Signature Research on Legacy Management at the National Nuclear Laboratory, United Kingdom - 10362

A. W. Banford
National Nuclear Laboratory, Risley, Warrington, Cheshire, WA3 6AS,
United Kingdom

ABSTRACT

The United Kingdom (UK) National Nuclear Laboratory (NNL) is establishing four Signature Research Areas, which will underpin the future requirements of the UK nuclear Industry. 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 Area on Legacy Management aims to address this challenge.

The key theme of the research area is to inform and underpin the development of strategies for legacy management through an understanding of the nature of the waste inventory, the potential endpoints and the identification of possible processing options. This strategic approach aims to identify the key challenges, identify required evolutionary changes to existing technologies and identify areas in which revolutionary change could make most impact.

This paper provides a technical overview of the UK's National Nuclear Laboratory Signature Research Area on Legacy Management; which will focus on the range of technical areas notably;

- strategy development
- waste, facility and land characterisation
- waste behaviour
- decontamination
- retrieval and remote deployment
- decommissioning techniques
- contaminated land and site end points.

INTRODUCTION

A series of four Signature Research Areas have been identified as being central to the United Kingdom National Nuclear Laboratory mission, to provide independent, authoritative advice on nuclear issues. These areas encompass activities which are of strategic significance to the NNL and both the UK and international nuclear industry. The four areas are defined as follows,

- Fuel and Reactors
- Spent Fuel and Nuclear Materials [1]
- Legacy Waste and Decommissioning
- Waste Processing, Storage and Disposal

Collectively these areas cover most of the nuclear fuel cycle. In each case, the National Nuclear Laboratory already performs research and development and technical services for customers and has a significant history and track record. This paper addresses the Legacy Waste and Decommissioning signature research area that will focus these existing skills on the future needs of the UK.

An important aspect of these Signature Research programmes will be collaboration, nationally and internationally, with other national laboratories, universities and the broader industry, to promote technology transfer and development of international best practice. Indeed the NNL is currently engaged in European collaborations, have strategic relationships with other national laboratories and are heavily engaged with the academic sector.

UK NUCLEAR INDUSTRY

The UK has had a long history in the nuclear industry and was the first country to introduce commercial nuclear power. The first Magnox Reactors opened at Calder Hall in Cumbria in 1956, and the most recent Pressurised Water Reactor started generation in 1995. Whilst most of the UK Magnox reactors (Figure 1) have now shutdown after long operating lifetimes, two remain in operation today at Oldbury and Wylfa. However, electricity continues to be generated by nuclear power stations, with a fleet of Advanced Gas Cooled Reactors (AGRs) and one Pressurised Water Reactor operated by British Energy.

Figure 1 Magnox Reactor

In addition to electricity generation the United Kingdom has a long history in other areas of the nuclear fuel cycle, notably fuel manufacture at Springfields, enrichment at Capenhurst and fuel reprocessing at Sellafield. Extensive research and development operations have supported these operations from the earliest days of the industry, on many sites, notably at Sellafield, Dounreay,

Winfrith and Harwell. Whilst most of these activities are ongoing in the, many of the early plants are now in the post operational phase of the plant lifecycle.

Consequently there is a significant programme of legacy waste management and decommissioning ongoing in the United Kingdom. A non-departmental government body, the Nuclear Decommissioning Authority (NDA), has responsibility for decommissioning and clean-up of the UK's civil, public sector nuclear sites. The total cost of decommissioning and cleanup of the Nuclear Decommissioning Authority Estate was estimated in 2006 at £44,610M (undiscounted) [2], additionally there are other facilities operated by British Energy and associated with defence which will also require decommissioning.

Typical Legacy Challenges

The waste and decommissioning challenges range from facilities such as fuel fabrication plant that have operated only with material before irradiation through to highly active plant associated with spent fuel reprocessing and highly active waste. Other challenges include the management of operational mixed waste and contaminated land. The level of technical challenge varies between ageing plant and more recently designed plant where decommissioning was considered as part of the design process.

Consequently the National Nuclear Laboratory Signature Research in Legacy Waste and Decommissioning is important in the UK context but is also internationally relevant to the wider industry.

SIGNATURE RESEARCH IN LEGACY WASTE AND DECOMMISSIONING

Aims

Broadly speaking the legacy waste and decommissioning signature research area covers management of the post operational legacy of nuclear operations through to the end point (in other words post operation to termination) and covers the associated legacy of inventory, equipment, plant and site.

The top level strategic drivers for Legacy Waste and Decommissioning customers are to underpin and reduce liabilities. The following aspects of the liabilities must be managed:

- Safer - Reduce hazard
- Faster - Accelerate decommissioning
- Cheaper - Reduce financial liability
- Reduction of Environmental Impact - Minimise waste

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.

The signature research area includes the following research themes which are of strategic importance in legacy management;

- strategy development
- waste, facility and land characterisation
- waste behaviour
- decontamination
- retrieval and remote deployment
- decommissioning techniques
- contaminated land and site end points.

Each of these themes is described in more detail below.

RESEARCH AREAS

Strategy Development

This area focuses on the development of strategies for management of legacy material, plants and sites. Development of an understanding of the nature of the legacy and identification of a range of options and potential end points are important activities in this area. However, the key challenge of strategy development is in the selection of the most appropriate end point and best route to achieving it. A wide range of factors influence the selection of the most appropriate strategies ranging from varied domains such as, political, environmental, technological, social and economic factors. Often these drivers are opposing and balancing them is the key to the decision making process. Therefore one aspect of this research area is the development of an understanding or interpretation of sustainability within the legacy waste and decommissioning context. Study in this area will develop a robust basis for balancing opposing drivers; and may even allow consideration of the trade off between benefits in different domains and so allow public money to be invested in the most significant areas.

The signature research in this area concentrates on developing knowledge and tools, that help to inform this decision making process.

Plans exist for the legacy waste management and decommissioning of all UK facilities which generally extend over decades. Indeed lifetime plans for the more complex Sellafield and Dounreay sites extend into the next century. Therefore another key aspect of the Signature Research is the development of roadmaps for decommissioning activities. The purpose of this is to identify insertion points, where changes in technology and technical strategy could lead to an evolution or revolution in approach and ultimately to improvements against the drivers to achieve the discharge of liabilities, safer, faster, cheaper and whilst reducing the environmental impact. These roadmaps will ultimately guide the development of techniques within the subsequent Signature Research Areas described below.

Furthermore our work in this signature area will also consider the application of a systems approach to the challenges, facilitating consideration of strategy from a local, regional and national perspective.

Waste, Facility and Land characterisation

One of the key technical challenges in the management of the nuclear legacy is developing an understanding of the physical and chemical properties of the wastes, facilities and contaminated land. There are several angles to this ranging from understanding the location and nature of land contamination, radiological inventory in post operational plant and even the layout of plant designed decades ago. This challenge is often made more difficult by the nature of the legacy;

- often facilities are old and limited design and operational information is available as a basis,
- the hazards present can make man access impossible and remote access difficult
- characterisation of waste inventory can be difficult to carry out remotely with traditional techniques
- stored wastes are usually mixed and not homogeneous.

The ability to characterise the type, nature, quantity and location of material, whether in the ground, inside a silo, at the bottom of a pond or within an active cell, represents a key step during the clean up and decommissioning of nuclear sites for a number of reasons, including,

- Knowing the type of material will impact the chosen decontamination technique,
- Knowing the location and quantity of material may impact the overall safety strategy, and the approach to deployment of equipment
- Knowing the quantity and nature of material impacts the overall remediation, treatment and disposal/storage route.
- Knowing the location of, the quantity of and the nature of legacy material is a requirement for any material recovery/clean up strategy to be cost effective, operationally efficient and safe.

To summarise, the ability to characterise material provides a means to define the problem that must be addressed during subsequent remediation. It allows the industry to formulate safe decommissioning strategies whilst minimising costs by reducing assumptions associated with the overall quantity of material to be recovered treated and disposed of.

NNL Signature Research in this area will focus on the development of techniques for characterisation of contaminated land, radiological inventory within facilities, and characterisation of plants to enable efficient decommissioning operations. The following characteristics are seen as crucial to effective characterisation techniques for use in this legacy context;

- easily and/or remotely deployable
- less intrusive than current techniques, offering a step change in approach
- able to detect, characterise and locate materials
- capable of operation in a radiological or conventionally hazardous environment
- represent good value financially

One example of such a technology that has been developed is RadBall [3] (Figure 2), which was presented at the WM 2009 conference, and which offers a novel approach to radiological

mapping. NNL has developed this remote, non-electrical, radiation-mapping device, which offers a means to locate and quantify radiation hazards and sources within contaminated areas of the nuclear industry. The positive results from initial deployment trials on the Sellafield Site in the UK and the anticipated future potential of RadBall have led to the UK National Nuclear Laboratory (NNL) partnering with the Savannah River National Laboratory (SRNL) to further underpin and strengthen the technical performance of the technology. This illustrates both the opportunity for innovation within the characterisation and the benefits of international collaboration which are core to the principles of NNL Signature Research.

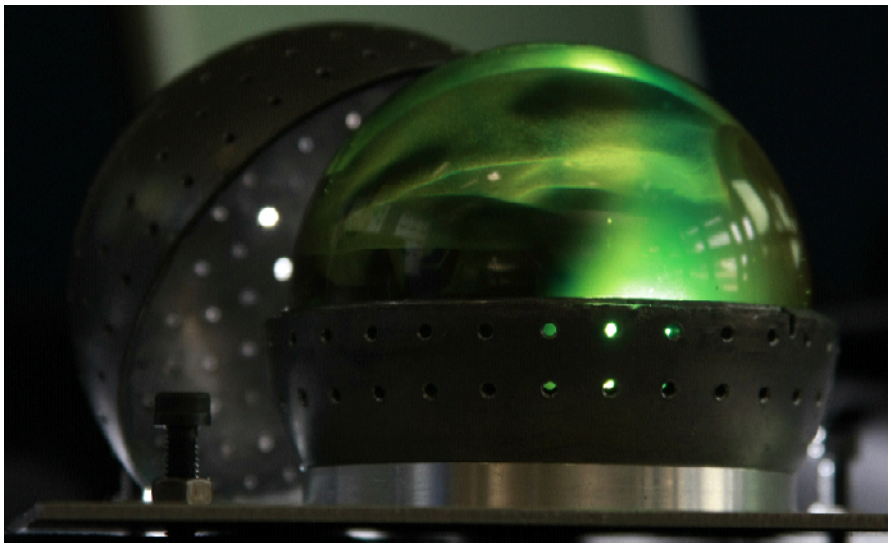

Figure 2 RadBall

Waste Behaviour

Following naturally on from characterisation, the next challenge associated with legacy material is understanding how legacy waste materials behave during retrieval and treatment. This is a broad area, including elements of interpretation of characterisation data, experimental analysis and modelling. This understanding is often required to support safety case development, process design and the operation of equipment.

One example is the requirement to understand the behaviour of radioactive sludges. This can involve predicting their behaviour in terms of mobilisation and transport, understanding the potential for the release of activity during processing and understanding their compatibility with approved waste forms. One example of signature research in this area is the investigation of new modelling techniques to simulate their behaviour.

Decontamination

Radioactive contamination of equipment and facilities is an inherent issue to all facilities handling these materials. Conceptually, decontamination offers the possibility of reducing the hazards within a facility to levels where manual decommissioning is possible and also offers the possibility of reducing the volumes of waste that must be disposed of in repositories. Whilst experience exists world-wide of effective decontamination both during operations and

decommissioning phases of a plant's life, opportunities still remain for further development. Novel approaches may offer step changes in performance as technology evolves. Decontamination development therefore offers the potential to make decommissioning safer by reducing dose to workers, to accelerate decommissioning by allowing manual operations for dismantling and reduce the volumes of radioactive waste for disposal. This however relies both on the ability to achieve target decontamination levels with certainty and appropriate assay techniques to validate performance.

Signature Research in this area will focus on identifying the key challenges and development of approaches with the following characteristics;

- achieving required decontamination,
- ease of deployment
- minimising secondary wastes and ensuring their compatibility with waste routes

One recent example has been the development of a foam decontamination process (Figure 3). This approach aims to provide a deployment method for aqueous decontamination reagents, whilst reducing the volume of liquid required for deployment and subsequently reducing the amount of secondary liquid waste.

Figure 3 Foam Decontamination Trial

Retrieval and Remote Deployment

In hazardous environments where manual operations are not possible for decommissioning, remote operation and the retrieval of material are an alternative to the decontamination approach. In certain circumstances remote operations are the only practicable approach.

Over the last 15 years significant investment in robotics development has been made by a number of industrial sectors which are now reaping the rewards of that investment in terms of increased productivity, increased reliability and increased value. The advances in industrial

robotics have lead to significant increases in productivity in the automated manufacturing sector and industrial robots are often off the shelf items. Robotics are now routinely used in manufacturing off shore operations, surgery and space exploration.

There are a number of factors which drive the development of remote systems for the future. Firstly the desire to reduce the number of man entries in hazardous areas, to reduce dose to operators during decommissioning operations, and to reduce the wastes associated with these entries, notably for personal protective equipment. Secondly the need to reduce bottlenecks associated with the operation of current remote systems and to improve the operator-system interfaces to facilitate easier operation.

The focus of the Signature Research in this area is on the evaluation of the potential enhancements in remote operations either through novel approaches or adoption of the next generation of more advanced techniques and equipment, for operations planned over the medium to long term.

Decommissioning Techniques
Decommissioning requires the deployment of devices for activities such as cutting, size reduction, retrieval and scabbling. There are a wide range of both tools and deployment methods available today. This area of the Signature Programme recognises the opportunity for innovative approaches and novel equipment to enable decommissioning. The focus of the NNL work will be identified following the completion of the technology road-mapping exercise. Research and development will be performed where new approaches could lead to significant improvements in baseline performance, in terms of safety, schedule, cost and waste volume.

Contaminated Land and Site End-points
In many respects, the challenges presented by contaminated land on nuclear licensed sites depend on the exact nature of the site, its location, operational history and decommissioning objectives and timescales. Nevertheless, several generic challenges exist for the effective management of contaminated land and these are the focus of our Signature Research in this area.

- Environmental risk assessment modelling is an important tool in the understanding of contaminated land issues both now and in the future,
- Effective decision making processes, including systematic planning of sampling regimes (e.g. Data Quality Objectives) and criteria/codes of practices for delicensing contaminated land, and
- Fundamental understanding of radionuclide behaviour in the environment.

This area is already heavily linked into the academic sector, largely through doctoral research.

CONCLUSION

Legacy waste and decommissioning are important stages of the life-cycle of any nuclear plant, with significant challenges both technically and financially. The UK National Nuclear Laboratory is establishing a Signature Research Programme in this area. The aim of the programme is to deliver improvements in current approaches to legacy waste and decommissioning challenges, through medium and long term focused research, collaboration and technology transfer. The following areas have been identified as the focus for the programme.

- strategy development
- waste, facility and land characterisation
- waste behaviour
- decontamination
- retrieval and remote deployment
- decommissioning techniques
- contaminated land and site end points.

Programmes are now being formulated against these research themes and will aim to collaborate with other national laboratories, universities, other research organisations and industry, both nationally and internationally, to promote best practice.

REFERENCES

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