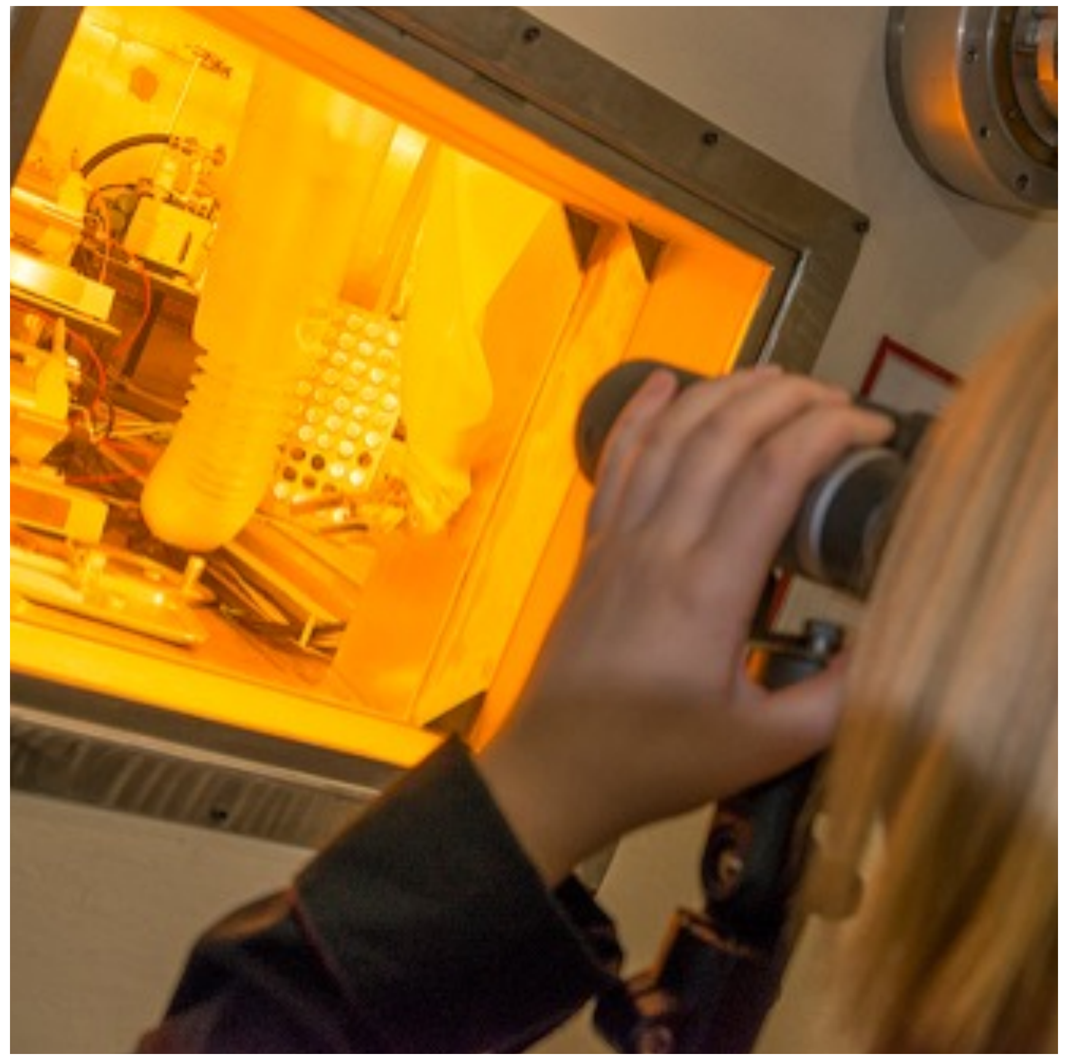
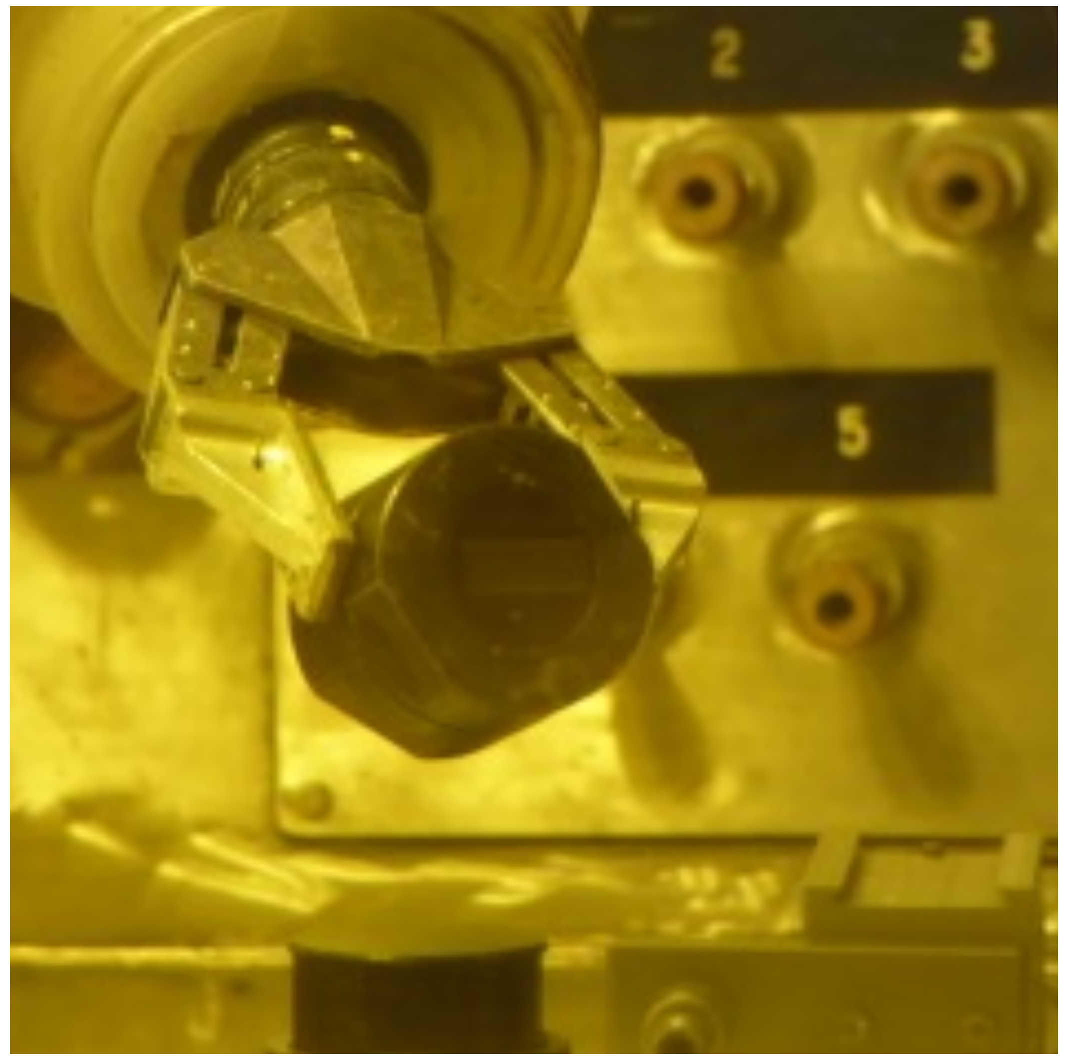


SCOPE

The UK Fission Materials Roadmap primarily focuses on civil materials, but it also recognises that there will be synergies and overlaps with defence and fusion needs. The scope includes:

- Key materials needed to ensure nuclear reactors can be designed, operated, monitored and subsequently decommissioned safely, effectively and efficiently
- Materials aspects across the fuel cycle from mining and enrichment, legacy plutonium and special nuclear materials, and disposal
- Disposability and waste minimisation
- Critical activities that are unique to nuclear



ROADMAP DEVELOPMENT

The roadmap was developed in three phases, with input and engagement from across the sector throughout the process.

Phase 1

Small workshop to define the scope

Phase 2a

Detailed technical topic workshops

- **21** online workshops
- **190** contributions
- **87** individuals
- **34** organisations

Phase 2b

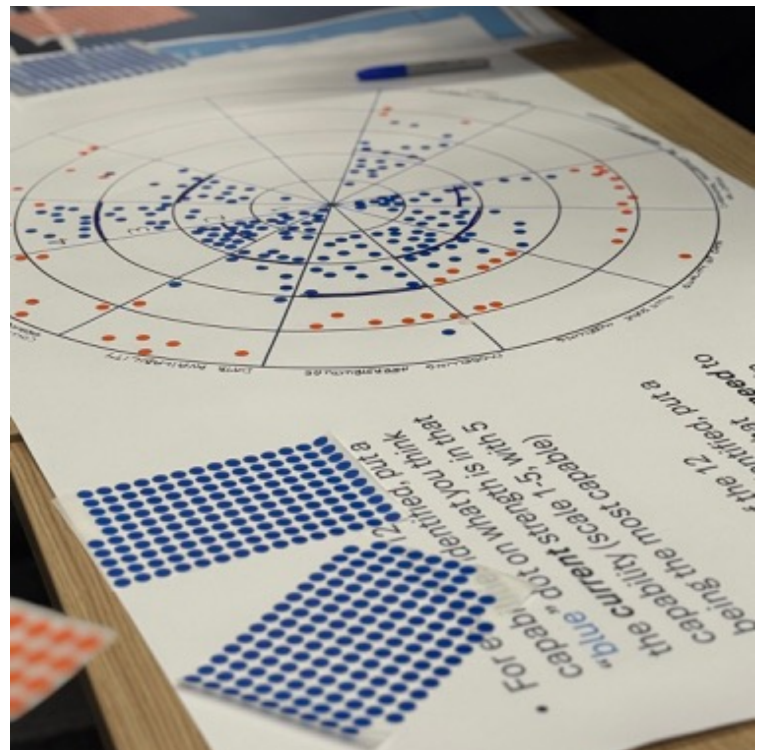
Cross-cutting workshop

- **2-day** in-person workshop
- **39** attendees
- **15** organisations

Phase 3

Write-up:

- analysis
- feedback
- reporting
- publication



THEMES

The roadmap identifies four major themes:

- **Structural Materials**
- **Fuels and Cladding**
- **Disposability of Materials**
- **Irradiation Damage**

The Disposability of Materials and Irradiation Damage themes interlink strongly with the Structural Materials and Fuels and Cladding themes.

STRUCTURAL MATERIALS

STRUCTURAL MATERIALS

This theme covers key structural materials used to build reactors.

For the roadmap, we have limited the scope of this area to materials integral to the reactor itself, including the reactor core internals, reactor pressure vessel, primary circuit coolant system pipework, structural graphite, steam generators and pressurisers (not all of these are relevant to all designs).

Key structural materials include, but are not limited to, ferritic and ferritic/martensitic steels, austenitic stainless steels, nickel-based alloys and graphite.

Within this theme, the roadmap addresses six subtopics or challenges. These are:

MANUFACTURING/JOINING

- This includes advanced manufacturing and joining and their qualification.

SURFACE ENGINEERING/MODIFICATION (including corrosion)

- This includes coatings (manufacture and in-service performance) and corrosion performance of materials.

GRAPHITE

- This includes waste volume reduction, qualification of new graphite grades and material performance, both in situ and ex situ.

HIGH-TEMPERATURE (600–1000 °C) STRUCTURAL MATERIALS

- This includes environmental and corrosion effects, high-temperature properties, structural integrity assessment and irradiation performance.

INSPECTION

- This includes corrosion monitoring and non-destructive testing/structural inspection.

MODELLING

- This includes phase diagram predictions and incorporation of models/instrumentation to validate modelling.

INITIAL OUTPUTS

Access to post-irradiation examination (PIE) facilities is key to success:

Access to reliable PIE facilities will be crucial to the characterisation of irradiated materials (either archive or new from MTR test programmes) and to understanding their performance. Easier access for academics and streamlined material transfers across sites are key.

Access to PIE facilities is also relevant to the fuels and cladding, and disposability themes.

The role of digital transformation

Digital transformation offers enormous potential to accelerate materials development through design-by-fundamentals and accelerated qualification. Multiscale modelling frameworks integrating atomic-to-engineering models with data and machine learning/artificial intelligence (AI) could provide rapid advancement of understanding.

Linking this to the development of a materials archive will allow a more rapid development of digital methods without the need for new irradiations, at least in the short term.

FUELS AND CLADDING

FUELS AND CLADDING

This theme covers the materials used in the reactor core, encompassing the fuels and their associated cladding.

Within this theme, the roadmap also touches upon the core design and aspects of reactor technology that can enhance materials performance.

Within this theme, the roadmap addresses five subtopics or challenges. These are:

MINING, ENRICHMENT, CONVERSION/ DECONVERSION

- This includes domestic production and deconversion of of high-assay low-enriched uranium (HALEU).

REACTOR TECHNOLOGY AND CORE DESIGN FOR MATERIALS PERFORMANCE ENHANCEMENT

- This includes reactor technology prioritisation of materials.

NOVEL ALLOY SYNTHESIS/MANUFACTURE

- This includes novel/advanced development of new fuel concepts, and advanced manufacturing capability.

FUEL PERFORMANCE AND QUALIFICATION

- This includes a UK-developed code for fuel performance and the timely establishment of Advanced Modular Reactor (AMR) fuel qualification capabilities.

CLADDING

- This includes hydrogen/corrosion effects, novel cladding/AMR cladding, reactor-relevant effects, supply chain and alloy manufacturing and pellet-clad interaction (PCI).

INITIAL OUTPUTS

Addressing diversity in the reactor technologies to be deployed in the UK

A consistent theme throughout the development of the roadmap was a lack of clarity surrounding which reactor technologies, such as High-Temperature Gas-Cooled Reactors and Molten Salt Reactors, are likely to be supported and deployed in the UK, and the implications of this uncertainty.

The Advanced Nuclear Technology framework adopts a market-driven approach, but in the absence of clarity, or at least a prioritisation of technologies, it will not be possible to identify and prioritise technology-specific R&D, risking the research community spreading itself too thinly and restricting R&D to generic, low technology readiness level activities. This will limit the UK's ability to act as an intelligent customer when presented with a specific technology, or to successfully transfer technology from R&D to industry for scale-up and exploitation.

Guidance on preferred reactor concepts and in-service environments is urgently needed in the short term (as provided, for example, by government's clear statement that the UK will not support plutonium-fuelled reactors). Such guidance would allow the UK to build and maintain the skills and capability needed to support the regulatory assessment and industrial development of these designs. In addition, regardless of the preferred technologies, the UK's multidecade history with gas-cooled reactors and the potential high-temperature cross-over with fusion is an asset which must be recognised.

DISPOSABILITY OF MATERIALS

DISPOSABILITY OF MATERIALS

When new materials are developed, it is vital that consideration is given to their disposability. This can be through reducing their activation so that they can be disposed of more easily or considering how existing materials can be disposed of in more economic or sustainable ways.

Within this theme, the roadmap adresses five subtopics. These are:

MATERIALS DESIGNED FOR DECOMMISSIONING

- This includes modularity and design with decommissioning in mind, supply chain - materials design and engagement.

CHARACTERISATION

- This includes risk mitigation and technology development - gaps and opportunities.

MINIMISATION OF EXISTING WASTE

- This includes treatment techniques and improved sentencing of wastes.

WASTE INVENTORY/WASTEFORM

- This includes waste processing technologies, wasteform performance and reduction in waste volume.

ACCESS TO REAL/ARCHIVE MATERIALS

- This includes access to structural materials and fuels, materials archive/database management, and ownership/cross-industry collaboration and agreement.

INITIAL OUTPUTS

The need for a National Materials Archive

Establishment of a National Materials Archive of key materials (both irradiated and non-irradiated) which can be used for national programmes is fundamental.

Historical materials may be at risk of disposal/loss, but replication may be impossible or expensive.

Capturing the provenance of the materials is also crucial. Ensuring this information remains available and associated with the physical material means that the archive contains useful, known, material.

Planning, funding and establishment of an archive (centrally located or distributed over several sites) is critically needed in the next 1–5 years.

IRRADIATION DAMAGE

IRRADIATION DAMAGE

Many materials operating in a nuclear environment will be subject to irradiation damage, whether from reactor operations, during post-use storage or wasteforms containing active material.

Understanding the effects of irradiation on materials is key to the prediction of long-term behaviour and thus to underpinning the safe operation of plant.

Within this theme, the roadmap adresses three subtopics. These are:

MODELLING

- This includes model validation needs, modelling the influence of irradiation on properties/microstructure, multi-scale modelling and surrogate irradiations.

CHARACTERISATION MONITORING

(technique development for in-line/on-line/off-line monitoring)

- This includes development of monitoring techniques, surveillance samples for different reactor types and on-line monitoring (e.g. chemistry, environment).

MEASUREMENT OF SINGLE AND SYNERGISTIC EFFECTS

(e.g. radiation and corrosion, flux effects etc.)

- This includes monitoring of radiation and corrosion, and development of monitoring techniques/ instrumentation.

INITIAL OUTPUTS

The importance of a Materials Test Reactor (MTR)

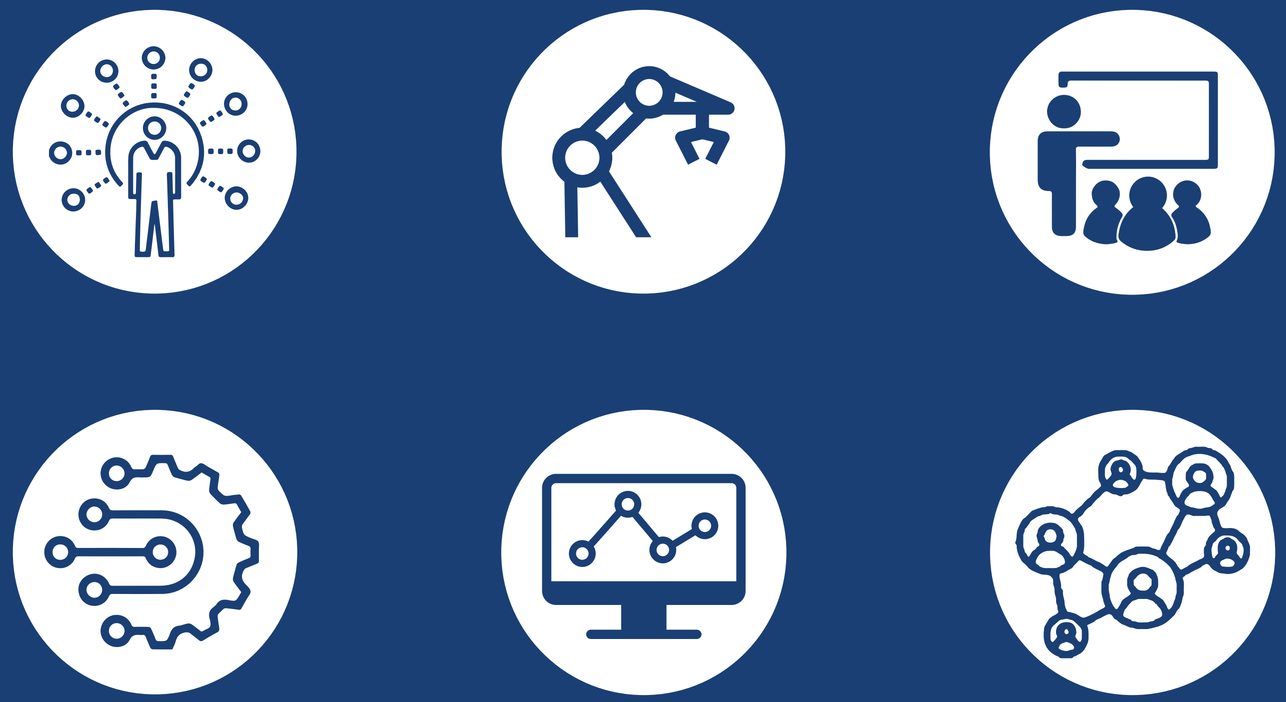
Access to irradiated materials is key to achieving many of the aims in this roadmap. The UK needs to establish access to international MTRs in the short term.

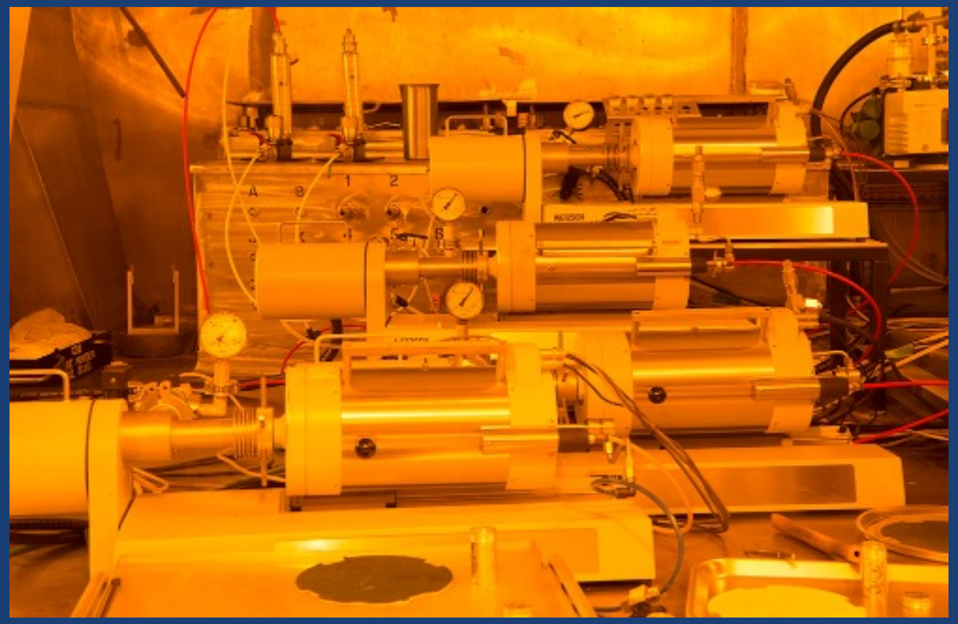
A rapid assessment is needed to determine:

- whether access to these international MTRs, irradiation devices and in-flux loops is sufficient to meet UK needs in the medium and long term
- what gaps a UK MTR could fulfil that are not offered internationally to support the civil needs case

Addressing both of these points will help to inform a decision on whether the UK should build its own MTR.

CROSS-CUTTING THEMES





CROSS-CUTTING THEMES

The roadmap identifies six cross-cutting themes (which are common to all of the areas in the roadmap).

SKILLS

This includes the establishment of a robust skills pipeline, particularly at pre-degree level, development of future technical leaders and retention of skills through knowledge management programmes.

QUALIFICATION

This includes accelerating qualification of materials, non-active facilities for long-term testing at different length scales and fit-for-purpose qualification over the whole fuel cycle (including waste).

INFRASTRUCTURE

This includes readily available access to neutron irradiations, a UK MTR, UK irradiated materials archive and fuel handling facilities. Enhanced facilities for alpha-emitting materials will also be essential to support national missions (e.g. plutonium disposition, minor actinide science).

MODELLING

This includes experimental programmes to validate models, availability of quality data (and its provenance) from which to develop models and enhanced collaborations.

POLICY

This includes prioritising reactor technologies, international/cross-sector collaborations and funding.

CHARACTERISATION

This includes PIE needs/facilities, characterisation standards and improved materials transport.

Skills

Access to a skilled workforce is critical to deliver the UK's nuclear ambitions. There is a need for materials skills at all levels (apprentices to PhD level).

Skills to deliver an MTR are needed should the UK decide to build its own MTR. The announcement of the nuclear-focused UKRI doctoral focal awards presents an opportunity to make some progress in this area at PhD level.

Infrastructure

Many challenges need test rigs and infrastructure to perform the necessary tests on active and non-active materials to deliver quality data in support of qualification/regulatory acceptance. Test rigs for non-active material should include capability for rapid screening/testing of fuels and materials, loops for corrosion testing with both conventional and novel coolants, and high-temperature (750–1000 °C) mechanical testing capabilities.

Material transport between institutions must be streamlined, and new facilities must be designed as part of an ecosystem to allow simplified transport between facilities from the outset.

Funding

Long-term funding (minimum of five years) is required to support technical programmes across the different themes and to develop national programmes to tackle these challenges.

Funding is needed to cover improvements to facilities and national R&D programmes (both at academic level and at national laboratory level).

Funding needs be secured within 1–5 years to support delivery of the roadmap. Initial steps have been made in this area with the announcement of the nuclear-focused Engineering and Physical Sciences Research Council (EPSRC) 'Addressing nuclear fission challenges for a prosperous future' call, which replaces other grants that have recently finished, but significant further action is needed to grow the sector.

Modelling and simulation facilities

Modelling and simulation provide ways to accelerate materials development/qualification. Access to state-of-the-art computing facilities is necessary to exploit the potentials of AI and digital transformation.

Regulatory engagement

Regulatory engagement was discussed across the workshop sessions as critical to support the validation and qualification of models and materials.

The sector should embrace the recommendations of the Nuclear Regulatory Review 2025 and establish guidelines to support the accelerated qualification activities and structural integrity assessments of novel materials and methods.

In addition, support in the development of pragmatic solutions for R&D activities is needed, for example where there are low quantities of materials and diversity of conditions.

Cross-sector collaborations

There are clear cross-sector opportunities with common goals and needs, for example between civil and defence sectors, and fission and fusion research.

Establishing common programmes and joint business cases provides opportunities for programme acceleration and cost-sharing. A joint fission, fusion and defence working group to identify potential collaborative opportunities is recommended.

International links and programmes, including access to EU programmes, should also be leveraged.

NEXT STEPS AND HOW TO CONTRIBUTE

Detailed development of the roadmap – including full details of the technical challenges across each of the themes, technical programmes needed and outline timescales – will continue over the coming months.

The full roadmap is expected to be published later in 2026.

We welcome any further comments and contributions from across the industry to help shape the final output. We are particularly keen to hear views from industry.

Please send any comments for consideration to:

royce@uknnl.com

ACKNOWLEDGEMENTS

Development of the roadmap was made possible through funding from UKNNL internal investment, the Henry Royce Institute and the Department for Energy Security and Net Zero (DESNZ) Advanced Modular Reactor Research, Development and Demonstration (AMR RD&D) Programme.

The roadmap could not have been developed without the support of many people, including: the UKNNL innovation team (Paul Knight, Andy Seferta and Tim Whitworth) in the design and facilitation of the workshops, UKNNL's David Kumar and Natasha Sweeney-Fort for facilitating the workshops, Louise Cheetham and Catrin Owen for UKNNL communications support, Royce Nuclear area leads Prof. Abbie Jones and Dr James Wade-Zhu and Research Business Engagement Manager Cathy Bell.

Finally, we thank all participants who have contributed to the workshops to develop the detailed underpinning evidence. Details of all contributors will be given in the full roadmap.

About the authors

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Her expertise centres on the microstructural characterisation of spent fuel and irradiated materials linked to in-reactor performance.