

DISTINCTIVE

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

Summary and Progress

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University of Leeds

UK Nuclear Academics Meeting, University of Bristol, 14th-15th September 2016



Background

- Started 10th February 2014 to 9th November 2018
- £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
Strathclyde
Glasgow

- Key project partners:

NATIONAL NUCLEAR
LABORATORY

NDA
Nuclear
Decommissioning
Authority

Sellafield Ltd

Research Councils UK
Energy
For a Low Carbon Future

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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 PuO₂ 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

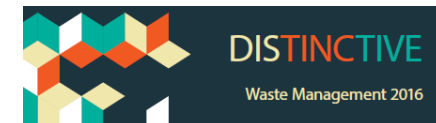
Impact, Outreach and Public Engagement (Lead: Neil Hyatt):

- Website, Bi-annual newsletter, Evening lecture/panel discussion at RAEng, Westminster meeting, Radio documentary, Engagement summer school, 3 Deliberative workshops (online and at Bristol Green Capital Event)

Waste Management Conference (WM2016)

6th-10th March 2016, Phoenix Conference Centre

- Dedicated session with 8 papers
- Over 40 attendees – new contacts for IAG and future collaborations
- Sponsored social (thanks to Longenecker & Associates and Laurie Judd)
- 7 additional papers presented by project researchers
- Five awards presented:
 - Stephanie Thornber, Luke Boast (Sheffield) and Dimitri Pletser (Imperial) – Roy G. Post Foundation Scholarship
 - Luke Boast (Sheffield) – UK Featured Nation
 - Andre Botha (Leeds) – NNL Bursary



092 EPSRC DISTINCTIVE Research Programme - Wednesday 9th March
13:30 - 17:00 - 106C

DISTINCTIVE is a multi-disciplinary collaboration of 10 universities and three key industry partners from across the UK's civil nuclear sector. Our world-class research programme focuses on the area of nuclear decommissioning and waste management.

Session Structure:

- Collaborative Research Programme in Decommissioning, Immobilisation and Storage Solutions for Nuclear Waste Inventories (DISTINCTIVE) (16466)
- Building Effective Collaborations to Bring Innovation into Waste Management and Decommissioning (16477)
- Novel Approaches for the Study of Corrosion and Ageing of Spent Nuclear Fuel (16467)
- Behaviour of Alpha Emitters in Cement (16399)
- Water Interactions with Actinide Oxides from First Principles: A Computational Study (16470)
- The Consolidation of Glass-Ceramic Wasteforms by Hot Isostatic Pressing: Sample Optimisation (16481)
- Is Glass Degradation only a Surface Effect? What Other Forms of Glass Degradation can Influence the Safety of Witrified Nuclear Waste Disposal? (16476)
- A Novel Technology for Complex Rheological Measurements (16471)

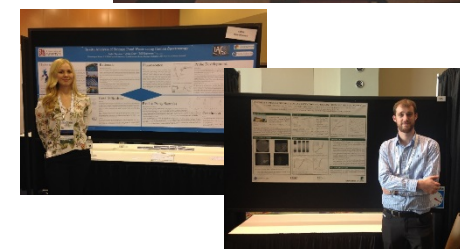
More information about the programme can be found on our website: www.distinctive.ac.uk

Other DISTINCTIVE associated presentations:

- Managing the International Compact Ingoing Solution with Nuclear Fusion Products (16464)
Poster - Monday - Session 101 - Mr. Peter Mahon - University College London
- In situ Assessment of Legacy Fuel Design using Remote Spectroscopy (16469)
Poster - Monday - Session 101 - Ms. Kate Wynne - University of Bristol
- Collaboration and Release from Nuclear Legacy Waste (16480)
Poster - Monday - Session 101B - Mr. Neil East - University of Leeds
- Choosing Your New Fuel Cycle: A Life Cycle Assessment Perspective (16472)
Oral - Tuesday - Session 101 - Mr. Andrew Phillips - University College London
- Understanding the Role of Water Adsorption on UO₂ and PuO₂ Surfaces (16473)
Oral - Tuesday - Session 101 - Mr. Joseph Waddington - University College London
- Utilising a Novel Acoustic Backscatter Array to Characterise Waste: Consolidation and Settling in a Horizontal Flow (16474)
Oral - Wednesday - Session 105 - Dr. Timothy Hunter - University of Leeds
- Immobilisation Process for Contaminated Zwitteric Ion Exchange Resin (16475)
Oral - Thursday - Session 104 - Mr. David Parker - Imperial College London

You are invited to a social in Room 106C immediately after the session. Please take the opportunity to meet the team, to discuss the research presented in more detail, and to explore opportunities for collaboration.

The social has kindly been sponsored by Longenecker & Associates:



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Active Research Fund

- At time of submission, number of PDRA projects indicated potential need for active research facilities
- Detailed understanding of facilities needs and duration of work could not be defined
- As a result, Active Research Fund (ARF) requested

Initial Budget	£288k fEC (inc. VAT)
Number of Calls	4 to date (4 th still open)
Number of Funded Sub-projects Awarded	8 (Bristol, Manchester, Sheffield, Strathclyde)
Budget Awarded	~ £188k fEC (inc. VAT)
Remaining Budget	~ £100k fEC (inc. VAT)

Public Engagement and Media Summer School

- 30 PhD students / PDRAs attended 3 day summer school at Halifax Hall in June
- Series of activities aimed at giving researchers confidence to communicate their research
- Included:
 - Virtual reality of Chernobyl exclusion zone
 - “Dragon’s Den” competition to win funding for public engagement activity
 - Day with news broadcasters and Science Media Centre, culminating in press conference
 - Tim Yeo (former MP and Chair of Energy and Climate Change Committee) after dinner speaker
 - Creative science writing with speakers from Nuclear Hitchhiker and free-lance science writers
- Thanks to Claire Corkhill



Neil Hyatt taking a stroll around Chernobyl with Mike Wood



Tom Sheldon of the Science Media Centre on how scientists can help the press to ‘get it right’



After dinner speaker, Tim Yeo



Announcing “New plutonium immobilisation technology” at mock press conference



Sheffield and Birmingham students working on their ideas for “a day-in-the-life-of” documentary about nuclear research

Building and Maintaining Relationships & Networks

- **Rheged 14th November 2016**
 - Management Board Meeting (Every 6 Months)
 - Theme 2 and 4 meetings (PuO₂ and Fuel Residues / Structural Integrity)
- **Rheged 15th November 2016**
 - Theme 1 and 3 meetings (AGR, Magnox and Exotic Spent Fuels / Legacy Ponds and Silo Wastes)
- **National Railway Museum 4th-6th April 2017**
 - Management Board Meeting
 - International Advisory Group Meeting (Every 12 Months)
 - 3rd Annual Meeting



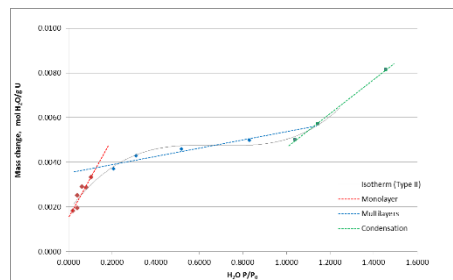
2ND ANNUAL MEETING	 DISTINCTIVE Decommissioning, Immobilisation and Storage solutions for Nuclear waste inventories
	<p>We invite you to join us at the 2nd Annual Meeting of the DISTINCTIVE University Consortium.</p> <p>Come and engage with a growing research and development community concerned with 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 two 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 research projects as we approach the programme's halfway point.</p>
19 TH – 20 TH APRIL 2016	<p>@BRISTOL & SS GREAT BRITAIN, BRISTOL</p> <p>        </p>



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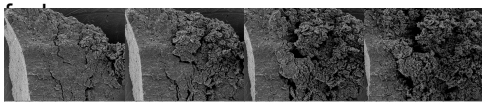
Technical Highlights

Dominic Laventine (Lancaster): Understanding the interfacial interactions of PuO_2 with water



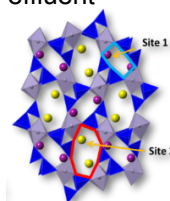
Ceria, Thoria and Urania thin-films synthesised on piezo-active crystals, absorption of water under range of humidities and temperatures measured. Installation of experiment in active area at NNL underway to allow analysis of plutonia interactions with water

Claudia Gasparrini (ICL): Immobilisation options for exotic carbide



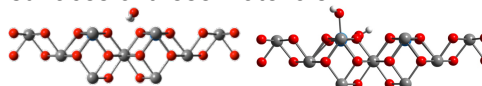
Experimental work on depleted UC from Dounreay performed at NNL, collaboration set up with ICSM, France, with further experimental work performed there on samples provided by CEA

Tzu-Yu Chen (Birmingham): Tailoring microporous tin silicates via solid state chemistry for improved Sr and Cs uptake from effluent



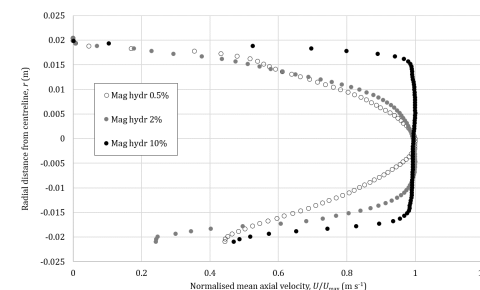
Tin umbite, shown, can accommodate substitutions at both the octahedral (Sn) and tetrahedral (Si) sites and this changes the ion exchange selectivity of the cations (e.g. K, Na or H) at site 2

Joe Wellington (UCL): Understanding electronic structure of actinide dioxides and interactions of water with low index surfaces of these materials



Side view of 1 molecular (left) and 1 dissociative water adsorption (right) on the (110) surface of UO_2

Hugh Rice (Leeds): In-line rheometry and flow characterisation of dense slurries in pipe flow using acoustic methods



Mean velocity profiles in vertical pipe flow with suspended magnesium hydroxide at several volume fractions showing flattening due to increase in effective viscosity of liquid-solid mixture

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

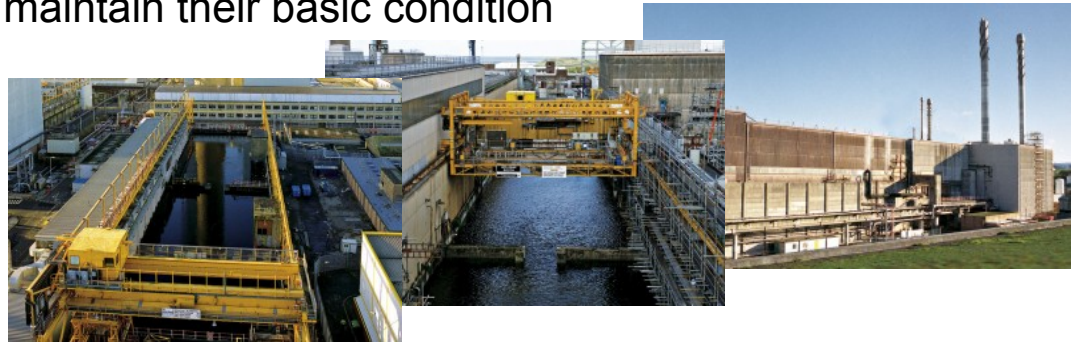
Theme 2 PuO₂ and Fuel Residues (Lead: Colin Boxall/Nik Kaltsoyannis):

- 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 PuO₂ during interim storage
- Behaviour of Pu bearing wastefoms 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
- 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

PuO_2 and Fuel Residues projects:

- Computational modelling of PuO_2 ageing and fuel residues
- In-situ characterisation of heavily-contaminated Pu finishing environments
- Modelling surface chemistry of 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 PuO_2 surfaces
- Understanding surface species and interactions between adsorbed chloride and water on stored 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

Research Plan: Cross-Cutting Activities

Active Research Projects (Lead: Simon Pimblott):

- Use of active research facilities at NNL and elsewhere
- Two major projects planned, 8 further projects received financial support from 1st, 2nd and 3rd calls for proposals, with further call open
- Simon acting as champion to promote use of active facilities and to ensure that consortium receives appropriate advice and support

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

- Proposal identifies three groups of non-academic beneficiaries: Site licence companies and supply chain; Government, regulators and implementation authorities; Society and stakeholder groups
- Impact in 4 key domains: Knowledge; People; Economy; Society
- 5 critical enablers at core of impact strategy: Building and maintaining relationships and networks; Communication and dissemination; Public, media and government engagement; Knowledge transfer and commercialisation; Training and development
- Website, Bi-annual newsletter, Evening lecture/panel discussion at RAEng, Westminster meeting, Radio documentary, Engagement summer school, 3 Deliberative workshops (online and at Bristol Green Capital Event)

Active Research Fund

Sub-projects funded:

- Investigation of Silica Grout-radionuclide Interactions: Impact on Radionuclide Mobility and Silica Gelation – Dr. Matteo Pedrotti, Strathclyde
- The Corrosion of Spent Nuclear Fuel – Dr. Leila Costelle, Bristol
- An Investigation of Wasteform Evolution During Wet-recovery and Drying of SNF – Dr. James Darnbrough, Bristol
- Building a Portable Ultra-high Vacuum (UHV) Chamber for Active Samples – Dr. Leila Costelle, Bristol
- Fission Product Effects on Spent Fuel Corrosion – Dr. James Darnbrough, Bristol
- Building and Commissioning a Vacuum Sampling System for PuO₂ Glovebox Experiments – Dr. Luke Jones, Manchester
- A Hot Isostatic Press Upgrade for Processing of Radioactive Materials – Dr. Shi-Kuan Sun, Sheffield
- Hard X-ray Absorption Spectroscopy Studies at the Photon Factory – Japan – Dr. Shi-Kuan Sun, Sheffield