Signature Research on Legacy Management and Decommissioning at the National Nuclear Laboratory, United Kingdom – 11588

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ABSTRACT

The UK's National Nuclear Laboratory (NNL) has established five Signature Research Programmes, which will underpin the future requirements of the UK nuclear industry and sustain and grow key research capabilities. The five programmes span the fuel/plant lifecycle: including (i) Fuel and Reactors, (ii) Spent Fuel and Nuclear Materials Management, (iii) Legacy Waste Management and Decommissioning, (iv) Waste Processing, Storage and Disposal, and (v) Nuclear Security and CBRN.

This paper outlines the basis of the Signature Research Programme in Legacy Waste and Decommissioning and describes the Research and Development (R&D) underway in the following areas:

- Decommissioning policy and strategy
- Remote operations for decommissioning
- Decontamination for waste management and decommissioning
- Characterisation of waste materials
- Understanding the behaviour of contaminants in the environment

The management of radioactive waste, nuclear plant and sites at the end of operations is a significant challenge in the UK and internationally. Therefore the NNL Signature Research Programme on Legacy Waste and Decommissioning aims to support and underpin this challenge.

INTRODUCTION

Five Signature Research Areas are central to NNL. These Research areas are shown in Figure 1 and cover the nuclear fuel cycle. In each area NNL currently carries out extensive programmes of work for customers, including research, technology development, and a range of technical support activities, delivering benefits to the industry.

The vast majority of work carried out in the Signature Research Area is customer funded. However, NNL utilises internal investment to perform research, develop products and services aligned to these areas and to develop or demonstrate our capability and expertise in ways which enable us to best support both UK nuclear industry and the industry internationally. The focus of these Signature Research Programmes is therefore on the medium to long term and on entrepreneurial investment in technologies and technology transfer.

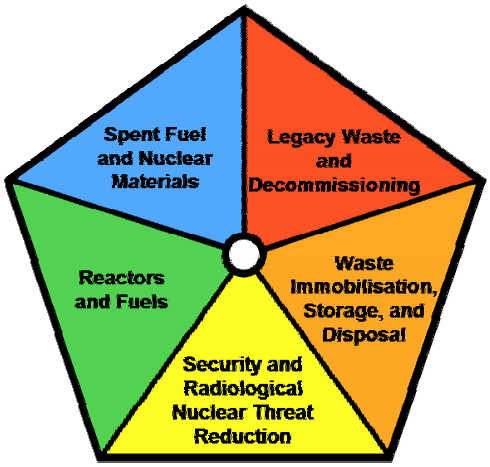

Figure 1: NNL Signature Research Programme Areas

Investment in the Signature Research Areas has allowed NNL to set up collaborations with other commercial organisations, national laboratories, and university centres of excellence. Such collaborations have allowed the laboratory to set up strategic and knowledge transfer partnerships to aid in both the development of NNL capabilities and current UK nuclear decommissioning and waste management activities. Both national and international partnerships have complimented NNL skills base and encourage technology developments and staff training that would not have otherwise been possible.

SIGNATURE RESEARCH AREAS

NNL has five Signature Research Areas identified earlier in Figure 1. An introduction and the key points from each of the research areas are given in Table 1.

Table 1: Brief Overview to the Signature Research Programme Areas

Signature Research Area	Hallmark Areas
Fuels and Reactors	• Establish NNL as a provider of services supporting current and future operations of Generation II plants. With emphasis on graphite performance and reactor material longevity. • Perform research on advanced reactors and fuel cycles. • Develop NNL knowledge on Generation III nuclear plants, with the emphasis on safety and performance assessments.
Spent Fuel and Nuclear Materials	• Develop a fundamental understanding of long term storage of nuclear material (spent fuel and civil separated Pu) in wet and dry environments. • Create non-proliferating recycling technology to reduce the costs of future UK fuel treatment facilities. • This research area also considers the potential options for the recycling of spent fuel and reprocessed U.
Legacy Waste and Decommis-sioning	• Establish NNL as a UK authority on legacy waste management and decommissioning policy and strategy. With emphasis on key technical issues, considered in the context of broader decision making. • Create step changes in approaches to remote operations for decommissioning. Focussing on technology transfer and collaboration with universities on next generation technology. • Create step changes in approaches to decontamination for waste management and decommissioning. Initial focus will be on technology road-mapping. • Building on existing capability for characterisation of waste materials and their behaviour, with a particular emphasis on higher activity waste and challenging environments. • Develop UK leading knowledge of the behaviour of contamination in the environment.
Waste Processing, Storage and Disposal	• Research into the performance of immobilised active waste. • Knowledge of waste chemistry with respect to corrosion, durability and ageing of waste packages and the inactive simulation of wastes. • Geochemistry research to understand the behaviour of waste packages in the near field. Both modelling and experimental work to support corrosion and geochemical behaviour. • Geochemistry research to understand the behaviour of waste packages in the far field.
Nuclear Security and CBRN	• Developments in detection technology, using existing NNL capability, expertise and facilities as a platform. Through developing and testing detection technology to prevent a CBRN event or rapid characterisation post event. • Develop NNL capability in civil non proliferation (including safeguards) and nuclear threat reduction. Specific focus on data access and characterisation and analysis of radiological signatures.

The remainder of this paper highlights some of the progress in the development of the Legacy Waste and Decommissioning Signature Research Area [1] and identifies how technology developments can assist the current and future decommissioning operations.

CURRENT UK LIABILITIES

The decommissioning challenges in the UK are held by a range of companies with the major challenges and liabilities managed by the Nuclear Decommissioning Authority (NDA), British Energy, the Ministry of Defence and various other smaller operations. The NDA is a Non-Departmental Public Body (NDPB), responsible for the 19 UK civil public sector nuclear sites, previously operated by BNFL and UKAEA, such as Sellafield and Dounreay. The planned expenditure for operations across the NDA's 19 sites during the next 3 years can be observed in Table 2, and illustrates the scale of the challenge.

Over the next 3 years especially, the UK will be focussing on hazard reduction; improving project and operational performance; reducing support and overhead costs; improving organisational effectiveness; and improving the robustness of their strategies and developing options. The NDA have identified the drive to achieve waste management and decommissioning goals, safer, faster, cheaper and in more sustainable ways.

NNL INVESTMENT IN IR&D

NNL invests in its IR&D programme to support innovation of developing technologies and strategic offerings to the nuclear sector. The current Signature Research Programme and the identified research areas have been running for the past 2 years. The Legacy Waste and Decommissioning area has since developed several collaborations with universities and industrial organisations and some of its programme areas benefit from funding and match-funding opportunities from bodies such as UK research councils and the EU framework projects.

Table 2: Forecast of planned expenditure across the 19 UK civil nuclear sites [2]

£m		Decomm & Clean-up Costs	Total Operations Costs		Total Planned Expenditure		2010/11 Plan
SLCs	Sites	A	Running Cost B	Capex C	(A+B+C)		
Magnox Limited	Berkeley	47			47		32
	Bradwell	71			71		51
	Chapelcross	60			60		53
	Dungeness A	41			41		43
	Hinkley Point A	27			27		32
	Hunterston	39			39		49
	Oldbury	3	74		77		78
	Sizewell A	40			40		42
	Trawsfynydd	86			86		64
	Wylfa	6	81		87		105
	Magnox Support	73			73		71
Electricity Trading	Electricity Trading		78		78		64
Research Sites Restoration Ltd	Harwell and Winfrith	66			66		67
Dounreay Site Restoration Ltd	Dounreay	159			159		166
Sellafield Ltd	Sellafield	621	623	311	1,555		1,500
LLWR Ltd	LLWR	36			36		34
Springfields Fuels Ltd	Springfields	49			49		54
Nuclear Transport and Contract Management	International Nuclear Services		108		108		129
Non-site expenditure		190			190		206
TOTAL		**1,614**	**964**	**311**	**2,889**		**2,840**
Income					**867**		**1,150**
Direct Government Funding					**2,022**		**1,690**

Notes:
1. Numbers may not cast due to rounding
2. Final Annual Site Funding Limits issued in March 2011 may be adjusted to reflect efficiency performance. The NDA reserves the right to reallocate funding to meet programme needs.

[1]

[1] Exchange rate on date of NDA draft publication: 1 GBP = 1.56261 US Dollars

LEGACY WASTE AND DECOMMISSIONING

The Legacy Waste and Decommissioning Signature Research Area encompasses the management of the post operational legacy of nuclear operations including the retrieval and clean-up of legacy wastes and contaminated land. The decommissioning signature research area has initially focused on technology developments in the areas of:

- Characterisation of legacy materials including site, plant and inventory
- Understanding the waste during retrieval, handling and pre-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

NNL has expertise and skills in the areas identified above. The challenge for NNL however, was to identify the areas where NNL's skill sets could be deployed to best effect and where NNL could develop strategic partnerships with other organisations (Universities, National Laboratories, Technology Providers, etc.) to develop technology missing from the market. Such may potentially benefit the UK and international current and future decommissioning operations.

The UK drive to achieve waste management and decommissioning goals, safer, faster, cheaper and in a sustainable way, creates opportunity for R&D. Advances in the technological understanding of problems and the technical approach to solving them, has the potential to underpin proposed approaches and ideally to achieve step changes in performance (safer, faster, and cheaper). Technology developments in the Decommissioning Signature Research Area represent an opportunity for real benefit to decommissioning projects. The programme aims to carry out R&D to underpin this, to grow capability to support this and innovate to achieve step changes in approach.

The current internal investment in the Legacy and Decommissioning Signature Research Area has focused on developing innovative technologies that could provide a step change in liability management, and supporting the development of new capabilities which enable expansion into new areas of research.

ILLUSTRATION OF NOVEL TECHNIQUES

The key philosophy of this Signature Research Area is to inform and underpin the development of strategies for legacy management, through an understanding of the waste inventory, the potential endpoints and the identification of possible processing options. This approach aims to identify the key challenges and initiate revolutionary technical advances and associated liability reduction.

Initial work in this signature area has focussed on the development of technology maps to identify key technology areas within these themes. These maps have been developed following a series of workshops held between staff and teams across NNL's sites.

NNL identified five of the seven technology development areas above as capable of making a significant step change to UK decommissioning programmes. The technology development areas identified were; Strategy development for legacy management and decommissioning, Decontamination technologies, Retrieval and remote deployment technologies, Characterisation, and Technologies to quantify and remediate contaminated land. The following section gives examples of five technologies developed under the drive of NNL's Legacy waste and Decommissioning Signature Research Programme in these areas.

Strategy development for legacy management and decommissioning

Effective selection and implementation of decommissioning strategy options for the UK's nuclear facilities is key to delivering UK Government policy [3]. Work in the area of 'strategy development for legacy management and decommissioning' is focussing on the decision making methodologies, lifecycle analysis of waste management options and evaluation of end state options.

One aspect of the work highlights the two principle decommissioning strategies for radioactive facilities in the UK, namely ex-situ and in-situ (often referred to as entombment). The in-situ decommissioning strategy has not been previously deployed within the UK, however the potential benefits of in-situ decommissioning has been previously reported [4]. In-situ decommissioning is not a new concept, rather it is one that has gained in credibility as the drive for accelerated and cost-effective decommissioning have become more evident, especially in the US [5]. NNL is producing a position paper identifying the key issues associated with these options.

Decontamination Technologies – PDX® Atomisation Technology

Decontamination technologies can be an essential part of some decommissioning operations, either to allow man access for dismantling or to segregate wastes. However, there can be challenges associated with the deployment of decontamination agents and with the generation of secondary waste.

Pursuit Dynamics plc (PDX®) and NNL have established a joint venture to develop, produce and market products for the global nuclear market. One of technology is an airborne and surface decontamination solution. The PDX® Atomisation technology is available in the commercial form of the Aerosonix™ system. This delivers a step change in process capabilities within both military and civilian sectors.

The technology has proven capabilities in airborne and surface decontamination, disinfection and detoxification, addressing the need for personnel, transport, particle scrubbing and sensitive equipment. The technology is robust and easy to use and is capable of delivering a wide range of materials such as liquid, slurry, powders or polymers through the option of fixed or mobile systems.

Through its rapid decontamination atomisation technology, the PDX® Aerosonix™ system creates a dense turbulent mist plume of super fine droplets (see Figure 2). This enables decontamination of complex and non-line-of-sight surfaces, with minimal impact on the decontaminated environment, including sensitive electronics. This technology requires less reagent, and thus delivers subsequent cost savings. The technology has been found to be 17 times more effective than other conventional systems available.

The technology has been identified for use in a number of civil nuclear applications, including: Glovebox decontamination, Ventilation system decontamination, Pipeline decontamination, and Particulate tie-down within facilities and for mobile plant. Efficient application of strippable coatings, and pyrophoric oxidation suppression. The technology is scaleable and can be applied to both large and small operations.

Figure 2: PDX® Atomisation Technology

Retrieval and remote deployment technologies – Robotics

Remote technology is currently used across nuclear industry operations but will be increasingly called upon to accelerate decommissioning projects requiring remote dismantling and demolition. NNL is currently collaborating with industrial partners on remote deployable innovation technology. The key benefit to remote robotic decommissioning activities is the increased level of safety and the reduction/removal of radiological dose to operators.

One of the current activities NNL is involved in specifically is to demonstrate control of decommissioning tooling operations in virtual reality. NNL objective of this project was to develop a simple prototype simulation for a remotely operated vehicle (ROV). The aim was to enable an operator to use the joysticks and switches of a standard Brokk Control Unit (BCU) in order to control a virtual simulation of an ROV within a simple physics engine enabled environment, which could be modelled to meet specific customer applications. The two principle applications of this technology development was for; a) operator training and b) testing remote intervention proposals.

Work in this area of the Legacy Waste and Decommissioning area of the Signature Research Programme has demonstrated the proof of concept. Future projects in this area could simulate (see Figure 3) any mechanical hardware that requires operator training or visual prototypes. Example models may include:

- Excavators
- Ariel Work Platforms
- Cranes
- Medical Surgery Robots

Figure 3: Virtual Simulator in operation

Characterisation of legacy materials including site, plant and inventory – HiRAD Radiation Detector

Evolving decommissioning challenges in the worldwide nuclear industry require the development of innovative new technologies to enable the characterisation of radiation hazards in a wide range of scenarios. The HiRAD device was developed under the Signature Research Programme to fulfil this brief. HiRAD has been developed by NNL in partnership with Tracerco Ltd (UK).

HiRAD is a real-time, remotely deployed, radiation detection device initially developed to operate in elevated levels of radiation (i.e. thousands of Sieverts per hour), but with an ability to also operate at low radiation levels. The technology offers operators improved information about their process operations through cost effective, responsive radiation level mapping of an environment with reduced radiation exposure to the operator. HiRAD's resistance to radiation enables it to be used in highly active waste processing and storage facilities. In addition, HiRAD is suited to low level radiation environments and underwater applications.

HiRAD consists of a small (3cm long) scintillating crystal coupled to a metal coated fibre optic cable (Figure 4). Scintillation light produced by the crystal in a radiation field is transmitted long distances down the fibre optic cable to a photon detection device. Data is then recorded on PC software and used to measure the radiation levels of the environment. HiRAD is a line of sight technique and is ideal for pipeline deployment. In large process areas, such as the deployment in a Vitrification Waste plant [6], the HiRAD device can be moved around using Master Slave Manipulators (MSMs).

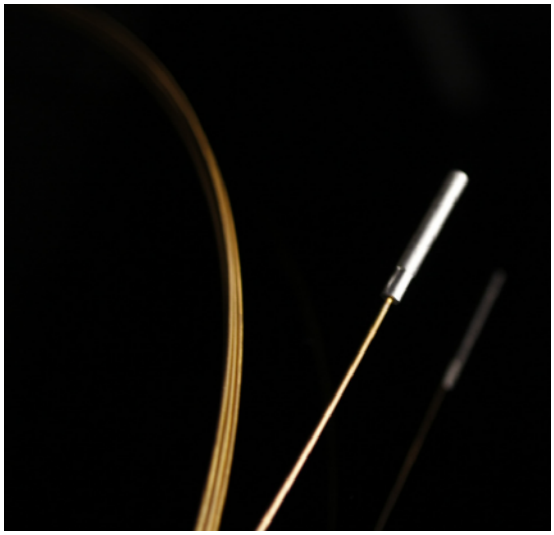

Figure 4: HiRAD's crystal head and fibre optic cable

Technologies to quantify and remediate contaminated land – Microdrilling

The sampling and characterisation of materials such as buried wastes, concrete slabs and geological materials has long been undertaken using traditional large scale techniques such as excavation, drilling/coring and subsequent laboratory analysis of the samples. These techniques are costly, time consuming and ultimately produce significant quantities of waste requiring disposal. The challenge faced by NNL was to obtain the high quality sample data analysis required in a more cost effective, timely manner while minimising waste disposal requirements.

Through the Signature Research Programme, NNL has developed a methodology for sample acquisition using small scale vacuum drilling technology. The equipment, shown in Figure 5, is small, portable, and suitable for use in a wide range of applications where shallow sampling is required. All material removed by the drilling process is collected as sample material and as a result, no secondary wastes are generated. The Micro-drill has been designed to sample miscellaneous building waste, trench fill material and natural geological materials. Because of its compact size, Microdrilling can also be used in difficult to access areas. Samples collected are in a powdered form, ideal for immediate laboratory analysis.

The system has demonstrated rapid, cost effective sampling of concrete slabs, collecting samples through concrete up to 970mm in thickness, at a rate up to three times quicker than traditional concrete coring techniques.

Microdrilling uses a hollow drill string through which dust created by the drilling process is drawn. A vacuum pump is used to draw this dust up the inside of the drill string to be captured in a suitable container/filter. The quality of the sample is ensured by drawing material only from the drill tip and it is possible to accurately access the depth range from which the sample has been taken. The drilling system has a maximum drilling depth of 5m and is available in both 15mm and 25mm diameter drill versions.

NNL is currently developing additional real time chemical and radiological characterisation tools to be used in association with Microdrilling to provide operators with fast, detailed information on organic contaminates found along the depth of the drill hole.

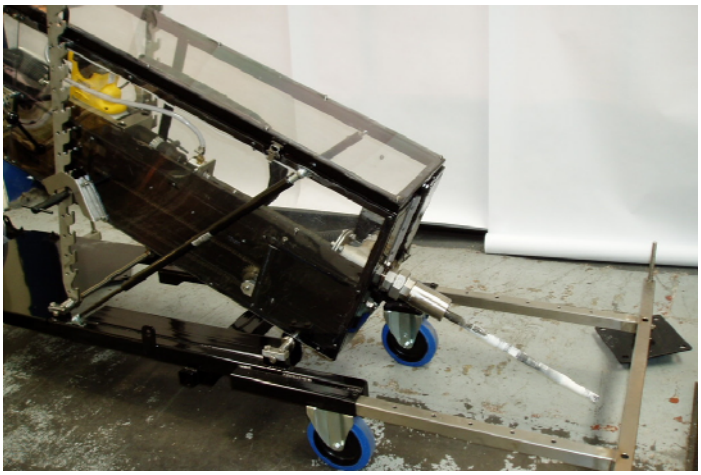

Figure 5: Microdrilling

CONCLUSIONS

As a result of its significant role in the development and deployment of the civil nuclear cycle, the United Kingdom has a significant legacy of nuclear plant and wastes. The costs associated with these challenges are significant and span many years. Similarly the global decommissioning challenges are significant. In all cases the drive is to achieve safer, faster and cheaper solutions to these challenges.

NNL has five Signature Research Areas which cover its activities across the fuel cycle, and also invests, and collaborates in its Signature Research Programmes to perform R&D to provide improved and often new approaches to future problems. The paper has identified several examples of developments in the Legacy Waste Management Programme, where NNL is striving to use technology to provide safer, faster, cheaper solutions to the legacy challenge.

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