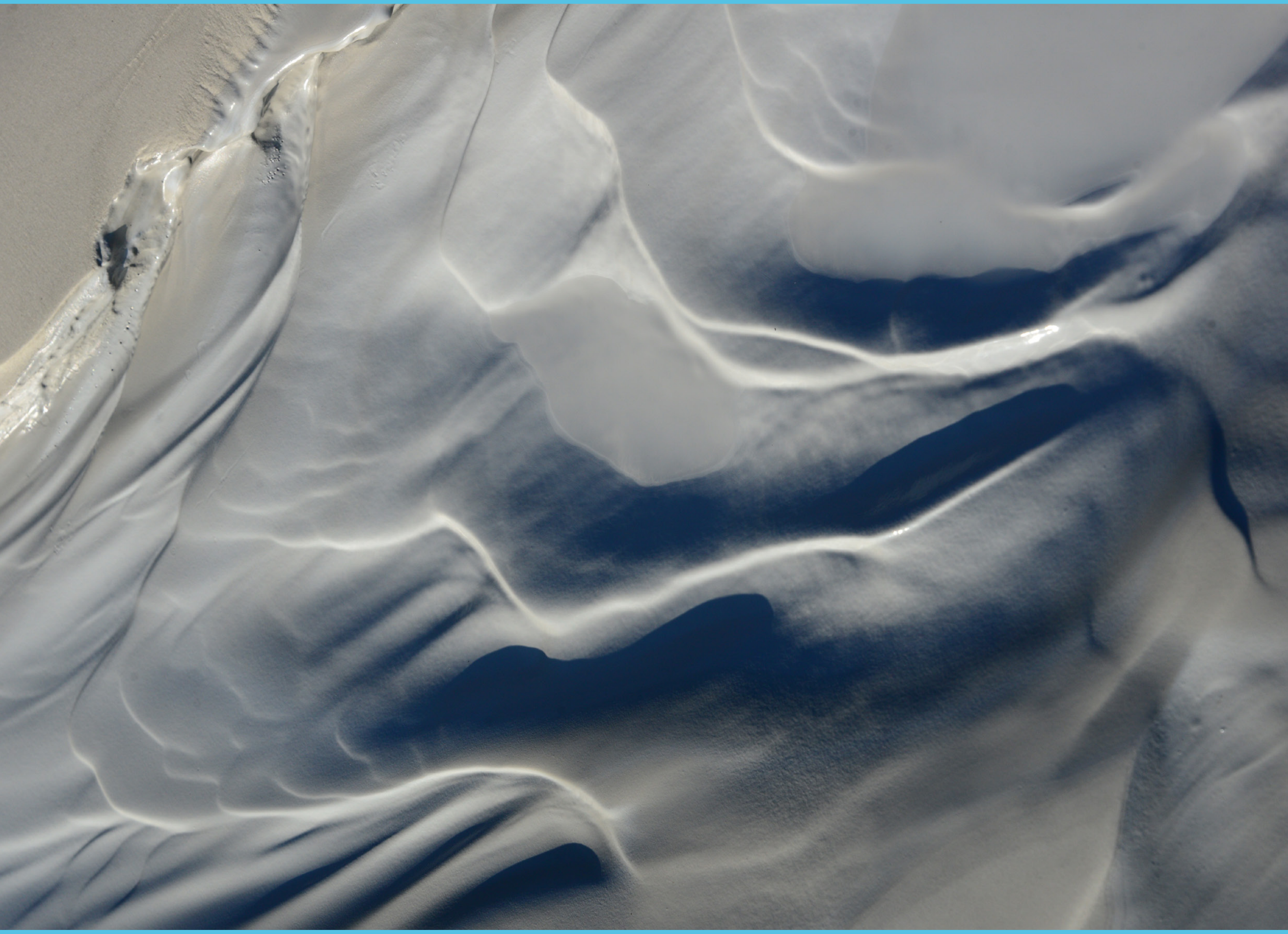

CHALLENGE:
Measuring Waste Bed Liquor Levels

Sellafield Ltd would like to explore techniques and technology which may be used to measure the liquor level within sludge beds inside waste storage silos. Approaches that either measure the water level directly or infer the water level via alternative methods of measurement, are of interest. In-situ and ex-situ solutions to this challenge are invited.

Introduction

The Magnox Swarf Storage Silo (MSSS), is a radioactive waste storage facility on the Sellafield site. It comprises of 22 storage compartments, which are split over four sections within the MSSS building. This challenge is only concerned with the MSSS Original Building (OB) that was constructed in 1962 and consists of 6 compartments.

MSSS OB Structure

The MSSS OB is a reinforced concrete structure comprising of:

- 1.5m thick base slab
- 1.4m thick external walls as primary containment
- No secondary containment
- Internally, the silo is divided into six compartments in a 2 x 3 arrangement
- Each compartment has internal dimensions of 6.4m x 6.4m x approximately 16m deep
- The compartments are covered by a 1.2m thick concrete slab which forms the operating floor of the MSSS OB
- Internal dividing walls between the compartments are 0.6m thick
- MSSS OB is embedded in the ground by approximately 6m
- MSSS OB is surrounded by complex infrastructure, making external visibility and access difficult
- Below ground, there is a bitumen layer around the concrete structure
- There is an additional 0.3m thick concrete wall between the silo and backfilled ground
- Above ground, some of the external walls are obscured by a free-standing shield wall

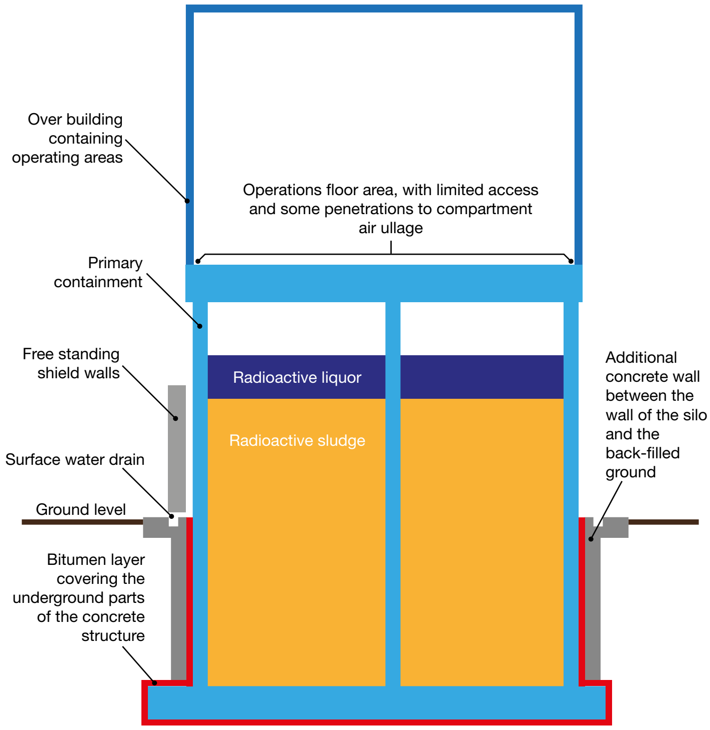

Figure 1: Schematic of a simplified cross section of the MSSS Original Building

MSSS OB Contents

The six compartments within the OB silo contain magnesium cladding or ‘swarf’ that was stripped from Magnox fuel prior to reprocessing. The swarf is stored under water and has corroded over time, forming a sludge which, as part of the corrosion reaction, released hydrogen. The facility is constantly monitored to understand hydrogen levels within the compartments, as well as any residual heat from the corrosion reaction. The material held within each compartment varies, however the contents are predominantly corroded sludge consisting mainly of magnesium hydroxide, uranium and uranium oxide. There are also solid items referred to as Miscellaneous Beta Gamma Waste (MBGW). In terms of radioactivity, the MSSS OB contents are classified as Intermediate Level Waste (ILW) according to UK standards.

The waste sludge is currently maintained under a wet storage regime. The compartments are regularly topped up with water to keep the sludge under a head of liquor. The level of the liquor is the same in each of the compartments but the depth of the liquor above the waste bed varies depending on the height of the waste bed within each of the six compartments. It should be noted that the surface of the waste bed in each compartment is uneven. The surface of the sludge features peaks and troughs due to the 'agricultural' manner in which the compartments were filled in the 1960s. All compartments have varying amounts of MBGW floating on the surface of the cover liquor.

Each compartment is hydraulically linked to adjacent compartments by a series of interconnecting ducts that run through the internal concrete walls. Currently, under the wet retrievals regime, these ducts allow compartment liquor to cascade into the adjacent compartments, preventing differences in the levels of liquor between the compartments. This mitigates against risk to the concrete structure from hydrostatic pressures that exert a load bearing on internal walls. There are six pairs of interconnecting ducts on each internal wall, making 84 ducts in total. It should be noted that some ducts are blocked due to sludge ingress and MBGW items that have been wedged into them.

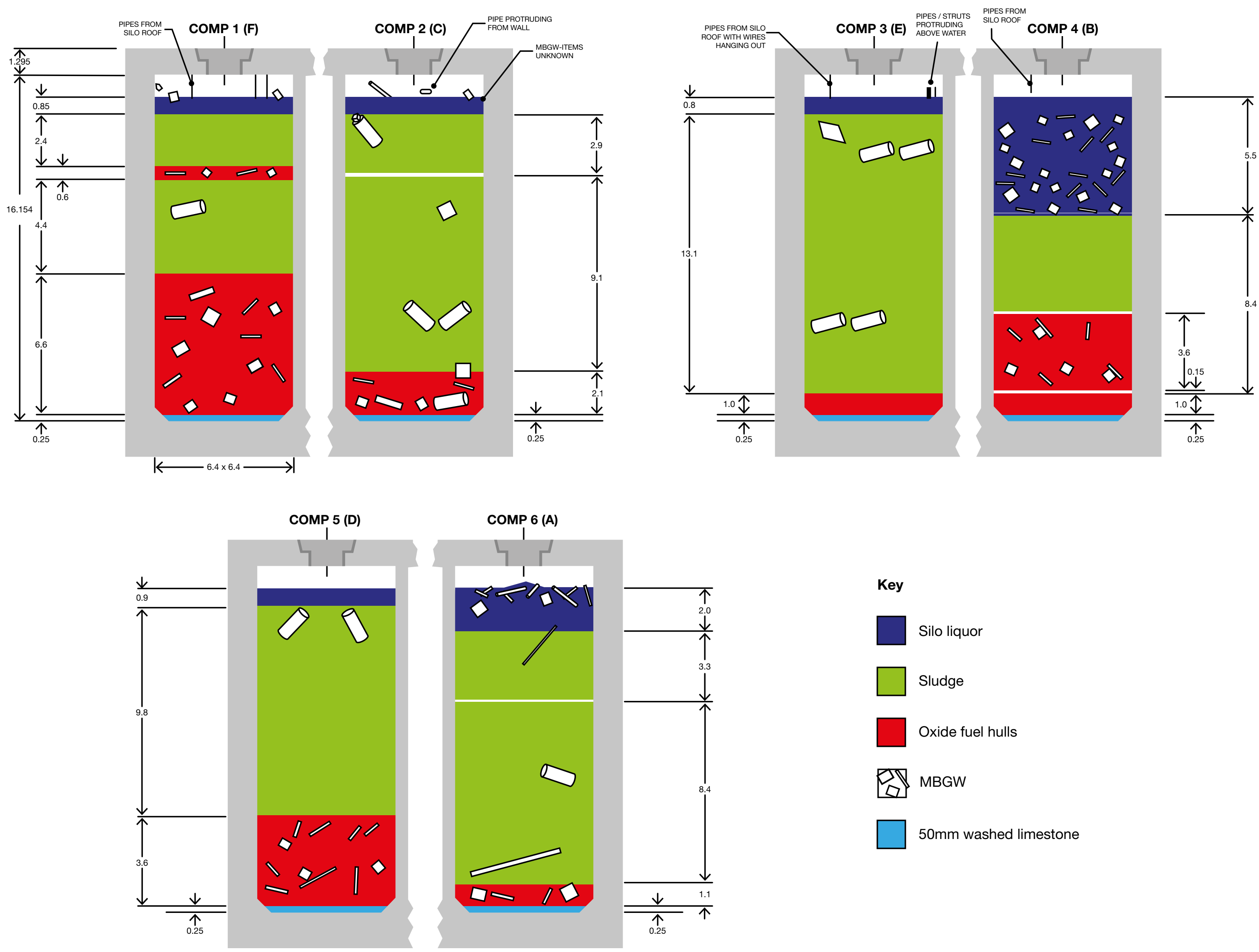

Figure 2: Schematic of six compartments and their contents

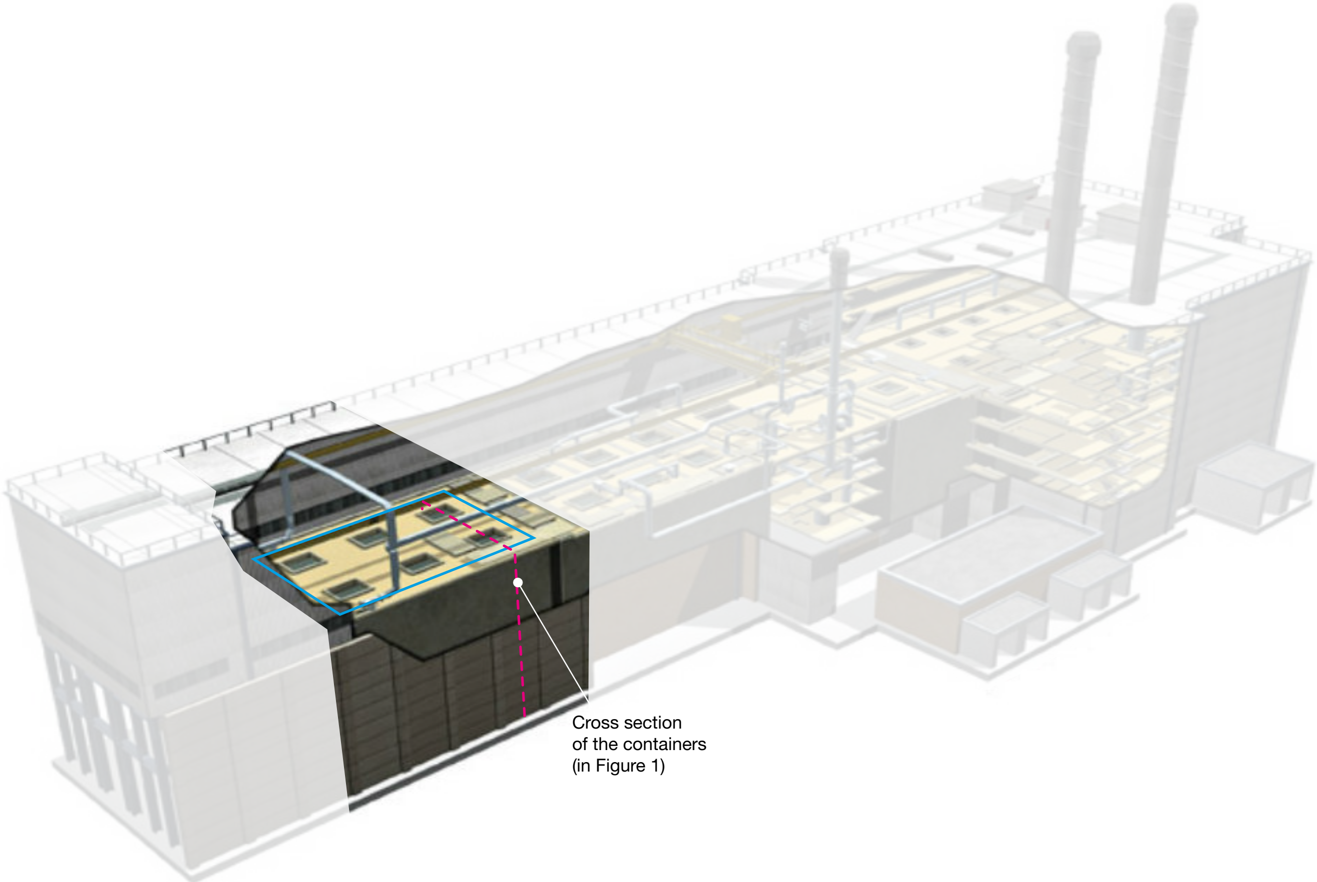

Figure 3: MSSS with OB Compartment Section highlighted

Retrieval of waste from the MSSS OB is due to begin within the next 3 years. The retrievals process will be performed by Silo Emptying Plant (SEP) machines that will travel on rails to a large hole above each storage compartment. A grab, not unlike an arcade machine grab, will be deployed to scoop the waste sludge and MBGW items into skips that will then be placed into shielded boxes for export from the facility.

MSSS leak and planned mitigation

In November 2019, a liquor imbalance that was being investigated in the MSSS OB was officially declared as a leak. The Original Building Leak Management (OBLM) sub-programme was established and then merged into Silos Strategy and Technical at the start of FY23/24. This team are carrying out a programme of works to gain understanding, manage and reduce or (if possible) stop the leak. The programme of works has been approved by the Environment Agency (EA) and Office for Nuclear Regulation (ONR).

The site of the leak is yet to be identified. The leak rate is maintaining a stable and manageable volume of between 1.5 and 2.5 m^3/day. Should the leak rate increase significantly, a plan must be in place to enable a damp/dry retrievals regime. This would be achieved by ceasing top-up operations, that keep cover liquor levels above the waste bed in each compartment, thereby allowing a gradual draining of the liquor level in each compartment. This would result in no cover water being present above the waste sludge. Effluent would still exist within the waste bed and between the waste and the compartment walls. Although this would reduce or even stop the leakage, there would be consequential operational challenges. These challenges would include the loss of the existing ability to measure liquor levels within the storage compartments. It is important to be able to measure liquor levels within the waste bed in order to understand the pressures being applied to the walls of the MSSS OB.

The essence of this challenge is to find a method of measuring the liquor level within a waste bed that has been allowed to drain naturally.

Current Practice

The effluent level above the waste bed is currently measured via two pneumercators located in the two furthest most compartments. In addition, measurements are taken by recently installed radar equipment located in all six compartments. Neither of these measurement methods will perform their function if the water level has dropped below the surface of the waste bed of sludge.

Challenge Aims

Sellafield Ltd needs to ascertain where the liquor level sits within a waste bed of sludge that is being stored under a damp/dry storage regime. This is analogous to measuring the level of groundwater in clay or soil.

If there were large differential liquor levels between the six compartments in the MSSS OB, an imbalance of loading would be created on the internal walls due to different hydrostatic pressures on either side of the wall. The capability to confidently measure the liquor levels within the waste bed would allow mitigating action to be taken to ensure that the structural integrity of the internal walls is not exceeded.

Sellafield Ltd are open to approaches that either measure the water level directly or infer the water level via other methods of measurement. Measurement of the pressure being exerted on the walls that does not provide measurement of the liquor level in the waste bed would not be discounted but would only partially satisfy the requirements of this challenge.

Any solutions to this challenge deployed within the storage compartments of the MSSS OB would need to be radiation tolerant as the compartments contain Intermediate Level Waste (ILW). Sellafield Ltd are open to both in-situ and ex-situ solutions to this challenge.

Sellafield Ltd are seeking solutions that can reach the end of the Game Changers Proof of Concept project phase by the middle of 2025. At this point, it is expected that a design scheme would be available with the technology ready for active deployment.

Benefits to Sellafield

A solution to this challenge would enable the execution of risk mitigating measures in the event of an unacceptable increase in the MSSS OB leak rate. Understanding the hydrostatic loading on the compartment walls, under a damp/dry storage regime, would allow strategic decisions to be made in a timely fashion, meeting key stakeholder requirements to prevent a deteriorating situation with regards to the release of liquor to the ground.

The ability to measure the liquor level in the waste bed would provide understanding of:

- The hydrostatic pressure loading on the internal walls of compartments
- The volume of liquor being lost to the ground over time
- The drying rate of the waste sludge bed over time

This capability will contribute to Sellafield Ltd complying with Licence Condition 34 - Leak and Escape of Radioactive Material and Radioactive Waste and its environmental permit conditions.

Implementation of a successful solution to this challenge would:

- Reduce the risks and hazards incurred during retrievals and under a damp/dry storage regime
- Remove the requirement for operators to undertake the topping up of water levels in the storage compartments
- Enable the Mission, by allowing operations to continue at MSSS with confidence, whilst potentially combating a worsening scenario

A solution may also have other potential application areas with waste beds on the Sellafield site.

Constraints

Any solutions to this challenge must work within the following constraining factors:

- Any equipment deployed within the storage compartments will need to be able to tolerate radiation levels of ~ 100 TBq/m^3 with 1 Tera Becquerel (TBq) being equivalent to $1x10^{12}$ Bq
- The temperatures within the liquor bed are approximately 10°C to 12°C

- Temperatures within the waste bed are warmer than the liquor bed, up to a maximum of 40°C
- Pressures above the water level within the storage compartments vary little from atmospheric pressure
- Human access is not possible within the compartments
- Preferred access to the storage compartments is via 150mm ports in the ceiling of each compartment, which are accessed via the operations floor above. Access for larger items may be considered but will be less convenient
- Any unit of equipment should be sealed for deployment on plant and operate whilst the compartment in which it is located is sealed off from the operations floor
- If active cooling of equipment is required, the cooling unit would need to be easily segregated and located outside of the compartment
- Must not obstruct access of retrievals equipment inside the compartment, would need to be sufficiently low profile to remain installed whilst retrieval equipment is located at a given compartment
- The operations floor may be crowded and/or restricted by retrievals equipment at times as shown in Figure 3. Spatial constraints should be taken into account
- The distance between the surface of the waste bed and the ceiling of the compartment is variable
- The compartments are dark, with no natural lighting
- The surface of the waste sludge bed is uneven with peaks and troughs and significant variations in the depth that could be likened to a rocky shoreline in places. The profile of the surface will also vary once the retrievals process begins
- The composition of the waste bed in each compartment may vary
- The liquor level that requires measuring may be many metres down in the waste bed

Figure 4: MSSS operations floor, above the six storage compartments

- It is likely that any technique that disturbs the waste bed may need to be conducted with an inert atmosphere in the ullage
- Any solution must have no (or very minimal) effect on retrievability of the waste, so the addition of chemical additives or anything that would produce large quantities of secondary waste is likely to be undesirable
- Modestly sized equipment may be left in-situ within the compartments but NOT attached to the compartment walls. Attachment to the underside of the operations floor might be acceptable, depending on the equipment
- There is access to electrical power on the operations floor. Any requirement for a specific power source would be have to be discussed with Sellafield Ltd's design team

Functional Requirements

Any solutions to this challenge should have the following capabilities:

- If deployed within storage compartment, be operable in a highly radioactive environment ~ 100 TBq/m^3 with 1 Tera Becquerel (TBq) being equivalent to $1x10^{12}$ Bq
- Be deployable from the operations floor above the storage compartments and ideally via the 150mm ports in the ceiling of the compartments
- Either be in the form of a low profile installation or able to be reasonably easily removed and re-installed to enable un-fettered retrieval equipment movements
- Remain functional during waste retrievals, maintaining measurement capability during the activities involved in removing the waste
- Provide a reliable measurement of the liquor levels in the waste bed, either directly or by inference from other measurements, for example, measuring hydrostatic pressure being exerted on the walls of the silo compartments
- Continuous or intermittent monitoring of the waste bed liquor levels would be acceptable, although the capability to continuously monitor with minimal need for operator input would be seen as a benefit
- In terms of reporting requirements, Sellafield Ltd would prefer a hardwired transfer of data to a USB drive or similar

At the Proof of Concept stage, the challenge owners are looking for solutions to be demonstrated on a simulated waste bed on a scale of several hundreds of litres.

Both in-situ and ex-situ solutions would be considered and it is recognised that some of the above constraints and functional requirements might not apply to some ex-situ solutions, depending upon how they are deployed.

Find Out More

Game Changers are hosting a workshop for this challenge where delegates will have the opportunity to meet challenge owners. Details are available on the Game Changers website www.gamechangers.technology.

If you have new ideas or innovations which can be applied to address this challenge, we invite you to join us. If you'd like more information about the funding available through the Game Changers programme, please visit Our Funding Process (gamechangers.technology).

The deadline for applications for this challenge is 4pm on Wednesday 27th March 2024.

Sellafield Ltd

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NATIONAL NUCLEAR LABORATORY

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