Sellafield Ltd is the company responsible for safely delivering decommissioning, reprocessing and nuclear waste management activities on behalf of the Nuclear Decommissioning Authority.
# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward</td>
<td>3</td>
</tr>
<tr>
<td>Introduction</td>
<td>3</td>
</tr>
<tr>
<td>Technology Development Summary for Nuclear Materials</td>
<td>4</td>
</tr>
<tr>
<td>Sellafield MOx Plant</td>
<td>4</td>
</tr>
<tr>
<td>Technology Development Summary for Spent Fuel Management</td>
<td>6</td>
</tr>
<tr>
<td>MOP Contingency Planning</td>
<td>6</td>
</tr>
<tr>
<td>SPRS Active Commissioning</td>
<td>7</td>
</tr>
<tr>
<td>THORP Receipt and Storage</td>
<td>8</td>
</tr>
<tr>
<td>Technology Development Summary for Integrated Waste Management</td>
<td>9</td>
</tr>
<tr>
<td>Highly Active Evaporation and Storage</td>
<td>9</td>
</tr>
<tr>
<td>Waste Vitrification Plants</td>
<td>11</td>
</tr>
<tr>
<td>Effluents and Encapsulation Plants</td>
<td>13</td>
</tr>
<tr>
<td>Technology Development Summary for Site Restoration</td>
<td>21</td>
</tr>
<tr>
<td>First Generation Magnox Storage Pond</td>
<td>21</td>
</tr>
<tr>
<td>Pile Fuel Storage Pond</td>
<td>26</td>
</tr>
<tr>
<td>Pile Fuel Cladding Silo</td>
<td>27</td>
</tr>
<tr>
<td>Solid Treatment Plant Technology Underpinning Project</td>
<td>27</td>
</tr>
<tr>
<td>Magnox Swarf Storage Silo</td>
<td>28</td>
</tr>
<tr>
<td>Decommissioning</td>
<td>36</td>
</tr>
<tr>
<td>Technology Development Summary for Analytical Services</td>
<td>38</td>
</tr>
<tr>
<td>Technology Development Summary for Technical Centres of Expertise</td>
<td>39</td>
</tr>
<tr>
<td>Decontamination CoE</td>
<td>40</td>
</tr>
<tr>
<td>Polymer CoE</td>
<td>43</td>
</tr>
<tr>
<td>Effluents CoE</td>
<td>44</td>
</tr>
<tr>
<td>Uranium and Reactive Metals CoE</td>
<td>48</td>
</tr>
<tr>
<td>Sludge CoE</td>
<td>49</td>
</tr>
<tr>
<td>Contaminated Land and Groundwater Management CoE</td>
<td>50</td>
</tr>
<tr>
<td>Flammable Gasses CoE</td>
<td>51</td>
</tr>
<tr>
<td>Technology Development Summary for Sellafield Ltd Technical Directorate</td>
<td>53</td>
</tr>
<tr>
<td>Technology Development Summary for Technology Specialist Trainees</td>
<td>55</td>
</tr>
<tr>
<td>Concluding Remarks</td>
<td>56</td>
</tr>
<tr>
<td>Future Research, Development and Technology Transfer Topics</td>
<td>57</td>
</tr>
<tr>
<td>Glossary</td>
<td>59</td>
</tr>
</tbody>
</table>
Foreword

Sellafield Ltd recognises that investment in research and development (R&D), and the active identification of technology transfer opportunities is critical to the successful delivery of its mission to safely operate, clean up and decommission the Sellafield Site.

Our customer the NDA, our Stakeholders, the local community and the UK tax payer have rightly placed an expectation on us to discharge these responsibilities efficiently, effectively, and above all safely. Our investment in R&D and our determination to seek new innovative solutions will help us to deliver on our promises. By sharing some of our successes via this report, we hope to demonstrate that not only is tangible progress being made in all key areas, but also the discharge of these responsibilities is in safe hands.

This report demonstrates the extent of R&D on the Sellafield Site. It also provides examples of key technology successes to provide an overview of the key projects delivered by the technical community. If you have a particular interest in any of these topics, I encourage you to get in touch with the named contacts. 2011-12 has been a year of close financial scrutiny within the business and this has led to a more focussed targeting of R&D resources against prioritised requirements.

We are sharing this information with our colleagues across the NDA estate and with the wider nuclear industry in the hope that this will provide an insight into our work. We would encourage interested parties to contact us should they see an opportunity for collaboration and/or coordination of research, development, or technology transfer.

Sylvain du Tremblay
Technical Director

Introduction

Sellafield Ltd invested £43m during 2011 – 2012 in research, development and technical support. The majority of this investment directly supported reprocessing and fuel fabrication plants, waste management facilities, clean up of the legacy facilities and the infrastructure of the site. Cross site research and development, in areas such as the evaluation of new technologies or techniques, was commissioned by the Technical Directorate and Technical Centres of Expertise.

This report provides an overview of our work, ranging from research in universities, development of existing technologies for nuclear use through to direct deployment of processes and technologies. It is not an exhaustive account of all R&D activities on the Site, the intention is to give the reader a précis of key research areas and high priority development work being delivered to support the safe delivery of site activities and to provide the future technology required at this stage of the site lifecycle. To deliver this work we’ve collaborated with a number of organisations such as academia, supply chain and government research bodies.

Key themes emerging from this year’s priorities are those of characterisation, remote operations and semi-autonomous systems. A good example of the type of R&D activities related to these requirements can be seen in the Legacy Ponds area in particular, where combinations of these technologies are being developed to perform remote survey and characterisation duties. The success of these particular programmes is significantly enhancing our understanding and capabilities in these areas.

Through this report the reader will gain

- An understanding of the depth and breadth of our research, development and technology transfer to deliver the site mission

- An awareness of and a desire to participate in professional network of R&D knowledge and experience at Sellafield Ltd.

- An insight into the R&D issues being addressed and so provides a basis for jointly addressing these issues where there is common interest.

If you have a general interest in learning more about R&D activities at Sellafield Ltd please contact Mr M R James, Head of Technology within the Technical Directorate in Sellafield Ltd at mike.r.james@sellafieldsites.com.
Technology Development Summary – Nuclear Materials

Sellafield MOX Plant

The Sellafield Mixed Oxide plant manufactured mixed plutonium uranium oxide fuel until the NDA announced its closure in August 2011. The main focus for the year has been to close out the R&D programmes efficiently and to shift attention into immediate clean-down activities and towards future POCO.

Contact mark.greaves@sellafieldsites.com.

More productive
Increased utilisation of recyclable material

Midway through the last production campaign, SMP had reached an annual production of 4.8tHM/yr and was beginning to consume recycle material at the same level of manufactured scrap (so-called “eating our tail”) but we were able to go further and trialled recycle inputs from 25% about 40 % with successful pellet quality resulting. This valuable work will present interesting learning for any future MOX facility or indeed other facilities still manufacturing MOX worldwide.

Improvements to product quality
Control of impurities

Work has reached an end on investigating the presence of low levels of iron contamination taking the form of sub-mm sized metallic shards originating from attritor mill balls. The work has been performed with Offline R&D support from NNL at the Springfields laboratories together with assistance from Southampton University. As a result, a source for the shard generation has been proposed following study of various wear mechanisms, The preparation of glancing cross-sections through mill balls has revealed the presence of discrete etch resistant regions close to the ball surface. The evidence suggested shard removal was caused by isolated severe impacts, rather than the cumulative damage of multiple impacts leading to spalling. The most likely cause of such severe impacts is balls being trapped at the base and sides of the mill and being clipped by the mill rotors.
Learning for decommissioning
Knowledge management sharing with NNL

As part of the cessation of activities on SMP, the R&D facilities located at NNL Springfields will be scaled back. There is much to learn from dismantling replica non-Pu-containing equipment in advance of performing the same task on the Pu-active Plant here at Sellafield. Programmes are drafted and are being further developed to share expertise and to capture the learning from NNL’s experience to drive efficiency into the delivery of clean-out and POCO for SMP.

Potential future uses of the SMP building has been a focus for the team in 2011-12 if this can benefit consolidation & storage of the NDA’s wider nuclear material legacy.
Development Summary – Spent Fuel Management

Spent fuel management involves reprocessing spent metal and oxide nuclear fuels to recover uranium and plutonium.

Contact: Gary.rothery@sellafieldsites.com

Fuel Storage

MOP Contingency Planning
Fuel Drying

Sellafield Ltd has been investigating contingency options for the future safe storage of Magnox spent nuclear fuel. We are doing this to ensure we have appropriate processes to safely manage Magnox spent nuclear fuel into the future to complement our current reprocessing capability. The fuel is currently safely stored in our fuel ponds.

Working with Babcocks and other specialists we have developed a process to dry and store the fuel in high integrity canisters. The canisters are manufactured from high alloy stainless steels able to store the material for 150 years if required. Specialised welding techniques are used to seal the canisters remotely in the shielded hot cell. The research needs to demonstrate that the processes meet the exacting standards required in the nuclear industry.

Extensive testing has been conducted and has successfully demonstrated the required quality standards.

Further work will be conducted to increase the engineering maturity of the application. The drying technology is also being considered for some of our legacy fuels.

Benefits – alternative and contingency option for future management of spent nuclear fuel from the Magnox fleet of reactors.

Can lid being welded on

Surrogate fuel elements in canister
Active Commissioning of the Sellafield Product & Residue Store – SPRS

The UK holds a quantity of PuO₂, most of which is on the Sellafield site where it is held safely and securely in a series of purpose built stores within sealed cans. The latest of these is known as the Sellafield Product & Residue Store, SPRS. SPRS is the first product store at Sellafield to utilise natural cooling, where the heat from radioactive decay is removed by an air flow driven by buoyancy effects without mechanical assistance.

Prior to the store going active a series of thermal analyses were undertaken to demonstrate that the cooling system within the store was capable of maintaining the correct temperatures under a range of conditions. A CFD (computational fluid dynamics) model of a storage cell was developed to predict the local flow and air temperatures around the cans in response to the overall cell heat load and the input external air temperature. The output of this model is then used in a finite element model which predicts the temperatures of individual cans and their components, such as product powder temperature, outer storage can temperature etc. for different power outputs and local air temperatures. Using these models a link is made between the global parameters, such as external weather and total store heat load down to the temperature of the individual components within each storage can.

SPRS is now undergoing active commissioning. The heat load within the cell is gradually increased and the store response, in terms of temperature and flow is monitored and compared with the predictions from the thermal analyses. Hold points are scheduled in 4 – 5 kW steps and satisfactory agreement with modelling must be obtained to justify further can loading. This process will continue to a heat load of up to 35 kW with the first cell almost full.

The paper will present results from the active commissioning programme. In particular,

• comparisons between measured and predicted can surface temperatures
• comparisons between measured and predicted store air temperatures
• comparisons between measured and predicted store air flows

For example, Figure 1 shows a comparison between predicted and measured can surface temperatures. The model generally slightly over-predicts the measured data, except for can 3. In the store, the next can is of significantly higher power which results in heating of can 3 higher than expected due to its power value.

Figure 2 shows a comparison between predicted and measured air temperature increase across the cell, as a function of cell power. The measurements follow a similar trend to the model predictions with increasing power but are off-set, in a conservative way, therefore over-predicting the local air temperature. This is at least partially due to over-estimating the resistance to flow within the CFD model.

To date, good agreement has been obtained with the model predictions, although a number of areas for improvement have been identified. The paper will discuss some of these lessons learned along with the wider scientific significance of the results, such as definition of temperatures typically experienced by product powders and storage packages of relevance to ongoing work in fields such as radiolysis and helium retention.
Technology Development Summary – Spent Fuel Management

**THORP Receipt & Storage - Continued Fuel Storage**

**Alternative Chemistry**
Thorp Receipt & Storage stores a mixture of Light Water Reactor (LWR) and Advanced Gas Reactor (AGR) fuel in support of reprocessing operations in Thorp. Storage is in demineralised water.

The forward plan for Thorp R&S, post reprocessing operations, is to store non reprocessed spent fuel (mainly AGR) in sodium hydroxide solution (pH 11.4). Sodium hydroxide is currently used elsewhere on the Sellafield site for the storage of AGR fuel and there is >25 years experience.

Sodium hydroxide is not currently used in TR&S due to compatibility issues associated with LWR storage. Until LWR pond furniture is removed the alternative water chemistry cannot be introduced. To mitigate removal of redundant furniture in the short term Sellafield Ltd. has been conducting research into alternative storage chemistries.

Potential new pond water chemistries are sodium nitrate or low dose sodium hydroxide. To evaluate the impact of these chemistries on LWR fuel Sellafield Ltd contracted Studsvik Nuclear AB (Sweden) to undertake immersion tests on irradiated LWR fuel cladding.

Test duration was 12 months in simulated pond chemistries. Analysis was a combination of standard coupon weight gain and the use of scanning electron microscopy (SEM) to measure metal/oxide growth or dissolution.

These tests have confirmed that there would be no impact on LWR fuel as a result of either chemistry being introduced into TR&S.
Highly Active Evaporation and Storage (HALES)

Increased Operational Life
Simulating and Modelling Boiling

The prediction of the remnant life of the Highly Active evaporators is key to maintaining the treatment of highly active liquors arising from our reprocessing operations. The evaporators are of kettle design and operate at relatively low pressures to minimise temperatures and corrosion rates. Operating evaporators under these conditions is unique and a thorough understanding of the boiling processes is required to enable results from condition monitoring to be used to assess the material thicknesses of areas that cannot be reached by the sophisticated monitoring equipment and predict the future operational life with a high degree of certainty and safety margins.

Boiling at low pressures is examined in the “boiling test rig” (shown) which uses simulate high active liquors obviating the need for detailed measurements of physical properties as the boiling heat transfer coefficients can be directly related to the measured temperature and pressure. The rig uses a piece of plate saved at the time of manufacture ensuring correct representation of the fabrication materials. The data from these trails is used in an “Evaporator” model that can be used to predict the metal temperatures of the heating components. The temperatures are used to predict corrosion rates using a corrosion rate expression derived directly from plant measurements, thus ensuring accurate and representative predictions.

The condition monitoring data is analysed using very sophisticated statistics to enable safety margins to be applied with the minimum predicted thicknesses being used for future planning.

All the models used have been peer reviewed by leading academics to ensure that the techniques used are the best available whilst remaining conservative. Further trials are planned to help understand the recirculation patterns with varying heating components to optimise use of the components and understand behaviour of the suspended solids.

The models are now being used to explore the whole of the evaporator operating envelope to ensure that the best use is made of the asset in its remaining life.

POCO Modelling

At the end of their operation life the Highly Active Storage Tanks (HASTs) will be emptied, leaving a small residual ‘heel’ and then ‘washed’ to remove their mobile inventory. This washing is known as POCO or Post Operational Clean Out. HAST emptying and POCO hold many complexities in terms of numbers of washes, tank sequencing and plant operational constraints. Added to this is the requirements to optimise feeds to the Waste Vitrification Plant (WVP) where the solids will be immobilised in glass and hence minimise overall numbers of containers produced.

A number of HAST Emptying and POCO simulation models have been built to understand and inform future strategy decisions and construct the POCO flowsheet. Model assumptions are to be underpinned a 4:10 scale HAST experimental rig which has been refurbished with the compliment of tank internals to fully represent the solids behaviour in and transfer out of the HASTs during emptying and POCO (Figure 2).
Technology Development Summary – Integrated waste management

Figure 1: Steady State flowsheet which examines POCO of HASTs with Ammonium Carbamate

Figure 2: Incorporating cooling coils into the 4/10th scale jet ballast rig (left), and a comparison between new and old POCO models.
Vitrification of Highly Active Liquor

Vitrification plants have been provided in order that Highly Active Liquid (HAL) waste, a by-product from spent nuclear fuel reprocessing, is converted into a form which is stable and not readily dispersible into the environment, prior to its storage and export to reprocessing customers, interim / long-term storage or transfer to a final repository for UK waste.

Dust scrubber performance

The off-gas produced from calcination and melting, which essentially contains entrained calcine dust, volatiles, water vapour and NOx, passes to the Primary Offgas System, consisting of a dust scrubber recycle vessel, a condenser and a NOx absorption column. Offgas from the dust scrubber enters the condenser where the water vapour and some nitric fumes are condensed. Blockages of solids occur on a regular basis in the off gas system and this has a significant effect to reduce the performance of the vitrification process causing numerous outages for recovery operations.

It has previously not been possible to analyse these solids. However advances in technology and the application of a new spectroscopic technique have made this possible. Sellafield Ltd working with Applied Photonics, a specialist in the application of Laser Induced Breakdown Spectroscopy (LIBS), have been able to deploy a fibre optic LIBS probe which was put into Line 2 breakdown cell in June 2011. A sample of solids was taken from the Dust Scrubber – Condenser coupling, placed in a mild steel can and then placed on the floor in front of the cell window in order to allow the LIBS probe to be positioned on the sample surface. The LIBS probe was attached to a 4 m length flexible umbilical cable fed in the cell through the traverse pot with a further 6 m length on the outside of the cell.

The findings from the study suggest that the solids are produced from the formation of caesium pertechnetate, which is most likely to have been formed in the melter and carried through the dust scrubber as a volatile gas.

In order to improve our understanding of this behaviour during the recent full scale inactive test rig experimental programme on the Vitrification Test Rig, a quantity of rhenium was added to the HAL simulant and a series of experiments were performed to observe the dust scrubber performance. Rhenium was used as a surrogate for technetium since there is no inactive isotope for technetium. The chemistry of rhenium is very similar to technetium. Upon completion the dust scrubber – condenser coupling was removed and solids were removed, which are believed to be caesium perrhenate. Further analysis is ongoing to review the findings from this study and a report will be produced by NNL later this summer.

Benefits – to understand solids blockages and reduce occurrences, to improve performance and reliability, and accelerate vitrification operations.
Post Operational Clean Out

To achieve an end state for the safe reduction of the highly active inventory from reprocessing operations the vitrification plants will be required to treat and immobilise the solids left in the Highly Active Storage Tank heels. Modelling indicates that that the heels will compose of precipitated solids containing high levels of molybdenum. Molybdenum generally has a low solubility in borosilicate glass which is used in the vitrification process. If too much molybdenum is added to the glass then there is a risk that this may form a substance called ‘yellow phase’ which is corrosive and produces poor quality glass which may not be acceptable for disposal in a geological disposal facility.

The plant washout programme may be accelerated to remove the solids from HASTs and combine the solids with reprocessing liquors and minimise the number of containers required to support POCO. A research programme has been performed to study POCO solids immobilised in glass and quantify the molybdenum limit. The study has shown that the acceptable incorporation rate is limited to 6 wt. % of molybdenum trioxide in the glass.

Benefits – To minimise the number of containers produced by maximising incorporation rates and achieve an earlier end date for vitrification.

Examples

A blockage occurred in the Waste Vitrification Plants in the Lines 1 and 2 HAL feed system in 2011. This has resulted in one of the feed tanks being unavailable to feed HAL to the vitrification process. Sellafield Ltd has worked in partnership with NNL, James Fisher Nuclear and AREVA to develop a means to remove the blockage and return the feed tank to operations.
Technology Development Summary – Integrated waste management

A simulant mix containing plaster and barium nitrate, which reflected the physical properties of HAL, was used to replicate the conditions which caused the actual feed line to block. The mix was poured vertically into 2 m sections creating a total blockage of the pipe. A series of high pressure jetting trials were performed to clear the blockage.

Equipment and techniques have been developed to clear the blockage. The clearance task is very challenging. The project has successfully combined a hybrid system with a high pressure nozzle on a reeling drum and camera for inspection. This has been safely and successfully tested on the full scale rig at James Fisher and the plan is to deploy the blockage removal equipment during 2012.

Unblocking Probe
Benefits – to unblock and recover the Line 1 and 2 feed line to the HAL feed tank to return the feed tank to service to support vitrification operations.

Effluents and Encapsulation Plants
Abrasion testing of drums
In order to prove Intermediate Level Waste (ILW) packages are suitable for transport, Sellafield Ltd has investigated the effect of the abrasion of a stillage twist lock pocket (corner stillage post) on a 500L drum with a protrusion.

The abrasion and indentation tests were carried out by the National Physical Laboratory on samples of 316L stainless steel used for the manufacture of 500L ILW drums and a Cromweld indenter.

The ramping load scratch tests and indentation tests were carried out using the indenter in Figure 2.

The tests found that the 316 stainless steel work hardened and did not penetrate the sheet when abraded and the indenter did not penetrate the 316L stainless sheet in the penetration tests.

This result will inform the safety case being built for transport of the ILW packages to the proposed Geological Disposal Facility and may mean that the requirements for containment during transport, or rework of packages before export, is reduced leading to long term savings in cost and effort.

Scratch test profile in metres
Technology Development Summary – Integrated waste management

Effluents and Encapsulation Plants

Hardness on an off scratch showing effect of work hardening

Hardness measured off and on the scratch

Graph showing effect of increasing number of passes left to right

Figure 1

Indentation test results (316L sheet over 8mm diameter hole)

The above images of the stainless steel sheet forced through an 8mm aperture with the indenter shown in Figure 3 resulting in no perforation. The left hand image shows reflection in the indentation base not perforation.
Technology Development Summary – Integrated waste management

**Figure 2**

Indenter used off scratch and perforation tests.

These before and after images of the Cromweld indenter show that the 316L stainless steel would be very resistant to any spike on the twistlock pocket with the indenter being considerably blunted during the test. The indenter shown left was used for the scratch test.

Use of Pulverised Fuel Ash from a Beneficiation Process

There are tight specification limits on the use of Pulverised Fuel Ash in cementation processes in the nuclear industry, compared to construction, due to the need to guarantee performance of waste packages in a repository for over a thousand years. Industrial recovery and beneficiation of fuel ash is being investigated as a means to guarantee the high specification supply the industry needs.

Grout made from the beneficiated ash has to be tested for a number of product quality parameters such as fluidity of grout, dimensional stability and strength. The consistency of supply is also important. Therefore test powders were taken over a 10 week period and showed to meet the specification requirements.

Currently there is a single supplier of Pulverised Fuel Ash for the industry to use. This powder has the potential to replace the current supply of Pulverised Fuel Ash and hence reduces the risk to supply.
 Effluents and Encapsulation Plants

Decontamination Trials for Effluent Plants Maintenance Facility

Improvements in the decontamination of items from the treatment of medium active liquors have been identified. Currently, items are decontaminated through heated washes with nitric acid. However, some items, suspected to be coated with organic material, have not been cleaned to the desired levels.

Alternative decontamination solutions have been trialled including hydrogen peroxide-nitric acid mixes and proprietary chemical cleaners. These will be compared against water, nitric acid (current decontamination solution) and standard detergents. Test-material grease is added to representative coupons that are then placed in a simulated decontamination cycle.

Trials are being carried out in laboratory scale tests that mirror the conditions in the Effluent Plants Maintenance Facility decontamination vessel as closely as possible. The temperature and concentrations are being kept the same and as is the ratio of the tank volume to the surface area of the item to be decontaminated.

The results are being assessed and will be used to implement an improved decontamination regime. Successful decontamination of this equipment may allow it to be reused in the same plants from which they have been recovered but would also allow for most of the activity to be removed from waste items ensuring the radioactive material is controlled.

All radioactive liquors generated from the decontamination process are fed to the Enhanced Actinide Removal Plant where the activity is removed from the water, prior to discharge to sea.

Decontamination Coupon following removal of grease

GGBS blending

GGBS (ground granulated blast furnace slag) is a key material for the encapsulation processes of MEP and WEP. Difficulties arising from the supply of this material to the encapsulation plants could impact both Thorp and Magnox reprocessing.

In response to continuing difficulties of supply of GGBS to Sellafield site and the rest of the NDA nuclear estate originating from the shut down of the Tata steel (Corus) Redcar blast furnace at Teesside and the closure of the BFS grinding mill there, Sellafield Ltd in conjunction with its main cement powder supplier Hanson Cement Ltd have initiated a 10 year supply contract for GGBS using a dedicated blending facility being built alongside an existing blending plant at Nuneaton.

This facility takes two GGBS powders of different particle size distributions and combines them into a single powder that exhibits the correct flow characteristics in an encapsulation grout that could not have been achieved using either of the constituent powders alone. The blending plant can vary the ratio of the two powders to give the required grout fluidity thus compensating for any variation in feed stocks.

The dedicated blender is currently under construction within the existing Hanson blending facility at Nuneaton that services the construction industry dry mortar market. This development has the potential to blend powders other than just GGBS for Sellafield Ltd operations.

Grout fluidity is a key parameter measured by the Colflow test. The use of too fine or too coarse a powder can make the Colflow too low or too high a value resulting in poor encapsulation characteristics or even halting the process completely. To date using the existing Hanson blending facility on a contract basis Sellafield Ltd has been able to successfully reduce the Colflow values of its encapsulation grout by implementing a stepwise change in the blend ratios of the different types of GGBS as shown in the graph below. This is the first time on site that grout fluidity has been modified at an industrial scale by modifying the particle size distribution of cementitious powders by a blending process.

![Colflow variation with GGBS blend ratio](image)
Technology Development Summary – Integrated waste management

Effluents and Encapsulation Plants

Radiation Profiling of Solvent Aqueous Interface in an Operational Tank

A review of the safety case for operating the Salt Evaporator plant identified a requirement to further examine the contents of the feed storage tanks. Specifically, the amount of radioactive material held in solids at the bottom of the tank, and at the interface between the aqueous feed and the floating solvent, had not been evaluated.

As part of the investigatory work into the activity levels present throughout the tank, HiRad surveys were carried out in collaboration with NNL. HiRad is a small, novel radiation detector that uses a crystal head and fibre optic cable to obtain gamma radiation measurements from difficult-to-access or large process areas over a wide radiation range. It consists of a small (3cm long) scintillating crystal coupled to a metal coated fibre optic cable. Scintillation light produced by the crystal in a radiation field is transmitted down the fibre optic cable to a photon detection device. The data is analysed off line and the radiation levels of the environment calculated.

The detector was lowered, measuring the radiation levels over the depth profile of the tank. The results of the scanning gave a bounding case for the dose rate across the tank that will support arguments for taking samples. There is the potential to improve the accuracy of the assessment using a more sensitive detector.
Effluents and Encapsulation Plants

High Resolution Thermal Imaging of Waste Packages

Through collaboration with the Nation Physical Laboratory an unshielded trial thermal imaging camera has been developed for scanning active Intermediate Level Waste packages during drum inspections in September 2011.

The trial system was successfully deployed generating images for some 39 retrieved drums whilst being reasonably robust in an ILW environment.

Background temp 14.2°C, average drum temp 15.4°C, hot base temp 16.4°C

Drum showing 'Cool' spot approx 15.8°C (highlighted with an arrow) surrounded by 16.5°C. Average drum temp 15.4°C background temp 14.4°C

IR video images were taken of the drums on a revolving turntable that made the drum features much more visible than is apparent in still photography. Also fixed place reflections from the cell environment were obvious as they did not move compared with the surface thermal features that moved with the drum.

This observation has created the possibility of using hyper spectral multi wavelength analysis to determine the onset of surface changes (corrosion) before it is observable in the visible spectrum and will be the subject of a future piece of work.

Image analysis carried out by NPL in conjunction with Sellafield Ltd and the manufacturer resulted in a specification for the generic design of a shielded high stability high resolution imager that can be used to produce database measurements against a traceable standard instead of just observations. Proving work on the specification will be required to define the achievable thermal stability for the system.

Some of the thermal images aligned with physical drum surface features indicating that the feature was associated with radiogenic heating.
Technology Development Summary – Integrated waste management

Effluents and Encapsulation Plants

Paint flakes
Epoxy paint flakes originating from the proposed decontamination of fuel skips by high pressure water sprays would be captured in a filter sock prior to being sent to WEP for encapsulation. Previous NPL work had shown that some simulant material could be formed into solid pucks under specified conditions of heat and pressure. Here the physical properties of compacted paint flakes were investigated as well as those of a filter sock paint flake composite. In doing so it was demonstrated that the paint flake waste stream had the potential to be processed and could be developed as a generic disposal route for coarse and fine particulates arising from decommissioning processes.

*Examples of compacted epoxy paint flake pucks*

Example of a paint flake puck encased in the polymeric fibre filter sock and heated resulting in a stable encapsulated waste form that could be easily handled and transported for grout overpacking in WEP.

This type of process could be varied to provide a generic process for various particulate wastes on site.

Use of Superplasticised Grout in the Encapsulation Process

The supply of consistent cement powders to the nuclear industry is needed to ensure encapsulation of intermediate level waste ensures the longevity of waste packages identified for long term geological disposal. The nuclear industry is a low volume user of cement powders and hence is at risk from changes in cement powders driven by the construction industry.

Polycarboxylate-based superplasticisers are being investigated as a potential additive to cement that will improve the qualities of the powder for use in nuclear encapsulation plants as well as meeting the long term product quality requirements.

There are risks associate with using superplasticisers, one is that there is the potential for them to associate themselves with radioactive material and enhance their solubility, potentially leading to transport out of the waste package.

Experimental work is ongoing to determine the behaviour of the grout and the set product that will determine whether the benefits of superplasticised grouts can be achieved in the nuclear industry and whether the long term storage risks would be realised.

The development of superplasticisers will reduce the risk associated with the supply of powders and open up the industry specification and allow other cement suppliers to be used.

White Light Scanning of Waste Packages

Research work had previously identified White Light Scanning techniques as being able to measure the changes in size and shape of Intermediate Level Waste packages held in the Encapsulated Product Store.

The technology works by projecting a series of vertical and horizontal fringes onto the target object, collecting the projected visible wavelength light signals from the object and using specialised algorithms to assess the data received. The result is a point cloud representing the surface of the target object which can then be analysed by specialist software packages to produce precise dimensional data and 3D images of the object.

A prototype system was developed and deployed in conjunction with Phase Vision and has been introduced into the active area during a campaign of encapsulated magnox drum inspections in September 2011. This is the first instance of applying such measurement techniques to active waste packages.
Technology Development Summary – Integrated waste management

The data collected has been used to generate 3D images of the drums, showing features on the drums due to the evolution of the contents of the packages. The next stage of work, once the 2011 data has been analysed, will be to optimise the operational process for White Light Scanning before monitoring the evolution of the product drums by performing repeat inspections at set time intervals.

Knowledge of the evolution of these drums is important as it will enable forecasting of performance of the drums against design expectation (by comparing the measured drum features to the modelled stainless steel strain) and determine the amount of reworking these packages will require before transfer to the planned Geological Disposal Facility.
Technology Development Summary – Site Restoration Decommissioning

This summary section highlights key work across the Decommissioning areas on some of the key aspects of research, development or technology transfer. The key benefits in undertaking these work packages lie in understanding the challenge, evaluations for project delivery, cost and hazard reduction, reduced dose uptake and improved delivery.

Contact: phil.reeve@sellafieldsites.com

First Generation Magnox Storage Pond

Subsurface Scanner

Technology is being developed to identify and characterise spent fuel elements on the floor of FGMSP to establish if it is potentially suitable for early retrieval and reprocessing. A Remotely Operated Vehicle (ROV) deployable Electrical Resistance Tomography (ERT) tool has been developed to identify the location of buried solids within FGMSP sludge. Electrical field distribution measurement will be used from the sludge surface of the ponds to generate a conductivity map which will highlight the occurrence of buried metallic solids. A purposely built tomography based sensor capable of achieving detection of buried metal up to a depth of 50cm (under trial conditions) has been developed. The proposed set of probes, arranged as a horizontal array, is encased in polytetrafluoroethylene (PTFE) and has no moving parts or electronics so to suit the requirements of operating under water. Further work is now ongoing to develop the technique to optimise interpretation of the volume and depth of the buried FGMSP spent fuel.

Freeze Sampling Tool

A remotely deployable technique is being developed to allow the remote sampling of FGMSP sludge. The technology will use a freeze sampling process to retrieve a known volume of sludge from the floor of the pond. This technique will allow a sludge sample to be retrieved from any depth in the sludge bed.

Using rapid freezing to solidify/stabilise the medium (rapid freezing also minimises the impact of freezing on the rheological properties of the sample), the technique can prevent any loss or release of sample during retrieval, while allowing a sample to be taken at a known depth and in a controlled manner. Once frozen, the sample can be safely retrieved whilst still attached to the frozen wedge and thawed by circulating an ethanol solution in the probe at room temperature.

Following the development of a manual freeze sampling probe, this tool will be tailored to be deployed using an ROV to enable access to all areas of the pond floor.
Freeze Sampling Tool

Manually deployable FGMSP Freeze Sampling probe tested using Magnox simulant

(sample taken at 20 cm depth, -30°C, 7 min freezing time, 30 mL retrieved)

In-Situ Dissolved Oxygen Survey

Using an oxygen sensitive ruthenium dye based optical sol-gel membrane deployed by ROV at the end of an optical cable; dissolved oxygen (DO) concentrations have been measured across FGMSP (49 locations were visited) to infer the potential corrosion rate below the sludge line. The data obtained revealed the concentration of dissolved oxygen and from this the likely fuel corrosion rate in the pond floor sludge has been extrapolated. The results obtained from the survey were uniform across the selected locations and, as oxygen is a key component in the corrosion of Magnox cladding and uranium, indicated that the fuel buried in the sludge is likely to have corroded at a faster rate below the sludge line, i.e. where the DO concentrations are 4 to 5 times more depleted, than above the sludge (U corrodes faster in de-aerated solutions). To further improve our understanding of FGMSP solid content and inform potential retrieval opportunities, the effect of corrosion on fuel stored in FGMSP over the past decades rates will be extrapolated.

VideoRay Pro3 equipped with DO and temperature probes
Compact ROV
Development work has been undertaken to further miniaturise the highly manoeuvrable Remotely Operated Vehicle (ROV) VideoRay Pro 4. This unit has previously been proven to operate in highly radioactive environments (tested to more than 1 Sv/hr) and in high pH environments. Capable of manoeuvring through tight spaces, and able to be deployed through penetration holes as small as 19 cm of diameter, it now allows for video inspection of storage areas which previously could not be fully accessed by an ROV.

FGMSP Compact ROV

Visibility Improvement Strategy
The effect of algal blooms and sludge particulate mobilisation on visibility in the FGMSP ponds has been a challenge for a number of years and could potentially impair retrieval operations as well as pond inventory work. Currently, visibility is lost for a number of months of the year while algal growth peaks. Work to mitigate the effect of algal blooms as well as particulate resuspension upon sludge mobilisation is underway:

PDX Reactor
PDX's reactor technology utilises a supersonic vapour flow and condensation shockwave, which is generated by the injection of high velocity steam. Steam is introduced into the reactor at supersonic conditions generating high levels of shear and turbulence within the process fluid. As well as taking the mixture to sterilisation temperatures using a recirculation system, this will lead to the creation of controllable, cross bore condensation shockwaves. As a result, the reactor is able to destroy suspended algae. The PDX reactor is also capable of fast and efficient mixing of powders with liquids, which could potentially be used to introduce flocculating agents for treatment of particulates. Trial to assess the suitability of this technology for improving visibility in FGMSP is being completed.

FGMSP Visibility Improvement small scale trial - PDX Reactor
Electrophoresis Process

As a mitigation against loss of visibility due to particulate resuspension, electrophoresis (a process similar to the one used for ink deposition on paper) is being investigated. Such technology could potentially be deployed in front of cameras to locally improve visibility while repelling particles under electric field (or electromagnetic pulses). Small scale trial has already shown the ability of clearing a limited area along electrodes. The potential of this technology to clear a “path” or localised area in front of operating cameras is being further investigated.

Chemical Treatment of Algae

As FGMSP is set within a liquid effluent stream terminating in liquor treatment at the Sellafield Ion Exchange Plant (SIXEP), the conditions for acceptance of a new chemical that might affect SIXEP performance are severe, therefore limiting the type of chemical that might be added to the stream.

Following an exhaustive set of review and trials, one particular compound has been identified as presenting the best potential. Mexel 432, an aliphatic biodegradable surfactant and biocide, was added to off-site tanks to assess its suppressive quality against biological growth. Mexel 432 works in two ways. Firstly, it creates a film on surfaces, preventing the build-up of biological growth (similar to an anti-fouling agent). Secondly, it also works as a biocide on the biological matter in suspension in the solution. A daily addition of the product also displayed the best result against the most likely strain of algae identified to be regularly blooming in FGMSP ponds. Further trials are now being setup to assess the effect that a potential deployment in FGMSP could have on the compatibility with the downstream process in place.
FGMSP Visibility Improvement – Mexel 432 trials

FGMSP Visibility Improvement – Mexel 432 High turbidity trial

FGMSP Visibility Improvement – Mexel 432 Low turbidity trial
Sludge Dispersion Modelling

Further developing on the Computational Fluid Dynamics (CFD) modelling to predict the behaviour of sludge potentially disturbed during FGMSP skip retrieval operations and its effect on retrieval schedule as well as downstream process, a more realistic model has been produced. Allowing for a more representative view of the FGMSP conditions (flow of water accounted for, multiple skip movement routes potential, reflective effect from other skips...), this new CFD model will allow a better understanding of plume dispersion volume and settling time.

*Mexel 432 process*

3-D representation of sludge disturbance (single FGMSP skip movement)

The process was tested using clinoptilolite and proved effective – the filtered water being very clean – but slow – taking a month for one batch to drain. In 2011-12 two ideas were tested to improve the rate of draining: applying a vacuum beneath the bed and using an air sparge to break up the very fine, low permeability surface of the bed. Both options considerably increased the throughput reducing the drain time to less than a week.

In addition a Magnox sludge simulant was tested. Under gravity alone this drained even more slowly than the clinoptilolite did but again, sparging and the vacuum improved the rate of drainage without compromising the quality of the produced water.

*Perspex column – 6 m high, 200 mm diameter*

Pile Fuel Storage Pond

Self Filtering Granular Waste

During the development of the SIXEP Waste Retrieval process in 2010-11, an idea for effluent treatment was tested and found to be potentially useful. In 2011-12 the Technical Directorate initiated further development of the idea to substantiate its viability.

The idea stemmed from the problem in hydraulic transfer of granular waste as to what to do with the excess water left over after the transfer. It is likely to contain fine particulate solids in significant amounts which could form an additional waste stream. The plan was to place the dilute slurry in a settling tank, let the bulk of the solids settle out and then to drain the excess liquor through the bed of solids to act like a filter – self filtering.

*Vacuum vessel*
Self Filtering Granular Waste cont’d

Plug of clino in the column

12 air sparger tubes to modify bed condition

Pile Fuel Cladding Silo

The safety case for waste storage, which enables the PFCS two-stage strategy for early hazard reduction, is dependant on a robust 3m³ container to provide the necessary safety functionality. During earlier development work to underpin the staged permissioning regime, PFCS produced a ‘concept’ waste container and performed drop tests to validate the Finite Element (FE) Analysis model. This has enabled development work on the prototype waste container to be performed in a more cost effective manner, utilising the validated FE model, instead of the more capital-intensive drop load testing.

Solid Treatment Plant Technology Underpinning Project (STPTUP)

The Solid Treatment Plant Technology Underpinning Project (STPTUP) undertook a successful option screening process in summer 2011 with the aim of down selecting 11 candidate technologies for the treatment of the Sellafield legacy pond solids. Candidates encompassed a wide range of technologies including encapsulation, hot isostatic pressing, dissolution, thermal and drying. A workshop was undertaken with regulators and stakeholders in attendance, ranking each candidate technology against the following agreed criteria:

- rate of hazard reduction
- cost
- process deliverability
- product sustainability
Solid Treatment Plant Technology Underpinning Project (STPTUP) cont.

Following analysis of the workshop output the recommendation was that encapsulation, In-Container Vitrification (ICV)™ and drying technologies be taken forward by STPTUP as the focus for future development work. This recommendation was accepted as the basis of a new Business Case and in support of this a Technology and Engineering Development Plan (T&EDP) was produced. This provided a firm foundation for future work, described the development programme to enable final option selection and highlighted key decision points which may lead to earlier completion.

™ In-Container Vitrification (ICV) is a trademark of Impact Services Inc

Solid Treatment Plant Technology Underpinning Project (STPTUP) cont.

Magnox Swarf Storage Silo (MSSS)

Understanding the Reactive and Corrosive Materials Challenge

The presence of reactive and corrosive materials within the waste retrieved from MSSS is a potential risk to retrievals, processing interim storage, transport and ultimate disposal.

Current Research and Development (R&D) work includes:

- Studying the properties and behaviours of uranium corrosion products
- Atomistic simulation studies of alpha- and beta-phase uranium hydride
- Trials to determine the corrosion rate of aluminium metal in various environments
- A review of general Magnox corrosion and, specifically in grout
- Trials to determine the rate of liquid water and water vapour transport through corroded Magnox swarf (CMS),
- Modelling of water vapour transport through magnesium hydroxide and CMS,
- Tipping trials to evaluate the potential spread of uranium within the MSSS compartments.
- State-of-the-art analytical equipment including a Thermo-gravimetric Analyser, an Adiabatic Calorimeter and an Isothermal Calorimeter are being employed to gather data.
Technology Development Summary – Site Restoration Decommissioning

Magnox Swarf Storage Silo (MSSS) cont’d

Waste Retrieval Technology Development: Retrieval Tooling Trial Raking

Waste has to be moved to a grabbing position from the walls of the compartment using a rake, specifically designed for the purpose. Initial trials had demonstrated that raking was generally acceptable but that removal from the corners of the compartment would require further optimisation.

Further trials performed following optimisation have demonstrated acceptable raking performance across the surface of the waste.

SDP

A demonstration of process performance is required to increase the design maturity and to verify the engineering work.

Settling and Decant:
- Settling to minimise burden on effluent treatment

Decant:
- To ensure volume of waste fits into the liner
- Waste retained under water cover at all times
- To realise opportunity of disposing of evaporator concentrate with the primary waste

Undersize Encapsulation

Viability of Dry Powder and Encapsulation Process; Dry Powders may give excessive rise to dust.
- Ensure waste is adequately mixed with Cement powders
- Dust evolution from Cement Powders addition/ Mixing is contained.
- Product loss from mixing/ Liner filling process is contained
- Undersize Mixing Vessel / Chute are adequately washed for continued use

Scanning Electron microscope image of UO2

Pieces of painted tungsten bar (representing uranium) falling through water onto a pile of Magnox Swarf

Raking Test Rig, NESL

Miscellaneous waste surrogate
Technology Development Summary – Site Restoration Decommissioning

Lattice structures of alpha- (left) and beta-phase uranium hydride

Wet rework
Wet Rework is required to minimise the number of out of specification products

Full-Scale Wet Rework Rig

Magnox Swarf Storage Silo (MSSS) cont’d

Oversize Encapsulation
Flood grouting of waste is established technology employed on several plants on the Sellafield site.

Rigs employ elements of technology new to Sellafield to improve process deficiencies identified by Sellafield Ltd Operations i.e. hydraulic pigging, radar etc.

Demonstrating Packages meet safety criteria for transport, and handling is an important element in securing a Letter of Compliance.

Waste package performance is being demonstrated via a combination of small scale trials, full scale trials and finite element modelling.
Technology Development Summary – Site Restoration Decommissioning

Test Materials

R&D trials required to demonstrate SDP design and technology solutions, mitigate risks, collect data and demonstrate throughput. The option to use actual MSSS waste for R&D trials is not practical.

• Actual MSSS sludge is created through corrosion of Magnox swarf and consists mainly of magnesium hydroxide – $\text{Mg}(\text{OH})_2$

• limited info on actual sludge properties:
  o Solids Content
  o Particle Size Distribution (PSD)
  o Basic Rheological Behaviour

---

Section showing internal damage

Drop Test on Top Corner

Actual Impact Damage

Predicted Impact Damage
Magnox Swarf Storage Silo (MSSS) cont.

- Actual MSSS sludge is created through corrosion of Magnox swarf and consists mainly of magnesium hydroxide – Mg(OH)₂
- limited info on actual sludge properties:
  - Solids Content
  - Particle Size Distribution (PSD)
  - Basic Rheological Behaviour

Sludge Test Material Development:
- Requirement that test materials are closely linked to the silo waste
- Corroded Magnox Sludge (CMS) believed to be the best available sludge test material
- CMS is relatively expensive and generation is a very slow process
- Corroded Magnesium Sludge (CMgS) is cheaper (than CMS), quicker to corrode and yields a product suitable to the SDP project
- CMgS blended with Hydromag to replicate average PSD

Effluent Test Material Development:
- Combination of flowsheeting and practical laboratory work to create chemical recipes
- Various effluent test materials tested at lab scale and small scale

MBGW Test Material Development:
- The MSSS contains a variety of Miscellaneous Beta Gamma Waste (MBGW) items
- Substantial amount of analysis performed to create manageable list
- Items subdivided into cylinders and pipes before further division into groups
- A single item from each group was chosen to represent the whole group
- Items fabricated to the correct size, weight & (depending on the type of trials) the correct material
- Various skip recipes have been created each providing specific challenges e.g. large items, silo cans etc

Application of Test Materials to Underpin TRL

Producing Test Materials: Magnesium Corrosion Tanks
Magnox Swarf Storage Silo (MSSS) cont'

Miscellaneous Beta Gamma Waste Project
The stream is investigating alternative routes for treatment of MBGW. A consideration for disposal of packages containing MBGW is whether sealed cans can be disrupted prior to encapsulation. NNL have recently concluded trials on grouting techniques to demonstrate the incorporation of grout throughout the beta gamma waste.

Trials to Demonstrate Disrupting sealed Cans Using a Manipulator

Grouting Trials
Magnox Swarf Storage Silo (MSSS) cont’

Infilled areas of disrupted top grouted 25 litre can containing light waste.

The photograph above shows the excellent penetration of the grout into the disrupted cans.

PAR Trials and Assessment

- Passive Autocatalytic Recombiners (PAR) are an innovative solution to the increased Hydrogen Risk from Pyrophoric Uranium in a transported Package.
- This technology has not been used in this scenario before.
- Key risks understood to be the start of the catalytic process at low temperature and the mixing of air and Hydrogen at the entry to the PAR unit.
- Bench top trials to mitigate these risks took place and assisted in the selection of two catalysts for further (full scale) trials.
- Test rig design and manufacture underway - Testing begins in May 2012 and runs for 1 month.
- Early indication is that the selected unit is more than adequate for the task. Data from the trials is expected to confirm this.
Improvements to Characterisation

Unmanned Ariel Vehicle with Laser Scanning

Decommissioning Technical department has sponsored a PhD student at the University Of Warwick Mobile Robotics Department to develop a flying remotely operated vehicle (ROV) which is capable of mapping its surroundings.

The student has adapted a commercially available hexacopter platform to enable it to be flown out of direct sight of the operator through the use of a stereo camera visor.

The hexacopter determines its position in 3D space using its on-board laser scanning sensors utilising Simultaneous Localisation And Mapping (SLAM) to continually create a map of its surrounding environment and simultaneously ‘localise’ itself. This enables the ROV to operate inside structures without any prior knowledge of its surroundings as it is not dependent on any external sensors/infrastructure. The operator simply directs it where to go, avoiding any obstacles en route, and the control system pilots the helicopter to the destination.

The student has also developed and integrated an anti-collision system using this same data to automatically prevent the operator from colliding the ROV during flight.

The figures show a snapshot of a laser scan ‘fly through’ taken from the Hexacopter of a facility at Warwick University.

For more information visit: http://www2.warwick.ac.uk/fac/sci/eng/meng/wmr/projects/uav/
Decommissioning Tools

Laser Cutting Research

Decommissioning Technical department has engaged TWI to undertake experimental evaluation study trials to assess the secondary effects of using high power fibre laser beams as cutting tools. The experiments were designed to understand and quantify the obvious hazards associated with deploying lasers in an enclosed environment - defined for these purposes as equivalent to the inside of the HANI cell. The experiments conducted include:

- Assessing the effects of stray laser beams on objects (steel, brick and concrete) at powers and ranges other than that intended for cutting operations.
- Heat and temperature generation in the work pieces and adjacent material exposed to the sparks produced during cutting operations.
- The ability of the laser to cut different geometry work pieces (representative of steel sections common in the HANI cell) from a single side.
- Effects of the release of fluid contents (water and sand) from within sealed sections of pipe when pierced by the laser.
- Analysis of fume generation associated with laser cutting.
- The work also included TWI providing reports covering:
  - Current laser safety regulations and recommendations of their implementation in the context of use within the HANI cell. Includes a description of safety features built in to fibre laser systems.
  - Paper to highlight possible circumstances that might result in unintended cutting, and suggested systems/procedures to prevent unintended cutting occurring.

Photos showing various test pieces used during the laser experiments
Improvements to Assessment, Process, Training & Safety

Virtual Environments

Recognising the benefits of using virtual environments by utilising computer gaming industry technology, Alpha Plants Decommissioning sought to exploit this technology during 2011/12 financial year.

A common understanding of facility layout is essential when undertaking work such as option selection, innovation, planning, optimising and training exercises. The ideal situation would be to perform all of these actions during or following a walkround of the facility in question but, in this case, it would have been both hazardous and impractical to do so due to the radiological conditions within the area. Photographs, sketches and drawings do not always convey the required detail and may cause confusion amongst the audience when trying to explain how one viewpoint relates to another.

Alpha Decommissioning therefore contracted Furness Engineering and Technology Ltd (FETL) to create 3D interactive ‘walk through’ model of a contaminated area which is only accessible by trained operators wearing specialist PPE. The Operations Team provided as-built drawings, measurement data and recent photos to enable the model to be scaled and rendered to produce a visually and dimensionally accurate virtual replica.

The resulting virtual model now gives anyone the opportunity to explore/ navigate the facility risk free and without having to dress in specialist PPE. An engineer or manager, together with their audience, can take a virtual tour at any time, and can become familiar with a facility without ever having to physically go there. So far, the model has been used in pre-job briefings, initial familiarisation training for new personnel and in pre-tender discussions with outside contractors.
Improved Analytical Analysis Capability:

• Scanning Electron Microscope - non destructive screening analysis which provides structural and composite information on major, minor and trace elements on the surface of samples. This screening technique enables multiple analysis paths to be chosen when more in depth analysis is required.

• New technique developed for the analysis of trace levels Iron in Uranium Trioxide. This new technique provides a significantly increased method precision and delivers an analysis cost savings in excess of £34,000.

• Turbidity - installation of new instrument has enabled turbidity analysis to be offered to customers for the first time. This extends our plant support in line with changing customer needs.

• Flashpoint Analysis - for the identification of unknown solutions; to aid in storage and segregation of plant solvents. This supports the accelerated decommissioning programme.

• New analysis technique developed for the determination of trace levels of Sodium in Uranium Trioxide. This technique provides significantly improved analysis turnaround to all site customers.

• Expanded pH analysis capabilities. Extensive validation of existing pH determination techniques was undertaken to provide increased accredited analysis range to meet changing customers needs.

This summary section highlights key work across the Infrastructure areas

The technical work in this area focuses on development of methods in analytical chemistry.

Please contact: ian.d.macpherson@sellafieldsites.com if you require any further information
Technology Development Summary – Technical Centres of Expertise

The Centres of Expertise are our community of recognised experts in a range of science and engineering subjects. Their work is to support the delivery of our technical work in operational plants and projects.

Many of the projects already described in this paper were supported by our CoEs. The following sections describe some of their work to support cross site requirements.

2011/12 has seen these groups develop and mature in their support to site operations and projects.

Please contact:

debbie.m.keighley@sellafieldsites.com if you require any further information

Our current Centres of Expertise are

<table>
<thead>
<tr>
<th>Technical CoE</th>
<th>CoE Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytical Chemistry</td>
<td>Clare MacLaren</td>
</tr>
<tr>
<td>Autonomous Intelligent Systems</td>
<td>Paul Mort</td>
</tr>
<tr>
<td>Cement chemistry</td>
<td>Steve Foster</td>
</tr>
<tr>
<td>Contaminated Land and Ground water management</td>
<td>Katherine Eilbeck</td>
</tr>
<tr>
<td>Decanning and Dismantling</td>
<td>Andy Richardson</td>
</tr>
<tr>
<td>Decommissioning Technologies</td>
<td>Paul Mort</td>
</tr>
<tr>
<td>Decontamination</td>
<td>Alex Jenkins</td>
</tr>
<tr>
<td>Effluent technologies</td>
<td>Luke O’Brien</td>
</tr>
<tr>
<td>Environmental</td>
<td>Tim Parker</td>
</tr>
<tr>
<td>Flammable Gas &amp; Radiolysis</td>
<td>Ian Kempsall</td>
</tr>
<tr>
<td>Fuel Manufacture</td>
<td>Rob Stephen</td>
</tr>
<tr>
<td>HALES Processes and Chemistry</td>
<td>Tina Wylie</td>
</tr>
<tr>
<td>ILW waste packaging / Graphite</td>
<td>John Clifford</td>
</tr>
<tr>
<td>Material Science &amp; NDE</td>
<td>Pat Liddicott</td>
</tr>
<tr>
<td>Maths and Statistics</td>
<td>Ian Teasdale</td>
</tr>
<tr>
<td>Modelling and Simulation</td>
<td>Steve Graham</td>
</tr>
<tr>
<td>Nuclear Physics</td>
<td>Andrew Cooper</td>
</tr>
<tr>
<td>Polymers</td>
<td>Penny Rathbone</td>
</tr>
<tr>
<td>Safeguards</td>
<td>Jacqueline Bishop</td>
</tr>
<tr>
<td>Sludge</td>
<td>Geoff Randall</td>
</tr>
<tr>
<td>Spent Fuel Storage</td>
<td>Paul Standring</td>
</tr>
<tr>
<td>Thermal Treatment technologies</td>
<td>Mike James</td>
</tr>
<tr>
<td>U/Pu (and other actinide) Chemistry and Processing</td>
<td>Steve Cope</td>
</tr>
<tr>
<td>Uranium and reactive metal</td>
<td>Ed Butcher</td>
</tr>
<tr>
<td>Vitrification processes and chemistry</td>
<td>Andrew Riley</td>
</tr>
<tr>
<td>Waste &amp; Facility Characterisation</td>
<td>Alister Dunlop</td>
</tr>
<tr>
<td>Waste Segregation and Compaction</td>
<td>Charles Mason</td>
</tr>
</tbody>
</table>
Decontamination Centre of Expertise

Wallrover™ Remotely Operated Vehicle (ROV) Prototype Development & Deployment

A small package of work led to the development and active testing of an unmanned wall-climbing ROV. Locally developed and manufactured its initial capability was demonstrated with great interest from a range of projects. The scope of the work included the integration of a new to market gamma spectrometry head from Kromek; and an inspection capability.

The device has genuine wall climbing capability across a range of surfaces as shown in the figures alongside. Its wall-climbing capability uses a patented system without the need for high airflow vacuum systems that would otherwise give rise to airborne contamination. Examples include inspection of a water line 3 metre from the floor. Its ability to climb different surfaces, e.g. brick, concrete or steel makes and in this configuration, makes it an ideal first entry early assessment tool for cells and inaccessible environments for decommissioning projects.

The package includes a simple Operator Control Unit with gamepad controls and real time communications along the power umbilical to a laptop and camera screen. This unit can be set up and operated in less than 5 minutes.

The characterisation capability of the Kromek device enables identification of gamma emitting isotopes. This device still requires formal assessment and endorsement, but as a new to market device this will be a natural progression. This device has been demonstrated to a variety of potential end users to identify other design options that would expand its application, e.g. higher payload capacity to accommodate standard radiometric instruments.
Technical Centres of Expertise

Decontamination Centre of Expertise

Ultra High Pressure Manual Lance Improvements
Ultra High Pressure (UHP) Water Jetting is a known very versatile method of decontamination. Manual operations with lances add huge levels of dexterity to any operation, but introduce risks, e.g. injury from joint failure. As on a lance some joints are close to the torso of the operator, encasement of these joints minimises the risk of injury should a joint fail.

Working with Nuclear Technologies, a manual lance of a type typically used at Sellafield, has been adapted. The principle is very simple, cheap and potentially lifesaving device that is readily transferred to each UHP lance design. This development will be shared with the water jetting industry.

Quick Erect C3/C5 Tent Enclosure
A demonstration of earlier works to a wide variety potentially interested plant bodies has given rise to modification and consent for an active plant trial. This type of tent enclosure can be erected by two people, e.g. plant operators in less than two hours saving valuable time and money against other enclosure construction methods.

A future active plant trial is planned to take account of the positive feedback given at the demonstration.

This showed that interests extend beyond Sellafield, including INS. Its portable and rapid erection structure has obvious application for emergency response and CBRN events in the UK and abroad, e.g. Fukushima.

Ice Pigging (University Of Bristol)
Ice pigging has been deployed in the food & drinks industries but also by water utilities companies to clean pipework systems of solids / debris over a range of pipe diameters (1”-36”). Ice Pigs are capable of moving bricks, scales and other solids. The performance of the process within other industries has encouraged Sellafield to examine the applicability to the nuclear sector for decontamination, POCO and decommissioning operations.

Inactive trials have been commissioned to provide the technical underpinning for any future active deployment. The areas of examination covered are:

- Conditions to create a self-blocking scenario
- Alternatives to ‘salt’ as an additive to sustain the Ice Pig
- An understanding of Ice Pig functional longevity, e.g. volume per time / distance.
- Multiple segment Ice Pig ‘trains’

Recognising the pre-existing licensing arrangements for Ice Pigging in non-nuclear sectors, it was essential to set out what the future licensing and intellectual property arrangements were in place, before investing in the underpinning datasets.
Technical Centres of Expertise

Decontamination Centre of Expertise

Enhanced Ultrasonics (University Of Southampton)

Sellafield Ltd has examined the use of ultrasonics to aid decontamination on several occasions from 1970-1990’s. These have been reliant upon immersion of items in a liquid to be effective. The University of Southampton has created a device that makes ultrasonic decontamination achievable in localised areas and without total immersion. They have further shown (as above) its potential for porous materials against a range of fouling media.

The work undertaken is the first stage of proving concept and understanding the applicability for potential deployment at Sellafield. A range of substrates were investigated, including steels, concrete and polymers used in glove boxes to remove sludges, entrained powders and particulates. An example of the intended future use would be to extend the use of Hypalon gloves by decontaminating them to avoid hand/extremity dose uptake. Some emphasis is given to this area due to the current supply issues with gloves. Furthermore, as a low liquid volume recirculating process, it has potential use in glove boxes.
Technical Centres of Expertise

Polymer Centre of Expertise

The Polymer CoE has been leading the development of a repair patch methodology for civil structures, specifically reinforced concrete structures. The technique developed can be used in isolation or in conjunction with the other polymers and sprayed onto a structure to form a repair or seal. This technology and methodology has been developed by the Polymer CoE and OU Technical Managers with significant input from expert specialist contractors. The repair applicator is required to work remotely using heating to enhance cure rates and be non-stick to remove the applicator from the cured patch once in place. The patches were proven using simulation and were proven to be climatically independent for deployment.

Polymer Patch Applicator during full scale trials

All containment gloves, leaded gloves and beaded port seals were manufactured from DuPont Hypalon material. In May 2009 DuPont announced the cessation of Hypalon manufacture requiring Sellafield Ltd to identify, test and certify an alternative material for the manufacture of these items.

A collaborative approach involving the main Hypalon users on Site, AWE and the two major glove suppliers led to the identification of a potential replacement material – Tosoh CSM (Chlorosulphonated Polyethylene) by early 2011.

Initial testing in alliance with AWE led to the confirmation of Tosoh CSM as the preferred replacement material and this selection was given NNGF approval in February 2012.

Specifications are currently being updated to allow the Tosoh CSM consumables to be available for use on Site from mid 2012 onwards.
Technical Centres of Expertise

Effluents Centre of Expertise

Decontamination systems (ELENDES)

Acceleration of decontamination can be achieved through the use of aggressive acids and complexants, however the residual corrosive reagent and complexants can have unacceptable consequences for downstream plant (corrosion risk and impact on abatement plant performance). For this reason the use of such reagents is limited and may limit the scope for local decontamination options. NNL along with CTech Innovation have developed a system that allows electrochemical treatment of spent decontaminant solutions to make them compatible with downstream infrastructure.

The system couples the option of low reagent delivery systems which keep the inventory of reagent down (e.g. 1 litre of reagent providing 4000m2 of droplet surface area) with an electrochemical process that removes chloride and oxidises complexant. The system also offers the option of a post-treatment step (in-line precipitation) to remove activity and other components for circumstances where tie-in to existing abatement facilities is not practicable.

Algae destruction (PDX)

Algal growth in fuel storage ponds can lead to issues with respect to operational visibility and waste behaviour. FGSMP is conducting a series of studies of technology options for the control of algal growth and visibility. One approach provided by pdx involved the application of steam to kill algal cells. The PDX reactor is essentially a direct steam injector, whereby the steam is injected into a moving process fluid. Units capable of processing from 5-5,000 kg/hr are available.

The studies showed that an effective kill was possible (at temperatures above 55°C). Further work to explore processing rate requirements and deployment configurations is under consideration.

Re-use of material for filtration duties

During the development of the SIXEP Waste Retrieval (SWR) process an idea for effluent treatment was tested and found to be potentially useful. In 2011-12 the Technical Directorate funded further development of the idea which has shown it to be viable.

The idea stemmed from the problem in hydraulic transfer of granular waste as to what to do with the excess water left over after the transfer. It is likely to contain fine particulate solids in significant amounts which could form an additional waste stream. The idea was to place the dilute slurry in a settling tank, let the bulk of the solids settle out and then to drain the excess liquor through the bed of solids to act like a filter – self filtering.
Technical Centres of Expertise

The process was tested using clinoptilolite (one of the SWR waste streams) and proved effective – the filtered water being very clean – but slow – taking a month for one batch to drain. In 2011-12 two ideas were tested to improve the rate of draining: applying a vacuum beneath the bed and using an air sparge to break up the very fine, low permeability surface of the bed. Both options considerably increased the throughput, reducing the drain time to less than a week.

In addition a Magnox sludge simulant was tested. Under gravity alone this drained even more slowly than the clinodid but again, sparging and the vacuum improved the rate of drainage without compromising the quality of the produced water.

Academic interactions

- Sponsorship of Engineering Doctorate study into solids deposition

The disturbance and processing of wastes stored in a variety of facilities at Sellafield could lead to an enhanced potential for solids deposition in transfer pipelines and storage vessels which in turn lead to operational and decommissioning issues. An Engineering Doctorate has been established under the Effluent Technology Centre of Expertise at the University of Manchester centre for Radwaste and Decommissioning to assess the conditions under which deposits are most likely to be formed, the nature of the formed deposits and to establish mitigation or control options that may be deployed on operational plant.
PhDs covering areas ranging from the development of novel ion exchange materials, enhancement of existing abatement processes, organic processing technologies and studies to improve the understanding of the actinides in effluent streams.

- Colloid transport through packed beds

During the recovery of sludge based wastes there is the potential for enhanced particulate burden to abatement plant filtration systems. Whilst the filtration performance for the removal of bulk particulate is well understood, the performance for colloid is less well understood.

Sellafield Ltd, through NNL, has partnered with the University of Sheffield to understand the transport of colloids through packed beds. Experimental mesoscale visualisation and modelling can be used to interpret and understand deviations in filtration performance. The study which uses methods developed through environmental and medical research is being used to develop data that can be transferred into enhanced versions of existing models of abatement plant with the ultimate goal of improving performance and the prediction of performance.

Figure 10 The effect of changes to process chemistry on colloid aggregation

- NDA bursary PhDs

The Effluent Technology Centre of Expertise is technically supporting a range of NDA sponsored

Time-lapsed fluorescence imaging of colloidal flow through a sand-bed. Differences in the plumes are a function of the ionic strength of the solution. (Copyright © 2006 American Chemical Society)
Technical Centres of Expertise

In parallel the Foundation Degree continued and there are now 66 trainees working on one or other parts of the scheme. The Foundation Degree has been jointly accredited by the Nuclear Institute and the IChemE allowing the TSTs to register for Eng Tech on completion of the Foundation Degree.

Permeability and porosity of a computer simulated sand filter as explored by numerical simulation compared with experiment (Copyright © 2011 National Nuclear Laboratory)

Images of disturbed sludge from activity partitioning experiments, device used for in-pond activity partitioning measurements and model output derived from the modelling of data

Sludge solution chemistry

A chemical model of sludge beds has been commissioned by FGSMP in order to assist in the development of a strategy for the management of sludge supernatant chemistry with particular emphasis on the role of pH management. The model makes best use of data developed from inactive and trace active experimentation on aspects of process chemistry including sludge pH buffering, carbonation, activity partitioning on sludge, sludge settling as well as recently derived plant data from deliberate sludge agitation trials. The model has enhanced confidence in effluent flowsheet predictions and in the justification of solution chemistry management strategies.
Technical Centres of Expertise

Uranium and Reactive Metals Centre of Expertise (U&RM CoE)

The focus of CoE work performed during the year has been in supporting the existing plants dealing with fuel and wastes containing uranium and reactive metals in particular mainly in the Legacy Ponds and Silos area, and in parallel developing the skill and capability base available for the Sellafield Ltd technical community to draw upon.

The uranium area in particular, is a very specialist subject, which will be required in both the short, medium and long term by Sellafield Ltd and the wider NDA estate for a range of projects. It is therefore of vital importance that the skills base and the facilities to perform work are maintained.

Ongoing Support to Projects

The CoE provides support to projects through three primary mechanisms

1. Direct consultancy support to projects to assist with specific technical issues including MSSS, SDP and FGMSP.
2. Provision of a mechanism for sharing of the technical information across projects through a regular meeting, at which all projects performing uranium related work are invited to attend. This sharing of knowledge maximises its value and ensures that a consistent view of the key technical issues are maintained across the projects.
3. Technical peer review of key reports produced by projects, through the Uranium Containing Waste Technical Group (UCWTG). This group utilises experts from across the Centre of Expertise’s network of suitably qualified experts, to provide an independent assessment of the work performed and conclusions drawn.

Simulated corroded Magnox sludge

Enhancing the Capability

In order to expand and strengthen the skill base available, a university link has been established to allow additional very specialist skills located in the university sector to be accessed in a faster manner through the placement of a sponsorship with the university.

The scope of the work required was defined within the CoE and then circulated to a wide range of stakeholders across Sellafield Ltd, to allow their views to be incorporated. An initial review of universities with a stated capability in performing uranium related work, identified 17 institutions, all of whom were contacted directly and provided with the scope, to allow them to assess the fit of the scope with their skills, capabilities and strategic goals.

The results of the exercise identified both a suitable university partner, and allowed us to gain a more complete understanding of capabilities in the university sector, this information was then disseminated across the Sellafield Ltd Centre of Expertise community.

After a detailed internal review of the submissions received, the Interface Analysis Centre (IAC) at the University of Bristol was selected as the link. The IAC has an extensive track record in performing world class research on uranium in particular which provides the opportunity for immediate assistance to ongoing Sellafield Ltd projects. The sponsorship has a duration of five years, with funding for research associate. This will be leveraged through application for funding from other sources, to increase the value of the work performed in support of Sellafield. Funding for a PhD project to gain a greater understanding of the reactions between cements and uranium has already been obtained through the NDA bursary scheme, a project which is of direct and immediate value to Sellafield Ltd and the wider UK nuclear industry.

External Links

Throughout the year the CoE has increased its contacts with Radiochemical Science and Engineering Group at Pacific Northwest National Laboratory (PNNL) in the United States. This group has been engaged to provide expert peer reviews of work which Sellafield Ltd has had performed in support of legacy waste projects.

The CoE also maintains contact with other site licence companies (SLCs) within the UK to disseminate knowledge of the ongoing work to this wider community.

Summary

The CoE has supported wide variety of projects through the year, through the ability to access and utilise individuals and facilities which are both specialist and high demand. The work performed to establish a university link with the Interface Analysis Centre at the University of Bristol and the engagement of PNNL, provides access to a wider range of specialist external expertise to strengthen support for providing assistance to ongoing projects.
Technical Centres of Expertise

Sludge Centre of Expertise

Supporting Hazard Reduction
Providing continuing support to projects – for example assisting in the resolution of operational problems with the PFSP. This assistance has included facilitating:

- Access to commercial modelling expertise built on work already done for FGMSP
- Access to independent advice
- Review of technical work.

Work done by the SIXEP Waste Retrieval project to validate a proposed vane penetrometer prior to operational deployment has been reviewed and presented across the Centre of Expertise as an example of how robust validation can avoid use of inappropriate techniques.

Collaborative working
National recognition – Sellafield Ltd won the 2011 I Chem E Core Chemical Engineering Award for Development work on the use of fluidic mixers for processing intractable sludge undertaken in collaboration with the University of Leeds and BHR group. The project drew on the characterization of the radioactive sludge combining this information with the rheological knowledge and numerical modelling expertise of BHR Group, and the skills Leeds University possessed in fracture mechanics and the ability to visualise fractures to gain a better understanding of the chemical engineering challenge.

Centres of Expertise are charged with developing links with academia, in part to allow promising technologies to be identified and transferred into the business as appropriate. The sludge centre of expertise has a partnership with Leeds University where work is ongoing on two technologies that have been identified as having significant potential to improve how we work.

Technology transfer – Quartz crystal microbalance
Experimental work at Leeds University has demonstrated at the bench scale that measuring the frequency shift of a vibrating quartz crystal can provide an indication of some important sludge and slurry properties – the solids concentration and the yield strength. Probe and flow cell configurations have been trialled which offer the potential to have an in-situ measurement in tanks and on-line measurement in pipe flow. This capability would significantly enhance our ability to monitor and control our processes. This research is supported by EPSRC.

Technology transfer – acoustic back scattering
As a part of the DIAMOND consortium, researchers at Leeds University have been exploring the deposition behaviour of very heavy particles in high-concentration slurry flows. A spin off from that has been the application of acoustic back scattering techniques – widely used in the environmental field to explore erosion and sedimentation in rivers and estuaries – to gain information about concentration profiles in pipes and settling tanks. This experimental technique offers the potential to have an in-situ measurement in tanks and on-line confirmation that an acceptable pipe flow regime is being maintained. This research is supported by EPSRC.
Contaminated Land and Groundwater Management

Assessment of historic information and data has identified evidence of interactions between the water bodies and has been used to design current data collection programme.

The data collection phase of the project has included the collection of spring water samples from the beach and the monitoring of groundwater and river levels. In the past year, Dynamic Density data loggers have been installed to monitor groundwater around the foreshore and River Ehen.

Within the site, groundwater elevation data is also being collected to improve the understanding of the groundwater movement around the main historical sources of groundwater contamination.
Technical Centres of Expertise

Flammable Gases Centre of Expertise

The CoE has developed a structured approach to management of hydrogen hazards across Sellafield Ltd, to enable efficient design. However, decommissioning from many of the high-hazard legacy plants presents significant hydrogen hazards. Often it is difficult to fully characterise hydrogen hold-up and release prior to retrieval. Therefore, there is value in developing innovative solutions.

Two areas of research have been pursued in recent years aimed at decommissioning, namely ‘ignition probabilities’, and ‘mitigation through water misting’, because they are areas that have been little explored and hence there is significant potential for a step change in hazard mitigation. These areas are now showing significant promise, and are likely to be of relevance to other Site Licence Companies and non-nuclear process industries.

Mechanical Impact Ignition
Ignition source control is used extensively when flammable gases may be present to prevent any explosion occurring. Ignition from electrical sources is well understood but mechanical impact sources have not, historically, been well researched. An extensive programme of work looking at the ignition potential of thermite and pyropohoric sources in a range of flammable hydrogen/air mixtures has provided, and is continuing to provide, an insight into the measures needed to control and evaluate such sources.

This work has already been of significant benefit to the design development of plant such as MSSS Retrievals and SDP Product Box Storage, where the judgement that hydrogen ignition is unlikely, can now be substantiated.

Explosion Suppression / Mitigation
In some instances, ignition source control is not sufficient to provide the level of safety required in a plant design and measures must be taken to suppress or mitigate the effects of an explosion. Two techniques which show promise as such measures are being investigated.

Oxygen availability controls the speed of any explosion and so reducing oxygen concentration can suppress or mitigate the overpressure experienced by a containment system, even where it is not possible to meet international inerting standards.

Photomicrograph of a rusted surface with some Magnox smears on the surface

The effect of oxygen depletion on the flame burning velocity

The effect of oxygen depletion on the overpressure time history for a vented enclosure
Technical Centres of Expertise

Flammable Gases Centre of Expertise (Cont...)

Water misting can be used to remove the heat from an initial ignition and by a different mechanism to oxygen control, to either suppress or mitigate an explosion. Alternative water misting technologies have been identified and characterised and experiments have shown how effective an ultrasonic generation technique is at suppressing an explosion.

Programmes of work are currently underway to:
- Develop a robust mist generation technology that can be readily implemented in nuclear plant environment
- Investigate the improvement in suppression ability by the use of additives.

Full Scale Experimental Work
To support the development of a hydrogen hazard management strategy for MSSS retrievals, full scale experiments investigating explosion suppression / mitigation have also been carried out at HSL Buxton. These have investigated the complex interaction of non-uniform mixtures of nitrogen / oxygen / hydrogen and the possibility of an explosion.
Muon Radiography – TRL from 2 to 4

Characterisation and imaging of the internal contents of drums, flasks and silos present significant technical challenges. The need to characterise these items has led to the development of a 3D imaging technique using Muon detection and reconstruction, and this work is progressing well. The ultimate goal of this development programme is to establish a range of Muon based imaging technologies capable of the non-intrusive characterisation of anything from the contents of a cemented drum to the contents of a whole silo or storage bin. The first step of this journey is to develop a technique to image the contents of suspect 500l cemented drums to establish package integrity.

This capability has been identified as a key technology gap within encapsulated product stores. A small (lab) scale prototype unit was successfully demonstrated in the summer of 2011, completing Phase I of the development programme.

Phase II, the next stage of development, has now commenced and will progress the TRL from 4 to 6. The aim of Phase II is to design, construct and commission a large-scale prototype detector system similar in design to the expected system which will eventually be placed on plant (e.g. in MEP).

The detector will be larger than the small-scale prototype system developed in Phase I, but will use many of the same underpinning technologies and approach. This will allow the experience and knowledge developed from Phase I to be imported into Phase II and reduce the overall R&D costs in these areas.
Technology Development Summary – Technical Directorate

The Sellafield Ltd Technical Directorate provides support to the business in the areas of technical capability maintenance, technology development and technical governance. Two of its key responsibilities are to fund innovation and research in support of the Centres of Expertise areas and to provide central funding for generic or breakthrough technology development.

Key development programmes funded during 2011-12, detailed elsewhere in this report under their relevant sections, include:-

- FGMSP Tomographic Survey
- FGMSP Freeze Sampling of Sludge
- Decontamination CoE WallRover development
- Decontamination CoE Ice Pigging
- Decontamination CoE Ultrasonic Decontamination
- ILW Packaging CoE Box Inspection Robot
- ILW Packaging CoE/E&EP Technical Cenosphere Grout Development
- ILW Packaging CoE Superplasticised Grout formulation
- ILW Packaging CoE Waste Form Accelerated Ageing studies
- ILW Packaging CoE Waste Form Repair development
- Sludge CoE University Partnership link
- Uranium and Reactive Metals CoE University Partnership link
- Flammable Gasses CoE University Partnership link
- Decommissioning Technical Dept Laser Cutting technology development and trials
- Effluents CoE Self Filtering Test Rig
- Polymer CoE Development of alternative glove material
- Thermal Treatment process optimisation and assessment for ILW and PCM wastes
- Support to Nuclear Advanced Manufacturing Research Centre
- Support to EPSRC Autonomous and Intelligent Systems Industry Group
- Uranium and Pu Chemistry CoE participation in Eu FP07 ACSEPT programme
Technology Development Summary – Technology Specialist Trainees

In January 2011 eight of the first cohort of Technical Specialist Trainees (TSTs), having all successfully passed their Foundation Degree, embarked on a Top-Up Honours Degree.

This was a pilot of the BEng Honours Degree and included modules delivered by Energus and also a materials module designed and delivered by Materials experts from Sellafield Ltd. The Sellafield Ltd module was the first of its kind and included practical work in welding, corrosion and polymers.

In parallel the Foundation Degree continued and there are now 66 trainees working on one or other parts of the scheme. The Foundation Degree has been jointly accredited by the Nuclear Institute and the IChemE allowing the TSTs to register for Eng Tech on completion of the Foundation Degree.
Concluding Remarks

Sellafield Ltd invested some £43M on research and development through provision of scientists and engineers to provide a technical service across the business, facilities, commissioning work packages to support the implementation of projects and operational plants as well as investment for future work streams. The report has demonstrated the extensive range of work conducted ranging from investment into novel innovative technologies through to the use of supply chain capabilities.

The focus of all this work has been, and continues to be, targeted toward meeting the specific needs, risks and opportunities to deliver the Sellafield Ltd mission. All of the programmes of work delivered were aligned to supporting the baseline operational plants and the decommissioning activities with a high priority and emphasis given towards safe, accelerated high hazard reduction inline with the Nuclear Management Partners vision.

The work is conducted through a number of technical teams within Sellafield Ltd supported by the central Technical Directorate. Extensive use is made of experts and specialist organisations from academia and the supply chain. Several are mentioned in this report and many others work alongside our technical and project teams to deliver the necessary research and development needed by the business. The main focus of our work has been development by transfer of technology into nuclear deployment with some investment in the areas of research through academia and specialist organisations.

Key themes emerging from this year’s programmes are those of characterisation, remote operations and semi-autonomous systems. A good example of the type of R&D activities related to these requirements can be seen in the Legacy Ponds area in particular, where combinations of these technologies are being developed to perform remote survey and characterisation duties. The success of these particular programmes is significantly enhancing our understanding and capabilities in these areas.

2011/12 saw eight of the first cohort of Technical Specialist Trainees (TST) embark on a top-up Honours degree. Together with the latest intake for the second cohort this means we have now have over 60 young trainees receiving high quality specialist training through the TST scheme. This scheme provides Sellafield Ltd with a development programme designed for young people looking to develop into technical roles and complements our recruitment of science and engineering graduates directly from university.

The implementation of Technology Road Maps has been a major change in our planning and delivery of our technical baseline. Although used in other industries this is the first time Sellafield has deployed the technique across the business. This will allow us to not only manage the near term work but also improve our long term planning and coordination.

Sellafield Ltd continues to support inter industry groups through membership of the Nuclear Waste Research Forum and the Diamond Consortium, to support collaboration and coordination of research and development.
Future Research, Development and Technology Transfer Topics

The Sellafield Technical baseline through the TBURD, R&D Tables and associated Technology Road Maps identify the future technological based requirements necessary to deliver Sellafield Ltd’s mission. These requirements are summarised in the following bullets.

Sellafield Ltd invites interested parties to contact the organisation through our Technology Innovation team with information on your capabilities through our web site - http://www.sellafieldsites.com/suppliers for our main supplier section describing our commercial activities and through www.sellafieldsites.com/suppliers/innovation--suggestions that provides a link to our innovation work and industrial challenges.

The key technology topics required by our current operational plants are technologies and processes that are ready to be transferred into our facilities that will benefit operations in the topics described. Operational plants fall within the categories of Spent Fuel, Nuclear Materials and Integrated Waste Management.

• Inspection and corrosion measurement technologies to improve assessment of plant equipment and its life expectancy
• Corrosion assessment
• Plant and equipment asset care techniques and processes
• Performance improvement

1. Site restoration

1.1. Post Operational Clean Out (POCO)

POCO is undertaken immediately after operations are complete in plants. This involves using the plant’s capability and any physical or chemical processes used in the operational phase to clean out the facility. The key capabilities that we require are
• Wash out of pipe work, vessels etc
• Plant survey and characterisation
• Removal/transfer/treatment of liquors, slurries, sludges and solids
• Develop ‘wet tapping’ tooling and drain fittings,
• Methods for remote operations and disposal routes

1.2. Sludges, floc and solid wastes from Legacy Ponds and Silos

Characterisation of material for processing and inventory
• Sludge behaviour, mobilisation and settling
• Storage of untreated sludges
• Packaging for disposal
• Behaviour of radioactive elements and radioactivity transfer

1.3. Storage of Intermediate Level Wastes

• Fuel – pond chemistry and safety case requirements
• Sludges – hydrogen management and retrieval R&D
• Unconditioned waste management
• Packaged waste – store conditions, monitoring and inspection

1.4. Characterisation of facilities, plant and equipment for decommissioning

• Sampling processes for pipe work, vessels, tanks
• Deployment of characterisation techniques
• Characterisation techniques – in situ, ex situ and laboratory based
• Non-intrusive detection measurement,
• Measurement sufficient for Condition for Acceptance
• Visualisation of plant and equipment

1.5. Decontamination – Sort and Segregation

• Processes for decontamination
• Removal/transfer of liquors, slurries, sludges and solids
• Deployment techniques
• Waste Disposal
• Radiological segregation techniques from ILW down to Exempt level

1.6. Treatment of concrete and metal arising from decommissioning

• Decontamination of large volumes of wastes
• Volume reduction techniques
• Radiological segregation techniques from ILW down to Exempt level

1.7. Manual and Remote dismantling

• Tools and techniques for retrieval, size reduction and dismantling
• Control, selection, cutting,
• Training, Mock-ups,
• Selection of the right system ,
• High power manipulators (not the development)
• Remote Operated Vehicles and robotics for characterisation, decommissioning and demolition
1.8. **Alpha Plant decommissioning**
   - Remote or semi-remote deployment
   - Retrieval and decommissioning techniques for alpha plant applications
   - Techniques to reduce manual intervention and minimise size reduction
   - Secondary waste generation,
   - Suite operations,
   - Decontamination
   - Radiological segregation techniques from ILW down to Exempt level

2. **Integrated waste management**
   2.1. **Conditioning processes for intermediate level wastes**
       - Thermal treatment processes
       - Encapsulation using inorganic and organic materials
       - Treatment of miscellaneous (small volume) wastes
       - Treatment of future decommissioning material and waste
       - Disposal options for specialist (small volume) wastes
   
   2.2. **Waste packaging**
       - Segregation and sentencing
       - Packing fractions (volume utilisation, incorporation rates)
       - Containers
       - Characterisation

   2.3. **Nuclear and non nuclear decommissioning waste conditioning**
       - Sort and segregation
       - Immobilisation
       - Encapsulation
       - Disposal routes
       - Disposal options for specialist (small volume) wastes
       - Provision of commercial

   2.4. **Low level waste operations**
       - Use of supply chain capability for treatment of Low level wastes

3. **Novel techniques and cross programme investment**

   The Technical Directorate commissions work in a number of areas to exploit opportunities from novel technologies and synergies for cross programme implementation. The overall purpose of this work is to seek radical and acceleration opportunities that will support the delivery of the strategic preferences. Current topics of research include:
   - Development of thermal treatment processes for the immobilisation of nuclear waste
   - Investment in alternative characterisation technologies
   - Muon tomography
   - Development of flexible robotic manipulators
   - Alternative designs for waste disposal boxes
   - Waste package monitoring using acoustic technologies and laser scanning
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGR</td>
<td>Advanced Gas Reactor</td>
<td>MEP</td>
</tr>
<tr>
<td>ALARP</td>
<td>As Low As Reasonably Practicable</td>
<td>MAGNOX</td>
</tr>
<tr>
<td>BFS</td>
<td>Blast Furnace Slag</td>
<td>MOX</td>
</tr>
<tr>
<td>BST</td>
<td>Buffer Storage Tank</td>
<td>MSSS</td>
</tr>
<tr>
<td>CFA</td>
<td>Condition for Acceptance</td>
<td>NDA</td>
</tr>
<tr>
<td>CoE</td>
<td>Centre of Expertise</td>
<td>NMP</td>
</tr>
<tr>
<td>EARP</td>
<td>Enhanced Actinide Removal Plant</td>
<td>NNL</td>
</tr>
<tr>
<td>E&amp;EP</td>
<td>Effluents and Encapsulation Plants</td>
<td>NWRF</td>
</tr>
<tr>
<td>FGMSP</td>
<td></td>
<td>OPC</td>
</tr>
<tr>
<td>FSIF</td>
<td>Full Scale Inactive Facility</td>
<td>PFA</td>
</tr>
<tr>
<td>FHP</td>
<td>Fuel Handling Plant</td>
<td>POCO</td>
</tr>
<tr>
<td>GDF</td>
<td>Geological Disposal Facility</td>
<td>PS1</td>
</tr>
<tr>
<td>HA</td>
<td>Highly Active</td>
<td>R&amp;D</td>
</tr>
<tr>
<td>HAL</td>
<td>Highly Active Liquor</td>
<td>ROV</td>
</tr>
<tr>
<td>HALES</td>
<td>Highly Active Liquor Evaporation and Storage</td>
<td>SDP</td>
</tr>
<tr>
<td>HANI</td>
<td>Highly Active Northern Inner</td>
<td>SIXEP</td>
</tr>
<tr>
<td>HAST</td>
<td>Highly Active Storage Tank</td>
<td>RWMD</td>
</tr>
<tr>
<td>HLW</td>
<td>High Level Waste</td>
<td>SL</td>
</tr>
<tr>
<td>HLWP</td>
<td>High Level Waste Plants</td>
<td>SLC</td>
</tr>
<tr>
<td>HP</td>
<td>High Pressure</td>
<td>SMP</td>
</tr>
<tr>
<td>ILW</td>
<td>Intermediate Level Waste</td>
<td>STP</td>
</tr>
<tr>
<td>IX</td>
<td>Ion Exchange</td>
<td>TBURD</td>
</tr>
<tr>
<td>LLW</td>
<td>Low Level Waste</td>
<td>THORP</td>
</tr>
<tr>
<td>MAGNOX</td>
<td>Magnesium Oxide</td>
<td>TST</td>
</tr>
<tr>
<td>MASFE</td>
<td>Medium Active Salt Free Evaporator Plant</td>
<td>UN</td>
</tr>
<tr>
<td>MBGWS</td>
<td>Miscellaneous Beta Gamma Waste</td>
<td>VTR</td>
</tr>
<tr>
<td>MEB</td>
<td>Multi Element Bottle</td>
<td>WEP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WVP</td>
</tr>
</tbody>
</table>