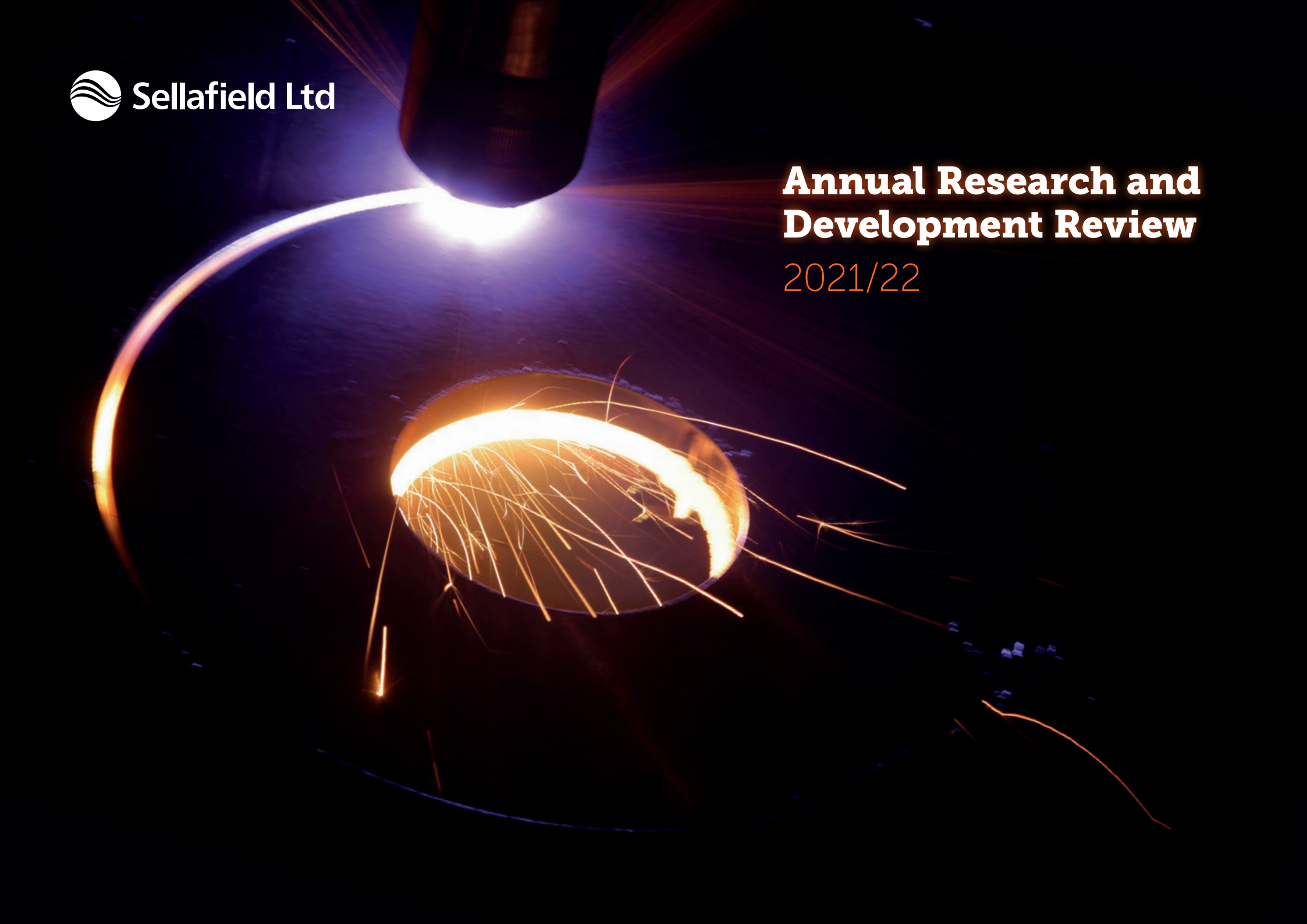
Sellafield Ltd

Annual Research and Development Review

2021/22



Contents

This report presents:

- Research and Development (R&D), managed by our value streams, driven by the needs of our business.
- Longer term R&D focused on opportunities for innovative technologies, tools and techniques to reduce costs, improve safety and reduce timescales.
- Collaborative R&D with a wide range of supply chain companies, organisations and universities.
- Some of the specialist staff from the research community working in and with our technical teams.

Our mission is to safely and securely remediate the Sellafield site to benefit the industry, nation and region. To create a clean and safe environment for future generations.

Introduction

I hope you enjoy this year's annual report on the Research and Development (R&D) that our technical teams both undertake and sponsor. This work is fundamental in delivering our purpose of a clean and safe environment for future generations.

Our aim to remediate the Sellafield site remains constant and with each year we progress with the reduction of the site hazards and the building of technically advanced facilities to manage and store legacy waste. This coming year marks the end of an era with the cessation of reprocessing nuclear fuel on the Sellafield site. This will allow our workforce to focus on decommissioning and waste management activities moving us closer towards the site end-state. The ability to make the decision to end Magnox reprocessing and to do this safely and effectively relied on the years of knowledge and experience built up in our technical teams and centres of expertise. It provides just one example where the technical support to our operational facilities and forward-looking projects ensures our endeavours to provide Lifetime Value for Money*.

I am, as always, in awe of both the quality of this work and the breadth of subject matter that our technical teams consistently deliver. In this report we discuss work as diverse as the use of robotics in the risk reduction of glovebox operations to the corrosion monitoring of our waste packages. To make the range of topics easier to digest we have divided the report into sections starting with our enterprise-wide R&D projects followed by those sponsored by our four value streams. Each section starts with that area's key research themes and includes introductions to some of the people involved in the R&D and the real passion they have for what they do.

We would be nothing without our partners and collaboration is a key theme of this report whether it is the joint research activities with the other Nuclear Decommissioning Authority (NDA) subsidiaries or work we sponsor with our technical supply chain and academia. The number and extent of interactions we have with others who hold similar challenges or hold the knowledge to solve our scientific and technical challenges are significant.

Finally, it is my privilege to introduce our new Chief Technical Officer Robin Ibbotson who started in January of this year. He brings a wealth of experience from BAE Systems to help shape and grow our portfolio of scientific and R&D activities putting us in the best possible position to tackle future opportunities and challenges.

Katherine Eilbeck
Head of R&D

*** Lifetime Value for Money**
Lifetime Value for Money reflects a wider holistic view of value. Remediating a legacy site and reducing the government's long-term liabilities is part of how we create value, but we can create additional value by leaving a positive legacy.

Foreword

I was honoured to accept the Chief Technical Officer role at Sellafield Ltd earlier this year recognising our world class science capability and the challenges inherent in such a position. We manage a significant proportion of the UK's nuclear legacy and inventory, and as such, we are custodians of the national reputation, and we need to underpin our decision with scientific evidence and leverage the best applicable technology.

I have been really enthused by the rapport we have with our stakeholders, the collaboration we have across our organisation, and our positive relationships with our partners and supply chain; the latter is hugely important, as when we look to the future, it is vital that we are a good industrial partner in West Cumbria, the North West and beyond.

It has been great starting out in the organisation and seeing the R&D projects described in previous reports now being deployed and adding value across our business. There is real opportunity to expand and improve our portfolio and consistently land the benefits of our work completed by our teams across the Sellafield site.

Robin Ibbotson
Chief Technical Officer

Nuclear Decommissioning Authority (NDA) Grand Challenges

				
Challenge theme	Reducing waste and reshaping the waste hierarchy	Intelligent infrastructure	Moving humans away from harm	Digital delivery – enabling data driven decisions
Challenge detail	Finding new ways to drive the waste hierarchy, increasing recycling and re-use in order to reduce volumes sent for disposal	Using autonomous technology to manage assets and buildings proactively and efficiently	Reducing the need for people to enter hazardous environments using autonomous systems, robotics and wearable technology	Adopting digital approaches for capturing and using data, to improve planning, training and aid decision making

To Find Out More Contact
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For more information about the NDA grand challenges visit:

https://www.gov.uk/government/news/nda-sets-out-its-grand-challenges

Enterprise Technical

The enterprise technical team reports to our Chief Technical Officer and is responsible for managing our technical capability and its key contract with the National Nuclear Laboratory (via the Technical Services Agreement). It also covers our technical baseline, and overseeing and managing the Research and Development (R&D) programmes that address the needs of our business.

There are several key R&D areas that the enterprise technical team is focused on:

- Robotics and Artificial Intelligence (RAI): Coordinating deployment across the enterprise and Technology Readiness Levels (TRLs).
- Higher active waste thermal treatment: Developing pilot plants to treat plutonium contaminated material, mixed beta-gamma wastes, and pumpable wastes.
- Science programme: Coordinating the needs of the business to undertake research in key universities and research organisations.
- Our medium to long-term research focus areas managed by our Integrated Research Teams (IRTs).
- Innovation activities including Dragons' Den style competition, Horizon scanning and our successful Game Changers programme.

Enterprise Research and Development

The role of enterprise research and development is to provide underpinning scientific information and technology options to improve safety, reduce costs and accelerate operations. Our R&D is focused on specific themes and is coordinated through Integrated Research Teams (IRTs) whose role is to:

- Work with end users to understand challenges and coordinate R&D efforts.
- Deliver R&D which provides value across the enterprise.
- Nurture a space for more speculative longer-term, high value R&D.
- Help the value streams engage with the wider external R&D community.
- Identify technology within the supply chain that can be of use to the value streams and demonstrate its value.

The longer-term enterprise led R&D programmes complement the shorter-term programmes, which are delivered by the operational plant facing parts of the business known as value streams, as illustrated here.

The current R&D science and technology focus themes are:

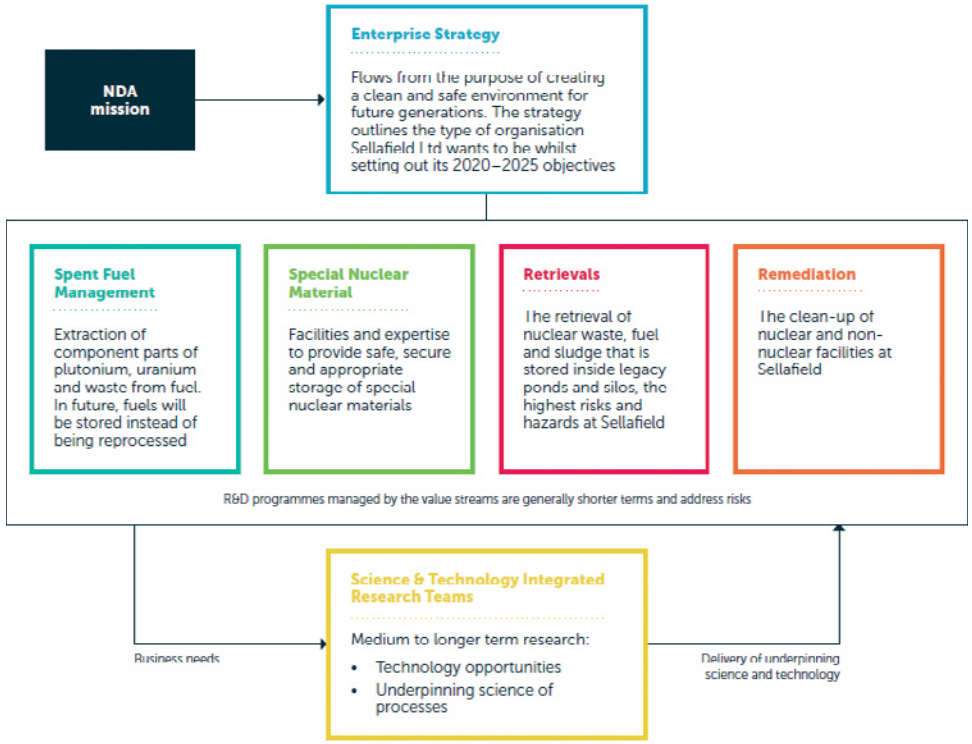
Science

- Material Science
- Process Chemistry
- Particulate Behaviour
- Environmental Science

Technology

- Measurement and Analysis
- Post Operational Clean Out (POCO)
- Robotics and Artificial Intelligence (RAI)
- Waste Management (radiological and non-radiological)
- Encapsulants
- Future Asset Management

These themes are described in more detail in the enterprise led Research and Development Plan.



Link between value streams and IRTs taken from 'Future research and development requirements' document

Collaborating across One NDA

Sellafield Ltd sits as part of the Nuclear Decommissioning Authority's (NDA's) group, one of four subsidiaries that NDA directly funds.

In 2021, NDA took the final steps to move to a group (subsidiary) operating model, away from the previous contractual, parent body organisation approach.

Dounreay Site Restoration Ltd (DSRL) became an NDA subsidiary in April 2021, followed by Low Level Waste Repository Ltd (LLWR Ltd) in July. These follow similar changes for Sellafield in 2016 and Magnox in 2019.

The subsidiaries have been further consolidated to create a more simplified structure. In January 2022 Radioactive Waste Management (RWM) and LLWR came together into one waste organisation, Nuclear Waste Services, and Dounreay is planned to join Magnox in 2023.

The NDA group is now made up of the NDA and its four key component parts:

- Sellafield
- Magnox with Dounreay.
- Nuclear Waste Services.
- Nuclear Transport Solutions.

NDA's estate has always worked closely together, undertaking joint research through the NDA's Direct Research Portfolio (DRP) and active membership of the Nuclear Waste Decommissioning Research Forum (NWDRF) but these changes in the group model are allowing for greater integration and collaboration and is a core part of the NDA's new innovation strategy.

Working on joint challenges with the NDA and the rest of the estate provides multiple benefits including:

- Additional locations to trial technology that is of interest to accelerate deployment at the Sellafield site.
- Sharing the cost burden and providing better value for the taxpayer.
- Providing a larger market that is of more interest to the supply chain.
- Pooling technical resources and knowledge.

Examples of joint R&D projects include:

- Laser decontamination technology development in partnership with Sellafield Ltd and DSRL. Technical support was provided from both organisations, and we subsequently led the development of a technology roadmap.
- Using the Game Changers programme, joint challenges that have gone out to the supply chain to find innovative technologies to support POCO, and looking for novel technologies and innovations for long-term monitoring of stored waste packages with Magnox Ltd.

  This joint approach benefits both the subsidiaries and the supply chain. At a recent Game Changers innovation event in Whitehaven one of the suppliers who attended commented:

"I don't know of anywhere other than a Game Changers event where I could have had direct contact with Sellafield, Magnox and Dounreay all under one roof."

- The 'Sort & Seg' innovation competition, which launched in July 2020 led and funded by the NDA and contracted through Innovate UK, sets the challenge of finding ways to sort and segregate mixed radioactive waste at NDA group sites. Five companies and their diverse consortia have now been awarded contracts, each worth up to £900k, to build demonstrators for their ideas. They are due to complete by March 2023.

NDA has also co-funded work with Defence Science and Technology Laboratory (DSTL) on Telexistence, that Sellafield Ltd are acting as the prime end user for innovative, next-generation technologies that will underpin the remote monitoring of sensitive sites by enhancing and improving upon existing methods. Some of the intended benefits of such technologies are the reduction of operatives from exposure to higher risk, difficult or time-consuming activities and the ability to take decisions based upon data gathered in line with NDA published Grand Challenges for technical innovation.

The NDA has also been collaborating with the oil and gas Net Zero Technology Centre (NZTC) through a number of workshops, and we are supporting the development of joint challenges in 'Characterisation of Inaccessible Pipes and Secure Communications in Difficult Environments', which are intended to leverage the learning and Best Available Technique (BAT) from both sectors.

A changing science programme

Our mission is changing. The year 2022 will see the end of Magnox fuel reprocessing and the start of retrievals from the Magnox Swarf Storage Silo (MSSS). The move from commercial nuclear fuel reprocessing to high hazard reduction and decommissioning of the Sellafield site will require a shift in focus for our science programme too.

Because our new mission has many unique, first-of-a-kind activities, it is not surprising that the science programme is packed with knowledge acquisition and hypothesis testing activities. We will use the critical knowledge gained from our scientific programme to inform and underpin our business decisions of the future.

Our science programme is compiled by science theme leads who belong to specific technical Centres-of-Expertise (CoEs). These leads work across the business identifying technical risks and opportunities associated with the current plan and future mission. These risks and opportunities form the basis for the science programme.

The technical CoEs and associated science programme have been designed to meet the future mission. The table summarises the main components of our science programme, together with a brief description of how they are supporting our future mission.

Most of our scientific work is commissioned through UK academic institutions where we engage with around 40 universities and commission research fellows, postdoctoral research associates and PhD researchers to undertake a broad range of activities.

Not only do these academic interests produce high quality research but they also serve to develop advocates for our business, across many scientific disciplines, which enable support, challenge and peer review for our work, methods and approaches.

Perhaps the most important benefit of this work is the development of highly trained people who will become the scientists of the future, within Sellafield Ltd and across the supply chain.

Science programme theme	Contribution to future post reprocessing mission
Material science and non-destructive evaluation	Justifying life extensions of plant and critical infrastructure through understanding material degradation and developing better measurement techniques.
Particles with fluids	Mobilise content in pipes and vessels following plant shutdown in order to clean out the systems.
Spent fuel science	Preparing for interim pond storage by understanding degradation, optimised storage regimes and measurement technology.
Special Nuclear Material (SNM) science	Preparing for interim storage of SNM through understanding the evolutionary mechanisms including radiolysis and oxidation to benefit re-use or waste disposition.
Science of uranium and reactive metals	Understand the behaviour of the wastes including radiolysis and expansion, and model the impact of the wastes arising from retrievals activities.
Effluent science	Understand and develop mitigation measures for the effluent treatment plant during retrievals, and as a result of mobilising content when cleaning out plant systems.
Container evolution	Understand the degradation mechanisms, predict lifetimes, and develop measurement methods of a range of interim stored containers including retrievals wastes and stored SNM.
Hydrogen management	Model hydrogen concentrations and develop understanding of generation rates, conditions, ignition potential and behaviour to inform future safety cases where hydrogen is present, such as SNM and retrievals recovery and storage.
Immobilisation science	Develop both cement encapsulation and thermal disposition technologies, so that future waste can be immobilised in the most efficient, sustainable and cost effective manner.
Environmental restoration	Look to beyond facility dismantling to develop both land clean-up strategies and mitigation measures to remediate large scale land environments.

University interaction and its broader value

Much of the science programme is delivered by UK universities. We actively manage a variety of mechanisms to develop capability and deliver our science programme. The primary mechanisms to deliver academic work are through the Engineering and Physical Sciences Research Council (EPSRC) funded Centres for Doctoral Training (CDTs), nuclear specific consortia and competed CoE university links.

GREEN CDT

The Growing skills for Reliable Economic Energy from Nuclear (GREEN) CDT is a consortium of five universities: Lancaster, Leeds, Liverpool, Manchester and Sheffield. It was formed in 2018 and currently has around 75 PhD students across the five universities. We currently sponsor 15 GREEN PhD projects across a variety of disciplines and take an active role in the industry aspects of running of the GREEN CDT.

NEF CDT

The Nuclear Energy Futures (NEF) CDT brings together PhD students from the universities of Bangor, Bristol, Cambridge, Imperial College London (ICL) and The Open University. This CDT was formed in 2018, and currently has over 70 PhD students. We take an active interest in many of the research projects and are in the process of supporting a second project.

FIND CDT

The Future Innovation in Non-Destructive Evaluation (FIND) CDT is an international centre of excellence in sensing, imaging and analysis for the field of Non-Destructive Evaluation (NDE). It comprises a consortium of six universities: Bristol, Manchester, Strathclyde, Warwick, Nottingham and ICL. The FIND CDT projects are of particular interest to the materials science and non-destructive evaluation CoE, who have provided industrial support to a number of projects.

Applied Photonics CDT

In the past few years, we have been exploring the benefits of photonic based sensing and analysis techniques, taking advantage of developments in lasers, photon counting and timing electronics. Two applied photonics CDT PhD students are working on our challenges, and we are engaging with this CDT to determine how it may be able to assist us with our future mission.

University interaction and its broader value

Fluids CDT

The University of Leeds CDT in fluid dynamics supports the delivery of many of the PhD projects that support the particles with fluids CoE. The ability to measure, model and predict fluid flows is critically important to the innovation of processes and products, and to the monitoring and prediction of fluids and particulates within our redundant chemical process facilities.

TRANSCEND

Transformative Science and Engineering for Nuclear Decommissioning (TRANSCEND) is a collaborative research consortium of 11 universities and eight industry partners. The £9.4m research programme comprises 40 projects to address some of the key challenges within nuclear decommissioning and waste management. We sponsor five PhDs, take an active role on the management board and take an interest in many non-Sellafield Ltd supported projects.

CINDe

The Centre for Innovative Nuclear Decommissioning (CINDe) was established in 2017, led by the National Nuclear Laboratory (NNL) working in collaboration with Sellafield Ltd and four universities: Manchester, Lancaster, Liverpool and Cumbria. The first five years of CINDe comprise 20 PhD students, with the first year graduating in 2021. We are working with NNL to develop a CINDe 2 starting in 2023, which will see at least 30 PhD students based at NNL Workington, working on our challenges over the next nine years.

Centres-of-Expertise University Links

A CoE university link is a contract that we award to a successful university for five years following a competitive commercial process. To-date we have CoE university links with the University of Leeds (particles with fluids) and London South Bank University (flammable gases). These links provide the platform to develop a deeper relationship on a specific subject and are extremely useful in supporting our CoE lead with world class expertise. We plan to extend the university themed links, starting this year with a link in uranium and reactive metals.

Spotlight on particles with fluids

Our CoE university link with the University of Leeds has a range of benefits from soft impacts to technological delivery. Members of the particles with fluids CoE community have an instant network of subject matter experts and technical specialists across our value streams, National Nuclear Laboratory (NNL) and the University of Leeds.

The University of Leeds has a strong pedigree in particle, sludge and slurry research for a number of industries (including nuclear) providing cross-industry context for problem statements, with the experience and knowledge to triangulate a nuclear regulatory satisfactory solution. Their academic staff are recognised as international experts who extend their vast network portfolio to the CoE if ultra-specialism is required.

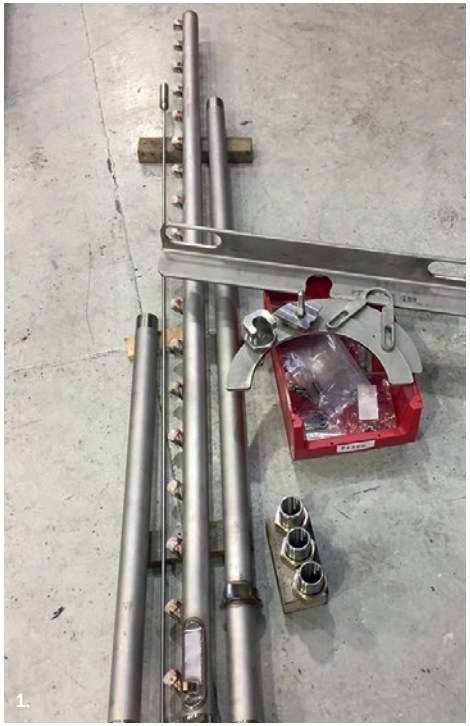
Cooperation with the NNL Workington facility allows the CoE to unilaterally address technical issues associated with process scale without consulting the external supply chain reducing project management complexities and costs of delivery. Examples of the outcomes of the cooperation are:

- The installation of an acoustic backscatter array, where the technological and theoretical development has been completed through the previous sludge CoE link and will be installed in the local sludge treatment plant in 2022.
- Increased understanding of hydrogen retention and release in sediments, which has a significant impact on the MSSS skip fill optimisation programme.
- Supporting analysis of sludge compaction in support of MSSS skip fill optimisation.

More invasive measures include the scope for our staff to gain visiting researcher status, allowing access to world class research facilities to either directly deliver research outcomes or supervise students and postgraduate researchers to complete experimental assays and data interpretation to strengthen or challenge the current scientific baseline. This builds the infrastructure needed to better define specifications for the supply chain to deliver our research portfolios in a more targeted way, saving time and money.

Visiting professor status is also a possibility for our Suitably Qualified and Experienced Personnel (SQEP) staff. The university offers continued professional development opportunities in training courses and software access, which are provided as part of the visiting researcher status.

Having our staff actively participating in research that pushes the scientific frontier allows for active horizon scanning for new technical and technological opportunities to deliver our mission safer, cheaper and sooner. This can manifest as new technology, developments in modelling software and approaches, or more detailed understanding of fundamental scientific processes that are foundational to our technical baseline.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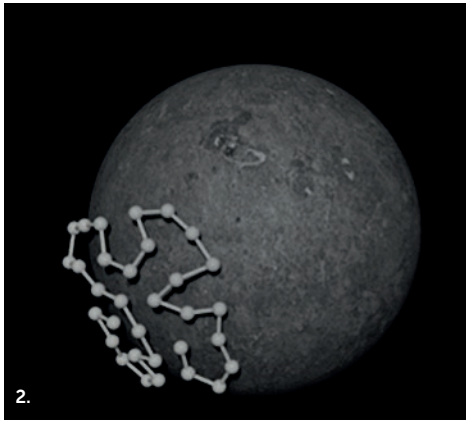
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1. Acoustic backscatter transducer array for sludge treatment plant

2. Instantaneous snapshot of particle-polymer configuration

Remote access and deployment

In 2019, we released a Game Changers challenge statement calling for innovative methods to deploy a payload above 5kg into a cell via a 150mm diameter port and away from the line of sight. A remote modular deployment solution to address challenges that involve working at height in high hazard areas is required. Use of such a system in POCO will enable cheaper decommissioning and reduce secondary waste generation. Specific opportunities include recovery of contaminated solids from an alpha cell and deployment inspection, characterisation and decontamination tools.

FIRMA Engineering submitted the FIRMArm which progressed to proof-of-concept phase where it was inactively demonstrated at the NNL Workington Laboratory. The FIRMArm can extend 3.6m horizontally or 7.3m vertically into cells with a 5kg payload. It has four mechanically controlled articulations: +/- 180° rotation, 300mm vertical fine control, and 0-90° arm tilt. The FIRMArm proved very popular with stakeholders and was recommended for a further feasibility study and an active demonstration on the Sellafield site.

In December 2021, FIRMA Engineering completed the feasibility study, which included: increasing the deployment distance/payload; developing a method for decontamination; incorporating a sighting camera or light; plans for better control of movement and repeatability; potential for horizontal deployment; and potential to increase the depth of deployment.

A second inactive demonstration took place at NNL, which impressed stakeholders and a decision was made to progress to an active trial. An active demonstration of the FIRMArm is in preparation, which will involve deployment of a camera and radiometric probe to provide characterisation data for a medium active cell.

Footage of the active demonstration will be distributed to raise awareness of the FIRMArm. It is intended to unlock additional funding to progress with the concepts developed in the feasibility study, providing further benefit by developing a tool for remote activities across the Sellafield site.

1. FIRMArm being deployed during inactive trial

Project

Game Changers challenge

Benefits

Several Sellafield facilities will transition to POCO in the next few years, presenting opportunities to implement alternative POCO approaches with significant benefits to short-term surveillance and monitoring and/or future decommissioning.

The FIRMArm will enable access and deployment into hard to access areas, aiding activities such as inspection, maintenance, sampling, material handling, decontamination, and dismantling. The FIRMArm has proved it can perform inspection and some decontamination tasks inactively and has the potential to perform additional activities by using different tooling.

The FIRMArm is not specific to POCO; it will provide benefit and solutions to deployment challenges across the Sellafield site. This transferability makes the technology promising across the nuclear industry.

Current Status

The FIRMArm has undergone two successful inactive demonstrations at NNL Workington. Work to progress an active demonstration is currently under way.

Delivery Partners

FIRMA Engineering Ltd, FIS360 Ltd, NNL

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Our ‘Dragons’ Den’ competition

Now in its fourth year, our Dragons’ Den-style competition has successfully enabled ideas generated by our employees to drive innovation across the business.

Each year, this initiative is intended to encourage creative thinking around specific themes, which are then judged by business leaders. The winners are given time and funding to develop and implement their ideas.

This year, all employees were invited to focus on innovation, developing the future work environment and improving our Knowledge Management capability. The winners were announced in August 2021.

Winners: Bernard Swinnerton & Sadia Samas

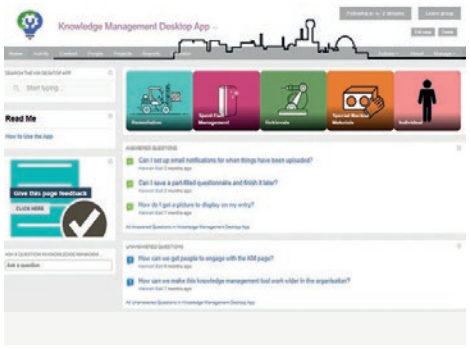
High strength High Efficiency Particle Air (HEPA) Filters

Development of high strength nuclear filters for ventilation systems on the Sellafield site. The intention of this idea was to implement a new stronger filter material in our HEPA ventilation system to increase the lifetime and reliability of our filters. By increasing the filter’s lifetime, it will lead to an overall reduction of maintenance time and costs as well as potential dose to our workforce through the periodic replacement of filters. The team is currently acquiring the new filter media to create replacement filters to be tested to get them certified to be used on Sellafield site.

Winner: Charlie Poate

Virtual visitor centre

Development of an interactive virtual visitor centre that enables anybody to learn about Sellafield Ltd and our projects, which will be hosted virtually. The aim behind this work was to enable external visitors and the general public to learn about our business and mission at any time. Charlie is currently working with our supply chain to develop a pilot of a virtual visitor centre based on his demonstrations.



Winners: Lauren Gillmore, Hannah Ball, Damien O’Kane & Martin Wright

Knowledge Management (KM) desktop app

Development of a KM app on an individual’s desktop which allows them to input their ‘top 5 pieces of knowledge’, which will create a database to store high level knowledge. Individuals will then be able to search this and engage with colleagues to share this knowledge effectively. The team have set up a pilot within the studies team utilising the functions on the NDA Hub, which includes data on the current projects in the team allowing them to be searched and key information to be shared. Following this pilot, a proof of value will be carried out to determine the value of this system.

To Find Out More Contact
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Game Changers

Now in its seventh year, Game Changers continues to find solutions and develop technologies to overcome some of the most complex challenges facing the nuclear industry. Providing a platform to connect challenge owners and solution providers, the programme witnessed further expansion across the NDA estate with Magnox Ltd joining forces with us to launch their first combined challenge.

A total of five innovation challenges were launched by Game Changers during 2021/2022 attracting over 80 applications for feasibility studies, which included:

- Post Operational Clean Out.
- Monitoring of waste packages (in partnership with Magnox).
- Remotely Operated Vehicle (ROV) positioning in featureless pond environments.
- Leaking crack identification, location and condition monitoring.
- Leak prevention or minimisation.

25 of these applications were subsequently awarded feasibility funding.

A total of 24 projects were supported with proof-of-concept grants. This funding is awarded to projects which demonstrate significant merit during feasibility. Some examples include:

- Fibre-optic distributed temperature sensing for characterising subsurface fluid flow in landfill and disposal areas with University of Birmingham Enterprise.
- In-situ solid, liquid and gas analysis using Raman spectroscopy with IS Instruments.
- Using an integrated multipurpose drone system fitted with sensitive detectors to analyse environmental radiation levels with Anamad.
- Concrete removal using controlled heat-induced spalling with the University of Sheffield.
- Exploring the use of super absorbent polymer materials designed for oil and gas applications to stop and prevent the leakage of radioactive materials into the ground with Resolute Energy Solutions.

In addition, Game Changers has continued to support projects to fully develop the technology including:

- Identifying and localising areas of radioactivity in gloveboxes with Loughborough University. A hybrid gamma-optical video imaging system originally developed for nuclear medicine, the Gamma Optical Video Imaging (GOVI) system can provide operators with real-time images showing the location, size, shape and relative activity of gamma emitting materials.
- Range resolved hydrogen sensing for in-situ monitoring of stored waste with Fraunhofer Centre for Applied Photonics. The technology uses Raman spectroscopy to remotely measure the concentration of hydrogen and to determine range.

Building on last year's successful pilot, a second cohort of Game Changers innovators took part in the programme's incubator. Featuring wraparound training designed to help innovators identify wider market opportunities and attract further funding to develop prototype projects and services, six organisations benefited from participating in the scheme: Createc, Resolute Energy Solutions, Hybrid Instruments, FIRMA Engineering, Barrnon and Clifton Photonics.

The incubator featured a three-day residential launch, regular virtual workshops, industry-leading training and one to one mentoring to help develop commercialisation strategies and to provide unique insight into the nuclear sector.

To Find Out More Visit
www.gamechangers.technology

GAMECHANGERS
DELIVERING NUCLEAR INNOVATION

1. Hydrogen sensor for in-situ monitoring

Mark Dowson

Waste IRT lead

As IRT lead, Mark Dowson looks for gaps and development opportunities relating to the treatment or conditioning of Low Level Waste (LLW). This includes supporting strategic level, NDA estate-wide studies as well as individual technology development programmes. A key part of his role is to understand what work is already ongoing and ensure that the team coordinates with current activities to provide enhanced solutions to the business.

Mark joined Sellafield Ltd in May 2002 with a background in heavy engineering after many years' experience working for organisations such as Simon Engineering and Rolls-Royce. He was initially brought in to develop the business case for the legacy ponds and silos early remediation project, but quickly moved to the central technical area. Initially his role was very plant support-orientated, to understand how technical issues in the business could be overcome, but this soon spread to include gap closure and technology development.

Notable achievements include the successful development of muon tomography (characterisation using naturally occurring high energy muon particles) with the University of Glasgow – a world first; and the proof-of-concept development of thermal treatment (vitrification) for a range of legacy wastes, which has now been handed over into service delivery.

Mark has ambitions to establish a range of solutions to improve capabilities relating to the alternative or LLW treatment arising from the cessation of operations and our changing mission. This includes the development of sustainable treatment technologies that are capable of maximising re-use and recycling opportunities, and to understand how technology development can support future ambitions relating to net zero carbon emissions.

"I have a natural interest in technology development and enjoy looking for new solutions to problems."

Andrew Gill

Land quality & manufacturing IRT lead

As IRT lead, Andrew Gill has a wide remit. His main responsibility within central technical R&D is for overseeing a portfolio of diverse and wide-ranging research projects for two recently formed IRTs: land quality and manufacturing.

Andrew is a chartered engineer with an honours degree in physics and a master's degree in nuclear and radiation physics from the University of Manchester. He worked for Jacobs (then AMEC NNC) for ten years as a senior consultant focusing on nuclear waste characterisation and the design and operation of full-scale process test rigs before joining Sellafield Ltd in 2014 as a process engineer.

He was first placed with the MSSS strategy and technical team where he was a study manager and delivered various strategic and technical assessments and multi-disciplinary pre-project type studies. In 2017, Andrew became the retrievals strategy implementation and optimisation manager where he delivered numerous strategic assessments to underpin and optimise the retrievals baseline strategy.

Andrew is currently in the early stages of planning the newly formed land quality IRT, which will facilitate the development of the key technologies necessary to deliver our land quality mission. In addition, he has completed early planning activities for the relatively new manufacturing IRT and identified areas of prospective R&D. The current focus of this IRT is the development of a generic metallic 3m³ box in collaboration with the manufacturing product organisation.

"Identification and prioritisation of our IRT activities will maximise the value from our R&D effort."

Spent Fuel Management

The Spent Fuel Management (SFM) value stream is responsible for the safe, secure and cost effective lifecycle management of spent nuclear fuel and associated waste, including:

- The receipt and long-term storage of Advanced Gas-cooled Reactor (AGR) fuels which enables continued electricity generation and efficient reactor defuelling, as well as the consolidation of spent fuel.
- The evaporation and vitrification of high-level waste and long-term storage prior to disposal along with completing the return of vitrified product to overseas reprocessing customers.
- Provision of effluent treatment and encapsulation capabilities to enable treatment of reprocessing effluent, enable high hazard risk reduction and treatment of future remediation effluent.
- Implement arrangements to transition facilities into 'Post Operational Clean Out' phase in a timely manner to enable effective lifecycle asset and waste management.

SIXEP waste treatment

The Site Ion Exchange Effluent Plant (SIXEP), which treats effluent on the Sellafield site, generates three forms of secondary waste; a Magnox based sludge, a filter sand and a spent ion exchange material called clinoptilolite (commonly known as clino). This waste is currently stored in-situ within the SIXEP facility and a means of retrieving the waste needs to be developed.

Treatment of the SIXEP waste is required prior to interim storage and final disposal within the Geological Disposal Facility (GDF). Three broad streams of treatment technologies are being considered and developed:

- Raw waste storage – Packaging and demonstrating the suitability for disposal 'as is', or after a finishing step e.g. adding a cement cap.
- Encapsulation – Mixing with cementitious or alternative encapsulants to make a solid waste product.
- Thermal treatment – Melting with glass formers to make a solid vitrified product.

A programme of R&D has been initiated to develop the retrieval and treatment concepts. The scope of the development work has been identified through a series of stakeholder workshops and desktop reviews of historic work. The key technical uncertainties to be addressed during the R&D programme include:

- **Waste characterisation and test material development** – Past sample data and experience has been used to develop bounding test materials and a strategy to manage the risks, but there is still significant uncertainty associated with the properties of the waste.
- **Solid transport** – Trials and modelling are required to identify the minimum velocity to keep clino, a fast settling solid, in suspension. Transport correlations developed with the University of Leeds have given high confidence for predicting this. Trials are also planned to identify how the waste bed can be broken up and mobilised around the vessel. Learning from US Department of Energy (US DoE) and Magnox reactor sites has been useful and preliminary flowsheets have been developed.
- **Effluent management** – The retrieval processes are likely to generate fine particulate and a means of settling these solids, prior to effluent treatment, is required. Work on settling aids for removal of pond particulates has been used as the basis for defining development requirements.
- **Alternative encapsulants** – Alternative encapsulants are being developed by the Encapsulation Integrated Research Team (EIRT). These offer improved waste incorporation factors when compared to existing grout encapsulation and may deliver other benefits such as reduced carbon footprint, improved product quality and reduced total package numbers.

There are clear areas of common interest with other ongoing R&D programmes, including the Higher Active Waste Thermal Treatment (HAWTT) programme and the medium active tank farm retrievals. Therefore, the different R&D teams are working collaboratively, together with NNL and other partners within the supply chain, to deliver the planned R&D programmes, ensuring that there is a joined-up approach to solve the common challenges.

1. Incorporation of clinoptilolite in geopolymer cements as part of EIRT programme

Project

SIXEP waste management retrieval and treatment

Benefits

This project enables the SIXEP secondary waste to be removed from temporary storage and packaged for disposal, in line with UK government policy.

The development and evaluation of options for the flowsheet allows the cost, schedule, waste volume and other impacts to be minimised. This demonstrates the use of Best Available Technology (BAT) and the application of the waste hierarchy.

Current Status

The SIXEP waste management development work has just started. Over 30 years of work on related topics has been reviewed to define what needs to be done. Two to three years of further work is planned to reach a decision on the treatment route.

Delivery Partners

NNL, University of Leeds

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Improved maintenance and control of pond water environment

Spent nuclear fuel from the UK's fleet of Advanced Gas-cooled Reactors (AGRs) will be held in long-term storage at the Thorp Receipt and Storage (TR&S) pond before eventual disposal in a future Geological Disposal Facility (GDF). The spent fuel pin bundles are stored in arrays or racks and this recent work has been targeted at the implementation of a new 63-can rack.

Proper maintenance and control of the pond water environment is imperative for safe storage of the spent fuel and a key control parameter is the pond water temperature. A need was identified to develop a model that could accurately describe the thermal profile of the TR&S in order to demonstrate that the temperature profile of the pond and hence the fuel within is maintained within operational tolerances.

A PhD project[1] was initiated with Northumbria University, with our industrial supervision, to develop a thermal model for the TR&S pond which was split into four parts:

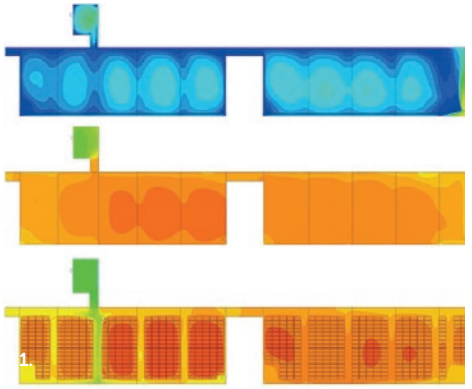
1. A calculation approach to describe the heat loss from the free water surface.
2. A spreadsheet tool to provide water temperatures across the pond.
3. Separate Computational Fluid Dynamics (CFD) models to determine boundary conditions and validate the spreadsheet tool.
4. Sensitivity studies to help optimise cooling pond management in both normal and fault scenarios.

The spreadsheet tool is now being used to support pond temperature measurements, and similar systematic approaches to modelling are being considered for other storage ponds on the Sellafield site.

As part of the ongoing validation of the TR&S thermal model, National Physical Laboratory (NPL) has been developing a method of remotely measuring the temperature of fuel containers using phosphor thermometry with a Remotely Operated Vehicle (ROV) attachment. This system needs a container to be painted with a strip of phosphor and binder, but subsequently allows for the surface temperature to be measured without physical contact with the container.

Trials were undertaken to ensure that the coating applied to the fuel container would not adversely impact its performance. This meant that the new 63-can racks did not require any additional coating of existing pond furniture. The prototype exceeded the distance and accuracy requirements under laboratory conditions and was shown to be capable of operating in the TR&S pond water environment.

In trials, the lengthy fibre-optic cable used to attempt off-boarding the signal processing equipment, from the ROV to a station at the 'pond side', were shown to degrade the signal significantly. Future iterations of the phosphor thermometer will seek to incorporate the processing equipment into a single package to be carried on-board the ROV.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Project
Long-term storage of spent nuclear fuel

Benefits
Thermal modelling and measurement allows the temperatures within the pond to be better understood. This ensures that the pond water environment is properly maintained and controlled, which underpins the safe storage of fuel.

Current Status
Ongoing with validation of the thermal modelling under way.

Delivery Partners
Northumbria University,
National Physical Laboratory

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1. CFD model of Thorp Receipt and Storage pond taken from PhD project[1]

2. Phosphor thermometer detector head

3. 63-can fuel storage rack

1 A. Ramadan, Investigation of Flow and Heat Transfer in a Large-Scale Spent Nuclear Fuel Cooling Pond, PhD thesis (Northumbria University, Newcastle): http://nrl.northumbria.ac.uk/id/eprint/42057/1/Ramadan.Ahmed_phd.pdf

Testing in preparation for POCO

The Highly Active Liquor Evaporation and Storage (HALES) facility receives radioactive effluent arising from the reprocessing of spent nuclear fuel. The effluent is concentrated by evaporation under reduced pressure and stored before it is immobilised by vitrification.

During the evaporation process, several solid species are formed. Whilst the majority of these solids are treated as part of normal operations, it is expected that some will remain and will need to be removed as part of Post Operational Clean Out (POCO).

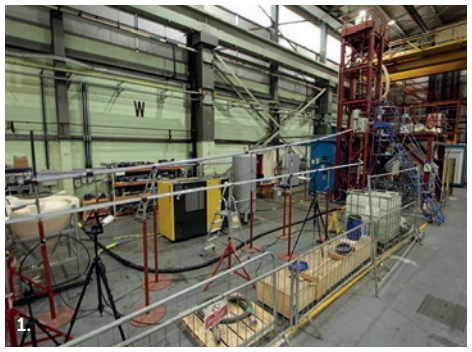
During POCO of the storage tanks, residual solids and soluble activity will be removed by washing with dilute acid. The wash liquors will be concentrated by evaporation and then fed forward to vitrification. These POCO liquors are expected to contain a higher concentration of suspended solids and a lower concentration of dissolved species than the liquors processed as part of normal operations. These changes to solids concentration, and liquor density and viscosity are known to affect the settling rates of the suspended solids which could result in an increased risk of blockages from solids settling out of suspension during transfers. This has, in part, been informed from previous blockages which have occurred during plant operations, and subsequent development work that has taken place.

To assess the potential challenge to future POCO operations, a modular test rig has been built which allows the most challenging vessels and sections of pipework (based on gradient, bend geometry and internal diameter) to be replicated. Using this rig, experiments have been performed using non-active test materials to assess the risk of solids deposition during the transfer of POCO liquors and establish the efficacy of existing plant wash protocols in clearing deposits.

The first phase of trials has been completed and has given confidence that transfer of POCO liquors between the HALES and vitrification facilities can be undertaken successfully. These rig trials incorporated representative sections of the pipe bridge connecting the two facilities and involved feeding simulated POCO liquors under a range of plant conditions to determine the solids handling capability of this section of the transfer system. The next phase of trials, looking at transfers within the vitrification process, is ongoing.

The rig has also been used to support fundamental research into solids transport in partially flooded systems as part of a PhD at the University of Liverpool, funded through the CINDe programme. This has helped grow capability to support future nuclear decommissioning, and the research undertaken has cross-industry application and has been published in the open literature[1].

1 Cunliffe, C., Dodds, J., & Dennis, D.; Flow correlations and transport behaviour of turbulent slurries in partially filled pipes; Chemical Engineering Science; 235; (2021); 116465



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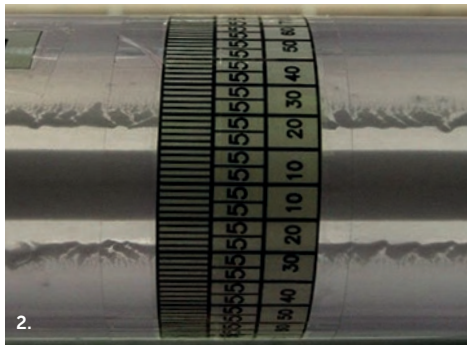

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1. Slurry transport test rig

2. Slurry transport and sedimentation in rig pipework

Project

Highly active liquor programme

Benefits

The research underpins the baseline approach for removal of activity from the HALES facility as part of POCO. The work is part of mitigation against a risk that the changing composition of liquors makes operations more challenging, leading to increased downtime (to recover from blockages) and extending the time needed to complete clean out operations.

The capability provided by the slurry test rig has supported fundamental research which has the developed skills needed to support future nuclear decommissioning and has produced new correlations that can be used to predict slurry transport across multiple industries.

Current Status

Ongoing – the first phase of work has been completed; further work is continuing with completion expected in the current financial year.

Delivery Partners

NNL, University of Liverpool

Contact Details

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Disposal and treatment of effluents

For nearly 30 years, the Enhanced Actinide Removal Plant (EARP) has provided a means of removing alpha emitting species from aqueous effluent streams associated with reprocessing operations and high hazard risk reduction activities.

The treatment process is based around chemical precipitation, ion exchange and ultrafiltration. An amorphous ferric hydroxide floc (ferrihydrite) is produced as the pH of the effluent is raised from pH <1 to >8. As the floc forms, it removes cationic radionuclides including the alpha emitting actinides from the solution. The process is enhanced by addition of Sodium Nickel Hexacyanoferrate (SNH) an ion exchange material with a strong affinity for caesium. The floc/SNH suspension (with the associated radionuclides) is separated from the liquor by ultrafiltration before the floc is encapsulated and the treated effluent is discharged to sea.

One of the key donor plant feeds arise from the analysis of special nuclear materials, resulting in a high alpha bearing aqueous effluent stream. It was identified that a small population of this bottled stream resulting from historical analytical operations had the potential to contain mercury and citrate. R&D was undertaken to understand the challenge, compatibility, and effectiveness of EARP to accept this high priority effluent stream.

This involved laboratory experimentation to investigate whether the chemistry of the EARP process would provide abatement to the low, but environmentally significant, levels of mercury in the feed. In addition, a complementary rig-based experiment, which made use of the non-active small-scaled version of EARP, assessed the operational capability to process higher citrate bearing feeds and their effects on the ultrafiltration performance. Through some previous trials and limited operational experience, it was known that EARP's tolerance to citrate was very low as the particle size would cause the ultrafilters to bind impacting on operations and resulting in increased Intermediate Level Waste (ILW) produced.

The research identified several key challenges associated with this effluent stream; some were newly identified, and some built on existing knowledge. The complex interactions that mercury has on the plant is now understood and abatement would be minimal under normal operations which enabled contingencies to be explored early. Operation of the rig confirmed the difficulty processing citrate but provided a better operational envelop for the plant to reduce the impact.

The collaborative nature of the R&D enabled key decisions to be made early that allowing forward plans to be developed to remediate risks, maintain the effluent capability, reduce the cost of waste disposal and minimise environmental impact.

1. EARP rig in NNL's Workington Laboratory

Project

Disposal and treatment of mercury and citrate contaminated high alpha effluents

Benefits

This R&D has enabled us to continue effluent treatment as our site transitions from reprocessing to remediation activities.

Donor plants and treatment facilities are working collaboratively together to generate future operational plans that remediate risks, maintain the effluent capability, reduce the cost of waste disposal and minimise environmental impact.

Current Status

This combined project is coming to an end with the outputs supporting key decision making.

Delivery Partners

NNL

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Stephen Ashley

Senior technical advisor

As senior technical advisor, Dr Stephen Ashley leads and supports the development of strategies for fuels and materials that are currently stored in the actively operating ponds.

Stephen recently joined Sellafield Ltd in November 2021, having previously spent six years as a consultant working for NSG Environmental Ltd, supporting a broad range of projects within the nuclear industry. He has a strong background in nuclear research with a degree in physics from Staffordshire University, a PhD in experimental nuclear physics from the University of Surrey and four postdoctoral research associate positions in nuclear structure physics and nuclear engineering over seven years in Athens, Kentucky, University of Cambridge and The Open University.

Stephen has used his previous industrial and academic experience to support the long-term fuel storage CoE and brought new ideas to existing projects. He has also been involved in the 2022 UK radioactive waste inventory submission, which involved a steep learning curve to source the underpinning work and gather the data required.

His current role involves working with the studies team on the pond metals studies, providing technical review of other research and supporting various multi-year projects. For example, Stephen is part of the inventory working group that is supporting the work to transfer spent fuel from Dounreay to the Sellafield site.

"Although there is still plenty more to learn, I have enjoyed getting up to speed with my role and the work being done across the Sellafield site."

Fayaz Ahmed

Technical advisor

During his 31-year career, Dr Fayaz Ahmed has developed significant experience in process plant operations and safety and risk management across the Sellafield site.

Fayaz joined the SFM strategy and technical team a year ago, after 26 years in the safety and risk department, and is responsible for developing technical solutions and strategies for major R&D programmes, including the SIXEP waste management R&D programme. Before joining Sellafield Ltd, he worked in the technical sales department at Water Technology Ltd after completing a degree in chemical engineering.

While working at Sellafield Ltd, Fayaz completed an MSc in nuclear decommissioning and environmental clean-up and a PhD on managing the uncertainty associated with hydrogen hazards and operability issues in nuclear chemical plants. He has used this expertise to develop an innovative way of dealing with safety case gaps associated with hydrogen generation in the SIXEP universal vessel using a claims, arguments and evidence approach that has not previously been used in the SFM technical area.

Fayaz is currently working on the retrieval of spent ion exchange material, which has been stored since the SIXEP plant started operating in the 1980s. This has involved critical review of previous R&D, development and specification of test materials and working closely with NNL. Once retrieved, this ILW needs to be immobilised in packages suitable for long-term storage and final disposal.

"I am driven by positive feedback and enjoy having the opportunity to provide innovative solutions to technical problems."

Special Nuclear Material

The Special Nuclear Material (SNM) value stream is responsible for the safe, secure and appropriate storage of special nuclear materials, with the R&D programme focusing on:

- Understanding the chemical and physical behaviour of plutonium-bearing materials to ensure long-term safe management and storage, focusing on aspects including radiolysis, evolution of sealed packages, corrosion, behaviour of impurities such as chlorides and the requirements for future conditioning.
- Innovative approaches to the safe operation of facilities handling and storing plutonium, possibly including technologies such as robotics, automation and digital applications for alpha environments.
- Continued technical underpinning of POCO and decommissioning plans for alpha facilities.
- Techniques for the monitoring, retrieval and processing of residual product in gloveboxes, plant, equipment and facilities during POCO and decommissioning.
- Direct support to the special nuclear materials consolidation programme.

Corrosion characterisation of Special Nuclear Materials containers

Certain historic populations of Special Nuclear Materials (SNM) stored at Sellafield and at US nuclear sites are contaminated by chloride salts and/or hydrochloric acid (HCl) which is produced by the breakdown of polyvinyl chloride (PVC). This can result in HCl gas being released inside the container which can induce corrosion. The interaction between stainless steel SNM containers and HCl vapour under realistic storage conditions is not well understood. In order to improve confidence in the ongoing storage of chloride-contaminated SNM, research was required into the corrosion of our stainless steel containers.

In a collaborative project between the NDA and the US DoE, corrosion tests were carried out at Los Alamos National Laboratory. Weld samples from a UK Magnox container and two US '3013' containers were exposed to HCl vapour for 109 days under carefully controlled environmental conditions. The welds were then sectioned and analysed using Laser Confocal Microscopy (LCM) and Wide-Area 3D Measurement System (WAMS) to measure the depth and number of corrosion pits. This allowed for statistical comparisons to be made between the two container types and gave an indication of the level of attack expected under these conditions.

It was found that, while the UK container underwent more aggressive superficial surface corrosion, the US DoE containers suffered from more aggressive localised corrosion. The pits found in the 3013 containers (up to 105 microns) were much deeper and more numerous than those in the Magnox container (up to 25 microns). The 3013 weld region also underwent cracking whereas the Magnox weld did not.

This supports the decision to utilise the same higher grade of 316L stainless steel in future UK SNM container designs rather than 304L stainless steel as used in the 3013. However, it raises further questions about whether the 3013 TIG weld joint is more susceptible to corrosion than the Magnox's resistance seam weld. Therefore, future experiments are planned which incorporate the upcoming '100-year SNM package' which we are currently developing. This TIG welded container will be used in the Sellafield Product and Residue Store Retreatment Plant (SRP) to repackage all of the UK's stocks of civil SNM into and will be expected to provide containment for at least 100 years to allow for long-term disposition options to be developed.

1. Experimental set up for hydrochloric acid exposure test

Project

International plutonium disposition programme

Benefits

This project has improved our understanding of the effect of HCl vapour on our current SNM storage containers and helped to inform the 'safe-to-store' case for the upcoming 100-year SNM package.

Current Status

An experimental scope has been agreed with researchers at Los Alamos to expand the testing to include different UK and US package types and a broader range of conditions. We have provided further Magnox weld samples, along with overpacks and welded samples of our new 100-year SNM package.

Work is intended to commence this financial year and will support the commissioning of the SRP and provide further information to support the 'safe-to-store' case for the 100-year SNM package.

Delivery Partners

Graham Engineering Ltd,
Los Alamos National Laboratory

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Special Nuclear Material package surveillance

The Special Nuclear Material (SNM) package surveillance programme is needed to understand how plutonium oxide (PuO2) and its packaging ages through long-term storage. This work can only be delivered through selective destructive examination of plutonium packages.

This plays a vital role in mitigating technical risks around the lifetime of packages within the multi-billion-pound SNM portfolio and will inform on the strategic tolerance for the delivery of the SRP.

The package characterisation facility at NNL received the first welded Magnox package in 2017. Since then, over 25 Magnox and three Thorp welded packages have been characterised to determine the gas pressure and composition in the package, the PuO2 characteristics, and detailed metallurgical characterisation of the package components. In addition, this year work has also started to derive the thermal conductivity of Magnox PuO2 and Thorp PuO2 to validate data used in the thermal models of the packages and stores by measuring the radial temperature distribution across PuO2 contained in the inner can as well as the can wall temperature.

In March 2021, the first SNM residue packages (tin plated rolled seal cans) were delivered to the NNL facility in stainless steel overpacks. The residue package was then punctured, and the ullage gas was successfully sampled and analysed for the first time. The Product Can Processing (PCP) suite of gloveboxes in the high alpha inventory laboratories is used for initial examination of the exterior of the packages and to puncture the can. The can is then transferred to a dedicated residue can opening glovebox for destructive examination and sampling of the as received powder within.

The PuO2 is subsequently transferred to the residue recovery furnace for heat treatment before it is returned to the PCP glovebox suite for repacking in a welded Magnox package. The PuO2 was characterised by measuring volatile content through loss on heating, powder specific surface area, X-ray powder diffraction and thermogravimetric analysis. Samples were also taken for additional characterisation in the complementary science programme.

The rolled seal containers were found to be gas-tight and in excellent condition with no evidence of corrosion. The PVC layers had maintained their integrity and plasticity, although the inner layer was highly discoloured from radiation damage. The results and observations support the design of the residue treatment line of SRP.

Next year there will be further examination of residue packages and an increased range of package types that can be characterised by NNL.


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Project

SNM package surveillance programme

Benefits

This project brings improved understanding of how the plutonium oxide and its packaging ages through long-term storage. This will ensure the safe storage of the material over the package lifetime until it can be retreated and or repackaged in the SRP.

Current Status

This programme will run until at least 2028 when the SRP is commissioned. The NNL facility will continue to examine the current package types as they continue to age, and the capability will be expanded to receive other material and package types.

Delivery Partners

NNL

Contact Details

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1. Inner rolled seal can condition

2. Experimental set up to measure radial temperature distribution across a Thorp inner can

3. PVC condition within residue package

X-ray package inspection

The Dounreay consolidation programme involved the movement of SNM packages from Dounreay to the Sellafield site. It was discovered that the inner package containment layers could be pressurised without any external evidence. Therefore, X-ray radiography was used to identify whether packages had become pressurised.

The use of X-ray radiography to examine the internal structure of our SNM packages is not new. In fact, 'film' radiographs from the 1990s exist for some of the Dounreay packages that originated at the Sellafield site. However, the equipment available to take such radiographs has advanced significantly since then. Modern X-ray equipment is far more portable and the images generated are digitised meaning images can be instantly downloaded.

The recent radiographs taken using a portable system successfully identified pressurised packages, but also provided invaluable additional information, such as:

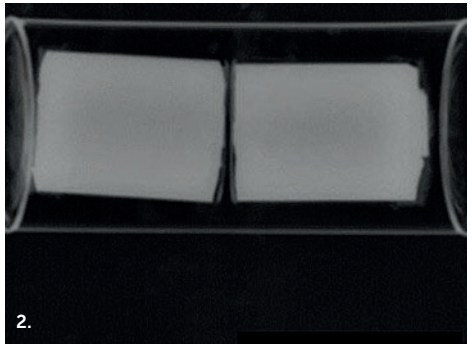
- Mechanical damage.
- Package configuration.
- Polymeric layer (e.g. PVC) location.
- Material form (e.g. powder, pellets etc.).
- Material outside of primary containment.
- Significant defects on crimped seals.

This information has clear safety benefits. For example, knowing that a package is potentially pressurised will ensure that it is processed down a line that has the ability to safely de-pressurise it.

Over 30% of packages were found to be different to the recorded information relating to the package configuration and material form. Therefore, the new data will be vital to informing future downstream processing. For example, some lines are designed to accept only powders or particular package configurations. Armed with the knowledge from radiography, plans can be made to re-route/re-package accordingly, therefore avoiding unexpected delays.

An opportunity arose in 2021 to trial a more powerful high resolution scanning X-ray machine. This was used to examine 46 ex-Dounreay packages.

Given the advantages of improved resolution, a similarly specified radiography booth has been ordered for our future package characterisation. Like the system trialled, the new system will also have the advantage of scanning the packages, avoiding image distortion which is common for a fixed source used in most systems (including the portable system).



1. High resolution scanning radiograph example

2. Older film type radiograph

Project

Dounreay consolidation programme

Benefits

The improvement in X-ray radiography has directly led to better characterisation of SNM packages to inform future downstream processing decision making.

Current Status

A dedicated high resolution scanning radiography booth has been ordered and is due to be delivered in November 2022. The experience gained with radiography equipment for package characterisation is being shared with other projects e.g. north stores transfers, to further grow our capability.

Delivery Partners

Dounreay Site Restoration Ltd (DSRL), Oceaneering International Services Ltd

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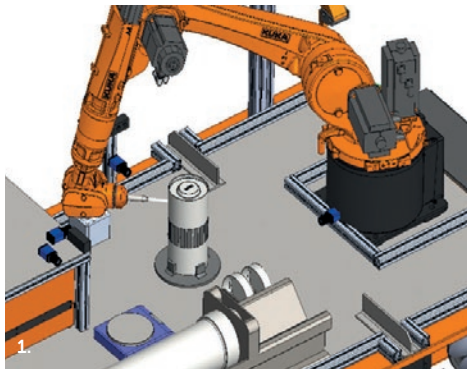
Automated stores robot

The older stores on site are currently all operated manually, requiring the presence of an operator, and in some cases wearing, Personal Protective Equipment (PPE) to enter the store to carry out any relevant operations including the use of a 1 tonne charge block when it comes to the transfer/ moving of cans. This requires various regulated processes to carry out any operations in this manner.

The idea is to automate processes within Store 9. This solution will provide the capability to fully automate the process of retrieving 600 packages per year, carry out analysis, then pack the package into a SAFKEG without the need for human intervention.

NNL has compiled a mock-up store channel on their premises identical to that of Store 9. The functional and testing specifications have both been completed and the different tools that the robot needs to complete a cans transfer have been designed in principle. NNL has produced a demonstration using a robot arm with a similar specification to the one that will be used on the finished product, replicating the movements that would occur during operation, displaying the accuracy and consistency of the kit.

Looking ahead to next year, the design and procurement of the robotic solution needs to be finalised followed by a second demonstration of the basic kit elements.



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1. Automated store machine

2. SAFKEG can and internals

Project

SNM innovation programme

Benefits

This capability will greatly reduce the dose risk to human operators, as well as their safety and well-being by significantly reducing the need for them to enter the store. It will also increase the productivity of the store by speeding up the processing and manoeuvring of packages.

An automated stores will also allow more time with the can to undertake detailed and high accuracy inspection of the can whilst transfers are carried out. The only changes that are required to the store will be a line on the floor for an Automated Guided Vehicle (AGV) to follow as well as a charging station for the robots.

Current Status

A mock-up of Store 9 has been built as accurately as possible at the NNL Workington Laboratory to facilitate the work they are carrying out. The tooling for the robot's arms has been designed prior to production. A first test of the robot arm has successfully demonstrated that it can remove and reattach the port plug consistently.

Delivery Partners

NNL

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Special Nuclear Material innovation programme

The Special Nuclear Material (SNM) innovation team is tasked with providing the SNM value stream with new technology, processes and facilities to:

- Provide safer working in gloveboxes.
- Protect SNM and packages.
- Look after SNM stores.
- Handle SNM more effectively and safely.
- Understand SNM and facilities by inspection and characterisation.
- Improve SNM operations and delivery.

A selection of SNM innovation projects being developed include:

SPARK
SNM knowledge management website based in the NDA Hub.

Hydrogen detection
Real time hydrogen detection to reduce containment vessel transfer times.

Automated stores
Development of an automated package removal system to improve transfer performance and remove the operator from the hazard.

Glovebox vacuum
A vacuum device to aid POCO operations by simplifying the removal of plutonium loaded material.

Heads up display for masks
A capability to provide information to the operative without the need to take hands in and out of a glovebox.

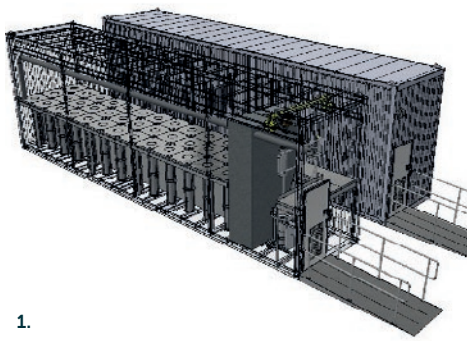
Glovebox bung
This simple device enabling power and signal cables to pass into a glovebox under POCO.

Wireless charging
A means of powering tools without the need to remove or replace batteries.

Emergency recovery capability
Concept study to consider using a modular store to accept recovered packages.

Smart sensor
Attaches to cans to wirelessly monitor temperature and pressure.

Window cleaner
Simplify cleaning of window panels of gloveboxes.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1. Emergency recovery capability
2. Glovebox bung
3. Smart sensor
4. Heads up displays for masks
5. Plutonium vacuum
6. Window cleaner

To Find Out More Contact
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Andrew Begbie

Scientific degree apprentice

Andrew Begbie joined the SNM innovation team in 2019 as part of the Sellafield degree apprenticeship scheme and will graduate with a BSc (Hons) in applied chemistry from the University of Cumbria in December 2024.

This five-year apprenticeship scheme has enabled Andrew to continue working at Sellafield Ltd while studying for his degree, with a day-release each week for courses and tuition. He has completed the three-year foundation course and is intending to apply to become a Registered Science Technician (RSciTech) with the Royal Society of Chemistry (RSC).

Andrew has been involved in a broad range of projects from small sensors to changing the workings of a store and is always looking at ways to drive innovation. This is demonstrated by his recent Wave Award, which is an internal awards scheme that celebrates success, in the 'value for money and return on public investment' category for his project working with hydrogen sensors.

His role has involved working in many different areas, including commercial, safety case, operators, plant managers, technical specialists and maintenance, as well as with stakeholders across the UK. After gaining knowledge and experience in processes, stores and packages, he is intending to further diversify his skills through an internal secondment to another area.

"Due to the wide variety of projects within the SNM technical team, my role can be different for each project."

Derek Leach

SNM technical support manager

Derek Leach couldn't resist the opportunity to join Sellafield Ltd (then BNFL) in 1991 as a commissioning officer on Thorp. 31 years later, he regards it as one of the best decisions that he has ever made.

With an early career as a process development chemist and a process engineer in the high volume electronics manufacturing industry, Derek took a leap into the nuclear industry. During his career at Sellafield Ltd, Derek has held a variety of posts, primarily within operations support, but more recently within the SNM technical team.

The variety of work has ensured that no two days have been the same, allowing new skills and experience to be picked up along the way. So, whether it is carrying out mass balance calculations during Thorp commissioning or working shifts at Dounreay to support a national strategic imperative relating to SNM consolidation, he has always found the working environment stimulating.

Derek's current work includes technical input to a feasibility study to consolidate further SNM from a remote site, continued support to interim storage arrangements for Dounreay and technical support to the SRP project. He has often found that the work requires specialist input/collaboration from external organisations and it is important to understand where this expertise lies so as not to 're-invent the wheel', be more efficient and benefit from life-long learning.

"Sellafield Ltd has been supportive of my career development, and I was grateful for the opportunity to complete an MSc in process technology and management through distance learning at the University of Strathclyde."

Retrievals

The Retrievals value stream mission is a reduction in the hazard and risk posed by nuclear waste stored in legacy ponds and silos by retrieving and transferring it to safe modern containment.

The waste is highly heterogenous and has been stored for many decades in non-ideal conditions, making it hard to characterise and retrieve. The R&D programme is focused on:

- Characterising the waste and assessing risks in order to develop and implement waste routes.
- Continued development of innovative techniques for waste retrieval.
- Managing the impact of waste retrieval activities on the continued safe operation of the legacy facilities and on downstream waste conditioning and effluent treatment facilities.
- Assessing treatment and finishing requirements for unconditioned waste together with Letter of Compliance (LoC) requirements.
- Developing Condition Monitoring and Inspection (CM&I) capabilities to demonstrate that retrieved waste behaviour is consistent with predicted behaviour during the storage period.
- Conditioning, storage and disposal solutions for metallic uranic fuel and uranium bearing material.

Skip fill optimisation

Our legacy facilities store huge amounts of radioactive materials from the operation of our nuclear reactors over the decades. In the early days of the nuclear industry, the cladding was removed from spent nuclear fuel and stored in large concrete silos. These building are now many decades old and the radioactive material must now be retrieved from the silos.

The radioactive waste is retrieved from the Magnox Swarf Storage Silo (MSSS) and loaded into large 3m³ steel boxes prior to being stored in a modern storage facility on the Sellafield site for up to 100 years. Over such long timescales, the waste will release hydrogen, heat up and expand as it corrodes. These hazards must be safely managed – the hydrogen needs to be removed to prevent explosions, the heat needs to be removed to keep the waste sufficiently cool and the expansion needs to be limited to ensure the box containment is not challenged. To manage these hazards, the payload of waste loaded into each box has been limited so far.

This project has undertaken extensive research to understand how radioactive wastes behave during storage over 100 years in areas such as:

- Hydrogen generation.
- Safe hydrogen management.
- The chemistry of radioactive materials (Magnox, uranium, carbonation products etc.).
- The development of new tools to measure waste properties (e.g. the use of photogrammetry in radiative environments).
- Unique computational modelling of heat transfer from wastes – accounting for the change in waste properties as the waste corrodes, dries out and nuclear decay occurs.

So far, the skip fill optimisation project has:

- Demonstrated that there is no increase in risk posed by the legacy facility or the retrievals operation over the skip lifetime.
- Reduced the number of boxes needed by over 1,000 by underpinning an increase in the amount of waste that can be stored in each skip.
- Accelerated radioactive waste retrievals by 18 months as more waste loaded into each skip means fewer skips need to be moved around.

The skip fill research is ongoing with further savings expected. Examples of future work includes:

- Developing new technologies for deployment in a radioactive environment (e.g. Lidar, fixed ultrasonics etc.).
- Developing knowledge of long-term carbonation product formation.
- Understanding how constraints such as the box itself might limit long-term expansion.
- Completing full-scale filter trials to understand how hydrogen egresses from the box.
- Better understanding of the rheology of sludges with regards to hydrogen retention, release and expansion.

Project

Magnox Swarf Storage Silo – Skip fill optimisation

Benefits

This work facilitates MSSS skip filling optimisation to maximise waste loading and to reduce the number of MSSS 3m³ boxes being used by over 1,000.

The skip fill research project has saved ~£150m by reducing box numbers and accelerating operations with greater lifetime savings expected in the future.

Current Status

The first phase of work has delivered significant achievements, the research is continuing and expecting to deliver further improvements still.

Delivery Partners

Fauske & Associates (USA), NDA, NNL, RED Engineering, Trent University (Canada), University of Leeds

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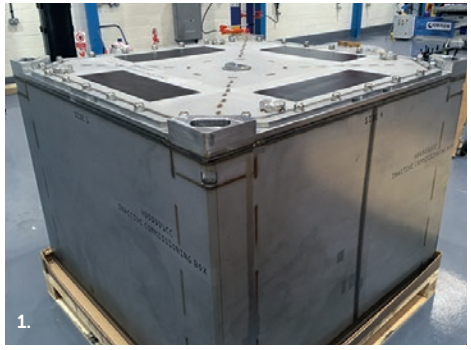

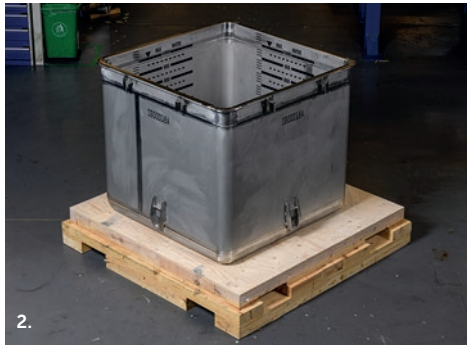

1. Example 3m³ box

2. Empty skip

Cement encapsulation evolution for net-zero

Ordinary Portland Cement (OPC) has been used at our encapsulation plants to immobilise Intermediate Level Waste (ILW) for over 30 years. However, the cement industry is evolving in response to the UK government's net-zero policy which economically impacts cement manufacture as it is associated with high CO_2 footprint. In response to this policy, the cement industry is progressing along its Technology Roadmap for Low-Carbon Transition.

The roadmap targets four key areas for CO_2 reduction; carbon capture, reduction of clinker use, alternative fuels and thermal efficiency. Clinker is the output from the kiln that is ground into cement powder. The simplest and most immediate measure to enact is reduction in clinker use. It is also the one that may most affect waste encapsulation throughout the NDA estate, as OPC is purely clinker and a nuclear industry bespoke supply. OPC is currently being phased out across Sellafield and some other sites for the CEM I (95% clinker) industry standard grade of cement.

The roadmap is in the process of switching the industry's bulk product to 'CEM II' or specifically Portland Limestone Cement (PLC), allowing reduced use of clinker per tonne of cement by increasing dilution with finely inter-ground limestone. This will correspond with the construction industry adopting PLC into widespread concrete use around mid-2023.

We initiated work to investigate the timeline for evolution, intentions for CEM I production, specific materials characteristics and chemistry of PLC, current learning from PLC users and potential for PLC to be a like for like replacement of OPC. This was to assess and start mitigating the risk to operations.

Key points were established:

1. Bulk supply of CEM I will be phased out in favour of PLC mid-2023. CEM I may remain available for some years post 2023, but likely become a bespoke material.
2. Supply of PLC will be the main bulk product for the foreseeable future, but the current driver for further change is strong.
3. At this stage it looks like the effect on our encapsulation processes and formulations will be small.
4. PLC is likely to evolve over the long term, particularly to higher amounts of inter-ground limestone.

We aim to make strategic decisions for CEM I to PLC switchover in 2023 allowing tactical decisions to be made for individual encapsulation plants. Engagement with the cement industry will continue to keep informed with respect to their roadmap progress and timeline.

1. Encapsulated Magnox product – typical product that has been produced historically using previous specifications of cement powders

2. CEM I powder

Project

Sellafield encapsulation plants CEM I to CEM II transition

Benefits

The security of supply of cement powders for waste encapsulation purposes is critical to our operations and heavily reliant on the cement industry. Properties of waste encapsulation matrices depend on consistent cement powders from reliable, predictable sources.

This work aims to mitigate potential loss of one cement powder source by making the emergent cement powder viable. This will either give a back-up or a reasonable transition depending on the reality of the roadmap. Ultimately this work ensures continuous waste encapsulation operations, and therefore retrievals, in light of uncertain cement industry changes.

Current Status

This initial phase of work is largely complete. The next phase of work will begin this year, funded by the NDA DRP, where physical trials will establish the viability of PLC in waste encapsulation formulations. These trials will expand to be relevant across the NDA estate.

Delivery Partners

NNL

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Corrosion monitoring of waste packages

We have developed a strategy to provide a suitable Condition Monitoring and Inspection (CM&I) capability for waste packages in interim storage. This includes monitoring the temperature and relative humidity to determine evolution of the store environment and waste packages, as well as using coupons to monitor corrosion and radiological and salt deposition.

Corrosion coupons manufactured from equivalent materials to the waste containers have been configured into corrosion coupon trees and deployed into the storage vaults through roof penetrations. The coupons provide a proxy for the waste packages in storage, enabling assessment for corrosion mechanisms and radiological and salt deposition, without needing any action that would be intrusive to the waste packages themselves.

Corrosion coupons have been deployed within a Sellafield interim store for ~8 years and now is the appropriate time to retrieve them for the first time to complete relevant analysis. A collaborative approach has been utilised to enable planning of this task which is due to take place shortly:

- Retrieval of corrosion coupons using specialist Gamma Gate/Scatter tube to maintain safe working conditions when breaking vault containment – equipment currently undergoing validation for use.
- Analysis of corrosion coupons for corrosion – Methodology determined NNL as Suitably Qualified and Experienced Personnel (SQEP) analyst to complete visual inspection of coupons to confirm any signs of visual corrosion. If necessary, further inspection via X-ray to be completed and destructive testing via block and needle to scrutinise level of any corrosion mechanism identified.
- Analysis of corrosion coupons for radiological and salt deposition – Methodology determined that our analytical services as SQEP analyst to complete assessment using radiometric and elemental analysis.
- Technical assessments were completed to determine future inspection requirements including frequency, the specific coupon trees which need to be retrieved and the individually numbered coupons to be removed from those trees and analysed at each inspection. The approach is holistic, sharing learning from across similar stores on the Sellafield site.

Any corrosion identified upon corrosion coupons analysed would initiate further actions to confirm the condition of the waste packages in storage is as expected.

The potential for deposition (and therefore corrosion) is largely controlled by maintaining appropriate humidity conditions within the store therefore all three parameters; relative humidity, temperature and deposition are continuously monitored to understand ongoing storage risks.

Project

CM&I technology development

Benefits

The importance of CM&I is to ensure that the waste packages and contents evolve as expected throughout interim storage. This is so that they remain retrievable and compatible for disposal via the GDF.

Corrosion coupons enable the condition of the waste packages to be monitored without time consuming and detailed inspection of individual packages.

Current Status

The coupon test plan has been agreed and retrieval of the first batch of coupons will begin later this year.

Delivery Partners

NNL

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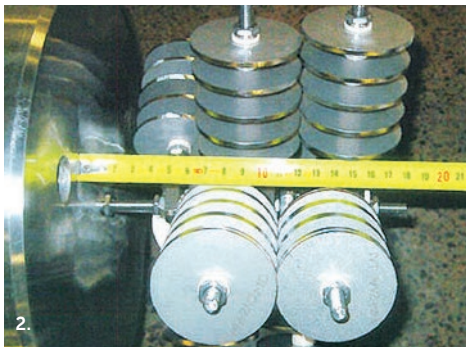
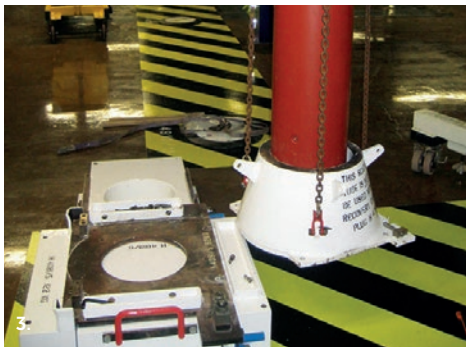




1. Corrosion coupon tree attached to base of through roof plug (retrieved)

2. Corrosion coupon tree arrangement

3. Through roof plug retrieved via Gamma Gate/ Scatter tube

Acoustic detection of deflagration events

We have developed a strategy to provide a suitable CM&I capability for waste packages in interim storage. A key aspect is the development of technologies for performing CM&I of waste containers within their vault stores (in-situ) to confirm waste package evolution is as modelled.

Hydrogen gas is produced from the waste and safely managed through filters on the waste packages and ventilation in the stores, however we want to confirm that hydrogen deflagrations are not taking place within the waste packages during long term storage (a deflagration is when a gas ignites and generates a sub-sonic flame front). While a deflagration is not a significant safety risk owing to the containment of the package and store, it could be a significant cost and business impact should it occur. The question was 'how would we know if one had happened?'. A large deflagration would lead to potentially deformed packages and should be detectable by visual inspection, but smaller ones would not necessarily be externally noticeable.

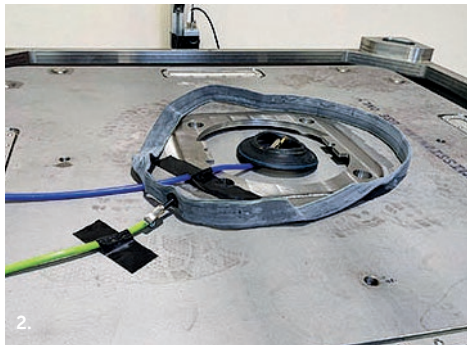
Therefore, a method is required to detect (and ideally locate) deflagration events occurring within individual waste packages stacked nine high at a secure storage site. It has been proposed that monitoring airborne acoustic noise may be an appropriate technique for detecting individual deflagration events and, ideally, both its location within the facility and likely impact (severity). Preliminary proof-of-concept work undertaken by NNL identified a significant knowledge gap relating to the sound characteristics generated by a deflagration event, which needed to be addressed.

National Physical Laboratory (NPL) were engaged to provide critical appraisal of existing scientific literature on modelling and measurement of hydrogen deflagration with particular focus placed on confined spaces. This was to better understand the sound production mechanisms caused by the deflagration process and the acoustic characteristics of the signals generated (time-duration, levels and frequency content).

NPL developed a realistic Finite Element (FE) model representing the waste packages to calculate the spatial distribution of sound level external to the waste package, including the frequency spectra of the acoustic signatures. Since the hydrogen combustion process can be highly sensitive to local conditions, repeated model evaluations are required to give reliable results.

Acoustic experiments and measurements were undertaken by Acoustic Sensor Networks at RED Engineering using microphones positioned external to a specifically configured test package incorporating an appropriate impulsive acoustic source to underpin the model.

This work confirmed that a deflagration event should be detectable using microphones and future work will be to develop the understanding of a deployable system and how well it could triangulate in a full store.



1. Setting up the acoustic signal experiments using inner tubes inside the inner package

2. Setting up the acoustic signal experiments – placement of small inner tube and bicycle inner tube at centre of the inner box lid

Project

CM&I technology development

Benefits

The importance of CM&I is to ensure that the waste packages and contents evolve as expected throughout interim storage. This is so that they remain retrievable and compatible for disposal via the GDF.

Deflagration detection technology has the potential to identify potential problems with waste packages as early as possible.

Current Status

This work is ongoing with the overall objective to develop a deployable acoustic detection system that could triangulate a deflagration event in a full store.

Delivery Partners

Acoustic Sensor Networks, NNL, NPL, RED Engineering

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Magnox Swarf Storage Silo 3m³ box substantiation

The robust functional performance of the Magnox Swarf Storage Silo (MSSS) 3m³ box is a critical element to achieving the safe storage of unconditioned MSSS waste. Significant areas of R&D have been undertaken over several years to provide the technical underpinning and engineering substantiation of the box performance. To provide adequate stakeholder confidence prior to proceeding with retrievals and storage, additional R&D was required in a number of key areas.

Convection driven fires

The boxes comprise an inner skip which holds the waste and a surrounding outer box. The outer box comprises the main box body and a lid which incorporates four filters. The lid is attached to the main box body via a bolted metal-to-metal seal all around the lid. Computational Fluid Dynamics (CFD) analyses were undertaken by us, working with Thornton Tomasetti, to provide confidence that in the extremely unlikely combination of events, that result in multiple missing bolts, correct combination of waste and presence of an ignition source, a waste fire could not be sustained. This work included additional validation studies against combustion trials within containers where the ability to sustain a fire decreases with decreasing aperture diameter.

Deflagration overpressure withstand

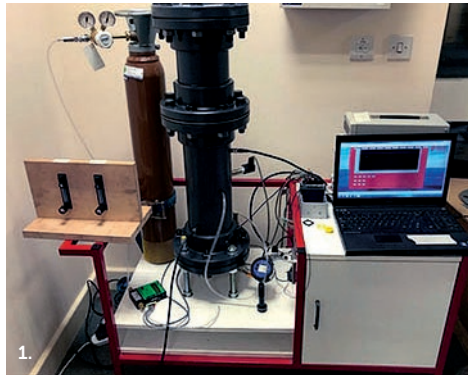
The four filters in the box lid are principally to manage hydrogen dispersion whilst controlling particulate or aerosol releases. In the unlikely event of an abnormal hydrogen release in combination with an ignition source, it is possible that the deflagration overpressure will threaten the integrity of the filters.

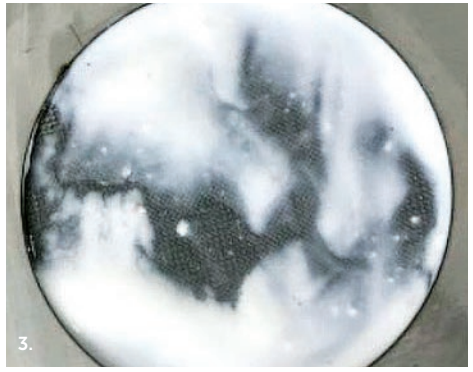
Working with RED Engineering, tests were performed using an air compressor to pressurise a receiver which was rapidly discharged to a test box. The box filter is bolted onto the test box where the pressure is measured. The results from the trials provided close correlation to the original Finite Element Analysis (FEA) modelling work and confirmed that the filters provide sufficient robustness to all unlikely deflagration events.

Filter resilience to sludge impedance

The MSSS waste contains reactive material such as Magnox which reacts with water to release hydrogen either continuously or acutely after getting trapped in the sludge. For an abnormal case of an overfilled skip, there is a risk of waste expansion caused by hydrogen hold up in the waste. In this unlikely event, the sludge may contact and stick to the skip filter impeding its performance.

Trials have been carried out to assess the impact on hydrogen diffusivity by coating the filters with a range of sludges in the same manner as would be expected from waste expansion, undertaking diffusion testing of the filters, allowing the sludge to dry and repeating the diffusion testing. The loss in filter performance was measured and compared to the minimum filter performance required to ensure that flammable atmospheres would not be achieved. The reduction in filter performance was deemed to not significantly increase the risk to the storage case even if this abnormal overfilling and expansion scenario were to occur.





Project

Sellafield 3m³ box project

Benefits

Adequate stakeholder confidence has been achieved by demonstrating the performance of the 3m³ box. This underpinning research is a critical enabler to initiating retrievals and storage of unconditioned MSSS wastes which is a key high hazard and risk reduction activity.

Current Status

This phase of work is complete with substantiated boxes now in use safely storing MSSS waste within Encapsulated Product Store 3 (EPS3).

Delivery Partners

RED Engineering, Thornton Tomasetti

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1. Filter diffusion test rig

2. Pressure test rig

3. Sludge coated filter

Digital twin of Magnox Swarf Storage Silo effluent

The Magnox Swarf Storage Silo (MSSS) is a wet storage facility comprising of 22 compartments storing solid Magnox waste. The solid waste retrieval process generates a net positive volume of liquor which is discharged from the facility and treated at the Site Ion Exchange Effluent Plant (SIXEP) prior to sea discharge.

MSSS liquor samples have been collected for over 60 years and 30+ species, which has resulted in a huge quantity of data. The sample data provides the sole effluent characterisation and the basis of design flowsheets and modelling, but manual data entry and manipulation has led to human errors, loss of data and lack of assurance.

The MSSS effluent modelling environment is digital twin of MSSS effluents. It has been implemented as a web application that provides a detailed data management system enabling a single source of truth for managing plant data and model outputs to support effluent management. The platform is hosted on cloud services enabling controlled access from across the Sellafield site.

The MSSS effluent modelling environment provides a tool that enables:

- Fast and easy upload of data from analytical services and MSSS operations.
- Validation and verification of data.
- Controlled access and audit trail of data edits.
- Real time operational trending.
- Predict future plant performance.
- Compatible with site wide modelling/ flowsheeting platforms.
- Minimises human intervention.
- Flexibility for additional features as requirements change.
- Web based platform for cross-site access.

The environment enables statistical analysis through end user 'apps' to support plant facing technical teams and incorporates tools to assist with quality assurance to ensure the credibility of the outcomes.

Project

MSSS effluent modelling environment

Benefits

The modelling environment has significantly reduced the time required to input and manage MSSS effluent sample data, which will save approximately £650,000 over the programme life and improve quality assurance.

The benefits associated with this modelling environment can be applied to sample data associated with any plant on the Sellafield site.

Current Status

The MSSS effluent modelling environment has been implemented for MSSS effluents and has been rolled out for use by MSSS facing teams.

Delivery Partners

NNL

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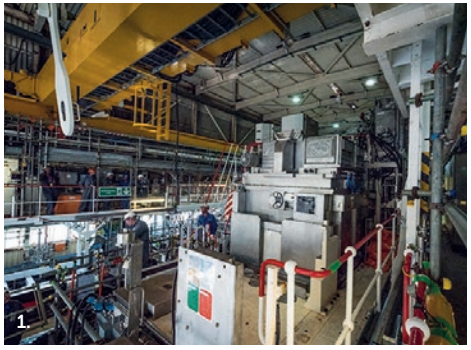

1. MSSS transfer package in MSSS building

2. MSSS transfer package in MSSS building

3. Workers inside MSSS building

Zeolite skip processing

Between 1975 and 1985, Zeolite skips were in service in the First-Generation Magnox Storage Pond (FGMSP) to remove caesium (Cs-137) and strontium (Sr-90) from the pond liquor prior to discharge. The skips contain AW500 which is a natural ion-exchange material. As pond liquor is pumped through the AW500 within the skips, radionuclides (Cs+ and Sr2+) are removed leading to a reduction in the overall activity of the liquor.

Zeolite skip use was discontinued in 1985 when the Site Ion Exchange Effluent Plant (SIXEP), a treatment plant that removes activity from the liquor via filtration and ion-exchange, was brought online. The used skips remained stored in the pond utilising the pond liquor as radiation shielding.

The skips are soon to be removed from the pond and placed into Self-Shielded Boxes (SSBs) within the interim storage facility. After a period of storage, they will be transferred to the Box Encapsulation Plant (BEP) where they will be removed from the SSBs, drained of the liquor inside and then encapsulated within 3m³ boxes ready for permanent disposal at the GDF.

Historic R&D has suggested that the AW500 could undergo degradation during interim storage. This could result in high concentrations of sorbed Cs-137 and Sr-90 being released into the liquor within the skip. This potential increase in liquor activity would pose a dose risk to the BEP operators during processing and sampling.

We tasked NNL to initiate R&D work to understand the following; firstly, if ion exchange was to be used as a resilience measure at the BEP, which media would be most suitable for removing Cs-137 from the effluent, and secondly, could a much less conservative assumption around the release of Cs-137 and Sr-90 from the AW500 be underpinned? The programme consisted of two desktop-based studies and a series of inactive lab experiments.

The first project demonstrated that of the materials tested, Ionsiv cartridges would be the most suitable for removing exclusively Cs-137 from the liquor. However, the final project demonstrated that estimates of Cs-137 release from AW500 as a result of degradation could be significantly reduced, with the dose implication for operators being removed.

The work highlighted that competing ions released into the liquor following AW500 degradation could be managed effectively via dilution before discharge to SIXEP for treatment.

1.

1. Image of a Zeolite skip

Project

Retrieval of Zeolite skips from FGMSP

Benefits

The work has provided the technical underpinning for a less conservative assumption for Cs-137 release from AW500 should degradation occur during interim storage.

As such, the dose rates and liquor activity issues at the BEP have been reduced and can be mitigated by dilution, which will enable future Zeolite skip processing in the BEP without plant amendment or incorporation of ion-exchange steps for liquor activity reduction.

Current Status

This programme of R&D is complete and has informed the concentrations of Cs-137 and competing ions to be used in the BEP medium active effluent flowsheet.

The flowsheet will be used to support upcoming safety case assessments and to establish dilution tactics at the BEP.

Delivery Partners

NNL

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Andrew Milligan

Senior technical advisor

Andrew Milligan joined Sellafield Ltd in 2014 as part of the technical specialist training scheme (now degree apprenticeship) and completed his degree in nuclear plant, process and technology at the University of Cumbria over five years on day release.

Initially part of the BEP technical team to adapt Commercial Off-The-Shelf (COTS) robot technology for the nuclear environment, Andrew worked closely with NNL for 2-3 years in their Workington Laboratory to understand how to operate and deploy robots to handle, reduce and package waste.

Andrew then supported the strategy development and safety case requirements for the retrieval of large items from legacy ponds and was actively involved in planning and managing items coming out of ponds. This allowed large items to be put into ISO containers, while the long-term waste route, involving size reduction, is being developed.

He is currently in the plant facing technical team working out how to maximise the BEP utilisation and drive value for money. He also implements CM&I strategies around corrosion, radiological and salt deposition, temperature and humidity monitoring to assure waste package condition within interim stores. This year he will lead the planning and execution of the process to retrieve and analyse the first batch of corrosion coupons.

The retrievals technical team has given Andrew the opportunity to continually develop his experience and level of responsibility. This includes producing the radioactive waste management case for the Office for Nuclear Regulation (ONR) and NDA that defines the strategy to manage waste from cradle to grave.

"It's really satisfying to see projects through to completion, and I'm looking forward to seeing the BEP begin operation."

Sara Higgins

Technical degree apprentice

After joining Sellafield Ltd in 2017, Sara Higgins is now in the final year of her degree apprenticeship with her dissertation project focused on the potential use of high energy X-ray radiography or muon tomography within the BEP.

This five-year degree apprenticeship scheme has enabled Sara to study as she works, committing to a demanding schedule of day-release learning to study for her BEng degree in Plant Engineering (nuclear plant and process technology) at the University of Cumbria, while contributing as a member of the Box Encapsulation Plant and Stores (BEPS) technical team.

Whilst at Sellafield Ltd, Sara has worked in several roles, including operations support and business improvement within FGMSP, and has spent the past two years working in the BEPS technical team, which is part of the wider retrievals team.

Her main responsibilities are helping the development of the BEP waste tracking and inventory system from a technical perspective, aiding in customer acceptance testing, and answering technical queries. Her dissertation project is also supporting the decision between high energy X-ray radiography or muon tomography for implementation within BEP.

She has recently become more involved with R&D on CM&I technologies and has observed some of the technologies being developed. An example of this is a recent trip to the University of Glasgow, to learn about a muon detector that can create images of objects inside the detector using the deflection of cosmic muons.

"I enjoy being involved in R&D and learning about new technologies that have the potential to be implemented onto plant."

Wallis Webber

MSSS effluents and modelling lead

Wallis Webber leads the MSSS effluents and modelling team, is responsible for delivering the MSSS effluent technical baseline, and leads the research, development and roll out of the retrievals modelling strategy. Wallis graduated from Newcastle University with a degree in chemical engineering and is a chartered engineer with the Institution of Chemical Engineers (IChemE).

Wallis has 13 years' experience in the nuclear industry, initially working on our projects via the supply chain (DBD Ltd), before joining the MSSS strategy and technical team in 2015 on the Silos Direct Encapsulation Plant (SDP).

Problem solving is a key part of her role, which includes updating plant models to reflect on plant learning and operations. For example, she recently integrated the MSSS effluent modelling environment (cloud-based data management and trending tool) with plant monitoring systems. Retrofitting information into models can be time consuming, so it is important to develop fit for purpose solutions that can meet decision making timescales.

Wallis is the integration lead for the modelling and simulation CoE, which has involved developing our engagement structure with the supply chain and universities to access external modelling expertise.

Working in collaboration with NNL on the Game Changer-funded digital twin project, she identified an opportunity for a digital twin to support the original building liquor imbalance. An MSSS effluent digital twin was shown to be beneficial to monitor conditions and look for any correlations between plant activities, building movements and leak rate, which won runner up in the global IChemE award.

"I enjoy feeling 'helpful', so I really enjoy work that I can see being used, such as data management systems or calculations that support operations."

Penny Rathbone

Research technologist

Research technologist Penny Rathbone studied chemistry at the University of Manchester and then joined the two-year Nucleargraduates programme sponsored by Sellafield Ltd. The Nucleargraduates programme gave Penny the opportunity to try lots of different roles across the nuclear industry, including spending time with Nuclear AMRC, ANSTO in Australia and the retrievals effluents team.

After successfully completing the Nucleargraduates programme, Penny joined the effluents chemistry team in November 2020.

Penny coordinates the MSSS plant facing technical support R&D programme and provides chemistry support to the legacy ponds and silos as well as their downstream treatment and storage facilities. A large part of the role requires working collaboratively with NNL to solve the complex challenges associated with managing the effluent.

As an intelligent customer, Penny works with NNL to scope out and plan R&D work, as well as manage the complex outputs of the work, to make decisions and implement changes. A lot of the recent R&D work has been associated with the potential changes in the effluents chemistry and the challenges they present, as a result of retrieving the solid wastes from the facilities.

She is a member of the Royal Society of Chemistry working towards chartership and supports several teams across the enterprise, including the MSSS and encapsulation teams. This support is important to ensure that changes in their effluent feeds do not impact their ability to discharge and treat.

"Solving complex chemistry-related problems that directly influence current and future retrieval operations is really satisfying and no day is the same."

Remediation

The Remediation value stream is responsible for the clean-up of nuclear and non-nuclear facilities across the Sellafield site with the R&D programme focusing on:

- Characterisation, POCO and decontamination of facilities.
- Forecasting and modelling to support decommissioning planning.
- Enablers such as access to facilities, deployment platforms, containment systems and operator working conditions.
- Tools and techniques for the removal of plant and equipment.
- Surveillance and maintenance and care and maintenance tools and techniques.
- A range of waste processing technologies for waste treatment and conditioning.
- Waste transfer, handling, storage and export.
- Developments in demolition techniques.
- Land remediation technologies.
- Waste disposal and records.

The remediation capability development team is responsible for identifying new technologies, supporting innovation in the supply chain, developing and industrialising technologies and techniques and delivering active demonstrations of technology, systems and facilities. This is achieved through a structured R&D strategy for each programme area (Alpha, Beta Gamma and Waste).

Increasing storage capacity

To meet the demand profiles from Retrievals for storage of their Contact Handleable Intermediate Level Waste (CHILW), there was a requirement to understand how the finite interim storage space currently available across the site could be maximised. Failure to do so could have resulted in nowhere for the waste to be stored and have a detrimental effect on High Hazard Risk Reduction (HHRR). The Waste Capability Development (WCD) team have developed a couple of solutions.

Increased storage capacity in store

Retrievals store their CHILW waste in the Windscale's Advanced Gas-cooled Reactor (WAGR) store in both Half-Height ISO (HHISO) and TC05 containers. Through working with design, safety case and radiological protection advisors, the WCD team have underpinned that the number of containers in a stack can be increased by a further row, which creates 40% extra space capacity for retrievals waste than is currently available in the store.

Increasing the fleet of shielded TC05 containers for skips

First Generation Magnox Storage Pond (FGMSP) skips once retrieved must be placed in a purpose built shielded TC05 container for shielding purposes. Skips are stored in these containers both pre and post going through the Skip Size Reduction Facility (SSRF). The site previously had an existing fleet of 50 of these TC05 containers, but this was not deemed enough to support the Retrievals skip campaign. WCD managed a contract with Integrated Decommissioning Solutions (IDS) and Barrnon, to manufacture another 25 shielded containers. This allows for continuation of skip retrieval.

1. Higher stacking trials taking place in the WAGR store

Project

Increasing storage capacity for CHILW

Benefits

The completion of this work acts as a defence in depth for retrievals to be able to retrieve and successfully remove their waste off the plant, whilst other, more permanent treatment and disposal solutions and capabilities are being developed and brought to fruition.

Current Status

The higher stacking in WAGR is completed.

All of the additional TC05 containers have been delivered to site and the work is complete.

Delivery Partners

Barrnon, Integrated Decommissioning Solutions (IDS)

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Alpha Active Demonstrator (AAD)

Gloveboxes used for research, development and operations that have come to the end of their life will be decommissioned as part of the site's clean-up programme.

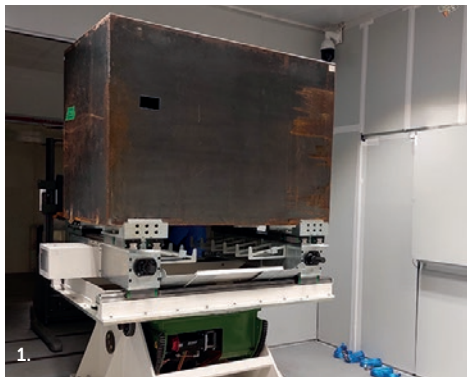
Many of these are contaminated with alpha-bearing material and current decommissioning plans include manual techniques which are often hazardous and time consuming. There is a driver to address this challenge using alternative technologies to deliver safer, more efficient decommissioning at a lower cost.

A facility for reducing the size of gloveboxes has been built in an existing laboratory on the Sellafield site. This self-contained laser cutting facility will reduce the risk to operators during remote size reduction of alpha contaminated gloveboxes.

This includes a laser cutting system mounted on a six degrees of freedom robotic arm with recovery of waste and minimum human intervention. The facility is now entering into system cycle demonstration with our commissioning team and IDS engineers, working with operators on plant to allow inactive commissioning. This has included laser cutting module installation, load testing the clamping arrangement, laser cutting tests and loading a clean glovebox into the facility as part of the site acceptance tests. The laser cutting trials on a clean glovebox have successfully confirmed the route from laser cutting to the vibro-trough, lifter table and into the 200-litre drum.

It is on track to gain permission from the ONR to go into active commissioning with the size reduction of one glovebox through the facility expected in November 2022. The next phase of work will reduce the size of up to seven additional gloveboxes from the same laboratory to further develop our knowledge and experience of using this facility.

The AAD project will determine whether to scale up and build a central breakdown facility or whether another engineered drum store or waste treatment complex is required to house additional waste from the decommissioning of alpha contaminated gloveboxes.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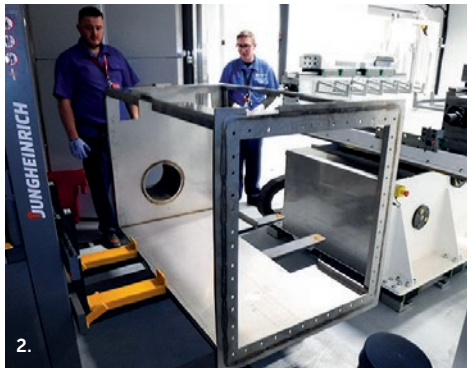

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Project
Alpha Active Demonstrator

Benefits
The project aims to develop a safer, semi-remote process for the size reduction of alpha contaminated items that is more efficient when compared to manual operations.

This is expected to have safety, cost and schedule benefits once the technology is proven and optimised.

Current Status
Met key target milestone set by NDA on 16 March 2022. Active commissioning of the facility is expected in November 2022, followed by the size reduction of up to seven additional gloveboxes.

Delivery Partners
Cyan Tec Systems Ltd, Integrated Decommissioning Solutions (IDS), Lasermet Ltd, Taylor Kightley Engineering Ltd

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1. Box loaded on cutting table

2. Clean glovebox loaded on cutting table

3. Laser cutting of clean glovebox

Integrated Innovation in Nuclear Decommissioning (IIND)

The IIND competition was launched in early 2017, with the objective of encouraging the supply chain to innovate, collaborate and transfer cross-sector technologies into the nuclear market to solve a 'grand challenge'.

Learning from previous innovation competitions, we were requested to steer the scope of the competition by identifying, specifying and bringing to life a decommissioning challenge which was timely, complex and diverse, with significant opportunity for a step change where Robotics and Artificial Intelligence (RAI) could be part of the solution. The end-to-end decommissioning of reprocessing cells was selected as the 'challenge statement' to focus the competition. The aspiration was for:

- A transferable, integrated decommissioning toolkit that minimises the interface between the operator and the hazard, whilst aspiring for a ten-fold increase in productivity and reduction in lifecycle cost.

The IIND competition sought integrated systems which were scalable and transferable and would ultimately lead to safer, faster, better value decommissioning for the future. The competition is now in the third phase and working towards Active Demonstration on the Sellafield site. Initially two consortia were chosen to go forward into Phase 3 but now only one remains.

The Barrnon Integrated Decommissioning System (BIDS) uses a 'Swiss army knife' approach comprising of two Remotely Operated Vehicles (ROVs), a large base vehicle with the ability to carry out a wide range of characterisation and size reduction operations on the ground and reaching up into the cell using a long reach telescopic boom. The main ROV is supported by a smaller Waste Transfer Vehicle (WTV) that will be used to collect and transfer size reduced waste items from within the cell to the waste export area.

The Barrnon BIDS vehicle is manufactured, and a number of the sub-assemblies are undergoing works testing, while the Barrnon WTV is partially manufactured and the potential to make the vehicle battery operated/umbilical free is being explored. Characterisation, design specification and modification of the deployment cell is almost complete prior to the active demonstration trials.

1.

1. BIDS vehicle – extended for first floor size reduction operations

Project

IIND competition

Benefits

The innovative products and new technologies that have been developed through this Active Demonstrator could provide a major cost saving in future decommissioning activities by reducing uncertainty, enabling greater transferability (plug and play) and developing spin out technology/ systems to address other challenges across the Sellafield site and NDA estate.

This approach maximises the opportunity for academics, SMEs and larger organisations to collaborate and integrate technology components, whilst also encouraging technology transfer from other sectors.

Current Status

BIDS vehicle is undergoing final manufacture and testing while the deployment cell modifications are being completed with active demonstration trials planned for late 2022.

Delivery Partners

Barrnon, NDA, Innovate UK

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Sellafield in the SPOTlight – teaching a new dog nuclear tricks

With significant advancements in RAI over recent years, many industries are recognising the benefits that this technology can provide, particularly when there is a drive to automate processes, increase efficiency and remove humans from hazardous operations. A key challenge across the enterprise is to deliver characterisation, investigations, surveillance and inspections in hazardous environments. These tasks are often hazardous to operators, time consuming to plan/deliver and can be monotonous/ prone to error. There is an opportunity to deliver this type of work remotely and in some cases autonomously, which will free up the workforce to deliver other value adding work.

The Boston Dynamics 'SPOT' is a quadrupedal (four legged) robot (resembling a dog) which is capable of carrying up to 14kg of sensors and autonomously (with remote human supervision) navigating extreme, difficult to access areas. It is capable of walking up and down stairs, clambering over obstacles, negotiating tight spaces and sharp bends with ease. It can be equipped with the sensors required for the specific objective (e.g. radiation mapping) and will send the data back to the operator wirelessly in real time.

Recognising the strategic benefits that SPOT could offer us and the wider nuclear industry, the remediation capability development team, Special Equipment Services (SES) remote handling team and central RAI team collaborated to deliver a number of active demonstrations, understand the benefits and make a decision (make vs buy) on future applications. The learning from the demonstrations also allowed the team to gain a good understanding of the requirements to make generic substantiation for business as usual deployments.

This work has increased collaboration and capability both internally and within the supply chain by supporting a local Small and Medium-sized Enterprise (SME) who engaged an organisation new to nuclear. Overall the understanding of needs and opportunities have increased which will help with future solution provision. This project has also upskilled and provided a fantastic opportunity for our newest recruits who have thrived on the opportunity to deliver this work, encouraging more young engineers to work in the nuclear industry.

The supply chain collaboration included the highly innovative local SME, Createc as lead contractor, SPOT manufacturer and supplier Boston Dynamics and the United Kingdom Atomic Energy Authority (UKAEA) Remote Applications in Challenging Environments (RACE) for their additional SPOT expertise and provision of a specially designed SPOT contamination suit.

Project

Robotics and Artificial Intelligence IRT

Benefits

The SPOT demonstrations were delivered within a very short timescale to bring both immediate benefit and open up a significant opportunity for SPOT to help deliver our mission in the future.

The safety, cost and schedule benefits are expected to be very significant. For example, health physics surveys in a facility as large as Thorp are estimated to be circa £6m per annum. A proportion of these surveys will be routine and monotonous which have the potential to be delivered by SPOT and free up a constrained workforce to deliver other value adding work. This is just one example in one facility.

SPOT has captured people's imaginations and this work has helped to bring the nuclear workforce on the RAI journey and help people understand that robots can help us deliver our work safer and more efficiently – they are not here to replace our workforce.

Current Status

The active demonstration has been completed however we are looking at improving the capabilities of SPOT, such as improving the contamination suit so that it is more functional for regular use.

Delivery Partners

Boston Dynamics, Createc, UKAEA RACE, University of Oxford

Contact Details

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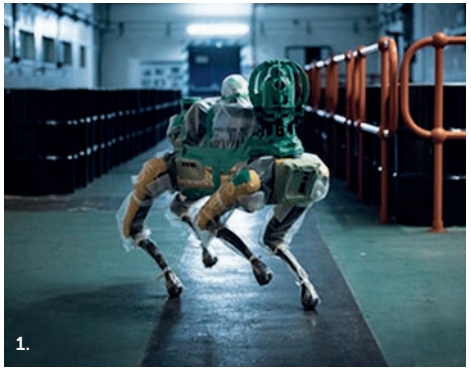
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1. SPOT surveying a drum storage facility, protected by UKAEA developed contamination suit

2. Photo from Calder Hall with representatives from Createc, UKAEA and Sellafield Ltd

Remotely operated Blimp for inspections

Unmanned Aerial Vehicle (UAV) technology is becoming increasingly prevalent in the nuclear industry and has the potential to transform our work practices. The transfer of these technologies to our site presents challenges but there is little doubt it will raise efficiency and safety levels, as well as provide enhanced levels of service and access to data.

This work has been undertaken to establish if there is merit in using a remotely operated helium filled Blimp as a platform for deploying cameras in hard-to-reach areas that would traditionally need a Mobile Elevating Work Platform (MEWP) or a scaffold structure. The potential benefits for removing scaffolds and MEWPs from building inspections could be enormous in terms of savings against cost and reductions in risk. The highest risk to a UK construction worker currently is working at height and more personnel are lost through falls than any other method. In terms of cost savings scaffold is not cheap and extremely labour intensive, it also takes time and resources and can hinder other operations occurring in the vicinity.

The Blimp was initially deployed inactively at an offsite location to test its suitability prior to active deployment. Following these inactive deployments, it was confirmed that the Blimp was suitable for active deployment. A suitable facility was identified for the deployment which included various inspection focal points. A general building inspection was carried out utilising the Blimp which was then followed up with a crane system inspection. This active demonstration presented specific challenges that tested the Blimp's capabilities.

The outputs from the active deployment were found to be very positive with key benefits over current technology identified. The learning gathered highlighted various development opportunities for the device which will be implemented prior to a second deployment of the Blimp.

1. The helium filled Blimp undertaking inspections in an active environment

Project

Remediation capability development

Benefits

The Blimp presents many benefits over current UAV technology. One of the main benefits is that there is minimal ground disturbance on take-off and during flight, this makes the Blimp very useful in highly active areas as currently available UAV technology presents large amounts of down wash.

Due to the Blimp's balloon like structure, there is minimal risk of damage occurring to plant or equipment in the event of a collision, which would most commonly occur in tight and cluttered areas.

Current Status

Following a successful active deployment, invaluable learning has been gathered providing specific areas that can be developed to improve the Blimp's functionally. The Blimp can then be further deployed to test and refine the improvements made.

Delivery Partners

Sellafield UAV team

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Laser decontamination

The use of laser ablation to decontaminate metallic waste surfaces has been identified as a promising technique that could be used across a variety of the NDA subsidiaries.

The remediation capability development team have already overseen a series of non-active trials with The Welding Institute (TWI) which explored a variety of different laser systems and evaluated their effectiveness in terms of removing surface layers and coatings from a range of substrates. The results from these trials were promising but further work was required prior to using this technique in a radioactive environment.

The objective of this project was to populate the technical gaps in the understanding of particulates and fumes generated during laser decontamination, including:

- Composition of the particulates and fumes and the potential hazard they present.
- Quantity of contamination that remains on the substrate material.
- Condition of the substrate material after the laser ablation trial.

There was also a need to consider the physical form of the particulates and fumes, such as size distribution (including and below the 1-micron size) and porosity as they are orders of magnitude smaller than those seen in laser cutting. This will enable the respective stakeholders to gain a comprehensive understanding of this technology and address key outstanding questions regarding its feasibility before being actively deployed across NDA subsidiaries.

Three different laser powers (100W, 500W, 1000W) were applied to investigate the particulate and fume formation, speciation, and concentration, which will be evaluated using various analysis methods. These experimental tests have provided a significant amount of data relating to the performance of the decontamination technology and the secondary waste generated to:

- Understand the secondary wastes (fumes and particulates composition, behaviour, and distribution) generated from laser ablation.
- Assess the effectiveness of the laser ablation technique for decontaminating a substrate material.
- Determine an appropriate waste disposal route for secondary waste produced (fumes and particulates).

Ultimately, this will create the ability to enable an effective dry decontamination solution along with the respective filtration management system to be fully utilised across the NDA estate to decommission legacy facilities safer, faster and cheaper. Sellafield Ltd, Magnox Ltd, and DSRL have identified this as a collective problem, and it presents a collaborative learning opportunity.

Whilst there are still some outstanding uncertainties relating to the particulate size distribution and extent of gaseous products, the data gathered to date is very promising and supports the technology being viable for decontamination of metallic waste (coated and uncoated) arising from nuclear facilities.

Project

Remediation capability development

Benefits

The NDA's clean-up mission covers 17 legacy sites lasting over 100 years at a predicted cost of more than £100 billion (NDA five-year plan). Exploring new, innovative methods that incorporate novel technologies and techniques within the nuclear industry to decommission legacy sites will enable the overall mission to be achieved safer, faster and at a lower overall cost to taxpayers.

The laser ablation technique has the potential to be added to the NDA's Decommissioning Portfolio meaning the technique could facilitate the development of the NDA's decommissioning strategy and enhance its delivery by adopting this technology across the NDA subsidiaries. While this will not be the sole solution to the decontamination challenges, laser decontamination has the potential to contribute to significant savings of £10s to £100s millions across the NDA estate.

Current Status

A collaborative roadmap to enable industrialisation of the technology for nuclear applications has been generated, which indicates that there are no technology gaps. However, there is a need to gather 'active' data to address outstanding questions and support routine application of the technology. It is therefore expected that an active demonstrator will be required. A proposal will be produced detailing the need to initiate a study for the delivery of an active demonstrator.

Delivery Partners

DSRL, Galson Sciences Ltd, Magnox Ltd, NDA, NNL, University of Bristol, VTT Technical Research Centre of Finland Ltd

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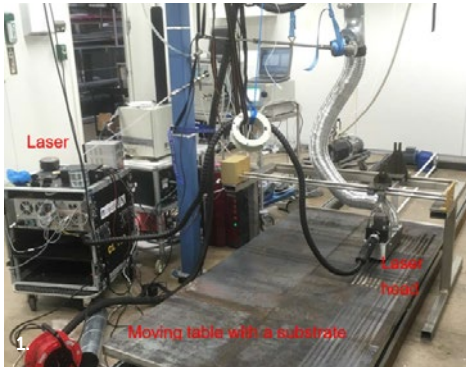

1. Laser decontamination test facility

Lachlann Peacock

Capability development team member

Lachlann Peacock is currently on an industrial placement from the University of Portsmouth where he is studying mechanical engineering.

Lachlann supports and runs the SPOT active demonstrator, which is aimed at using robots to conduct tasks previously undertaken by people, therefore reducing operator dose. His role involves arranging staff training, engaging with stakeholders and preparing risk assessments and method statements, as well as acquiring equipment and developing the future roadmap.

Delivering the first active deployment of SPOT in the UK is a major milestone, which will be used as an example for future deployments, and Lachlann has been responsible for ensuring that the work is delivered to a high standard. The project is now changing from active demonstration to getting the equipment performing missions, and he continues to work with the remote handling team as the end users of SPOT and the equipment.

Lachlann has been actively involved in changing people's expectation of robotics and how they can benefit us. As a result, he has been nominated for both a Wave Award for driving innovative solutions for the future and an NDA group employee award for excellence in innovation in 2022.

"I am driven and motivated by achieving set goals which I believe will make a real difference."

Andrew Beattie

Technical team member

Andrew Beattie leads and delivers improvements to the Sellafield site's waste management capability, which is aligned to the waste programme and capability development roadmap.

Andrew played professional Rugby League and Rugby Union for over 10 years, followed by a career in further education, teaching sports science, public services and functional skills. He started working at Sellafield Ltd as a training developer/instructor in 2014 covering a wide range of areas before progressing to a training lead role in 2018. He moved into the waste capability development team in October 2021 for a change in career and to experience something different.

He has been involved in various projects since joining the team, including the WAGR store higher stacking capability project, the MEBIS store storage proposal and the consignment of C-type flasks from legacy ponds to Tradebe. As part of the higher stacking project cameras were added to the forklift, so that forklift operators and banksmen can get a better visual of stacking different iso-freight containers to reduce error and increase safety.

Andrew's previous roles and training background give him a good, rounded approach to work life, which enables him to effectively collaborative with teams from across many different areas of the business as well as external stakeholders. His tasks include development, demonstration and implementation of technologies, processes, routes and facilities for both short-term and long-term waste capability.

"I enjoy learning new things from all levels of life and business and am driven

David Procter

Active demonstrator lead

As active demonstrator lead, David Procter is responsible for the delivery of the IIND active demonstrator and manages a team of people that are preparing and delivering new technology demonstrations across the Sellafield site.

David's 31-year career in nuclear decommissioning began as an instrument mechanical apprentice with UKAEA, followed by remote inspection and control at Harsh Environment Systems and then working in the plant inspection team at Nexia Solutions, he then joined the alpha decommissioning projects team in 2005 before starting his current role in the remediation capability development team at Sellafield Ltd in 2016.

A key part of David's role on the IIND active demonstrator is to ensure progress against milestones and working with the building operations and remediation facility characterisation teams to deliver all aspects of in-cell sampling and plant enabling works. In addition, the IIND team have identified innovative ways to improve data gathering, in cell pipe identification and deployment of size reduction equipment within challenging environments.

David supports the younger team members to enable them to deliver technology demonstrations and captures all learning from experience gained from active demonstrators. This includes the initial phase of the LongOps programme and the SPOT quadruped deployments. He is also a member of the NI and was part of the team that won an NDA innovation award for the Laser Snake 2 deployment.

"It's really satisfying to see new technology progress to active demonstration, so that it can then be used on site to make decommissioning safer, faster and cheaper."

Yolande Smith

Robotics capability development manager

As robotics capability development manager, Yolande Smith develops, manages and coordinates our roadmap for land-based RAI and is the lead for land-based robotics in the RAI CoE.

After graduating in Engineering Science from the University of Durham, Yolande worked in R&D at Pilkington delivering complex technical projects, such as bespoke instrumentation at the end of a robotic arm. She has worked at Sellafield Ltd for 13 years, initially in the engineering design team before moving to her current role in the remediation technical team 11 months ago.

Yolande has been exploring a range of solutions that can enable safer, faster, better value remediation of nuclear sites. She is working with stakeholders in the adoption of new RAI technology and developing confidence in the use of artificial intelligence and autonomous systems in the nuclear sector. This includes new robotic navigation, sensing and haptic technologies aimed at remote supervised deployments, such as decommissioning reprocessing cells and operating gloveboxes.

Working across value streams enables Yolande to maximise opportunities across the NDA estate and expand the use of robots to perform dull, dirty and dangerous tasks in a safe and secure way. She is a Chartered Electrical Engineer, Fellow of the Institution of Engineering and Technology and STEM Ambassador, inspiring the next generation of engineers.

"It's great to see technological innovation and capability being used to remove humans from hazardous environments and increase efficiency through automation."

Robotics and Artificial Intelligence

Robotics and Artificial Intelligence (RAI) are being embraced across the NDA estate, with Sellafield Ltd at the forefront. They provide us with the means to remove people from extreme hazardous environments and assist in its mission to decommission and clean up the site in a safer, faster and cheaper way.

Using RAI effectively can have a positive impact on both nuclear and conventional safety. They can be used to perform repetitive, difficult and time-consuming jobs remotely while freeing up employees to take on roles that are more fulfilling and rewarding, ultimately helping to deliver our mission.

The RAI capability team has been set up to focus on the long-term uses of these technologies as they continue to develop and evolve, covering four domains:

- Water: robots are needed to scour ponds, pick up and cut material and then sort the nuclear inventory sitting underneath the surface.
- Land: robots are needed to be lowered into hard-to-reach areas, such as the silos and compartments and then to operate in what can be extremely toxic environments for significant periods of time.
- Air: drones have been identified as ideal to carry out detailed infrastructure inspections quickly and safely, at a reduced cost. The inclusion of Artificial Intelligence (AI) means that they can operate independently and spot degradation much sooner.
- AI centre of excellence: working collaboratively to identify opportunities and to take full advantage of what robotics can offer across the site and the NDA estate.

Each of these domains is being managed across Sellafield Ltd within the remediation and retrievals value streams, as well as in engineering and maintenance and technology groups.

The use of robots has already proven to keep our people safe but there is still potential for them to help speed up the mission, making our site safer, sooner, whilst also contributing towards delivering some of the NDA's grand challenges.

Robotics and Artificial Intelligence Collaboration Laboratory (RAICo1)

The Robotics and Artificial Intelligence Collaboration (RAICo1) is comprised of Sellafield Ltd, NDA, NNL, UKAEA's Remote Applications in Challenging Environments (RACE) programme and the University of Manchester.

The group was formally founded, following collaborative work by the central RAI team with the academic and industry partners, to progress research projects supporting the NDA's nuclear decommissioning mission.

The RAICo1 facility in Whitehaven has been developed to further grow the collaboration. This facility provides a co-working space for robotics projects to be initiated and allows scenario-based research to continue before undertaking on-site deployments.

The space has been designed to allow robotic and AI solutions to be developed for real-live scenarios, such as within radiologically shielded enclosures, gloveboxes, pipework and water tanks. The space has been formatted to include a control room that can facilitate remote working techniques, such as Virtual Reality (VR) and Augmented Reality (AR).

Current collaboration projects include the Risk Reduction of Glovebox Operations (RrOBO), automated SNM stores, and the LongOps project. These projects are ongoing with a number of collaborative and supply chain partners and will utilise the co-working space in RAICo1.

RAICo1 is also set to be a flagship for socio-economic and community engagement, with plans to host school Science, Technology, Engineering and Mathematics (STEM) robotics events, and summer camps for students interested in furthering their robotics and AI skills.

To follow on from this, RAICo1 is instrumental in the development of a robotics apprenticeship scheme, which will foster links with the local robotics supply chain companies and provide career options for local students, increasing the expertise for nuclear and non-nuclear robotics, which will last long after our decommissioning mission is complete.

1. *SPOT demonstration at RAICo1*
2. *SPOT demonstration at RAICo1*

To Find Out More Contact
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Risk Reduction of Glovebox Operations (RrOBO)

Having people reach into gloveboxes through ports is a potential safety hazard and has led to incidents in the past. There is now an opportunity to consider alternatives to hands-in-box manual operations, which had not been available to previous generations. Therefore, the aim of the RrOBO project is to get robots to carry out much of the work that is currently done by human hands.

The project is being delivered through the Design Services Alliance (DSA) and represents a multi-discipline collaboration, that includes supply chain and academic experts, to study how technology can bring about a revolution in the way gloveboxes are operated. The project is based at the new RAICo1 facility and includes contributions from UKAEA's RACE and the Robotics and Artificial Intelligence in Nuclear (RAIN) hub.

In our facilities, there are over 300 gloveboxes which are used to contain and conduct tasks with nuclear materials, which vary in size, age, design, purpose, condition and materials. Therefore, it is necessary to understand and characterise the existing gloveboxes, alongside the development of robotic solutions, through a phased approach.

Phase 1 (complete)

Since the current generation of gloveboxes are developed for manual intervention, it was decided that Phase 1 should focus on the manual glovebox activities that are being undertaken/planned for POCO. This includes identifying the tasks associated with the removal and reduction of the glovebox and its contents that could be considered suitable for remote operations.

The robotic development and testing in Phase 1 included a sandpit environment at RAICo1 to trial the robotic technology to the limits of its capability and developed a number of proof-of-concept solutions using COTS equipment.

Phase 2 (under way)

Focus has now moved on to understanding, researching, and analysing the health and safety risks of manual glovebox operations, to understand which glovebox tasks carry the most significant levels of risk to operators and so allow these tasks to be prioritised for automation.

The Phase 1 concepts will be matured to develop the product and reduce the technical risk in preparation for active demonstration and commissioning on the Sellafield site.

In the long-term, this work will focus on influencing the purpose and design of future gloveboxes, so that gloveboxes will be automated internally as much as possible. This will reduce the requirement for manual intervention other than for routine maintenance of the robotics or automated machinery within the gloveboxes of the future.

Project

RrOBO project

Benefits

Using robotics technology will reduce the risks associated with putting hands into gloveboxes and will provide the interface between the hazardous workspace and the operator.

This project will potentially allow our operators to perform tasks remotely through VR and haptic solutions, allowing glovebox operations to be carried out more efficiently and remotely from a control room.

Current Status

The robotic glovebox solutions are currently being developed into working products in preparation for active demonstration and commissioning on the Sellafield site.

Delivery Partners

Atkins, Cavendish Nuclear, Taylor Kightley Engineering, UKAEA RACE, The University of Manchester

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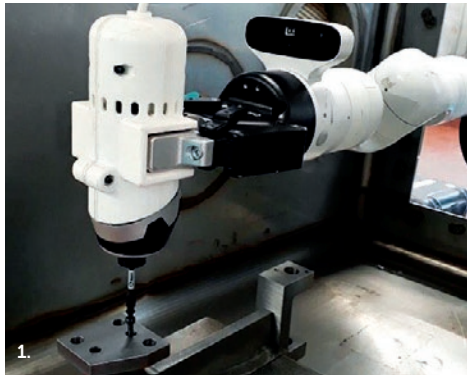
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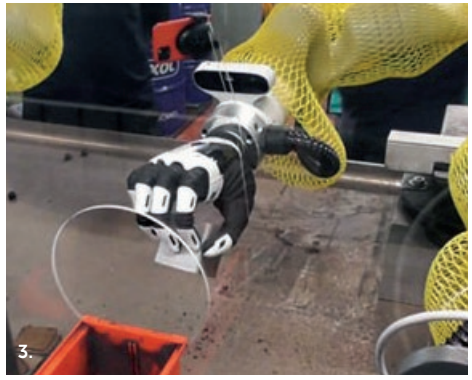
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1. Remote glovebox operation testing

2. Robotic arm in containment sleeve with plasma cutter

3. Robotic arm with COVVI robotic hand

Robotics and Artificial Intelligence deployment acceleration

Robotics and Artificial Intelligence (RAI) technologies are becoming more commonly used within the industrial, academic and public domains. The benefits of such technology for the nuclear sector are currently being investigated by us on behalf of the NDA.

RAI applications consist of multiple connected physical devices (hardware) such as robots and robotic tooling and pre-programmed and emergent logic, designed to control them (software).

In addition to the complexity of operating within the stringent reliability requirements and safety regulations of the nuclear sector, robotic technology is evolving at pace and its use often results in bespoke deployments. This bespoke nature creates complications for the nuclear sector when considering factors such as operator knowledge transferability and the maintenance of multiple nuclear decommissioning deployments.

Over the past 18 months, the RAI standardisation project has focused on accelerating the time to deploy new technologies onto the plant. Typically, the development of a robotic solution through to the point of inactive demonstration (TRL 6/7) is rapid. However, the void between inactive demonstration and active demonstration, commissioning and permissioning can take several months or in some cases years to complete at a cost of over £5m.

Working with our external regulators (ONR) and our control, safety and engineering colleagues, the RAI team has been looking at developing a good practice guide and supporting process that, when agreed, will significantly reduce the time and cost of deployments onto the nuclear plant.

The process signposts and ensures that the right interactions with key stakeholders occur at the right time, and all evidence and agreements are captured. Likewise in answer to our challenge, the ONR has developed a sandbox in which advice and guidance can be sought through optioneering to TRL 7, where at this point the role changes back to that of regulation.

It is hoped that following the defined process from optioneering through to commissioning will ensure a significant reduction in the time and cost in providing solutions to the most complex challenges.


1.


2.

1. The use of Remotely Operated Vehicles (ROVs) is now common practice at Sellafield

2. SPOT the robot dog has been going through its paces at Sellafield as part of an active demonstration

Project
Standardisation for robotic deployments on Sellafield site

Benefits
A standardised process to develop and deploy new technologies onto the plant will significantly reduced the time and cost in delivering RAI solutions to the most complex challenges.

Current Status
The improved RAI development process and good practice guide is currently going through final approval.

Delivery Partners
NDA, NNL

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Artificial Intelligence strategy

Robots, autonomous systems and Artificial Intelligence (AI) are expected to be integral to delivering our clean-up mission. To support wider adoption of these technologies, the central RAI programme and RAI IRT have collaborated with Ada Mode to create an AI strategy that will ensure the organisation takes full advantage of what AI can offer across the Sellafield site and the NDA group.

In parallel with our increasing focus on AI, the UK Government, ONR and NDA have all produced recent publications associated with digital strategy, AI adoption and the use of innovative technology more generally. This collective momentum towards adopting more cutting-edge technology, both from the regulator and site licence holder, is a key enabler for successful deployment of AI over the long-term and demonstrates widespread enthusiasm for this technology, rooted in government policy.

The development of our AI strategy comprises three phases:

- Discover: Understand current technical maturity, existing AI and digital applications, levels of AI engagement from people and ONR objectives.
- Develop: Develop objectives that enable AI to deliver our mission more efficiently.
- Deliver: Specify objectives for successful AI adoption over short, medium and long-term.

The discovery phase is now complete, which included a detailed document review, in-depth one-to-one interviews with over 50 senior stakeholders and an online AI survey available to all our employees. The aim of this work was to capture information from people working across the organisation, ONR and wider NDA group, to establish a deep understanding of perceptions, opportunities, hurdles, concerns, and ideas associated with our AI adoption.

This information provides the foundational knowledge base to develop the vision, objectives and associated enablers that will form the body of our AI strategy.

Project
AI strategy

Benefits
There is now an opportunity to develop a coherent and holistic, long-term AI strategy, with a supporting roadmap, to facilitate the successful adoption of AI tools and technologies over the coming years by us and the wider NDA group. The aim is to use AI to enhance productivity by making work efficient and more effective.

Current Status
Ongoing with future work expected. The focus of the next phase of work will be the development of the AI strategy and roadmap documents. The roadmap will specify the priorities and timescales for when the objectives will be realised over the next decade.

Delivery Partners
Ada Mode, NDA, ONR

Contact Details
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Tracy McGrady

Programme development manager

Joining the central RAI team has given Tracy McGrady the opportunity to foster links with the STEM community, provide work experience opportunities for local children, and engage with academia in order to develop an apprentice scheme for robotics in West Cumbria.

Tracy has wide-ranging site experience, having worked for Sellafield Ltd for 33 years, since the days of BNFL. Her work as an analytical chemist includes obtaining plant experience and gaining knowledge of the radiological and industrial hazards associated with the Sellafield site.

After 20 years working in B229, one of the oldest buildings on the site, Tracy has developed wide ranging experience of radiological working techniques, such as glovebox and remote handling in-cell work, along with compliance to ISO, quality and safety case standards. Following this, a natural progression was for her to move to the training department, using her former teaching skills, combined with plant experience, to generate learning material in a wide range of formats.

Tracy's knowledge of radiological working techniques means that she is ideally suited to understand and assess how robots can be used to operate in gloveboxes, such as for the RrOBO project. She is an advocate of inclusion, utilising her experiences as a special needs parent, and being autistic herself, to provide a unique outlook on life, work and problem solving.

"A love of life-long learning has provided me with a wide variety of qualifications, from science, to teaching, to languages, and into transport and logistics."

Melissa Willis

Robotics and artificial intelligence IRT lead

As IRT lead, Dr Melissa Willis (Mel) is responsible for the development and technical delivery of low Technology Readiness Level (TRL) RAI solutions from universities and supply chain companies. Mel has an integrated chemistry degree and a PhD in materials science, through the CDT for advanced metallics, from the University of Manchester and is a member of the Institute of Materials, Minerals and Mining (IOM3).

Mel joined Sellafield Ltd in 2018 on the two-year graduate training programme, which is designed to offer secondments in a variety of disciplines across the business.

Her secondments included the inspection and certification group and legacy ponds innovation team before joining the central technical team at the end of her graduate training. Mel now leads the RAI IRT and enjoys finding synergies between materials science and robotics.

Her role involves working closely with the central RAI team and understanding the decommissioning challenges, across the wider NDA estate: creating networks of complementary technologies from industry, including those outside of nuclear, SMEs and academia. For example, she has been working on the collaborative robot autonomy and localisation project with the University of Manchester, focusing on communication and localisation of heterogenous robotic systems in Global Positioning System (GPS) denied environments, as well as the long-term AI strategy.

Mel wants to change attitudes towards robotics and AI, so that the benefits can be realised, and workforces supported in their operations. She has already noticed an increased confidence in the robotic systems being deployed across the Sellafield site.

"It's satisfying to use my technical background to support innovative projects and forge new relationships."

Engineering Development Solutions

Engineering Development Solutions (EDS) turn problems into solutions and along the way develop people through collaboration. EDS are based at the Engineering Centre of Excellence in Cleator Moor, which provides Sellafield Ltd and the wider NDA estate the opportunity to test solutions off-site, engage with supply chain companies to find solutions to industry challenges, and implement proven innovations back on site.

EDS has already achieved success across a wide range of projects, saving time, money, improving safety and upskilling members of our team. The Engineering Centre of Excellence is intended to unlock the potential of our workforce as we have brilliant people, and this centre gives them an opportunity to show how good they are.

EDS work across a range of areas to:

- Deliver engineering solutions.
- Drive supply chain collaboration.
- Demonstrate savings and value for money.
- Develop and grow existing and future capability.
- Enable delivery.

Improving intrusive maintenance

On the Highly Active Liquor Evaporation and Storage (HALES) facility there are numerous bulges (shielded out of cell compartments) that house process equipment which require regular maintenance. The current method for maintaining equipment inside bulges requires a large PVC enclosure to be constructed and checked before use. The whole process of carrying out the maintenance is very time and resource intensive, taking up to two weeks.

A known issue of carrying out maintenance inside these bulges is that containment must be broken to replace perishable equipment, which could lead to contamination spread. A new method of conducting the maintenance was investigated to improve safety and the ease of maintenance.

A team gathered at the Engineering Centre of Excellence at Cleator Moor to take the problem through to a proof-of-concept solution in six weeks. Each team member had different areas of expertise allowing for diversity of thought and collaborative decision making. This sprint project focused on reducing the risk of contamination spread and improving the ease of maintenance on bulges across the plant.

The team followed a project flow process that involved creative thinking exercises; discussing the constraints, variables and functions of the solution; generating concepts; and producing a weighted criterion that was used to score each concept. Concepts were presented to the client and stakeholders to gather feedback and shortlist potential solutions to take forward for testing and development.

Four concepts were tested and improved using a purpose-built test rig. Following each test, we noted what worked well and what could be improved. This continuous improvement mindset coupled with in-house manufacturing allowed rapid testing and improvement of our design until we had a fit for purpose solution which met the functional specification.

The successful proof-of-concept solution used a bespoke blister bag, designed with glove ports, posting hatches for tools and a hole at the base of the bag to go over the inlet to the bulge. The blister bag improves safety by preventing the area outside the bulge being contaminated, including personnel as they will no longer be working in the PVC enclosure.

Although the sprint project has finished, the team have continued to work collaboratively to see the solution implemented on plant, which has included further tests and walkdowns to improve the design of the blister bag. Working with local supplier Romar, four improved prototypes are now ready for on-plant trials to confirm the final design.

The blister bag solution will allow for faster task delivery with fewer resources and improved safety over the previous method of maintenance.

Project

EDS sprint project

Benefits

The blister bag solution is estimated to save approximately £12,000 and 280 hours each time the maintenance is carried out. This will allow resource to carry out other important maintenance and significantly reduces the amount of PVC waste.

The improved ease of operation also means that the health physics team will investigate removing the safety requirement for maintainers to wear a PVC suit and respirator, once sufficient confidence has been gained in the blister bag.

This solution has simplified the process for performing intrusive maintenance inside a bulge, and there is the potential to use a blister bag for other applications, such as camera inspections inside bulges.

Current Status

Our bespoke blister bags are being supplied by Romar Innovate Ltd, who has been involved in the iterative design process throughout the project.

Four blister bag prototypes are now on plant and will be trialled at the next available opportunity to confirm the final blister bag design.

Delivery Partners

Romar Innovate Ltd

Contact Details

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1.


2.

1. Bulge on HALES facility

2. Blister bag on test rig

Bags to re-contain hazardous waste

In March 2021, a 210L drum in the Engineered Drum Store showed signs of leaking. While the area was made safe, it was identified that a permanent solution that would not affect the future waste route was not available. To address this, a team was put together to carry out a six-week sprint project with the Engineering Development Solutions team.

Following a root cause analysis, the team went through concept generation and an optioneering phase with all options considered. Four viable concepts were selected, which then underwent detailed research and testing to see if and how they would work. The proposed methods for regaining containment were simple in nature, but containment of waste is a complicated process, so the team spoke with all possible stakeholders throughout to give the concepts a much higher chance of rollout. The four concepts were:

- Open and repack the drum.
- Protect the drum in a purpose-built container.
- Replace the degraded bottom of the drum.
- Contain the drum in a durable bag.

The Fluorinated Ethylene Propylene (FEP) Teflon bag was identified as the best option. This is due to the material's chemical resistance to drum leaks, its tolerance for long-term storage and the clear polymer allowing the drum's condition to be inspected. Implementing the use of these bags will enable a COTS solution for this issue in the future, reducing clean-up costs and contamination, benefitting the business and making the area safer for our workforce.

The clarity of the bag allows the condition of the drum to be inspected, while the simplicity of the bag's construction provides a low cost solution. The future waste route for the drum is also unaffected by the bag, as the drum can be compacted in the bag or the bag removed in the glovebox just before compaction.

Project

EDS sprint project

Benefits

This work provides safe long-term storage for drums with a unique problem. Due to the chemical inert qualities of the FEP, it will provide a containment for drums and not restrict their onward waste route.

The bag also provides a quick solution to a drum which has lost containment, minimising down time as well as freeing up operators from long clean-ups to help the site progress at pace.

Current Status

This innovation is currently in the final stages of implementation on plant. All required testing is complete, and the first bags are ready to be used.

Delivery Partners

Forth Engineering,
Holscot Fluoroplastics Ltd

Contact Details

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1. Teflon bag on test drum

2. Teflon bag on test drum

Concrete spall monitoring

EDS completed a six-week rapid prototyping project to identify a method of monitoring concrete spall at height. Concrete spalling is the breakdown of concrete by natural weathering or chemical reaction and can be caused by:

- Poor quality concrete.
- Poor finishing techniques.
- Corrosion/oxidization of reinforcing rebar (due to water exposure).
- The wear and tear of the freeze-thaw cycle.

Spalling of legacy assets is a concern across the NDA estate; however the current monitoring method of a hammer test cannot be used above two metres without expensive scaffolding or Mobile Elevated Working Platform (MEWP) access.

Design and prototyping

Concept generation and optioneering in the early stages of the project found that ground penetrating radar and thermal imaging were the technologies that best met the specification. Potential deployment methods were also investigated.

Testing and demonstrations

The proposed technologies were taken forward to testing, where their ability to identify voids and rebar in a concrete slab was evaluated.

A number of demonstrations took place at the Engineering Centre of Excellence to identify a suitable deployment method, including Unmanned Aerial Vehicles (UAVs) and wall-climbing Remotely Operated Vehicles (ROVs).

Final recommendations

Two solutions were recommended for further consideration; the first was a wall-climbing ROV with integrated ground penetrating radar, and the second was a thermal imaging sensor deployed on a UAV.

Project
Concrete spall monitoring

Benefits
This work identified a method of monitoring concrete spall at height. In doing so, it helped address a concern across the NDA estate and allowed for spalling to occur without expensive scaffolding or mobile elevated working platforms.

Current Status
The project recommended two solutions for further consideration. Further testing at an off-site location with known concrete spall will take place before deployment across the NDA estate.

Delivery Partners
None

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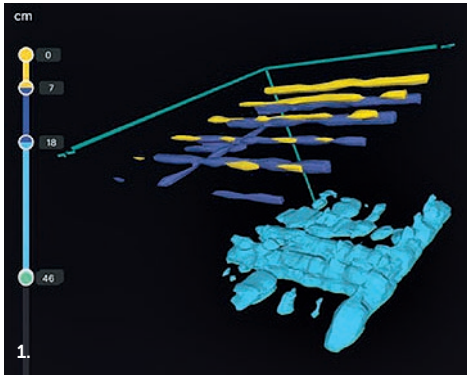

1. Modelling concrete spalling

2. Wall-climbing ROV being assembled

Fiona Lambert

Graduate chemical engineer

Fiona is currently on a five-month secondment in the studies team, conducting a strategic study for broad front decommissioning. Before this, she was working in the SIXEP system engineering team, using acoustic monitoring to better understand the condition of our assets.

Fiona attended the University of Sheffield and achieved a First Class MEng in Chemical Engineering. She completed an industrial placement at Sellafield Ltd supporting the transition from active commissioning to operations. During her final year at university, she investigated the use of novel silica based resins loaded with metal ions to remove radioiodine from aqueous nuclear waste streams, and received first prize for her research project poster presentation.

Since re-joining Sellafield Ltd, she has worked in the plant facing design office and site wide task delivery team, conducting walkdowns to understand the requirements and designing solutions for the plants.

Fiona completed an innovation sprint project at the Engineering Centre of Excellence, improving intrusive maintenance in bulges across higher activity plants, and was a finalist for a Wave Award.

Fiona is a strong advocate for Women in Engineering and uses her positions as STEM ambassador and member of the graduate council to talk about her career pathway, offer advice and represent her peers. Additionally, she has volunteered to become a Manifesto Changemaker and is passionate about ensuring staff understand how to use it day-to-day.

"I am proud to work at Sellafield Ltd, working on a wide range of activities that support our purpose, creating a clean and safe environment for future generations."

Analytical Services

Analytical Services is one of the longest serving facilities on the Sellafield site. The department provides central analytical support to our plants, including for:

- Nuclear material accountancy.
- Plant and safety control.
- Product quality and characterisation.
- Effluent and environmental monitoring.
- Decommissioning.

Our analysis capability includes activity, elemental, isotopic, speciation and physical properties. The department is fundamental to the Sellafield site as it can receive and analyse samples from all over site with few limitations on activity levels or matrix.

The 200 staff ensure the continued operation of site with a shift team providing 24/7 analysis every day of the year. Analytical Services is accredited to the International Standard ISO/IEC 17025:2017 as a testing laboratory.

Across more than 50 functional laboratories, the teams perform 300,000 analyses per year using more than 120 Quality Assured Analytical Methods (QAAMs), making analytical services one of the largest and most diverse nuclear analytical facilities in the world.

Ensuring our analytical services capability for the future

The analytical services facility includes approximately 70 laboratories. It has provided on-site chemical analysis of highly radioactive and toxic materials for over 70 years, supporting reprocessing operations, waste processing and hazard/risk reduction activities across the site.

This facility is essential to support our mission through to 2070, although analytical requirements will change as reprocessing ends and our focus moves towards decommissioning, remediation and waste retrieval. However, due to the age and condition of the building, a replacement facility is required.

Therefore, teams have been formed to support the delivery of the Replacement Analytical Project (RAP), which is currently in the design phase. This project is intended to transition our analytical services into the NNL Central Laboratory and wider supply chain to ensure our analytical capability throughout the lifetime of the business.

Analytical services has consistently provided a central analytical support to Sellafield site, including nuclear material accountancy, plant and safety control, product safety and characterisation, effluent and environmental monitoring and decommissioning. Much of the original infrastructure is still in place despite not being originally designed as a nuclear laboratory.

Analytical services is evolving with the changing business and a strategic decision has been made to move analysis into the supply chain. The degrading condition of the existing facility and changing analysis requirements require a new facility. The expectation is that the current analytical services laboratory will continue to operate until ~2030:

- Highly active and medium active samples from ~2028 onwards.
- Special Nuclear Material (SNM) samples from ~2030 onwards.
- Low active and very low active samples will be analysed in the broader supply chain – subject to competitive tender.

Currently, work is being carried out to determine customer demand and implications on capability with strategic and tactical decisions made through studies.

Project

Analytical services' transition to the Replacement Analytical Project (RAP)

Benefits

The current analytical facilities are degrading, and new laboratories will support Sellafield's essential analysis requirements through to 2070.

Current Status

Ongoing. The current estimated transition date is 2030.

Delivery Partners

NNL

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1. Existing laboratory building

2. Example laboratory

3. NNL Central Laboratory building

Developing new methods to replace solvent extraction

Sellafield Product and Residue Store Retreatment Plant (SRP) has committed to repackaging legacy nuclear product to ensure safe storage for 100 years, which is aligned with the UK's decommissioning programme. The product is stored in steel cans which serve as one of the multilevel barriers that prevent radioactive material being released into the environment.

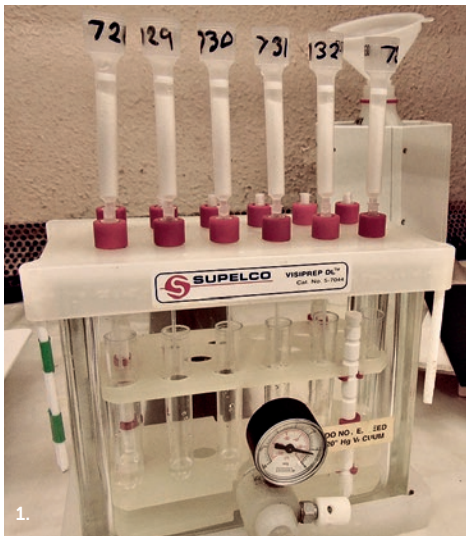
The levels of atmospheric corrosion on the storage cans must be established prior to long-term storage – elements indicative of can corrosion are iron, nickel, chromium and aluminium (Fe/Ni/Cr/Al). Analytical services is required to quantify the Fe/Ni/Cr/Al concentrations, as well as other trace elements, within the can contents using an optical emission spectrometer.

The corrosion indicators and elemental composition is determined by dissolving and analysing a sample of the can contents. However, high levels of actinides, such as plutonium and uranium, in the samples interfere with the peaks of interest on the spectrometer. Hence, these elements must be removed prior to analysis. In our reprocessing plants, this has always been achieved using solvent extraction. For over 20 years, solvent extraction has been performed in analytical services laboratories, but handling solvents in gloveboxes is messy, poses fire risks, and has the potential to damage glovebox gloves and expose operators to the radioactive contamination within. The contaminated solvents produced by this method also do not have a future disposal route.

The aim of this work was to investigate alternative methods of sample preparation for trace elemental analysis on plutonium (Pu) bearing matrices. It was determined, based on a literature review, that the use of solid phase extraction (using UTEVA® Resin by Eichrom Technologies Inc) was the Best Available Technique (BAT) because it resembles the chemistry taking place during solvent extraction but eliminates the use of solvent. Using existing analytical methodologies, proof-of-concept experiments were designed and carried out on multiple samples, blanks and standards.

Standards prepared using UTEVA® Resin showed similar levels of recovery to those prepared using solvent extraction for 32 different elements. It was shown that 99.96% of Pu content was removed by the resin, and samples spiked with reference materials also showed satisfactory recoveries (i.e. trace elements were not retained by the resin alongside Pu). The use of UTEVA® Resin had superior environmental factors to solvent extraction techniques which demonstrated green chemistry benefits.

The new method will be validated to enable UK Accreditation Service (UKAS) accreditation to ISO/IEC 17025 before SRP commissioning begins. Further work is also planned to determine the levels of uranium and americium extraction by the resin to widen its applicability in analytical services.



1.


2.

Project

Improving preparation techniques for trace elemental analysis on plutonium samples

Benefits

Reduced waste and reduced dose to operators by eliminating the use of solvents in the preparation of samples.

Current Status

Proof of concept complete, method validation and future opportunities initiated.

Delivery Partners

University of Cumbria

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1. UTEVA® Resin column rig

2. Glovebox for sample preparation using UTEVA® Resin

Disposal of legacy aqueous waste bottles

Analytical services is burdened with a legacy of aqueous waste bottles generated during routine and R&D operations. These bottles require characterising to enable assessments to be carried out to enable their disposal using a suitable waste stream.

A suitable waste route for our high alpha activity aqueous waste bottles is the Enhanced Actinide Removal Plant (EARP). However, the EARP ultrafiltration bed is susceptible to citrate-bearing waste due to complex formation, resulting in deterioration of filtration performance.

One set of the waste bottles was generated from a routine historical operation that used a sodium citrate reagent. An analytical method to determine citrate content is therefore required to quantify the citrate content for each waste bottle before the stream can be considered for disposal to EARP.

Ion chromatography was selected as the most suitable analytical technique for the project.

A suitable ion chromatography column was purchased and a bespoke analytical method was developed to separate all of the anions present in the aqueous mixture and resolve the citrate peak.

Analytical standards were prepared and the method was calibrated, and a full method validation carried out.

Analysis of samples from the waste bottles were carried out and the data collated and submitted to the Low Active Effluent Management Group (LAEMG). The data, combined with the higher EARP citrate limits (page 20), will be used to assess which bottles can be discharged through the EARP and which bottles will need pre-treatment to destroy the citrate before approval for discharge.

The method can then be used to assess the effects of any treatment on the citrate concentration.

Project

Analytical services legacy waste bottles disposal programme

Benefits

The project enables some of the legacy aqueous waste bottles to be potentially discharged through the EARP within the permitted citrate budget and thus protecting the ultrafiltration process.

Bottles with high citrate concentrations that require treatment, can be identified and the efficacy of the treatment monitored.

Current Status

Analysis of the whole population of citrate-containing bottles is complete.

Delivery Partners

None

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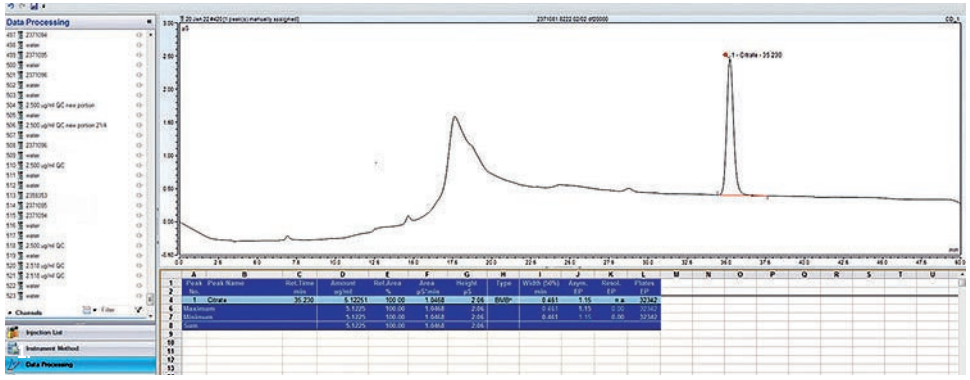

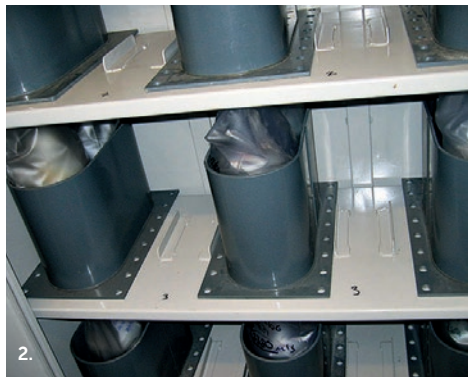

1. Chromatogram with citrate peak

2. Waste bottle store

Katie Bell

Technical specialist

After studying combined arts (theology and philosophy) at Durham University, Katie became a trainee microbiologist before joining Sellafield Ltd in 2005 as a junior analyst in the analytical services mass spectrometry section and has never looked back.

Katie gained her HND in applied chemistry while working at Sellafield Ltd on a day release scheme and has continued to develop her expertise and knowledge of mass spectrometry measurement techniques. She is now an RSC Chartered Chemist, working on the development of new methods and instrumentation within analytical services.

Her role involves understanding future analysis requirements to support the instrument specifications for the RAP, defining strategies for the analysis of future samples expected from SRP, as well as providing support to the maintenance, breakdowns and fault-finding of instruments.

Katie has recently been looking at new and alternative sample preparation and analysis techniques to develop more efficient techniques that produce less waste. Going forwards she will be investigating potential upgrades to current instrumentation to increase its life-expectancy, together with new methods to expand the type of samples that can be analysed in the future.

Katie is a member of the UK nuclear mass spectrometry users group and was awarded the RSC Industry Technician of the Year Award in 2020.

"I am driven by a desire for efficiency and high standards, and an intense dislike of waste in any form."

Ashley Hill

Organics laboratory analyst – plant control

Ashley has been on secondment from NNL for two years and joined Sellafield Ltd at the beginning of 2022. He is one of the most experienced members of his laboratory and so oversees lots of training for new team members.

Ashley has an MChem in Chemistry from the University of Manchester and is an associate member of the Royal Society of Chemistry. He is currently applying to become a member and aiming to gain a chartership qualification.

In his role, he undertakes instrumental analysis on samples from around the Sellafield site, ensuring day to day operations are carried out within set parameters and that regulatory requirements are met. A number of instruments are approaching the end of their lifecycles, so as part of Ashley's role he also carries out the maintenance of old machines and has assisted in the installation and validation of new methods and machines.

Ashley has been preparing for the next phase of our future, including determining the changing analytical needs of the site and ensuring that we have the necessary capabilities. As the Sellafield site moves into decommissioning, the work will become less routine as routine samples may produce results that are outside the expected range and require further investigation.

In order to increase the accuracy of analysis, Ashley devised amendments to greater match the calibration standards of the setup to the samples. He is also creating a Fourier transform infrared library of chemicals on site that could be used to help identify any future unknown samples.

"I love analytical science and analysing samples, especially the problem-solving aspect and challenge that comes with non-routine work."

Appendix

Supply chain companies and organisations

Acoustic Sensor Networks	Galson Sciences Ltd.	RED Engineering
Ada Mode	Graham Engineering Ltd.	Resolute Energy Solutions Ltd.
Anamad Ltd.	Holscot Fluoroplastics Ltd.	Romar Innovate Ltd.
Atkins	Hybrid Instruments	Taylor Kightley Engineering Ltd.
Barrnon	Innovate UK	The University of Manchester
Boston Dynamics	Integrated Decommissioning Solutions	Thornton Tomasetti
Cavendish Nuclear Ltd.	IS-Instruments Ltd.	Trent University (Canada)
Clifton Photonics Ltd.	Lasermet Ltd.	UKAEA RACE
Createc	Los Alamos National Laboratory	UKRI
Cyan Tec Systems Ltd.	Loughborough University	University of Birmingham Enterprise Ltd.
Dounreay Site Restoration Ltd.	Magnox Ltd.	University of Bristol
Fauske & Associates (USA)'	National Nuclear Laboratory	University of Leeds
FIRMA Engineering Ltd.	National Physical Laboratory	University of Liverpool
FIS360 Ltd.	Northumbria University	University of Oxford
Forth Engineering	Nuclear Decommissioning Authority	University of Sheffield
Fraunhofer Centre for Applied Photonics	Oceaneering International Services Ltd.	VTT Technical Research Centre of Finland Ltd

Abbreviations and acronyms

AGR	Advanced Gas-cooled Reactor
AI	Artificial Intelligence
BAT	Best Available Technology or Technique
BEP	Box Encapsulation Plant
BNFL	British Nuclear Fuels Ltd.
CDT	Centre for Doctoral Training
CFD	Computational Fluid Dynamics
CHILW	Contact Handleable Intermediate Level Waste
CINDe	Centre for Innovative Nuclear Decommissioning
CM&I	Condition Monitoring and Inspection
CoE	Centre-of-Expertise
COTS	Commercial Off-The-Shelf
DSRL	Dounreay Site Restoration Ltd
EARP	Enhanced Actinides Removal Plant
EDS	Engineering Development Solutions
FIND	Future Innovation in Non-Destructive evaluation
FGMSP	First Generation Magnox Storage Pond
GDF	Geological Disposal Facility
GREEN	Growing skills for Reliable Economic Energy from Nuclear
HALES	Highly Active Liquor Evaporation and Storage
HEPA	High Efficiency Particle Air
IIND	Integrated Innovation in Nuclear Decommissioning
ILW	Intermediate Level Waste
IRT	Integrated Research Team
LLW	Low Level Waste
MEWP	Mobile Elevated Working Platform
MSSS	Magnox Swarf Storage Silo
NDA	Nuclear Decommissioning Authority
NEF	Nuclear Energy Futures
NNL	National Nuclear Laboratory
NPL	National Physical Laboratory
ONR	Office for Nuclear Regulation
POCO	Post Operational Clean Out
PVC	Polyvinyl Chloride
RACE	Remote Applications in Challenging Environments
RAI	Robotics and Artificial Intelligence
RAICo	RAI Collaboration
R&D	Research and Development
ROV	Remotely Operated Vehicle
RrOBO	Risk Reduction of Glovebox Operations
RSC	Royal Society of Chemistry
SFM	Spent Fuel Management
SIXEP	Site Ion Exchange Effluent Plant
SME	Small and Medium-sized Enterprise
SNM	Special Nuclear Material
SPARK	Sellafield Plutonium Application for the Retention of Knowledge
SQEP	Suitably Qualified and Experienced Personnel
SRP	Sellafield Product and Residue Store Retreatment Plant
STEM	Science, Technology, Engineering and Mathematics
Thorp	Thermal Oxide Reprocessing Plant
TR&S	Thorp Receipt and Storage
TRANSCEND	Transformative Science and Engineering for Nuclear Decommissioning
TRL	Technology Readiness Level
UAV	Unmanned Aerial Vehicle
UKAEA	UK Atomic Energy Authority
US DoE	US Department of Energy
VR	Virtual Reality
WAGR	Windscale's Advanced Gas-cooled Reactor

Sellafield Ltd

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