

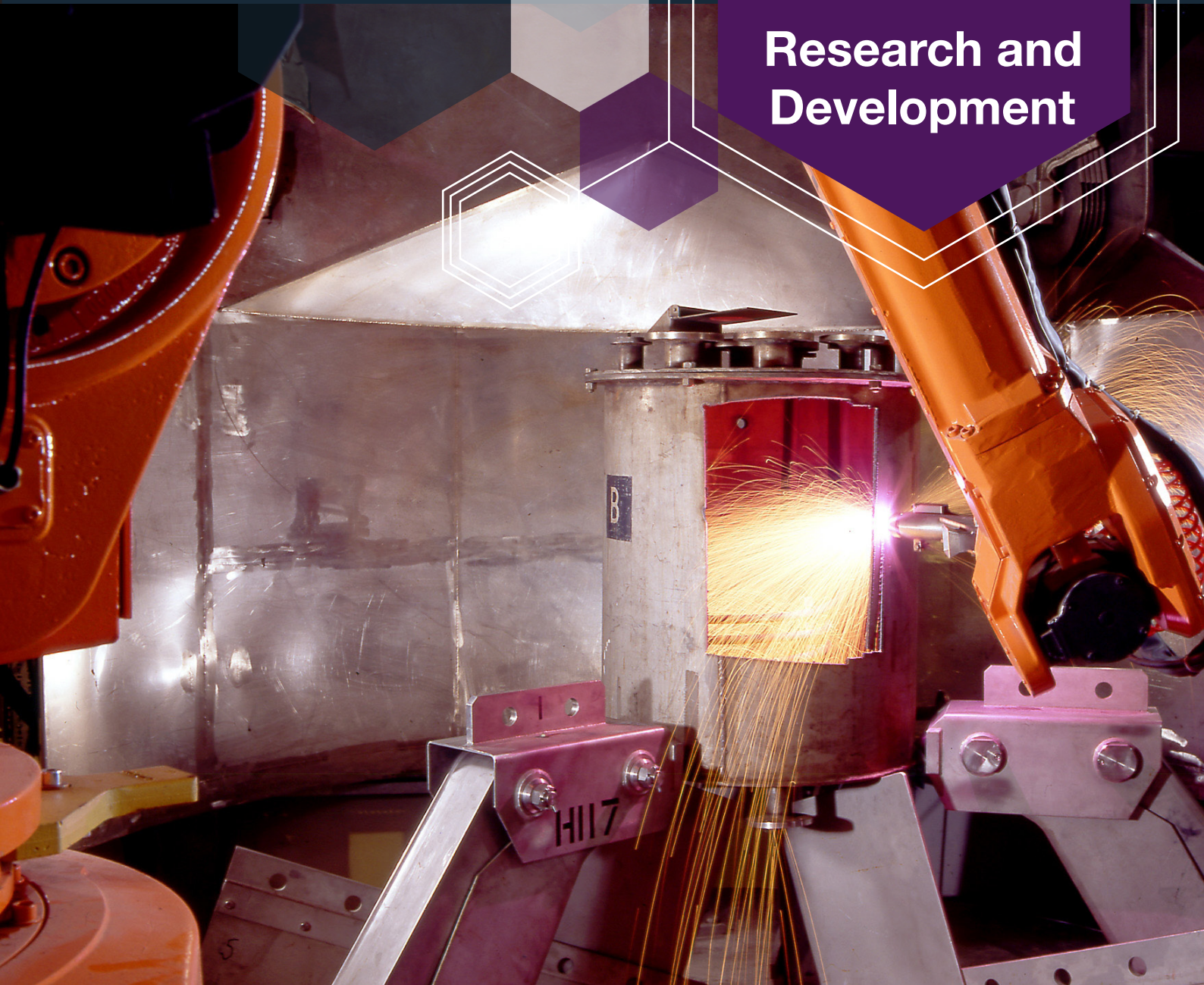
NDA

Nuclear
Decommissioning
Authority

Direct Research Portfolio Annual Report 2013/14

R&D

Research and
Development



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1 Introduction

The Energy Act (2004) specifies that Research & Development (R&D) is a supplemental function of the Nuclear Decommissioning Authority (NDA). As such the NDA is required to promote and, where necessary, carry out research in relation to its primary function of decommissioning the UK's civil nuclear legacy. Technology and the underpinning R&D are fundamental to ensuring the safe, cost-effective delivery of our mission. Together with innovation and the sharing of good practice, both nationally and internationally, the intelligent application of R&D can reduce costs and timescales.

This document is the annual summary of work delivered through NDA's Direct Research Portfolio (DRP) Framework contracts in financial year 2013/14. Each Lot is summarised in a table that covers the project title, the R&D topic with which it aligns (as stated in the Research and Development 5 year plan¹), the lead supplier, Purchase Order number, the driver for the R&D, a brief description of the project and the status of the project at the end of FY2013/14.

The overall objective of our R&D programme is to ensure that the delivery of the NDA's mission is technically underpinned by sufficient and appropriate R&D. Our R&D strategy is that where possible, R&D is undertaken by the Site Licence Companies (SLCs) and their supply chain. Where necessary the NDA will directly maintain and sponsor a strategic R&D programme, the Direct Research Portfolio (DRP). The DRP focuses on targeted, estate-wide R&D needs, risks and opportunities to inform and develop strategy, deliver innovation and maintain and develop key technical skills. The DRP does not focus on site-specific R&D issues as they are the responsibility of the relevant SLCs.

In the last NDA Strategy published in March 2011², we identified six strategic themes under which we group all of our activities. Four of the six strategic themes relate to what NDA does. These 'key themes' are:

- Site Restoration (SR)
- Integrated Waste Management (IWM)
- Nuclear Materials (NM)
- Spent Fuels (SF)

The two remaining themes are enabling activities which are required to achieve the NDA's mission:

- Critical Enablers
- Business Optimisation

From the Energy Act requirements and NDA's R&D Strategy, we have identified the following drivers for our directly funded programme:

1. Inform Strategy

¹ Research and Development 5 year plan 2014 to 2019, Issue 1, December 2013, available from www.nda.gov.uk

² NDA Strategy – Effective from April 2011 (2011) available from www.nda.gov.uk

Under Energy Act (2004) obligations, NDA must review and publish its Strategy at least every five years. It is essential that the strategy is technically underpinned. R&D is focused on two areas:

- a. *Develop Strategy* – This is R&D to underpin strategic options.
- b. *Support Current Strategy* – This is R&D around risk mitigation, exploring the tolerance of an existing strategy to change or challenging existing assumptions that foreclose options.

2. Deliver Innovation

If a common R&D need, risk or opportunity is identified across multiple SLCs then it may be more effective and efficient for NDA to fund a project directly on behalf of its estate. This also minimises the potential for duplication of work. R&D is focused on two areas:

- a. *Incremental Improvements to Multiple Sites' Lifetime Plans* – This is R&D targeted at increasing efficiency and effectiveness within more than one SLC.
- b. *Step Change to Multiple Sites' Lifetime Plans* – This is R&D seeking to drive early innovation and look at the feasibility of a step change. The R&D needs to be applicable to more than one SLC.

3. Maintain and Develop Skills

Where possible, R&D to maintain and develop skills is funded by the SLCs. Where there is an estate-wide need, NDA may support R&D projects that maintain and develop skills. Wherever possible this will be delivered whilst informing strategy or delivering innovation. The R&D may fall within one of four categories:

- a. *Estate-Wide Capability Gaps* – This is R&D to maintain skills in a subject area that impacts on a number of SLCs.
- b. *Future Strategic Gaps* – This is R&D to maintain skills in areas that will be required beyond an SLC's current contracted scope.
- c. *Knowledge Transfer and Resources* – This is R&D that contributes to understanding and consistency of approach across the NDA estate.

R&D is also required to maintain of the Intelligent Client Role within the NDA. This is R&D to enable NDA to act as a strategic body and crosses all three strategy drivers.

In alignment with our R&D strategy, the majority of R&D to underpin our mission is carried out by our SLCs and their supply chain. This R&D is not reported here but details can be found on the respective SLC websites. The decision to undertake

R&D through the DRP is informed both by the NDA's Strategy² and the SLC technical baselines. The SLCs set out their technology development plans through the Technical Baseline and underpinning Research and Development (TBuRD) documents. This information will be used to create the NDA Technical Baseline which provides an overview of technology development and deployment across the NDA estate. The output of the DRP informs both NDA Strategy and the Technical Baseline. Our approach to R&D management is summarised in Figure 1.

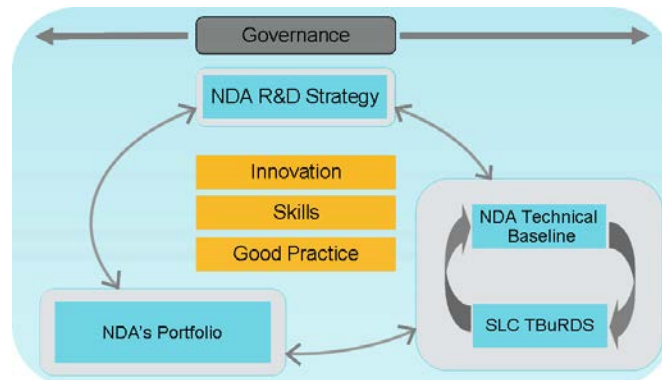


Figure 1: Approach to R&D Management

The delivery of the overall R&D programme is supported by a number of groups:

- NDA Research Board³ – an independently chaired Board with a broad strategic role, co-ordinating national research and development in decommissioning, radioactive waste management and radioactive waste disposal. This Board reports to the NDA Board via the NDA Director of Strategy & Technology. It meets on a biannual basis.
- NDA Internal R&D Board⁴ – a Board chaired by the NDA Head of Technology. The main purpose of the Board is to support the development, delivery and impact assessment of the NDA's directly funded research. Sanctioning of NDA R&D expenditure is via this Board and is the accountability of the Head of Technology. The NDA Head of Technology is also member of the NDA Research Board and reports to NDA Director of Strategy & Technology. The Board meets on a monthly basis.
- Nuclear Waste Research Forum (NWRF)⁵⁶ – A forum with members from NDA, Radioactive Waste Management Directorate (RWM), SLCs⁷, Regulators and organisations with significant nuclear decommissioning liabilities (e.g. EDF Energy). It is chaired by industry and reports to the NDA

³ Nuclear Decommissioning Authority Independent Research Board Terms of Reference, Issue 2, available from www.nda.gov.uk, 2012.

⁴ Technology/Research Investment Process, Doc Ref EGPR04, available from www.nda.gov.uk

⁵ Nuclear Waste Research Forum Terms of Reference, available from www.nda.gov.uk, 2012

⁶ Now known as Nuclear Waste and Decommissioning Research Forum (NWDRF – was NWRF at the time of this work

⁷ Now known as Radioactive Waste Management Ltd (RWM) – was RWMD at the time of this work

Research Board. Its role is to enhance coordination of R&D across UK Site Restoration and Integrated Waste Management activities. It meets on a quarterly basis.

- NWRF Working Groups – Working groups formed as required by the NWRF to address specific areas of R&D where common needs or opportunities have been identified. Their role is to share knowledge and to recommend specific technical projects for funding. Projects may be funded via individual SLCs, the DRP or through wider collaboration.

2 Delivery of the DRP

The DRP is delivered through four framework contracts, which were awarded through a competitive process to various consortia during Financial Year (FY) 2011/12.

The framework contracts or 'Lots' are:

- Lot 1: University Interactions
- Lot 2: Integrated Waste Management
- Lot 3: Site Restoration
- Lot 4: Spent Fuels & Nuclear Materials

This contractual mechanism provides:

- a good balance between ease of placing work and getting a good range of technically competent and cost-effective R&D proposals;
-
- a good range of organisations to provide R&D experience across the NDA mission (there are over 60 organisations involved including SMEs, universities and international organisations) and;
- an opportunity to develop relationships and capability within the supply chain

Lot 1, the University Interactions Lot, has been awarded to a single contractor, the National Nuclear Laboratory (NNL), to ensure co-ordination of our interactions with Universities across the NDA's remit.

The scope of Lots 2, 3 and 4 are aligned with the four NDA key strategic themes identified in our Strategy. This is to ensure consistency of approach and enable the full range of NDA's R&D requirements to be met. The Spent Fuels & Nuclear Materials themes have been amalgamated as the projects typically require contractors with the same technical capabilities.

R&D proposals can be developed by NDA Strategic Authorities or with support from the Nuclear Waste Research Forum (NWRP) and Theme Overview Groups (TOGs)⁸. A standard mini-tender process using technical and commercial scoring criteria is used to select the preferred supplier for each work package.

The DRP is managed within the NDA Strategy & Technology Directorate and is constantly reviewed to ensure that the portfolio is balanced across the key themes and that any synergies are captured.

In December 2013, the NDA published a 5 year Research and Development Plan⁹. This document covered the entire R&D programme (including DRP Epidemiology research programme and collaboration with Innovate UK (formerly the Technology

⁸ TOGS provide NDA with strategic oversight and cover the following areas; Integrated Waste management, Site Restoration and Spent Fuel and Nuclear Materials

⁹ Research and Development 5 year plan 2014 to 2019, Issue 1, December 2013. Available from www.nda.gov.uk

Strategy Board (TSB)). This document set out a number of R&D topics for each Strategic Theme / Lot that the NDA expects to fund from January 2014 onwards.

3 University Interactions (Lot 1)

The key focus of the NDA's DRP University Interactions is to maintain and develop nuclear decommissioning technical skills. This is done to ensure that the required technical skills are available when key strategic decisions need to be implemented.

Table 1 summarises the activities that are undertaken in this Lot. While the majority of the funding is targeted at maintaining skills through directly-funded PhDs or leveraged iCASE awards, the current framework contractor National Nuclear Laboratory also undertake tasks in support of this area, such as:

- Providing technical support to PhDs at Universities across the country,
- Organising a PhD seminar to spread knowledge and build contacts between students and industry and monitoring the impact of NDA-funded PhDs.

Table 2 shows the PhDs that are ongoing or which were chosen as part of the NDA Bursary call in FY2013/14. Included in the table are the first tranche of PhDs that the NDA is funding (or co-funding) from the Engineering and Physical Sciences research Council (EPSRC) DISTINCTIVE Project (Decommissioning, Immobilisation and Storage Solutions for Nuclear Waste Inventories) in addition to those funded by the NDA Bursary or by EPSRC iCASE¹⁰ award.

As well as direct funding of university R&D through the DRP, NDA's R&D team is also involved in a number of activities which support university based R&D:

- Membership of Nuclear Research Coordination Group (NRCG) – This group brings together a representative core of UK stakeholders involved in UK nuclear activities to enable co-ordination of existing R&D programmes and future funding initiatives and was sponsored by the EPSRC at the time of this work.
- Membership of Management Committee of Centre for Doctoral Training in Nuclear Fission – Next Generation Nuclear (Universities of Lancaster, Leeds, Liverpool, Manchester and Sheffield) – An EPSRC-funded programme which aims to address a doctoral skills gap in nuclear fission research.
- Membership of Dalton Cumbrian Facility (DCF) Management Board and Research Steering Group – the D C F on Westlakes Science and Technology Park is the result of an initial £20m joint investment by the University of Manchester and the NDA that will bring world-leading academic research to West Cumbria.
- Membership of the Nuclear Innovation Research Advisory Board (NIRAB) – The NDA is an observer to this Board, established in January 2014, to advise Ministers, Government Departments and Agencies on publicly funded research and innovation required to underpin Government policy in the civil nuclear sector.

¹⁰ Industrial Cooperative Awards in Science & Technology (iCASE)

Table 1: Lot 1 University Interaction Projects

Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status at 31/03/14
Bursary Facilitation	Direct support of capability in targeted areas	NNL	12960	N/A	This project involves co-ordinating NDA's annual bursary call and involves advertising the call, collecting proposals from universities, co-ordinating the industry review of proposals and providing feedback to universities.	Annual Project
NDA Bursary Call	Direct support of capability in targeted areas	NNL	13275 / 13258 / 13257 / 12717 / 12713	Maintaining Skills / Delivering Innovation	This project provides funding to PhD studentships selected through NDA's annual Bursary Call. To steer the scope of the PhDs, a number of research themes were provided by members of the NWRF Working Groups and NDA Strategic Authorities. From over 40 applications, seven PhDs were funded (see NDA funded PhD table). The NDA also funded three PhDs this year in support of DISTINCTIVE (Decommissioning, Immobilisation and Storage solutions for Nuclear waste Inventories). All these PhDs maintain skills / deliver innovation across the NDA's key themes for R&D. A list of all PhDs being funded in 2013/14 is shown in the NDA-funded PhDs table (Table 2).	Annual Project



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status at 31/03/14
Capability at University of Sheffield	Direct support of capability in targeted areas	NNL	12493	Maintaining Skills	This project provides support to the University of Sheffield to develop capability in radioactive waste immobilisation, management and disposal. The support includes a five-year commitment involving partial funding of Chair and Immobilisation Science Laboratory (ISL) Manager. Professor Neil Hyatt has been appointed to the Chair in Immobilisation Science. This position is jointly funded by NDA and Royal Academy of Engineering. Immobilisation science is a key strategic area for the NDA supporting the development and implementation of NDA's Integrated Waste Management strategy. It is important to ensure that there is sufficient capability in this technical area.	Ongoing
Industrial Supervision of NDA Sponsored PhD students	Direct support of industrial supervisors for NDA funded PhD projects	NNL	12702	Maintaining Skills / Delivering Innovation	NNL supervised and provided technical support to 35 NDA-funded PhD/EngD projects in 2013/14. A one-day seminar was also arranged (29th January 2014, Manchester Conference Centre, Manchester) to facilitate the transfer of knowledge between the NDA-funded projects and industry (SLCs and wider supply chain).	Annual Project



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status at 31/03/14
CASE/iCASE Awards	Support the development and delivery of Research Council programmes	NNL	12768 / 12769 / 13045	Delivering Innovation / Maintaining skills	There are PhDs co-funded by EPSRC and the NDA. Traditionally, these PhDs have been instigated to drive strategic partnerships; for example with universities or SLCs. In 2013/14, the EPSRC offered the NDA the opportunity to co-fund six PhDs, two of which were directly funded by the NDA (see NDA-funded PhDs table) and the remainder were funded by SLCs. A list of all PhDs being funded in 2013/14 is shown in the NDA-funded PhDs table (Table 2).	Annual Project
Research Centre for Non-Destructive Evaluation (RCNDE)	Support the development and delivery of nuclear decommissioning specific academic capability - <i>Working with other interested parties to identify and support appropriate areas of academic technical capability</i>	NNL	12494	Maintaining Skills / Delivering Innovation	This project involves managing NDA's involvement with the RCNDE (www.rcnde.ac.uk) and is delivered by NNL. RCNDE is an Engineering and Physical Sciences Research Council (EPSRC) sponsored collaboration between industry and academia on research into non-destructive evaluation (NDE) technology relevant to the future needs of industry. The project includes membership of the RCNDE, provision of Subject Matter Experts to support the interaction of the NDA estate with RCNDE and attendance at the British Institute of Non-Destructive Testing (BINDT) conference.	Annual Project



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status at 31/03/14
DCF Support - Radiation Sciences	Support the development and delivery of nuclear decommissioning specific academic capability - <i>Support to existing programmes</i>	NNL	12550	Maintaining Skills	This project provides Subject Matter Experts to support the interaction of the NDA with universities in the subject area of radiation sciences, particularly the Radiation Science group within the Dalton Cumbrian Facility (DCF), University of Manchester. The DCF is the result of a joint investment by the University of Manchester and the NDA to establish new research capabilities in Radiation Sciences and Nuclear Engineering Decommissioning. The facilities at the DCF include a 5MW ion-beam accelerator and a cobalt-60 irradiator which provides UK universities with a unique opportunity to carry out research that will increase our understanding of how materials behave when exposed to radiation.	Annual Project
DCF Collaboration - Access to NNL's Central Laboratory	Support the access to specialist facilities (e.g. facilities capable of handling radioactive materials) for academia to ensure the benefit of individual projects is maximised	NNL	13300	Maintaining Skills	As the owner of NNL's Central Laboratory, the NDA is able to make NNL's unique facilities available to PhD students for active research. Instigated initially for University of Manchester Dalton Cumbrian Facility students, this option is now extended to any research that broadly meets the NDA's mission.	Annual Project



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status at 31/03/14
University Contract Management	Management of contracts with universities	NNL	11846 / 12492	N/A	For efficiency and to ensure consistency of approach, NNL manage NDA's contractual arrangements with universities. This also provides a single point of contact for the university contracts.	Ongoing
University Interactions Impact Assessment	Monitoring the impact of NDA's University R&D Strategy	NNL	11876	Informing strategy	This project has developed an approach to assessing the impact of NDA-funded university interactions to key stakeholders. The project refined the Value Scorecard methodology developed for the NDA in FY2008/09. A pilot assessment was carried out using available data for FY2012/13. During FY 13/14, year two of data was compiled to continue to assess progress and impact of funding PhDs.	Ongoing
PhD Community Building	Monitoring the impact of NDA's University R&D Strategy	NNL	12963	Maintaining Skills	One of the NDA's aims is to foster a community among NDA-funded PhD students. This should enable each student to take a broader view of their research, to place it in the context of the NDA estate and generate better value for the NDA. It should also allow the student to share their experiences with a wider audience and hopefully enhance their own PhD experience and quality of research. This project facilitates the use of the NDA's Knowledge Hub by creation of a community for knowledge sharing among the PhD students.	Complete



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status at 31/03/14
Other	University Strategy Support	NNL	11973	Informing Strategy	An NNL employee was seconded to NDA to support the review and updating of the NDA's University R&D Strategy. This approach was taken to facilitate NNL's understanding of NDA's drivers for supporting university based R&D and improve co-ordination between NDA's and NNL's university R&D programmes.	Ongoing

Table 2 : University PhDs

University	Title	Type
University of Lancaster	Enhancing the Information Content of Near-Real-Time Geoelectrical Imaging Applied to Nuclear Site Characterisation - <i>chosen by NWRP Decommissioning Working Group</i>	2013/14 Bursary
University of Surrey	Development of a Novel Gamma-ray Detection System for Fission Fragment Decay Data Measurement and Evaluation - <i>chosen by NWRP Characterisation Working Group</i>	2013/14 Bursary
University of Glasgow	Development & Industrial Testing Of Multi-Radiation Systems For Characterisation of Nuclear Facilities - <i>chosen by NWRP Characterisation Working Group</i>	2013/14 Bursary
University of Birmingham	Optical Detection of Stainless Steel Container Corrosion - <i>chosen by NWRP Waste Packaging and Storage Working Group</i>	2013/14 Bursary
University of Manchester	Assessment of Natural Attenuation and Targeted In-Situ Remediation for In-Situ Groundwater Treatment Sites - <i>chosen by NWRP Land Quality Working Group</i>	2013/14 Bursary
University of Manchester (DCF)	Wet Oxidation of Uranium Dioxide in Sealed and Unsealed Enclosures in Radiation Fields	2013/14 Bursary
University of Manchester	Investigation of Anomalous Radiolytic Hydrogen Production from Water Absorbed Oxides	2013/14 iCASE Award
University of Sheffield	Conditioning of Legacy Radioactive Wastes Requiring Additional Treatment	2013/14 iCASE Award
Newcastle University	Investigate the Kinetics & Mechanism of Cracking of Sensitised 20/25/Nb Stainless Steel	2013/14 Bursary
University of Lancaster	Computational Simulations of Storage Pond Sludge Disturbance	2013/14 iCASE & DISTINCTIVE
University of Strathclyde	Nano Cracking of Cement Phases: Reactivity and Dissolution	2013/14 iCASE & DISTINCTIVE
Queens University Belfast	Irradiated Sludges, a Joint Theoretical/Experimental study	2013/14 DISTINCTIVE

University	Title	Type
University of Birmingham	Vision-Based Trajectory Control of Unsensoried Robots to Increase Functionality, without Robot Hardware Modification	2012/13 Bursary
University of Leeds	Co-treatment of Mixed Radionuclides in Large Volumes of Contaminated Water by Carbonate Precipitation Reactions	2012/13 Bursary
University College London	Optimising the Absorption of Radionuclides by Graphene Oxide Flakes	2012/13 Bursary
Cardiff University	Rapid ⁹⁰ Sr Determination by Improved Liquid Scintillation Counting	2012/13 Bursary
Swansea University	Mapping of Corrosion Sites on AGR Fuel Cladding in Long Term Pond Storage	2012/13 Bursary
University College London	The Interaction of Brucite Surfaces with Uranium and its Fission Products	2012/13 Bursary
University of Sheffield	Moisture Movement in Cemented Wasteforms: the First 500 Years	2012/13 Bursary
University of Sheffield	The Development of Glass Ceramics for Actinide Immobilisation	2012/13 Lot 4 support
University of Manchester	Elucidating the Mechanism of Environment-Assisted Cracking of Stainless Steel Storage Cans in Hydrochloric-Acid Containing Vapour Environment	2012/13 NDA/SL co-funded
University of Manchester / Arvia Technology Ltd	The Electrochemical Break Down of Radioactive Organic Waste.	2011/12 Bursary
Loughborough University	Superplasticisers Tailored for Applications in Nuclear Decommissioning and Storage (STANDS)	2011/12 Bursary
University of Southampton	Development of robust automated techniques for radionuclide separation.	2011/12 Bursary

University	Title	Type
Lancaster University	Real Time Nanogravimetric Monitoring of Corrosion in Radioactive Environments.	2011/12 Bursary
University of Southampton	Assessment of High Efficiency Sorbent Materials for Application in the Remediation of Radionuclide Contaminated Groundwater:	2011/12 Bursary
University College London	Advancing Solvent Extraction Technology for Improved Management of Contaminated Liquors.	2011/12 Bursary
Queen Mary University of London	Radiation Damage in "Real" Zirconolite: Simulating the Effects of Grain Boundaries	2011/12 Bursary
Imperial College	Rapid & Accurate Assessment of Radiologically Contaminated Rubble.	2011/12 Bursary
University of Bristol	Assessment of the Behaviour of Metallic Uranium during Encapsulated Product Evolution.	2011/12 Bursary
University of Manchester	Providing a Mechanistic Understanding of Stress Corrosion Cracking of AGR Fuel Cladding During Pond Storage	2011/12 Lot 4 support
Aberdeen University	Investigating Uranic Interactions in Cementitious Systems	2011/12 Lot 4 Support
University of Southampton	Expanding the Analysts Toolbox: Using Latest Plasma Source Mass Spectrometers for Waste Characterisation	2011/12 Lot 2 Support
University of Manchester	Development of a Mechatronic System for Underground Sensor Deployment	2011/12 iCase Award
University of Sheffield	Thermal Treatment of Plutonium Contaminated Material Wastes	2011/12 iCase Award
University of Leeds	Developing an Acoustic Backscatter System for In-Situ Industrial Suspension Characterisation	2010/11 Bursary

University	Title	Type
Loughborough University	Surface Modified Minerals for Radiochemical Applications	2010/11 Bursary
University of Manchester	Bioremediation Options for UK Radwaste Impacted Land	2010/11 Bursary
University of Birmingham	Robot Assisted Decommissioning in Alpha Contaminated Environments	2010/11 Bursary
University of Sheffield	Understanding the Radiation Stability of Alternative Phosphate Cement Systems	2010/11 Bursary
University of Birmingham	New Materials for Cs and Sr Encapsulation	2010/11 Bursary
Createc (Lancaster)	Quantitative Assessment of Nuclear Material with Combined Neutron and Gamma-ray Imaging	2010/11 Bursary
University of Manchester	Experimental Studies and Modelling of Nitric Acid Radiolysis	2010/11 iCase Award
Aberdeen University	Reactivity and Corrosion Behaviour of Nuclear - Grade Magnesium Alloys During Storage	2010/11 iCase Award
University of Lancaster	Applied Electrokinetic Migration of Radionuclides Through Water Saturated Concretes	2009/10 Bursary
Loughborough University	SAMPL: Surface Attached Modular Polymer-bound Ligands for Radionuclide Sequestration	2009/10 Bursary
University of Manchester	Nuclear Data Measurement, Evaluation and Application in the Nuclear Industry	2009/10 Bursary
University of Manchester	Actinide colloids and Nanoparticles: Relevance to Legacy Waste, Clean Up and Geological Disposal	2009/10 Bursary

University	Title	Type
University of Leeds	Innovative System for Deploying Novel Biosensors for Groundwater Contaminant Monitoring.	2009/10 Bursary
Liverpool University	A Three-Dimensional Integrated Gamma-ray and Vision System	2009/10 Bursary
University of Lancaster	Mechanisms of Fixed Contamination of Commonly Engineered Surfaces	2008/09 Bursary
University of Lancaster	Fast, Smooth and Co-ordinated Control of a Dual-Arm Manipulator used for Nuclear Decommissioning	2008/09 Bursary

4 Integrated Waste Management (Lot 2)

The key focus of the NDA's DRP Lot 2, Integrated Waste Management, is to support the NDA in its development and analysis of strategic options for Higher Activity Waste, Lower Activity Waste and Non-Radioactive and Hazardous Waste management. The objective is to allow the NDA to act as an informed strategic body by sponsoring R&D activities that allow the NDA to respond to decisions on government policy and oversee SLC activities with regard to Integrated Waste Management.

The strategies underpinning Integrated Waste Management (IWM) are:

- **Higher Activity Waste (HAW)** – This area covers High Level Waste (HLW), Intermediate Level Waste (ILW) and a relatively small amount of Low Level Waste (LLW) that is unsuitable for disposal in current LLW facilities.
- **Lower Activity Waste (LAW)** – This area covers the management of solid LLW and liquid and gaseous discharges from NDA owned sites.
- **Non-Radioactive and Hazardous Waste** – This area covers non-radioactive waste (e.g. building rubble) and non-radioactive hazardous waste (e.g. asbestos).

During FY2013/14 the DRP Lot 2 only contained R&D projects relating to HAW. This was because

- i) Low Level Waste Repository Ltd leads the delivery of the LLW National Waste Programme (NWP) on behalf of the NDA;
- ii) R&D associated with liquid and gaseous discharges tends to be site specific; and
- iii) the UK has a well-established, comprehensive and prescriptive regulatory regime for the management of non-radioactive and hazardous waste and there is therefore limited R&D identified against this area. However, these areas are still retained in the NDA R&D 5 year plan as there may be specific UK or estate-wide strategic needs, risks or opportunities in the near future.

Table 3 shows the projects that continued from FY2012/13 or which were newly commissioned in FY2013/14. The R&D driver of the majority of the projects in this year was to Deliver Innovation and a number of projects were set up to conduct laboratory-based R&D (see Purchase Orders (PO) 12074, 11981, 12283, 13007 and 10952 in Table 3). The NWRF Working Group in Waste Packaging and Storage instigated a number of these projects (POs 11769 and 12757) and is interested in the applicability of lab-based results.

Table 3: Integrated Waste Management DRP projects

Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Radioactively Contaminated Waste Oil: Phase 1 - Nature and Quality	Application of the Waste Hierarchy - <i>Development of technologies to improve the application of the Waste Hierarchy (e.g. waste characterisation technologies, sorting and segregation technologies, understanding technical barriers to material re-use)</i>	Hyder Consulting	12785	Delivering Innovation	This work is focused on identifying the characteristics of the contaminated waste oil and the technologies that have been trialled in the UK and overseas. The project was part of an innovation based open tender.	Complete	Phase 1 report completed and available. Lead supplier to produce proposal for Phase 2.
Graphite Behaviour (phase 2b & 2c)	Alternative Waste Treatment - with a particular focus on volume reduction - <i>Understanding and, where appropriate, addressing the technical barriers to implementation of new thermal, mechanical and chemical treatment technologies across the NDA estate</i>	Cavendish Nuclear	12074	Informing Strategy	Graphite from reactor decommissioning accounts for a significant proportion of the packaged volume of the ILW inventory currently destined for geological disposal. This project aims to increase our understanding of the behaviour of graphite during treatment to inform the technical underpinning for alternative options for the long-term management of irradiated graphite. This project started in FY2010/11 and will continue through FY2013/14.	Ongoing	-



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Low Dose Rate Irradiation Testing of Piles Candidate Polymers	Alternative Encapsulants - <i>Understand options and technical barriers to implementation of alternative encapsulants</i>	AMEC	11981	Delivering Innovation	The NWRF identified an opportunity across the NDA estate to continue research started by Sellafield Ltd and RWM on the use of epoxy resin based polymers as a waste encapsulant. This project is investigating the structural integrity and chemical stability of epoxy resin based polymers to low dose rate gamma irradiation. The results will be compared with previous high dose rate irradiation results to investigate the impact of dose rate on polymer performance. It has been suggested that diffusion limited oxidation may result in reduced polymer performance at low dose rate irradiation when compared with high dose rate irradiation. This project started in FY2010/11 and will continue through FY2013/14.	Ongoing	-



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
New uses of cementitious grouts (Reactive Encapsulants)	Alternative Encapsulants - <i>Consolidate work and understanding on improving existing encapsulation technology</i>	NSG Environmental	12283	Delivering Innovation / Maintaining Skills	The role of all encapsulants within the nuclear industry has been to provide chemical and physical stability to the materials they encapsulate for as long as possible. Traditionally cementitious grouts have been the material of choice but have, for some waste streams, performed sub-optimally where reactive metal stabilisation is required. This project is to develop grouts, using well-understood encapsulation systems and inherent performance attributes that react with reactive metals to produce wasteforms that evolve in a controlled manner and can maintain product integrity. The project was started in FY2012/13 and continued through FY2013/14.	Ongoing	-



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Solubility Studies in the Presence of Bespoke Superplasticisers	Alternative Encapsulants - <i>Understand options and technical barriers to implementation of alternative encapsulants</i>	NSG Environmental	13007	Delivering Innovation	Within the UK, ILW has traditionally been encapsulated in cement. Outside of the nuclear waste encapsulation industry superplasticisers have been added to cement formulations to improve their workability and allow lower water content grouts to be produced. However, they have been shown to increase radionuclide mobility and as a result could impact the safety performance of a Geological Disposal Facility. A new generation of superplasticisers may avoid this problem. Previously NNL have investigated the processing envelope for these new cement formulations and compared the resulting products with existing products (FY2009/10: Superplasticisers (8618) & FY2010/11: Superplasticisers (9760)). This project continues the corrosion tests started in FY2009/10.	Ongoing	-



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
SMART Coupons (phase 4)	Alternative Encapsulants - <i>Consolidate work and understanding on improving existing encapsulation technology</i>	National Nuclear Laboratory	10952	Delivering Innovation	The aim of this project is to develop a 'Smart' coupon for monitoring corrosion within ILW stores. Initial work was successful and a decision was made to progress to the next stage of the project which involves commissioning and testing a commercially available Environmental Condition Monitor (ECM) in a non-active environment and demonstrating its performance to measure corrosion. The project continued through FY2013/14.	Ongoing	-
Development of a Waste-Storage System Baseline Approach to Support the Industry Guidance on Interim Storage	Underpinning of Interim Storage - <i>Store environments and their impact on long-term interim storage</i>	National Nuclear Laboratory	11769	Delivering Innovation / Informing Strategy	The aim of this project was to develop an approach to waste package storage system baselining. The baseline condition of a variety of safety-related waste package functions needs to be established at each stage of the package lifecycle so any departure from these initial conditions can be identified through regular monitoring. This can be used to help store operators determine whether intervention is needed. The basic methodology was developed by an earlier project (FY2009/10 – Package Failure Definition (8316)) which formed a key component of the Industry Guidance on Interim Storage of Higher Activity Waste Packages.	Ongoing	-



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Waste Packaging Database	Underpinning of Interim Storage - <i>Material and design of packages</i>	AMEC	12757	Informing Strategy / Maintaining Skills	This project was required to develop a simple, verified and standalone database which mirrors the broad structure of the Industry Guidance Database and provides information on previously implemented waste packaging schemes, which can be shared with key stakeholders.	Ongoing	-

5 Site Restoration (Lot 3)

Site Restoration, including decommissioning and land remediation, is the NDA's driving strategic theme and all other strategic themes support or enable its delivery. The sites can only be restored if final management solutions for spent fuels and nuclear materials are secured and effective waste management solutions are established,

The strategies underpinning Site Restoration (SR) are:

- Decommissioning – to deliver Site End States as soon as reasonably practicable with progressive reduction of risk and hazard
- Land Quality Management – to ensure that land quality is managed to protect people and the environment
- Site End States – to define credible objectives for the restoration of each site (or part of a site)

During FY2013/14, projects were commissioned in all three strategic areas.

The NWRF Working Group in Land Quality proposed a number of topics for delivery by the DRP Framework contractors in Lot 3. The focus of this group has generally been on the production of Codes of Practice (PO 11979) or best practice guides (PO's 12574 and 12575) to inform SLCs on how best to manage monitoring and sampling of their sites for regulatory purposes and inform decommissioning activities.

A number of projects have also been initiated by the NDA Strategic Authority in Site Restoration, with the driver to Inform Strategy in the areas of Decommissioning and Site End States.

Table 4 summarises all these projects. The advisory nature of many of these projects means that many stakeholder opinions have been sought and most will carry over into FY 2014/15.



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Table 4: Lot 3 DRP Projects - Decommissioning

Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Decommissioning							
Review of Asset Management Prioritisation for Decommissioning	Strategic Approach to prioritisation of restoration activities - <i>Influence of different factors (e.g. asset condition, radioactive decay profile of facility)</i>	AMEC	13077	Informing Strategy	One of the factors identified within government policy to aid the assessment of priority and pace of decommissioning is the "maintenance of adequate site stewardship". A significant part of this is asset management. At present the production of an Asset Lifecycle Model (ALM) and Asset Life Expectancy (ALE) Chart requires a significant amount of time and resource. The purpose of this project is to determine whether a more efficient approach can be developed based on existing good practice and the approach being developed at Sellafield.	Ongoing	-



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Use of decommissioning rubble for void filling and landscaping on nuclear licensed sites	In-situ disposal of structures and waste - <i>Understanding appropriateness of and, where appropriate, addressing the technical barriers to implementation of in-situ disposal of structures and waste across the NDA estate</i>	Cavendish Nuclear	12767	Informing Strategy	Decommissioning and dismantling work can potentially create large volumes of concrete block and brick rubble. Depending on whether it has a subsequent use and/or the level of contamination, the rubble can be categorised as material suitable for re-use or waste. Rubble can be re-used to backfill voids created when below ground structures are removed and/or used to landscape the site where the site contours need to be modified. This project considers how radioactive and / or chemical contaminated rubble may be used and will inform NDA's strategy development plans, assisting the NDA in fully considering, and implementing suitable strategic alternatives.	Ongoing	-
Pipeline characterisation and decommissioning	Improved decommissioning - <i>Improving the approach to decommissioning (e.g. pipeline decommissioning, pond decontamination)</i>	AMEC	12315	Delivering Innovation / Informing Strategy	The overall aim of this project is to bring together all relevant information concerning past and current practice and experience (good and bad) in pipeline characterisation and decommissioning across the NDA estate, and broader experience from other industries (e.g. oil and gas) and internationally. This information will then be used to assess the advantages and disadvantages of the available technologies and methods, and to develop a Good Practice Guide. This project will continue into 2014/15.	Ongoing	-

Table 4 (cont): Lot 3 DRP Projects - Land Quality and Site End States

Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Land Quality Management							
Dual beta-gamma probe for in situ measurement of radioactively contaminated materials	Improved characterisation of land and groundwater - <i>Improving the approach to land and groundwater characterisation</i>	AMEC	11934	Delivering Innovation	Following on from a previous DRP project (2009/10 – Rapid characterisation of material (Serco) (8609)) this project is reviewing the current status of dual beta-gamma probes for the in-situ measurement of radioactively contaminated materials and investigating what technologies are either commercially available or are considered to be technically feasible. The ideal probe should be able to provide information on beta activities associated with Sr-90, Y-90 and Cs-137 and on gamma activity associated with Ba-137m (the short-lived daughter of Cs-137).	Complete	No immediate action required. Watching brief on development of technology.



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
NICoP - Routine Water Quality Monitoring	Improved characterisation of land and groundwater - <i>Improving the approach to land and groundwater characterisation</i>	AMEC	11979	Delivering Innovation	Most UK nuclear sites have ongoing programmes for the monitoring of groundwater and/or surface water bodies. This project is preparing a Nuclear Industry Code of Practice (NICOP) which sites can use to design, review and implement their routine water quality monitoring programmes. It is important that sites implement an internally consistent water quality monitoring strategy that is fit for purpose, meets its stated objectives and aligns with the NDA's stated aims for Land Quality Management and protection of people and the environment. This project will continue into 2014/15.	Ongoing	-
Emerging Issues in Land Quality Management	Improved characterisation of land and groundwater - <i>Improving the approach to land and groundwater characterisation</i>	Arup	12306	Maintaining Skills	Land Quality Management (LQM) is a diverse field, with constantly adapting regulation and best practice, and a complex regulatory regime. Keeping up to date with recent developments can be time-consuming, but it is a necessary exercise for land quality professionals. This project aims to provide regular updates on changes and developments in policy, legislation, regulation and guidance relevant to LQM. The updates are circulated in the form of quarterly Briefing Notes and News Alerts (circulated when there is a need for a more urgent update). This project will continue in 2014/15.	Ongoing	-



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Key Documents and Resources Library for Land Contamination	Improved characterisation of land and groundwater - <i>Improving the approach to land and groundwater characterisation</i>	Arup	12573	Maintaining Skills / Informing Strategy	A review of the Land Quality TBuRDs highlighted that a barrier to effective and efficient land quality management (LQM) was the lack of an information portal that could be relied upon for up to date information. The aim of this project is to collate and maintain a library of key contaminated land management documents and resources updates in the thematic area for the Nuclear Industry using a web-based 'knowledge hub' as part of the NDA Information Governance Programme.	Ongoing	-
Time Series Data	Improved characterisation of land and groundwater - <i>Improving the approach to land and groundwater characterisation</i>	Hyder Consulting	12575	Delivering Innovation / Maintaining Skills	The objective of this project is to produce a guide to collecting time-series data that are suitable and optimal for analysis, and analysing the data in a robust and defensible way. The collection of time series data, primarily in relation to groundwater in order to analyse how its composition and level varies with time, is a key element of understanding the fate and transport of contamination within the environment. Best use of available techniques in the collection and analysis of time-series data is not always being made and thus this project is conducting a review of the use of statistical analysis for contaminated land within the nuclear industry.	Ongoing	-



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Estimation of Means and other statistical parameters for contaminated land data	Improved characterisation of land and groundwater - <i>Improving the approach to land and groundwater characterisation</i>	Hyder Consulting	12574	Delivering Innovation / Maintaining Skills	Although there is guidance on the design of sampling programmes and the assessment of results from this, the guidance is regarded as patchy, not necessarily aligned with modern ideas of data quality objectives, and some may be technically inadequate or even flawed. The objective of this project is to produce a guide to appropriate techniques for use in the nuclear industry, for regular use.	Ongoing	-
Site End States							
Site Restoration Roadmap Templates	Mechanisms for communication Site End States and the preceding journey (e.g. roadmaps)	Arup	12605	Informing Strategy	A Site Restoration Roadmap describes the journey of decommissioning and remediation that will take us from where we are now to where we want to be. It is envisaged that there will be a roadmap for each NDA site (or even part of a site) as well as an estate-wide picture. The NDA aims to publish a restoration roadmap for the estate and each site. The roadmaps will be living documents that are updated whenever significant changes are made to lifetime plans. The aim of this project is to develop the concept of what a roadmap looks like and share it stakeholders for comment.	Complete	Phase 2 of project to be completed in FY 14/15

6 Spent Fuels and Nuclear Materials (Lot 4)

The key focus of the NDA's DRP lot 4 is to enable the NDA to act as an informed strategic body by sponsoring R&D activities that allow the NDA to set and monitor the SCL's delivery of the Magnox Spent Fuel Strategy as well as respond to external factors.

The strategies underpinning Spent Fuels (SF) and Nuclear Materials (NM) are:

- Magnox Spent Fuels – to ensure safe management then ultimate disposition of spent Magnox fuel
- Oxide Spent Fuels –to ensure safe management and ultimate disposition of UK owned oxide fuel and optimise the management of overseas owned oxide fuel held in the UK.
- Exotic Spent Fuels – to ensure that all exotic fuels are managed in a safe and secure way for the lifetime of the fuel
- Uranium – to ensure safe, secure management of our uranium inventory
- Plutonium – to ensure safe, secure and cost-effective lifecycle management of plutonium stocks

The vast majority of the work projects in these areas are driven by the need to Inform Strategy. Some projects were instigated to ensure that the current position and understanding of Spent Fuel and Nuclear Materials is recorded (e.g. POs 11274, 11957, 12854, 12582, and 13155). Others consisted of experimental work to develop new techniques in corrosion monitoring which would help inform the strategy for long term storage of these fuels, whether wet or dry storage. In addition, these technologies may be of benefit to SCLs for the near term monitoring of their spent fuel. Table 5 summarises all the work that was conducted during FY2013/14.

It should also be noted that a small number of projects do not appear in Table 5 as they are commercially or security sensitive. However, the projects are included in the figures used in the Summary section.

Table 5: Lot 4 DRP Projects - Oxide Spent Fuels

Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Oxide Spent Fuels							
OECD-NEA Economics of the back end of the nuclear fuel cycle	Improving our understanding of spent fuel storage - <i>Modelling the impact of operational changes on the oxide spent fuel strategy</i>	NNL	11274	Informing Strategy	Bench-marking the cost for spent fuel management across nations supports NDA's strategic studies on the assessment of spent fuel management options. This project involved the participation in the OECD-NEA (Organisation for Economic Co-operation and Development - Nuclear Energy Agency) nuclear development study 'The Economics of the Back End of the Nuclear Fuel Cycle'. It produced a definitive study across OECD-NEA member countries of the costs of management and disposal of radioactive waste from the nuclear fuel cycle.	Complete	The information gained has informed current strategic thinking in this area.
Scoping study on the comparison between AGR fuel cladding stored in caustic and demineralised water	Improving our understanding of spent fuel storage - <i>Improve the mechanistic understanding of the behaviour of AGR spent fuel under wet storage conditions</i>	NNL	13076	Informing Strategy / Maintaining Skills	The purpose of this work is to strengthen the foundations for the interim storage of AGR fuel by establishing whether there is any significant impact on AGR cladding, affecting future management of the fuel, from a period of demineralised water storage, or lower pH caustic transients, prior to subsequent storage under the higher pH conditions. The project is reviewing literature for available data and identifying any gaps or potentially significant consequences that could affect a long-term strategy.	Ongoing	-



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Why does caustic work?	Improving our understanding of spent fuel storage - <i>Improve the mechanistic understanding of the behaviour of AGR spent fuel under wet storage conditions</i>	Cavendis h Nuclear	11957	Informing Strategy	The NDA is continuing to improve its understanding of how AGR spent fuel might perform under wet storage regimes. Caustic-dosed pond waters have been shown to be very effective for storing AGR fuel but fundamental scientific work to increase our understanding of why this medium is so effective supports the case for storage and helps to maintain a UK capability to manage this fuel over the long-term storage period. This project provided independent review of the adequacy of information to predict the performance of AGR stored in caustic for the current anticipated interim storage timescale (at least 25 years). The review identified uncertainties, assumptions and mechanisms that could threaten adequate storage performance in high pH water. This will help to substantiate previous studies. These findings will aid NDA in helping to ensuring future work is focused on the unknowns which could have an impact on baseline and contingency strategies, as well as the design of facilities to accommodate existing and future AGR fuel over all its types and histories.	Complete	The understanding gained is informing current strategy and informing the scope of future R&D projects in this area

Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Further work on technologies for monitoring the evolution and behaviour of AGR spent fuel in storage - Electrochemical Noise technique	Improving our understanding of spent fuel storage - <i>Improve the mechanistic understanding of the behaviour of AGR spent fuel under wet storage conditions</i>	AMEC	12284	Informing Strategy	This project is to look at Electrochemical Noise (ECN) as a passive technique monitoring the current and voltage perturbations associated with normal dissolution and deposition of ions on a metallic surface. When corrosion occurs the technique detects the subtle changes caused by localised corrosion. The work aims to understand the potential suitability of ECN to detect the initiation of corrosion on AGR fuel cladding and the potential for such technologies to signal whether corrosion has either ceased or diminished to a low level. As part of this project a detailed experimental programme will be developed defining specific experimental conditions and materials.	Complete	This underpinning work in this project has led to Sellafeld Ltd picking up ECN as a research project



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Further work on technologies for monitoring the evolution and behaviour of AGR spent fuel in storage - Potential Drop Technique and Ultrasonic Immersion technique	Improving our understanding of spent fuel storage - <i>Improve the mechanistic understanding of the behaviour of AGR spent fuel under wet storage conditions</i>	NNL	12304	Informing Strategy	Methods for in-situ monitoring of AGR fuel over the period of long-term storage could be used to determine how well the fuel is performing in the storage medium. This information could be used to inform decisions on whether to adjust storage conditions and inform future decision on how to retrieve and package the fuel for disposal. The project assessed the feasibility of using Potential Drop (PD) methods through computational modelling and has now moved forward to laboratory testing of an instrumented dummy fuel pin which will be used to validate model results. This package of work has included ultrasonic immersion testing. A well proven and mature technology ultrasonic immersion testing provides a non-contact remote method of undertaking general thickness measurements of the actual AGR clad along its length whilst the pin is still submersed.	Complete	A second phase of work is to be initiated in FY 14/15 to confirm and develop the promise shown in the first phase.

Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Review of international approaches to management of spent fuel	Improving our understanding of spent fuel storage - <i>Explore potential for extending wet storage from 25 years up to 100 years</i>	NNL	12854	Informing Strategy	Ongoing developments in the wider fuel cycle, including nuclear 'new build' and NDA involvement in consideration of potential reuse options for UK plutonium, have spent fuel management implications. This project provides a foundation for ongoing NDA consideration of an integrated approach to spent fuel management in the UK. It is essential that NDA has (and maintains) strategic intelligence in this area. The project looked at technology issues associated with both wet and dry storage, best practices in other countries and developments and trends since 2011 and then draw comparisons between the different approaches and the UK, identifying any potential implications for the UK.	Complete	The information gained has informed current strategic thinking in this area.
Scoping Study on the Correlation of AGR Fuel Cladding Characteristics with Irradiation Conditions and Pin Design	Improving our understanding of spent fuel storage - <i>Extending corrosion inhibition for AGR fuel cladding - physical and chemical opportunities</i>	Cavendish Nuclear	13103	Informing Strategy / Maintaining Skills	The purpose of the work proposed here is to undertake a scoping study to determine what data can be accessed relating historic fuel cladding examination to fuel design variations and variations in reactor exposure and fuel management practice, and whether it would be possible and profitable to try to correlate cladding characteristics with this data	Complete	The understanding gained is informing current strategy and informing the scope of future R&D projects in this area

Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Radiation Induced Sensitisation (Modelling and Experimental)	Alternative long-term storage options to wet storage such as dry storage - <i>Establish technical basis for dry storage of AGR i.e. How dry does the fuel need to be to reduce corrosion to the minimal levels observed in wet storage? This will include establishing the behaviour of reactor-induced sensitised stainless steel AGR cladding under dry storage conditions</i>	AMEC	13197	Informing Strategy	The purpose of this work is to contribute to the understanding of Radiation-Induced Sensitisation (RIS) in AGR fuel in support of strategic risk management for NDA's Oxide Fuels Strategy. This is to be achieved in two parts; the first is to carry out a literature review models of the phenomenon of radiation induced sensitisation (RIS), and recommendations made to update previous models to produce a state-of-the-art capability to model both proton and neutron-induced RIS; secondly, experimental investigations will be carried out on AGR fuel cladding using a particle accelerator to induce the sensitisation.	Ongoing	-
How dry does AGR Fuel need to be to prevent corrosion under dry storage conditions? - Part 1	Alternative long-term storage options to wet storage such as dry storage - <i>Establish technical basis for dry storage of AGR i.e. How dry does the fuel need to be to reduce corrosion to the minimal levels observed in wet storage? This will include establishing the behaviour of reactor-induced sensitised stainless steel AGR cladding under dry storage conditions</i>	Cavendis h Nuclear	11975	Informing Strategy	Recent work on the mechanism for the corrosion of AGR fuel in nominally dry environments has suggested the level of moisture at which a slow rate of corrosion may occur could be lower than that currently assumed. Work is required to determine the level of dryness in nominally dry environments required to protect sensitised AGR fuel during long-term storage. The main conclusion of the assessment is that there is a general benefit in reducing water/moisture levels. However the assessment concludes that attempts to predict fuel clad performance over multiple decades is likely to be very unreliable. Therefore it is likely that dry storage designs will need to consider a fuel population containing a significant fraction of pre-existing or	Complete	The understanding gained is informing current strategy and informing the scope of future R&D projects in this area



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order (PO)	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
					future failed fuel.		

Table 5 (cont): Lot 4 DRP Projects - Exotic Fuels, Plutonium and Uranics

Title	5 year plan R&D Topic	Lead Supplier	Purchase Order	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Exotic Spent Fuels							
Review of UK Research Reactor Spent Fuels	Consolidation of fuels and materials in storage - <i>Characterisation, storage, treatment and disposal</i>	NNL	12582	Informing Strategy	The NDA is reviewing the records and history of the UK's nuclear power development to ensure that, given the long and complex history and restructuring of the UK nuclear industry, the 'final resting place' for all UK reactor fuels can be unequivocally confirmed. The UK's domestic research programme has resulted in over twenty different reactors designs. This includes research, experimental and prototype reactors. The purpose of this review was to support the NDA in establishing that, within reason, the fuels irradiated in these reactors can be readily accounted for. The review focused on fuels from the more unusual reactors where the circumstances are less obvious, especially where the fuels irradiated were of higher than natural enrichments or contained mixed actinide fuels.	Complete	The information gained has informed current strategic thinking in this area.
Technical and engineering study of contingency options for DFR breeder material	Options for long-term management of uranium enriched fuels and materials - <i>Characterisation, storage, treatment and disposal</i>	Cavendish Nuclear	12967	Informing Strategy	The purpose of this project was to produce a detailed 'Technical and Engineering Study' to be carried out to consider the technical/engineering issues associated with the contingency options for management of Dounreay Fast Reactor 'Breeder' material at Sellafield. This work has been used towards choosing a preferred contingency option for the breeder material.	Complete	The understanding gained has informed a recent strategic decision regarding this fuel.



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Plutonium							
Quality of uncharacterised plutonium powder	Understanding the suitability of the UK's plutonium inventory for re-use as MOx - <i>Investigation of methods to enable the re-use of the vast majority of UK plutonium as MOx fuel</i>	NNL	12771	Informing Strategy / Maintaining Skills	This project is part of a scheme to carry out further assessment work and laboratory scale studies to decide if out-of-specification plutonium can be made suitable for use in a MOX plant. The project is review existing information, and considering novel approaches to physically/thermally treat plutonium to allow it to be reused for manufacture of MOX fuel. Understanding the current knowledge on possible powder treatments and developing suitable test matrices is the purpose of this initial work package. This work is continuing into FY 2014/15.	Ongoing	-



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Study to develop a strategy for a Fuel Qualification Programme for MOx re-use	Understanding the suitability of the UK's plutonium inventory for re-use as MOx - <i>Investigation of methods to enable the re-use of the vast majority of UK plutonium as MOx fuel</i>	NNL	12907	Informing Strategy / Maintaining Skills	The Government's preferred option for the management of the UK's civil plutonium stocks is to reuse it as MOX fuel in a next generation of reactors. To this end, the NDA is undertaking a number of technical activities to support the business case which underpins this policy position. The project is preparing a Fuel Qualification Plan (FQP) for the use of MOX fuel manufactured from the UK stockpile of plutonium in reactors that could potentially operate in the UK (EPR, AP1000 and ABWR). The purpose of this work scope is to define the strategy and the process by which such qualification can be attained (the FQP). The FQP is expected to illustrate to the NDA how the performance of MOX fuel in potential new build reactors will be established to meet Regulatory, Utility and public expectations in terms of safety and performance compared to equivalent UO2 designs. This work is continuing into FY 2014/15.	Ongoing	-



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Advanced fuels for generation IV reactors: reprocessing and dissolution (ASGARD)	Understanding the suitability of the UK's plutonium inventory for re-use as MOx - <i>Investigation of methods to enable the re-use of the vast majority of UK plutonium as MOx fuel</i>	NNL	11170	Maintaining Skills	The NDA is continuing to develop and analyse options for the management of UK plutonium stocks. Key to this is an understanding of potential treatment options for UK plutonium prior to its reuse as fuel in new reactors. ASGARD is a European Commission Community Research and Development Information Service 7th Framework Programme (CORDIS FP7) project investigating the reprocessing and dissolution of spent fuel. The key areas of research within the project are the recycling of high plutonium-bearing oxide and carbide spent fuels, the stabilisation of plutonium-bearing oxide and carbide materials for storage and disposal and the separation processes for the treatment of spent fuels and reuse of plutonium. The project is due to continue until the end of December 2015 and is supporting key UK skills in the area of actinide processing, especially in evaluating potential options for the potential treatment of plutonium-bearing materials.	Ongoing	-



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Review of Advanced Sodium Technical Reactor for Industrial Demonstration (ASTRID) programme	Re-use of plutonium in modern reactors - <i>Benchmarking emerging technologies</i>	AMEC	13155	Informing Strategy / Maintaining Skills	One of the credible options for the management of the UK plutonium stockpile is the use of General Electric - Hitachi (GEH) PRISM technology (a metal-fuelled fast reactor with integrated fuel fabrication facility). The NDA is interested in increasing our overall understanding of fast reactor technology. It is the intention that this review of publically available information on the French ASTRID programme would support this purpose. This project is reviewing key features of the ASTRID reactor and test programme and highlighting key similarities and differences with the PRISM technology.	Ongoing	-
Options to improve MOx fuel disposability	The disposability and disposal of relevant spent fuel and immobilised plutonium	NNL	12106	Informing Strategy	The objective of this project is to explore strategies by which the disposal of MOX spent fuel can be optimised. The decay heat output of MOX fuel assemblies falls off with time at a slower rate than UO2 assemblies at the same discharge burn-up as the heat output for MOX is driven by longer lived transuranics rather than fission products. This is important because it can affect the heat load in the GDF and how this fuel would have to be managed to optimise its disposal	Complete	The understanding gained is informing current strategy and may inform the scope of future R&D projects in FY 14/15



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Title	5 year plan R&D Topic	Lead Supplier	Purchase Order	R&D Driver	Project Commentary	Project Status	Next Steps (following completion)
Front to back end options to improve the disposability of Mox spent fuel	The disposability and disposal of relevant spent fuel and immobilised plutonium	AMEC	12303	Informing Strategy	The purpose of this work is to improve our understanding of potential fuel cycle options (fuel, reactors, spent fuel management) on the disposability of MOX spent fuel and to suggest and investigate ideas to improve the disposability of MOX spent fuel without overly detrimental impacts on the economic case. In this project, the uncertainties due to nuclear data were compared for two different types of fuel: UO2 and MOX.	Complete	The understanding gained is informing current strategy and may inform the scope of future R&D projects in FY 14/15
Uranics							
Development of encapsulants for the management of the NDA-managed uranium inventory	Identification of appropriate forms for disposal	NNL	10734	Informing Strategy	This project provided a larger scale demonstration of potential encapsulants for NDA-managed uraniums. This is important as NDA-managed uraniums inventory is considerable and comprises a wide-range of material types including Magnox Depleted Uranium (MDU), uranium hexafluoride and uranium metal. For various materials containing uranium we now know what loading of material can be tolerated and how pre-treatment may enable processes to be optimised.	Complete	The understanding gained is informing current strategy and may inform the scope of future R&D projects

7 Summary

The NDA directly funded ~50 R&D projects during FY2013/14 with a value of approximately £3.1 million (2.6M in FY12/13). The majority of the spending was in Lot 1 (University Interactions) followed by Lot 4 (Spent Fuel and Nuclear Materials) as illustrated in Figure 2.

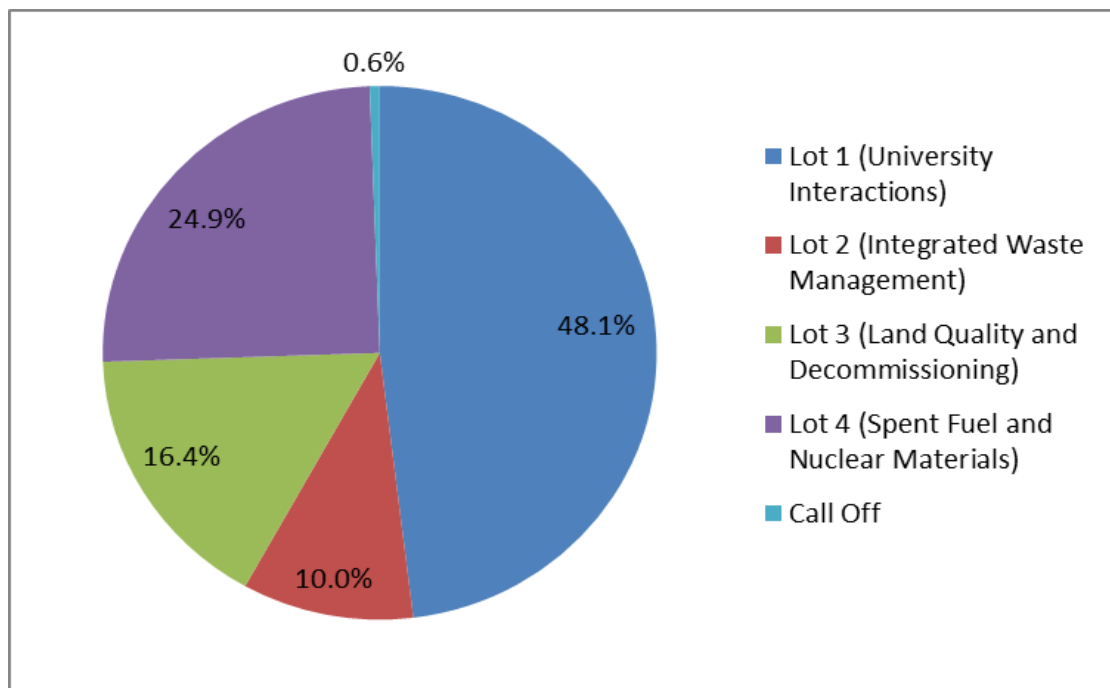


Figure 2: The percentage of £3.1M spent by the NDA in FY13/14 on DRP-funded R&D projects by Lot

This is reflective of the number of PhDs that were commissioned in FY2013/14 and also the expenditure by the NDA to ensure that the students were provided with industry guidance by the managing contractors, the National Nuclear Laboratory. Similarly, almost one quarter of the spending was invested in Lot 4, Spent Fuel and Nuclear Materials. As illustrated in Figure 3, this is reflective of the large number of projects ongoing in Lot 4, due to the NDA requirement to make progress on developing strategies in this area.

Lot 3 increased the number of projects and spending on R&D projects, in comparison with FY2012/13. Lot 2 had an increase in the number of projects ongoing but the percentage spend was lower than in FY2012/13, due to some of the laboratory-based projects not making as much progress as was intended.

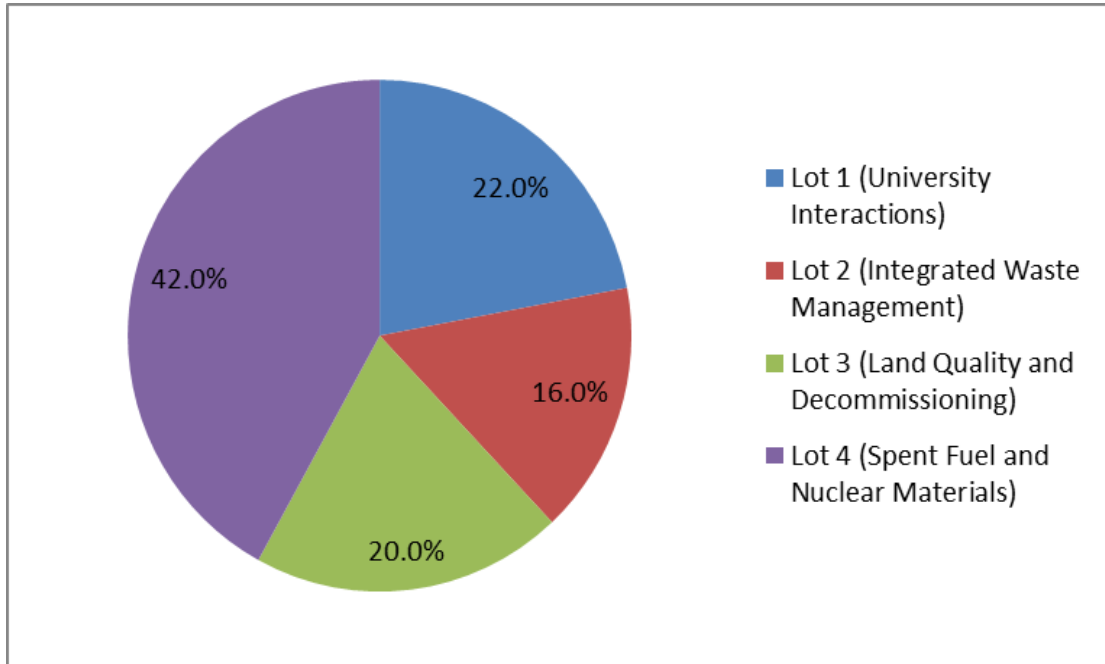


Figure 3: The percentage of the total number of DRP projects undertaken in FY13/14 by Lot

By using R&D Drivers, the NDA is now able to track the spending profile and number of projects using these differentiators. The results are shown in Figure 4 (percentage of spending) and Figure 5 (percentage of total number of projects).

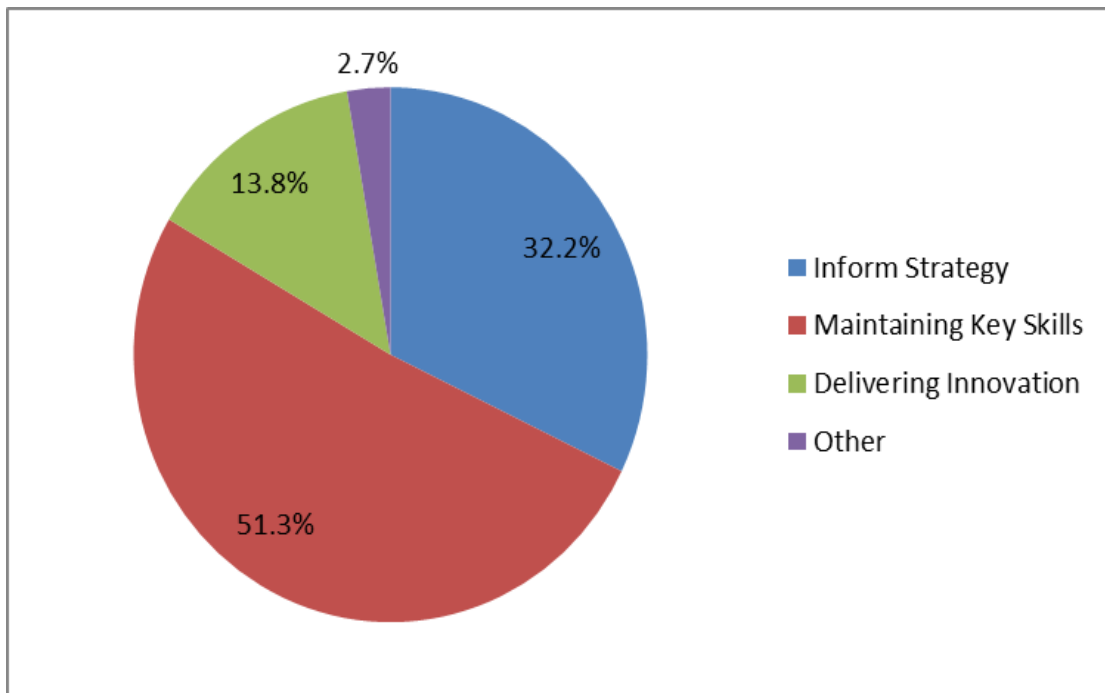


Figure 4: The percentage of the £3.1M spent in FY13/14 on DRP-funded R&D projects by R&D driver

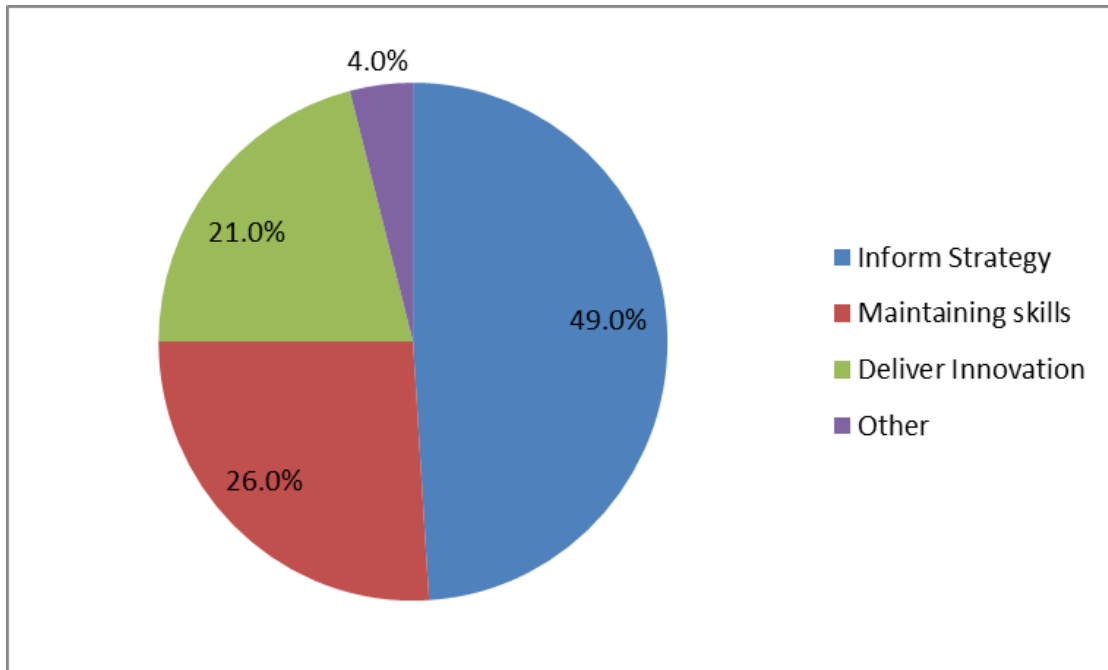


Figure 5: The percentage of the total number of DRP projects undertaken in FY13/14 by R&D driver

These two figures illustrate that Maintaining Key Skills and Informing Strategy were the key drivers in FY 2013/14.

8 Looking Forward

The NDA 5 year R&D plan set out our longer term view of what R&D we expect to focus on and a baseline from which to review our progress and update as appropriate. This document will help to ensure that our R&D portfolio is balanced and that activities continue to be aligned with our strategies as they develop.

Raising awareness and communication of NDA funded R&D work is important. The DRP contractors continue to produce summary documents upon completion of each project to help with communication. Some examples of these summaries are produced in this annual review as illustrations of the type of projects that have been undertaken in FY2013/14 and also to demonstrate their impact. Others have been turned into flyers for use at conferences. In addition, it is the NDA's intention to produce regular R&D brochures of both NDA directly funded work as well as work funded via our SLCs to raise awareness of the range of activities and demonstrate success and impact. This will be supplemented by articles in the NDA Insight magazine.

In addition to work in the DRP, the NDA supports innovation in the wider supply chain and is directly collaborating with Innovate UK (formerly the Technology Strategy Board (TSB)) on a joint innovation project called "Developing the Civil Nuclear Power Supply Chain"¹¹. The first call took place in 2012 and was supported by £18 million

¹¹ For further information please see www.connect.innovateuk.org/

of joint funding following contributions from the Engineering and Physical Sciences Research Council (EPSRC) and the Department of Energy and Climate Change (DECC). The programme supported the development of the civil nuclear power supply chain, including decommissioning, through feasibility projects, collaborative research and knowledge transfer projects. In total thirty five projects were supported across the UK to develop new technologies for the construction, operation and decommissioning of nuclear power plants. The projects have also leveraged an additional £13 million from industry making the total value of the programme £31 million. These projects involved over 60 experienced organisations including potential end users (e.g. NDA SLCs such as Sellafield Ltd, R&D organisations (e.g. National Nuclear Laboratory) and diverse organisations (e.g. large companies, universities and small and medium sized enterprises (SMEs)) both established within the market and new to the decommissioning market. It is intended that the progress made with some of these projects will be reported in the Annual Review in FY 2014/15.

In addition, a further call has taken place in 2014, concentrating specifically on feasibility studies and collaborative R&D projects. This call is jointly funded to a total of £13 million pounds by NDA, Innovate UK and DECC and is expected to bring in a further £6 million of private sector funding.

9 Direct Research Portfolio Case Studies

Radiation Sciences at The Dalton Cumbrian Facility (DCF)

The NDA recognises that the nuclear decommissioning industry has an ageing population and is committed to ensuring that young scientists and engineers have the technical knowledge to support the NDA's mission. As part of that commitment, the NDA and University of Manchester have jointly funded the Dalton Cumbrian Facility (DCF). The DCF is a facility for post-graduate and post-doctoral research into radiation sciences and decommissioning engineering. The DCF comprises offices, laboratories and a range of irradiation and analytical equipment. The building is the focus of the University of Manchester's interactions in West Cumbria.

In addition, the NDA wanted to ensure that the students and staff were guided by experienced, industry-based senior technical experts and have commissioned, via the Direct Research Portfolio, NNL to provide support to DCF in the area of Radiation Science. NNL's activities include; (i) supervision of PhD students, (ii) support to staff on radiation chemistry, (iii) preparing proposals for EPSRC funding and (iv) design of high pressure irradiation cells. In addition, students can make effective use of the local proximity of radioactive research facilities in NNL's Central Laboratory at Sellafield. Access to these facilities is funded by the Direct Research Portfolio and managed by NNL in co-operation with Sellafield Ltd.

There is now a sizeable group of research students at DCF with a vibrant working atmosphere. The facility is currently expanding its range of irradiation facilities and making them available to other academics via the National Nuclear Users Facility (NNUF). Opportunities for research to maintain skills and deliver innovation to NDA's mission continue to be sought and funded.

Challenge: To develop skills and radiation science knowledge relevant to the NDA mission.

Solution: Provision of support and supervision by National Nuclear Laboratory (NNL) staff to students and staff members of the Dalton Cumbrian Facility (DCF).

Technology: Radiation Sciences

Benefits: The development of a vibrant radiation chemistry community at DCF and the provision of skills in a key area of the NDA mission.

Status: The DCF is growing, it now has a sizeable group of research students and irradiation facilities are currently being expanded. Staff and students are benefitting from NNL's technical experience and access to NNL's Central Laboratory.

Research Organisation: National Nuclear Laboratory Ltd

Dual Beta-Gamma Probe for In-situ Measurement of Radioactively Contaminated Materials

Decommissioning redundant nuclear plant will result in the removal and disposal of radioactively contaminated concrete, masonry, soil, rock and other similar materials. By correctly categorising and segregating the material, in terms of the levels of radioactive contamination, Site Licence Companies (SLCs) can apply the most appropriate waste treatment or storage solution and save the UK taxpayer money, particularly if the material is not contaminated. Currently, this material must be sampled and sent off-site for analysis. By applying a suitable hand probe to measure beta contamination (and the subsequent gamma emissions) in-situ, time and cost savings could also be achieved.

The Nuclear Waste Research Forum Working Group on Land Quality successfully sought funding from the NDA Direct Research Portfolio to assess whether these benefits were realisable in the near-term future. The aim of this project was to identify whether dual beta-gamma probes are commercially available “off-the-shelf” or identify if the technology is in development and its current level of technical maturity. The project was led by the DRP Framework contractors AMEC Foster Wheeler and technical oversight was provided by a Land Quality expert from Research Sites Restoration Limited (RSRL), based at Harwell.

Challenge: To correctly segregate and categorise radioactively contaminated materials (e.g. concrete, soil, rock and other similar materials) at the point of the decommissioning waste arising to save analytical and disposal costs.

Solution: Conduct a literature and technology review of the state-of-the-art of dual beta-gamma hand probes.

Technology: Dual beta-gamma probe for in-situ measurement.

Benefits: Fast and accurate categorisation at source. Reduction in the volume of excavated material. More non-contaminated material available for re-use.

Status: The study clarified that there are no suitable dual beta-gamma probes available commercially. Six potentially relevant systems were identified of which two were recommended for their potential, although still at relatively early stages of development. At this stage, a watching brief on technology development is being maintained.

Research Organisations: Amec and Nuvia Ltd

A Template for Site Restoration Roadmaps – Phase 1

The NDA's end goal is to restore its sites to the point where they are released for other uses. A Site Restoration Roadmap is a potential tool to visually articulate the journey of decommissioning and remediation from where we are now, via interim states, to a final usable end state. This journey is also known as a "lifetime plan". The Site Restoration Road Maps will be living documents that are updated whenever significant changes are made to lifetime plans. The aim of the roadmap is to enable identification of issues, threats, risks and opportunities across the NDA estate and explore alternative futures of decommissioning options. Importantly, it could also be a tool to easily explain lifetime plans to stakeholders.

The first phase of this project was to develop a template for the roadmap. Firstly, the successful DRP contractor, Arup, focused on tailoring the needs of the strategy development community (i.e. NDA Strategic Authorities, SLCs, Regulators and Government). A roadmap structure was developed focusing on the NDA's key strategic themes with the flexibility to display a wide range of information and metrics. A detailed review of NDA reported information was conducted to select appropriate content. The development process also involved stakeholder engagement with the NDA, regulators and Site Licence Companies.

Challenge: To visualise NDA site lifetime plans in a concise format

Solution: Tailoring the roadmap content to meet the needs of the strategy development community. The roadmap structure was developed focusing on NDA's strategic themes, with the flexibility to display a wide range of information and metrics.

Technology: A communication tool in the form of a paper-based concept demonstrator.

Benefits: Presentation of the relevant roadmap information in a clear, consistent and comparable manner.

Status: Following approval of the concept in phase 1, a second phase has been commissioned using DRP funding to validate the concept using selective data.

Research Organisation: Arup

Use of Electrochemical Noise as a Corrosion Monitoring Technique for Used Fuel Cladding in Fuel Ponds

When fuel is removed from a reactor, it is subsequently stored under water. The water in these spent fuel ponds is chemically controlled to minimise corrosion to the external metal alloy, known as cladding. The NDA is investigating options for storage of spent fuel over extended periods until a geological disposal facility is ready, including storage in water. In order to understand what happens to fuel cladding over 25 years plus, it is necessary to ensure that Site Licence Companies have the technology to monitor early corrosion or degradation of fuel cladding in order predict the likelihood and extent of fuel failures. In turn, this will inform strategic decisions on how to manage spent fuel over the longer term.

Following an initial review of monitoring technologies, an opportunity was offered to DRP Framework Contractors to suggest other technologies that would be suitable for development. One suggestion was that ElectroChemical Noise (ECN) monitoring techniques may be viable. ECN is a technique that is used extensively elsewhere to monitor corrosion. One of its advantages is that it is a non-intrusive, passive technique, capable of measuring subtle changes at the surface of the material. Amec Foster Wheeler conducted a literature review of the viability of this technique and incorporating their own experience of using ECN in their laboratories.

Challenge: To detect early signs of corrosion of fuel cladding in chemically controlled storage ponds

Solution: To carry out a literature review to determine if monitoring ElectroChemical Noise (ECN) is viable as an in-situ monitoring technology.

Technology: Electrochemical Noise (ECN) Monitoring

Benefits: A viable monitoring technique will be able to give early warning of any corrosion initiation so that pond chemistry can be altered to inhibit any corrosion process. It should also be able to be used to predict cladding behaviour and the likelihood of fuel cladding failure.

Status: The literature review strongly indicated that electrochemical noise monitoring is a viable technique for use in spent fuel ponds. This underpinning work has resulted in Sellafield Ltd funding a research project to look at some of the issues identified in the report.

Research Organisation: Amec