NATIONAL NUCLEAR LABORATORY

NDA PhD Bursary Call 2021:

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]. Those research areas are the responsibility of the individual subsidiaries and SLCs.

This year, up to £750,000 is available from the NDA PhD bursary to support projects that will lead to the award of a PhD. Universities and Research Institutes are invited to make proposals up to a value of £120k per project in the following thematic areas:

A) Characterisation

The industrial need can be summarised as follows:

- Remote/Rapid Building, Plant, and Contaminated Land Surveillance
- Remote/Rapid Sampling Techniques for Hazardous Environments
- Improved and/or new techniques for in-situ analysis of contaminated land, buildings, effluents and waste packages

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

(A.1) (Rapid) 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.

(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 improve analysis cost, turnaround and improved supply-chain capacity. Key focus is on improved analysis/assay capabilities for alpha and beta radionuclides.

(A.3) 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.

(A.4) Universal sampling tools

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.

(A.5) Innovative ways of measuring or estimating the activity of a waste item or package.

(A.6) Improving characterisation techniques at waste category boundaries

Specifically, 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 addressing needs for waste types as outlined in the NDA radioactive waste strategy[2].

(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 associated with nuclear waste.

(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 disposal 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:

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[2] NDA Radioactive Waste Strategy September 2019, https://www.gov.uk/government/consultations/nda-radioactive-waste-management-strategy/outcome/radioactive-waste-strategy-september-2019#radioactive-waste-strategy

- 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.

(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.
- Understanding the fate and characterisation of land contamination in the biosphere.

(C.6) The application of modern techniques of machine learning, novel sensors and robotics for the characterisation and monitoring of radioactively contaminated land and groundwater. The research aim is to obtain a complete picture of contamination that can be communicated to all stakeholders in a manner useful for building confidence in remediation and end states.

(C.7) Innovative techniques for groundwater remediation or the remediation of radioactively contaminated land is of interest. In particular, research should address issues arising from long-term consequences of remediation which may have an impact upon sustainability and our responsibilities to future generations.

D) Decommissioning

(D.1) Remote deployment methods to enable Characterisation, Inspections, Deplanting and Demolition

The ability to identify "what" is "where" within an enclosed radiological environment enables proportionate post-operational clean out (POCO) and decommissioning plans to be produced. The ability to take measurements at the workface, within vessels, pipes and a cell will markedly reduce the burden upon existing labs and furthermore eliminate the need for samples, coupons etc.

There is a need to focus on pipeline deployment methods. The navigation of pipelines is a problem yet to be solved, particularly in long (40 m), thin (2 inch diameter) pipes. In addition, there is a need to deploy inspection devices, decontaminants or other tools both inside and outside of the pipework.

Development in this area has the potential to significantly reduce radioactive waste volumes, to enable easier characterisation and sentencing to underpin decisions on management and decommissioning of inaccessible structures. This challenge also extends to being able to access / characterise below ground and marine off-site structures such as buried discharge pipelines to determine the end states and methods in being able to demonstrate the residual risk.

(D.2) Asbestos Management

Asbestos management is a priority area to overcome the challenges relating to retrieval and packing / disposal as part of decommissioning plant and structures e.g. reactor vessels. For Magnox, it has the potential to be the dominant risk to workers given the volume of material and its friable nature. There is work ongoing as to disposal options i.e. melting or chemical destruction vs landfill, but there is a significant R&D gap in areas such as remote retrieval and hazard management aspects to facilitate decommissioning.

There is also the challenge for disposability, where asbestos may have low levels of radioactive contamination and so would be consigned to the Low Level Waste Repository. Again, there would be a preference for Asbestos Contaminated Materials to be in a non-friable form to meet the LLWR safety case disposability requirements. (Note where alternative approaches are being explored, the goal will be to destroy the hazard).

(D.3) Managing Ageing Assets and Conventional Decommissioning Hazards

Given the long timescales for decommissioning, there is a need to manage and maintain plant, buildings and structures until they can be decommissioned. The condition management of aging assets covers: material / structure degradation including aging steelwork and reinforced concrete which is an area that would benefit from R&D, as well as understanding the balance between using the condition and predicted condition of assets to inform decommissioning priority.

Identified gaps and opportunities for improvement in the following areas;

- The requirement for an improved health and safety (H&S) focus on processes supporting plant health;
- The need for improved risk-based assessments & approaches;
- The requirement for improved systems and/ or processes for information capture & management;
- The need for the clarification of responsibilities for safety (functional, programme & site);
- The need for improved governance to ensure expedient risk-prioritised investment.
- The above points also apply to Atomic Weapons Establishment (AWE) sites – there are many obsolete assets built in the 1950's, awaiting decommissioning.
- Conventional decommissioning risks such as working at height.

(D.4) Sorting & Segregation & Minimising Waste Volumes (including Graphite)

Segregation of waste to achieve lower waste volumes for disposal e.g. brick / concrete contamination.

Investigation into the application of automated systems e.g. conveyor belt systems which allow quicker identification of wastes. Review the potential to use this technology across the wider NDA estate.

Given the regulatory and government drive for sustainability and zero waste, there is increasing concern regarding disposal of Very Low Level Waste (VLLW) / Low Activity-Low Level Waste (LA-LLW). One of the barriers to resolving this is the lack of a technology that can be deployed on a large scale for the decontamination of concrete. This prevents reclassification to Out of Scope (OoS) and the potential to open different uses of the material to reduce the focus on disposal.

Methods that allow for the segregation of contamination from a substrate can enable the consolidation of contamination into a smaller, yet more active waste form E.g. LLW to very low volume ILW. Such processes need to be cheap to employ and require minimal infrastructure to support it, given a context of a large LLW inventory.

The methods should also consider size reduction, dismantling and waste handling. Also improvements in packing efficiencies e.g. compaction, super compaction, cutting techniques, thermal treatments.

There is a significant graphite inventory across the NDA estate destined for a Geological Disposal Facility (GDF).Proposals relating to the compaction or repurposing/reuse of graphite would be of interest.

Identify which wastes could be identified for reuse to minimise waste volumes, e.g. feasibility of using VLLW / LLW as shielding materials for construction in new build or optimising concrete waste for use as infill. This may tie in with graphite reduction / reuse.

(D.5) Retrieval of Heels and Residues / Methods for Penetrating Vessels and Pipework

There are a large number of tanks / vaults / tubes which are difficult to access and although bulk volumes can be removed there is a need for easy removal of any remaining heels and residues.

The means to penetrate vessels and pipework simply, cheaper, faster and (e.g. from MSMs) in a secure manner.

Remote tools for size reduction, dismantling and waste segregation (general waste handling).

Challenges arise from all dose rate levels, sludges & solids of different rheology and physical properties.

The integrity of the seal is important to eliminate any release fraction when applied, be water / chemical proof and functional for several years after insertion to allow further washout of plant etc. Further learning and development is needed into sludges and solids, covering different methods e.g. hydrogen hot tapping, what works well, challenges etc. Again, cell geometry / environment makes this a challenge and a topic for further research.

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 (α) damage and helium

Plutonium and related materials are α active. Each α 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 α damage and leaching. NDA is interested in proposals in α damage and helium distribution in special nuclear materials, both product powders and engineered ceramics relating to interim storage or final disposal. Any proposals would be ideally targeted at supporting the NDA mission but naturally in any PhD programme there will be an element of skills / capability development.

(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. NDA would welcome proposals that seek to understand this issue using characterisation methods that may not readily be available in active laboratories, such as synchrotron light sources, providing such proposals are within the bounds of radiological protection and other relevant regulation. There is an element of both supporting the mission and capability development anticipated with this proposal area.

(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 production technologies that may be relevant, SPS, flash sintering etc. NDA welcomes proposals aimed at developing the production routes for ceramic plutonium wasteforms. There is an element of both supporting the mission and capability development anticipated with this proposal area.

(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, groundwater leaching etc with a particular focus on post closure behaviour in GDF. There is an element of both supporting the mission and capability development anticipated with this proposal area.

(E.8) Radiation Induced Segregation (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 https://www.gov.uk/government/consultations/nuclear-decommissioning-authority-nda-draft-strategy-for-consultation) 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.
Aligned with site end state and nuclear archive themes, the NDA is considering the management of information associated with long term and post remediation controls. It may be necessary for information about site condition to be available in the very long term. Parallels can be drawn from historical records which provide information regarding land use which were generated one or two millennia ago. The NDA is keen to understand from historians: the nature of records that have survived from history; why they may have been retained; how have they remained available for contemporary review; and the challenges historians have in access and interpretation. This piece of work will help inform the nature and longevity of controls to protect people and the environment as part of determining the site end state. (For description of site end state strategy development see the NDA Draft Strategy https://www.gov.uk/government/consultations/nuclear-decommissioning-authority-nda-draft-strategy-for-consultation).

(F.2) Low CO_2e construction for decommissioning
Some civil decommissioning activities will require the construction of substantial infrastructure such as new intermediate storage facilities and eventual disposal facilities. Research is required into how to minimise the carbon footprint of these structures whilst maintaining the necessary engineered levels of confidence during their operational lifespan.

(F.3) Low CO_2e alternatives for waste packaging
Nuclear waste packages often have a high CO_2e either through the use of energy intensive construction materials for the outer packaging (e.g. steel) or via the waste matrix itself (e.g. grout). These materials are likely to become more expensive or less freely available in the future, as well as contributing to the carbon footprint of the NDA group and our supply chain. Research is required into alternative, low CO_2e materials for use in waste packaging that can meet the necessary storage and disposal requirements.

(F.4) Nuclear Cost and Schedule Benchmarking

Research is required to identify the key elements that drive cost and schedule outcomes for nuclear decommissioning projects with a view to establishing key ratios and heuristics capable of being used to benchmark estimates for future decommissioning against past outcomes. This research could feed into NEA's proposed cost and schedule database and will aid structuring the database and help to identify the cost and schedule drivers that are most mismatched between estimate and outcome, i.e. what it is that the industry keeps underestimating. Ultimately, the research will lead to greater accuracy in nuclear provisioning and thus better strategic decision making.

(F.5) Organizational Insularity

Large industries, including the nuclear decommissioning sector, often display "siloed" behaviour, such as systemic tendencies not to seek external insights and learning from other industries. Research is required to identify the root causes of such behaviour and proposals for effective intervention and remediation, to minimise duplication of effort and ensure the swift adoption of appropriate best practice.

(F.6) Long term carbon accounting

The NDA mission will take many decades to complete and, over that time, we will need to be able to measure and monitor our group CO_2 footprint to enable appropriate planning and decision making. Research is required into the methods and predictive tools and techniques that would allow comprehensive carbon accounting to be integrated into long term strategic planning.

(F.7) C-14 radionuclide of interest for near-surface disposal

C-14 is released from a range of materials, particularly steels and graphite, in waste streams which are candidates for disposal in near-surface facilities. The C-14 is in a range of different chemical forms, depending on the source material, but a significant component is likely to be present as volatile species that will be easily transported in a gas phase to the surface environment. Another fraction may be initially released as inorganic carbonate species that are expected to interact with the cement-based encapsulation grout and be immobilised within or close to the waste packages. However, there are uncertainties around the chemical forms of the C-14 released from different waste materials. Research is required to determine the likely chemical forms and mechanisms for interaction with the surrounding environment. For example, will inorganic C-14 remain immobilised despite potential microbially mediated processes?

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 not mandatory 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 Direct Research Portfolio University Interaction 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 **Friday 15th January 2021.** 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.