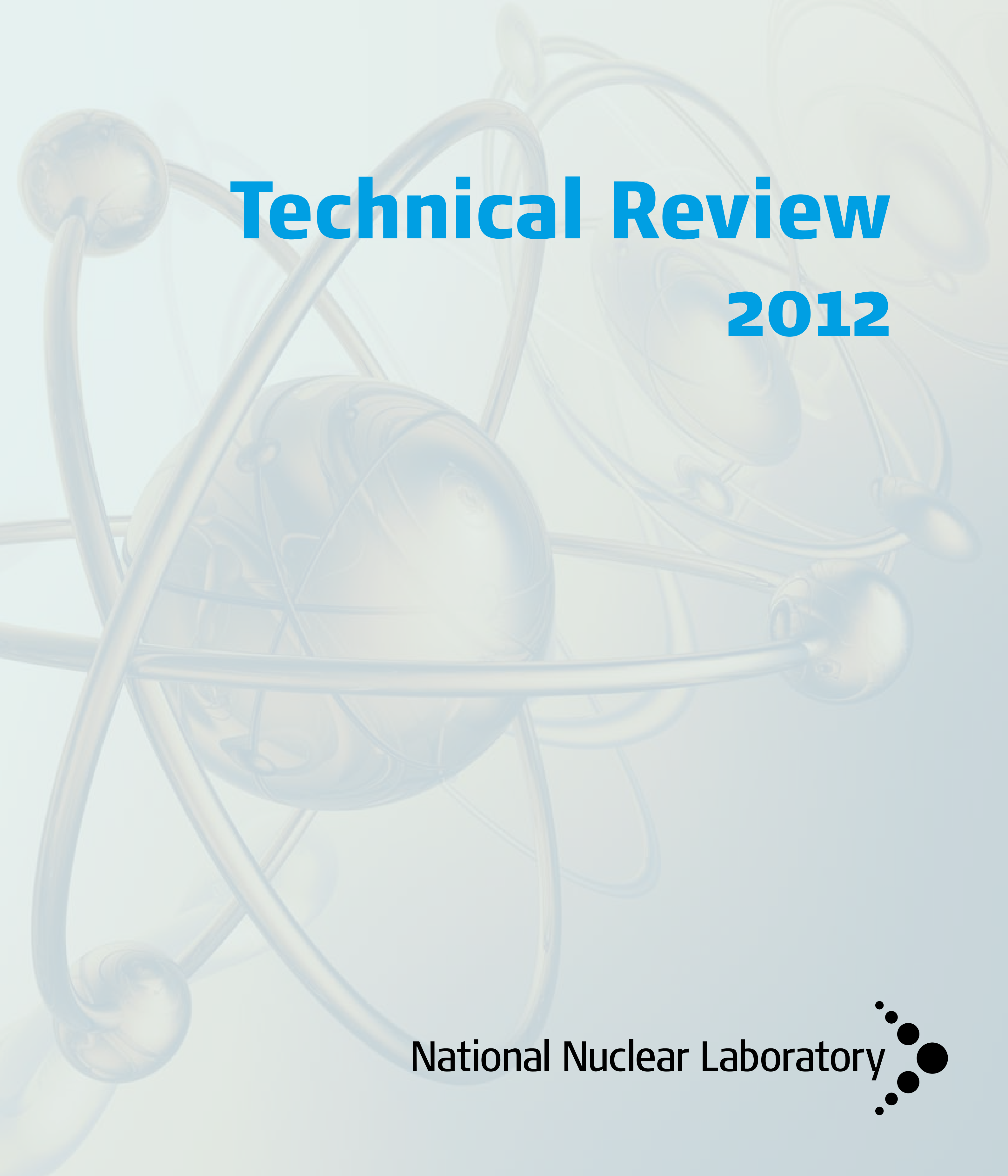
Technical Review 2012



National Nuclear Laboratory

Table of Contents

Chief Science and Technology Officer Overview

Welcome to the National Nuclear Laboratory's 2012 Technical Review. This looks at our technical activities and achievements over the past year or so; and we've had some outstanding highlights in the past year. Significant progress has been made in establishing NNL as a fully operational National Laboratory.

An important part of a fully functioning National Laboratory is its interactions with other key stakeholders and organisations. A 'Hub and Node' model (presented on page 28) sees NNL helping to bring a range of stakeholders together for the benefit of the industry and ultimately for UK plc. Our research and development programme generates Intellectual Property (IP), develops capabilities and supports collaborations across the entire nuclear fuel cycle.

We work with over 20 universities and a number of national and international research and development organisations, including US National Laboratories.

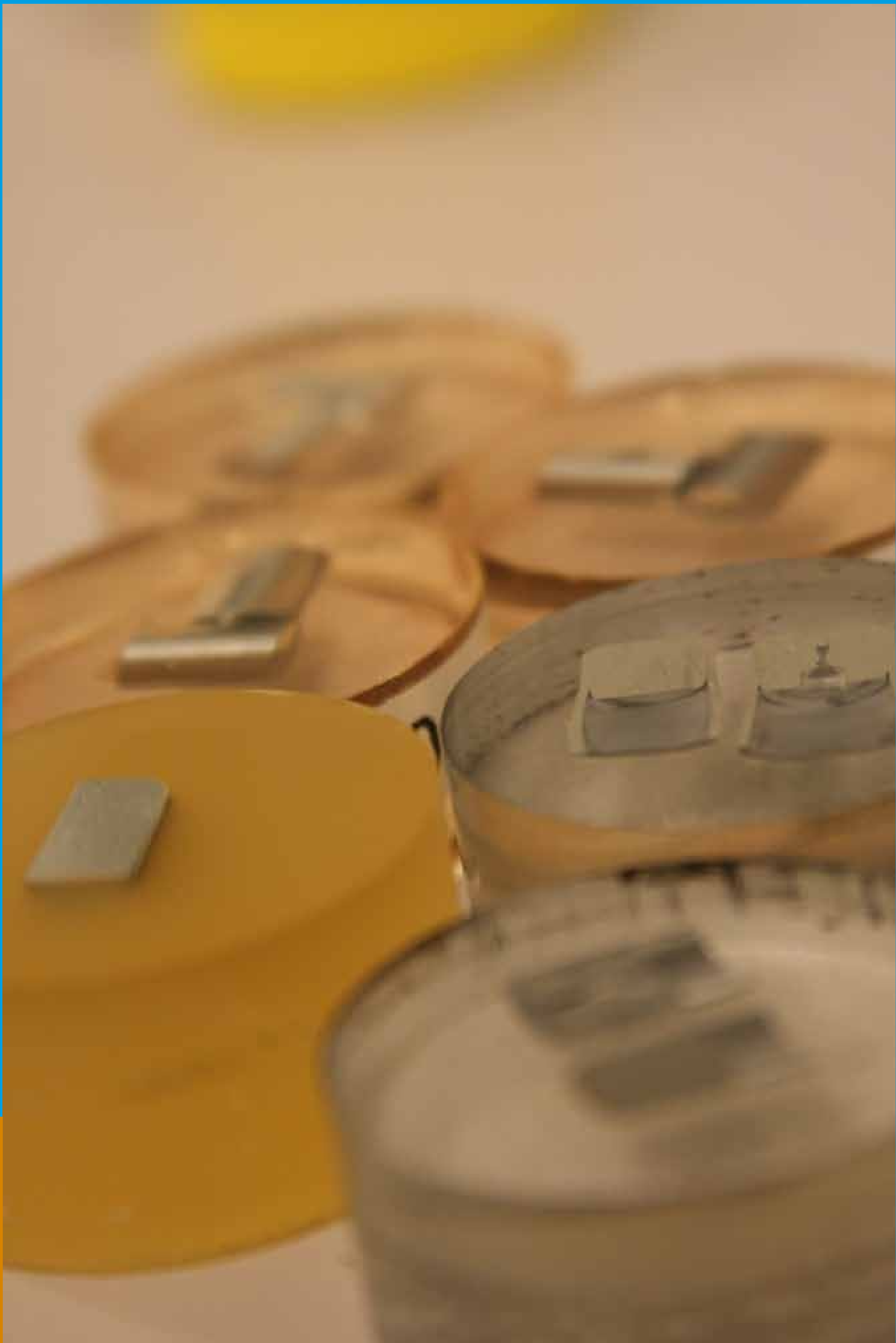
Although we are fully funded through our own commercial work, NNL's breadth goes beyond this to include independent and authoritative advice to the UK Government. We have played an integral role in offering technical advice to the government and the nuclear regulator in support of determining the UK position on nuclear following the unfortunate events in Japan last year. Some 40 of our people have been involved one way or another ranging from the Managing Director advising Mike Weightman to a secondee in the British Embassy in Tokyo.

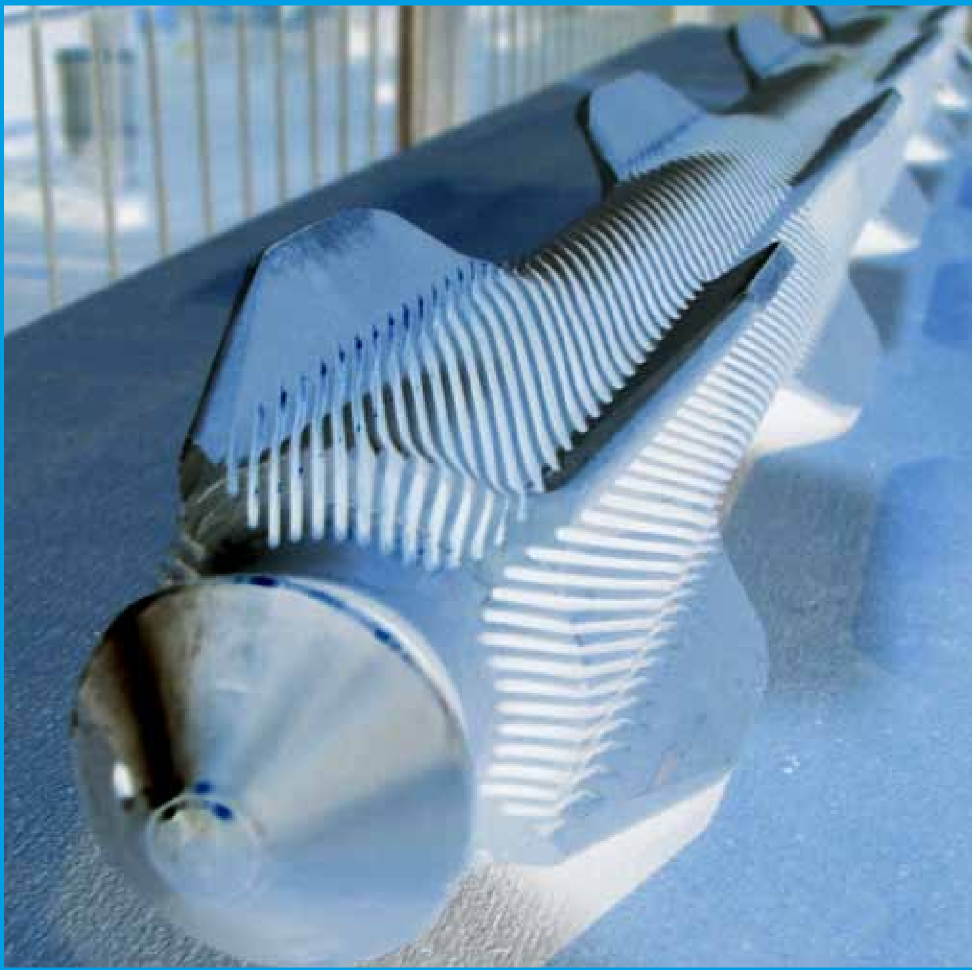
NNL has published a number of position papers in the past year, providing a clear, high level view on specific technical and policy issues. Our position papers on Thorium and UK Nuclear Horizons can be downloaded from www.nnl.co.uk/positionpapers.

But these are just the tip of the iceberg. This review covers a wide range of our technical activities but you can find more, including regular updates on our website: www.nnl.co.uk.

Graham Fairhall

NNL has been working with ANSTO to develop a ceramic matrix for the long term storage of plutonium residues. See: Hot Isostatic Pressing (page 13).





Residues Treatment Plant

One of our major customers, Springfields Fuels Limited, treats residues arising from decommissioning uranium processing plants.

The facility used to deal with these residues – the Residues Treatment Plant (RTP) - is coming to the end of its life and needs decommissioning. This presents a situation which will create significant amounts of residues requiring treatment while simultaneously removing the major capacity for dealing with them.

NNL was asked to use its experience and expertise to identify a range of options, in the form of a Best Practicable Environmental Option (BPEO) study. This determines the choices available and assesses them against safety, technical, environmental and financial criteria, enabling them to be systematically ranked.

Once the study was complete, experts from NNL and Springfields Ltd carried out a joint weighting analysis to demonstrate and support the robustness of the preferred options. The output will provide evidence of the rigorous process undertaken before a final decision is taken which will support the business case for decommissioning the RTP.

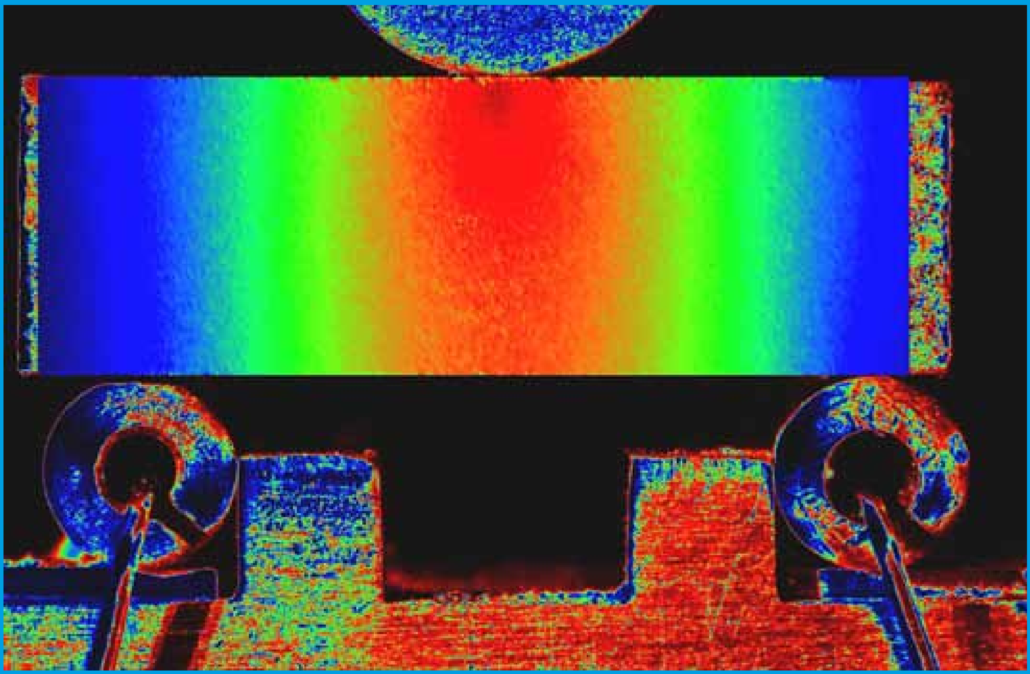
New Graphite Examination Techniques

The strength and integrity of the graphite moderator in Advanced Gas-Cooled Reactors (AGR) is an important consideration for safe operation and plant life extension. Samples of core graphite are routinely taken for monitoring physical properties, including the Young's modulus (the amount a material stretches when pulled). In addition, reactor operators need to know the material's Poisson's ratio (the effect in other dimensions to stretching). These parameters are required for computer code used during reactor core assessments.

The UK's National Nuclear Laboratory has developed a technique which uses electronic speckle pattern interferometry (ESPI) to accurately measure the 3D displacements which occur during a 3-point bend test. This mechanical testing arrangement was used to accommodate the available size of material extracted, sampled from the AGR cores. These displacements can be used to determine both Young's modulus and Poisson's ratio over the range of loading conditions up to failure.

This technique has never been used for quantitative measurements before and NNL has spent 3 years perfecting it in partnership with EDF, as part of a project for developing new techniques. Development of the technique highlighted that assumptions normally made during such mechanical testing may be invalid when compared to the accurate three dimensional motions measured by ESPI. Extensive development was required to both understand and overcome these effects by comparing the measured movements with those of 3D finite element modelling.

The technique will ensure that more accurate measurements are taken during sampling in an efficient and effective way. This will save customers time and money and provide assurance that the data they are using to support safety cases is highly accurate.



Assessment of Radionuclide Release from Spent AGR Fuel in a Geological Disposal Facility

NNL carried out a study of used Advanced Gas-Cooled Reactor (AGR) fuel to help the Nuclear Decommissioning Authority (NDA) further understand its characteristics and suitability for long term disposal in a Geological Disposal Facility (GDF) and identify any further potential issues. Specifically, our study looked at the impact of water on the fuel once it has been disposed of. Initially, easily accessible radionuclides are released; this is known as the Instant Release Fraction (IRF) and takes place over a period ranging from days up to several hundred years. Over a longer period of time (from about 100,000 years), the fuel matrix dissolves, releasing the fission and activation products and actinides held within.

The timescales involved vary depending on a number of factors, including the condition of the fuel when it is stored. NNL's study took account of the full range of factors in assessing the IRF and long term dissolution issues.

NNL's first step was to acquire available data including: fuel and cladding weights; locations and reactor histories; fuel and cladding radionuclide inventories and fuel condition and output from previous work in this area. We then reviewed the work and made updated recommendations for both IRF and longer term values.

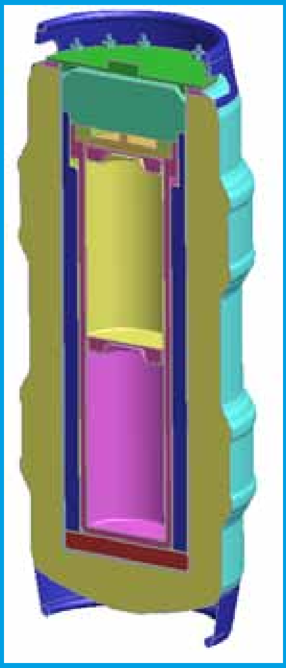
NNL's assessment provided key underpinning information to support:

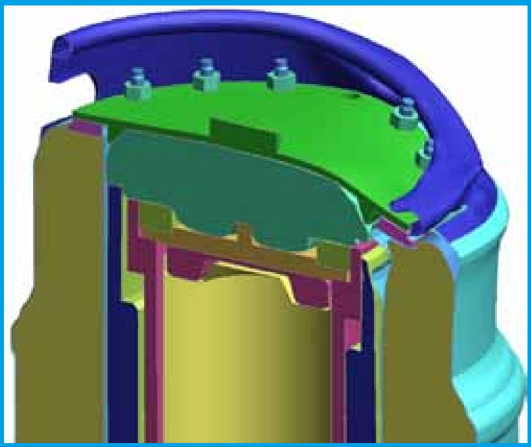
- calculations of radiotoxicity and potential dose hazard over time
- assessment of how fuel and packaging will interact with a GDF
- potential radionuclide release to the environment if a canister fails.

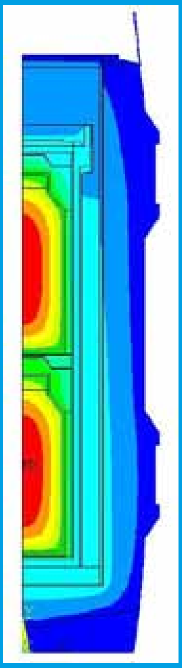
Microbial Characterisation of Storage Pond Water

NNL carried out a characterisation of the microbial communities present in one of the storage ponds in the Thermal Oxide Reprocessing Plant (THORP) at the Sellafield site. This exercise was essential in support of a strategy to use nitrate dosing in the pond to help counter corrosion of fuel rods stored there. Micro-organisms, including denitrifying bacteria, in the pond have the potential to undermine this anti-corrosion strategy. In addition, NNL also examined any algal species present in the pond water which have the ability to utilise nitrate as an electron acceptor, again undermining the anti-corrosion strategy.

The testing revealed that the levels of the denitrifying bacteria and algae were low enough to ensure that the anti-corrosion nitrate strategy would not be undermined.







Thermal and Impact Modelling Support for a Transport Safety Case

Several thousand canisters of plutonium oxide need to be moved from their existing location to a new facility. A safety case for the proposed transport package to be used for this relocation needs to demonstrate safe performance of the package in hypothetical impact accident scenarios and that acceptable temperatures are maintained throughout the package due to heating from the contents.

The current design of the package has an internal cork liner used for shock absorbing and thermal insulation purposes. For operational efficiency reasons, there is significant benefit in replacing the cork with a material which offers increased heat transfer away from the internal canisters, while retaining impact shock absorbing properties.

A thermal finite element modelling assessment identified aluminium honeycomb as a potential suitable alternative material. Further modelling assessment of the structural integrity of the package in impact accident scenarios enabled us to specify the grade of aluminium honeycomb that will provide optimum impact protection.

Following on from this work, a prototype is now being built and physically tested to substantiate the modelling approach.

As a result, a safe, viable, efficient way to transport these containers is currently being developed. This has a number of advantages including reducing the amount of transports and avoiding the cost of developing a completely new transport package. The use of modelling has validated the performance predictions and verified the design prior to any physical testing taking place.

NNL works for a range of customers around the world.

Our technical expertise supports activities across the whole nuclear fuel cycle.

Physics Support to THORP

Sellafield Limited's Thermal Oxide Reprocessing Plant (THORP) primarily deals with standard commercial fuels from Pressurised Water Reactors (PWR), Boiling Water Reactors (BWR) and Advanced Gas-Cooled Reactors (AGR). However, they can also deal with a number of miscellaneous, non-standard fuel types, known as exotic fuels. One such type of fuel contained in the receipt and storage ponds at THORP is from the Vulcain reactor - an experimental reactor in the 1960s. Before being reprocessed, it is essential to know the plutonium content of the fuel.

Unfortunately the records kept with the fuel are incomplete, so a straightforward determination of plutonium content is not possible.

Using two specialist computer codes – WIMS and FISPIN – NNL was able to take what information was available and construct a reactor physics model. This enabled an accurate representation of the plutonium content in the fuel and the isotopic information to be determined.

As a result, this fuel can now be reprocessed, helping to accelerate work at the Sellafield site.

Support to the Bio-Decontamination of Open Ponds at Sellafield

Some of the older storage ponds at Sellafield are open to environmental factors and as a result have a problem with algal contamination.

In an excellent example of the way in which the National Nuclear Laboratory operates, Professor Jon Lloyd of The University of Manchester, a Visiting Senior Fellow at NNL, investigated the problem. As part of his work he needed to know the radiation field around the Multi-Element Bottles (MEB's) stored in the ponds in order to determine the effect on the algae.

NNL has an excellent relationship with the National Physical Laboratory (NPL) who were able to help by creating a 3D model of a Steam Generating Heavy Water Reactor (SGHWR) fuelled MEB. They were able to use this to calculate the surrounding gamma and radiation fields. NNL's physics team also devised a method to deal with the problem of the increase in gamma radiation from Cobalt 60 activation in the steel structures at the top and bottom of the fuel elements. NNL's modelling methodology avoided the significant expense of developing an actual physical model and the costs of any associated experimental work.

Hot Isostatic Pressing

NNL provides support to customers in the development of waste immobilisation process and products. There are a number of waste streams which are not suitable for processing using currently established methods, for example cement encapsulation and vitrification.

NNL has been working for a number of years with the Australian Nuclear Science and Technology Organisation (ANSTO) to develop a new immobilisation technology using Hot Isostatic Pressing (HIP) – using high temperature and pressure to create a stable ceramic matrix. A programme funded by Sellafield Limited has successfully demonstrated the immobilisation of plutonium containing wastes and residues in ceramic based wasteforms using this HIP technology.

With the development and demonstration phases largely complete, NNL is now supporting Sellafield Limited in a studies phase as a precursor to the design and build of a pilot plant. The design of this plant will start later this year and the plan is to carry out active demonstration of the technology using actual residues in NNL's Central Laboratory at Sellafield.

Wider application

The experience gained in the development and demonstration stages has shown there are wider applications for the technology. NNL, with Sellafield Limited's support, is exploring the use of encapsulation using metals such as copper for the immobilisation of other waste streams. Experiments have also shown that other materials such as aluminium, glass and polymers may be suitable candidates for the HIP'ing process and in some cases, acceptable wasteforms can be produced at relatively low temperatures. NNL has utilised its non-active pilot plant, Workington Laboratory, to support this work.

NNL understands the complex needs of our customers and develops innovative and simple solutions.

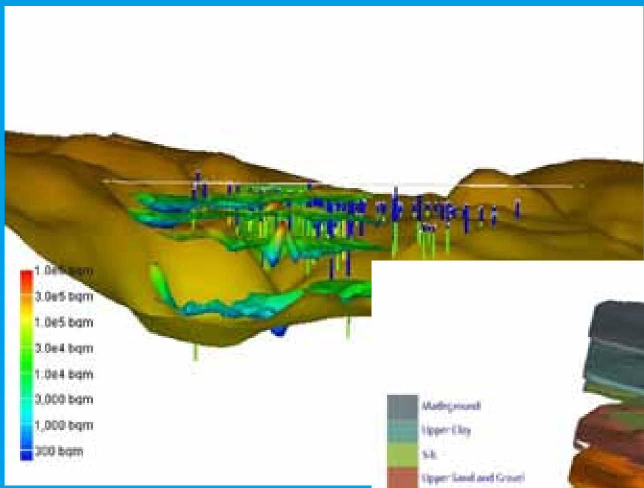
Radioactive Risk Assessment for the Magnox Swarf Storage Silos at Sellafield

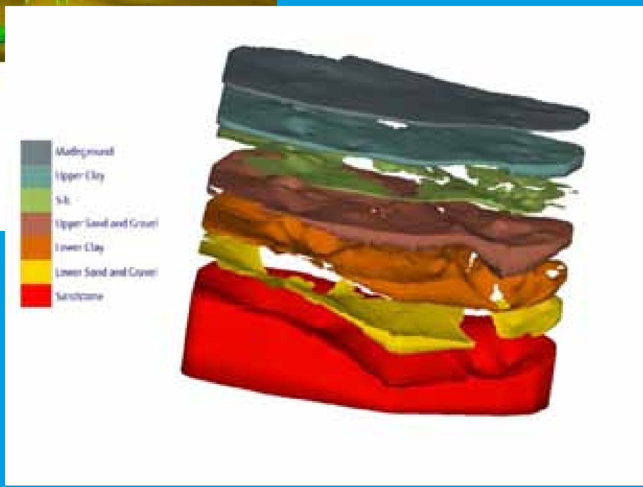
In line with the NDA's requirement to accelerate clean-up and decommissioning on the Sellafield site, a series of silos are being readied for emptying prior to the decommissioning process. The silos were used to store Magnox Swarf (fuel cladding) arising from reprocessing operations in the 1960s, 70s and 80s. A complication to the process is that during the 1970s there was a leak from one of the silos. Although no further breach of containment has occurred since, the potential for renewed leakage during decommissioning is a risk that needs to be considered and mitigated.

As part of this process, NNL undertook a radiological risk assessment to consider the potential consequences from any further loss of containment. This looked at:

- Additional dose risks, who might be affected and what reduction in risk was required to bring impacts within a tolerable range
- Increases in volumes of contaminated soil
- Timelapse concentrations of activities at various site locations.

NNL's study showed that potential impacts to human health and the wider environment associated with the historical leak and the potential future leaks were below levels of concern, but a future leak could result in a significant increase in contaminated soil volumes. This assessment informed our customers in their discussions with regulators in determining the necessary requirements for leak mitigation.





3D Geological Modelling for a Safety Case Project

NNL has carried out several projects in support of the Low Level Waste Repository's (LLWR) Safety Case needed to continue operations. One such project was to develop a 3D model representing the geology from the Quaternary Period (the most recent geological period) underneath the LLWR site. This incorporated the latest data from a recent geophysical survey of the site.

This type of 3D modelling is often difficult due to variations in the distribution of available data. In addition, data tends to decrease in quality as the size of the area studied increases – especially when looking at an area the size of the LLWR site. NNL was able to use mathematical algorithms to interpolate between data points and provide an accurate picture of the site.

In order to ensure LLWR had the most accurate map available, NNL also used a different modelling technique which relies on geological interpretation rather than mathematical interpolation. This second map meant that LLWR was provided with two equally valid but alternative geological models, ensuring they had the best available data to inform their future strategy.

NNL Support to Highly Active Waste Work at Sellafield

One of our proudest achievements over the past few years has been the combined work we have carried out to support the ongoing operation of the evaporators in the Highly Active Liquor Evaporation and Storage (HALES) plant at Sellafield. The HALES plant is an essential part of reprocessing and therefore of key strategic importance to Sellafield Limited and the NDA. Work we have carried out in close consultation with our customer has, over the past few years, directly ensured that the evaporators and several other key plants have been able to continue operating. Our work includes:

- Inspection devices development and deployment
- Evaporator boiling rig
- Evaporator structural assessment
- Evaporator thermal asessment.

Work in each of these areas was focused on providing an updated corrosion rate assessment and accurate prediction of remaining operating life of the evaporator.

Future Work Programme for Modelling of Flow and Temperature in HALES Evaporator C

Previous Computational Fluid Dynamics (CFD) and process modelling work has suggested a potential flow regime in Evaporator C at Sellafield. Applying this flow regime helps to bring predicted wall temperatures within the evaporator into better agreement with plant observations. To integrate the separate flow and temperature assessment approaches, additional rig work needed to be carried out in order to produce a robust remnant lifetime assessment.

This matter is of significant importance for our customer – given that reprocessing cannot continue without an operational evaporator. As such, NNL developed an issue resolution strategy by working with both our own experts and external academics who support and peer review the HALES programme.

This strategy has identified the necessary rigs and experimental analysis required to deliver a robust understanding of temperatures and flows in Evaporator C. Six separate trials were identified.

NNL's work has provided a route map of what is required and the key decision points. A clear programme of work required to underpin modelling work predicting temperatures within Evaporator C has been developed speedily, ensuring our customer has the required information to continue with its operations.

Vitrification of Uranium-Bearing Liquors

High Active Storage Tanks (HASTs) 1 and 2 were filled between 1955 and 1975 and contain highly active liquors from the earliest production scale reprocessing operations to take place on the Sellafield site. The composition of the liquors is different to current wastes because of technical advances. NNL was asked to carry out a number of experiments to determine how the materials behaved and how best to treat and vitrify them.

NNL established facilities at the Central Laboratory to manufacture and test glasses containing uranium. Much of the equipment required to carry out the experiments was located in our Non-Active Laboratory. NNL determined that the safest and most cost efficient way to carry out the experiments was to set up a special nuclear material accountancy area with additional security and safety measures.

NNL provides a safe, secure and cost effective capability to perform research utilising existing equipment. The results of the work have allowed Sellafield Limited to develop a strategy for the vitrification of the contents for HASTs 1 and 2 and to reduce highly active liquor stocks with the knowledge that the resulting glass product will be of an appropriate quality.

Modelling of Flow in HALES Evaporator C

Plant observations from Evaporator C were not in line with current theories for flow and boiling. This meant there was uncertainty around the predictions for heating jacket temperatures and therefore the remnant life of the evaporator. This in turn had potential implications for reprocessing.

NNL deployed a combined process/Computational Fluid Dynamics (CFD) modelling approach. A CFD model was used to indicate the likely flow regime in the evaporator up to the boiling point. However, developing a CFD model to represent boiling would have been too time consuming so a process model was developed.

Building on the CFD results, an existing process model of the medium active salt-free evaporator was modified to represent Evaporator C. The effects of boiling could then be predicted.

This innovative solution allowed an answer to be generated much more quickly than was possible using experimental trials or either modelling technique in isolation.

**NNL has carried o
of work related to
This includes mod
work. We have als
world-leading ana
remaining life of t**

Helping Iraq to Clean Up Nuclear Sites

NNL has signed an agreement with the European Union (EU) and Iraq to help scientists dismantle, decommission and decontaminate nuclear facilities built during the Saddam Hussein regime.

Iraq has tried to clean up ten old nuclear sites around the country but progress has been slow since work began two years ago. This new EU programme will see NNL involved in training Iraqi scientists and provide equipment to speed up the clean-up operation which had been previously estimated to take up to ten years.

NNL, along with BelgoProcess, will support the programme requirements in areas such as dismantling, decommissioning and decontamination activities, radioactive waste management and disposal. Up to 80 Iraqi nuclear scientists will be involved in the programme with the aim of exchanging scientists and gaining mutual experience for the benefit of the overall programme.

Technology and Economic Development

NNL was approached by Stopford Projects, a North West based engineering consultancy company, to provide support on a novel nuclear decommissioning process. Stopford believe the process, already used by other industries to reclaim used metal equipment, could make savings to Low Level Waste disposal costs. However, as a non-nuclear company, they needed access to nuclear expertise and facilities.

NNL agreed to support Stopford in an application to the Technology Strategy Board (TSB) to receive funding towards proving the process at a laboratory scale. The application was successful and NNL have now been contracted to undertake laboratory scale experiments.

This is an excellent example of NNL helping a business transfer its technology from another industry and test it in a nuclear environment. If successful, an opportunity for further funding from TSB is possible to help them scale-up their process.

ut significant amounts
the HALES Evaporator C.
elling and experimental
o contributed some truly
lysis to help determine the
he Evaporator C.

Signature Research Programmes

NNL has five Signature Research Programmes:

- Spent Fuel and Nuclear Materials
- Legacy Waste and Decommissioning
- Waste Immobilisation, Storage and Disposal
- Fuel and Reactors
- Nuclear Security

Each of these programmes plays an integral part in helping to deliver NNL's key mission of providing a coherent and integrated research and development programme. These programmes are customer funded with additional support from NNL.

This section explains the key areas of interest under each programme.

Spent Fuel and Nuclear Materials

Encompasses all aspects of the management of spent fuel, uranium and plutonium and includes:

- Technical support for spent fuel storage and reprocessing operations and all of the associated waste and effluent treatment operations such as highly active waste evaporation and storage
- Evaluation of available options for future disposition of uranium and plutonium and supporting the continued safe storage of separated plutonium
- Development of treatment/packaging options for miscellaneous fuels, including the generation of data to inform future decisions on disposition
- Post Irradiation Examination (PIE) of fuel from operating reactors
- Advanced fuel cycle and flow-sheeting studies.

Legacy Waste and Decommissioning

Encompasses management of the post operational legacy of nuclear operations including the retrieval and clean-up of legacy wastes and contaminated land:

- Characterisation of legacy materials including site, plant and inventory
- Understanding the behaviour of waste during retrieval, handling and treatment
- Strategy development for legacy management and decommissioning
- Retrieval and remote deployment technologies
- Decontamination technologies
- Technologies to quantify and remediate contaminated land
- Development of orphan waste treatment technologies.

Waste Immobilisation, Storage and Disposal

This programme includes all of the research carried out by NNL in support of activities at the back end of the fuel cycle from waste management to disposal:

- Waste immobilisation and processing to produce wasteforms suitable for disposal
- Physical and chemical evolution of wasteforms over time in both interim storage and disposal environments
- Disposal of radioactive waste, including near surface disposal of Low Level Waste and geological disposal of higher activity waste.

Fuel and Reactors

NNL is home to some of the key specialist nuclear skills required to support the design and operation of both current and future reactors. This research area supports:

- Design of both the reactor and its fuel
- Assessments of the safety performance of the reactor and its fuel
- Assessments of the operational performance of the reactor and its fuel.

Nuclear Security and CBRN (Chemical, Biological, Radiological, Nuclear)

Covering research associated with the nuclear security of facilities and nuclear materials, with a key focus on non-proliferation of nuclear technology and materials; and the enhancement of UK resilience to CBRN threat:

- Development of novel detection technologies to assist in the detection of concealed nuclear materials
- Technology transfer and development of civil nuclear decontamination and detection technologies for UK civil response
- Understanding the behaviour of nuclear materials to aid development of CBRN response
- Waste management following CBRN events
- Decontamination technology
- Enhancing UK efforts to detect and prevent the proliferation of nuclear technology and materials
- Enhancing nuclear forensic and characterisation capability.

NNL in Europe

NNL has a long history of involvement in European nuclear matters. We are board members of the Sustainable Nuclear Energy Technology Platform (SNETP). In addition, we take part in a number of working groups: Training and Knowledge Management, European Sustainable Nuclear Initiative (ESNI), Gen II/III and an SNETP working group.

NNL is co-chair of the SNETP Education, Training and Knowledge Management Working Group. As part of this role, we have made a significant contribution to the production of the 'Key Elements of a Sustainable European Strategy for Education and Training' report published in December 2010. Most nuclear member states were involved in the preparation of the report which addressed the key issues such as skill gaps that the industry will face over the next couple of decades.

The skills gap is likely to be in the thousands per year, across a variety of disciplines, skills and professions. Some member states, including the UK and France, have carried out comprehensive reviews to identify specific skill gaps, while others are still collating data.

NNL and other UK Working Group participants, such as the sector skills council, Cogent, have worked with other stakeholders including the National Skills Academy (Nuclear), Nuclear Institute and universities to demonstrate that the UK has a comprehensive knowledge of the needs of the industry for ongoing operations, current and future decommissioning and new build.

The report's eight recommendations address a common taxonomy of skills and competencies linked to jobs, optimisation of the curricula of academic programmes related to nuclear energy, a framework for mutual recognition of qualifications and co-operation with non-EU countries in education and training.

FORATOM

NNL is the UK's representative on the FORATOM (the European Atomic Forum) Research and Development (R&D) Task Force. This Task Force provides support to FORATOM by providing a collective EU industrial view on R&D trends and future needs. It also assists in the preparation of papers, reports for MEPs and in helping to influence the scope and priorities of wider European Atomic Energy Community (EURATOM) framework programmes.

EU Programmes

NNL plays a key role in several programmes, with a major role in the ACSEPT and Carbowaste programmes. Our recently commissioned Plutonium and Minor Actinides (PuMA) Laboratory (pictured right) is providing key research and development work to support the ACSEPT programme. Further information on both of these programmes can be found at: www.acsept.org and www.carbowaste.eu.

Senior Fellows

NNL's leading technical specialists are called Senior Fellows. Their remit is to provide the technical vision and leadership for their specialist area. In addition, they are expected to mentor and coach other employees and finally they act as ambassadors for NNL in external technical roles and relationships. Three of our Senior Fellows provide an overview of their activities from the past year.

Martin Metcalfe, Senior Fellow, Graphite

NNL is the lead organisation internationally for the measurement and characterisation of irradiated nuclear graphite. Measurements and characterisation can be performed on material taken from operating nuclear plants to monitor condition and to generate databases to support continued operational safety cases. When a measurement is performed on a piece of graphite, it is essential that the measuring facility employs methods consistently and in a manner compliant with internationally recognised standards.

A Senior Fellow initiative to consider this issue has been implemented on two fronts. The development of graphite standards for nuclear application is being actively pursued through NNL participation and leadership on the ASTM International Committee for Manufactured Carbon and Graphite Products.

An improved understanding of sample size effects on property measurements is being undertaken through a Signature Research Programme and in collaboration with the US National Laboratories at Idaho (INL) and Oak Ridge (ORNL). It is anticipated that this collaboration will expand to include other organisations.

On the ASTM International Committee, NNL has been leading sessions on physical properties for some years with the objective of aligning standards with practice in the nuclear industry. Over the last year, NNL has authored a new guidance standard for measurements on small graphite samples. This addresses non-compliance for a range of property measurements. The collaboration with US laboratories involves a definitive review of historical work on graphite strength to identify knowledge gaps followed by new experimental work to fill these gaps.

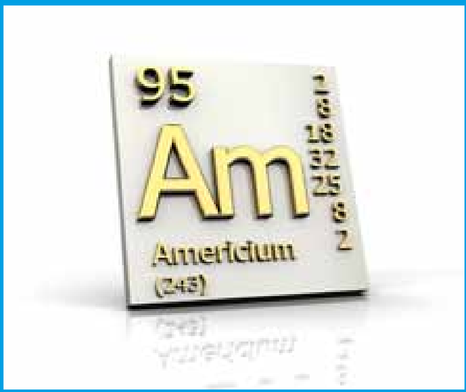
The output of this project is likely to lead to a revision of the guidance standard and there are plans for the study to be extended to other properties. The project also has broader objectives of developing new measurement techniques and physically-based models to describe and to predict graphite property behaviours as a function of temperature and fast neutron irradiation.

Joe Small, Senior Fellow, Waste and Environmental Geochemistry

Collaborative research in the field of geological disposal of radioactive waste has progressed through the Natural Environment Research Council (NERC) Bigrad project (www.bigradnerc.com). The Bigrad (Biogeochemical Gradients and Radionuclide transport) consortium undertakes fundamental research concerning the chemical speciation of multivalent radionuclides across the chemical gradients that will develop between a cementitious disposal facility and geological host rock. The consortium includes research groups at Manchester, Leeds, Loughborough and Sheffield Universities. NNL contributes modelling expertise and knowledge transfer to apply the outcome of the Bigrad research to disposal programmes. The four year Bigrad project has seen NNL undertake modelling to support the design of experimental research.

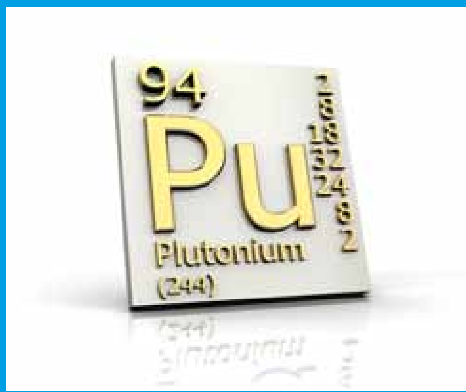
The appointment of Professor Jon Lloyd (University of Manchester) as a Royal Society Industrial Fellow based at NNL, provides a further link to academic research. Through this appointment, further opportunities for NNL involvement in Research Council funded research into geomicrobiology are in preparation and are focused on geodisposal and carbon capture and storage.

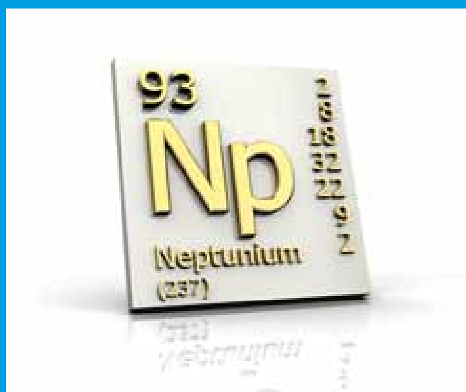
Internationally, NNL's geochemical modelling expertise has been recognised by an invitation to participate in a modelling study of the Mont-Terri nitrate reduction experiment. This study is focused on reactions associated with nitrate geological disposal and its effect on radionuclide speciation and mobility. The collaboration will involve partners in the Mont-Terri project and other international modelling groups with the ambition to develop a benchmark validation of biogeochemical models now being developed for application to geological disposal.



NNL's facilities and expertise ranges across the entire nuclear fuel cycle.

Our PuMA Laboratory is unique in the UK in its ability to experiment on the minor actinides.





Robin Taylor, Senior Fellow, Actinides

A key step in the development of NNL's capability was the commissioning of the Plutonium and Minor Actinides (PuMA) Laboratory during 2010. This world class facility for actinide separations research and development, supports present and future fuel cycles operations.

The laboratory contains a suite of 4 gloveboxes equipped with solvent extraction cascades, batch reactors and on-line/in-situ analytical and spectroscopic equipment. In the first experiments with uranium and plutonium mixed oxide (MOX) powders and pellets in the PuMA Laboratory, we are gaining a mechanistic understanding of the chemical processes occurring in bulk solution and at the solid solution interface during the nitric acid dissolution process.

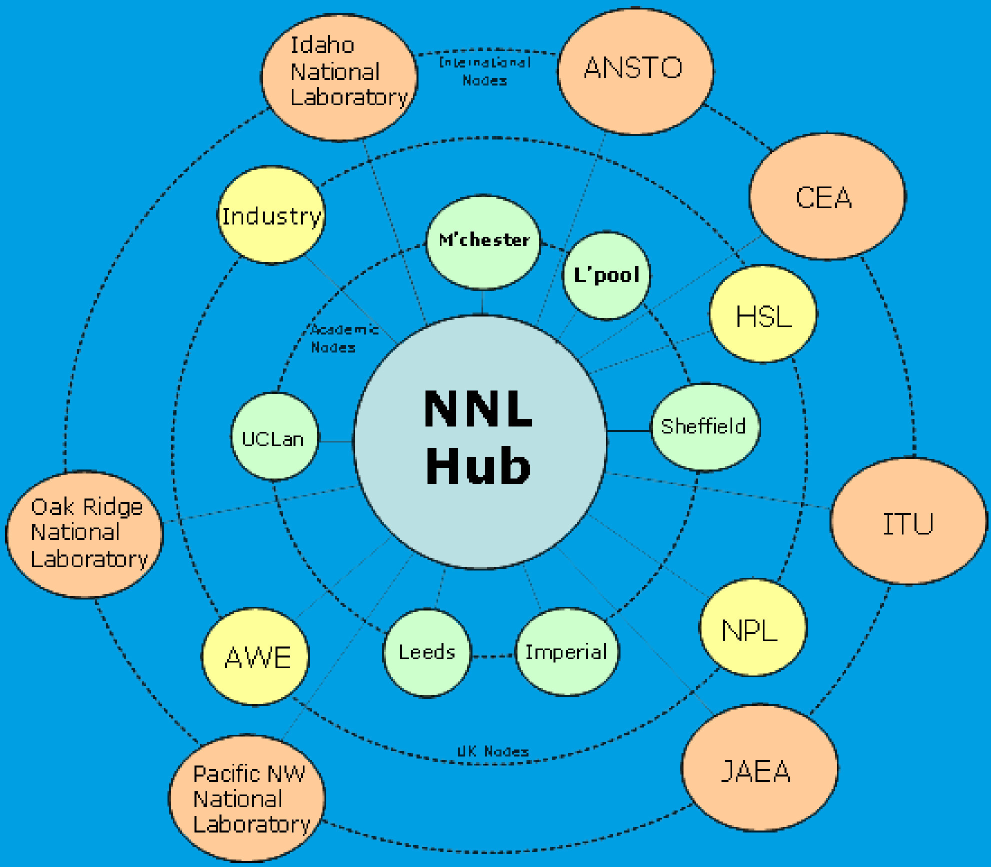
Work in the PuMA laboratory for the European Union Framework Programme 7 project, ACSEPT, is leading to the development of an innovative Grouped Actinide Extraction (GANEX) process that recovers all the transuranic actinides together for homogeneous recycle in future sustainable fuel cycles. We have shown that the behaviour of plutonium is the key aspect of the GANEX process and have successfully developed a new solvent formulation.

Plutonium Science

NNL has been commissioned to undertake a multi-year experimental programme to support the long term safe storage of plutonium at the Sellafield site. The aim of the programme is to provide experimental data on water desorption and radiolysis – mechanisms that can potentially lead to pressurisation of stored packages under certain conditions. NNL is developing a customised reaction vessel capable of measuring pressure and temperature above a plutonium sample that will be installed in the PuMA laboratory this year.

External Links

Collaboration with other organisations is essential in fulfilling NNL's strategy. The 'Hub and Node' model has been tried and tested at other national laboratories around the globe and truly supports collaboration with national and international organisations including universities, research institutes, industry and other national laboratories.



NNL has had a clear strategy for managing our relationship with universities for a number of years. The aims of the strategy are to establish a network of key links, that supports our interests in the 3Rs:

Research
Maintain a university skills base, enhance an NNL skills base to create Intellectual Property (IP).

Recruitment
Attract students from the beginning of their studies into a future career either directly into NNL or the UK nuclear industry.

Reputation
Raise the profile of NNL and enhance our international standing.

There are a wide range of roles in our organisation that have specific functions in terms of supporting our external links strategy:

Royal Academy of Engineering (RAEng) Visiting Professors

There are 4 NNL RAEng Visiting Professors in Nuclear Engineering (Anthony Banford, Bruce Hanson, Richard Taylor and Andrew Worrall), providing links into Manchester, Leeds, Liverpool and Birmingham Universities.

Senior Fellows

NNL has 7 Senior Fellows with an additional one on sabbatical to the Nuclear Energy Agency (NEA). Senior Fellows promote links with external organisations. Three of them are Visiting Professors - including Colin English who is Visiting Professor at Oxford University and the University of Manchester.

Research Fellows

NNL has 16 Research Fellows, each of whom has a link to a nominated University department.

NNL works with a range of universities and other external bodies to ensure we deliver the best service for our customers and the UK Government.

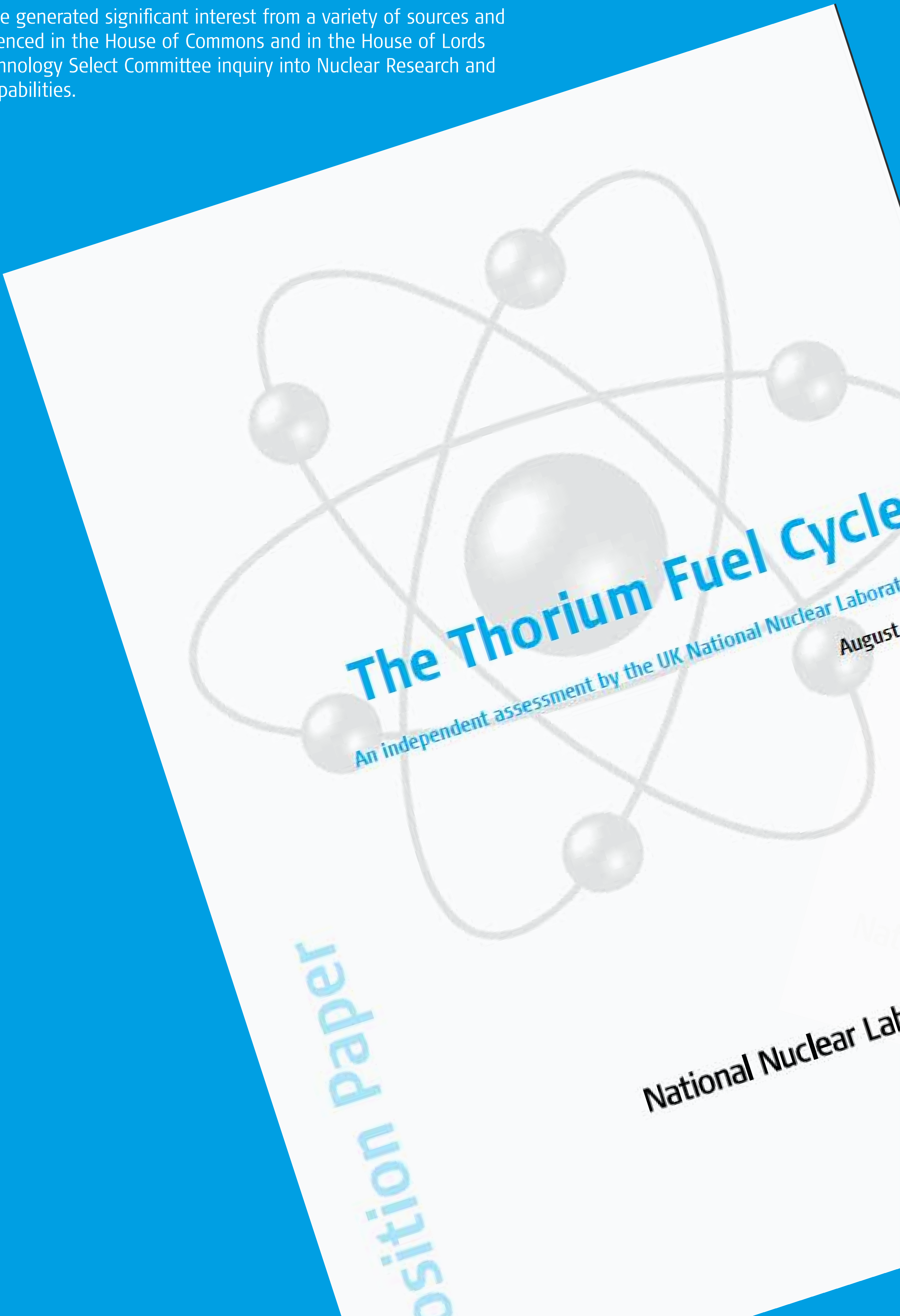
MANCHESTER 1824

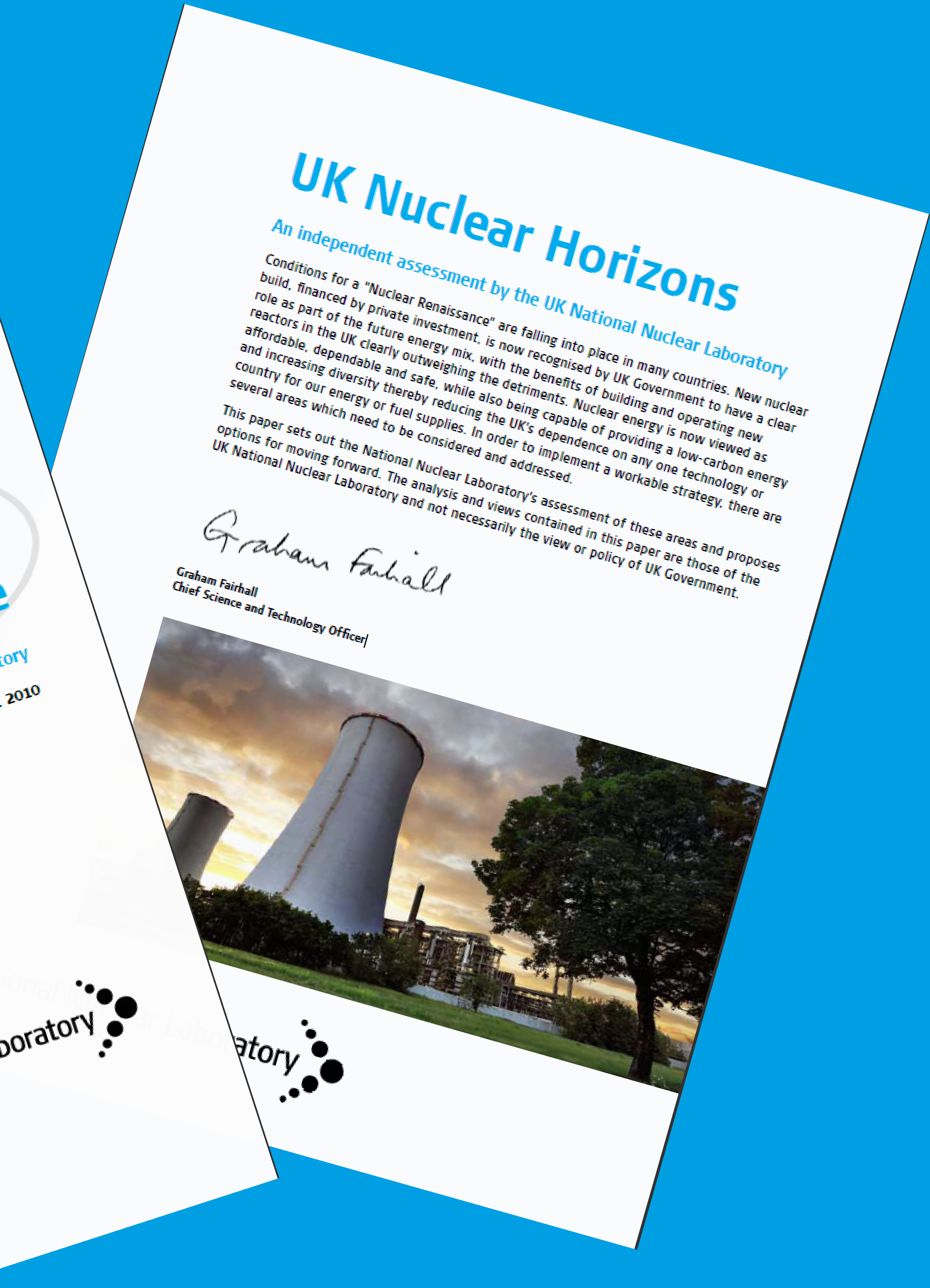
Imperial College London

Position Papers

NNL has published position papers on Thorium and Nuclear Energy Horizons providing independent and authoritative advice. Part of this remit is to develop a proactive view on key issues relevant to national nuclear agendas. The papers were written as part of the Fuel and Reactors Signature Research Programme.

Both papers have generated significant interest from a variety of sources and have been referenced in the House of Commons and in the House of Lords Science and Technology Select Committee inquiry into Nuclear Research and Development capabilities.





UK Nuclear Horizons

An independent assessment by the UK National Nuclear Laboratory

Conditions for a "Nuclear Renaissance" are falling into place in many countries. New nuclear build, financed by private investment, is now recognised by UK Government to have a clear role as part of the future energy mix, with the benefits of building and operating new reactors in the UK clearly outweighing the detriments. Nuclear energy is now viewed as affordable, dependable and safe, while also being capable of providing a low-carbon energy and increasing diversity thereby reducing the UK's dependence on any one technology or country for our energy or fuel supplies. In order to implement a workable strategy, there are several areas which need to be considered and addressed.

This paper sets out the National Nuclear Laboratory's assessment of these areas and proposes options for moving forward. The analysis and views contained in this paper are those of the UK National Nuclear Laboratory and not necessarily the view or policy of UK Government.

Graham Fairhall

Graham Fairhall
Chief Science and Technology Officer

Innovation and Commercialisation

Technology commercialisation is an important part of NNL's core operations. In addition to directly helping customers, we carry out research on broader issues to create new products and services which helps our customers introduce improvements - whether that means quicker, cheaper or more effectively.

RadBall

NNL has developed the RadBall technique, equipment and software to create a passive tool which can map radiation sources in inaccessible areas. This is currently being licensed in the USA and will shortly be available to the decommissioning market in the USA and Canada. NNL is supplying RadBall to the UK market. A more sensitive version of RadBall, which will be more applicable to the reactor and environmental markets, is currently under development.

Reactor and Fuels Software

NNL has extensive experience in underpinning nuclear reactor and fuel performance. As a result, we have a range of software which can be used by nuclear reactor operators to improve the performance and efficiency of their reactors. NNL has recently begun to make these software packages available and two of our codes – ENIGMA and ORION – have been received well by the market. NNL has recently signed an agreement with Studsvik Scandpower AB to supply NNL codes alongside Studsvik codes.

Innovation Ventures

Building on our relationships with a range of companies both inside and outside the nuclear industry, NNL is creating a portfolio of 'Innovation Ventures' – technologies which can be transferred into the nuclear industry from other industries. One example of this portfolio is our joint venture with PDX to create NDX Solutions which brings exceptionally efficient misting and mixing technologies to meet the challenges of nuclear projects.

NNL's RadBall device has had year, with successful trials at River and becoming fully read UK market.

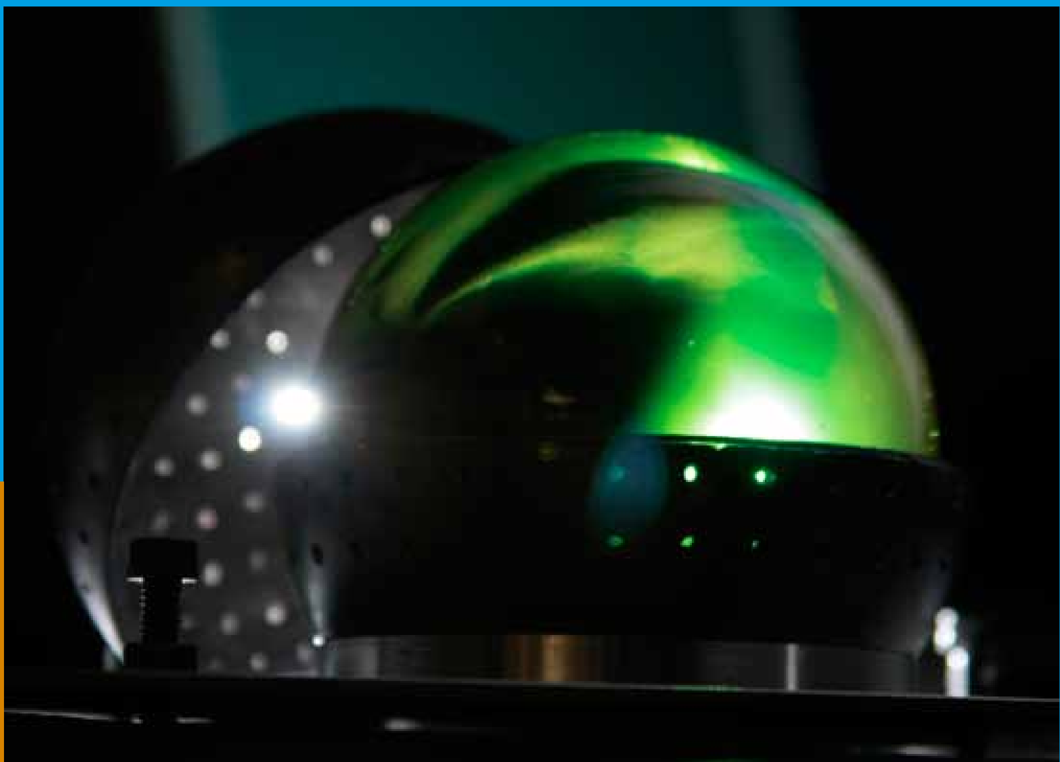
Research and Development Programme

NNL runs a research and development programme with funding of £1 million a year - part of our continued investment in developing products and services that will benefit the UK and international nuclear industry.

The programme has been running for two years now and has been an immense success. During this time we have:

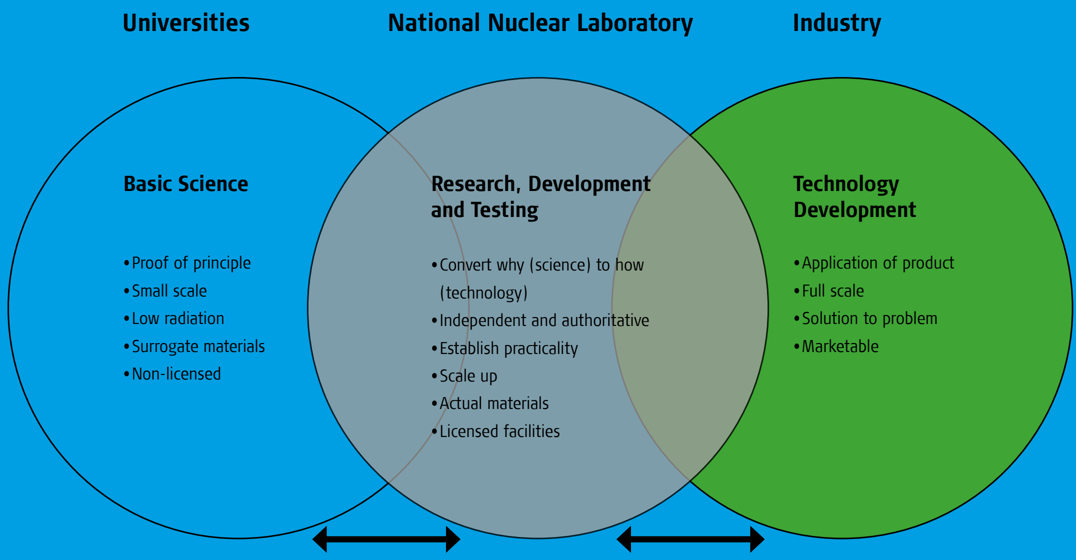
- Collaborated with over 20 research organisations
- Seen a leverage of investment of over five times
- Been directly involved in 11 sponsored PhDs which involved over 25 research scientists
- Published three position papers giving our authoritative view
- Had nearly 300 ideas submitted for consideration with around 10% being technologically developed
- Had six patent families protecting intellectual property across the UK, US and EU territories
- Developed significant new commercial relationships including a joint venture to look at decontamination technologies
- Brought a number of key products, including RadBall, to market.

a great
Savannah
ly for the



Partnering with Academic Organisations

A key function of the National Nuclear Laboratory is to bring together academic research with industry needs. NNL acts as the bridge between the two domains.



NNL has worked closely with academic organisations and individuals for a number of years. The most visible outputs from this were a number of University Research Alliances set up some 10 years ago. People we work with include:

- Professor Simon Biggs at Leeds University specialises in Sludges and Particulates and was head of one of the original University Research Alliances (Leeds). Professor Biggs also acts as a key partner on related research programmes.
- Professor Robin Grimes leads nuclear research at Imperial College. Professor Grimes also acts as the EPSRC Network Champion. NNL has two Visiting Professors at Imperial College.
- Professor Andrew Sherry, Director, Dalton Institute. Professor Sherry was Head of the Unviersity of Manchester Research Alliance on Materials and now works with NNL through a number of interfaces, as Co-Chair of the Dalton Nuclear Industry/NNL Steering Group.
- Professor Jon Lloyd, Visiting Senior Fellow. Professor Lloyd spends part of his time based at NNL. He mentors NNL employees and is involved in joint research.
- Professor Tim Abram, Visiting Senior Fellow. Professor Abram is a former NNL employee and now heads up the Centre of Nuclear Energy Technology, launched in early 2011.
- Professor Frances Livens, Research Director at Dalton Institute. Professor Livens is a committee member at CORWM and set up the first doctoral training centre specifically for nuclear related subjects.
- Professor Simon Pimblett, Director of the Dalton Cumbria Facility. Works closely with NNL on radiation science.

All of these links work to the benefit of the Universities, NNL and our customers.

RoSPA 20 11
Winner
RESEARCH & DEVELOPMENT
Sector Award

Winner 2004-2008, 2010-11
Highly Commended 2009

www.nnl.co.uk

National Nuclear Laboratory
5th Floor
Chadwick House
Warrington Road
Birchwood Park
Warrington
WA3 6AE

T: +44 (0)1946 779000
E: customers@nnl.co.uk