



NDA

Nuclear  
Decommissioning  
Authority

**R&D**

Research and  
Development

Driving solutions, delivering progress

November 2014

# Research and Development

is essential to nuclear decommissioning

We are responsible for ensuring the UK's most complex decommissioning challenges are resolved. Our mission includes taking facilities apart, dealing with the waste and ultimately restoring the sites. Progress depends on developing a clear understanding of the issues, finding the right solutions and ensuring the cost to taxpayers is acceptable.

Research and Development (R&D) plays a critical role in solving the wide range of complex, often unique challenges that have accumulated over the decades and now need to be addressed.

Our aim is to solve these problems more effectively, more efficiently and, where possible, for less cost.

We channel R&D funds through two main routes: as a portion of the main budget allocated to our sites who seek support for specific projects; and directly, through work we commission.

## R&D to meet on-site challenges

The four private-sector companies that operate our 17 sites, the Site Licence Companies (SLCs), target R&D spending at individual site-level issues, using part of the overall annual budget agreed by the NDA and based on detailed annual plans. We are responsible for overseeing these projects from a strategic perspective and ensuring proposals are technically robust, as well as identifying opportunities for sharing or applying technologies across multiple sites. This work, which is carried out by the SLCs and their suppliers, accounts for the bulk of our R&D spending.

**“ We are very proud of the progress that has been achieved from our R&D investments. Our aim is to leverage our funding where possible, share progress and encourage further collaboration to address the unique challenges on our sites. ”**

*Prof Melanie Brownridge, NDA Head of Technology*

## R&D to support long-term solution for radioactive waste

Our subsidiary Radioactive Waste Management Limited (RWM) is responsible for developing a permanent repository for the UK's higher-level radioactive waste and carries out R&D to support its programme.

Over the last five years, our sites have spent, on average, more than £85 million a year on R&D. In addition, the NDA commissions projects directly, totalling approximately £5 million per year.



## Our R&D investments have resulted in:

- Safer working environments through the development of innovative remote technologies, including laser cutting, robotics and improved radiation detection.
- More funding available to the supply chain through our collaborations with other public organisations.
- A vibrant supply chain working to solve long-standing technical challenges.
- A sustained programme of academic research into nuclear decommissioning.
- The establishment of a unique, world-class research centre, the £20 million Dalton Cumbrian Facility (DCF), specialising in radiation science and decommissioning engineering.
- Postgraduate-level training and development for hundreds of potential nuclear specialists.

*NDA-sponsored research student Dr Victoria Evans studied the DNA of microbes found in Sellafield open-air ponds, aiming to understand how the organisms respond to radioactivity. The research was carried out at the University of Manchester*



# NDA's R&D portfolio

We invest funds directly in R&D projects to:

- Inform our UK-wide strategy
- Deliver innovation across multiple sites
- Maintain and develop vital technical skills

In this brochure, we look at where this investment has brought benefits.

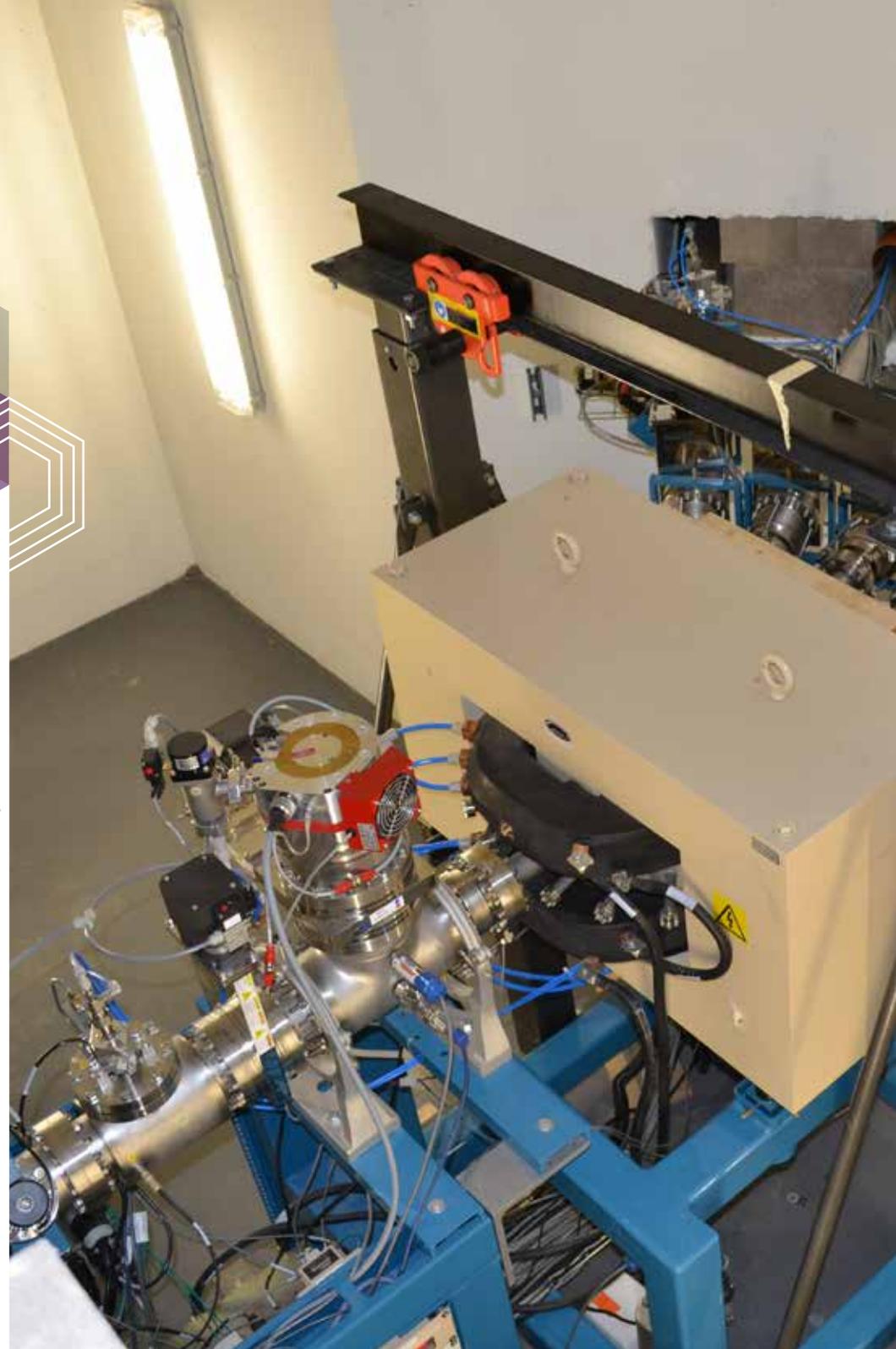


Our approach is flexible:

- We seek to encourage collaboration as much as possible.
- We are willing to explore the potential of creative concepts.
- We fund academic studies at many universities to support maintenance of a diverse technical skills base.
- We aim to support technologies on the journey from early concept to market acceptance.
- We work in partnership with other public and private organisations to increase the funding that can be made available.
- We seek to ensure duplication of work is avoided.
- We support active sharing between and beyond our sites.

It is critical to identify multi-site R&D needs and opportunities, and to share good practice as widely as possible. To encourage this, we sponsor the Nuclear Waste and Decommissioning Research Forum (NWDRF) comprising representatives from across our estate, the wider nuclear sector and the nuclear regulators. Governance for the whole R&D area is provided by the NDA's independently chaired Research Board, which draws on nuclear expertise from the UK and overseas.

Ion accelerator beam lines at the Dalton Cumbrian Facility (DCF)



## Quick facts

55

peer-reviewed  
publications from NDA  
sponsored R&D in the  
last two years

Up to  
**£6  
million**

of NDA funding to support more  
than 25 decommissioning-related  
projects with InnovateUK  
since 2012

22

UK universities host  
NDA-sponsored  
students

We  
currently  
support more  
than

59

PhD projects

**Active  
collaboration**

with US Department of  
Energy and the French  
government-funded  
technological research  
organisation, CEA

NDA's R&D  
portfolio delivered by  
more than

40

supply chain organisations in the  
UK and beyond

# Types of work funded directly by NDA

Last year, we invested in a wide range of projects, divided into the following categories:

**Direct Research Portfolio (DRP).** This portfolio addresses issues that could affect multiple sites, or SLCs, in areas of strategy, technology innovation and skills. These projects are delivered through competed framework contracts awarded to a wide range of supply chain organisations, based on the following themes:

- University-based work
- Managing waste (radioactive and conventional)
- Decommissioning and restoring sites
- Managing spent fuel and nuclear materials

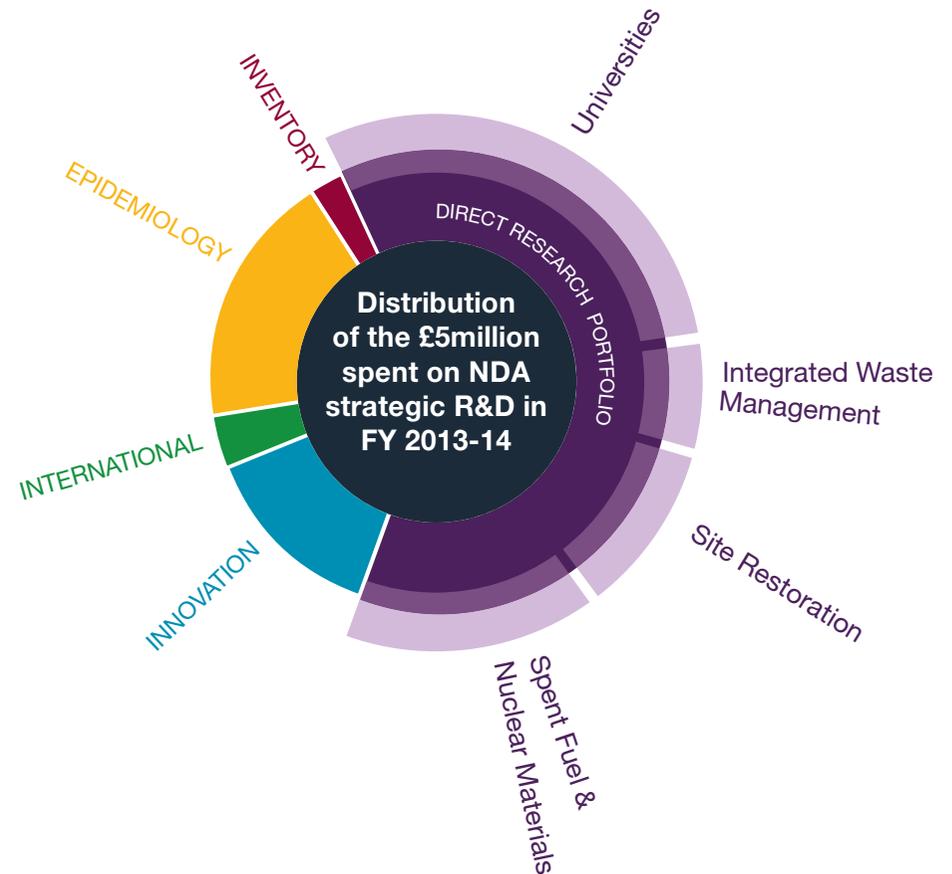
The most recent contracts were awarded in 2012 for periods of up to four years maximum. Page 14 shows the diversity of supply chain organisations supporting us. A further round of contracts will be available for competitive tender in late 2015.

**Technical innovation.** This work is focused on supporting the supply chain to develop new ideas and technologies. Projects are often jointly funded with other public sector partners, such as InnovateUK whose interests cross all sectors of UK industry including nuclear decommissioning. Collaboration such as this can more than double the funding available for projects and brings in additional expertise and technologies from outside decommissioning.

**International collaboration.** Our focus is on sharing and gaining access to global good practice, experience and information about innovative technologies. NDA has bilateral agreements with key international organisations, where R&D is a common theme in these. We contribute to the UK's membership of the Nuclear Energy Agency (NEA) and support the NDA estate's membership of the NEA Data Bank which collates and shares computer codes and nuclear data.

**Radiation epidemiology & radiobiology research.** Public Health England investigates, on our behalf, the health impact on our workforce of exposure to man-made radiation.

**UK inventory of radioactive waste & materials.** NDA produces the comprehensive inventory of radioactive wastes and materials across the UK which is currently updated every three years: [www.nda.gov.uk/ukinventory](http://www.nda.gov.uk/ukinventory)



# Funding

To deliver maximum value from our investments we seek to collaborate with other key UK R&D funders. We are exploring how best to gain similar benefits from international funding partners.

Our funding partners include:

- The Government's innovation agency InnovateUK, part of the Department for Business, Innovation and Skills
- Research Councils UK (RCUK) and specifically, Engineering and Physical Sciences Research Council (EPSRC)
- The Department of Energy and Climate Change (DECC)
- The Government's cross-functional UKTI, which supports UK businesses in the international market
- Universities

*Silicone polymer-based materials may offer a flexible alternative to cement-based encapsulants for certain wastes*



*Funding partners announce the 2012 joint investment in the supply chain, totalling £15 million*

## The projects on the following pages are funded through various mechanisms:

- Case study 1: Monitoring stored waste
- Case study 2: AGR fuel cladding in wet storage

Both received direct NDA funding through the NDA's Direct Research Portfolio (DRP)

- Case study 3: Radiation mapping
- Case study 4: ILW immobilisation
- Case study 5: Lasers
- Case study 6: On-site characterisation of concrete

These technologies have benefitted from collaborative funding through the joint 2012 initiative by the Government's InnovateUK (formerly the Technology Strategy Board), along with the NDA, the Department of Energy and Climate Change (DECC) and the Engineering and Physical Sciences Research Council (EPSRC). A further 2014 collaborative initiative by InnovateUK, DECC and the NDA will provide additional funding to some projects.

\*Some projects also received funding through additional sources

# Case study 1: Monitoring stored waste

Higher activity radioactive waste will be stored above ground for many decades before being transferred to a more permanent facility. Monitoring the condition of packaged waste is vital for confidence in safe disposal. A combination of technologies is being explored that will enable data collected from within the package to be transmitted externally, while tolerating radiation. Radio Frequency Identification (RFID), widely used to track packages through warehouses, transfers data to a reader via a battery-less tag powered by the electromagnetic fields used to read them - inductive coupling. Inductive Coupling Telemetry (ICT) extends this technology, allowing the tag to power attached sensors and analyse its environment. In this study, ICT was investigated as a potential tool for non-intrusive monitoring of packaged waste.

Firstly, it was determined that the technology would comply with requirements for waste storage and disposal when incorporated into a waste package. Next, an ICT demonstrator was embedded in a 500-litre inactive sample package, proving the concept of two-way communication through the filter on the lid. Wasteform temperature and strain measurements were also successfully recorded. Finally, each tag was tested inside a gamma radiation chamber up to the cumulative dose expected during 100 years of storage, proving the tolerance to radiation and ability to collect data during irradiation.



Data can be collected without opening storage containers

## Summary

**Challenge:** How to monitor the condition of stored higher activity waste without the need to open the container

**Solution:** A combination of Radiofrequency Identification (RFID) tags and attached sensors

**Technology:** Inductively Coupled Telemetry (ICT)

**Benefits:** Allows waste storage operators to check their waste is safely stored, allows checks prior to disposal, reduces worker dose by removing the need to open the container

**Status:** The tag technology is mature but further circuit development is required for demonstration

**Research organisation:** National Nuclear Laboratory

**Website:** [www.nnl.co.uk](http://www.nnl.co.uk)

# Case study 2: AGR fuel cladding in wet storage



*The University of Manchester's Dalton Cumbrian Facility and, below, the facility's 5 MV tandem ion accelerator.*



## Summary

**Challenge:** Predicting the impact of Radiation Induced Sensitisation (RIS) on the long-term wet storage of Advanced Gas-Cooled Reactor (AGR) spent fuel

**Solution:** Modelling studies validated through characterisation results on irradiated samples

**Technology:** Computer modelling / 5MW tandem accelerator

**Benefits:** Limits the need for experiments with actual spent AGR fuel

**Status:** Development of experimental programme under way

**Research organisation:** AMEC-led programme with support from Universities of Birmingham, Manchester and Michigan (US)

**Website:** [www.amec.com](http://www.amec.com)

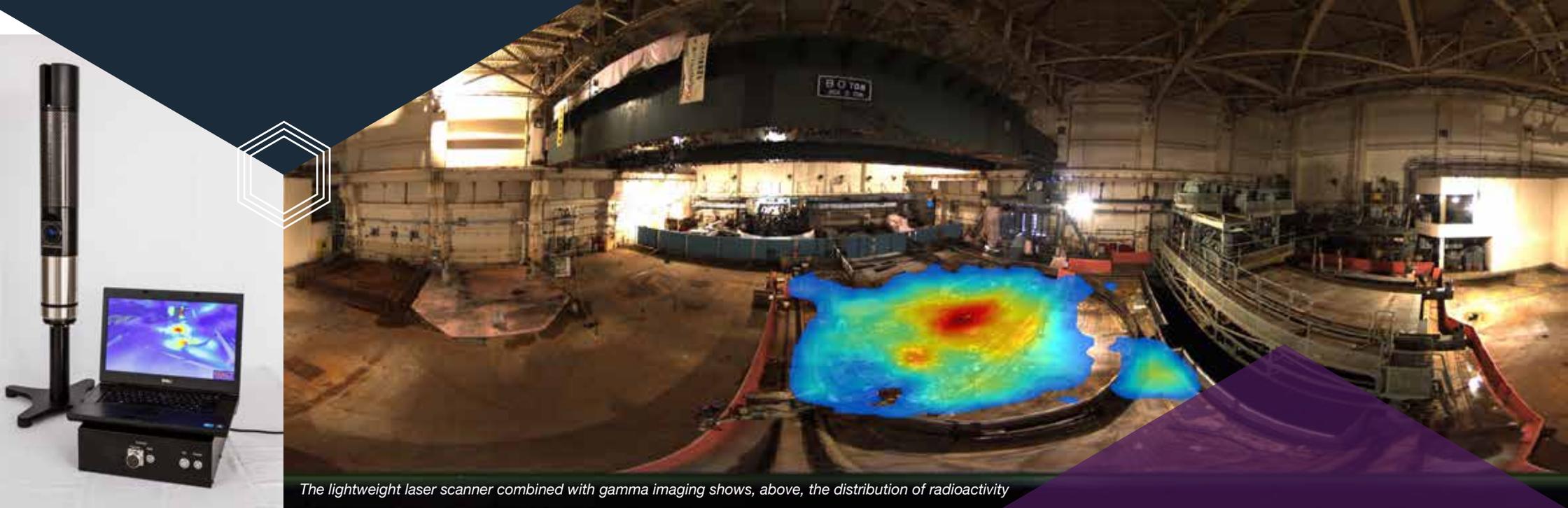
From 2018 onwards, spent fuel from the UK's second fleet of nuclear power stations, the Advanced Gas-Cooled Reactors (AGR), will be stored in ponds awaiting geological disposal. This follows the planned closure of reprocessing facilities at Sellafield.

During wet storage, however, the fuel's cladding can be susceptible to corrosion due to radiation exposure during reactor operation. This phenomenon, known as Radiation Induced Sensitisation (RIS), has seen significant research over the last decades. Experiments with actual spent AGR fuel cladding present obvious difficulties but understanding has increased in recent years. This follows improvements in corrosion modelling and material characterisation, alongside the availability of irradiation facilities such as the Dalton Cumbrian Facility (DCF), with a particular focus on whether RIS will limit long-term (ie, more than 25 years) wet storage of AGR fuel.

An RIS research project has recently started, led by AMEC and supported by academics from the Universities of Birmingham, Manchester and Michigan (US). The DCF, developed through a £20 million collaboration between University of Manchester and NDA, will be used to irradiate small samples of cladding materials to induce RIS and the characterisation results used to validate our corrosion models. This will reduce the level of experimental work required on actual spent AGR fuel.



# Case study 3: Radiation mapping



*The lightweight laser scanner combined with gamma imaging shows, above, the distribution of radioactivity*

A key challenge in decommissioning nuclear plants is understanding the distribution of radioactive sources and the resulting radiation fields. Radiation levels often rule out sending in people to measure levels, while historic radiation surveys may be out of date. A new system, developed by Createc, combines the mapping of gamma radiation with laser scanning and dose modelling (N-Visage™) to provide detailed information on the location of radioactive sources and the consequences of either shielding or removing that source.

The information enables comparisons between different decommissioning strategies and identification of optimised solutions. The lightweight technology can be deployed through small openings or remotely, using robotic vehicles, allowing even the most challenging facilities to be characterised. As well as being used in the UK, the system is now being used internationally (eg, clean-up at the Fukushima Daiichi nuclear power plant). Createc is further developing the characterisation technologies with funding and support from the Government body InnovateUK (formerly the Technology Strategy Board) and NDA.

## Summary

**Challenge:** Remote characterisation of nuclear facilities

**Solution:** Combine gamma imaging with laser scanning and dose modelling

**Technology:** N-Visage™ Gamma Imager with N-Visage™ Source Mapping Software

**Benefits:** Allows optimised decommissioning strategies to be identified

**Status:** In use in the UK and internationally

**Research organisation:** Createc

**Website:** [www.createc.co.uk](http://www.createc.co.uk)

# Case study 4: ILW immobilisation

A versatile means of encapsulating liquids and solids is being further developed after exceeding expectations during a feasibility study.

The heat-resistant and mineral-like slurry, based on geo-polymer technology, can be poured onto Intermediate Level Waste or pumped into skips from below, where it penetrates void spaces before solidifying.

Hundreds of skips across the estate, particularly at Sellafield, contain varying kinds of ILW, in both wet and dry conditions.

The geo-polymer solidifies at room temperature and, unlike existing cements and polymers, worked well with both dry contents and containers that held an aqueous phase. Its viscosity can also be altered, enabling careful control of its behaviour and solidity.

The technology is being pioneered by materials technology company Lucideon, who have previously carried out materials testing of the new sarcophagus designed to contain radiation from Chernobyl's reactor and whose expertise grew out of Stoke-on-Trent's ceramics industry. Potentially, the technology offers a wider range of applications than existing methods, which use a cement-based grout to encapsulate waste that is subsequently packaged for storage.

Further trials with active waste are envisaged before the technology is ready to deploy on a site, potentially at Sellafield.

## Summary

**Challenge:** Immobilisation of Intermediate Level Waste to provide resilience during long-term storage

**Solution:** Geo-polymer slurry that can be poured or pumped into containers, solidifying contents

**Technology:** Geo-polymer encapsulant

**Benefits:** Reduced costs, works with solids, liquids or both, fills gaps, avoids need to drain off liquid and dose associated with breaking open skips

**Status:** Feasibility study successful, larger-scale trial on active waste required

**Research organisation:** Materials technology company Lucideon (formerly CERAM), Stoke-on-Trent

**Website:** [www.lucideon.com](http://www.lucideon.com)

*Lucideon's technology is named MIDAR*



# Case study 5: Lasers – a cut above the rest

Remote technology is a common requirement to enable the cutting up of vessels, support structures, flasks and pipework in areas where radiation levels are high. The current approach tends to rely on large robots with conventional mechanical cutting technologies. Laser cutting tools are, however, compact, lightweight, extremely precise and leave only small amounts of residual debris.

Minimal force is applied to the material being cut, and lasers can therefore operate with small and light conventional articulated arm robots or other novel technology, such as snake-arm robots.

The combination of laser cutting and snake-arm robot technology is currently being developed through an industry collaboration. The developments will provide a flexible and highly manoeuvrable lightweight tool, LaserSnake2, that can navigate in areas inaccessible to larger robotic machinery.



## Summary

**Challenge:** How to remotely cut metalwork in inaccessible areas

**Solution:** Laser cutting tool deployed using a snake-arm robot

**Technology:** LaserSnake

**Benefits:** Avoids using large, heavy robots to remotely deploy mechanical cutting tools; enhanced precision

**Status:** Further development and on-site demonstration trials currently under way

**Research organisation:** Industry collaboration led by OC Robotics with TWI, NNL, Laser Optical Engineering and ULO Optics

**Website:** [www.lasersnake.co.uk](http://www.lasersnake.co.uk)



# Case study 6: On-site characterisation of concrete



An estimated two million cubic metres of concrete rubble will be generated as historic nuclear facilities are demolished in the decades ahead, and accurate determination of the extent of radioactive contamination will be critical to waste disposal decisions.

Current practice involves drilling into the concrete to remove samples which are then packaged and transported to a lab for analysis. The process takes time, can lead to changes in the sample's condition, thereby increasing the margin of error and subsequent costs. Alternative methods are a key area of research.

A novel approach, currently undergoing development, uses a remotely deployed laser to remove surface material, which is transported to a sample collection pod in a safe area - located metres, rather than miles away - where it can be processed and analysed.

ViridiScan was developed jointly between specialised UK micro-company Viridian Partnership and Sellafield Ltd. ViridiScan will utilise results from a previously NDA-funded PhD (Viridian and Imperial College) looking at bulk and surface monitoring of concrete for site characterisation.

This project team is currently developing the technology for on-site trials and market deployment. This highlights the benefit of ongoing funding to ensure the progress of fundamental research through to technology demonstration.

## Summary

**Challenge:** Reduce disposal costs by accurate characterisation of radioactively contaminated concrete: re-classification from intermediate- to low-level waste.

**Solution:** In-situ remotely deployed laser removes surface layer material and transports it to a nearby location for accurate analysis

**Technology:** ViridiScan

**Benefits:** Reduced worker exposure to radiation, avoids off-plant transport and lab analysis, rapid and flexible deployment, potential £10 million savings through waste re-classification

**Status:** Continued laser delivery and automated on-line sampling development and on-site trial preparations

**Research organisation:** Viridian Partnership, Surrey

**Website:** [www.viridianpartnership.co.uk](http://www.viridianpartnership.co.uk)



*Top, Viridian's Dr John Williams with the unit developed to collect material samples. Meanwhile, the team is working on further development of the technology*

# 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 Laboratories (NNL)	Supported by National Physical Laboratory, NuVision Engineering	<ul style="list-style-type: none"> <li>To ensure the right level of academic technical capability is available.</li> </ul>
	AMEC	Brenk Systemplanung and Jülich Research Centre GmbH, EnergySolutions, MMI Engineering Ltd, Quintessa Ltd, University of Leeds, University of Manchester, Oxand Ltd, Westinghouse Electric Company UK Ltd	<p><i>Higher Activity Wastes (HAW)</i></p> <ul style="list-style-type: none"> <li>Development and analysis of options for HAW management.</li> <li>Development of innovative technologies.</li> <li>Sponsoring R&amp;D that enables the NDA to respond strategically to Government policy and oversee SLCs' HAW work.</li> </ul> <p><i>Lower Activity Wastes (LAW), non-radioactive and hazardous waste</i></p> <ul style="list-style-type: none"> <li>Sponsoring R&amp;D that enables the NDA to respond strategically to Government policy and oversee SLCs' work on these wastes.</li> </ul>
Integrated Waste Management	Cavendish Nuclear	Frazer-Nash Consultancy Ltd, GMS Abingdon Ltd, WSP Environment & Energy / NRG, University of Birmingham, Nympsfield Nuclear Ltd, SA Robotics	
	Hyder Consulting	Inutec, ONET Technologies UK, Bradtech Decon Technologies Ltd, The University of Manchester, AdvanSci, REACT Engineering Ltd, Lancaster University, Fortis Mechanical Design Ltd, Hybrid Instruments Ltd, Createc	
	NNL	Galson Sciences Ltd, NuVision Engineering, Bristol-Oxford Nuclear Research Centre, Cogentus Consulting Ltd, Immobilisation Science Laboratory at University of Sheffield	
	NSG Environmental Ltd	Abbott Risk Consulting Ltd, DBD, The Environmental Scientifics Group Ltd, Gardiner and Theobald, International Nuclear Services UK, Loughborough University, Nuclear Graphite Research Group – School of Mechanical Aerospace & Civil Engineering at University of Manchester, SKM Enviro, Studsvik UK Ltd, Synergy Health Ltd	
Site Restoration	AMEC	Brenk Systemplanung and Jülich Research Centre GmbH, EnergySolutions, MMI Engineering Ltd, Quintessa Ltd, University of Leeds, University of Manchester, Oxand Ltd	<ul style="list-style-type: none"> <li>Technical underpinning for the NDA's Strategy on decommissioning, land quality and site end states.</li> <li>Enhanced delivery by SLCs.</li> </ul>
	Ove Arup & Partners	Costain, Poyry Energy Ltd, James Fisher Nuclear Ltd, Corporate Risk Associates Ltd, Westlakes Engineering Ltd, Cardiff University, University of Cambridge	
	Cavendish Nuclear	Eden Nuclear and Environment, WSP Environment & Energy, University of Birmingham, Frazer-Nash Consultancy Ltd, GMS Abingdon Ltd, SA Robotics, Corporate Risk Associates, Nympsfield Nuclear Ltd	
	Hyder Consulting UK	Bradtech Decon Technologies Ltd, AdvanSci, ESI Technology, Dalton Nuclear Institute - University of Manchester, University of West England, Erith Group, REACT Engineering Ltd	
	RSK	Siempelkamp Nukleartechnik Technology UK, Land & Marine Project	
Spent Fuel and Nuclear Materials	AMEC	Brenk Systemplanung and Jülich Research Centre GmbH, EnergySolutions, MMI Engineering Ltd, Quintessa Ltd, University of Birmingham, University of Manchester, Westinghouse Electric Company Ltd, Imperial College London	<ul style="list-style-type: none"> <li>Sponsoring R&amp;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.</li> <li>Ensuring skills in spent fuel management are maintained over the longer term.</li> <li>To support NDA development of options for managing the UK's uranics inventory and stockpile of separated plutonium.</li> <li>Sponsoring R&amp;D that enables the NDA to respond to government policy and oversee SLC activities on management of uranics and plutonium.</li> </ul>
	Cavendish Nuclear	WSP Environment & Energy, University of Birmingham, Institute of Transuranic Elements (ITU), SA Robotics	
	NNL	Galson Sciences Ltd, NuVision Engineering, Immobilisation Science Laboratory at University of Sheffield, Bristol-Oxford Nuclear Research Centre, Cogentus Consulting Ltd	



## Through our investment programme, we are:

- A significant funder of nuclear R&D in the UK
- Supporting growth in the UK supply chain, particularly with SMEs
- Contributing to delivery of the Government's Nuclear Industrial Strategy
- Building a skills pipeline of technical experts
- Bridging the gap between innovators and end-users



*Laser cutting can be deployed with conventional equipment*

# Find out more

This brochure briefly outlines some examples of how recent investments in the Direct Research Portfolio and Technical Innovation areas have impacted on the NDA's mission. If you're interested in getting involved or want to find out more, please visit our website or contact: [research@nda.gov.uk](mailto:research@nda.gov.uk)

## Further information

[www.nda.gov.uk/research-and-development/](http://www.nda.gov.uk/research-and-development/)

## Useful documents to download from our website

EGPR04 Technology Research Investment Process (in publications section)

Research and Development 5 Year Plan 2014 to 2019

NDA Research Board Terms of Reference

Nuclear Waste Research Forum Terms of Reference

EGG10 Technical Baseline and Underpinning Research and Development Requirements Rev6



The Nuclear Decommissioning Authority (NDA) is a Government-funded body, created in 2005 and tasked with overseeing clean-up of the legacy from the UK's pioneering post-war experiments with nuclear power. This includes the world's very first nuclear power station, a fleet of 10 other power stations built in the 1950s-1970s, experimental research centres, fuel-related facilities and the Sellafield complex, home to some of Europe's most difficult nuclear challenges.

