

Game Changers

A Sellafield Ltd initiative, delivered and managed by Innovus

Plant Dismantling and Decommissioning Challenges

Part of the “Sellafield Ltd Game Changers” Series

How to use this document

This document is designed to introduce the challenges associated with the dismantling, size reduction and decommissioning of the legacy nuclear plants on the Sellafield site.

The document has been formatted to provide information on

- The current baseline technologies which are available for use today
- The limitations which those technologies present, that could potentially be addressed with innovation
- Perceived gaps with the existing approaches and suggestions on areas where there is an opportunity for innovative solutions

Innovation may take the form of technologies or approaches which have been successfully deployed in other industrial sectors, or may take the form of completely novel ideas and concepts.

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Introduction to Decommissioning

Decommissioning of ageing nuclear engineering facilities represents one of the major challenges of the 21st century. The international market in **nuclear decommissioning and waste management** relating to power generation and reprocessing plants **is estimated to be in the region of £250 billion**, with the operations requiring **in excess of 100 years to complete**¹. The UK component of this is estimated to be approximately £70 billion², with completion on similar timescales.

The UK has been at the forefront of the development of nuclear technology since the early 1940's progressing through the post war period in the design, build and operation of power reactors and their associated reprocessing and waste treatment facilities. This has resulted in significant technical waste management and decommissioning challenges and **opportunities for the UK to develop and deploy technological solutions on UK sites, including Sellafield, and for the international nuclear market.**

Sellafield Site Overview

Sellafield is the most complex industrial site requiring remediation in Western Europe, comprising approximately 6 square kilometres in West Cumbria. Nuclear operations on the site commenced in the late 1940's, with the site operations performed reflecting the full range of activities undertaken by the UK civil nuclear industry. **The site consists of more than 2200 buildings including 170 major nuclear facilities.** As the site transitions from reprocessing operations, which will cease around 2020, the major focus will shift to Post Operational Clean Out, waste management and decommissioning activities. Due to the variety of operations performed at Sellafield, a wide range of challenges will need to be addressed including:

- Dismantling and associated waste management of enclosed cells containing redundant chemical operations
- Decommissioning glove boxes used for research, development and fuel fabrication operations
- Emptying facilities used for the storage of spent fuel
- Building and operating waste storage and handling facilities
- Reprocessing spent nuclear fuel
- Dismantling pipe and ductwork within a range of plants
- Decommissioning sewers, pipe bridges and trenches

One of the most significant influences on the cost of dismantling plant at Sellafield, is the age and legacy of the plant which at the time were not designed with decommissioning in-mind. This means we often have to create access for equipment and disposal routes for waste when there is little or no available lifting equipment.

This will ramp up significantly as the site prepares for an increased intensity in decommissioning activity in the next 5 to 10 years. **Innovative, fit for purpose tools, will be a key enabler to efficient decommissioning and waste management** which has the potential to significantly reduce the decommissioning liability.

¹ A Review of the UK's Nuclear R&D Capability, Technology Strategy Board, 2008.

² Nuclear provision – Explaining the cost of the cleaning up Britain's nuclear legacy, Nuclear Decommissioning Authority, February 2015

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The current projected cost of decommissioning relies on numerous assumptions, such as the extent of radioactive contamination and waste generated during decommissioning. However, due to uncertainties with the data available, the expected cost of decommissioning covers a wide range. Consequently, there is a **significant opportunity and need to reduce the decommissioning cost and duration through the deployment of innovative plant dismantling and associated waste management tools and techniques.**

Business Benefit

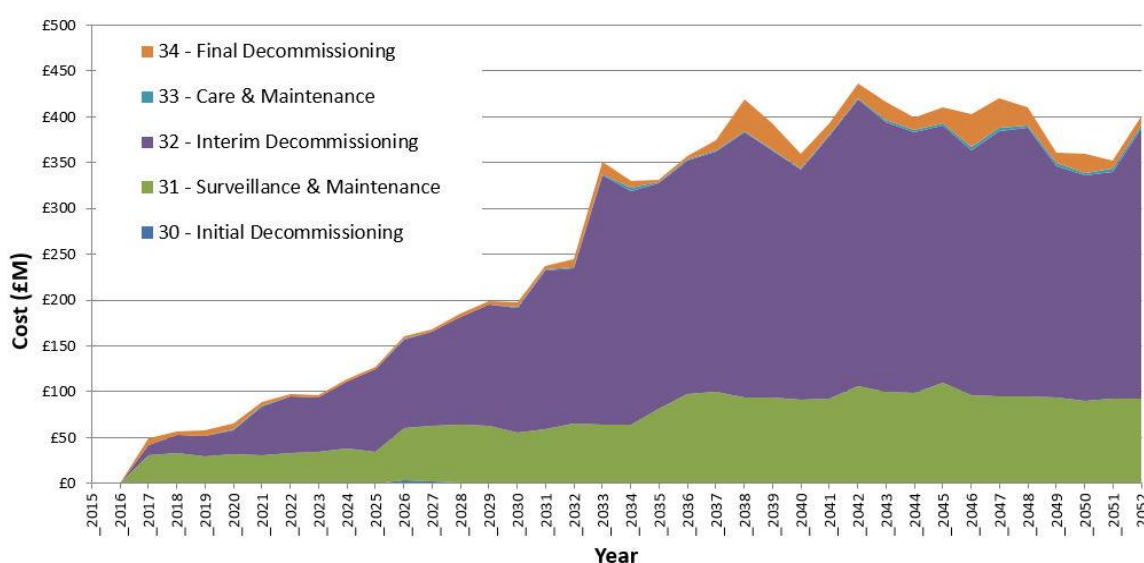
We need to innovate to reduce the cost and decrease the time required to perform decommissioning at Sellafield. The scope of decommissioning considered here includes dismantling of plant and equipment, size reduction and packaging of the waste arising.

Whilst the industry has been decommissioning plant for many years, the future challenge at Sellafield is significantly greater than the projects performed previously. The projects performed to date have utilised a combination of manual and often bespoke remote decommissioning equipment and forecasts have been based on these techniques as a baseline.

Improvements in dismantling have potentially significant secondary influences on lifetime costs; improved tools and techniques can substantially reduce costs for waste treatment and geological disposal.

Sellafield has substantial costs from maintaining facilities which quicker decommissioning can reduce. Planned decommissioning activities carry a large risk to cost and schedule due to the uncertainty of future operations. By providing robust, tested solutions, the decommissioning risk can be reduced, providing savings against the baseline plan.

Sellafield also **needs to reduce the cost of decommissioning and have identified 'improved plant dismantling' as a key area of focus.**



Baseline Costs of Decommissioning at Sellafield

The baseline cost of decommissioning is estimated to run at £150m per annum in 10 years' time and £300m per annum in 15 years' time.

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Plant Dismantling and Decommissioning Challenge Overview

During dismantling we need to be able to use the characterisation data discussed in the 'Characterisation Game Changer' to efficiently plan and execute work to:

- Gain access and egress from the cell
- Locate the work-face in the cell and move dismantling equipment into position
- Use the dismantling equipment to cut, unscrew etc. the piece of plant
- Lower waste to floor level
- Move the waste to the disposal package
- Possibly size-reduce at ground level (possibly in a new or repurposed sort and segregation cell)
- Export the waste package

A combination of people and machines are involved in these steps.

Innovative dismantling tools and techniques will seek to complement the existing 'baseline methodologies' to perform better dismantling and associated Waste Management activities. Decommissioning operations have numerous challenges including:

- Difficult deployment in areas of restricted access:
 - Access may only be possible via small holes (approx. 100mm diameter)
 - Access sometimes located at height and through several meters of concrete, lead shielding or water
 - High radiation, loose and fixed contamination
 - Complex and highly congested environment due to numerous pipes, vessels, vents and cables in close proximity that criss-cross large closed spaces
- Standard set of high integrity and heavy containers, up to 3m³ which constrain the size of items which can be disposed of, without the use of size reduction operations
- A range of different pH environments (pH<0 to greater than 11) in different plants
- Heterogeneity of materials being measured
- Speed of deployment; currently weeks
- The duration and expense of data assessment and reporting, desire for real time and cheaper techniques
- Lack of efficient and secure data transmission in large robust buildings across the Sellafield site
- Requirement to collaborate widely without sophisticated or costly IT packages, data that can be exported to standard Microsoft office packages
- Requirement for equipment deployed to be either cheap enough to be disposable or robust and designed for easy maintenance and decontamination.
- Desire for operation by non-specialists without the need for complex commissioning or recalibration

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Plant Dismantling and Decommissioning Vision

Imagine if with minimum, or no, intervention into hazardous environments we could dismantle plant, segregate waste and pack it efficiently into a form fit for disposal, leaving the remaining building able to be repurposed or in safe, low cost state for the long term.

Could we follow a trajectory like the automotive industry, which has moved from bespoke one-off operations, through production line hand build to being fully robotized? Could a similar trajectory be applied to decommissioning? Could we use a standard set of out-sourced components, modular facilities and common architecture to reduce the perceived high cost of remote decommissioning?

To do this, technology development will have to address the scale of facilities and unstructured environments on Sellafield site which are unlike a factory.

At the moment, our decommissioning activities adopt to a human scale; what if we used smaller scale, collaborative robots or larger scale to move glove boxes and vessels without breaking containment? To support this we would need a range of flexible fit for purpose decommissioning waste packages.

The current approaches tend to cut up plant and equipment and lower it to the cell floor to be possibly further size reduced and packaged; how can we adopt processes that have fewer steps?

We are looking for technology that allows buildings to be placed into a care and maintenance regime that monitors them whilst they are in a long term quiescent state; we need to prevent degradation of the building, prevent migration of contamination and provide assurance efficiently for perhaps 70 years whilst the rest of the program continues. To reduce cost and risk during the period it would be ideal if they did not require any external services.

At the moment, the level of manual work is such that we tend to decommission during the 5 day working week, as we move to autonomous working we will be able to mount work continuously which could have a significant impact on the duration of projects and the associated costs.

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Plant Dismantling and Decommissioning – Improve operator working conditions and communications, primarily in alpha plants

The objective is to **provide improved protection to the Operator primarily in an alpha decommissioning environment**. The purpose is to **understand the benefits from solving or alleviating the issues to enable alpha operations to be delivered safer, quicker and cheaper prior to a number of facilities enter the decommissioning phase**. Containment of highly mobile alpha contamination is a major challenge for decommissioning plutonium active facilities. At the moment the majority of alpha decommissioning is done manually using hand-held tools or via manually deployed remote operated tools.

It would be desirable to increase remote decommissioning to remove the requirement for the use of air fed suits which provide a challenge to remove, maintain and dispose of after use due to the radioactive contamination.

Baseline Methodology

- Air-fed Suit Operations
- Handheld Power tools
- Remotely controlled power tools deployed (e.g. Brokk on a tether)

Limitations

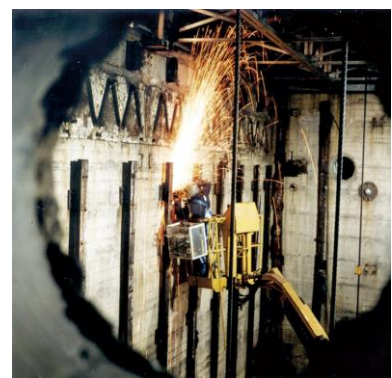
- Risk to operator from using power tools such as grinders
- Restriction in movements

Perceived Technology Gap / Opportunity

- Improved two way communication between suited operators and job controllers in real time[radio mics currently used, compromised by the noise of air in the suit]
- Ability to carry out personal monitoring for suited operators while at work face i.e. core temperature[heat stress] dose monitoring and measurement
- Easy clean surface → reusability [currently significant secondary waste from disposal of air fed suit]
- Improved working time to above 2 hrs for operators [Currently limited to 2hrs per operator per day]
- Increase comfort, and dexterity for operations
- Safer operations for operators [tears in suits, smart tools]
- Innovative alternatives for air fed suit operations. The restrictive nature of the PPE impacts on human capability with dressing and undressing being complex
- Determine whether self-contained breathing apparatus would remove the need for air lines
- Situational awareness- improve field of view, real time data for operator



Operator working in an air-fed suit



Operator working in an air-fed suit

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Plant Dismantling and Decommissioning – Tank, vessel, pipework and other infrastructure dismantling, size reduction and packaging

The objective is **for size reduction of vessels, pipework and steelwork in medium or high dose areas. This includes being able to pick up, hold, sort and move materials and items within a cell.** The purpose is to **remove waste inventory from active areas to enable further decontamination or demolition;** there is a requirement to be able to sort and separate material allowing implementation of the waste hierarchy and to package waste ready for disposal in e.g. 3 m³ boxes.

Deployment of tools and remote machines to active areas needs to be possible with maintenance and cleaning of tools and machines in-situ a requirement. Advanced robotics for tooling deployment and for task performance (cleaning, lifting, drilling etc.) is a key area for development.

Baseline Methodology

- Bespoke deployment platforms, hydraulic or electric
- Use of existing Master slave Manipulators (MSM)s, cranes, and other existing cell infrastructure
- Brokks demolition machines
- Manual operations including scaffolding in cells
- Remotely deployed tooling such as reciprocating saws, drills, nibblers and grinders
- Plasma cutting
- Cut items at height and lower them to the floor and package locally
- Creation of additional waste treatment and export facilities



Operator using a Brokk



Infrastructure Dismantling

Limitations

- Limit to what can be undertaken due to high radiation and dose environments
- Reliability of bespoke equipment
- Cost of decontamination and maintenance of equipment
- Existing equipment not able to perform plant dismantling and decommissioning
- Access needs to be made to allow installation of new equipment, through shielded concrete
- Weight and loading limitations within existing structures
- Complex pipework and geometry limits deployability of tools
- Requirement to be able to dismantle a range of items from delicate glass vessels to lead shot reinforced concrete
- Potential for residual radioactive material to be stored in items
- Existing cutting techniques limit the ability to control spread of contamination
- Inability to use certain hydraulic fluids

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- Need to avoid or minimise use of water based effluents from cutting operations
- All items of waste must fit into a range of existing packages (maximum 3m³ box)

Perceived Technology Gaps / Opportunities

- Quicker, cleaner cutting
- Many robots designed today for structured known environments such as production lines
- Simpler more reliable deployment systems in complex environments
- Tools and techniques that minimise spread of activity or dust
- Long reach (greater than 10 m) remote deployment systems for existing wall penetrations and large cells
- Autonomous control of equipment to improve productivity
- Highly dexterous, manoeuvrable deployment mechanisms to overcome constrained environments
- Improve ease of maintenance and decontamination
- Develop a range of interchangeable tooling for a range of tasks from highly dextrous to high reaction force activities
- Identification of optimal cut paths. Intelligent waste segregation to minimise waste and reduce number of cuts
- Balance between cheap disposable equipment and more capable redeployable equipment
- Sorting- Faster, easy to deploy systems for moving items within cell
- Optimisation of size reduction and subsequent sorting step to enable efficient packing
- Item recognition for sorting and segregating and application of characterisation data into process

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Plant Dismantling and Decommissioning – Glovebox decommissioning (Alpha)

The objective is **to dismantle and size reduce glovebox and its internals into sections**. The purpose is to **efficiently dispose of glove boxes in a safe form to improve the way we manage contamination removing the need to use airfed suits during dismantling**. A whole glovebox should be reduced to pieces that can fit into 200l waste drums or 3m³ boxes. Typical gloveboxes contain redundant equipment, with the oldest dating back to the 1950s. A standard glovebox will be around 2m high, 3m across and 1m deep.

Baseline Methodology

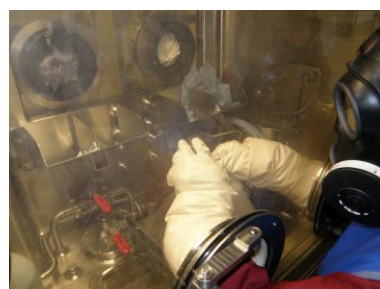
- Decommissioning using a mix of both manual and semi remote tooling
- Man access where possible to allow Air Fed Suit operations
- In one facility use of central glove box handling facility to size reduce using Brokks

Limitations

- Poor knowledge of previous use and residual contaminants
- Structure varies greatly across facilities from Lead brick shielding to basic Perspex windows
- Either preserve ventilation to contain contamination or provide external containment to allow dismantling
- Resuspension of fine dust during dismantling operations
- Assume glovebox is a C5 (air fed suit) area (>40Bq/cm² alpha, >400 Bq/cm² Beta)
- Glove boxes vary from those who stand alone with their own power, water and ventilation system, to those which are interconnected and have common systems
- Complex, challenging environments with limited space around the glove box. Some gloveboxes will be flush against walls



Glovebox Decommissioning



Working Inside a Glovebox

Perceived Technology Gaps / Opportunities

- More efficient cutting techniques to reduce the time to carry out dismantling
- Opportunity for Modular reusable glovebox processing unit
- Development of techniques for the safer size reduction of redundant gloveboxes which may be fragile and degraded due age and radiation damage
- Identification of optimal cut paths
- Decontamination of glove boxes to optimise the process in the waste management hierarchy
- Alternative waste management solutions

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Plant Dismantling and Decommissioning - Heel and residue removal

The objective is to **remove heels (layer of solid) and residues from pipes and vessels prior to dismantling**. The purpose being **to enable safer and more efficient decommissioning**. **Heels and residues are left over after Post Operational Clean Out (POCO) are the remnant materials (liquids or solids) which are not removed during routine operations**. Generally they require removal by pumps or creating additional penetrations into the vessels or pipes. The nature of the residues depends on the plant and operations and would be identified during characterisation.

Baseline Methodology

- Remove as much material as possible using standard plant operations, augmented by water jetting
- Remove heels from top of vessels using suction
- Allow evaporation
- Drain into a disposal container and encapsulate

Limitations

- Difficult to determine residual amount of material before and after cleaning
- Plant not designed to allow for heels and residues to be removed
- Compatibility of plant to additional chemicals needs to be investigated
- May require additional local effluent treatment
- Potential for airborne release of activity when cutting pipes or vessels particularly dried materials
- Chemical and radioactive hazardous materials which may have undergone change during storage
- Evaporation of material may have led to formation of solid residue permanently adhered to vessel walls



Highly Active Storage Tank

Perceived Technology Gaps / Opportunities

- Characterisation of heels and residues including physical state
- Technology to remotely couple drain line to pipe to remove residue with minimal spread of contamination
- Ability to quickly tap into vessels and remove heels without exposing operators
- Maintaining containment
- Process assessment and verification
- Localised deployment of equipment and chemicals in pipes
- Localised immobilisation and containment of heels