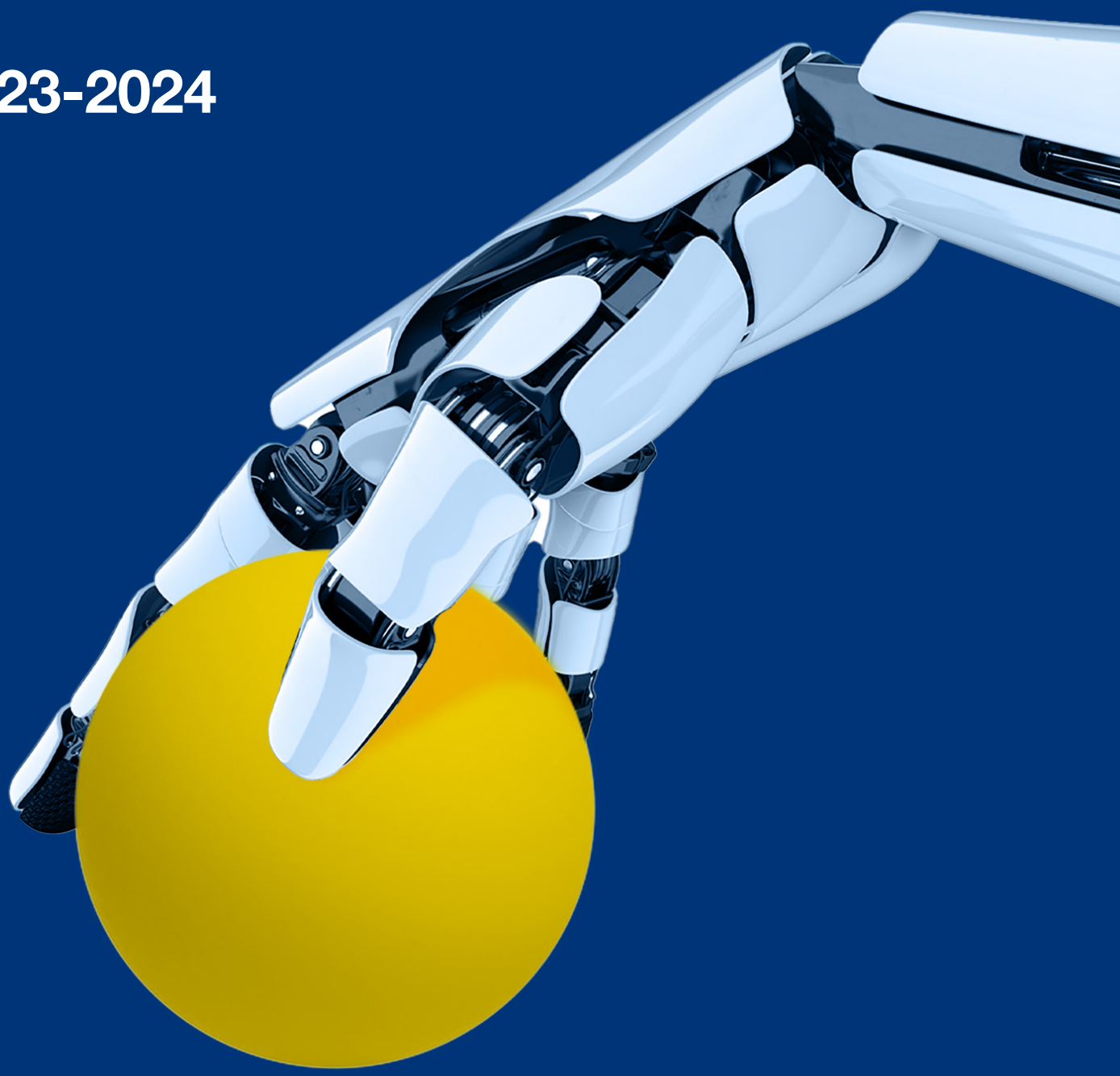
United Kingdom
National Nuclear
Laboratory

Public Interest Reinvestment Contributions to

# Environmental Restoration

## 2023-2024



# Contents

# Introduction

**Wayne Muckley**
Vice President for Legacy Sites, UKNNL

**As the UK's lead civil national laboratory for nuclear, UKNNL has formed effective, strategic partnerships to deliver world leading science and technology. UKNNL is committed to working collaboratively, taking responsibility to deliver a step change in Environmental Restoration of the UK's nuclear legacy; the commitment to achieving this is reflected in the strong relationships established with organisations such as Sellafield Ltd, the Nuclear Decommissioning Authority (NDA) and its operating companies.**

The work undertaken through UKNNL's science and technology agenda remains key in addressing some of the biggest challenges faced in clean-up operations of nuclear facilities. This work is funded via the reinvestment of earnings that UKNNL generates through customer-focused projects. I am therefore pleased to present the following report detailing the delivery of public interest reinvestment in FY23/24, featuring the work carried out relevant to UKNNL's Environmental Restoration Focus Area.

Whilst focusing on the science and technology achievements over the last year, this report will additionally showcase examples of how we build on prior projects, develop science, technology and capability over several years, and what we plan to achieve over the coming financial year.

We aim to maintain and further develop the thriving partnerships formed, by collaboratively working with Sellafield Ltd, the NDA, Ministry of Defence (MOD) and others to help play our part in delivering Environmental Restoration of the UK's nuclear sites, harnessing nuclear science to benefit society. We also continue to focus long-term via the Collaboration Agreement in place with Sellafield Ltd, to identify key challenges and technologies which would aid the clean-up of the Sellafield site.

The following report highlights examples of work that may have started as small investments into core science from the reinvestment of earnings to progress technologies and the people working on them, as well as how UKNNL engages with international and academic partners to contribute to a broader range of collaborative work programmes.

The contribution UKNNL makes to many technical areas of importance is, of course, underpinned by technical skills and capabilities and enabled by factors such as our facilities, infrastructure, supporting capabilities and supply chain.

UKNNL continues to strive towards the vision for a cleaner, safer environment for generations to come, whilst observing that this would not be possible without the commitment, trust, and integrity of our collaborating partners.

**Robin Ibbotson**
Chief Technology Officer,
Sellafield Ltd

## The synergistic relationship between Sellafield Ltd and UKNNL continues to thrive, co-operating closely to deliver our purpose of creating a clean and safe environment after the completion of nuclear operations. This dedicated partnership enables the sharing of technical expertise to help in delivering our mission, which aligns with the values of both Sellafield Ltd and UKNNL as organisations.

The ambition we have, to give future generations a clean, safe environment, begins with our responsibility to ensure safe, secure, and sustainable management of nuclear material on the Sellafield site. UKNNL offers specialised technical assistance in each of these areas, to support us in delivering our purpose.

In particular, the unique lifetime collaboration agreement between our organisations, held since 2017, has been a significant factor in pushing forward innovative ideas and investing in people, skills, science, and technology. The agreement has enabled the fostering of innovation to aid the progressive development of the nuclear industry in the UK.

The collaborative agreement we have with UKNNL allows us to be committed to a long-term effort, developing and strengthening in preparedness for the future. We have seen that investment can lead to enhancement of key skills, technology, and capabilities to reinforce site strategy and the safe management of nuclear material.

This report detailing the reinvestment of UKNNL's earnings clearly shows the motif of collaboration between organisations to deliver science and technology to help address challenges that Sellafield has.

**Clive Nixon**
Group Chief Nuclear Strategy Officer, NDA Group

## To clean up the UK's earliest nuclear sites safely and efficiently, collaboration between the organisations involved in their remediation is pivotal. The NDA promotes effective, working partnerships to deliver an ambitious and effective strategy to ensure that clean-up operations are a success.

The NDA and our subsidiaries (Sellafield, Nuclear Restoration Services, Nuclear Waste Services and Nuclear Transport Solutions) work closely together, and crucially, with academia and other industry partners to help deliver our mission to safely reduce the hazard and risks of the UK's nuclear legacy.

The collaboration between these entities, including UKNNL, is a fundamental element which ensures that the environmental restoration of nuclear sites in the UK is delivered efficiently and effectively, and ultimately delivers value for money for the UK taxpayer.

The progression of innovative technologies through the technology readiness level scale to become deployable on nuclear sites will also be key for decommissioning activities. It is therefore encouraging to see that the earnings of organisations such as UKNNL are being reinvested in this way to progress the technologies, people and supporting infrastructure capable of delivering a step change in environmental restoration.

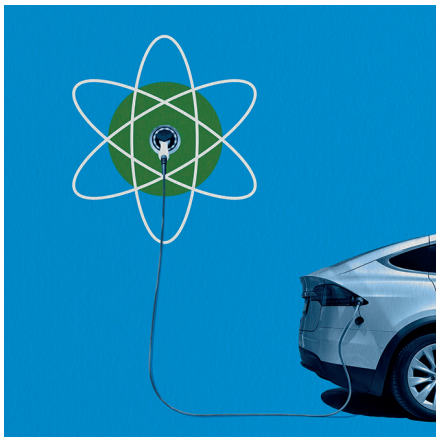
Such investment represents a commitment to safely transforming the landscape, removing the shadows of the past, and returning nuclear sites to future generations in a way that respects their surrounding communities and the environment.

The decommissioning journey is a challenge, but also a source of great pride for the NDA and the UK, as we ensure that our actions today make way for a cleaner, safer tomorrow.

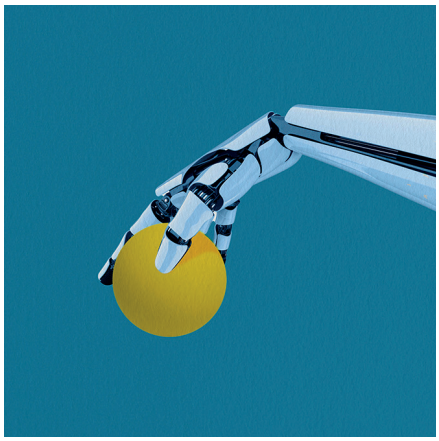
# Context

**By reinvesting its surplus earnings into science and technology, UKNNL is delivering nuclear science to benefit society. UKNNL is continuously committed to reinvesting in science and technology. Such reinvestment enables the fulfilment of UKNNL's responsibility as a national laboratory and Public Sector Research Establishment (PSRE).**

**Delivering value for Sellafield Ltd, the NDA, the Department for Energy Security and Net Zero (DESNZ) and other customers, UKNNL has defined four focus areas to develop solutions that are most relevant to nuclear, via the development of technologies designed to tackle the challenges faced by the industry.**



Clean Energy



Environmental Restoration

Health and Nuclear Medicine

Security and Non-Proliferation

The management of hazardous waste produced by nuclear operations is a long term challenge facing the industry. One of four focus areas, the environmental restoration area, centres on the investment in innovative, sustainable and safe solutions to manage hazardous nuclear waste. The further three focus areas at UKNNL also utilise capabilities developed in environmental restoration.

Our science and technology agenda includes a range of core science themes, several of which are associated with delivery of environmental restoration aims.

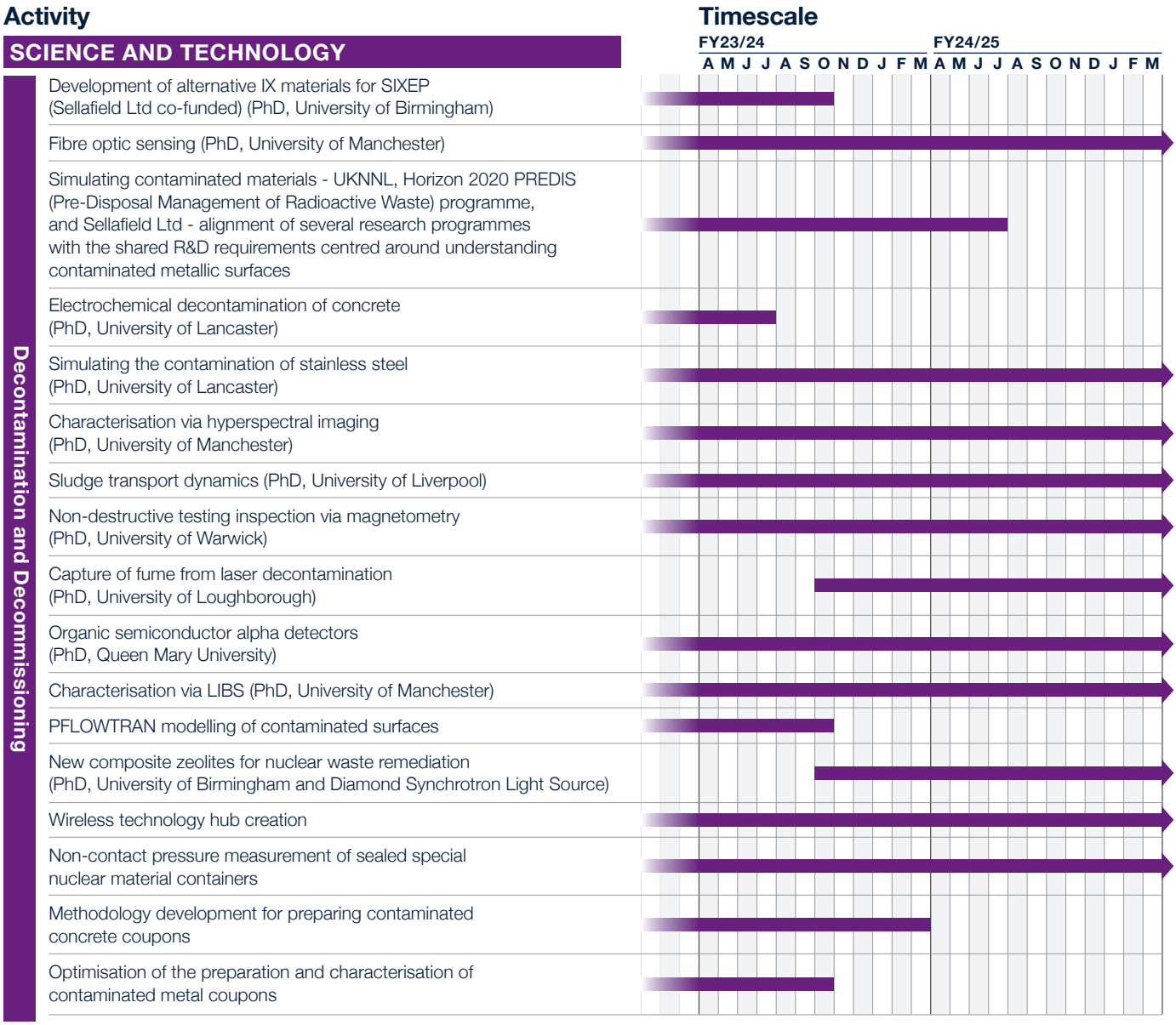
Investment in this area aims to bring lifetime value for money through:

- Longer term and/or innovative research and development activities which maintain and develop key skills
- Demonstrable investment in facilities and infrastructure
- Strong investment in people, processes, and systems to develop the skills, capabilities and facilities needed to sustain the technical and analytical knowledge base to deliver solutions to the significant technical challenges across nuclear licensed sites

# Overview

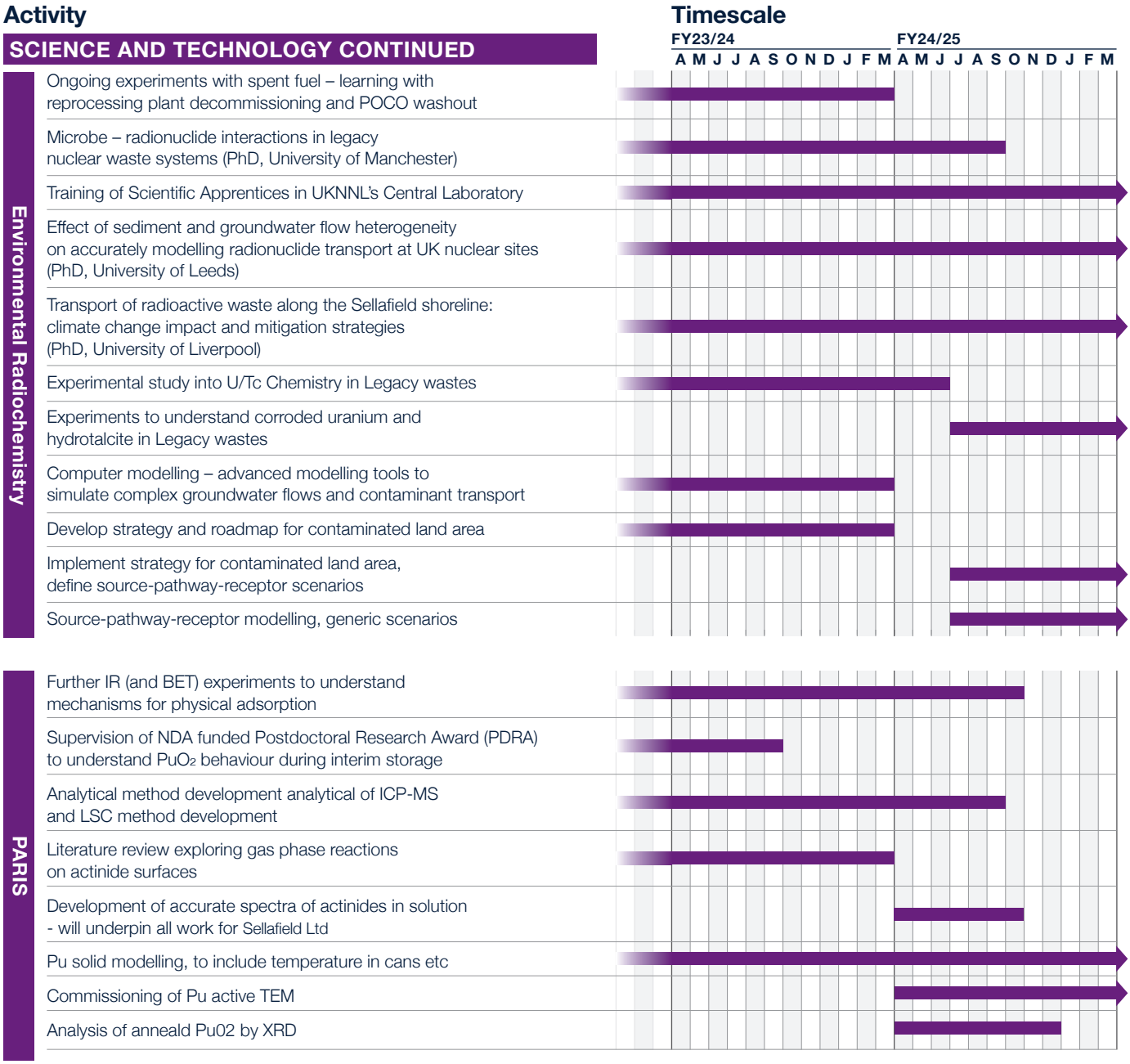
## The following Gantt Charts provide an approximate indication of timescales for projects.

There is focus on the delivery within the FY23/24-24/25 timescale and as such some projects are multi-year and may have commenced prior to this or are due to finish after these dates. Where possible this has been indicated. Exact timings may be subject to change. The core science themes featured are relevant to Environmental Restoration.



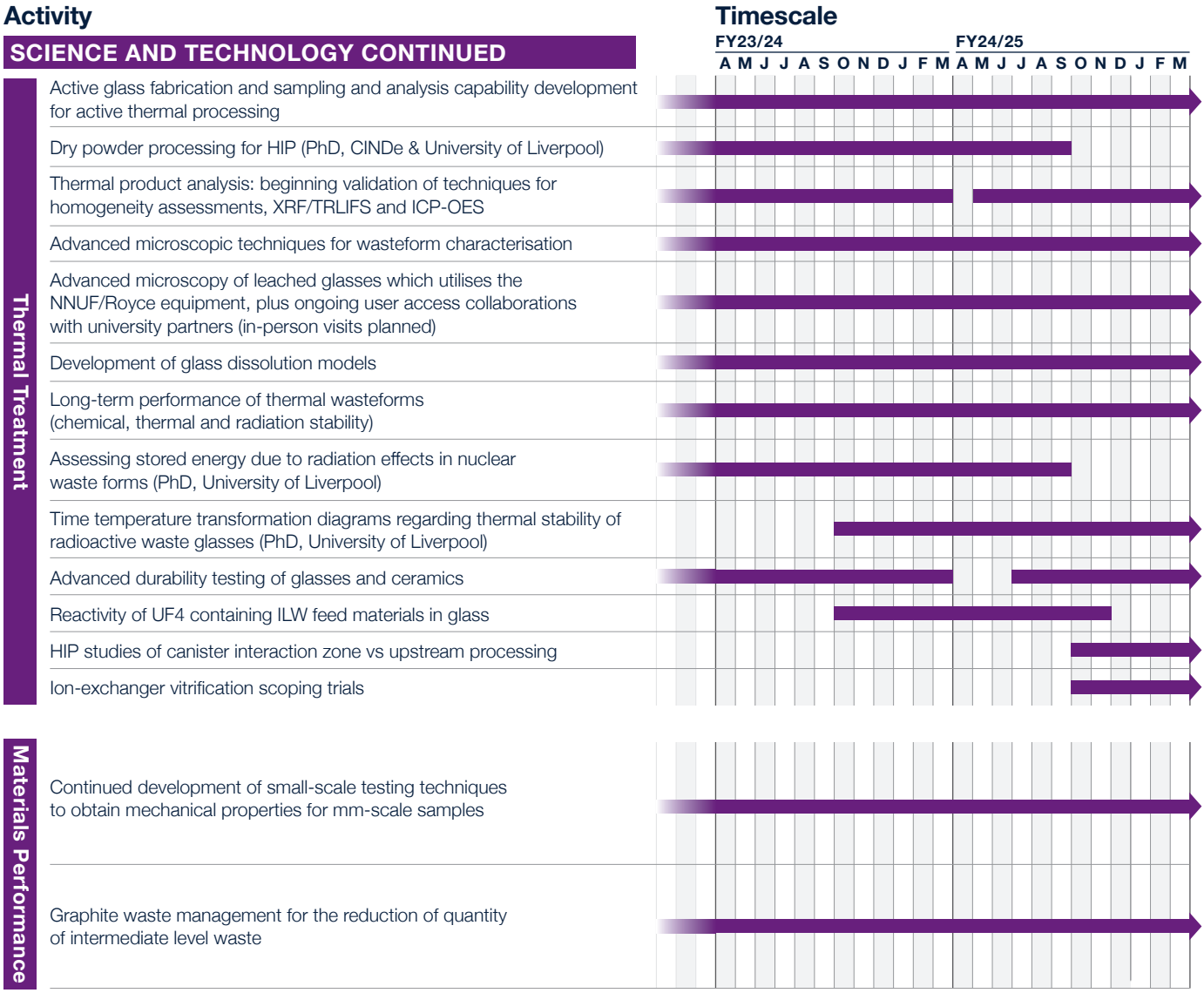

SIXEP – Site Ion Exchange Effluent Plant
LIBS – Laser induced breakdown spectroscopy
PFLOWTRAN – Parallel Reactive Flow Transport model

## SCIENCE AND TECHNOLOGY CONTINUED




POCO – post operational clean out
IR (and BET) – infrared (and Brunauer-Emmett-Teller)
ICP-MS – Inductively coupled plasma mass spectrometry
LSC – liquid scintillation counting
TEM – transmission electron microscopy
XRD – X-ray diffraction

## SCIENCE AND TECHNOLOGY CONTINUED




HIP – Hot isostatic pressing
XRF/TRLIFS – X-ray fluorescence / time-resolved laser induced fluorescence spectroscopy
ICP-OES – inductively coupled plasma optical emission spectroscopy
ILW – Intermediate Level Waste

## SCIENCE AND TECHNOLOGY CONTINUED

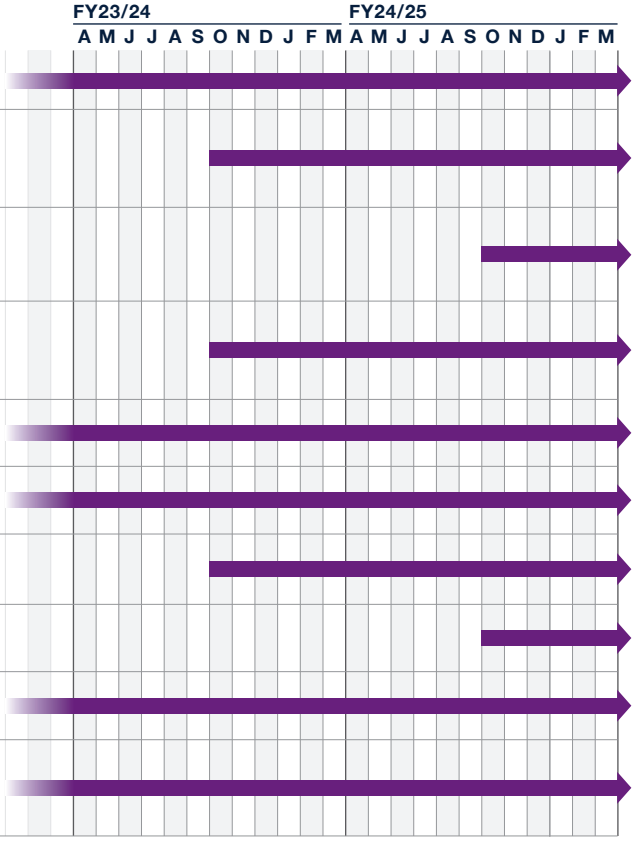
| | Activity | Timescale |
|---|---|---|
| Nuclear Safety | Fulfilling the UK lead role on criticality-related ISO standards, facilitating appropriate input from the rest of industry | |
| | Leading on the development of 'fit-for-purpose' solutions in chemotoxic safety and external hazards assessment | |
| | Leading on various safety-related aspects identified of national strategic importance to the UK nuclear industry, e.g. providing the strategic industry lead on (i) criticality professional development, (ii) nuclear data awareness and emerging sensitivity / uncertainty tool application, (iii) driving innovative new thinking on 'As Low As Reasonably Practicable' (ALARP) solutions, and (iv) improved integration between safety and engineering | |
| | Taking a leading role on the UK Shielding Forum to ensure effective collaboration between organisations and delivery of good practice guides | |
| | Providing thermal and criticality support to Lawrence Livermore National Laboratory on the CED-3A 'Initiate Facility Plan' stage associated with a low temperature critical benchmark experiment | |
| | Providing thermal and criticality support to Lawrence Livermore National Laboratory on the CED-3B surrogate thermal testing and experimental execution stage associated with a low temperature critical benchmark experiment. Building involvement and formal links with the International Criticality Safety Benchmark Evaluation Project (ICSBEP) | |
| | Co-ordinate the UK working party on criticality continued professional development webinar series with SL | |
| Robotics | Conducting physical trials and setting up of capability demonstration | |
| | Investigation, development, and benchmarking of OCR techniques for automated text reading | |
| | Completion of New National Nuclear User Facility for Hot Robotics (NNUF-HR) for nuclear robotics R&D. In partnership with the University of Bristol, University of Manchester and the UKAEA's Remote Applications for Challenging Environments (RACE) | |
| | Utilise the NNUF-HR to test and develop remote operations and equipment for use in sort and segregation, size reduction, laser cutting, waste management and retrieval, and glovebox operations | |
| | Co-funded PhD studentship with University of Strathclyde on 'Ensuring Decommissioning Safety, Integrity and Verification through Advanced Sensor-Enabled Cutting' | |
| | Co-funded GREEN PhD studentship with Lancaster University on Advanced control system design for enhancing the situational awareness of the robotic platforms in the nuclear environment | |
| | Proposed approach to improving reliability claims on computer-based robotic systems for safety casing | |
| | Contribution to UK Cross-Industry RAS Development Task Force and co-chairing of the National RAS Regulations, Standards, and Ethics Committee | |
| | UKNNL cut path planning demonstrator for laser size reduction | |


ISO – International Organization for Standardization
OCR – optical character recognition
GREEN – Growing skills for Reliable Economic Energy from Nuclear
RAS – Robotics and autonomous systems

## SCIENCE AND TECHNOLOGY CONTINUED

**Disposal**

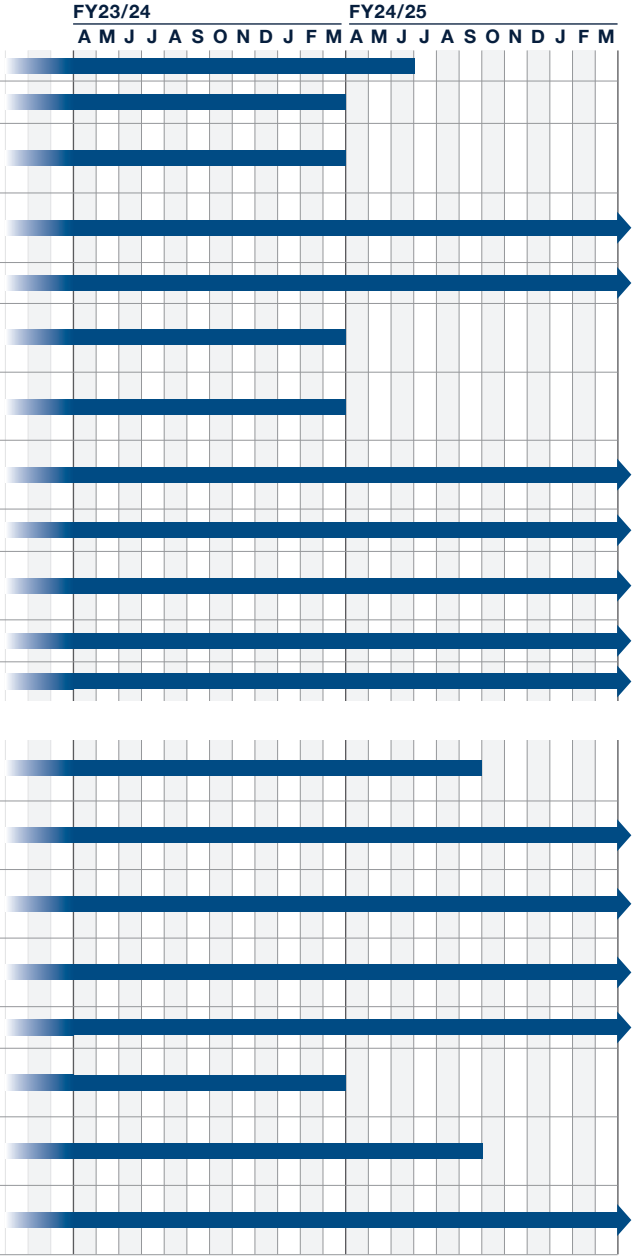
| Activity | Timescale |
|---|---|
| Theme Leadership: Management, strategy and business development | |
| Depositional and diagenetic controls on fluid flow in fractures in a potential geological disposal facility in the Mercia Mudstone Group, UK (UoL and UKNNL funded) | |
| Building resilience to coastal flooding resulting from climatic changes: the application to decommissioning NDA assets (NDA PhD bursary) | |
| Upscaling fundamental controls on fluid migration in the Mercia Mudstone Group based on 3D multi-scale imaging and modelling (ESPRC & UKNNL funded) | |
| Characterisation of the Mercia Mudstone Group to support geosphere evolution studies | |
| THMC modelling of the Mercia Mudstone Group to support containment, pathways, and receptors studies | |
| GeoSafe (UKRI project): derisking geological disposal of radioactive waste | |
| RAMPEC (EURAD2 project): radionuclide mobility under perturbed conditions | |
| Screening of future low carbon cement powders for nuclear waste disposal | |
| Retention of caesium and strontium in next generation Portland Limestone cement powders for use in nuclear waste management and disposal | |



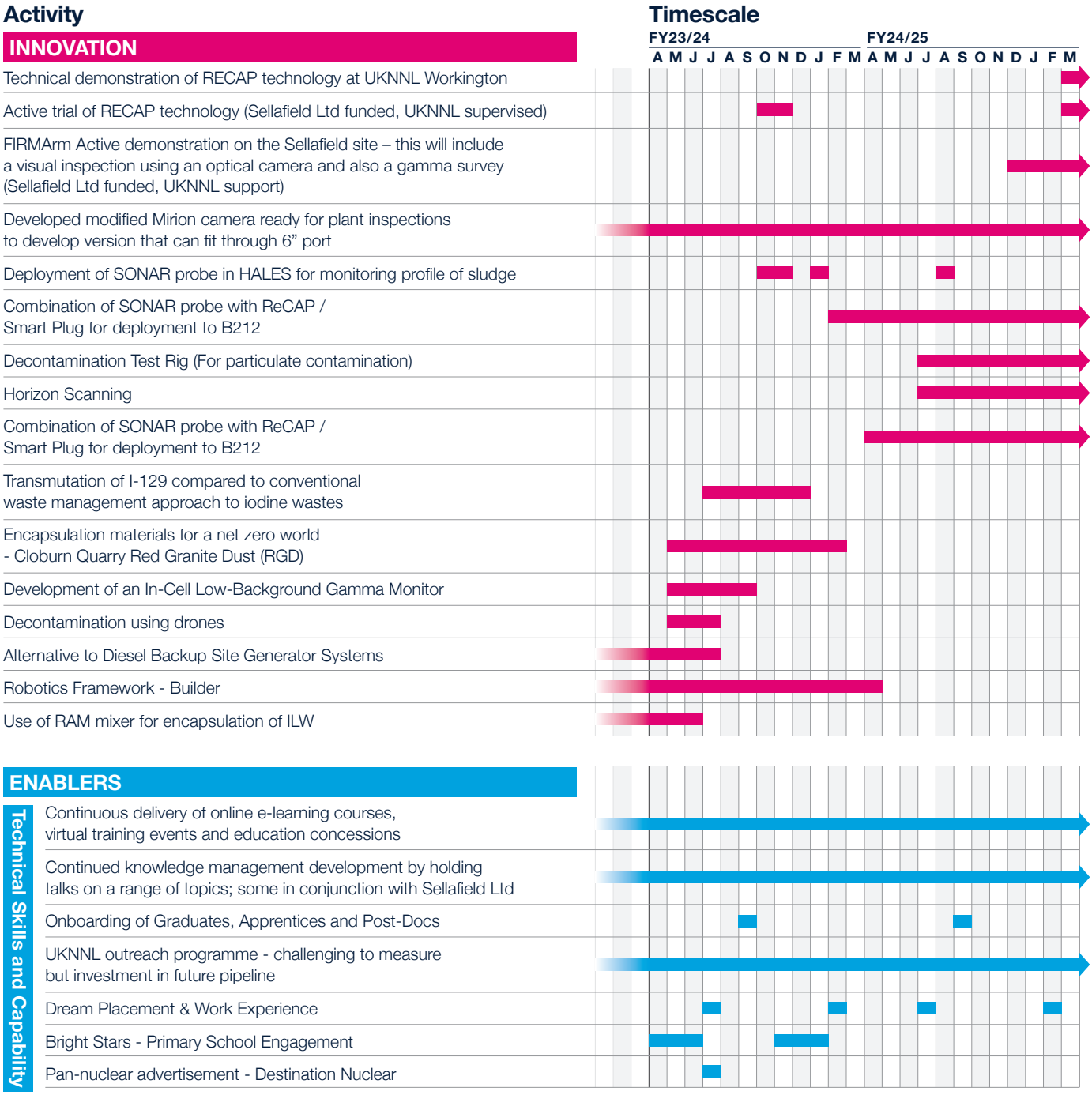

UoL – University of Liverpool
EPSRC – Engineering and Physical Sciences Research Council
THMC – Thermo-hydro-mechanical-chemical
UKRI – United Kingdom Research and Innovation
RAMPEC (EURAD 2) – Radionuclide Mobility under PErturbed Conditions (European joint program on Radioactive Waste Management)

## COLLABORATIONS

| | Activity | Timescale |
|---|---|---|
| International Collaborations | PREDIS (Pre-Disposal Management of Radioactive Waste) | |
| | JHOP 2040 (Jules Horowitz Operational Plan 2040) | |
| | ENTENTE (European Database for Multiscale Modelling of Radiation Damage) | |
| | PATRICIA (Partitioning and Transmuter Research Initiative in a Collaborative Innovative Action) | |
| | PUMMA (Plutonium Management for More Agility) | |
| | FRACTESUS (Fracture mechanics testing of irradiated RPV steels by means of sub-sized specimens) | |
| | A-CINCH (Augmented Cooperation in Education and Training in Nuclear and Radiochemistry) | |
| | FREDMANS (Fuel Recycle and Experimentally Demonstrated Manufacturing of Nuclear Solutions) | |
| | Gemini 4.0 | |
| | HARPERS (International regulatory framework in Waste management and Decommissioning) | |
| | SECURE | |
| | OPERA - High performance modelling of systems | |
| University Collaborations | Electrochemical decontamination of concrete (PhD, University of Lancaster) | |
| | Simulating the contamination of stainless steel (PhD, University of Lancaster) | |
| | Decontamination of bricks (PhD, University of Lancaster) | |
| | Capture of fume from laser decontamination (PhD, University of Loughborough) | |
| | Wireless instruments for nuclear digitalisation | |
| | Non-contact pressure measurement of sealed special nuclear material containers | |
| | Dry powder processing for HIP (PhD, CINDe & University of Liverpool) | |
| | Graphite Waste Management (PhD, CINDe & University of Manchester) | |




SECURE - Strengthening the European Chain of sUpply for next generation medical Radionuclides
HIP – Hot isostatic pressing




RECAP - Remote Cutting And Plugging
SONAR - sound navigation and ranging
HALES – Highly Active Liquor Evaporation and Storage
RAM – Resodyn Acoustic Mixer
ILW – Intermediate Level Waste

# Environmental Restoration: Vision, Ambition and Role

## Our Vision

To drive a step-change in the clean-up and management of the UK's nuclear legacy, supporting the UK's national missions and enabling the sharing of expertise and decommissioning solutions internationally.

## Our Ambition

- Delivering the next generation of decommissioning science and breakthrough technologies.
- The natural custodian of strategic nuclear capability on behalf of the UK.

## Our Role

- The embedded Technical Authority providing specialist services and innovating new solutions.
- A proving ground for industrialising technologies from academia and SMEs.
- Informing and underpinning government policy with technical insights.

# Environmental Restoration: Objectives Work Breakdown Structure

Our Vision

To sustainably benefit the sector by deploying expertise and capability across the waste life-cycle, from access through to end states, whilst developing the next generation of skills, advanced tools, techniques and science for faster, cheaper, and safer decommissioning

Our Strategic Objectives

| Access and Characterisation | Treatments and Processing | Storage, Disposal and End States |
|---|---|---|
| **Decommissioning Strategy**<br>Grow UKNNL's integrated offering for upfront decommissioning strategy to support national policy | **Waste Treatments**<br>Develop and demonstrate waste treatments, including effluents, for an increasing diversity of waste streams arising from the decommissioning agenda | **Disposal**<br>Grow UKNNL's capability and understanding of long-term waste and barrier behaviour in disposal facilities to support NWS and defence programmes |
| **On-Site Characterisation**<br>Maintain our capability in on-site inspection, monitoring and characterisation, to provide safe and cost-effective support to EDF and Sellafield across their full missions | **Decontamination**<br>Translate decontamination science and technology into robust customer solutions | **Packaging and Encapsulation**<br>Support the nuclear industry with tailored formulations at all scales to encapsulate new and emerging waste types |
| **Measurement, Analysis and Characterisation**<br>Define and establish the analytical capability required to enable the UK's nuclear programmes, including legacy, new build, defence and forensics | **Uranics**<br>Maintain and expand UKNNL's uranics capabilities at Springfields, providing waste processing and recycling solutions to deliver a sustainable nuclear fuel cycle | **Land Quality & End States**<br>Develop UKNNL's capability and capacity to support decommissioning sites with land management and remediation plans |
| **Robotics**<br>Establish UKNNL as a specialist integrator in nuclear robotics and AI, by exploiting our unique ability to develop and deploy systems in both non-active and active environments | **Graphite**<br>Develop graphite characterisation, treatment and recycling technology to support legacy and future decommissioning | **Thermal Treatment**<br>Embed UKNNL as the trusted technical partner for the NDA estate, underpinned by active and non-active demonstrators and hosting the UK's Centre of Excellence |

**Special Nuclear Materials**

Be the UK's technical authority on Special Nuclear Materials and develop sustainable skills and capabilities through ARC to help inform and carry out UK policy on disposition

Our Strategic Partnerships

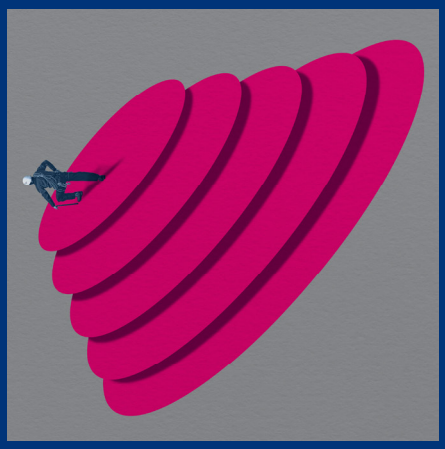
**Partnerships and stakeholders**

To see UKNNL properly recognised as a collaborative national laboratory, resulting in long-term strategic partnerships across the nuclear sector

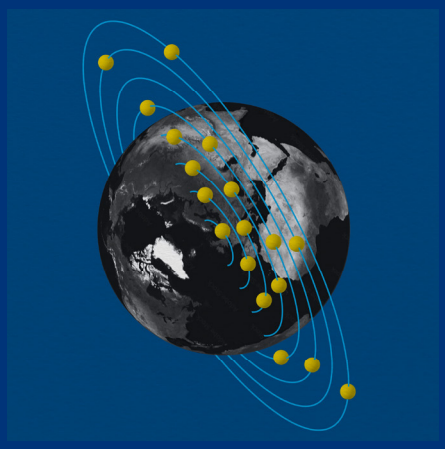
| Academia and National Labs | Defence | Industry and Supply Chain | International | NDA Estate | Regulators |
|---|---|---|---|---|---|
| To develop strategic relationships through academic and national lab networks to facilitate innovation and build the talent pipeline | Develop UKNNL's position as a trusted partner to the Defence Nuclear Enterprise, providing technical expertise to support the national strategy | Build long-term strategic relationships in the supply chain, complementing our strengths to support the Environmental Restoration agenda | Position UKNNL overseas to develop capability, share expertise and catalyse export of UK capability | Maintain and embed the strategic partnerships with Sellafield and the NDA group to meet their national mission | Enable accelerated regulatory approval of new technology through the development of our relationship with regulators and sharing of technical expertise |

# Science and Technology

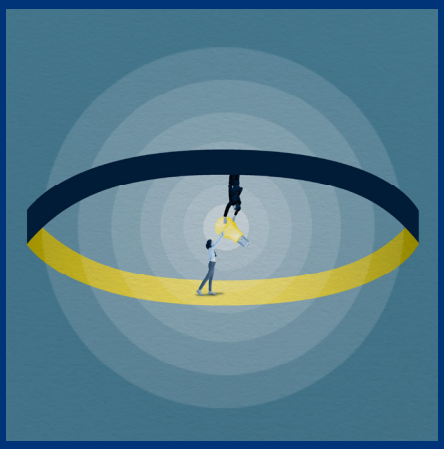
**The Science and Technology agenda at UKNNL is consistently reviewed to maintain its involvement in topics which remain relevant to the nuclear industry today and into the future. It consists of three pillars, led by scientists working collaboratively on a national basis and internationally.**



Core Science



Strategic Research



Innovation

The three pillars of the Science and Technology agenda are Core Science, Strategic Research and Innovation. This report focuses on work across the core science themes that support the delivery of environmental restoration aims across the nation and further afield.

Developing skills and capabilities in these themes enables UKNNL to provide support to organisations like Sellafield Ltd, the NDA, and the MOD. Investment also allows UKNNL to be flexible between pushing technology directed towards existing requirements and allowing the market to pull our work into other areas.

"Our S&T investment is instrumental in enabling us to engage nationally and internationally, providing inspiring opportunities to work with leading academics and national laboratories to deliver world class research in support of the nuclear sector."

**Jon Hyde**
Head of Science and Technology, UKNNL

### UKNNL Core Science Themes

- Advanced Fuels
- **Decontamination & Decommissioning**
- **Disposal**
- **Environmental Radiochemistry**
- Hydrogen
- Irradiated Fuel Characterisation
- Medical Radionuclide Science
- **Materials Performance**
- Nuclear Safeguards & Security
- **Nuclear Safety**
- **Plutonium, Advanced Recycle & Isotope Separation (PARIS)**
- Reactor Chemistry & Corrosion
- Reactor Technology
- **Robotics & Artificial Intelligence**
- **Thermal Treatment**

(**Bold** indicates themes delivering significant environmental restoration investment)

# Decontamination and Decommissioning Science

## Summary

The Decontamination and Decommissioning core science theme focuses on the development of innovative characterisation and decontamination technologies for deployment within radioactive environments to contribute to the environmental restoration of nuclear sites.

### Core Science in focus

The core science theme was originally named 'Decontamination Science', however was renamed in 2023 to recognise the importance of decommissioning activities when taking responsibility for cleaning up after nuclear operations. Decontamination and Decommissioning consists of a broad range of collaborative projects which aim to progress the technology readiness level (TRL) of technologies to help achieve cost reductions of technology implementation, waste volume reduction, reduced radioactive hazards and improved decision making for the decommissioning of nuclear facilities. In turn, the output from Decontamination and Decommissioning projects helps to restore the environment surrounding nuclear facilities once operations have ceased and allows for greater consideration of the environment for future operations.

Many of the technologies developed through the core science theme have relevance to the UK's nuclear legacy, designed to address challenges at sites such as Sellafield. UKNNL also contributes globally to research and development focused on decommissioning through international programmes of work such as the EU-PREDIS project, working collaboratively with research organisations across Europe on pre-disposal treatment of radioactive waste streams.

# Non-Contact Pressure Management of Special Nuclear Material (SNM) Packages.

## Challenge

The UK has a legacy stockpile of Special Nuclear Material (SNM) packages arising from operations. Monitoring the behavioural markers, such as pressure, of these packages is essential for the safe storage, processing, and disposal of the SNM contained within them for the decommissioning of the facilities that currently house these packages.

**Presently, a non-destructive, non-contact method to record the internal pressure of the SNM packages is not available for plant use.**

## Solution

Research was carried out investigating the relationship between the internal pressure and external vibrations of SNM packages using acoustic techniques. This work was carried out by PhD student Elizabeth Sharp at the University of Warwick, in collaboration with Sellafield Ltd, the NDA and UKNNL, and has been developed further through investment by the Decontamination and Decommissioning core science theme.

## Technology

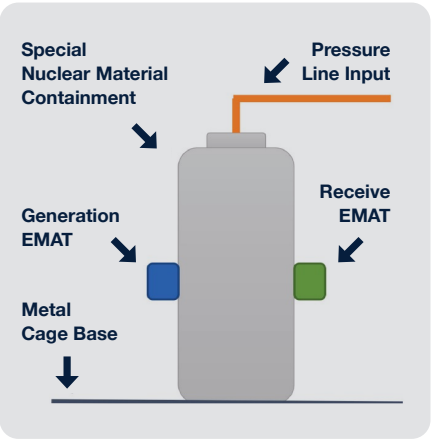
Electromagnetic Acoustic Transducers (EMATs) were the principle behind the non-destructive method developed for pressure measurements of SNM packages. EMATs placed on the outer surface of a package can generate and detect acoustic waves within a material's surface. The vibrational output recorded from this is related to the internal pressure of the package. As the package's internal pressure increases, the vibrational resonant frequencies also increase in value. Using the technology requires no surface preparation or mechanical coupling for the generation or detection of vibrations. To accompany the prototype of the technology, a 3-D model of a Magnox can was constructed in Solidworks to perform resonant frequency and modal analysis.

## Outcome

Since completing a PhD and a post-doctoral research project developing the EMAT technology for the application to SNM packages, Elizabeth has joined UKNNL and has continued working on the technology. Collaboration with industry and university partners on the technology has allowed for the development of capability in this area through Elizabeth, harnessing the skills and knowledge established thus far. Employing the EMAT technology for package inspection on the Sellafield site will allow for non-contact, non-destructive quantitative measurement of SNM from the site's stockpile; the non-destructive aspect of the technology means a lower radioactive dose emitted during the analysis of the can, so that operators at the facilities could continue to work with the material for longer time periods.

## Status

Recently, the technology has been used at UKNNL's Central Laboratory for pressure measurements of Magnox SNM cans. The software behind the EMAT technology has been further developed, and operability of the technology has been 'down skilled'; this means that the technology is simpler to operate now, hence is more appropriate for use in a nuclear plant.




# Disposal

## Summary

Launched in April 2023, this theme is committed to establishing an impactful R&D portfolio and leading the development of critical 'sovereign capabilities' to support the UK Government's mission (led by Nuclear Waste Services) to dispose the UK's higher activity radioactive waste in a geological disposal facility (GDF).

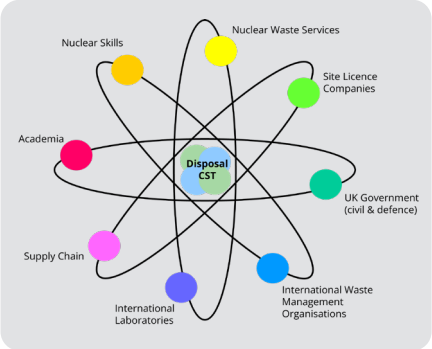
**The theme leverages UKNNL's unique facilities and expertise, in collaboration with UK and international organisations, with the ambition to become world-leading experts in the two core components of the GDF 'multi-barrier' safety concept (i.e., engineered barrier system and the geosphere) which work in unison to isolate intermediate- and high-level wastes for hundreds of thousands of years.**

### Core Science in focus

As a pioneer of nuclear technology, the UK has been producing and managing radioactive waste on an industrial scale since the 1940s. The loss of material or release of radiation from a UK nuclear installation following an accident, or physical attack, would be catastrophic and lead to significant prolonged long-term security, health, environmental and economic impacts. To date, the risk is considered extremely unlikely, however, the UK's ageing nuclear fuel storage ponds and waste silos were not designed to store higher-activity waste indefinitely, and the risk of an accident or physical attack may increase in the future. Aligned to international consensus the UK has opted to construct a GDF to contain and isolate the UK's higher-activity waste for hundreds of thousands of years; the UK's GDF programme is led by Nuclear Waste Services (NWS).

To support this critical national mission, UKNNL's Science and Technology Board approved the establishment of a core science theme focused on Disposal in December 2022, which was launched in April 2023. In collaboration with UKNNL's existing core science themes, in particular Thermal Treatment and Environmental Radiochemistry, UKNNL can provide holistic 'cradle to grave' understanding (e.g., fuel manufacturing to disposal). Specifically, the Disposal theme was established with the following objectives:

- **Objective 1:** to undertake impactful R&D which will provide UKNNL with a clear identity and a visible R&D programme aligned to imperative UK and international milestones
- **Objective 2:** to foster a diverse and innovative 'sovereign capability' and forge strong international collaborative partnerships




- **Objective 3:** to become world-experts in subsurface and engineered barriers to provide impartial, trusted, high-quality, and independent R&D to advise UK government and inform national policy.

More recently, the theme has defined a fourth objective, which is to establish a Disposal Hub comprised of bespoke facilities and a modelling centre of excellence to promote collaboration and integrated working.

# Geosphere and Engineered Barrier Systems

## Challenge

**A geological disposal facility (GDF) is a Nationally Significant Infrastructure Project (NSIP) which requires appropriately packaged waste, a suitable site (host-rock geology), and a willing community. To date, whilst undertaking non-intrusive site characterisation investigations Nuclear Waste Services (NWS) is engaging with three communities to better understand the feasibility of a GDF being hosted by one of the two localities (mid- and south Copeland and Theddlethorpe).**

The host-rock geology in Theddlethorpe (Jurassic Ancholme Group) is analogous to several international GDF programmes (e.g., Belgium, Switzerland, France), however, the host-rock geology in Copeland (Triassic Mercia Mudstone Group; MMG) is internationally unprecedented and contains a complex stratigraphy comprised of mudstones, siltstones, sandstones, and evaporitic units (salt rock; leading to high ionic strength groundwaters).

## Flagship projects: solution, technology, status

The theme has two flagship projects to help provide evidence to underpin the disposability and long-term evolution of low and high heat generating wasteforms, and the performance of waste packages to be disposed of via site-specific GDF disposal concepts.

## Geosphere

The theme, in collaboration with UK and international organisations, is involved in several programmes which aim to better understand the potential transport and retention of contaminants in the geosphere arising from wastes within site-specific GDF disposal concepts. The principal project being a £5 m UKRI and NWS funded project to understand and predict how potential lower strength sedimentary rock environments might be impacted by the introduction of a geological disposal facility (GDF).

The programme is led by Imperial College London, in collaboration with, UKNNL (Disposal and Environmental Radiochemistry CST's), British Geological Survey, and the Universities of Heriot-Watt, Leeds, Manchester, Liverpool, and Helsinki. Results of this project will also be used as part of a knowledge exchange programme in EURADII (RAMPEC) with several international organisations (including waste management organisations), laboratories, and universities. In addition, the theme is committed to Early Career Worker development through the investment in PhD and MSc projects; based at the Universities of Manchester, Liverpool, and Aberdeen.

## Engineered Barrier Systems

The cement industry is moving to reduce its carbon footprint in support of UK Net Zero targets with several different options being developed including higher limestone loading, calcined clay and alternative chemical matrices.

To assess the compatibility of low-carbon cements with UK site-specific GDF disposal concepts, the theme (leveraging our understanding from the themes geosphere work programmes), in collaboration with the University of Manchester (RADER and SIMFUEL laboratories and Lancaster University (UTGARD laboratory), was successful in our National Nuclear User Facility (NNUF) large project application entitled 'Screening of Future Low Carbon Cement Powders for Nuclear Waste Disposal'.

The project is ongoing and will assess how:

- The corrosion of uranium metal may vary between different cement formulations over time using X-ray Computed Tomography analysis and elemental mapping
- Next generation cements may evolve under three end-member groundwater simulant compositions which are reflective potential host-rock groundwaters (e.g., assessing the effect of salinity and carbonate concentrations).

"Collaborating with UKNNL on waste disposal has been an immensely rewarding experience, broadening my perspective on research areas and challenges and helping with my career development. Throughout the couple of projects we are working on together, I've gained valuable insights into many waste management techniques and a comprehensive understanding of the complex issues faced by the nuclear industry, along with the critical scientific questions we aim to resolve. I am grateful that my expertise can contribute to advancing solutions in the nuclear sector, and I look forward to a continued partnership that fosters further growth and discovery"

**Dr Lin Ma**
Senior Lecturer at the University of Manchester

## Virtual Outcrop Modelling - University collaboration with the University of Aberdeen

In February 2024, Joshua Griffiths, Disposal core science theme lead, was an invited speaker at the 51st Herdman Symposium on Energy and Sustainability at the University of Liverpool, alongside Dr Jessica Pugsley from the University of Aberdeen (UoA), who presented on "Virtual outcrops in the modern geological toolkit".

In May 2024, Josh (UKNNL) and Jess (UoA) set-up an MSc project, funded by UoA, to demonstrate how virtual outcrops may help derisk deep geological disposal of radioactive waste in the Mercia Mudstone Group (MMG).

The project has been a success by producing high-resolution models which will help inform ongoing and future UKNNL-funded R&D, demonstrating the value of UKNNL's Disposal core science theme programme to Nuclear Waste Services and the NDA Group, and leveraging decades of experience and innovation at the UoA through collaboration.

"Having UKNNL involved in co-supervising a Sustainable Energy Geoscience MSc project at the University of Aberdeen provided our student with an exciting opportunity to apply their geological knowledge. Our student benefited from industry experience and mentorship, enabling them to make better interpretation of geological 3D models (virtual outcrops) and advancing their modelling skills. We hope to continue this collaboration"

**Dr Jess Pugsley**
University of Aberdeen

image: Watchet West (Warren Bay), Jess Pugsley, VOG, https://v3geo.com/model/768

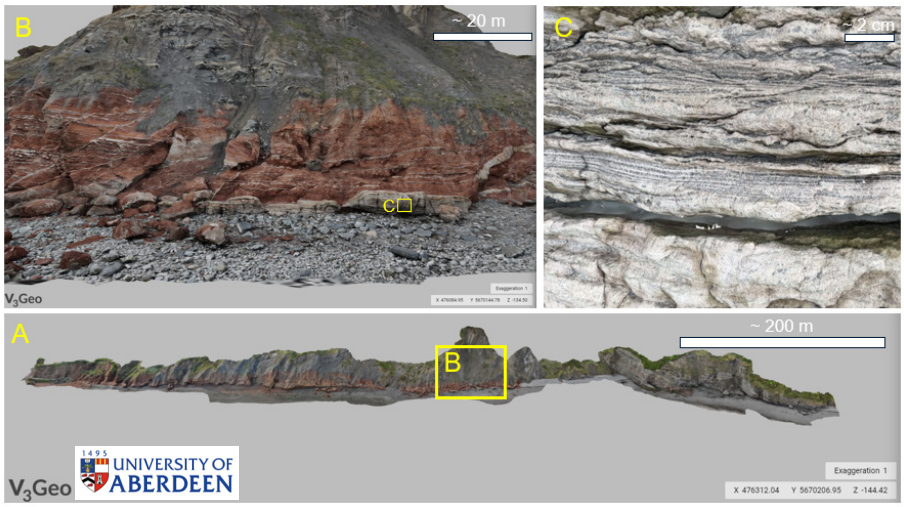



Figure 1: Virtual outcrop model of Watchet cliff section. (A) Approx. 800m length MMG section, (B) example of a densely fractured and faulted interval, and (C) example of a potential high-permeability sand interval (mm resolution)

# Environmental Radiochemistry


## Summary

**Through an increased understanding of how radionuclides behave in the environment, better decisions can be made about how to manage legacy wastes.**
**This theme aligns with the high hazard risk reduction missions at Sellafield for legacy ponds and silos, finding methods to reduce our environmental legacy.**


### Core Science in focus

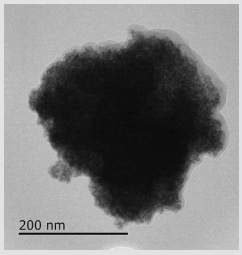
This theme focuses on understanding the behaviour of radionuclides under a range of environmental conditions, including effluent treatment, waste storage and disposal, and contaminated land. The work has helped to improve knowledge, build skills and enhance UKNNL's experimental and modelling capabilities.

Over the past year, we have continued our study of technetium during air exposure, with an updated case study provided on the next page.

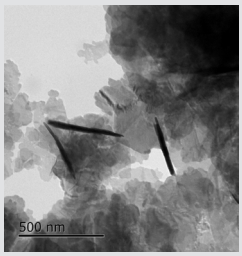
We have also made initial steps to study systems of corroded uranium and magnesium. The behaviour of uranium corrosion product (UCP) is important for any environment where uranium fuel has been stored underwater, such as the legacy ponds and silos. It can form non-settling particles known as colloids, which can increase the mobility of uranium, as well as fission products including strontium, presenting challenges to waste storage, retrievals and effluent treatment.

For fuels with magnesium cladding, such as Magnox, hydrotalcite (Mg6Al2CO3(OH)16·4H2O) is also known to be an important solid phase in these underwater storage environments. Hydrotalcite itself can form non-settling colloids and these can interact with UCP colloids and radionuclides, presenting a complex ternary system that is difficult to predict.

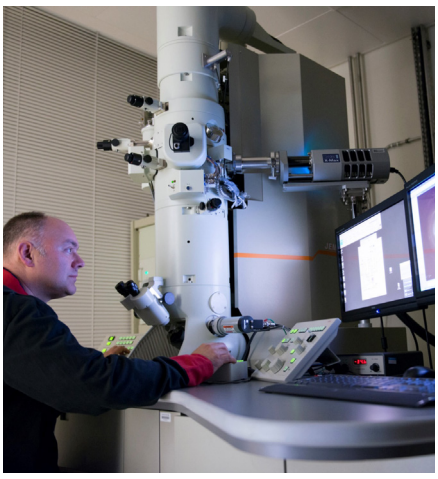
Future experiments will utilise active facilities at Central Laboratory to generate and study UCP and hydrotalcite and their interactions with radionuclides.




**Top:** 0 h timepoint sample showing large, nano-crystalline $UO^2$ aggregates.




**Bottom:** 1 week timepoint sample showing large sheet-like particles more typical of U(VI)-oxyhydroxide phases



Sample images supplied courtesy of NWS Research Support Office

"This project allowed me to apply skills I'd previously developed during my PhD in an industrial setting. Through this, I now have a wider appreciation of the complementary analytical capabilities available across UKNNL and the University of Manchester's RADER facility. Having access to this capability provides a unique opportunity to support ongoing waste retrieval and decommissioning activities through knowledge building of the fundamental chemistry."

Chris Foster
Research Technologist, UKNNL

# Understanding the fate of technetium in legacy wastes during retrievals

## Challenge

Retrievals of legacy wastes can expose them to air, which might alter their chemistry and the mobility of radionuclides in effluents.

**In the previous Earnings to Reinvest Report, we presented a case study on initial experiments to understand the fate of technetium during waste retrievals and exposure to air. These experiments are now complete.**

Tc-99 is one of the most significant long-lived fission products present in nuclear wastes and its solubility increases significantly upon oxidation from Tc(IV) to Tc(VII). In the legacy ponds and silos, if this oxidation process occurred it could present challenges to downstream effluent treatment plants.

The large uranium inventory present in legacy wastes may oxidise in preference to the technetium. However, this has not been demonstrated experimentally.

## Solution

To confirm the behaviour of reduced forms of Tc and U during exposure to air, the Environmental Radiochemistry theme has collaborated with The University of Manchester to perform a series of novel experiments, utilising the expertise and facilities of both organisations. The project has allowed for early career researchers to gain experience of performing the experiments and analysis, supported by subject matter experts at both UKNNL and The University.

## Technology

To mimic the behaviour of waste materials exposed to air, a series of novel batch and dynamic experiments was performed on mixtures of U and Tc under reducing conditions in aqueous media. Solid samples from the experiments were characterised using the synchrotron at the Diamond Light Source. UKNNL's advanced microscopy capabilities were also utilised to understand the morphology of the solid phases and the distribution of elements throughout.

## Outcome

Initial batch experiments, which involved introducing Tc (as Tc(VII)) to anoxic systems containing nano-UO2(s), were carried out under inert atmosphere to mimic the anoxic pond and silo sludge bed environment. The results confirmed that nano-UO2(s) was interacting with, and ultimately reducing, the Tc(VII) to Tc(IV).

Building on this initial finding, dynamic experiments were conducted, with alkaline nano-UO2(s) slurries, both with and without the additional presence of Tc(IV), exposed to atmospheric conditions. Changes in pH, redox potential and dissolved oxygen were continuously measured in-situ, under constant stirring, while regular sampling of the slurry allowed for characterisation of the solids and filtered solution via inductively coupled plasma mass spectrometry (ICP-MS), liquid scintillation counting (LSC) and Extended X-ray Absorption Fine Structure (EXAFS).

For both the U-only and U-Tc systems, ICP-MS results evidenced an increase in the U solution concentration (3 kDa filtered) over the experimental timeframe, suggesting nano-UO2(s) oxidation was occurring. EXAFS analysis confirmed that, prior to air exposure, U was in a local coordination environment consistent with nano-UO2. However, after 24 hours air exposure, EXAFS analysis showed evidence of U oxidation, with 75-90 % U present as U(VI). For the U-Tc system, Tc(IV) oxidation was also observed, with close to 100% entering solution (3 kDa filtered) within 120 hours (confirmed via LSC analysis).

Transmission Electron Microscopy (TEM) was conducted on samples taken from the dynamic experiments. Bright-field imaging confirmed that a nano-crystalline UO2 phase was present prior to air exposure, with no evidence of a separate Tc-rich phase. Elemental mapping indicated that the Tc was uniformly associated with the UO2 particles. Further bright field imaging, in combination with Selected Area Electron Diffraction (SAED) analysis, evidenced morphological changes consistent with nano-UO2 to U(VI) oxyhydroxide transformations.

Geochemical modelling of these systems was conducted using PHREEQC and the Thermochimie v11a database, with the results suggesting that sodium compreignacite, a U(VI)-oxyhydroxide phase, gradually became the key solubility controlling phase over the course of the experiment, which aligns with both the TEM and EXAFS results.

## Status

These results indicate that freshly mixed systems of U(IV) and Tc(IV) exhibit rapid oxidation and almost complete release of Tc into solution upon exposure to air, with only a small fraction of U having dissolved. This research is intrinsic to improving knowledge of how physicochemical factors, such as dissolved oxygen and carbonate concentrations, impact nanoparticulate UO2 oxidation, and by extension, the mobility of other fission products and actinides. Future work will look to focus on systems where U and Tc are more intimately mixed over a prolonged period, given that Tc may gradually incorporate into the UO2 structure, which may limit its release.

# Materials Performance

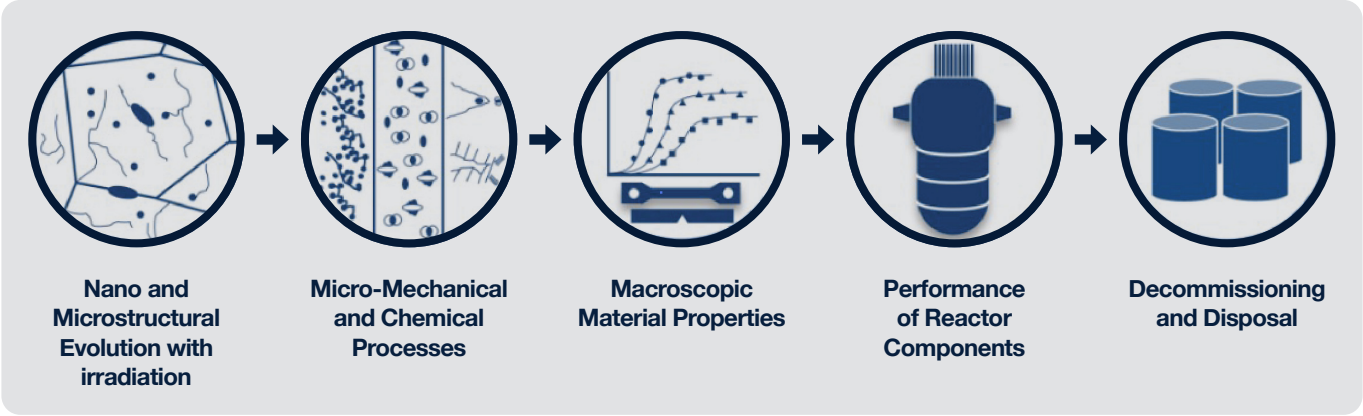
## Summary

Recognising that materials issues are often life-limiting for reactors, this theme targets the delivery of world leading scientific programmes to understand the behaviour of materials in an irradiation environment. Driving the theme's purpose are three key objectives: to improve mechanistic understanding of in-reactor materials performance; to support safety cases for plant operation; life extension and decommissioning strategies and to develop capabilities to support reactor operations. The importance of this theme is highlighted by the knowledge that many components are non-replaceable and safety critical.

### Core Science in focus

The work carried out by materials performance is essential in helping to understand materials issues to ensure safe reactor operation, reduce conservatisms to maximise plant lifetimes, maximise fuel usage, enable new reactor technologies, and reduce costs with innovative materials and manufacturing methods.

Research performed by the theme is directly relevant to a wide range of our collaborators and customers, including Sellafield Ltd, NDA, the MOD, ONR, and EDF Energy. Contribution from materials performance has demonstrated UKNNL's expertise in these areas and breeds a positive consideration towards continued collaborative work.



# Minimisation of Graphite Waste Volume using the Nibble and Vacuum Technique

## Challenge

There are over 96,000 tonnes of irradiated graphite waste in the UK, most of which remains in the reactor building it served in. The current accepted method of removal is by keeping the graphite intact in the form of full bricks. However, this comes with limitations such as brick deformation or having no current viable full brick universal tooling due to significant reactor design differences.

## Solution

This graphite work is a PhD project by student Nathalie Edwards from the University of Manchester, under the Centre for Innovative Nuclear Decommissioning (CINDe), based at UKNNL Workington, Cumbria. The aim is to investigate the nibble (grinding) and vac (vacuum extraction) method as a graphite core removal option. The eventual goal is to demonstrate that this method can be used efficiently and safely in the graphite decommissioning field, and is in the early stages of experimentation. The investigated variables which impact the breaking down and collection of graphite are sample shape and mass, graphite type, vacuum distance, and angle from the graphite source.

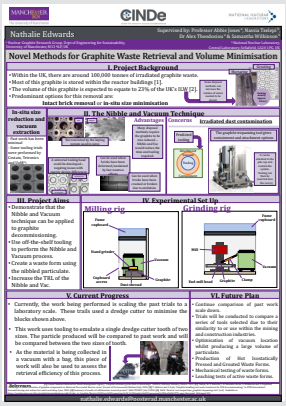
## British Carbon Group Meeting

The British Carbon Group hosted an Early Careers Researchers Meeting at the Royce Hub in Manchester on June 4th, 2024. As part of the event, presentations and posters were presented on carbon research, particularly graphite and graphene technologies. Nathalie attended this meeting and presented a poster regarding the work undertaken as part of her CINDe PhD.

Attending this meeting allowed Nathalie to meet other early-career researchers within the field of carbon-based research. It gave Nathalie the opportunity to ask questions to the wider research community about aspects of the project they deem to be important which has helped to refine Nathalie's future experimental aims.

The poster presentation sessions involved answering questions regarding the poster and Nathalie's PhD project in general. Nathalie's poster won the Early Careers Researchers Meeting Poster Competition.

Nathalie Edwards, University of Manchester, CINDe PhD project poster




> My project is focused on the retrieval and disposal of reactor core graphite, the British Carbon Group Meeting was a great opportunity to share my work and get input from the wider graphite and carbon community

**Nathalie Edwards**
University of Manchester

# Nuclear Safety

## Summary

Maintaining a high quality safety record delivered in a cost-effective manner is an absolute priority for nuclear facilities and UKNNL's environmental restoration objectives. Innovative new ideas are essential to achieving this, but so too are As Low As Reasonably Practicable (ALARP) assessments and regulation.

**Through Core Science investment, UKNNL is leading on various initiatives nationally and internationally, helping to drive solutions that are optimal from both a safety and cost viewpoint. A keystone in the implementation of these techniques is the training and continued professional development (CPD) of nuclear safety specialists.**

### Core Science in focus

ALARP is the bedrock of UK health and safety law and whilst permitting flexibility in safety considerations, there is often a risk of it driving overly conservative decision making. This issue can be influenced by either (i) onerous standards / Good Practice Guides (GPGs), (ii) compensating for significant uncertainties, or (iii) cautious judgements from inexperienced safety specialists. The projects in the Nuclear Safety Theme are all linked with initiatives that help to positively influence these three aspects. Some of the activities supported in the past financial year included:

- Shaping national and international safety standards and Relevant Good Practice (RGP) which influence regulatory thinking through the following roles:
  - UK Technical Lead on the International Organization for Standardization (ISO) committee dedicated to nuclear criticality safety (ISO/TC 85/SC 5/WG 8).
  - Secretary of the "Fissionable Material Outside Reactors" American National Standard committee (ANS-8), plus support to multiple ANS-8 working groups.
  - Core membership of the UK Working Party on Criticality (WPC), plus support to multiple sub-groups.
  - Chair of the UK Shielding Forum.
  - Former Chair of the Safety Case Forum Safety and Engineering Integration Workstream.
- Collaborating with Lawrence Livermore National Laboratory (LLNL) on a multimillion dollar "world-first" critical benchmark experiment designed to fill a nuclear data gap at sub-zero temperatures (which may help to reduce conservatism in transport cases). UKNNL also supported the International Criticality Safety Benchmark Evaluation Project (ICSBEP) Technical Review Group through providing an independent review of an upcoming benchmark report.
- Collaborating with the US Department of Energy (DOE) Nuclear Criticality Safety Program (NCSP) and the WPC to develop an international Criticality Learning from Experience database.
- Providing external thought leadership through publishing a journal article with Abbott Risk Consulting on the regulatory and safety case considerations of nuclear-enabled co-generation, particularly the balance between nuclear and chemical production / handling hazards.
- Initiating and leading a WPC sub group investigating code validation using novel techniques to inform an appropriate safety margin for novel fuel types.

# Supporting Training and Continued Professional Development

## Providing national and international leadership in influencing “fit-for-purpose” (ALARP) nuclear safety approaches and solutions through the development of key new standards, guides and methodologies is one important facet of the theme.

## A second important facet is to support the development of the next generation of nuclear safety Subject Matter Experts (SMEs) who are able to implement and influence these approaches and solutions.

**Safety case specialists were acknowledged as a key industry skills shortage area by the Nuclear Skills Strategy Group (now Nuclear Skills Delivery Group), and hence efforts in the last year have been directed towards two national CPD initiatives that have helped to train both UKNNL staff and the wider industry:**

## CPD Webinar Series

In partnership with Sellafield Ltd., UKNNL leads and coordinates the UK WPC CPD Webinar Series. This series is primarily aimed at early-to-mid career criticality safety professionals and provides an opportunity for CPD, knowledge transfer and sharing of experience, helping to develop the next generation of nuclear safety SMEs.

As of September 2024, 21 webinars have been given by a wide range of presenters from the UK, US and France. Each webinar routinely attracts around 100 attendees with an invitee list of over 200.

## CPD Workshop

In November 2023, UKNNL took the lead in organising the technical programme of the first day-long CPD Workshop since the pandemic on the topic of ALARP (with the event sponsored by Nuclear Transport Solutions). As well as educating the community and providing an opportunity to network, the workshop provided a valuable platform to advocate the key ethos of the Nuclear Safety core science theme to the next generation – i.e. the need to ensure that nuclear safety solutions are ALARP (and not overly-pessimistic / restrictive). The Workshop was attended by around 70 people, which was an increase on the pre-pandemic numbers.

Significant focus is also placed by the theme on developing the next generation of nuclear safety SMEs within UKNNL. Early and mid career staff are actively encouraged to seek national and international development opportunities. Some of the activities supported by the theme in recent months include (i) attendance at the hands-on criticality safety training course in the US, (ii) presenting a paper and chairing a session at the 2023 International Conference on Nuclear Criticality Safety, plus (iii) more broadly, participation in international collaborations on novel challenges which help to add impactful value to the nuclear industry.

“A huge thank you for the support provided by UKNNL for the WPC CPD Workshop on ALARP. The WPC CPD workshops have been running since 2003 and form a core part of the WPC objective of sharing learning within industry. Whilst the introduction of the successful WPC webinar series (also strongly supported by UKNNL) has provided CPD opportunities, it was really important to restart the workshops to regain the benefits from this being an in-person event. The success of the workshop was due largely to the efforts of UKNNL in leading the planning and organisation of the event.”

**Fred Winstanley**
Outgoing Chair of the UK Working Party on Criticality

# Robotics


## Summary

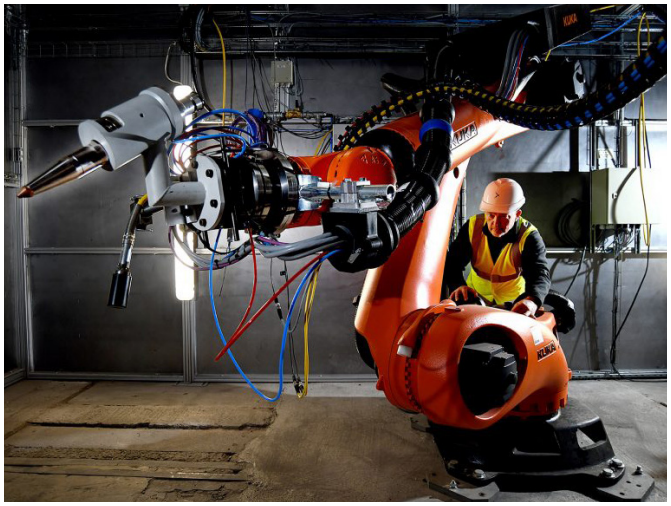
Within nuclear, it has been identified that robotics can be a key enabler to decommissioning, reducing the associated hazards by enabling operations remotely and removing humans from potential harm where possible. UKNNL's robotics core science theme holds a vision to develop enabling capability for the safe and robust deployment of innovative and advanced robotic technologies, to meet the demands of current and future nuclear decommissioning challenges.

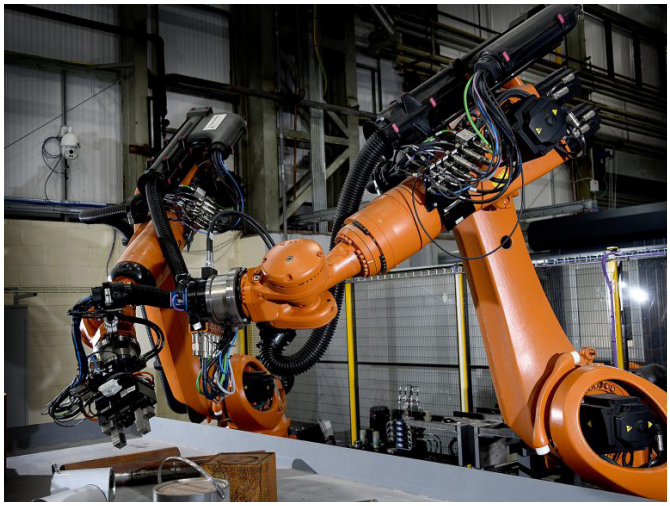

### Core Science in focus

Striving towards establishing UKNNL as a technical leader in nuclear robotics, the core science theme supports UKNNL's robotics capability by participating in international forums, involvement in world-class R&D programmes, and contribution to the development of standards and best practices for the safe, secure adoption of robotics in the nuclear sector.

A key focus is on carrying out scientific analyses for the development of tools, techniques, and methods that support the integration and deployment of digital technology (including aspects of machine learning and AI) and novel robotics solutions such as mobile, collaborative, soft, and continuum robots. Given the hazards and security requirements associated with operational nuclear facilities, the delivery of this focus is always centred around safety and reliability.

UKNNL's Robotics core science theme works closely with various collaborators through provision of technical contribution, steering board involvement, and in-kind support to several research grants and programmes.





# Robotics system substantiation and the Hazards Forum RAS safety event

## Challenge

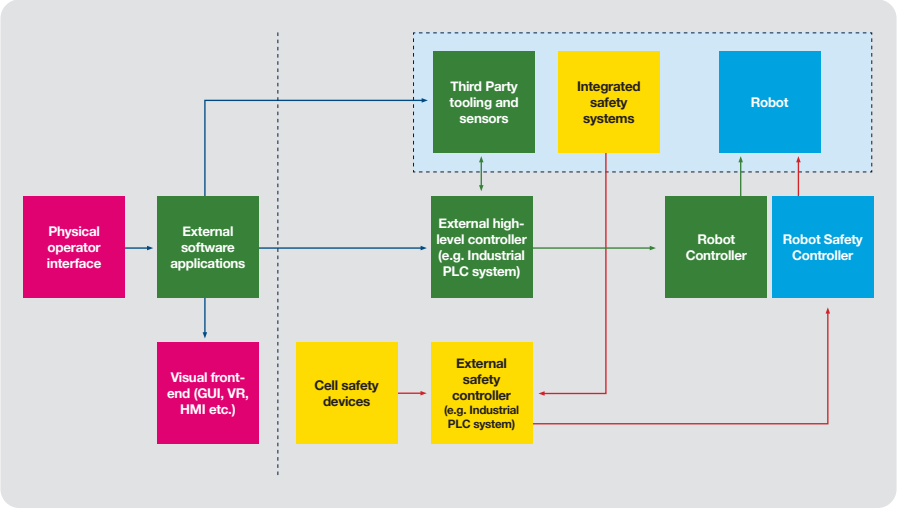
Current standards and policies have placed difficulty on the robotics capability regarding the deployment of robotics on site, for example on Sellafield sites where robotics has been identified as an enabler in the decommissioning journey. UKNNL has been working towards developing these standards and policies to allow an easier deployment of new technologies and equipment.

## Solution

Working collaboratively with the former Professional Lead for EC&I at ONR, UKNNL has developed guidance to support the navigation of regulatory assessment guidance NS-TAST-046 on Computer Based Safety Systems.

This guidance intends to help with improving reliability claims for robotic systems in nuclear decommissioning safety cases, therefore enabling easier deployment of systems on site.

UKNNL has been researching approaches to support safety claims placed against robotic systems.




Generalised example of an industrial robotic system for substantiation in a nuclear decommissioning safety case.

Cuebong Wong delivering the robotics capability presentation on the challenges and proposed pathway to improving reliability claims for robotic systems inn nuclear decommissioning safety cases.


The UKNNL Robotics Capability co-chairs the National RAS (Robotics and Autonomous Systems) Regulations, Standards, and Ethics Committee alongside the HSE, enabling the collaboration of regulatory bodies and public infrastructure organisations. This is supported by a cross-sector industry working group of organisations driving RAS implementations.

UKNNL's Cuebong Wong was invited as a guest speaker and panellist at an event co-hosted by the National RAS committee and the Hazards Forum. The event was held at the Institution of Civil Engineers in London and Cuebong presented on behalf of UKNNL's robotics capability.

Cuebong presented a piece on the challenges and pathway to improving reliability claims for robotic systems in nuclear decommissioning safety cases. Nuclear decommissioning was discussed as a key opportunity for the UK to develop significant learning in the navigation of regulations and standards and to build experience in the safe use of RAS technology.

The audience comprised cross-industry stakeholders from academia, supply chain, end-users, regulators, and policy makers. Challenges and learning in the adoption of RAS Technology were shared constructively.

The collaborative work of the Robotics capability has continued to address challenges associated with the process for substantiating robotics systems in safety applications, enabling significant progress to be made in the use of robotics in nuclear decommissioning.

Another key objective is to develop UKNNL personnel's skills, knowledge and understanding of robotics to grow and retain capability within the organisation, supporting the delivery of work for new and existing customers.

### National RAS Regulations, Standards and Ethics Committee

The committee is co-chaired by the HSE and UKNNL. The committee brings together regulatory bodies and public infrastructure organisations and is supported by a cross-sector industry working group of organisations driving robotics and autonomous systems (RAS) implementations.

Collaboration across sectors and their regulators creates significant opportunity to clarify how risk profiles are changing with these technologies and inform how industry can effectively communicate assurances that develop trust and accountability.

# PARIS

## Summary

The Plutonium and Advanced Isotope Separations (PARIS) core science theme builds internationally recognised capabilities to work on solutions to some of the nuclear industry's biggest challenges.

This theme has a supporting role in the long-term storage and future use of the UK's civil plutonium stockpile. In 2023, the theme was permanently renamed 'PARIS' (Previously 'ARIS') to emphasise the importance of plutonium science within the theme.

PARIS is strongly aligned to key customers including Sellafield Ltd for the safe and secure storage of plutonium and the NDA for plutonium disposition.

PARIS has also been very successful in participating in European programmes from FP5 to Horizon 2020.

Internationally, key customers include the European Space Agency (ESA) for the provision of isotope-based space power sources and Idaho National Laboratory for radiation chemistry.

### Vision

PARIS will develop internationally recognised capabilities and impact by integrating customer and internally funded R&D projects. It will focus on advanced reprocessing of spent fuel and recycling of actinides for future closed nuclear fuel cycle options; plutonium characterisation and storage science, and separations of other isotopes of potential value for non-fuel cycle applications.

The Key Objectives for the PARIS core science theme are:

- Extend measurement and analysis capabilities for actinides in solution
- Understand the characteristics of long-stored plutonium under conditions relevant to the UK stockpile
- Support PhD and PDRA projects based at strategic Universities, supported through PARIS and national funding bodies
- Provide opportunities for earlier career researchers to develop towards SME status and develop their practical "alpha skills"

The theme supports key industry challenges:

- Building capability and knowledge of advanced nuclear technologies with enhanced safety and sustainability by virtue of fuel recycling and reducing wastes for disposal
- Understanding routes to the production and isolation of key isotopes or elements using non-reactor based technologies
- Safe and secure storage of plutonium
- Disposition of UK plutonium

# Thermal Treatment


## Summary

Thermal treatment has a key role to play in nuclear waste clean-up and nuclear material management and disposal. The ultimate strategic goal of this core science theme is to reduce the volume of waste, improve the safety and stability of nuclear waste for storage and disposal, and reduce the costs associated with waste management.

**UK nuclear sites such as Sellafield and Dounreay are progressing towards decommissioning and thermal treatment will provide support in dealing with the UK's nuclear waste and clean-up operations. UKNNL is in a strong position to be leading players for small scale active and large-scale inactive development and demonstrations of existing and new thermal technologies.**


### Core Science in focus

The Thermal Treatment core science theme carries out essential work involving thermal product fabrication, characterisation, and analysis to support wasteform thermal technology. This theme has the vision of becoming an international Centre for Excellence, and currently has a focus on identifying and providing evidence of the benefits of using thermal treatment in waste management.

Collaborations play an important part, both within the UK and internationally, boosting the expertise which UKNNL holds. In turn, this area of work significantly increases the knowledge of the capability and helps us to align our research to the needs and priorities of our key customers such as Sellafield Ltd.

Thermal technologies are flexible to produce a range of products including glass wasteforms, ceramics and glass-ceramics. UKNNL has leading materials experts in both glass and ceramic science and the theme is driven to expand our capabilities and knowledge transfer to early career colleagues.

Existing thermal technologies operated by UKNNL include hot isostatic pressing (HIPing), Geomelt®, cold-press and sinter (CPS), MOx fabrication and the vitrification test rig (VTR) in support of Waste Vitrification Plant (WVP). This theme is supporting investigations looking at additional waste feeds that may be treatable via such technologies as well as other novel thermal technologies that may be selected for future waste-streams.

The Key Objectives for the Thermal Treatment core science theme are:

- Develop a future UKNNL workforce with the necessary skills and experience in the fabrication, characterisation, analysis and modelling of thermally treated materials and products (especially active)
- Align our research with the priorities of our customers and regulators to demonstrate the significant benefits of thermal treatment to realise the future opportunities for the business
- Create long-term and productive collaborations with academic and other strategic research partners to influence the UK (and global) agenda

# Examples of PhDs supported by the Thermal Treatment core science theme include research into both ceramic and glass wasteforms

**Jenny Ayling**
The University of Sheffield

Measuring the effect of alkali metal cations on UK High Level Waste Glass dissolution

In relation to glass waste, Jenny Ayling has been researching the dissolution and the release of radionuclides of when glass comes into contact with ground water. This work aims to support the durability and integrity of the vitrified waste when placed in a deep geological disposal facility.

It is understood that all UK vitrified HLW will eventually be consigned to the Geological Disposal Facility. It is highly likely for groundwater to ultimately come into contact with the HLW glass. This signifies the importance of understanding dissolution and the release of radionuclides. Potential sites in the UK have high salinity.

A range of test methods were used to probe different stages of dissolution, with Jenny presenting results at two conferences in Cambridge, between June and July of 2024.

**Aine Black**
The University of Liverpool

Understanding the role of Al and quantifying the ratio of 3- to 4-coordinated B sites in UK nuclear waste glasses using Nuclear magnetic resonance

Aine's research has investigated the long term effects of radiation exposure to glass by inducing changes in its structure, again looking to support the integrity of vitrified waste in a deep geological disposal facility. The nuclear waste glass is currently stored at Sellafield pending disposal in the geological repository. This indicates the importance of understanding how long-term radiation damage affects its performance, a key consideration contributing to its safe disposal.

The results of this research were presented as a poster at the Ion Beam Modification of Materials (IBMM) international conference held in London, between the 1st and 5th of July 2024. Aine received an award for her poster.

Aine said, “The IBMM conference spanned many fields across material science, characterisation techniques and radiation damage. It was a remarkable conference to attend and to hear the current ongoing research in the field but the highlight for me was receiving the award for best poster presentation in the historical Church House in Westminster.”

**Einan Soloman**
The University of Liverpool

Finding Novel Production Routes for Ceramic Wasteforms in Support of Plutonium Disposition

For use of ceramic wasteforms, Einan’s research looked at Hot Isostatic Pressing for Pu disposition. The project successfully fabricated wasteforms without the need for milling liquids, avoiding the need for an off-gas capture system, furthermore lowering criticality risks associated. These ceramics are designed to place the plutonium beyond use for over a 100,000 years.

Einan said, “The UK’s stockpile of separated plutonium, currently stands at 140 tonnes, poses significant economic and security concerns. This project aimed to explore one of the two major routes under consideration by the NDA for managing this stockpile, focussing on incorporating plutonium into a mineral phase called zirconolite ($CaZrTi_2O_7$) using a specialised furnace known as a HIP (hot isostatic press).

The aim of this project was to adapt laboratory bench-scale experiments into methods suitable for industrial-scale application. Specifically, it aimed to eliminate the need for processing liquids without compromising sample quality or processability. As a result of this project, three alternative production routes that met these criteria were identified.”

Ultimately, investment into these projects has allowed for the development of new capability in Thermal Treatment, building a foundation of knowledge in preparation for disposal of vitrified high level waste in a deep geological disposal facility, and the use of HIP for Pu waste. Without this investment, this capability would not have been able to expand and investigate these novel areas.

# Innovation

**Innovation is one of the fundamental pillars underlying the foundation of the Science and Technology Agenda at UKNNL. The organisation maintains its enthusiasm in constructing and encouraging an environment in which our people feel inspired to innovate; to explore their ideas and interests for developing new solutions.**

The Innovation programme has been created in order to build a successful broad-ranging and balanced innovation portfolio that addresses UKNNL, industrial and customer needs. The programme aims to create space to think and provides access to funding through a clear process that takes ideas through technology readiness levels to product delivery.

Over the last few years, the Innovation team has been using a clear process to take ideas through the technology readiness levels to product delivery. This provides an optimistic environment to really assess the merit of ideas for commercialisation. There are three distinct funding levels:

- Innovation Primer – supporting early stage ideas with up to £1,000 funding to allow a review of scientific material to validate the proposed idea
- Innovation Builder – supporting initial proof of concept trials, with a maximum of £20,000
- Innovation Delivery – enabling commercialisation through product development with awards of > £20,000

**Approved and funded Primer applications**

**19**

FY23/24

**Approved and funded Builder applications**

**7**

FY23/24

**Approved and funded Delivery applications**

**0**

FY23/24

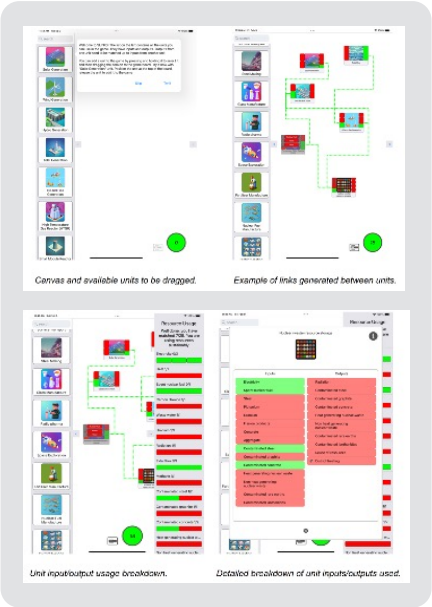
### Overview of the innovation programme's funding streams

| | Primer | Builder | Delivery |
|---|---|---|---|
| Purpose | Idea stimulation | Prototype | Commercialisation |
| Award size | < £1,000 | < £20,000 | > £20,000 |
| Duration | 2 months max | 12 months max | Unlimited |
| Review time | 1 week | 4 weeks max | 6 weeks max |

# S-LINKS Project

## Summary

This innovation project focuses on the topic of nuclear and sustainability. Initially funded through the innovation lab process, it highlights the benefits of having the innovation funding streams, demonstrating the potential each idea may hold. S-LINKS progressed through the process, firstly as a primer, then as a builder to develop a prototype.




**The foresight stories for S-LINKS were:**

- **The development of symbiotic technology and industry clusters, where industry clusters are designed to operate in a way that decarbonises industry and optimises the use of resources in a sustainable manner.**
- **The development of an information driven circular economy, where digital technologies enable a circular economy by using data to enable a better understanding of resource usage and in the development of sustainable technology.**
- **The need to change the perception of nuclear waste and decommissioning by demonstrating and being able to communicate full lifecycle thinking and approaches when developing nuclear technology.**

The vision for S-LINKS was to develop a digital tool/application to enable visualisation for the user, allowing the user to explore circular economy and whole system thinking concepts.

This app will allow users to explore industry synergies, demonstrating the energy and material flows between sectors. The tool can be used to promote engagement and discussion, by exploring industry clusters. The aim is to have a downloadable app accessible by a wide audience to promote sustainability, whilst there also being an outreach/educational potential.

The app shows a collection of 'units', each representing an industry function, for example solar generation, wind generation and small modular reactors. On each unit, there is a detailed list of inputs and outputs. To explore links between units, drag them onto the clear 'board' area of the screen. To demonstrate sustainable resource usage, the app will show matches between the outputs of one unit, and the inputs of another. If there are links, a green link will appear on the screen. Each unit has an overview, highlighting its inputs and outputs.

With user friendliness in mind, the layout shows clearly how components of a 'system' interrelate, and it considers the entire system in a 'big picture' fashion.

### Progress

Within a year, the project has gone from the origin of the idea to a prototype app on a tablet device. It began with the coding of inputs and outputs then progressed into an early prototype to demonstrate the interconnectedness of the networked 'units'.

A graduate project has started, with the aim of further developing the project. There is the potential for this app to be developed into a web app. S-LINKS provides a development opportunity for new UKNNL graduates, both in terms of exposure to information and building networks by speaking to subject matter experts during research.

### Mobetrics Collaboration

A highlight from the S-LINKS project is the collaborative work alongside Mobetrics. Based in Penrith, Cumbria, Mobetrics is an app developer and local SME responsible for developing an iPad version of the S-LINKS app. Quick progress has been enabled due to the collaboration with Mobetrics, with the project continuing to develop via the UKNNL graduate project.

# Strategic Research

## Advanced Nuclear Fuel Cycle Research

UKNNL is working to develop skills, knowledge, and capabilities in the areas of “advanced recycle and waste management" and “advanced nuclear fuels".

This involves development of new technologies and processes which can contribute towards a reduction in the whole lifecycle costs of nuclear energy. The programme also aims to ensure international co-operation, with an emphasis on promoting and maintaining the role of the UK as a global leader in these areas.

The programme is founded on the investment UKNNL made in two of our Core Science areas: PARIS and Advanced Fuels.  These Core Science programmes continue in tandem with advanced nuclear fuel cycle research, indeed part of the commitment that UKNNL made to continue to invest our ETR into these technical areas.

## Alpha Resilience and Capability (ARC)

The programme to underpin and enhance the national Alpha Resilience and Capability (ARC) is a long-term collaboration between the UK Government and the nuclear sector.

Creating upskilling opportunities for current employees is an important element of this and so ARC's technical workstream is seeking proposals for:

- Technical interventions
- Travel bursaries
- Secondments at ARC partner organisations

# Recycle and Waste Management


## Summary

Building on the past success of the Government-funded Advanced Fuel Cycle Programme (AFCP), this is an integrated research programme to maintain essential skills and capabilities in separations and recovery of strategic materials from spent nuclear fuels and other wastes or materials.

**The programme focuses on research and development of innovative separations and waste management technologies as well as the development of skills and next generation expertise that are needed not only for advanced nuclear fuel cycles but also for the environmental restoration and nuclear security missions across the UK's nuclear sites. There is a strong focus on promoting sustainability and aligning with the goals of the circular economy.**


### Strategic Research in focus

Under some future nuclear energy scenarios, a closed nuclear fuel cycle may be needed to enable energy security and reduce the impacts of geological disposal, so it is prudent to keep this option open. This Strategic Research programme is designed to deliver these needs, supplementing the broader portfolio of customer-driven plutonium and alpha-active projects in UKNNL. It continues to support a broad range of skills and capabilities in advanced recycling and waste processing as well as practical alpha-skills. The long-term objective is to develop more sustainable options for future nuclear energy systems and separations of strategic materials in both aqueous and molten salt media, including the associated waste treatments. The programme supports UKNNL's Focus Areas in Clean Energy, Security & Non-Proliferation and Environmental Restoration.

The core of the programme is based on the development and testing of advanced aqueous separations processes designed to recover potentially valuable materials for recycling. This builds on more than two decades of UKNNL research as well as past support to the reprocessing operations at Sellafield. In addition, the wastes generated from recycling processes themselves must be minimised.

There is a substantial emphasis on the waste management aspects within this research programme ensuring an integrated approach to materials processing and recycle. An approach based on the waste management hierarchy and life cycle assessment is adopted, with specific tasks covering off gas capture and immobilisation and treatment of liquid effluents and solvents.

The Strategic Research programme combines experimental work, including active work with plutonium and other alpha-active materials, alongside modelling and simulation. It uses skills in chemistry, chemical engineering and process modelling as well as practical laboratory skills in alpha-active materials handling (see Figure) and on engineering-scale rigs and is supporting the development of the next generation of subject matter experts. There is a strong emphasis on international collaboration to leverage investment and maintain UK impact and influence. The programme collaborates with US national laboratories (under the bilateral agreement between US-DOE and DESNZ), international organisations like the OECD Nuclear Energy Agency (NEA) and International Atomic Energy Agency (IAEA) and European-level projects such as "PUMMA" (Plutonium Management for More Agility) which is funded by the Horizon 2020 framework

programme. Furthermore, the programme is also championing how the recognised concepts of sustainability are applied to nuclear energy and nuclear fuel cycle options; including the application of tools and techniques such as life cycle assessment and fuel cycle models to evaluate different scenarios and technologies.

### Technical highlights

One highlight in 2023/24 was the publication of a special issue of the Progress in Nuclear Energy journal dedicated to "Development of Advanced Nuclear Fuel Recycling Options" which featured 12 articles arising from this programme and AFCP including two papers on iodine behaviour and abatement in process off gases. Indeed, "Off Gas Capture" is a key theme in the programme.

# Collaboration

Collaboration remains a core value of UKNNL.

Since becoming eligible for UK Research and Innovation (UKRI) funding as a Public Sector Research Establishment in 2022, UKNNL has been successful in being awarded UKRI funding for collaborative research with universities spanning across our Science and Technology Agenda.

While this funding covers 80% of the research costs, the remaining 20% is sourced from the reinvestment of UKNNL's earnings.

**UKNNL aims to bring together researchers, customers, academia and government to develop efficient partnerships to help deliver a global step change in environmental restoration.**

**Through funding opportunities such as UKRI, and with our network of engaged partners, we are committed developing new technologies and the people who work with them. This is one way in which UKNNL is demonstrating taking responsibility for ensuring the environment is safe and clean for the next generations.**

# International Collaborations


## Summary

Utilising its investment into Science and Technology, UKNNL continues to be involved in a wide variety of international collaborations, with emphasis on the importance of effective collaboration in facing international industry-wide challenges.

Helping to bring international best practice into the UK, UKNNL continues its development of a UK capability and our people to address the challenges of Environmental Restoration. Since Brexit took place, these international programmes in scientific collaboration of benefit to the UK remain ongoing despite the political and economic change brought on.


**Collaboration and Environmental Restoration**
Two examples of ongoing collaborations related to environmental restoration in particular are the HARPERS and NERC GEOsafe programmes.

## Harmonised Practices, Regulations and Standards in Waste Management and Decommissioning (HARPERS)

**This is an international collaboration project funded by €2.4m from the European Commission, plus additional associated countries' contributions including the UKRI supported UKNNL element of €263k.**

The project is focused on the opportunities and challenges for harmonising practices, approaches to regulation and standards in waste management and decommissioning. There are 30 pan European partners delivering the project and UKNNL is on the project Management Team and lead the Advanced Technologies Work Package.

In phase 1 of the project, an exercise was delivered to prioritise the needs and opportunities in advanced technologies. During the current phase of the project the partners are seeking further input from a range of stakeholders to capture findings into a position paper that will be completed in January 2025. The project will reach completion in May 2025.

## NERC GEOsafe

**This is a UKRI Natural Environment research council funded collaboration project of £0.4m with Imperial College London, Liverpool, Leeds, Manchester and Heriot Watt universities and also the British Geological Society.**

The project is focused on the challenges of moving Towards Safe Geological Disposal of Radioactive Waste in LSSRs (GeoSafe), namely the safe disposal of the UK's existing ~750,000 m3 Intermediate and High-Level Waste (ILW/HLW) and future waste.

The UK government policy is to dispose of the higher activity wastes in an underground geologic disposal facility (GDF) at an estimated cost of £20-53 billion over a multi-decadal lifetime. One of the rock types identified as a potentially suitable host rock for the siting of a GDF are lower strength sedimentary rocks (LSSRs).

The purpose of a GDF is the safe disposal of radioactive waste for periods of tens of thousands of years, in a manner that ensures that any transport of radioactive materials into the surrounding biosphere is kept below specified limits. Fundamental gaps still exist in our knowledge of the issues related to performance of these host rocks as a geological barrier to radionuclide transport. Addressing these gaps requires fundamental new understanding, which will require development and application of the next generation of experimental, analytical, and modelling approaches to meet the challenges of characterising key physical and biogeochemical processes from the molecular to field scale in these complex systems.

UKNNL is contributing to a number of Work Packages.

# University Collaborations

## Summary

A key role UKNNL has, as the UK's lead civil nuclear laboratory for fission, is to develop new technologies and future subject matter experts. Enabled by the geographical locations of UKNNL sites, the successful partnerships continue to address some of the biggest environmental restoration challenges.

### University Collaborations

**● Universities**

1 University of Aberdeen ●
2 University of Cumbria ▲
3 University of Lancaster ▲
4 University of Central Lancashire ■▲●
5 University of Manchester ■▲●
6 University of Liverpool ▲●
7 University of Leeds ■●
8 University of Sheffield ■●
9 University of Birmingham ●
10 University of Warwick ●
11 University of Oxford ●
12 University of Bristol ■●
13 Queen Mary University of London ●
14 University College London ●
15 University of Surrey ■
16 University of Southampton ■

**● UKNNL facility locations**

17 Workington
18 Sellafield
19 Preston
20 Warrington
21 Leicester Space Park
22 Central London
23 Abingdon
24 Stonehouse
25 Gaerwen


**Key**

▲ CINDe
■ TRANSCEND
● Core Science R&D

**Centre for Innovation in Nuclear Decommissioning (CINDe)**
The first CINDe programme enabled researchers to work closely with industry by co-locating their workspace at UKNNL's Workington Laboratory. The programme has funded 16 PhD students across five cohorts in Cumbria with three subsequently joining UKNNL. Eleven journal articles and one book chapter have been published over the last year. The success of the joint UKNNL, Sellafield and NDA programme has been recognised by the NDA (see pg. 41). A second programme, CINDe 2, has an expected duration of nine years.

**TRANSCEND**
TRANSCEND (Transformative Science and Engineering for Nuclear Decommissioning) is a £9.4m collaborative research consortium of 11 universities and eight industry partners (including support from public interest reinvestment), and it comprises 40 PhD and post-doctoral projects. The programme aims to unite academic and industrial research communities to enable the adoption of a comprehensive approach to decommissioning and waste management. This programme has now entered its final year.

**Core Science Theme PhDs**
Core science themes play a key role in supporting projects that have direct relevance to Sellafield challenges. The flexibility provided by each theme enables projects to be created that target relevant issues and ensure that critical skills are developed and maintained.

# Laser Induced Breakdown Spectroscopy (LIBS) for remote underwater measurement

## Challenge

Various storage ponds on the Sellafield site currently contain radioactive materials which will require moving into alternate, long-term storage. Due to decades of aqueous storage, degradation has occurred, rendering the provenance and state of some of the materials to be uncertain or unknown. Characterisation of materials and pond chemistry monitoring is necessary to inform the decommissioning strategy.

## Solution

This project is aimed at the development of the necessary tools for the use of LIBS in the characterisation of underwater materials and the monitoring of pond chemistry. LIBS is a pseudo non-destructive characterisation technique which uses laser induced plasma to provide elemental characterisation of a target material.

Overall, the goal is to produce a probe capable of in-situ characterisation of both submerged solid materials and conditions within the storage ponds.

## Outcome

In March 2024, work was done focusing on proving concepts with simulants using a benchtop instrument in the CINDe lab at UKNNL Workington. This work analysed water, suspended or dissolved solids, and undissolved solids stored in liquids at the surface.

The aim is to eventually introduce this in-situ analysis of waste in ponds as it would significantly reduce the need for lab analysis, reducing the cost and time associated with sampling and offline analysis.

"My work is focused on the development of the Laser Induced Breakdown Spectroscopy technique for underwater elemental analysis. This was initially planned for with a focus on the storage ponds on Sellafield site however, following discussions with staff from Sellafield, we have identified several other possible areas of application for this technology such as MSSS and SIXEP.

Working as part of CINDe has allowed me to utilise the expertise and equipment from both UKNNL and the University of Manchester. I had spent my first year at the university to develop understanding of the technique and general laser\optical skills before coming to UKNNL Workington to get a better understanding of the nuclear industry and the challenges involved in deploying any equipment onto site"

**George Cook**
University of Manchester, UKNNL CINDe

**The Centre for Innovative Nuclear Decommissioning (CINDe) was established in 2017 and is based at UKNNL Workington, Cumbria. This programme is led by UKNNL working in collaboration with Sellafield Ltd (SL), the University of Manchester, Lancaster University, the University of Liverpool and the University of Cumbria.**

It's purpose is to provide additional underpinning and innovation to the Research and Development (R&D) needs for the Sellafield and wider nuclear industry decommissioning mission.

Performing innovative R&D to support the national decommissioning mission, CINDe brings together leading academics from UKNNL and SL, enabling access to UKNNL facilities to our university partners.
Allowing more frequent interactions between the academic partners and industry to enable closer more effective working relationships to be developed, it enhances the chance to build on technical reputation through the publication of high quality, peer-reviewed scientific journal publications.

CINDe is an enabler in bringing new talent to the industry and building skills in the next generation nuclear R&D skills pipeline in West Cumbria. Immersion inside the industry via CINDe is valuable for university students and for the nuclear industry alike.

# Enablers

UKNNL has world-leading scientists, engineers, technologists and experts across multiple fields, focused on nuclear research and championing new ideas for industry.

We ensure continuous investment into our people and facilities to continue to deliver globally recognised, world leading science and technology, that has impactful benefits.

This investment enables UKNNL to provide knowledge, technology and access to cutting-edge facilities to partners and customers, operating our unique nuclear facilities and cutting-edge laboratories that enable our people to push the boundaries of science and innovation.

# Facilities and Infrastructure

## Summary

In 2022/23 UKNNL commenced a long-term programme of refurbishment, modernisation and remediation of the Windscale, Workington and Central Laboratory facilities. This programme allows the growth of UKNNL, our partners, the supply chain and the nuclear sector but importantly ensures our ability to meet customer needs and enhance academic collaborations.

UKNNL's unique capabilities continue to support the nuclear industry whilst ensuring achievement of national and organisational goals. With our strongest asset being our people, we strive to utilise technology and innovation to ensure UKNNL facilities and infrastructure are world class.

"Investment in our facilities and delivering projects to support science and technology is a challenging task, that requires enhanced project management skills and unique capabilities. UKNNL recognises that sustained investment is required to support the nuclear mission and to deliver infrastructure that is world leading for our customers now and for the future"

**Gail Smith**
CapEx Customer Workstream Lead, UKNNL

In 2023/24 Capex delivered over £30m of improvements to Windscale, Central and Workington sites that included:

- Completing major milestones of the Security Enhancement project at the Windscale site that brings resilience and state of the art security enhancements
- Completing phased physical upgrades to the facilities that improve safety and reduce operational risks
- Building defence in depth by replacing outdated machinery and refurbishing caves and equipment.
- Increasing our capability and capacity to deliver by bringing underutilised and new technology into service
- Enhancing IT infrastructure for emergency arrangements
- Enhancing the health, wellbeing, and safety at work facilities for staff and users of the sites

Further investment will continue to support the refurbishment of aging assets and to continue to provide support for national programmes and to meet customers future needs.

### CapEx project team

**Number of project team members – 16**

**Number of live projects – 54**

**Successes**

- APM nomination for Project Professional of the Year
- BECBC Collaboration Award finalist
- BECBC Rising Star finalist
- Go awards – finalist for social value award
- Continued investment in the local communities through sustained social value activities

# IT

## Summary

In 2023/24, the IT department has made numerous improvements and enhancements to ensure UKNNL is equipped with stable, secure and reliable IT services.

"IT reaches every part of our organisation, meaning a healthy IT function is something we all benefit from. We are investing to lay the foundations for reliable, effective, and scalable IT. The new IT strategy sets out how we can provide UKNNL with IT capability that is fit for our role as HMG's National Laboratory"

**Lee Downie**
Vice President for IT, UKNNL

## IT Services Improvements

- Superfast Broadband Rollout (SDWAN): This upgrade is a major step towards providing IT services that are consistently stable, secure, and resilient and is a critical component of our Core Stability Programme.
- LAN (Local Area Network) Upgrade & Wi-Fi Enhancements: Alongside superfast broadband, we're upgrading our internal networks, or LAN, within each UKNNL site. This will fully enable the benefits of superfast broadband.
- Core Stability Programme: this program is designed to create a stable and dependable IT service that supports the business every day.
- Infrastructure Modernisation: This will give UKNNL better performance, security, and the flexibility to grow.

## Strategic objectives

**Investing in our people to release their potential:** ensure our workforce has the right skills and tools to effectively do their job.

**Always stable, resilient, secure & compliant:** Stability is our first step to setting the foundations in which UKNNL can grow.

**Operationally and strategically aligned to the business:** strategically support the business to drive efficiency and capability.

**Enabling business value through data:** combine and leverage our data to create meaningful information and reports.

**Efficiency through technology innovation:** use our expertise and industry insight to deliver innovation that enables UKNNL to work smarter and continue to grow.

# Technical Skills and Capability

## Summary

The complexity of operations in nuclear facilities requires an advanced level of specialised knowledge in many areas to support safe and efficient practices. A commitment to technical excellence enables nuclear facilities to meet safety and operational standards, progress technologies and foster public trust in nuclear to contribute to the long-term sustainability of the industry.

Started in September 2023

**10** Postdocs

**17** Graduates

**14** Apprentices

**Continuous learning and upskilling are critical to the delivery of science and technology, especially in an industry where personnel are required to be at the forefront for the public's best interests. UKNNL therefore invests in a range of areas to support upskilling, highlighted here.**

## Early careers

UKNNL runs an early careers programme that provides apprenticeships (including degree apprenticeships), a post-graduate scheme and a post-doctoral scheme. Following a structured early careers programme where junior professionals are integrated into teams, allowing them to develop specialised knowledge in their technical area; this is complemented by training opportunities that occur alongside their technical work to help each person develop holistically throughout the programme.

"Being on the Post Doc scheme has facilitated a smooth transition from academia to industry. I have got involved in a wide variety of projects, enhancing both my technical skills and knowledge of the industry. Furthermore, the time provided has allowed me to pursue my own research and develop academic collaborations beneficial to both UKNNL and the wider sector."

**James Reed**
Research Technologist, UKNNL

"The network of graduate cohorts is a friendly and inspirational group of people working across the business, and I have the benefit of developing professionally alongside them. The graduate scheme, as well as the variety of work I have been involved in, has given me the opportunities to enhance my technical skills and increased my understanding of UKNNL and the wider nuclear industry."

**Caitlin Painter**
Statistics Graduate, UKNNL

## Scientific Technical Leadership Programme (STLP)

The STLP is a collaborative programme between UKNNL and the University of Liverpool. It aims to upskill the next generation of Technical Leads in the organisation by focusing on skills such as report writing, data management and general technical leadership skills.

Embedding such skills in those who will be leading the nuclear industry in the years to come will equip them with a solid foundation in the critical thinking skills to address emerging challenges.

"STLP offered the opportunity for me to be truly reflective about technical strengths and weaknesses, in a constructive environment. With a good blend of experiential training and expert insight, I feel that in only a few short sessions I gained great experience, and confidence in my own abilities as well as identifying areas to push my professional development. The course brought together a great mix of diverse colleagues from across the business who I otherwise would not get the chance to interact with, so I feel much more connected as a result."

**Gareth Mannion**
Research Technologist, Waste Management and Decommissioning

## Education Concession

Funding of Education Concessions aims to support individuals in reaching their full potential, while also aligning with the needs of the organisation. Education Concessions can take the form of academic or vocational qualifications for those outside of the early careers bracket.

Carrying out formal qualifications that will contribute to an individual's role at UKNNL allows for personal development in a technical area that is directly fed back into the organisation.

"Completing my MSc alongside my role as a Research Technologist is something that I would not have been able to do without an Education Concession. I know that balancing my studies and work at UKNNL has allowed me to develop into a more well-rounded scientist, with the qualifications to back up my knowledge."

**Jessica Blenkinsop**
Senior Research Technologist in Waste Management & Decommissioning, MSc Analytical Chemistry at the University of Manchester

## NewClear Leaders Programme

The NewClear Leaders programme is a development programme for people who lead others, including line, technical and matrix leaders. Its purpose is to create a culture where best practice leadership is embedded in all of UKNNL's activities to ensure employees can lead confidently and contribute positively to achieving our strategy and delivering our 'NewClear Future'.

The programme contains both formal and informal learning elements, consisting of 360 feedback, workshops, coaching, and self-led learning. To reflect subtle differences in leadership that may be required for line management and, for example, technical leadership, UKNNL runs two formats of the NewClear Leaders Programme: the 'Managers Programme' and the 'Leaders Programme'.

"The NewClear Leaders Managers' programme allowed me to learn about different leadership styles, understand team culture and how my behaviours can influence my team. It was also beneficial to obtain valuable personal feedback from my team and others within UKNNL through the 360 Feedback Exercise. I have used a number of tools which I learnt through the programme to enhance my leadership style which has positively impacted and benefited my team."

**Barbara Dunnett**
Senior Technology Manager, UKNNL

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