NDA PhD Bursary Call 2020:

Developing and Maintaining Skills and Innovation Relevant to Nuclear Decommissioning and Clean-up

The NDA is requesting applications to its bursary scheme, to support the NDA mission to deliver safe, sustainable and publicly acceptable solutions to the challenge of decommissioning and clean-up of the UK's civil nuclear legacy. The NDA's goals for the scheme are as follows:

- Maintain and develop the key technical skills that will be required to help us carry out the mission over the coming decades
- Provide fundamental understanding of technologies and processes across the NDA estate
- Develop early stage technologies (TRL 1 – 3)
- Encourage two-way knowledge transfer between the academic and industrial communities working on nuclear decommissioning

What is not covered under the scheme is R&D focused on site-specific challenges such as improving the efficiency of an existing plant or process or on training resource in a specific capability[1]. This year, up to £750,000 is available to support projects that will lead to the award of a PhD and Universities and Research Institutes are invited to make proposals in the following thematic areas:

A) Characterisation

(A.1) In-Situ Analysis

Improved techniques for the surveillance and characterisation of plant, structures, waste, land and effluents for radiological and chemical contamination. Remote (field sensing) for contaminated land, buildings, effluents and waste packages. Improved detectors for more rapid analysis/more flexible deployment/improved information content (etc).

(A.2) Rapid and Automated Analytical Techniques

More rapid analysis methodology to support automation especially in labour-intensive areas of sample preparation and radionuclide separations to reduce analysis cost, increase turnaround times and better

[1] Please contact mark.bankhead@uknnl.com in the first instance to discuss your project idea if you are unsure if it is applicable.

manage supply-chain capacity. The key focus is on improved analysis/assay capabilities for alpha and beta radionuclides, (for example Sr-90) at environmental levels.

Examples of generic industry needs against the challenges above:

- Characterisation of Materials in Sealed Containers
- Improvements in existing non-destructive assay methods e.g. for Fuel/Fissile Material content in cans and other packages
- In-Line, Real-time materials characterisation, e.g. Fuel/Fissile Material content of sludge during transfer/pumping operations
- Improvements in Real-Time/Near-Time 'rapid' analysis methods - radiological and chemical analysis
- Developments in simple universal sampling tools to collect representative samples from solids, liquids or sludges that can be deployed in constrained spaces (e.g. through small apertures) or at height and potentially in high radiation areas
- Innovative ways of measuring or estimating the activity of a waste item or package
- Improving characterisation techniques at waste category boundaries
- Understanding of Errors, Accuracy and Precision and confidence levels in 'decision making' and/or 'acceptability criteria' with respect to (correct) waste categorisation

B) Waste Packaging & Storage

(B.1) Grout formulations

Security of supply - develop alternatives to established encapsulation formulations, alternatives to established powders, develop approaches for ensuring powder quality

(B.2) Immobilisation

Immobilisation/conditioning of mixed/heterogeneous waste/co-processing and deliberate mixing – compatibility of waste components and immobilisation matrices

(B.3) Waste treatment and conditioning

Waste treatment and conditioning technologies

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(B.4) Waste evolution

Tools and techniques for the monitoring of container and waste evolution, degradation and corrosion of materials, and the monitoring of waste store conditions (Control Condition Monitoring & Instrumentation).

(B.5) Knowledge management

Improved or innovative technologies for management of records

(B.6) Uranium hydride

Behaviour of uranium hydride under accident conditions

(B.7) Alternative materials & construction techniques

Research and development of alternative materials for waste container construction and improved techniques for manufacturing of waste containers

C) Land Quality

(C.1) Development of the understanding of the migration of radioactive and chemotoxic contaminants from buried concrete structures, including mechanisms of mobilisation of these into the environment such as diffusion & desorption, effective characterisation methods and the generation of modelling and assessment tools to support the production of more robust Environmental Safety Cases.

(C.2) Development of effective stakeholder communication tools for the representation of uncertainty and assessment of variability in determining the long-term safety of radioactive waste disposals and management of contaminated land.

(C.3) Expansion of the performance envelope of the latest generation of sampling equipment and analytical instruments to address the radioactive contaminants found at NDA sites, and to allow characterisation of groundwater conditions (including anoxic groundwater at geological repository depths 200-1000mbgl).

(C.4) Novel investigation techniques for radioactive discharge pipelines from nuclear sites, including:

- methods for determination and application of fingerprints (using easily measured gamma emitters and the relationships between radionuclides of interest and easily measurable physical parameters (pH, eH, etc.)) to determine the presence of and quantify more 'difficult to detect' radionuclides
- innovative remotely operated vehicle designs to characterise pipelines, linked to (D.2) theme

(C.5) Research to develop the understanding of the fate of radioactive particles in the environment:

- understanding the long-term fate of radioactive particles in marine and estuarine environments
- research that develops the understanding of degradation mechanisms for a range of particle types under typical environmental conditions

D) Decommissioning

(D.1) Graphite - Waste Volume Reduction

There is a large graphite inventory (>68,000 m^3) across the NDA estate destined for Geological Disposal Facility this represents a major waste challenge. Irradiated graphite represents one of the largest volumes of irradiated materials and poses technical challenges. It is also a material for which there is a range of possible treatment and disposal options.

(D.2) Remote deployment methods for tools to support deplanting and decommissioning

Given the premise of any intrusive work considers access, characterisation, "the activity" and wastes, one area for concern is the ability or inability to access pipework systems, with bends, tee pieces (etc). The challenge therefore is to have a device that is capable of 1 or more of the following:

- Navigation of a pipe at 2" diameter over 20-25 metres
- Navigate 6 swept bends with a small contribution from gravity
- Steering to selectively direct itself into branches, tees etc with and against gravity
- Selectively be flexible and rigid
- Act as a carrier for other technology without being integrated, of nominal mass of 1.5kg

(D.3) Managing ageing assets and conventional decommissioning hazards (condition management)

Material/structure degradation is a major challenge affecting the NDA estate. This includes degradation of ageing steelwork and reinforced concrete. Research challenges include:

- Autonomous and remote systems to allow monitoring, inspection and characterisation of inaccessible areas to be able to automatically detect and quantify plant anomalies from video and photographic records

- Inspection data either in real-time or during post-processing. Support for asset care and decommissioning and an enabling tool for managing and monitoring facilities safely and reliably. Use for building and package inspections during Care and Maintenance. What learning, and technology can be taken from other industries and applied in decommissioning

- Improved risk-based assessments & approaches

- Improved systems/processes for information capture & management

(D.4) Asbestos management and processing

The NDA SLC's have a significant volume of both Out of Scope (non-radiological contaminated) and In Scope (radiological contaminated) asbestos waste which we will remove during Care and Maintenance preps and Final Site Clearance (FSC) which warrants research. Out of scope wastes are outside of the scope of legislation for the control of radiological hazards. There are several potentially relevant research topics:

- Options for identification/characterisation and potential for in-situ denaturing or management

- Asbestos processing – potential to vitrify or melt asbestos (including potentially contaminated asbestos) or other potential technologies – review of current state of the art, relative performance, up-scaling issues

- Passivation of 'Out of Scope' asbestos waste (that is not a radiological hazard) plus potential for 'In Scope' treatment (low active waste)

- Explore valid opportunities for waste passivation (including in-container vitrification)

- Sampling & analysis of asbestos in contaminated areas

(D.5) Methods for real-time sentencing and segregation of waste arising from deplanting, decommissioning and demolition

(D.6) Costing of projects – development of a cost norm model for costing decommissioning projects on a whole-life basis

- Develop skills and methods to improve cost forecasting and opportunities for innovation to reduce decommissioning costs

E) Spent Fuel & Nuclear Material

(E.1) Fundamental mechanisms of the corrosion of AGR fuel cladding

Research into determining the fundamental mechanisms of the corrosion and corrosion inhibition of irradiation sensitised AGR fuel cladding, under pond storage conditions. This should, for example, consider the potential impact of stress and the microstructure on corrosion mechanisms and corrosion inhibition by agents such as hydroxide or boron in the presence of potential impurities such as chloride or sulphate in the water.

(E.2) Behaviours of irradiation sensitised AGR fuel cladding

Research into the behaviours of irradiation sensitised AGR fuel cladding under moist and dry storage conditions, including the potential impact of stress and the microstructure of the cladding; notably behaviours which could compromise future containment or mechanical strength. This might consider the impact of surface oxides, potential storage gas compositions and impurities including the influence of variables such as temperature, humidity, radiation dose rate and free or 'fixed' moisture presence.

(E.3) Detection of onset of cladding corrosion

Research into potential novel approaches which may detect at an early stage the onset of general or local conditions which might promote corrosion of cladding or other fuel containment in fuel storage ponds. The approaches may, for example, involve real time measurement mapping of minute concentration changes of aggressive ions, or other species, or use corrosion electrochemistry measurements which may signal potential changes in the corrosion risk at an early stage.

(E.4) Alpha damage and helium

Plutonium and related materials are α active. Each alpha decay results in local damage to the host material, heat and a helium atom which can subsequently be released, pressurising any sealed systems. Helium pressurisation is a current topic in the lifetime of storage cans. Helium is a factor in the pressurisation of MOX fuel rods during irradiation and subsequent storage/disposal and will also be a factor in immobilisation products and any relationships between alpha damage and leaching. NDA is interested in proposals in alpha damage and helium distribution in special nuclear materials, both product powders and engineered ceramics relating to interim storage or final disposal.

(E.5) Absorption of species on fuel precursor powders

Product powders are known to absorb gases from the atmosphere. This can include atmospheric gases such as CO_2 or H_2O, products of radiolytic reactions such as nitrous oxides or in some cases HCl from degradation of storage packaging. The conditions under which these species remain chemically bound or can be released can impact on continued storage or disposition processes. However, the details of the chemical bonding to the product surface are not well understood. Recent studies with chlorine contaminated materials show there are a range of possible chemical states some of which are more readily released during stabilisation treatments and it is possible for the chlorine to 'switch' state over time. Gaining better insights into the nature of bonding between absorbed gases and PuO_2 and the conditions under which they remain stable is a further R&D priority.

(E.6) Plutonium immobilisation

The NDA is currently evaluating production processes for plutonium immobilisation. Manufacture of Zirconolite by HIP (Hot Isostatic Pressing) is considered one option. Alternatives including MOX fuel optimised for disposal (e.g. containing large amounts of neutron poison) are also being considered. There is a need to further optimise the production routes and product formulations for these immobilisation matrices and there are new technologies that may be relevant, SPS, flash sintering etc. NDA welcomes proposals aimed at developing the production routes for ceramic plutonium wasteforms.

(E.7) Long term ageing of plutonium

Separated plutonium is a relatively young material. Over time radioactive decay leads to a change in chemistry as americium, neptunium, uranium 'grow-in' to the material. In addition to helium generation, self-irradiation damage/heating may drive changes in physical properties, change particle morphology etc. Changes might be relevant on a timescale of decades appropriate to processing and current storage or longer term, appropriate to disposal scenarios. NDA welcomes proposals that seek to investigate how decay drives changes in relevant behaviour of product powder or engineered ceramics such as gas retention, ground water leaching etc.

(E.8) RIS modelling

AGR cladding composition changes (most notably chromium depletion at grain boundaries) can occur due to irradiation damage under specific reactor conditions (mainly temperature); this phenomenon is known as Radiation Induced Segregation (RIS). RIS-affected cladding, often referred to as being 'sensitised', is known to be vulnerable to localised corrosion if exposed to corrosive environments. Currently, a model to predict RIS (especially chromium depletion) in AGR cladding exists and has been validated against experimental data within a certain envelope of material composition (i.e. for AGR cladding alloy) and irradiation history (reactor dwell time, irradiation temperature, burn-up etc.). The model has not, however, always been able to match experimental data outside of this envelope (e.g. for LWR pressure vessel steels). There is an interest, therefore, in exploring ways in which confidence in the existing RIS model could be improved by developing the model so that it can predict composition changes across a broader envelope of material compositions and irradiation histories, e.g. by modifying the model so that it more fully represents the phenomena occurring in a material under irradiation that contribute to RIS.

(E.9) Pond water activity monitoring

Eventually, several thousand tonnes of spent fuel (mostly AGR fuel) will be marshalled into the THORP Receipt and Storage (TR&S) ponds at Sellafield for interim storage, pending final disposition, alongside a smaller quantity of other miscellaneous fuel types. The fuel will be stored in several hundred separate containers. In the unlikely event of fuel failure occurring during interim storage, the ability to respond to the incident could be strengthened if the location of the failure could be identified. There is an interest, therefore, in any methods that could be used to physically locate the source of activity release due to fuel failure, i.e. which container(s) of fuel are the source of the release. There is also an interest in any methods that could be used to distinguish between a release from the majority AGR fuel and other more minor fuel types of different composition, burn-up, cooling time etc.

(E.10) Water detection and quantification

There are a variety of circumstances in which it could be useful to be able to detect and quantify water associated with spent fuel, e.g. when transferring fuel from pond storage into sealed dry storage or disposal containers. In these circumstances, the condition of the fuel could be anything from assemblies containing complete but failed (and therefore potentially waterlogged) pins through to fuel debris. There is, therefore, an interest in novel, non-destructive techniques that could be used to detect and, if possible, quantify water associated with fuel in a variety of conditions.

(E.11) Managing gas generation in sealed containers of fuel

Sealed containers of spent fuel e.g. for storage or disposal of the fuel might, in some circumstances, contain material that could generate gas e.g. water that could undergo radiolysis. This gas generation could have several undesirable consequences, e.g. over-pressurisation of the containers or the formation of flammable gas mixtures within the containers. There is an interest, therefore, in novel methods that could be used to detect, quantify and manage gas generation inside sealed containers of spent fuel.

F) Open Criteria

This category will be left open for civil nuclear decommissioning related proposals that might be of interest to the NDA and are not encompassed by the above themes. This would also cover research supporting the NDA's mission in effluent treatment and management and alpha-decommissioning of contaminated plant and wastes. When constructing proposals for the open theme, respondents should ensure their idea aligns with the NDA mission (see NDA Strategy 2019 to 2024) and demonstrate this in their proposals.

In addition to the proposals outlined, the NDA is specifically interested in research proposals in the following areas:

(F.1) Functional longevity of land quality information.

- What has survived from history, what formats have been useful, how have they remained available for contemporary review

Additional considerations

The following additional topics may be considered alongside bursary proposals for any of the theme areas (A-F). N.B. Inclusion of these elements is <u>not mandatory</u> for bursary proposals, and applications without these elements will not be "marked down".

Collaboration with US research organisations:

Respondents will have the opportunity to include an element of collaboration with research institutions in the United States in their research proposals on topics of mutual interest to NDA and US DoE. The Principle Investigator for the proposal should be a UK academic and he/she will need to have an established relationship with the US academic/research institution with whom the collaboration is proposed. The proposal should include separate costs for any secondments and/or work in the US, and any associated supervision costs. It should also indicate how overseas working would be managed. It should indicate whether the collaboration is essential or desirable to the proposal and the associated benefit of the collaboration. If work in the proposal is deemed relevant to US nuclear decommissioning challenges, the US DoE may fund part of the proposal.

Access to UK R&D facilities for handling radioactive material:

The NDA would welcome proposals where a PhD project would benefit from gaining access to UK research facilities for handling radioactive material. Applicants are encouraged to include estimated costs of undertaking R&D using radioactive materials in the proposal where a realistic estimate can be made (e.g. based on previous experience, or through discussion with the facility operator), or alternatively to state the nature and likely duration of the work they would like to undertake highlighting whether the active work would be ***essential*** to the success of the project or would just add value. If the proposed work involving radioactive materials is judged to bring significant benefits to the project, then the NDA will consider funding this work ***in addition*** to the PhD project scope.

Cross industry collaborations:

Recognising the cross-industry similarities between the decommissioning missions of the NDA and the Oil and Gas community, we would be interested to receive research proposals that build on these synergies and address common challenges. More information on the challenges surrounding decommissioning in Oil and Gas can be found here:

https://www.theogtc.com/roadmaps/decommissioning/

https://www.ukndc.com/research/

Whilst this element of call has not been formulated in conjunction with the Oil and Gas Technology Centre or the National Decommissioning Centre, any relevant proposals will be shared and assessed together with these organisations.

Details and further information

Funding will be available to UK academic institutions for PhD projects and to SMEs seeking 'top-up' funding for CASE awards and EngDocs in relevant areas. Only project proposals with a total cost to NDA of less than £120,000 will be considered (excluding cost of any collaboration with US research organisations or access to specialist facilities R&D facilities for handling radioactive material – as outlined above). Eligible projects will include PhD projects involving universities or subcontractors where the bursary is used as a grant top-up to access national facilities for research involving the handling of radioactive materials. NDA does not stipulate how this money is to be spent and will not penalise proposals that utilise some of the bursary funding to increase the stipend to the PhD candidate.

To comply with the Government's protective security procedures all employees/contractors will be subject to an Industry Assurance check and a level of National Security vetting. Proposals will be assessed by a group of nuclear industry specialists. Contractual arrangements will be administered by the University Research Framework contract holder (currently the National Nuclear Laboratory (NNL)) on behalf of the NDA.

Proposals must be submitted using the submissions site which is linked from the NNL bursary site **www.nnl.co.uk** and need to be submitted online at **www.nnl.co.uk** by 15:00 on **Thursday** 2nd **January 2020** Further information on the scheme, the assessment criteria and selection process is also available by contacting the administrator, Dr Mark Bankhead directly at the following email address (**mark.bankhead@uknnl.com**) and within the documents posted on the NNL website.

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Registered office: 5th Floor Chadwick House Warrington Road Birchwood Park Warrington WA3 6AE