Sellafield Ltd

GAMECHANGERS
DELIVERING NUCLEAR INNOVATION

CHALLENGE: Leaking crack identification, location and condition monitoring

Sellafield Ltd are seeking ideas, innovations and technologies that will deliver game changing solutions to identify leaks and cracks in ageing, liquor retaining structures.

Sellafield Ltd has experience in managing and maintaining buildings and understands the durability of ageing structures. Known cracks are small and stable and therefore not a structural concern – this may be termed a “crack under control” and may only require monitoring and not repairing. However, some cracks have the potential to change over time and may leak as a result if they are through-thickness cracks.

Current monitoring techniques detect movement and general condition of the structure but cannot detect and, importantly, identify the precise location of the cracks.

This call for innovation is open to applicants from any sector including industries such as oil and gas, mineral mining, chemicals, and water.

Sellafield Ltd are seeking a proof of concept capable of deployment in a real environment as soon as practicably possible.

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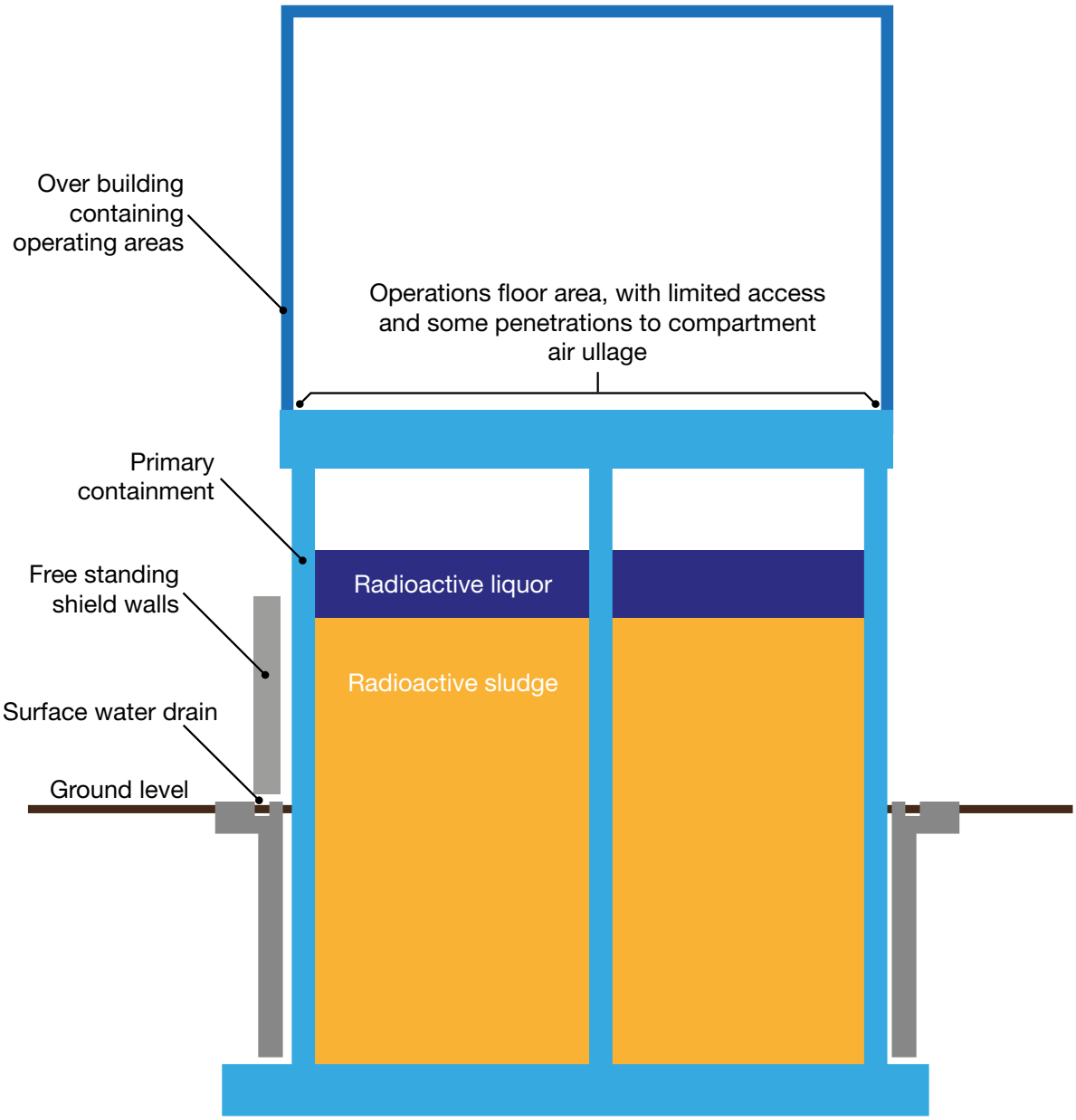
Introduction

The Magnox Swarf Storage Silos (MSSS) at Sellafield comprise an Original Building constructed in 1962 and three subsequent extensions constructed between 1972 and 1982. The silos contain magnesium cladding or 'swarf' that was stripped from Magnox fuel prior to reprocessing. The swarf is stored underwater in the silo structures, but over time the stored contents corrode, releasing heat and hydrogen meaning the facility requires constant management and monitoring. Historically, 'thermal excursions' have occurred within the contents, which significantly increased the temperature of the contents and adjacent structural elements in localized areas.

The construction of the Original Building silo is a reinforced concrete structure, comprising a 1.5m thick base slab with 1.4m thick external walls as primary containment, with no secondary containment. Internally, the silo is divided into six compartments in a 2 x 3 arrangement, each with internal dimensions of 6.4m x 6.4m x 16m deep. The compartments are covered by a 1.2m thick concrete slab which forms the operating floor, and the internal dividing walls between the compartments are 0.6m thick. The original building is embedded in the ground by approximately 6m, with complex infrastructure in places, making visibility and access difficult. Below ground, there is a bitumen layer around the concrete and a 300mm thick concrete wall between the silo and backfilled ground. Above ground, some of the external walls are obscured by free-standing shield walls.



The ageing concrete structure is known to have leaked in the past and may have some cracks that are difficult to identify and locate. Sellafield Ltd has experience in managing and maintaining buildings and understands the durability of ageing structures. Known cracks are small and stable and therefore not a structural concern – this may be termed a "crack under control" and may not require immediate repair but should be monitored for further degradation. It is valuable to know where such cracks are, in order to inform leak mitigation proposals, ongoing structural monitoring, and if and where necessary, to feed that information into structural analysis models to reveal stress concentrations and allow Sellafield Ltd to manage the facility within safe limits.

There are numerous potential mechanisms that can cause cracking in concrete. Cracks could appear in walls, floors and expansion or construction joints. PVC waterbars are fitted at both horizontal and vertical construction joints to prevent water ingress. Over time, the materials may have become brittle, but the waterbars can still mitigate leakage even if they have become embrittled.

It is known that parts of the silo have been subjected to extreme temperatures as a result of thermal excursions within the waste contents. Sudden increases in temperature creating differential temperatures across concrete sections could have initiated or worsened any crack present.

Where through-thickness cracks occur, there is the possibility that they may seep liquor. It is difficult to identify and locate cracks within the silo due to the local environment – for example, it is currently unknown whether there is a crack at 6m below ground in a radiation active environment. Such cracks may typically be found at horizontal or vertical construction joints which might provide a starting point for investigations.

Current Practice

Current techniques deployed for monitoring the structures include:

- Carbonation testing
  - pH based testing of concrete in situ to determine the depth of carbonation
- Chloride ion content
  - Testing of hardened concrete for the presence of both free and bound chlorides
- Cover meter surveys
  - Non-intrusive measurement of the depth to reinforcement from the concrete surface
- Building movement monitoring
  - A number of prisms are located in the building to monitor movement
    - This method can detect building movement down to ±0.15mm
- Strain gauges are used to monitor identified cracks
  - This data may be used in conjunction with other techniques
- Liquor level management would indicate a leak but would not identify a crack's location or condition
- Radscans
  - A dose map of external above ground areas of the original building could indicate leak from original building

None of these techniques can identify and locate cracks.

Challenge Aims

The primary aims of this challenge are to:

- Identify and locate leaks and through-thickness cracks in water retaining concrete structures, which may be partially below ground level
- Feedback information about cracks in the structure, including:
  - Their location (which compartment, precise location if possible)
  - How deep they penetrate through the structure
    - Specifically interested in through-thickness cracks
  - Information relating to the condition of reinforcement at crack location (rebar indicator)
- Observe and monitor cracks during the material retrieval process

Opportunity

An initial survey identifying leaks and cracks is required to inform the leak mitigation proposals, the structural assessments and plans for decommissioning. Assuming a steady state with respect to the condition of the building, intermittent monitoring of leaks and cracks would be required. Over the next two years more load (e.g. 50T+ loads) will be added to the structure, potentially changing internal stresses accordingly.

The material retrieval process is expected to commence within the next 10 years in the silos. This process will involve material removal and de-watering of the silos. Sellafield Ltd need to have a solution to help them understand the condition of the structure as things change.

Benefits to Sellafield Ltd

A viable solution would provide information for Sellafield Ltd to create and maintain more accurate structural analysis models – based on knowns (confirmation). This in turn allows the ability to optimize plans for retrieval based upon prioritization.

Sellafield Ltd will be able to make more confident predictions of structural integrity and hence more confident decommissioning plans.

A solution may also have other potential application areas across site.

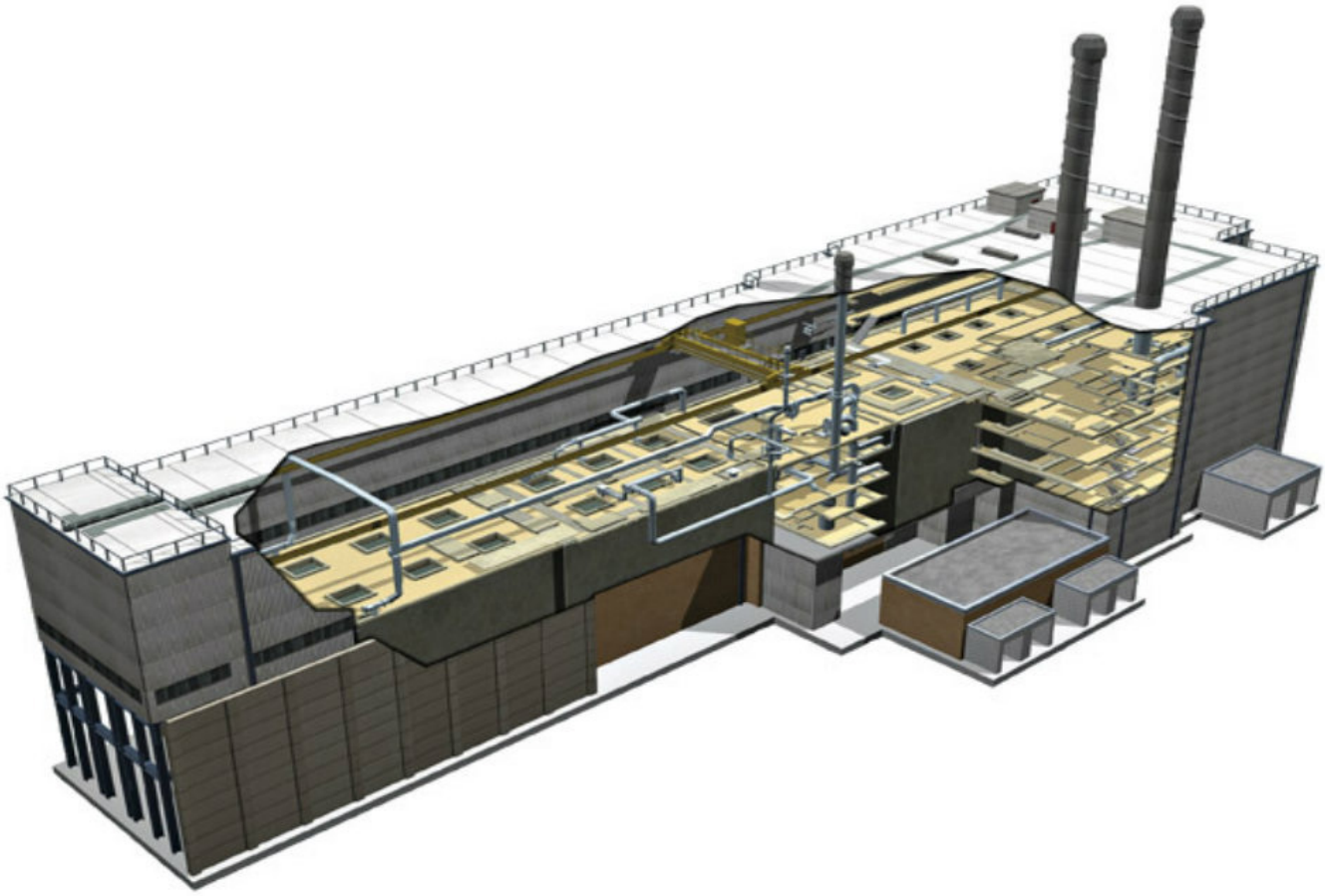
Constraints

- Internal surfaces of interest may be below liquor level
- External surfaces of interest may be below ground level
- High pressures - 17m hydrostatic head
- Radioactive environment and associated contamination risk (radiation)
- Water is cloudy and parts of the structure are covered by radioactive sludge (up to 14m deep) and waste material
- External shield walls may obscure access and visibility
- Leak path may be convoluted – liquid can travel a long way from a defect to where it is noticeable (tracing movement in the liquid would not be ruled out as a method of finding a crack location)
- Bitumen layer may obscure surfaces of interest and divert otherwise noticeable leak paths
- No reference case – although the building is known to have leaked in the past, the exact locations and knowledge about the cause and effect of the leak is limited
- Non-intrusive methods of investigation would be preferred
- Solutions can connect to the wall during deployment (subject to approval by Sellafield Ltd based on design and operational methods)

Functional Requirements

- A solution must be able to detect and locate leaks
- Detection of where a leak exits the structure would be of interest
- Able to confirm the dimensions of a located crack
- Range of crack widths that are desirable to detect are > 0.1mm
- Able to monitor a crack to detect change in size/depth
- Able to detect a crack covered in sludge and waste materials
- Operate in a highly radioactive environment
- The detection technique should be able to differentiate between through-thickness cracks and other imperfections such as spalling and surface cracking
- The detection technique and communication methods should be able to cope with signal noise from rebar
- Able to assess the condition of the rebar at crack location

If you consider that you are strong in only one aspect of the challenge, we would still like you to put your application forward for consideration.



What next

Game Changers are hosting an online briefing webinar for this challenge. Details of the webinar will be 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 www.gamechangers.technology/content/GameChangersFunding

The deadline for applications for this challenge is 1pm, 15 June, 2021.

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