Sellafield Ltd

GAMECHANGERS
DELIVERING NUCLEAR INNOVATION

CHALLENGE: Special Nuclear Material Package Inspections – In-situ

Sellafield Ltd is responsible for the storage of Special Nuclear Materials (SNM) that are a legacy of 60 years of reprocessing activities on the Sellafield site. To provide confidence that SNM packages remain safe for continued storage within Sellafield's stores, it is necessary to closely monitor the exterior surface of the packages whilst they are in their storage location (in-situ). Such monitoring will inform the selection of packages for ex-situ inspection. The essence of this challenge is to provide accurate and reproducible image capture at precise locations on the surface of SNM packages whilst resident in the store. This challenge does not require radiation hardened equipment.

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Introduction – Special Nuclear Materials at Sellafield

Sellafield Ltd is responsible for the safe, secure, long-term storage of the UK's stockpile of special nuclear materials (SNM). These materials have been produced as a result of spent nuclear fuel reprocessing activities undertaken on the Sellafield site over the last 60 years.

In order to deliver Sellafield's mission to create a clean and safe environment for future generations, existing SNM packages will be repackaged into more robust containers for safe and secure long-term storage. The Sellafield Retreatment Plant (SRP) is a facility that will play a key role in this operation.

Prior to repackaging, the existing SNM packages must be stored safely and securely so inspection is necessary to provide confidence that they remain safe. The design of the current stores did not account for the inspection capabilities required for long term storage.

SNM packages and their inspection

SNM packages, as shown in Figure 1, are cylindrical and vary in size, with a typical length of 310mm and diameter of 152mm and typical mass of around 10kg (maximum 20kg). An SNM package typically consists of a lidded outer body (outer can), within which resides an inner sealed body (inner can) which contains the SNM. The outer parts of the packages are constructed from 316L stainless steel. The intermediate layer may be constructed from low-density polyethylene (LDPE) or 316L. The inner container is made from either 316L or aluminium alloy. Sellafield has around 30,000 such packages on site and these mainly fall into two key populations: welded packages and a range of screw-top containers, known as overpacks.

Figure 1: Images of typical SNM canisters, the left hand image is a welded SNM package and the right hand image is a screw-top 'overpack' SNM package.

Sellafield have developed inspection strategies that detail the number of each type of SNM package that should be inspected on an annual basis. The safety case that underpins the inspection strategies has moved away from assigning expiry dates to packages to using inspection data to support the justification for continued storage.

SNM packages may be inspected both in-situ and ex-situ, although this does depend on the layout of each SNM store. During package inspections, it is only the outer surface of the package that is inspected. All inspections are via cameras and information obtained from in-situ inspections informs the selection of packages of interest for ex-situ inspection. **This challenge is purely focused on in-situ inspections.**

Layout of a typical SNM store

SNM stores typically hold 100s-1000s of packages within an array of storage channels. Within each storage channel, packages are positioned horizontally, they are placed into the channel base first, with the lid facing the channel opening. The storage channels are typically between 4.0m to 6.5m long. Figure 2 below illustrates the interior of a typical SNM product store. The left of the image shows the charge face, through which the SNM packages are loaded into the storage channels. **The port within the charge face wall is the only route of access to each storage channel.**

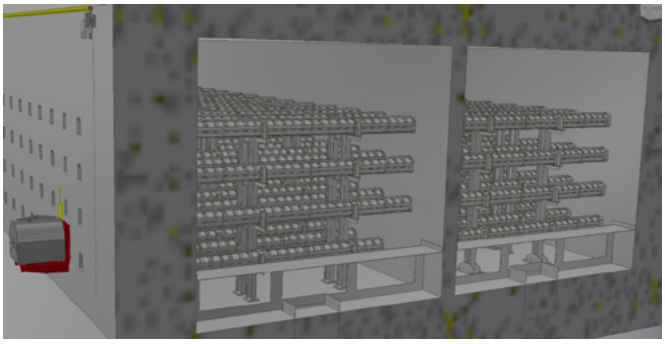


Figure 2: 3D model of the interior of a typical SNM store

Access to the interior of an SNM store

Each access port in the charge face wall is shielded by a 25kg concrete shield plug which is inserted into the port from the exterior side of the charge face wall. Removal of the shield plug may be automated or manual depending on the particular store. There may also be a metal lockable port plug cover in front of the shield plug that secures the port. The port plug covers are what can be seen in rows and columns in the charge face shown in Figure 3. **Humans can access the charge face, but not the interior of the SNM store.**

Figure 3: Image of the charge face wall within the charge corridor of a typical SNM store

In-situ inspection via the charge face ports

An in-situ inspection involves the deployment of a camera or other recording device through the charge face port, into the storage channel. This deployment will always be via an **accessible aperture** below the packages within a storage channel as illustrated in Figure 4. This is the required zone of operation for any proposed solutions to this challenge.

The structure of the storage channels that support the SNM cannisters varies from store to store. Some stores have an 'open rack' storage channel system as shown in Figure 5 and others have enclosed aluminium extrusions as shown in Figure 6.

Figure 5: Image of an open rack storage system with SNM cannister visible in the bottom right hand corner.

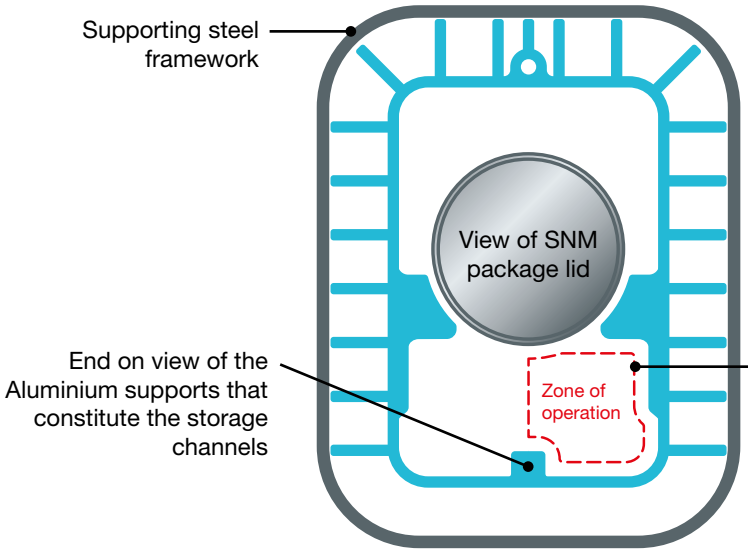
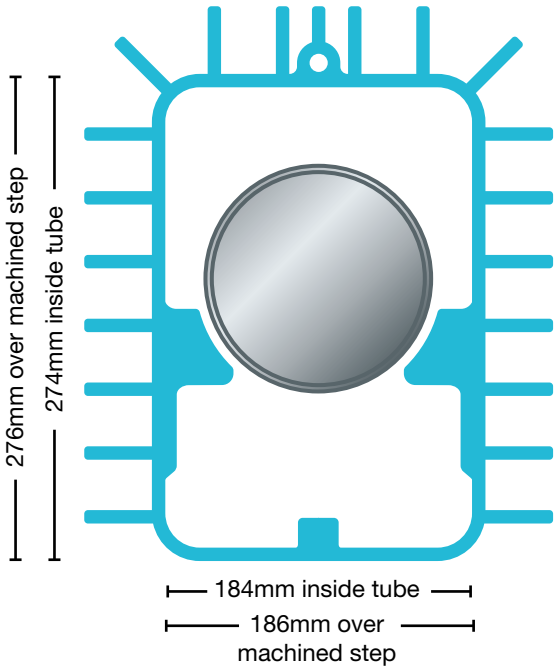


Figure 4: Simplified schematic of the view through a charge port of an 'open rack' storage channel system (as depicted in Figure 5).



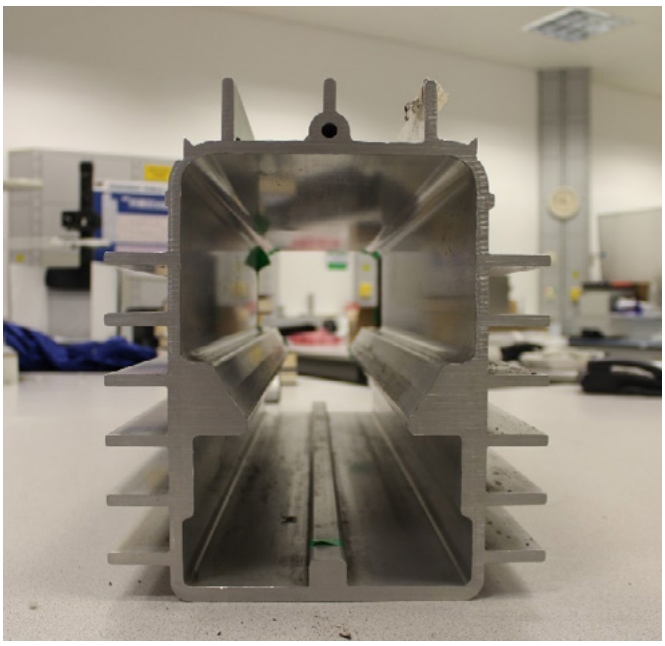


Figure 6: Schematic (left) and image (right) of the structure of an enclosed aluminium extrusion. The schematic on the left also depicts an end-on view of an SNM can.

The precise dimensions of the access port and the accessible aperture for deployment of equipment vary between stores, but are typically around 100mm in diameter. **Developing a precise, reproducible and possibly automated method for gathering inspection images in-situ is the essence of this challenge.**

Current Practice

The SNM in-situ package inspections are currently performed manually by extending a camera through a charge wall port on the end of a pole. During this operation, the camera is facing upwards, taking images of the underside of the packages as illustrated in Figure 7.

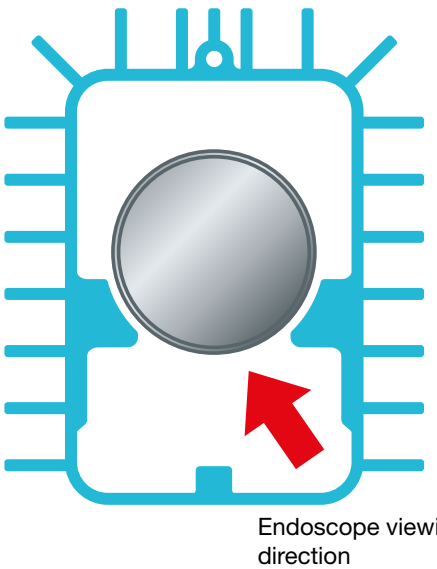


Figure 7: Field of view for current in-situ inspections

The camera is inserted all the way into the channel until the furthest package is reached. The footage is then recorded as the endoscope is withdrawn from the channel ensuring that all packages in the channel are visible. Drawbacks of the current system include:

- Occasional omission of the rearmost packages in a channel
- As shown in Figure 7, the typical field of view is approximately one quarter of the curved surface of the cannister and excludes the lid and the base. It is therefore entirely possible that defects could go undetected
- The interior of the stores is dark, so ‘onboard’ lighting is required, the current lighting provision causes reflections which can make it difficult to identify some features but also accentuates others
- The pole used to deploy the camera system is operated by hand, so speed of withdrawal is not accurately controlled
- The deployment pole is not fixed in position, so repeatable images are not achievable
- No positioning information is available to enable direct comparisons over periods of time

Challenge Aims

Sellafield are seeking a solution that:

- Provides accurate and reproducible capture of images in precise locations on the surface of SNM packages whilst resident in the store
- Is able to image any package, no matter where it is positioned within the store
- Achieves images of packages at the very rear of a storage channel (essential)
- Could image the entire surface of the SNM package in-situ (nice to have, not essential)

There are a number of physical characteristics that are of interest and must be captured by any proposed imaging system. Full details of these are provided in the Functional Requirements section.

Sellafield ideally require a solution that can be deployed within approximately one year of successful completion of a Proof of Concept project.

Benefits to Sellafield

A system that can generate reproducible, standardised images from visual inspections will contribute to Sellafield satisfying one of its site licence conditions, which is to obtain robust and accurate data.

Generating images of a fixed location, with consistent lighting and focal length will enable the application of image analysis techniques to generate meaningful quantitative trending data on any defects. This is required in order to prove that the packages are safe for continued storage and will also provide evidence for the substantiated lifetime extension of these packages.

Achieving the aims of this challenge will enable reliable assessment and forecasting of the longevity of SNM packages within Sellafield's stores, as well as reducing operator time required for review of inspection footage.

Constraints

Any proposed system must:

- Be able to fit through the stores' outer access doors, which are approximately 1 metre wide
- Operate from the charge face corridor which is 2.4 metres wide and 4 metres high
- Enter the charge port horizontally
- Operate along a straight, horizonal aperture (beneath the storage channel) of approximately 100mm diameter and 6 metres length
- Have onboard lighting as the interior of the store is completely dark
- Be straightforward to setup and dismantle as time for inspections may be limited
- **The use of Serapid chain technology for deployment of inspection equipment is not desirable**
- Be easily operable by the inspections team
- Equipment does not need to be radiation hardened
- Power supplies are available

It is also worth noting that the storage channels in some stores are sealed to comply with regulatory controls that apply to SNM. In these situations, it will be necessary to break the seals to allow for inspection. The seals will be remade post-inspection.

Functional Requirements

Any proposed system must:

- Provide images at an accurately defined position on the surface of the SNM package under inspection
- Be able to reliably re-locate packages and positions on packages months/years later
- Give a reference for each image by individual package and position on that package
- Provide a live feed to the operator whist the image capture system is in operation
- Adjust for variable lighting conditions
- Be able to image reflective surfaces
- Provide high enough quality images to allow the quantifiable analysis of the following characteristics of SNM packages:
    - Dimensions and depth of any dents, scratches or scuffs
    - Evidence of cracking
    - Original manufacturing defects
    - Overall expansion or other evidence of pressurisation
    - Any form of deformation
    - Evidence of corrosion/colour change

Any proposed system would ideally, but not essentially:

- Be able to rotate either an individual or number of packages within the storage channel
- Have image stitching capability that gives a ‘laid flat’ view of the whole of the package exterior
- Utilise machine learning to identify anomalies
- Have the capability to simultaneously accommodate a range of sensors
- Be fully automated

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 Thursday 24th November at 12 noon.

Sellafield Ltd

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