

# **DISTINCTIVE**

**Decommissioning, Immobilisation and Storage Solutions for  
Nuclear Waste Inventories**

## **Summary and Progress**

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*UK Nuclear Academics Discussion Meeting, Lancaster University, 4<sup>th</sup>-5<sup>th</sup> September 2017*

# Background

- Started 10<sup>th</sup> Feb 2014 and no-cost extension granted to 9<sup>th</sup> Feb 2019 (due late PDRA starts and transfer of work to Surrey)
- £4.91M EPSRC → total £6.13M, plus £2.23M from industry = £8.36M
- World-class University network:

Imperial College  
London

Lancaster  
University

Loughborough  
University

UNIVERSITY OF  
BIRMINGHAM

University of  
BRISTOL

UCL

UNIVERSITY OF LEEDS

MANCHESTER  
1824  
The University of Manchester

The  
University  
Of  
Sheffield.

UNIVERSITY OF  
SURREY

University of  
Strathclyde  
Glasgow

- Key project partners:

EPSRC  
Engineering and Physical Sciences  
Research Council  
Research Councils UK  
Energy  
For a Low Carbon Future

NATIONAL NUCLEAR  
LABORATORY



NDA  
Nuclear  
Decommissioning  
Authority

Sellafield Ltd



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# Technical Themes / Cross-Cutting Activities

## Theme 1 AGR, Magnox and Exotic Spent Fuels (Lead: Tom Scott/David Read):

- Preferred options for disposal of UK's spent nuclear fuel inventory (2 PDRA / 6 PhD)

## Theme 2 PuO<sub>2</sub> and Fuel Residues (Lead: Colin Boxall/Nik Kaltsoyannis):

- Challenges presented by UK's civil plutonium inventory (4 PDRA / 8 PhD)

## Theme 3 Legacy Ponds and Silo Wastes (Lead: Joe Hriljac/Bill Lee):

- Clean-up of Sellafield legacy ponds and silos (3 PDRA / 19 PhD)

## Theme 4 Structural Integrity (Lead: Rebecca Lunn):

- Challenge of ageing nuclear infrastructure (1 PDRA / 6 PhD)

49 research projects across four research themes

## Active Research Projects (Lead: Simon Pimblott):

- Promote use of active research facilities

## Impact, Outreach and Public Engagement (Lead: Neil Hyatt):

- Website, Bi-annual newsletter, Westminster meeting, Project documentary, Engagement summer school, Deliberatorium, Deliberative workshops (including Bristol Green Capital Event)

# Active Research Fund

- At the time of submitting proposal to EPSRC, number of PDRA projects indicated potential need for active research facilities
- Detailed understanding of facility needs and duration of work was unable to be defined
- As a result, Active Research Fund (ARF) was requested

Initial Budget	£288k fEC (inc. VAT)
Number of Calls	4 to date
Number of Funded Sub-projects Awarded	13
Budget Awarded	~ £280.5k fEC (inc. VAT)
Remaining Budget	~ £7.5k fEC (inc. VAT)

# Project Impact

Information on **Key Findings** and **Project Impact** on Gateway to Research

For impact, three groups of non-academic beneficiaries

- **Site licence companies and associated industrial supply chain:**
  - Annual Research Conference and Theme Meetings
  - Challenge-Led Meetings on specific industry needs-led research challenges
  - Industrial supervisors on projects
  - Management Board and International Advisory Group
  - Number of presentations at industry roadshow events, Nuclear Operations and DECOM Summit, International Waste Management Conference, etc.
- **Society and stakeholder groups:**
  - Public engagement as part of Bristol European Green Capital Programme on public perception of risk posed by radioactivity and nuclear power
  - Three-day Public Engagement and Media Summer School for PhD students and PDRAs on public engagement, media and science writing
  - Stakeholder engagement exercise – Deliberatorium
  - Project documentary planned for use online and at science festivals, and World Café (informal “drop in format” for public to discuss issues with researchers) targeted at National Science Week

# Project Impact

- **Government, regulators and implementation authorities:**

- Neil Hyatt and Stephanie Thornber attended All Party Parliamentary Group on Nuclear Energy to discuss research on immobilisation of plutonium residues and stockpile material
- Tom Scott appointed as member of Radioactive Waste Management working group on fuel disposal and behaviour
- Tom Scott appointed as Special Advisor to House of Lords to assist with running Science and Technology Committee investigation into future of UK nuclear R&D
- Bill Lee, Neil Hyatt and Colin Boxall presented at Oak Ridge, Idaho and Argonne National Labs in US as part of HMG Foreign & Commonwealth Office delegations to potential UK partners overseas
- Colin Boxall and Neil Hyatt made presentations to Annual Meeting of Atomic Energy Society of Japan, Japan Atomic Energy Agency and Nuclear Damage Compensation and Decommissioning Facilitation Corporation of Japan, again as part of HMG Foreign & Commonwealth Office delegations to potential UK partners overseas
- In process of arranging meeting with All-Party Parliamentary Group on Nuclear Energy

# 3<sup>rd</sup> Annual Meeting

National Railway Museum, York, 5<sup>th</sup>-6<sup>th</sup> April 2017

- 19 technical oral presentations across 4 mixed technical sessions
- 40 technical poster presentations
- 3 keynote presentations:
  - Ian Pegg and Andrew Cooney – Key Findings of DISTINCTIVE to Date
  - Stephen Hepworth – Innovation at Sellafield, the New Integrated Innovation Teams
  - Albert Kruger – Hanford; The Creation and Remediation of the Legacy
- 4 employability-related presentations
- Costain / Hydrock NMCL / NNL / NDA / Sellafield Ltd. recruitment information provided
- PhD awards for best oral and poster presentations



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# Building and Maintaining Relationships & Networks

- **Rheged 16<sup>th</sup> October 2017**
  - Management Board Meeting (Every 6 Months)
  - Theme 3 and 4 meetings (Legacy Ponds and Silo Wastes / Structural Integrity)
- **Rheged 17<sup>th</sup> October 2017**
  - Theme 1 and 2 meetings (AGR, Magnox and Exotic Spent Fuels / PuO<sub>2</sub> and Fuel Residues)
- **Final annual meeting around April 2018**
  - Management Board Meeting
  - International Advisory Group Meeting (Every 12 Months)



<p>3rd ANNUAL MEETING</p>		 <p><b>DISTINCTIVE</b></p> <p>Decommissioning, Immobilisation and Storage solutions for Nuclear waste in Ventories</p> <p><a href="http://distinctiveconsortium.org/">http://distinctiveconsortium.org/</a></p>
	<p>5<sup>TH</sup> – 6<sup>TH</sup> APRIL 2017</p>	<p>We invite you to join us at the 3rd Annual Meeting of the DISTINCTIVE University Consortium.</p> <p>Come and engage with a growing research and development community concerned with nuclear waste and decommissioning issues in the UK. The meeting will bring together academics, researchers and industrial stakeholders from across the UK's civil nuclear sector. Keynote presentations will also be given by internationally leading speakers. As such, the event will provide an invaluable opportunity to promote collaboration and to foster knowledge exchange.</p> <p>By attending this event you will gain an update on our current research projects.</p> <p>Please contact Dr Lois S Tovey (l.tovey@leeds.ac.uk) for further information.</p>
<p><b>EPSRC</b></p> <p>Engineering and Physical Sciences Research Council</p> <p>Leeds University</p> <p><b>Energy</b></p> <p>For a Low Carbon Future</p>	<p><b>National Railway Museum</b></p> <p>York</p>	<p><b>AUGL</b></p> <p><b>UNIVERSITY OF BIRMINGHAM</b></p> <p><b>Strathclyde</b></p> <p><b>Glasgow</b></p> <p><b>MANCHESTER</b></p> <p><b>Loughborough University</b></p> <p><b>Imperial College London</b></p>





# Research Areas: Technical Work Packages/Themes

## Theme 1 AGR, Magnox and Exotic Spent Fuels (Lead: Tom Scott/David Read):

- Addresses UK's spent nuclear fuel inventory, and preferred options for disposal. Includes retrieval of fuel from current storage facilities and repackaging options available. Concerned with Advanced Gas-Cooled Reactor, Magnox and other so-called 'Exotic' spent fuels, with goal to increase knowledge and mechanistic understanding of processes involved during management
- Wet fuel storage issues
- Transitions to dry fuel storage
- Long-term storage effects and exotic fuels

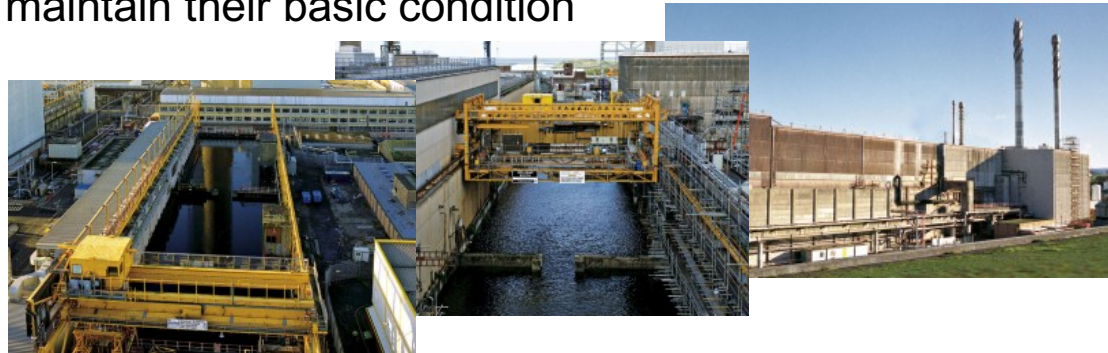
## Theme 2 PuO<sub>2</sub> and Fuel Residues (Lead: Colin Boxall/Nik Kaltsoyannis):

- Addresses challenge presented by UK's civil plutonium inventory. Plutonium is bi-product of reprocessing spent fuel received from UK's fleet of nuclear power generators, with approximately 125 tonnes of Pu in interim storage in UK. However, no decision has yet been made regarding its final treatment and disposition
- Behaviour of PuO<sub>2</sub> during interim storage
- Behaviour of Pu bearing wasteforms and encapsulants
- Methods for characterisation of stored Pu, Pu-contaminated materials and facilities

# Research Areas: Technical Work Packages/Themes

## Theme 3 Legacy Ponds and Silo Wastes (Lead: Joe Hriljac/Bill Lee):

- Addresses clean-up of UK's biggest safety and security threat; Sellafield legacy ponds and silos, care and maintenance programme for which currently costs UK tax payer approximately £70M per year to maintain their basic condition
- Wasteform durability
- Effluent treatment and analysis
- Pond and silo sludges



## Theme 4 Structural Integrity (Lead: Rebecca Lunn):

- Addresses challenge of ageing nuclear infrastructure, and how to ensure continued safety of workforce involved in nuclear decommissioning and management. Aim is to develop reliable systems for nuclear infrastructure characterisation, restoration and preservation
- Physical ground barriers for in-situ contaminant containment
- Remote crack detection, infrastructure health prediction, building preservation
- Development and real-time management of autonomous systems for decommissioning

# Research Areas: Theme Projects

## AGR, Magnox and Exotic Spent Fuels projects:

- Life cycle approach as decision tool for waste management/ decommissioning of plants
- Investigation of wasteform evolution during wet-recovery and drying of SNF
- Determination of optimum drying conditions for AGR fuels
- Grain boundary damage mechanisms in strained AGR cladding under irradiation
- Options for exotic carbide fuels
- $\text{UO}_2$  surface reactivity and alteration
- Use of time resolved laser fluorescence spectroscopy to investigate dissolution rates
- Behaviour of used nuclear fuel in wet storage



Includes associated PhDs

## $\text{PuO}_2$ and Fuel Residues projects:

- Computational modelling of  $\text{PuO}_2$  ageing and fuel residues
- In-situ characterisation of heavily-contaminated Pu finishing environments
- Modelling surface chemistry of  $\text{PuO}_2$  at molecular level
- Real-time fast neutron plutonium assay for Pu storage and ageing applications
- Understanding actinide sorption and binding to cement materials for radioactive waste management
- Understanding interfacial interactions of plutonium dioxide with water x 2
- Ceramic materials for actinide disposition
- Development of glass-ceramics for Pu disposition using hot isostatic pressing
- Interaction of water with  $\text{PuO}_2$  surfaces
- Understanding surface species and interactions between adsorbed chloride and water on stored  $\text{PuO}_2$
- Investigation of anomalous hydrogen production from water adsorbed on oxides
- Simulation of low-energy electron radiolysis of water adsorbed on oxides



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# Research Areas: Theme Projects

## Legacy Ponds and Silo Wastes projects:

- Characterisation of flocculated waste suspensions with acoustic backscatter
- Computational simulations of storage pond sludge disturbance
- Development of Raman spectroscopy techniques for remote analysis of nuclear wastes in storage
- Durability of heterogeneous ILW glass/ceramic wasteforms from complex wastestreams
- Enhanced shear micro- and ultra-filtration without recycle pumping
- Gas retention and release from nuclear legacy waste
- Measurement and modelling of sludge mobilisation and transport
- Novel ion exchange materials
- One step extraction and quantification of radionuclides using superparamagnetic bead and nanopore technologies
- Magnetic nanoparticles for waste separation or sequestration
- Glass composite materials for Fukushima ILW immobilisation
- Glass composite materials for Sellafield LP&S ILW immobilisation
- Thermal treatment of PCM and ILW
- New ion exchange materials for effluent clean-up
- Novel ceramic wasteforms for Cs and Sr encapsulation

## Legacy Ponds and Silo Wastes projects:

- Corrosion of uranium in water and hydrogen
- Evolution of grouted wasteforms containing uranium
- Development of characterisation techniques for intermediate level waste sludges
- Irradiated sludges – modelling and experimental
- Interaction of brucite surfaces with uranium and its fission products
- Autonomous systems for nuclear decommissioning in extreme radiation environment

## Structural Integrity projects:

- Crack sealing and water transport
- In-situ ground contaminant containment (physical barrier) × 2
- Nano-cracking of cement phases: reactivity and dissolution
- Production of real-time segmented as-built CAD models for planning and execution of remote and human intervention
- Integrated sensors for infrastructure
- Impact of recycled concrete fines on engineering performance of cementitious infill
- Development of novel, low cost biomineral permeable reactive barriers for radionuclide remediation

# Active Research Fund – Sub-Projects Funded

- Investigation of Silica Grout-radionuclide Interactions: Impact on Radionuclide Mobility and Silica Gelation – Matteo Pedrotti, Strathclyde
- The Corrosion of Spent Nuclear Fuel – Leila Costelle, Bristol
- An Investigation of Wasteform Evolution During Wet-recovery and Drying of SNF – James Darnbrough, Bristol
- Building a Portable Ultra-high Vacuum (UHV) Chamber for Active Samples – Leila Costelle, Bristol
- Fission Product Effects on Spent Fuel Corrosion – James Darnbrough, Bristol
- Building and Commissioning a Vacuum Sampling System for PuO<sub>2</sub> Glovebox Experiments – Luke Jones, Manchester
- A Hot Isostatic Press Upgrade for Processing of Radioactive Materials – Shi-Kuan Sun, Sheffield
- Hard X-ray Absorption Spectroscopy Studies at the Photon Factory – Shi-Kuan Sun, Sheffield
- A Lab-Scale Fixed Bed Reactor to Investigate Gas Phase Kinetics for Long Term PuO<sub>2</sub> Storage – Luke Jones / Thomas Donoclift, Manchester
- Study of Physico-Chemical Interactions Between PuO<sub>2</sub> and H<sub>2</sub>O – Dominic Laventine, Lancaster
- Developing ERT Equipment for the Detection of Colloidal Silica Grout – Matteo Pedrotti, Strathclyde
- Investigation of Radiation Damage by Mossbauer Nuclear Spectroscopy – Shi-Kuan Sun, Sheffield
- In Situ High Resolution Neutron Diffraction Studies of Glass-Ceramic Crystallisation – Shi-Kuan Sun, Sheffield
- Undertaking work at: British Geological Survey, Dalton Cumbria Facility, GANIL (France), Little Forest Legacy Site (Australia), National Nuclear Laboratory Central Laboratory, Oak Ridge National Laboratory (USA), Photon Factory (Japan) and Surrey University Ion Beam Facility