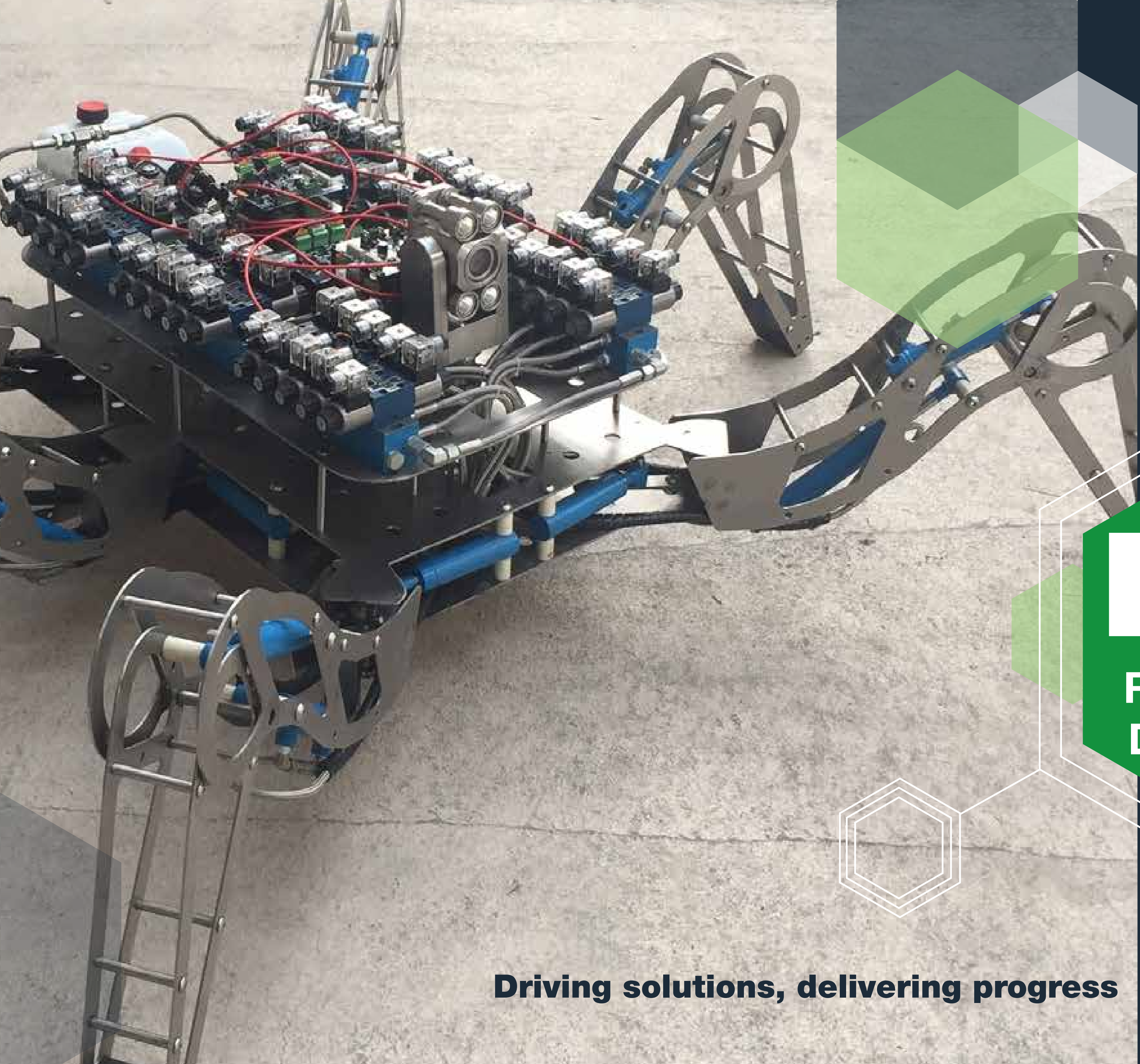


NDA
Nuclear Decommissioning Authority

R&D
Research and Development

Driving solutions, delivering progress

November 2016

Research and Development is essential to nuclear decommissioning

The Nuclear Decommissioning Authority (NDA) was created by the government in 2005 and is responsible for cleaning up the legacy from the UK's pioneering post-war nuclear programme.

The historic programme created a diverse technical and engineering challenge for decommissioning: prototype reactors, fuel-manufacturing plants, research centres, reprocessing plants and 11 power stations. Many of the facilities are associated with the defence sector as well as electricity generation, and are unique. Covering 17 sites, the NDA's mission includes taking all the structures apart, dealing with the waste and ultimately restoring sites. Progress depends on understanding the issues clearly, finding solutions and ensuring an acceptable cost for taxpayers.

One of our responsibilities is to ensure the right amount of Research & Development (R&D) is carried out to deliver the full decommissioning programme. Many 'never-done-before' projects require significant innovation and novel engineering approaches.

The aim is to solve the challenging technical problems more effectively, more efficiently and, where possible, for less cost to taxpayers.

R&D is required for ensuring the fundamental technical areas relevant to the challenges are understood, encouraging the development of innovative ideas and enabling the demonstration of new technologies, followed by successful on-site implementation.

To maximise the benefits of R&D and avoid duplication, the NDA promotes the estate-wide sharing of good practice and, where appropriate, the adoption of innovative ideas across multiple sites. The NDA also works with the wider nuclear sector and beyond, both in the UK and internationally. This enables us to secure best value for money from R&D investments and learn from experiences elsewhere.

This brochure highlights work carried out recently both by:

- The NDA and our suppliers on estate-wide issues
- The site operators (the Site Licence Companies) and their suppliers

“There are many unique technical challenges on our sites and we are proud of the progress achieved from our R&D investments, both at site level and through broader cross-estate projects.”

Prof. Melanie Brownridge,
NDA Head of Technology

Front cover: Latro, the robotic spider developed by Forth Engineering *(see page 13)*

Quick facts

We fund R&D through two main routes:

- **Directly** through projects commissioned by the NDA, to support strategic R&D and innovation that focuses more on estate-wide issues
- **Via our Site Licence Companies** (SLCs) and subsidiaries on specific site projects, where the spend is part of their main annual budget

NDA's R&D portfolio is delivered by more than **70 supply chain organisations** in the UK and beyond

The majority of work is targeted at Sellafield's technical challenges - around **80% of total R&D spending**

The NDA is a significant funder of nuclear R&D in the UK

We are supporting **58 PhD projects**

More than **£85 million** a year is spent on R&D across the whole estate

£6 million of NDA funding invested in decommissioning-related projects with Innovate UK since 2012

24 UK universities host NDA-sponsored students

Overall R&D spending has resulted in:

- Innovative remote technologies, including laser cutting, robotics and improved radiation detection, which help to create safer working environments
- Sustained funding for the supply chain through our collaborations with other public organisations
- An ongoing programme of academic research into nuclear decommissioning providing depth and breadth in expertise
- Postgraduate-level training and development to support a pipeline of potential nuclear specialists

Addressing technical challenges at our sites

SLC role

The majority of R&D work is carried out by our SLCs and their supply chain. SLCs follow a rigorous process to identify research needs and opportunities, estimate associated costs and measure progress. This provides the NDA with visibility across the estate and confidence that the plans can be achieved.

SLCs are required to produce a comprehensive analysis of R&D plans that:

- Link R&D needs to a site's overall lifetime plan
- Outline any links with other on-site work
- Estimate timeframes and costs
- Describe technical risks, their management and possible opportunities
- Monitor progress and how projects are governed
- Use a consistent system for assessing the maturity of a technology, known as Technology Readiness Levels (TRLs)

This suite of documents is collectively called the Technical Baseline and underpinning R&D (TBuRD).

Currently, the bulk of the site-related R&D work is carried out at Sellafield, focused on decommissioning the highest risk and hazard facilities.

Sellafield, as the most complex site, offers the greatest potential for cost reductions through R&D.

However, other sites have technical challenges and require specific solutions to support their decommissioning.

Photograph: A radiological survey of Dounreay's old liquid effluent discharge system will be carried out by a remotely operated vehicle to deploy radiation detectors inside the pipework. Understanding the condition of pipework will enable the best options to be identified for closure of the complete system

NDA role

The NDA is responsible for:

- Taking an estate-wide view of all site-based projects
- Ensuring that SLCs' overall programmes are technically robust
- Identifying opportunities for sharing or applying technologies across multiple sites

The NDA funds a strategic R&D portfolio directly to:

- Help shape and underpin our UK-wide strategy
- Deliver innovation across multiple sites
- Develop vital technical expertise

Our approach is flexible

- We encourage collaboration
- We are willing to explore the potential of conceptual ideas
- We fund academic studies at many universities to support diverse technical skills (e.g. distinctiveconsortium.org)
- We aim to support technologies on the journey from early concept to market readiness
- We work with other public and private-sector organisations to increase the funding that can be made available
- We seek to avoid duplication of work
- We support sharing between our sites and beyond

Direct Research Portfolio (DRP)

This portfolio of work is funded directly by the NDA to address issues that could affect multiple sites or SLCs.

Projects are delivered through framework contracts awarded by competitive tender to a wide range of organisations.

The contracts, of up to four years duration, are awarded to collaborative consortia and focus on four themes:

- University-based work
- Managing waste
- Site decommissioning and remediation
- Managing spent fuel and nuclear materials

The latest contracts, awarded earlier in 2016, involve 10 consortia comprising around 70 organisations (including 20 SMEs), global corporations and UK universities. They will share in contracts worth up to £12 million in total (See page 19).

Securing value for money

Collaboration

We seek to collaborate with other UK funders of R&D to maximise available funding and secure real value. We are also exploring potential collaboration with international organisations. The collaborative approach has the potential to double the amount of available funding.

Our funding partners include:

- The Department of Business, Energy and Industrial Strategy (BEIS), formally known as the Department of Energy and Climate Change (DECC)
- Innovate UK, part of BEIS
- Research Councils UK (RCUK) and specifically, Engineering and Physical Sciences Research Council (EPSRC)
- The government's cross-functional Department for International Trade, which supports UK businesses globally
- Universities

It is vital to identify R&D needs and opportunities on a multi-site basis, and to share good practice widely.

Advice and guidance for co-ordination of nuclear decommissioning R&D is provided by the NDA's Research Board. Independently chaired, its membership comprises senior representatives from UK government, UK industry, NDA, regulators and from overseas.

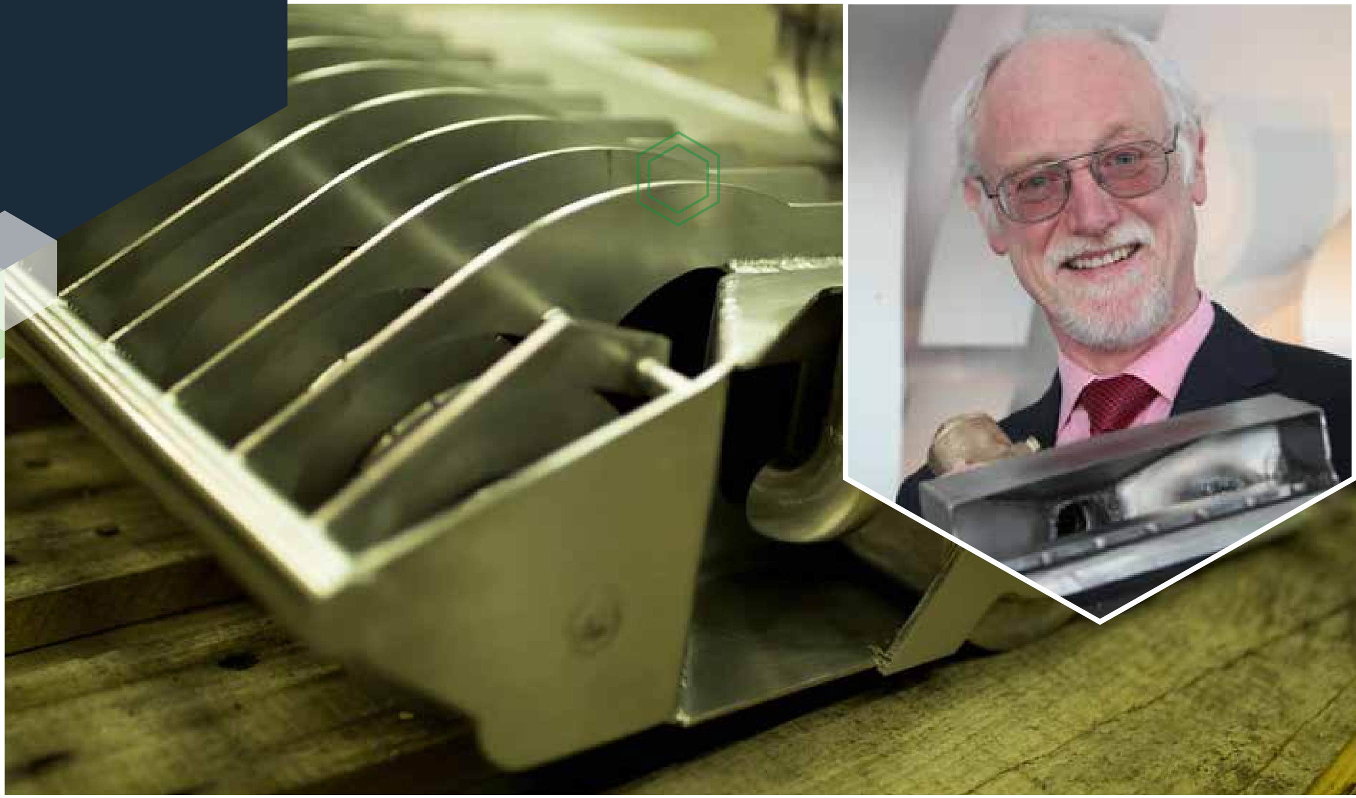
On a working level, the Board is supported by the Nuclear Waste and Decommissioning Research Forum (NWDRF).

The NWDRF promotes collaboration across the NDA estate and the UK, while ensuring innovation is delivered more efficiently, more cost-effectively, more rapidly, and with less duplication.

Its working groups focus on prioritised topics related to waste, decommissioning, characterisation, effluents, land quality and university interactions.

Photograph: Attendees at a meeting of the university-based DISTINCTIVE consortium which brings together academics, researchers and industry, helping to ensure science and innovation is aligned to the decommissioning mission

From dredging scallops to radioactive sludge



Challenge: Removal of sludge from spent fuel ponds

Solution: Remotely operated dredging equipment

Technology: Horizontal and vertical sludge dredge

Benefits: Cost-effective, efficient means to deal with sludge across the estate

Status: Further technological development and on-site trials at Sellafield

Research organisations: Barrnon Ltd (www.barrnon.com), National Nuclear Laboratory (www.nnl.co.uk), Sellafield Ltd and Magnox Ltd

Innovation route: Technology transfer from the fishing industry. With support from Innovus, Barrnon developed the working prototype at the National Nuclear Laboratory (NNL) in Workington. Further funding was received through an Innovate UK call co-supported by NDA.

Fishing equipment used by trawlers to dredge for scallops on the seabed has been re-designed for a new market scooping sludge from spent nuclear fuel ponds.

The technique was developed by a small Cumbrian engineering business in response to an enquiry from Magnox Ltd and has already been successfully deployed in the ponds at Hunterston A.

All the NDA estate's ponds contain radioactive sludge, generated via the corrosion of fuel elements, that has accumulated in the water over the decades and must be removed for treatment.

Using the experience of trawling, the sludge dredging design has undergone extensive modifications to be operated remotely. It is capable of operating horizontally along extensive sections of pond floor and also vertically where space is more restricted or difficult to access. The sludge is effectively sucked into a sealed container, fluidised and then pumped out for treatment.

A study of the prototype has been undertaken at Sellafield while interest has also been shown by the US market and organisations involved in the Fukushima clean-up.

Further developments, meanwhile, are under way to continue development of the technological capabilities and enable further enhancements for a range of additional scenarios across the NDA estate and further afield.

Innovus assists businesses, aiming to bridge the gap between research and marketable technology by offering access to specialist development facilities, funding and technical expertise.

Innovus is a partnership between the National Nuclear Laboratory (NNL) and The University of Manchester.

Photograph: Barrnon's Steve Thompson (inset) and (main picture) the sludge dredging equipment

A cut above the rest

The NDA's estate contains large quantities of contaminated metal vessels and pipework. Sellafield alone has thousands of items that must be cut up for removal before the buildings can be decommissioned. Much of this metal is in hazardous or very difficult to access areas.

Decommissioning often requires the development of bespoke tools for remote deployment or for workers in protective air-fed suits to use hand-held tools. Such approaches can be more hazardous for the operators (radiologically and conventionally), extremely time consuming and hence costly.

Laser cutting is faster and far more efficient than conventional cutting techniques and is a well-established process used in aerospace, automotive and defence industries. It is also safer, cheaper and produces less secondary waste. One approach to laser cutting in a remote environment is LaserSnake2, an accurate snake-arm robot with a long reach arm, carrying a decommissioning-specific lightweight laser cutting head with the capability to cut metal sections up to 100mm thick. The snake-arm robot is highly dextrous and allows the robot to access areas where other robotic technologies would have difficulties. LaserSnake2 can be customised to suit a range of conditions and is now ready for commercial deployment. LaserSnake2 can therefore benefit both remote and historically manual decommissioning schemes.

Sellafield Ltd, as part of its Active Demonstrator programme, has recently completed a cutting demonstration using LaserSnake2 in a radioactive environment in the First Generation Reprocessing Plant. A 5 tonne, double-walled stainless steel vessel, with a 32mm thick inner shell, was entirely and successfully size reduced. This trial has shown LaserSnake2's capability to remotely cut some of the thickest materials on the Sellafield site, and its potential to access challenging radioactive areas. Other NDA sites could benefit from the LaserSnake2 approach.

A high degree of collaboration between project partners and in particular end-users has accelerated the demonstration on site and provided valuable insight in how to introduce innovative technologies from other industries. This deployment is the first of a kind on a UK nuclear site and a significant achievement.

R&D Approach

The development of LaserSnake2 and application of the associated technologies illustrates the routes for encouraging innovation and technology developments:

- Early innovation funding from NDA's R&D Portfolio to demonstrate the effectiveness of lasers in cutting metal and removing contaminated concrete surfaces
- Effective leveraging of funding from government-led initiatives to enable the combination of a cutting head with a snake-arm robot and demonstrate its potential as a decommissioning tool in a non-radioactive environment
- Leveraging of NDA funding from a collaborative innovation competition with Innovate UK and BEIS to develop LaserSnake2, a new, larger, more accurate snake-arm robot, with an improved laser cutting head. This included demonstration in a radioactive environment.
- End-user support to take the LaserSnake2 technology for demonstration at the Sellafield site
- Sellafield Ltd now looking for opportunities to accelerate risk and hazard reduction using LaserSnake2

Website: www.ocrobotics.com/lasersnake2

Photograph: LaserSnake2 is highly manoeuvrable and can access hazardous environments. The team watch an active demonstration at Sellafield via a monitor

Challenge: Accurate cutting and removal of radioactive metal vessels and pipes from hard to access areas

Solution: An innovative snake-arm robot with purpose designed lightweight laser cutting head for laser powers up to 10kW - LaserSnake2

Technology: Remote laser cutting

Benefits: Cheaper, faster and safer than conventional cutting techniques and produces less secondary waste

Status: Ready for commercial deployment and demonstrated in a radioactive environment at Sellafield

Research organisation: OC Robotics (www.ocrobotics.com/lasersnake2), TWI, ULO Optics, Laser Optical Engineering and the National Nuclear Laboratory

Turning up the heat - vitrification for diverse waste types

Challenge: Dealing efficiently and effectively with large quantities of mixed, diverse radioactive waste

Solution: Thermal treatment technology already used overseas for asbestos and soils treatment to produce stable, passively safe material that can be disposed of

Technology: GeoMelt®

Benefits: Volume reduction, passivation and capacity to treat mixed contaminated waste cost-effectively

Status: Further analysis of any remaining activity and offgases, testing with higher levels of activity and establishing acceptability for disposal

Research organisation: Kurion (www.kurionveolia.com), National Nuclear Laboratory (www.nnl.co.uk) and Sellafield Ltd

Innovation route: Existing technology adapted with additional support through the NDA's Direct Research Portfolio to develop wider application across the nuclear sector

New, more efficient ways of dealing with radioactive waste are an ongoing and important focus for the whole nuclear industry. Recent pilot trials in Cumbria have demonstrated that vitrification using thermal treatment has the potential to be used cost-effectively for mixed waste streams containing medium and lower levels of activity.

The Geomelt® technology was developed in the US to treat a range of problematic wastes. Across our estate such wastes are traditionally encapsulated in cement which increases overall waste volumes significantly. Thermal treatment is currently used only for high level liquid waste, a by-product of reprocessing spent nuclear fuel, which is vitrified at Sellafield.

Trials have been completed on a GeoMelt® demonstration rig to convert mixed lower activity material into a robust, durable glass wasteform. The demonstration rig was initially tested with non-radioactive materials at NNL's Workington facility then moved to the active rig hall in NNL's Central Laboratory on the Sellafield site to tackle radioactive wastes. With a half-tonne capacity, the demonstrator has now successfully treated contaminated soil.

There is potential to develop the technology on an even larger-scale and to treat diverse waste with increasingly higher levels of radioactivity, including organics, metals, sludges and plutonium-contaminated material. Meanwhile, treatment of contaminated asbestos is a further possibility that will be investigated. Once vitrified, the waste is passively safe, corrosion-resistant and is expected to be suitable for final disposal.

Demonstrating this technology on a pilot scale with active material is a key step in making the process viable for the wider NDA estate.

Photograph: The Geomelt® rig has been tested with contaminated soil in NNL's rig hall, (inset) the melting taking place

Building skills for the future - optimising strontium-90 analysis

Large quantities of decommissioning waste are already being safely managed across the estate and more is set to arise as facilities are decommissioned. The radioactive isotope strontium-90 is produced by nuclear fission. Significant amounts are found in radioactive wastes which therefore require appropriate management. Characterisation is an important step in understanding how best to manage these wastes, so the distribution and concentration of strontium-90 require accurate measurement.

Current analytical techniques rely on radiochemical methods which measure the energy released during radioactive decay. However, these procedures are labour-intensive and lengthy, requiring the strontium-90 to be chemically separated before it can be analysed. The potential for a more rapid alternative is being investigated, which enables the selective removal of interfering isotopes so that the strontium-90 can be measured accurately.

Using the latest-generation triple quadrupole inductively coupled plasma mass spectrometry (ICP-QQQ-MS), the research focuses on assessing the effectiveness of the interference removal, and determining the achievable limits of detection for a range of decommissioning waste samples. The objective is to develop a methodology that could significantly reduce the time and labour required for strontium-90 analysis, hence providing more information to plan decommissioning programmes.

Dr Ben Russell is part of the National Physical Laboratory (NPL) team carrying out this NDA-funded research. The former NDA-sponsored PhD student has been able to deploy and build on the skills developed through his PhD to address NDA decommissioning challenges. This highlights the benefits of our longer-term investment in technical skills.

Challenge: Improve speed and accuracy of strontium-90 analysis to provide better information to generate waste management plans

Solution: Investigate capabilities of ICP-QQQ-MS and develop an optimised method

Technology: Latest generation commercial technology - Agilent 8800 ICP-QQQ-MS

Benefits: Reduced analysis time, increased accuracy

Status: Instrument capabilities and sample preparation techniques investigated, radioactive sample trials about to start

Research organisation: Unity2 collaborative team – led by NSG Environmental Ltd (www.nsgltd.com) with National Physical Laboratory (www.npl.co.uk) delivering the project

Innovation route: Competitive tender, via NDA's Direct Research Portfolio

Photograph: NPL's work is supporting faster measurement of strontium-90

Cocktail of light

Challenge: Faster, in situ monitoring of groundwater contamination in and around civil nuclear sites

Solution: Automated liquid scintillation counting techniques and remote fluid handling

Technology: Wilma On-line Water Radiation Monitor

Benefits: Cost-effective, mobile and accurate automated system for monitoring radioactivity levels with reduced manpower requirements

Status: Instrumental capabilities developed and site trial due to take place at Sellafield

Research organisation: LabLogic Systems Ltd (www.lablogic.com)

Innovation route: Technology from pharmaceutical industry adapted by an SME, developed and supported through a Knowledge Transfer Partnership with the University of Sheffield, followed by a feasibility study funded through an Innovate UK call co-supported by NDA

A new system for monitoring levels of contamination in groundwater is set to improve the quality and accuracy of data.

Information on conditions above and below ground is vital in the clean-up of our sites, enabling environmental requirements to be met and identifying any leaks or seepage from facilities. Current practice relies on physically taking samples from boreholes on a periodic basis followed by analysis at a lab which is resource intensive and generally produces results within 4-8 weeks.

Work is under way to assess the potential of liquid scintillation counting technology, which was developed from pharmaceutical research equipment used to detect low levels of radiation in biological samples following radio-labelled drug treatment. The technique uses a fluid ‘cocktail’ which interacts with the radioactive sample to produce measurable photons of light.

Existing principles were used to combine elements of hardware and software, producing a portable, automated system.

Mounted in a mobile enclosure, the equipment can be left in situ over a period of several weeks to collect small samples on a frequent basis, perform the analysis and record and transmit the data to a remotely located base station. This produces more frequent, accurate data on both radioactive and non-radioactive contamination, which allows trends to be identified more easily, while analysis times are faster and costs are reduced.

Photograph: A Wilma module analysing alpha radiation in situ

Nimble steps from Latro the spider

Contaminated radioactive environments that are too hazardous or difficult for workforce access pose a constant challenge for decommissioning.

Additional difficulties arise when remotely operated vehicles (ROVs) with tracks or wheels disturb waste and struggle to deal with rough ground.

One of the newest additions to the toolkit of robotic equipment is a nimble spider (Latro) that can step delicately round obstacles or climb over them to reach where it is needed for characterisation or even decommissioning work. With a wide range of tools including camera equipment, powerful cutters, laser scanner and smart software, Latro can navigate over items using its own internal sensors, relaying back information to the remote operators via live 3D imaging.

Latro can also grab waste or items such as a scaffold pole, cut it up and drop the pieces in a skip. Its hydraulically operated stainless steel legs are strong enough to carry heavy weights.

Further development will enable it to walk under water potentially picking up, size reducing and transferring radioactive material from Sellafield's most hazardous ponds.

Latro was developed by the University of Manchester and the hydraulics specialist Forth Engineering, an SME based in Maryport, Cumbria. Collaboration between academia and industry has brought together complementary skills in electronics and hydraulics, benefitting all parties.

Challenge: Develop equipment able to manoeuvre around hazardous legacy facilities to retrieve and deal with waste or equipment

Solution: Agile remotely operated vehicle with climbing and self-navigating capabilities and potential to carry a range of tools

Technology: Latro robotic spider

Benefits: Latro can retrieve, characterise and cut up materials, minimising worker dose while speeding up decommissioning and cutting costs

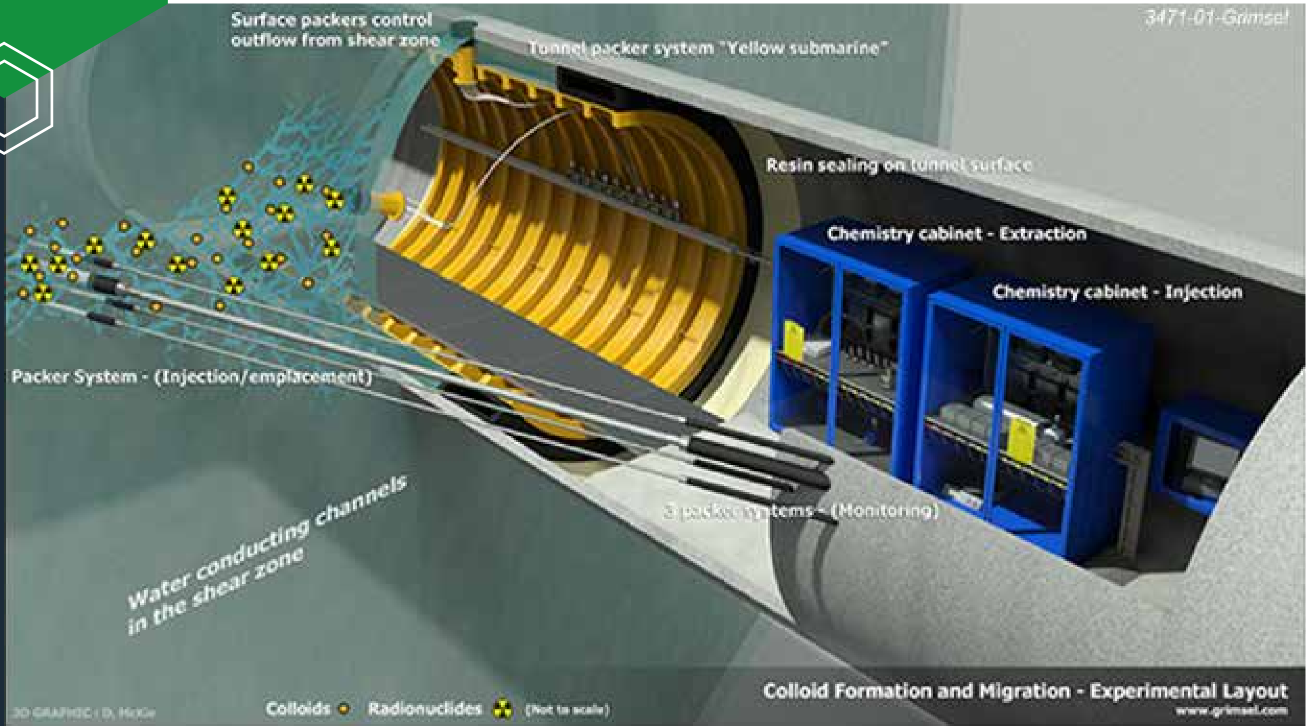
Status: Currently undergoing further development to build a new model with additional dexterity; additional testing in an off-site underwater facility prior to on site application

Research organisations: Forth Engineering (www.forth.uk.com), the University of Manchester (www.manchester.ac.uk) and Sellafield Ltd

Innovation route: Collaboration between an SME and a university funded through an Innovate UK call co-supported by NDA

Photograph: Latro the spider with the University of Manchester's Farshad Arvin

Underground movements in the spotlight



Challenge: Understand long-term processes that may impact on the performance of buffer materials in a potential GDF

Solution: Collaborate on international experiments to measure possible migration route of radionuclide-carrying colloids in groundwater using existing international facilities

Technology: Underground research laboratory, radionuclide tracer sampling

Benefits: Knowledge will enable development and refinement of future barrier systems

Status: Further comparison of data from sampling points with modelling predictions to determine next steps

Research partners: For the current phase BMWI/KIT (Germany), JAEA (Japan), SKB (Sweden), CRIEPI (Japan), KAERI (Korea), POSIVA (Finland), DOE (USA), RWM (UK), NUMO (Japan), NAGRA (Switzerland)

Website: www.grimsel.com

Innovation route: Collaboration with overseas partners to ensure benefit from existing international facilities and programmes

Natural rock formations and multiple engineered barriers will protect containers of high-level radioactive waste in underground repositories for many thousands of years.

RWM, a wholly owned NDA subsidiary, is responsible for delivering a Geological Disposal Facility (GDF) and provision of radioactive waste management solutions for the UK's higher activity radioactive waste.

As part of a collaboration with seven international partners, Radioactive Waste Management (RWM) is carrying out work to understand how the packaged waste will react with the surrounding geology and groundwater over the long-term.

Experiments are being carried out over a number of years at Switzerland's underground laboratory in Grimsel to investigate the ways in which radionuclides could migrate via groundwater through the thick layers of bentonite clay that will be used as a buffer around the containers.

In addition to the underground work, a complementary computational modelling programme is looking at how radionuclide particles could attach to bentonite dissolution products to form colloids and be mobilised by groundwater flow. This will help predict the long-term behaviour and movement of the radionuclides beyond an engineered barrier system.

The underground and computational modelling programmes are combined with lab studies using different materials that will typically be present around a GDF, such as granite. This enables comparisons with controlled underground experiments based on existing boreholes and injected radioisotopes in a wide range of conditions. International collaboration is an effective way to ensure a comprehensive programme is addressing all potential areas of theoretical and experimental work.

Image: Schematic of the experimental layout for the colloid formation and migration studies

Plumbing the depths

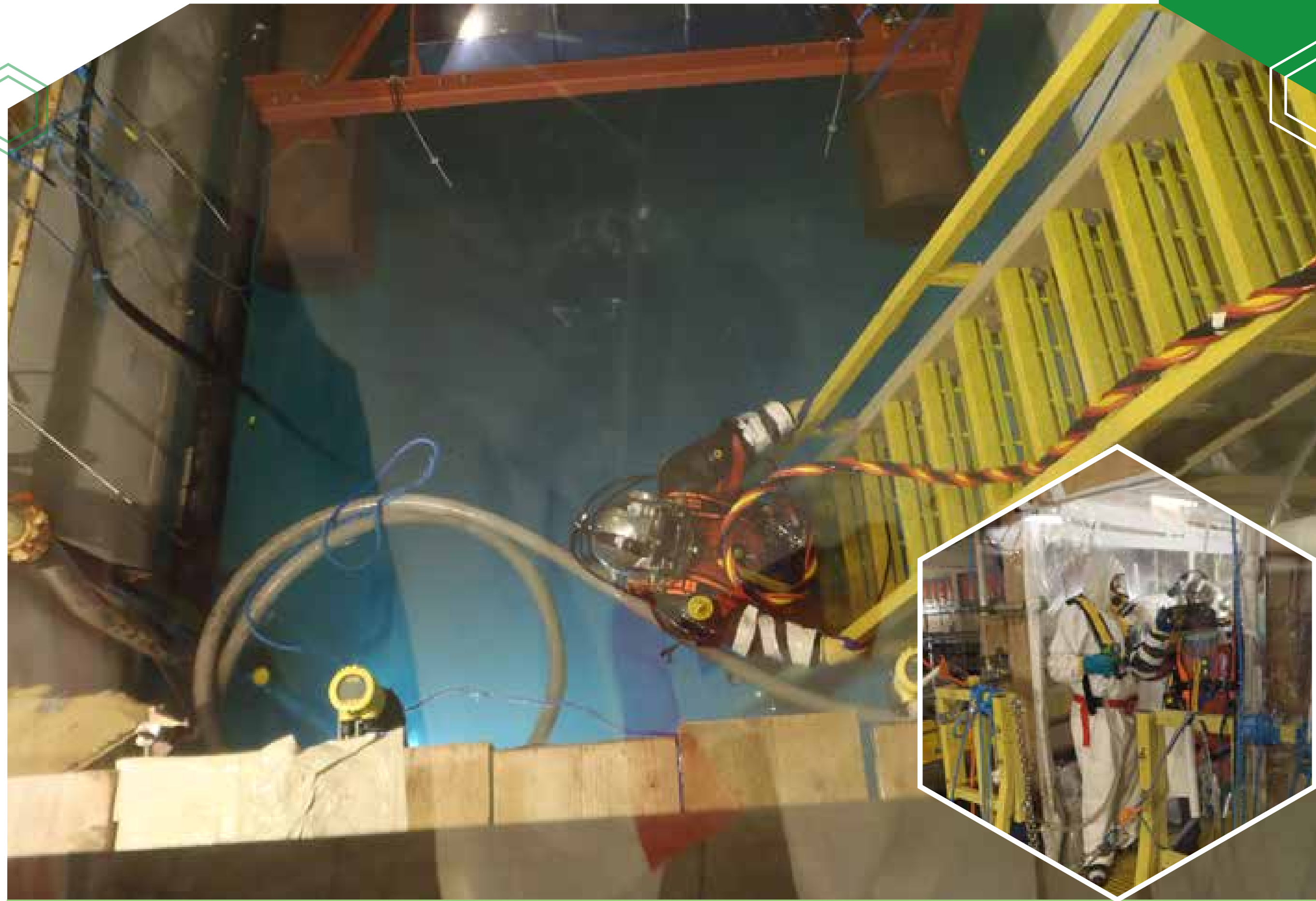
In a trial at Dungeness spent fuel pond, divers have been cutting up items before retrieving the contents from deep below the water's surface.

The radiation shielding provided by water enables divers to work near empty fuel storage skips, sludge and equipment, gaining access to awkward areas.

Fuel skips are now being cut up under water and sludge cleaned up. The conventional approach would be to deploy remotely operated equipment to retrieve the intact skips from the ponds and subsequently cut them up in air, a slow process exposing workers to potentially higher doses.

A range of measures were needed to prepare for the dives, including the installation of a platform with ladders, electrical arrangements, cranes to receive and move retrieved packages, rigorous dose monitoring equipment, as well as agreement from the Office for Nuclear Regulation (ONR). The specialist divers wear full protective gear with breathing apparatus and are carefully guided while under water. Even with the water shielding, high-dose items must still be dealt with from a distance.

The trial has demonstrated that the new approach reduces dosage to workers, while enabling faster, more productive removal of the pond's contents. Diving is used more widely in the US nuclear industry, but the Dungeness project is believed to be the UK's first extensive deployment in a spent fuel pond. After the success of the trial and subject to agreement from regulators, it is planned to use divers at Sizewell A and Oldbury, where the learning from Dungeness can benefit their pond decommissioning.



Challenge: Retrieve pond contents effectively while minimising potential worker dose

Solution: Test process established in the US using underwater divers with view to full deployment

Technology: Divers working in fuel storage ponds

Benefits: Fully protected divers can work under water to retrieve and cut up items, minimising worker dose while speeding up decommissioning and reducing costs

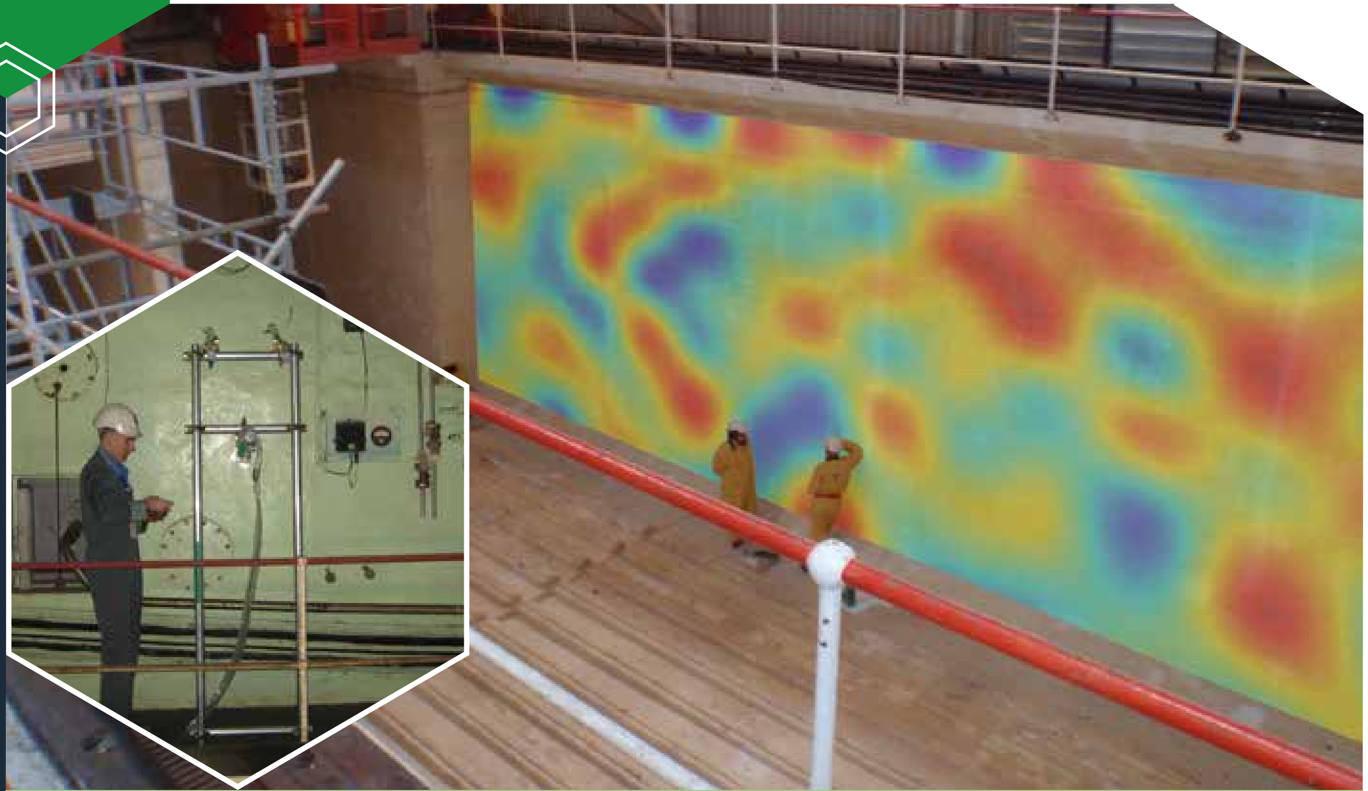
Status: Successful demonstration of process, to be extended to other Magnox ponds

Research organisations: Underwater Construction Corporation (www.uccdive.com) and Magnox Ltd

Innovation route: New approach brought in by US specialist Fluor, one of the parent body organisation partners for Magnox Ltd

Photographs: Divers have been cutting up waste under water in the fuel storage pond

Deep below the concrete surface



Challenge: Rapid, accurate profiling of radioactivity levels within contaminated concrete

Solution: On-plant trials in a radioactive environment to assess improved technologies for measuring contamination in concrete

Technology: Gamma spectroscopy integrated with contamination modelling

Benefits: Faster, cheaper profiling of bulk quantities with less risk for workers and potential for UK-wide deployment. Measuring radioactivity levels also enables improved waste segregation, and therefore optimum treatment and waste routes to be identified

Status: Further on site measurements, selection of most appropriate system(s) and deployment on site

Research organisations: Sellafield Ltd, working with D:EEP partnership of Createc (www.createc.co.uk) and Costain (www.costain.com), Cavendish Nuclear (www.cavendishnuclear.com) and Canberra (www.canberra.com)

Innovation route: Radioactive demonstration on site in collaboration with the supply chain to take innovation through to plant testing

More than one million cubic metres of waste concrete are set to arise as Sellafield's above-ground structures are demolished. The dismantling of other facilities across the estate will also produce large volumes of rubble. Research is therefore vital to understand the best method of measuring how contaminated the concrete is, enabling it to be categorised appropriately and a suitable treatment route identified.

The current method relies on taking multiple core samples and sending the extracted cores off-site for lab tests, a time-consuming process that affects the integrity of the remaining concrete and can take up to nine months. To access the best option, Sellafield Ltd is working with three suppliers to evaluate potential improved technologies which use in situ detectors rather than off-site tests. Each would be faster, cheaper, non-destructive and less likely to risk dose exposure for the workforce.

The detectors can be placed against a wall, floor or other structure and left for a period of time, typically no more than a few minutes, to measure the gamma radioactivity levels. Detailed analysis of the data allows the depth of radioactivity penetration to be measured. Each system has undergone trials in different radioactive environments at Sellafield and the data is being evaluated against core samples to enable a cross comparison with the current method.

This approach, trialling several technologies from the supply chain, has provided the greatest potential for success and fostered a competitive environment. If successful, the technologies could benefit Sellafield and other UK nuclear sites, with potential for deployment using remotely operated vehicles in environments where human access is not possible.

Photograph: Simulation of the radioactivity penetration and (inset) one of the systems undergoing testing

No block to a new approach

Challenge: Demolishing a highly contaminated facility

Solution: Bulk waste disposal

Technology: Diamond-track saw and diamond-wire cutting

Benefits: Faster and cheaper with reduced secondary waste, less spread of contamination and fewer air-fed suit operations

Status: Complete

Research organisation: Dounreay Site Restoration Ltd

Innovation route: Reviewing overall approach to bring together more effective use of technology

The establishment of a Low Level Waste (LLW) disposal facility at Dounreay enabled the adoption of a new approach to demolishing one of the site's highly contaminated facilities, the Post Irradiation Examination (PIE) Cave.

The traditional approach was to reduce the thick concrete walls of the cave into hundreds of small blocks that could be handled by operators wearing air-fed suits.

The Dounreay team decided to use a combination of diamond-track sawing and diamond-wire cutting to reduce the walls into a small number of huge blocks that could be lifted by crane and transported the short distance to the new LLW facility.

This new approach was both cheaper and faster as well as significantly reducing secondary waste, the spread of contamination and the number of entries by operators wearing air-fed suits.

The same approach was even used for the steel doors measuring 45cm thick and 26 tonnes, lifting them by crane through the roof of the facility.

In total around 300 tonnes of concrete and steel, equivalent in weight to 20 double-decker buses, were consigned to the site's LLW facility using this approach.

A change in disposal options created the opportunity to simplify the decommissioning approach.

Photographs: Above, a section of wall ready for lifting and (inset) one of the 26-tonne doors ready for transfer to the LLW facility after being winched out through the roof

Mercury solidification for disposal

Challenge: Treatment of radioactively contaminated mercury, a 'problematic' waste that currently lacks an established waste route

Solution: Adaption of US treatment to stabilise the liquid

Technology: Perma-Fix mobile system

Benefit: Single affordable process that could be deployed across the UK

Status: Further trials and analysis ongoing

Research organisations : LLW Repository Ltd, Amec Foster Wheeler (www.amecfw.com) and Perma-Fix Environmental Services Inc (www.perma-fix.com)

Innovation route: Technology transfer from overseas, delivered via the NDA's Direct Research Portfolio with technical leadership from LLWR

Radioactively contaminated mercury has been produced by the UK's nuclear industry in relatively small quantities, but, as a toxic liquid waste, is difficult and expensive to deal with.

The hazardous liquid is stored in various locations, with the UK's largest inventory at Dounreay, where the site's experimental research activities left a legacy of several tonnes in storage vessels.

Sellafield, Magnox and other non-NDA organisations have smaller quantities making it an issue relevant across the industry. In one of the first attempts to identify a cost-effective, cross-industry solution for the UK, Low Level Waste Repository Ltd (LLWR) in Cumbria, is leading a project funded through the NDA's Direct Research Portfolio to solidify the mercury using the Perma-Fix chemical treatment process.

Deployed in the US for more than 10 years, mostly with non-radioactive material, the Perma-Fix technology stabilises the mercury through a carefully controlled reaction with sulphur.

Work is now under way to identify the best process for applying the technology. A mercury simulant will be treated, the resulting solids analysed and subject to leach testing. This phase of the work will be carried out by Amec Foster Wheeler. If successful, the material could be disposed of at the LLWR.

Further tests will be carried out on solidified mercury that has been encapsulated in concrete, replicating the standard process for waste disposal at LLWR. The testing phase will also provide information to establish whether the material meets the disposal criteria for Dounreay Site Restoration Ltd (DSRL) and RWM.

Photograph: Leach testing trials of mercury samples solidified using the Perma-Fix process

Contractors currently supporting the NDA's Direct Research Portfolio

This table highlights the diversity of supply chain organisations bringing excellence in innovation to our R&D programme

Contractors	Consortium	R&D Objectives
University Interactions		
National Nuclear Laboratory	Supported by Frazer-Nash Consulting	To ensure the right level of academic technical capability is available.
Integrated Waste Management and Site Decommissioning and Remediation		
Amec Foster Wheeler Ltd	Brenk Systemplanung and Jülich Research Centre, Andra, Cogentus Consulting, DAS Ltd, Imperial College London, Longenecker & Associates, MMI Engineering, NuVision, OC Robotics, Fortum, University of Birmingham, University of Bristol, University of Cambridge, University of Manchester.	**Integrated Waste Management** **Higher Activity Wastes (HAW)** • Development and analysis of options for HAW management • Development of innovative technologies • Sponsoring R&D that enables the NDA to respond strategically to government policy and oversee SLCs' HAW work **Lower Level Wastes, non-radioactive and hazardous waste** • Sponsoring R&D that enables the NDA to respond strategically to government policy and oversee SLCs' work on these wastes **Site Decommissioning and Remediation** • Technical underpinning for the NDA's Strategy on decommissioning, land quality and site end states
Arcadis Consulting (UK) Ltd	AdvanSci, Applied Photonics (APL), Areva RMC, Aurora, ESI, MDecon, Pöyry, ProNu-Dec, Tradebe Inutec, TWI, University of Liverpool, Dalton Nuclear Institute, University of Surrey.	
Arup	Costain, Pöyry, Studsvik, James Fisher Nuclear Ltd, SN3, AdvanSci, MCM, Bilfinger GVA, Pinsent Masons, CL:AIRE, r3 Environmental Technology, Dalton Nuclear Institute.	
Eden NE Ltd	Cavendish Nuclear, DBE TECHNOLOGY GmbH, Golder Associates Limited, Tradebe Inutec, Project Time and Cost International Limited.	
Galson Sciences Ltd	National Nuclear Laboratory, Frazer-Nash Consulting, Advansci, Amphos 21, Cogentus Consulting, Integrated Decision Management, Jacobs, Kurion, Rodgers Leask, VTT, University of Bristol, Lancaster University, University of Leeds, University of Manchester, University of Sheffield.	
NSG Environmental Ltd	AECOM, ARC, Oxford Technologies, NPL, ESG, Quintessa, React Engineering, KDC, Tradebe Inutec, Synergy Health, Nuclear AMRC, Loughborough University, University of Manchester, University of Surrey.	
Spent Fuel and Nuclear Materials		
Amec Foster Wheeler Ltd	Andra, Brenk Systemplanung and Jülich Research Centre, Imperial College, DAS Ltd, Fortum, MMI Engineering, NPL, NRG, OC Robotics, Studsvik, University of Birmingham, University of Manchester, University of Bristol, University of Cambridge, Loughborough University.	• Sponsoring R&D that enables the NDA to set and monitor SLC delivery of our Strategy on Magnox spent fuel, oxide spent fuel, exotic fuels and uranics • Ensuring skills in spent fuel management and plutonium handling are maintained over the longer term • To support NDA development of options for managing the UK's uranics inventory and stockpile of separated plutonium • Sponsoring R&D that enables the NDA to respond to government policy and oversee SLC activities on management of uranics and plutonium
Areva NC	NSG Consultancy, MDecon, Quintessa, University of Liverpool, University of Sheffield.	
National Nuclear Laboratory	Frazer-Nash Consulting, Galson Sciences Ltd, ALD France, Aquila Nuclear Engineering, DBD, DAS, IDM, Jacobs, Kurion, Rodgers-Leask, University of Bristol, Lancaster University, University of Leeds, University of Manchester, University of Sheffield, Imperial College.	

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...protecting the future.

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If you want to find out more, please visit our website www.nda.gov.uk or email: research@nda.gov.uk

Useful documents from NDA's website

- EGPR04 Technology Research Investment Process
- Research and Development 5 Year Plan 2014 to 2019
- NDA Research Board Terms of Reference
- Nuclear Waste and Decommissioning Research Forum Terms of Reference
- EGG10 Technical Baseline and Underpinning Research and Development Requirements
- RWM Science and Technology Plan

Further information from SLC websites

- www.sellafieldsites.com
- www.magnoxsites.com
- www.llwrsite.com
- www.dounreay.com

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