nirab
NUCLEAR INNOVATION AND RESEARCH ADVISORY BOARD

# The Current Landscape for Publicly Funded Civil Nuclear R&D

NIRAB-70-4

## Purpose

This paper presents a summary of the level of publicly funded nuclear fission research in 2014/15. It also presents a summary of the arrangements for the management of research within the NDA estate, which currently dominates the public nuclear R&D funding landscape. An analysis is presented of the extent to which there is any opportunity to redirect funding to better align the research to the NIRAB recommendations without straying beyond the remit of the funding organisations.

The paper is presented for information and to inform NIRAB's future recommendations.

**At the meeting NIRAB members will be asked to endorse or propose amendments to the recommendations.**

## Introduction

The aim of NIRAB, as stated in the Terms of Reference is "*to ensure that public R&D programmes are aligned to support industrial and energy policy, and to maximise synergy across different aspects of the nuclear sector, including fusion and the NDA portfolio*". The Terms of Reference also explicitly identify the need for NIRAB *"To oversee a regular review of the nuclear research and innovation capability, portfolio and capacity in the UK…"*

At the 6th meeting of NIRAB the Chair highlighted the fact that NIRAB needs to review the entire public R&D funding landscape in order to meet these requirements. The purpose of carrying out such a review will be to establish sufficient understanding of the current public funding landscape to determine whether there is any potential to redirect public funds to better effect. This paper sets out an initial analysis of the current public funding landscape for civil nuclear R&D and comments of the extent to which opportunities have been identified to redirect funding to meet the recommendations set out by NIRAB in its first annual report without prejudicing the ability of current funders to meet their remit.

## Public sector nuclear R&D funders

Public funding for civil nuclear R&D is primarily channelled through a small number of organisations including the Nuclear Decommissioning Authority (NDA), the NDA Site License Companies (SLCs), the Research Councils (primarily EPSRC, but also including NERC and STFC) and Innovate UK. Figure 1 illustrates the level of civil nuclear R&D expenditure by each organisation in the 2014/15 financial year.

### NDA Estate

#### Sellafield Ltd

In 2014/15 the NDA estate accounted for more than 80% of the public sector expenditure on nuclear R&D. In practice the NDA estate R&D expenditure is dominated by Sellafield Ltd.

Taking this factor into account the NDA Chair and the NIRO Director met with senior representatives of NDA and Sellafield Ltd to gain a detailed understanding of expenditure on R&D across the NDA estate with a view to answering the following questions:

- How much does the NDA estate spend on R&D and innovation?
- What is it being spent on?
- What are the drivers to spend this money now?
- How is the R&D budget controlled?

The aim was to be able to formulate a view to be taken on the extent of the potential to adjust either the content or timing of the NDA programme to better address any of the R&D gaps identified by NIRAB, whilst recognising that any adjustment must neither damage the ability to meet NDA's needs nor cut across NDA's vires.

Figure 2 shows the planned expenditure in 2014/15 and Figure 3 shows a projection of the lifetime expenditure on R&D by the NDA SLCs. These figures show that Sellafield Ltd expenditure dominates in the short term (about 75% of SLC total) and even more dominant in the long term (84% of SLC total). A number of salient facts emerged from a discussion of the scope and governance of R&D funded by Sellafield Ltd.

1. About 95% of the Sellafield Ltd R&D budget is managed either by the major decommissioning projects in carrying out the development needed to deploy the technology required for the project or is the application of technology to complete the reprocessing missions. In practice this means that this expenditure primarily funds the late stage development of technologies that have already been selected.
2. Inspection of Figure 4 shows that in 2014/15 R&D expenditure was dominated by projects associated with some of the highest hazard facilities (and consequently highest priority) on the Sellafield Site including the Magnox Swarf Storage Silos (MSSS), Highly Active Liquor (HAL) storage tanks, the Pile Fuel Cladding Silo (PFCS) and the First Generation Magnox Storage Pond (FGMSP). Late stage development is inevitably expensive when it involves either large scale engineering demonstrations or active demonstrations of technologies developed using non-active or trace active simulants. Examples of costly but necessary large scale projects include one funded by the Magnox Swarf Storage Silo project to integrate and adapt commercially available industrial 500 kg capacity robots to handle solid wastes retrieved from the silos. The Highly Active Liquor project has funded the construction and operation of a 4:10th scale Jet Ballast rig to establish the effectiveness of the re-suspension, agitation and transfer systems for a range of conditions during future Post Operational Clean-Out operations in relation to Highly Active Storage Tanks.
3. The balance of the Sellafield Ltd R&D expenditure is controlled by a small central technology function. This technology function provides some oversight and review of the R&D funded by projects to ensure that an appropriate balance is maintained and that the management of R&D within separate projects does not result in unintended consequences. For example a site wide perspective is

maintained to ensure that, a single project does not take action to shut down facilities that will be needed by other projects in the future.

4. The technology function also invests in the development of Centres of Expertise and other capability programmes in order to ensure that Sellafield Ltd can continue to access the skills and expertise needed to underpin its decommissioning mission. There are currently 25 Centres of Expertise, as listed in Table 2. The technology function commissions work through these Centres of Expertise on behalf of, or in conjunction with decommissioning projects to ensure capability and knowledge is available to projects across the NDA estate. An example of this would be the work of the Flammable Gas Centre of Expertise to better understand and characterise the ignition of hydrogen gas mixtures via both mechanical and electrostatic stimuli. This knowledge is key to a number of safety cases across the Sellafield site. This principle is similarly illustrated by work led by the central Technology function to consider longer term application of technologies such as the development of thermal treatment for waste conditioning and development of muon tomography for characterisation.
5. The Technology function also commissions a small amount of early stage research driven by the site wide priorities which are themselves driven by considerations including risk and hazard reduction.
6. The Technology function allocates funding to address research needs and to mitigate risks. More than 100 topics have been identified where carrying out research could help to realise opportunities. However the current allocation of research budget is insufficient to address any of these opportunities.
7. The extent to which research is driven by decommissioning milestones and site wide priorities, including risk and hazard reduction, means that innovation is usually regarded as a low priority.

## Other NDA SLCs

Although the level of R&D expenditure across the remainder of the NDA estate is much lower than that at Sellafield there is the same focus on late stage technology development. For example DSRL fund R&D relating to decommissioning the Dounreay shaft and silo is a key priority. The DSRL programme also includes remote handling programmes to support the implementation of decommissioning, waste conditioning and storage for a number of waste streams.

The Magnox technical programme is also project/programme led with work streams including characterisation and dismantling of pond furniture and structures and waste conditioning using encapsulation or polymeric materials. The Magnox programme also includes R&D relating to site clearance on the Winfrith and Harwell sites.

A number of cross industry working parties have been established to direct and make best use of technologies funded by NDA. These include representatives from NDA, SLC's and the wider UK Nuclear Industry.

## NDA

Although research funding across the NDA estate is dominated by the SLCs the NDA also commissions research directly to address the following objectives:

- To inform the NDA's strategy. This might involve commissioning research to technically underpin strategic decisions or to mitigate risks associated with strategy implementation.
- To support innovation relevant to multiple SLCs. This includes innovation to deliver either incremental or step-change improvements in technology relevant to the decommissioning mission.
- To maintain key technical skills. NDA will support the maintenance of key technical skills to address existing estate-wide capability gaps or to address strategic gaps that can be identified in the future.

The majority of research funding is commissioned through the Direct Research Portfolio which is managed through 4 Lots which align to the NDA strategies, as follows:

- University interactions
- Integrated waste management
- Site restoration
- Nuclear materials and spent fuels

In addition to research funded through the Direct Research Portfolio the NDA also funds the following research activities:

- Part of the cost of UK membership of the NEA databank
- Co-funding innovation projects with Innovate UK
- Radiation epidemiology and radiobiology

Where possible NDA seeks to leveraged its investment in research through collaboration.

## Research Councils

The Research Councils have a remit to support underpinning or fundamental research capabilities and fund a diverse programme of research projects. In discharging this remit the Research Councils also fund research which addresses scientific challenges that may be informed by real world problems. There has not yet been the opportunity to carry out a detailed analysis of the nuclear fission research portfolio. A list of research projects is reproduced in Appendix 1. This comprises all of the projects that were live in 2015 and therefore excludes projects completed before this time and any project which may have been approved, but had not started at that time. The projects are collected together by research theme. The title of each project is listed along with the size of the grant and the institution to which the grant is awarded. The projects vary in duration from 1 year to more than 8 years. The following salient features can be identified:

- The bulk of nuclear R&D is funded directly by the research councils, although there are also examples of collaboration with other funders. For example the Research Councils collaborated with Innovate UK and co-funded academic participation in some projects funded and co-ordinated by Innovate UK. Similarly NDA has

collaborated with the Research Councils to co-fund research primarily in areas relevant to geological disposal.

- A number of projects are funded with the express intention of furthering collaborations with international partners, for example India, Japan, South Korea, and the USA.

Taking into account the lead time for preparing and publishing research calls, preparing grant applications and peer review almost all of the existing grants will have begun their life before NIRAB was formed in January 2014. Nonetheless the majority of current projects align with either the NDA mission or the research needs identified by NIRAB.

Research Council spend on nuclear fission R&D in 2014/15 was approximately £12M.

In addition the Research Councils also fund nuclear fusion research. Some of this research is relevant to nuclear fission. For example the fusion programme includes, for example, research into materials, remote handling, tritium handling, neutronics, nuclear data and other cross-cutting areas such as health and safety, radiation protection etc. About £1M of the public funding for fusion funds research relevant to nuclear fission.

## Innovate UK

Innovate UK has awarded research funding in 3 competitions:

- Developing the Civil Nuclear Supply Chain (2012)
- Developing the Civil Nuclear Supply Chain (2014)
- Energy Catalyst (Round 1)

The Civil Nuclear Supply Chain competitions resulted in the award of funds for short feasibility studies and larger collaborative projects. Appendix 2 lists the projects that are currently being funded by Innovate UK. The total spend in 2014/15 was approximately £5M.

## National Nuclear Laboratory

The National Nuclear Laboratory (NNL) is owned by the Department of Energy and Climate Change (DECC) and operates on a commercial basis. A proportion of its profits are reinvested in research activities that are of strategic importance to the nuclear industry. This is carried out in 4 broad areas, as follows:

- **Nuclear energy** – including research on fuel fabrication and fuel performance as well as spent fuel and nuclear materials management
- **Waste management, decommissioning and disposal** – including all aspects of managing legacy facilities, wastes and materials as well as the immobilisation and processing aimed at producing waste forms suitable for safe interim storage and subsequent geological disposal.
- **Nuclear security** – including research associated with the security of nuclear facilities and materials, with a key focus on non-proliferation of nuclear technology and materials.

The total spend on these programmes in 2014/15 was approximately £2M.

## Summary

Public sector expenditure in 2014/15 was dominated by the NDA estate. An inspection of the management arrangements and the near term and long term priorities leads to the following conclusions:

1. Public sector nuclear R&D expenditure is dominated by the NDA estate. Within the NDA estate the total expenditure is dominated by Sellafield Ltd.
2. The vast majority of R&D expenditure across the NDA estate is needs driven and funds the late stage development of technologies that have already been selected for deployment on decommissioning projects. This R&D is crucial to the timely implementation of decommissioning projects. In the short term the priority is the decommissioning of the highest hazard, and consequently highest priority, facilities on the Sellafield site. This late stage development of technology for deployment is inevitably expensive, frequently involving the construction of large inactive rigs to prove technology prior to deployment in active environments or development work using active materials. This development work is an essential enabler to ensure that site decommissioning milestones can be met.
3. The balance of the SLC R&D budget funds:
    - Centres of Expertise and capability programmes to ensure that the NDA continues to be able to access the capabilities needed to underpin its mission
    - Early-stage development driven by site priorities associated with risk and hazard reduction
4. R&D expenditure across the NDA estate is running at the minimum levels required to support the NDA's decommissioning mission and mitigate the key risks associated with that mission.
5. No opportunity has been identified to make significant savings within the NDA R&D budget or to redirect funds to better support the R&D programme recommended by NIRAB in its Annual Report.
6. A significant proportion of Research Council funding for nuclear R&D aligns broadly with either NIRAB or NDA priorities at the level of individual projects.

## Recommendations

Based on the information presented in this paper NIRAB recommends that:

1. Sellafield Ltd reviews its process for managing R&D to ensure that the management process itself does not stifle innovation.
2. The NDA estate finds the opportunity to increase funding for R&D to develop innovative solutions to support the decommissioning mission.
3. NIRAB's research recommendations are used, to the extent possible within the remit of the Research Councils, to shape future calls for directed programmes or capital investment issued by both Research Councils and Innovate UK (recognising that the normal peer review process and the Haldane principle will then apply).

Figure 1 2014/15 public sector nuclear R&D expenditure

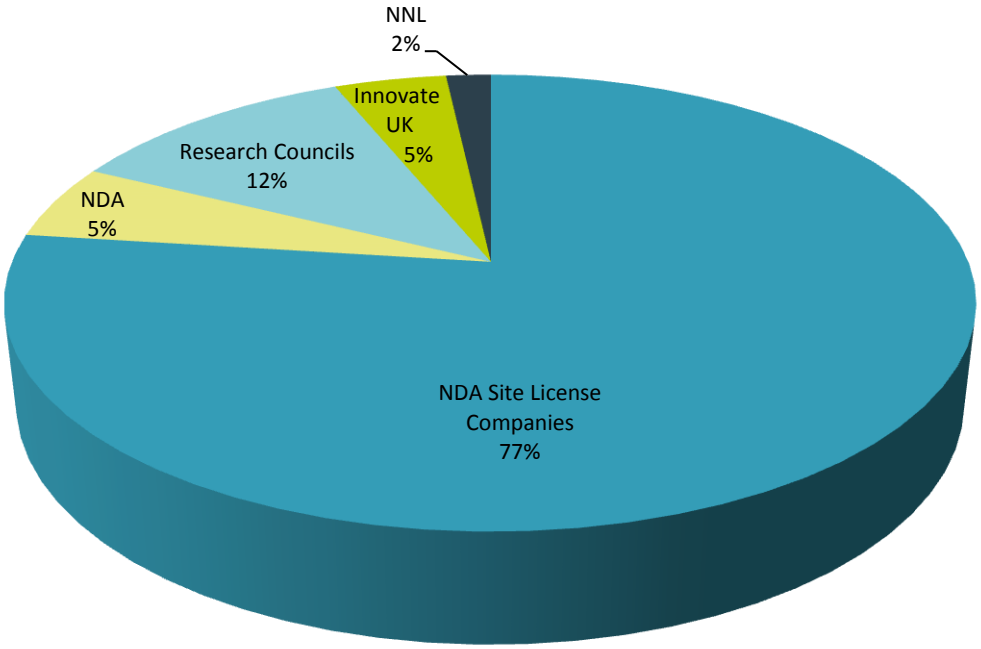


Table 1 Data supporting Figure 1

| Organisation | 2014/15 Spend / £M |
|---|---|
| NDA Site License Companies | 87 |
| Research Councils | 13 |
| Innovate UK | 5 |
| NDA | 6 |
| NNL | 2 |
| Total | 113 |

Notes

1. Figures rounded to nearest £1M
2. There could be a small double count arising from NDA and Research Council co-funding of Innovate UK projects

Figure 2 Planned NDA Site License Company expenditure on R&D in 2014/15

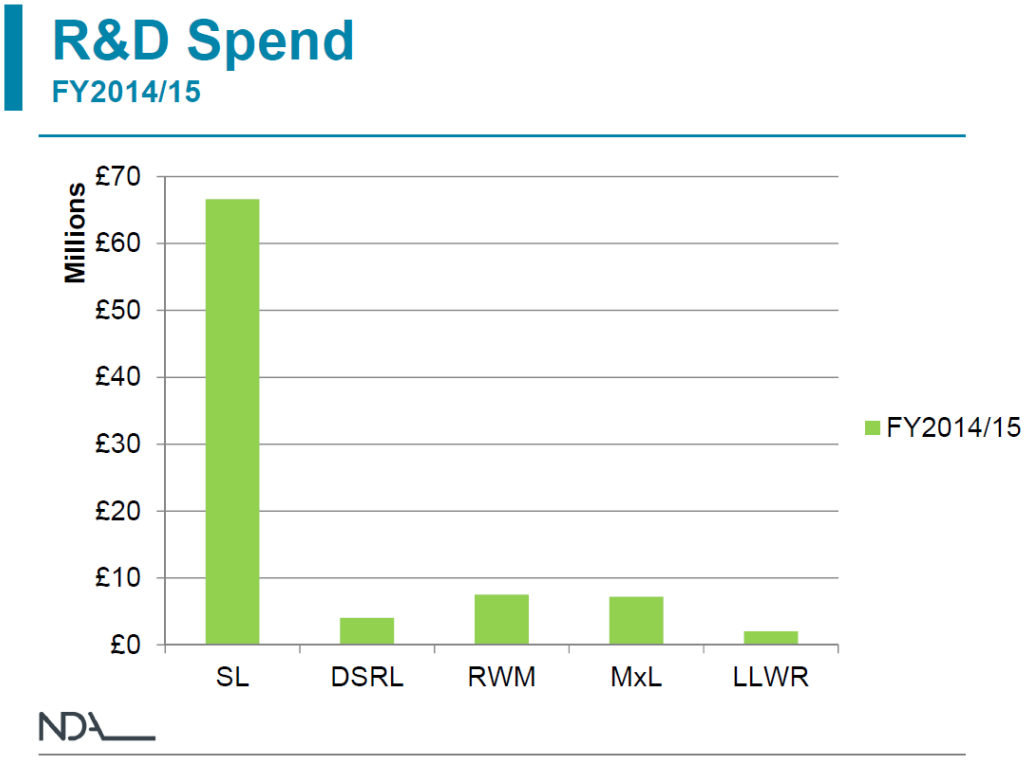


Figure 3 Lifetime projection of NDA Site License Company expenditure on R&D

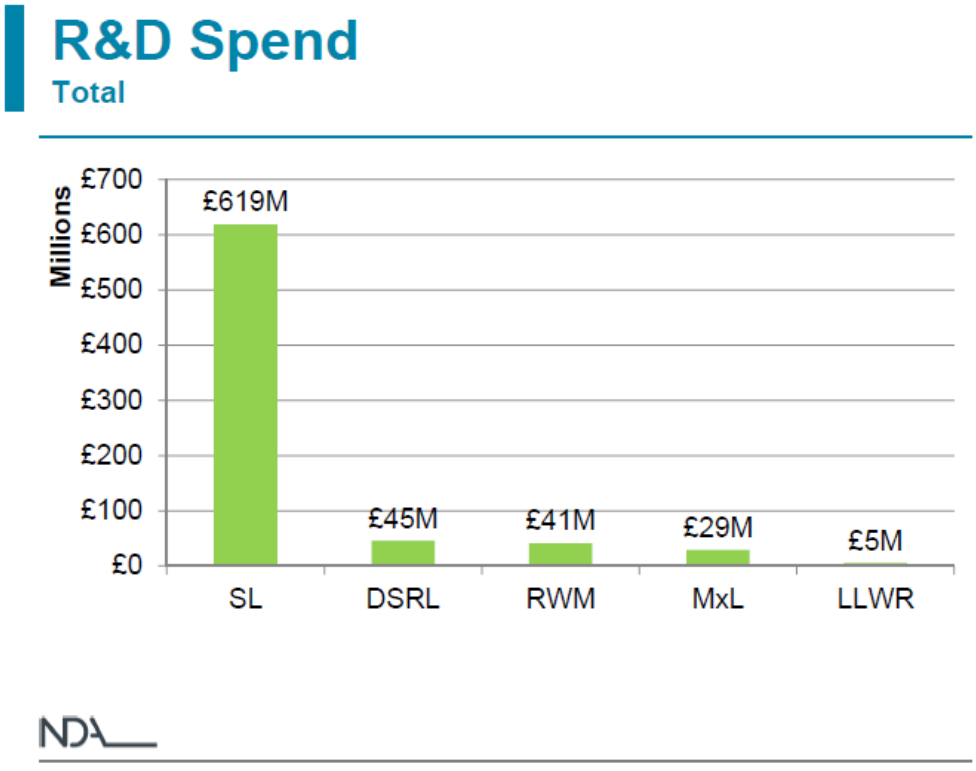

Figure 4 Planned Sellafield Ltd expenditure on R&D in 2014/15

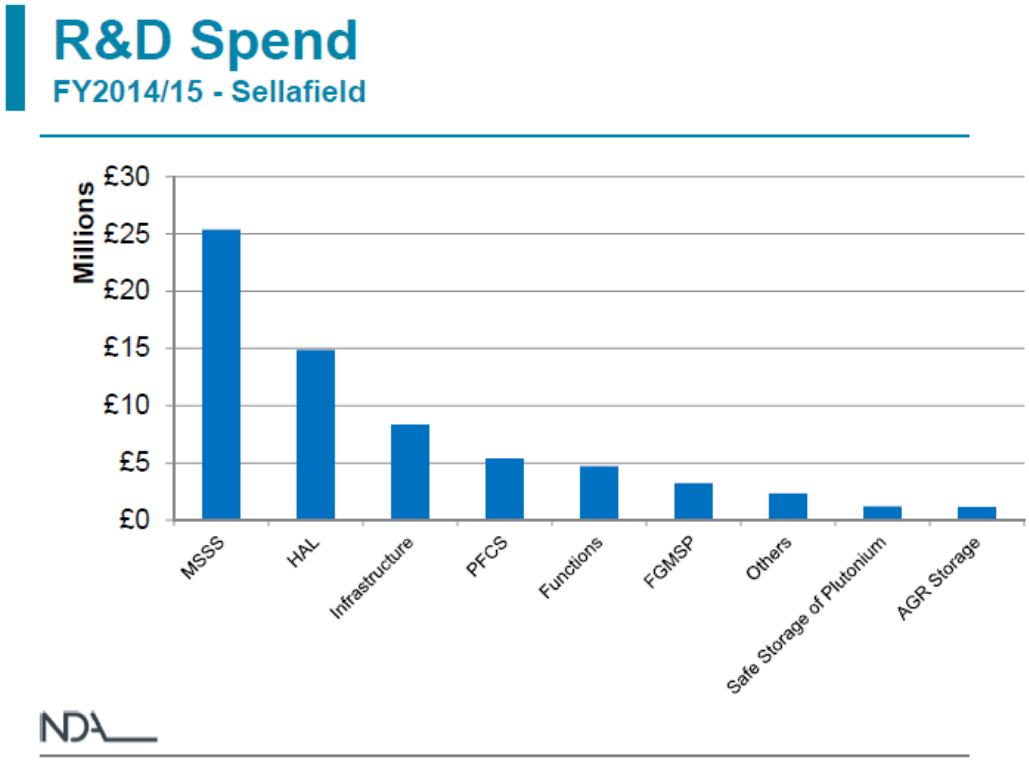


Figure 5 Lifetime projection of Sellafield Limited expenditure on R&D by project area

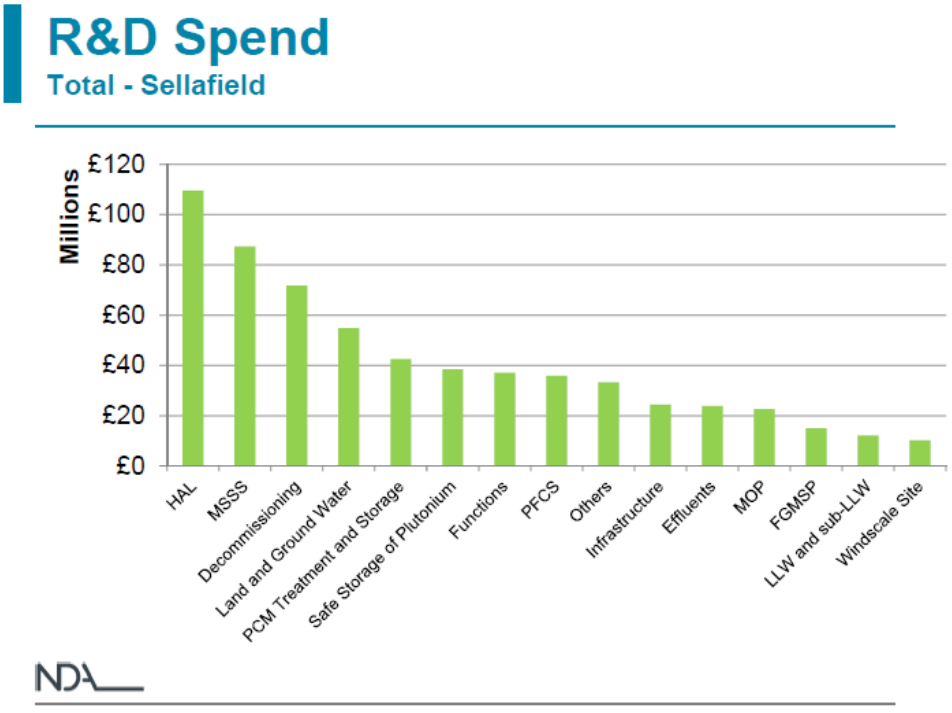

Table 2 Sellafield Ltd Centre of Expertise

| | |
|---|---|
| Alpha Processing & Storage | Material Science |
| Analytical Chemistry | Modelling and Simulation |
| Autonomous Intelligent Systems | Nuclear Physics |
| Cement chemistry | Polymers |
| Contaminated Land and Ground water management | Safeguards |
| Decanning and Dismantling | Sludge |
| Decommissioning Technologies | Spent Fuel Storage |
| Decontamination | Thermal Treatment Technologies & Vitrification |
| Effluent technologies | U/Pu (and other actinide) Chemistry and Processing |
| Environmental | Uranium and Reactive metals |
| Flammable Gas & Radiolysis | Waste & Facility Characterisation |
| HALES Processes and Chemistry | Waste Segregation and Compaction |
| Maths and Statistics | |

## Appendix 1 Summary of lifetime cost of current projects funded by Research Councils

| | Title | University | From | To | Value |
|---|---|---|---|---|---|
| Training | Nuclear Fission Research, Science and Technology DTC (Nuclear FiRST)- Underpinning UK Energy and Defence Strategies | The University of Manchester | 01-Oct-09 | 31-Mar-18 | £7,063,271 |
| | Industrial Doctorate Centre: Nuclear Engineering | The University of Manchester | 01-Oct-09 | 31-Mar-18 | £3,591,267 |
| | EPSRC Centre for Doctoral Training (CDT) in Nuclear Fission-Next Generation Nuclear | The University of Manchester | 01-Apr-14 | 30-Sep-22 | £5,181,479 |
| | EPSRC Centre for Doctoral Training in Nuclear Energy: Building UK Civil Nuclear Skills for Global Markets. | Imperial College London | 01-Apr-14 | 30-Sep-22 | £4,153,231 |
| | | | | | **£19,989,248** |

| | Title | University | From | To | Value |
|---|---|---|---|---|---|
| Safety | Reactor core-structure re-location modelling for severe nuclear accidents | Imperial College London | 30-Nov-14 | 29-Apr-17 | £244,071 |
| | Design and Maintenance of Nuclear Safety Systems for Life Extension (DaMSSLE) | University of Nottingham | TBC | TBC | £558,355 |
| | Grace Time | Imperial College London | TBC | TBC | £692,524 |
| | Smart on-line monitoring for nuclear power plants (SMART) | Kingston University | TBC | TBC | £304,924 |
| | | University of Liverpool | TBC | TBC | £96,890 |
| | | University of Reading | TBC | TBC | £185,588 |
| | | | | | **£2,082,352** |

| | Title | University | From | To | Value |
|---|---|---|---|---|---|
| Nuclear Champion Group / NNUF / Networks | Nuclear Universities Consortium for Learning, Engagement And Research: NUCLEAR (funding includes NNUF) | Imperial College London | 01-May-11 | 30-Apr-15 | £15,534,654 |
| | Indo-UK Civil Nuclear Network | Imperial College London | TBC | TBC | £203,313 |
| | | | | | **£15,737,967** |

## Appendix 1 Continued

| | Title | University | From | To | Value |
|---|---|---|---|---|---|
| Decommissioning, Waste, Geo-disposal | In situ time-dependent characterisation of corrosion processes in nuclear waste storage and GDF environments | University of Birmingham | 01-Oct-11 | 31-Mar-15 | £746,015 |
| | Atomistic modelling and experimental verification of vitrified matrices for waste encapsulation | Loughborough University | 01-Oct-12 | 30-Sep-15 | £502,863 |
| | The Post-Disposal Behaviour of C-14 and Irradiated Graphite | University of Huddersfield | 01-Sep-11 | 31-May-15 | £728,414 |
| | Behaviour of UK Specific Spent Fuel under conditions relevant to Geological Disposal | University of Cambridge | 24-Aug-11 | 23-Aug-15 | £728,842 |
| | Atomic and Macro-scale Studies of Surface Processes: Towards a Mechanistic Understanding of Surface Reactivity and Radionuclide Binding Mechanisms | Imperial College London | 01-Apr-12 | 31-Mar-16 | £961,432 |
| | Performance Assessment and Development of Mineral-Based Cements at High Pressure and Temperature for Deep Borehole Disposal of HLW and SNF | University of Sheffield | 01-Oct-13 | 30-Sept-16 | £424,704 |
| | Decommissioning, Immobilisation and Storage soluTIons for NuClear wasTe InVEntories (DISTINCTIVE) | University of Leeds | 01-Feb-14 | 31-Jan-18 | £4,905,730 |
| | SAFE Barriers - a Systems Approach For Engineered Barriers | University of Strathclyde | 01-Apr-12 | 31-Mar-16 | £1,339,398 |
| | Robotic systems for retrieval of contaminated material from hazardous zones | University of Birmingham | 01-Apr-15 | 31-Mar-18 | £556,624 |
| | Silicate Nanoparticles for Extraction of Radionuclides (SINNER) | University of Sheffield | 01-Apr-15 | 31-Mar-18 | £315,475 |
| | Innovative separation of Caesium and Strontium using flotation and magnetic particles, to convert large waste volumes into small waste packages | University of Leeds | 30-Apr-15 | 29-Mar-18 | £317,663 |
| | Extraction of radionuclides by functionalised silica coated magnetic nanoparticles and their subsequent vitrification. | University of Reading | 09-Apr-15 | 08-Apr-18 | £120,287 |
| | Advanced Waste Treatment using Nanostructured Hybrid Composites | University of Reading<br>University of Central Lancashire | 09-Apr-15<br>09-Apr-15 | 08-Apr-18<br>08-Apr-18 | £202,604<br>£183,809 |
| | | | | | **£12,033,862** |

| | Title | University | From | To | Value |
|---|---|---|---|---|---|
| Radioactivity and the Environment | Long lived radionuclides in the surface environment | The University of Manchester | 01-Oct-13 | 30-Sep-19 | £2,619,153 |
| | Transfer Exposure effects | NERC centre for ecology and hydrology | 01-Oct-13 | 30-Sep-19 | £2,506,869 |
| | Hydromechanical and Biogeochemical Processes in fractured Rock Masses in the vicinity of a Geological Disposal Facility for Radioactive Waste. | Imperial college London | 01-Oct-13 | 30-Sep-19 | £2,351,413 |
| | Novel restoration materials for clean-up of radionuclides in the environment | University of Birmingham | 01-Nov-14 | 31-Mar-17 | £257,195 |
| | | | | | **£7,734,630** |

Appendix 1 Continued

| | Title | University | From | To | Value |
|---|---|---|---|---|---|
| Nuclear Systems | Validation & Verification for Critical Heat Flux and CFD | Imperial College London | 01-Oct-10 | 31-May-15 | £207,496 |
| | Thermal Hydraulics for Boiling and Passive Systems | Imperial College London | 01-Oct-12 | 17-Dec-15 | £796,575 |
| | Nuclear Data: Fission Yields, Decay Heat and Neutron Reaction Cross Sections | University of York | 01-Oct-10 | 31-Mar-15 | £96,021 |
| | | University of Surrey | 01-Oct-10 | 31-Mar-15 | £173,964 |
| | | The University of Manchester | 01-Jul-10 | 31-Mar-15 | £294,964 |
| | Transferability of small-specimen data to large-scale component fracture assessment | The University of Manchester | 01-Oct-12 | 30-Jun-15 | £524,298 |
| | Adaptive hierarchical radiation transport methods to meet future challenges in reactor physics | Imperial College London | 01-Dec-11 | 30-Nov-15 | £1,159,335 |
| | DMW-Creep: Influence of Inhomogeneity on Creep of Dissimilar Metal Welds | University of Bristol | 01-Oct-12 | 30-Sep-16 | £752,157 |
| | New Nuclear Manufacturing (NNUMAN) | The University of Manchester | 01-Oct-12 | 30-Sep-17 | £4,078,015 |
| | Active Sensor Structures for Extreme Environments | Newcastle University | 01-Oct-11 | 31-Mar-15 | £474,858 |
| | Integral Inherently Safe Light Water Reactor (I2S-LWR) | University of Cambridge | 01-Jan-13 | 31-Dec-15 | £278,731 |
| | Advanced structural analysis for the UK nuclear renaissance | University of Bristol | 31-Aug-15 | 30-Aug-18 | £289,499 |
| | Predictive Modelling for Nuclear Engineering | Imperial College London | 01-Jan-16 | 31-Dec-20 | £662,151 |
| | Indo - UK: Premature, Oscillation-Induced Critical Heat Flux ("Premature OICHF") | Imperial College London | TBC | TBC | £114,842 |
| | | | | | **£9,902,906** |

| | Title | University | From | To | Value |
|---|---|---|---|---|---|
| Nuclear Fuel | Enhancing nuclear fuel efficiency through improved understanding of irradiation damage in zirconium cladding | The University of Manchester | 01-Jan-11 | 31-Dec-15 | £1,499,011 |
| | Fundamental Properties of Thoria Based Mixed Oxides | Imperial College London | 01-Oct-12 | 30-Sep-16 | £380,770 |
| | Fundamentals of the Behaviour of Fission Products in Oxide Nuclear Fuels | University of Oxford | 01/08/2013 | 31/07/2018 | £780,352 |
| | PACIFIC - Providing a Nuclear Fuel Cycle in the UK for Implementing Carbon Reductions | The University of Manchester | 01-Mar-14 | 28-Feb-18 | £3,053,898 |
| | Advanced Waste Management Strategies for Technetium and Iodine in the Nuclear Fuel Cycle | University of Sheffield | 01-Apr-15 | 31-Mar-18 | £526,604 |
| | | | | | **£6,240,635** |

## Appendix 1 Continued

| | Title | University | From | To | Value |
|---|---|---|---|---|---|
| Materials | Irradiation Effects on Flow Localisation in Zirconium Alloys | The University of Manchester | 01-Apr-11 | 31-Mar-15 | £318,896 |
| | Indo - UK Civil Nuclear Collaboration on Damage and Radiation Effects in Amorphous Materials (DREAM) | University of Sheffield | 01-Dec-10 | 31-May-15 | £217,384 |
| | Performance and Reliability of Metallic Materials for Nuclear Fission Power Generation | Loughborough University | 01-Dec-10 | 31-Mar-15 | £106,955 |
| | REFINE: a coordinated materials programme for the sustainable REduction of spent Fuel vital In a closed loop Nuclear Energy cycle | University College London | 01-Oct-11 | 30-Sep-15 | £215,399 |
| | | University of Edinburgh | 01-Oct-11 | 30-Sep-15 | £1,099,515 |
| | | University of Nottingham | 01-Dec-11 | 30-Nov-15 | £445,520 |
| | | University of Cambridge | 23-Mar-12 | 22-Mar-16 | £276,871 |
| | | The University of Manchester | 06-Feb-12 | 05-Feb-16 | £340,674 |
| | Ceramic Coatings for Clad (The C^3 Project): Advanced Accident-Tolerant Ceramic Coatings for Zr-alloy Cladding | University of Sheffield | 01-Jan-13 | 31-Dec-15 | £1,075,144 |
| | Engineered Zircaloy Cladding Modifications for Improved Accident Tolerance of LWR Fuel | University of Manchester | 01-Jan-13 | 31-Dec-15 | £990,300 |
| | Materials for fusion & fission power | University of Oxford | 01-Dec-09 | 31-Mar-15 | £5,810,166 |
| | Atomistic Scale Study of Radiation Effects in ABO3 Perovskites | University of Oxford | 22/11/2013 | 21/05/2017 | £960,559 |
| | | University of Huddersfield | 22/11/2013 | 21/05/2017 | £292,083 |
| | | University of Sheffield | 22/11/2013 | 21/05/2017 | £472,588 |
| | | Imperial College | 22/11/2013 | 21/05/2017 | £240,879 |
| | A whole-life approach to the development of high integrity welding technologies for Generation IV fast reactors | The University of Manchester | 01-Apr-14 | 31-Mar-19 | £1,024,548 |
| | High Fidelity Ion Beam Simulation of High Dose Neutron Irradiation | The University of Manchester | 01-Apr-14 | 31-Mar-17 | £507,738 |
| | US DOE IRP on Simulation of Neutron Irradiation | University of Oxford | 01-Feb-14 | 31-Jan-17 | £495,253 |
| | Radiation Damage in Nanoporous Nuclear Materials | University of Huddersfield | 01-Apr-15 | 31-Mar-18 | £390,552 |
| | | University of Surrey | 01-Apr-15 | 31-Mar-18 | £291,341 |
| | UNIGRAF: Understanding and Improving Graphite for Nuclear Fission | Loughborough University | 01-Jun-15 | 31-May-18 | £132,474 |
| | | University of Oxford | 01-Jun-15 | 31-May-18 | £204,107 |
| | | Loughborough University | 01-Jun-15 | 31-May-18 | £487,427 |
| | Carbides for Future Fission Environments (CAFFE) | University of Cambridge | 01-Apr-15 | 31-Mar-19 | £437,733 |
| | | Imperial College London | 01-Apr-15 | 31-Mar-19 | £458,983 |
| | | The University of Manchester | 01-Apr-15 | 31-Mar-19 | £357,974 |
| | Corrosion and hydrogen pick-up mechanisms in zirconium nuclear fuel cladding alloys in active environments | University of Oxford | 01-Apr-15 | 31-Mar-18 | £579,688 |
| | Understanding the In-Reactor Performance of Advanced Ceramic Cladding Materials | The University of Manchester | 01-Apr-15 | 30-Sep-17 | £244,598 |
| | A Study of the Combined Effects of Displacement Damage and Helium Accumulation in Model Nuclear Materials | University of Huddersfield | 24-Feb-15 | 23-Aug-18 | £889,839 |
| | ZEISS Xradia 520 Versa High-Resolution 3D X-ray Tomography Microscope System | University of Bristol | 01-Aug-15 | 31-Jul-17 | £821,058 |
| | Glass-Ceramics: Damaging Bubble Formation | University of Sheffield | TBC | TBC | £419,114 |
| | From Processing to Simulated In-Reactor Performance of Zr Cladding. | The University of Manchester | TBC | TBC | £485,809 |
| | | University of Sheffield | TBC | TBC | £24,132 |
| | Extension to Transferability of Small-Specimen Data to Large-Scale Component Fracture Assessment (TRANSFER-EXT) | The University of Manchester | TBC | TBC | £15,914 |
| | Diffusion Bonding Titanium Alloys to Stainless Steels | Open University | TBC | TBC | £31,113 |
| | Effect of Zr on the microstructure of corrosion resistant ODS steels | University of Oxford | TBC | TBC | £291,890 |
| | | | | | **£21,454,218** |

Appendix 1 Continued

| | Title | University | From | To | Value |
|---|---|---|---|---|---|
| Nuclear Supply Chain (with Innovate UK) | The Development of Nuclear Manufacturing Techniques for Nuclear Applications | University of Sheffield | 01-Mar-13 | 30-Apr-15 | £170,405 |
| | Advancement of Castings in the Nuclear Supply Chain | University of Sheffield | 07-Jan-13 | 06-Jan-15 | £178,154 |
| | Intelligent Condition Monitoring for Civil Nuclear Structures | University of Bristol | 01-Apr-13 | 30-Sep-15 | £123,535 |
| | Fracture of Graphite Fuel Bricks | The University of Manchester | 01-Apr-13 | 31-Mar-15 | £411,438 |
| | High temperature radiation hard detectors (HTRaD) | Brunel University | 01-Apr-13 | 31-Mar-16 | £645,849 |
| | Optimisation of large concrete DfMA structures for the Nuclear Industry | Imperial College London | 07-Jan-13 | 06-Jan-16 | £266,364 |
| | On line and global structural health monitoring of high temperature steam lines | Brunel University | 01-Mar-13 | 29-Feb-16 | £174,908 |
| | Innovative Forging and Fabrication Solutions for the Nuclear Industry | Sheffield Hallam University | 01-May-15 | 31-Oct-17 | £138,010 |
| | | University of Sheffield | 01-May-15 | 30-Apr-18 | £119,903 |
| | | | | | **£2,228,566** |

Summary of the lifetime cost of current Research Council funded projects

| Topic | Lifetime grant value / £k |
|---|---|
| Training | £19,989,248 |
| Safety | £2,082,352 |
| Nuclear Champion / NNUF / Networks | £15,737,967 |
| Decommissioning , waste and geo-disposal | £12,033,862 |
| Radioactivity and the Environment (RATE) | £7,734,630 |
| Nuclear Systems | £9,902,906 |
| Nuclear Fuel | £6,240,635 |
| Materials | £21,454,218 |
| Nuclear supply chain (with Innovate UK) | £2,228,566 |
| | £97,404,382 |

Appendix 2 Summary of the lifetime cost of live research projects funded by Innovate UK

**Developing the Civil Nuclear Supply Chain (2012) – Collaborative R&D projects**

| Project Title | Grant |
|---|---|
| LaserSnake2 | £5,653,710 |
| The Development of Novel Manufacturing Techniques for Nuclear Applications | £1,097,589 |
| Environmental Impact on the Structural Integrity of Nuclear Components | £1,085,854 |
| Advancement of castings in the Nuclear Supply Chain | £1,060,375 |
| Optimisation of large concrete DfMA structures for the Nuclear Industry | £998,988 |
| Plasma Vitrification of Intermediate Level Waste | £857,853 |
| High temperature radiation hard detectors (HTRaD) | £845,849 |
| The Influence of Graphite Irradiation Creep on Plant Life Optimisation | £726,863 |
| REsidual Stress and structural Integrity Studies using Thermography (RESIST) | £650,217 |
| Measurement and modelling of sludge transport and separation processes | £591,953 |
| Fracture of Graphite Fuel Bricks | £469,568 |
| ELectrochemical ENhancement of Nuclear DEcontamination Solutions 2 (ELENDES) | £400,888 |
| Monitoring Complex Assets using Patterns in Signal data (MCAPS) | £336,282 |
| Intelligent Condition Monitoring for Civil Nuclear Structures | £298,881 |
| On line and global structural health monitoring of high temperature steam lines | £262,407 |
| Total | £15,737,277 |

NB this table includes only the projects which were live at the beginning of 2015. It excludes projects that were funded through the 2012 call, but completed before 2015.

Appendix 2 Continued

**Developing the Civil Nuclear Supply Chain (2014) – Feasibility studies**

| Project Title | Project lead | Grant |
|---|---|---|
| Feasibility - pre-industrial research of horizontal sludge dredge | Barrnon Ltd | £136,800 |
| Feasibility study to develop DEnsification processing of a Ceramic MAtrix composite material for Nuclear waste containment (DECMAN) | Fiberstone Products Ltd | £129,900 |
| Development of a Robotic Spider for Remote Characterisation and Retrievals | Forth Engineering Ltd | £123,750 |
| TRIBECA (TRItium detection By ElectroChemically Assisted radiometrics) | Hybrid Instruments Limited | £123,313 |
| SeeSnake | Create Technologies Limited | £112,089 |
| Large-scale hot-isostatic pressing of waste forms for the treatment of Magnox sludge and other wastes | GeoRoc Limited | £112,000 |
| Enhanced learning through the use of virtual, augmented reality and simulation | GSE Systems Limited | £111,751 |
| Project CLAIMS (Coolant Leak Artificially Intelligent Monitoring System | STS Defence Ltd | £111,509 |
| High Dynamic Range Spectroscopic Radiation Detectors | Kromek Group PLC | £110,978 |
| Metrology using Optical and X-ray Inspection - MOXI | Metrix NDT Limited | £110,447 |
| Feasibility study into novel new materials for heat tracing applications inside nuclear containment | Heat Trace Ltd | £110,193 |
| Development of a driftless thermometer to improve safety and efficiency in the nuclear power industry | Metrosol Limited | £107,901 |
| A condition-based structural integrity and remaining life model for austenitic stainless steels | Metamet Consultants Ltd | £107,537 |
| Submersible treatment of pond waters | Arvia Technology Ltd | £105,837 |
| LaserPipe - Remote in-bore laser welding of nuclear pipelines | Oliver Crispin Robotics Ltd | £105,830 |
| Improving the decommissioning process with intelligent semantic Building Histories | Tacit Connexions Limited | £105,123 |
| In-Situ Monitoring of Tritium and Carbon 14 in Groundwater | XCAM Limited | £104,538 |
| TransForge - Production of forged dissimilar metal transitions for improved reliability in new nuclear power plant | Somers Forge | £101,855 |
| Composite model-based signal and image processing algorithms for semi-automated crack characterisation | Soud Mathematics Ltd | £101,652 |
| An investigation into the use of the Arvia Technology in treating radioactive organically contaminated resins | Arvia Technology Ltd | £99,580 |
| Modular Radiochem Sample Analysis for Integrated Fast/Cost Efficient Workflow | MicroLab Devices Ltd | £98,016 |
| New Techniques for the rapid characterisation of low-level waste and surface contamination | Symetrica Security Ltd | £92,966 |
| Study of the feasibility of setting up and operating a pilot-scale nuclear molten salt reactor demonstration | Energy Process Developments Ltd | £75,477 |
| Novel system for localised, real-time radiometric measurements of ground water at civil nuclear sites | LabLogic Systems Limited | £73,748 |
| Stability of Piezoelectric Materials for Nuclear Applications | Ionix Advanced Technologies Ltd | £60,563 |
| Interoperability for ultrasonic NDT data | Ferroday Limited | £39,015 |
| Total | | £2,672,368 |

Appendix 2 Continued

**Developing the Civil Nuclear Supply Chain (2014) – Collaborative R&D projects**

| Project Title | Project lead | Grant |
|---|---|---|
| Hazmelt | Glass Technology Services Ltd | £1,041,917 |
| SmartScan | Symetrica Security Ltd. | £954,741 |
| Fabrication and Erection of Steel Concrete (SC) Modular Construction for Nuclear Power Plant (NPP) | Caunton Engineering Limited | £938,993 |
| Mosaicing for Automatic Pipe Scanning (MAPS) | National Nuclear Laboratory | £832,869 |
| UNION (Ultrasonic Nuclear InspectiON) | Plant Integrity Ltd | £786,935 |
| Immobilisation challenges with Post Operational Clean Out (POCO) residues | Sellafield Ltd | £767,781 |
| Thermal Treatment of Irradiated Graphite | Costain | £747,307 |
| Noise and Vibration Data Compressor (NVCOMP) - embeddable health monitoring solution to assist in the capture and replay of events to identify deterioration / damage in nuclear plant | Beran Instruments Ltd. | £565,372 |
| Net Shape Manufacture for Energy Efficient Reactors (NEER) | TTI Group Ltd | £563,188 |
| Influence of creep and geometry on strength of irradiated graphite components | EDF Energy Nuclear Generation UK Ltd | £535,147 |
| Development of the first Detectable Permeation Grouting System (DETECTAGROUT) | BAM Ritchies division of BAM Nutall Ltd. | £431,090 |
| Flexible Charged Particle Detector for Nuclear Decommissioning | Kromek Ltd | £395,864 |
| JellyMonitor: developing a jellyfish early warning system for coastal power stations | Cefas Technology Limited | £383,415 |
| D:EEP : Estimating Entrained Products | Create Technologies Ltd | £380,349 |
| ViridiScan: a novel mobile NDT sensor for nuclear decommissioning | Viridian Partnership | £330,178 |
| Total | | £9,655,146 |

**Energy Catalyst Projects**

| Project Title | Project partners | Grant |
|---|---|---|
| Innovative Forging and Fabrication Solutions for the Energy Sector | Sheffield Forgemasters ,<br>Rolls-Royce plc,<br>NAMRC,<br>Sheffield University,<br>Sheffield Hallam University,<br>TWI | £2,511,150 |
| Remote Fissile Material Monitoring of Operational Reactor Cores | John Caunt Scientific Ltd | £569,500 |
| Total | | £3,080,654 |