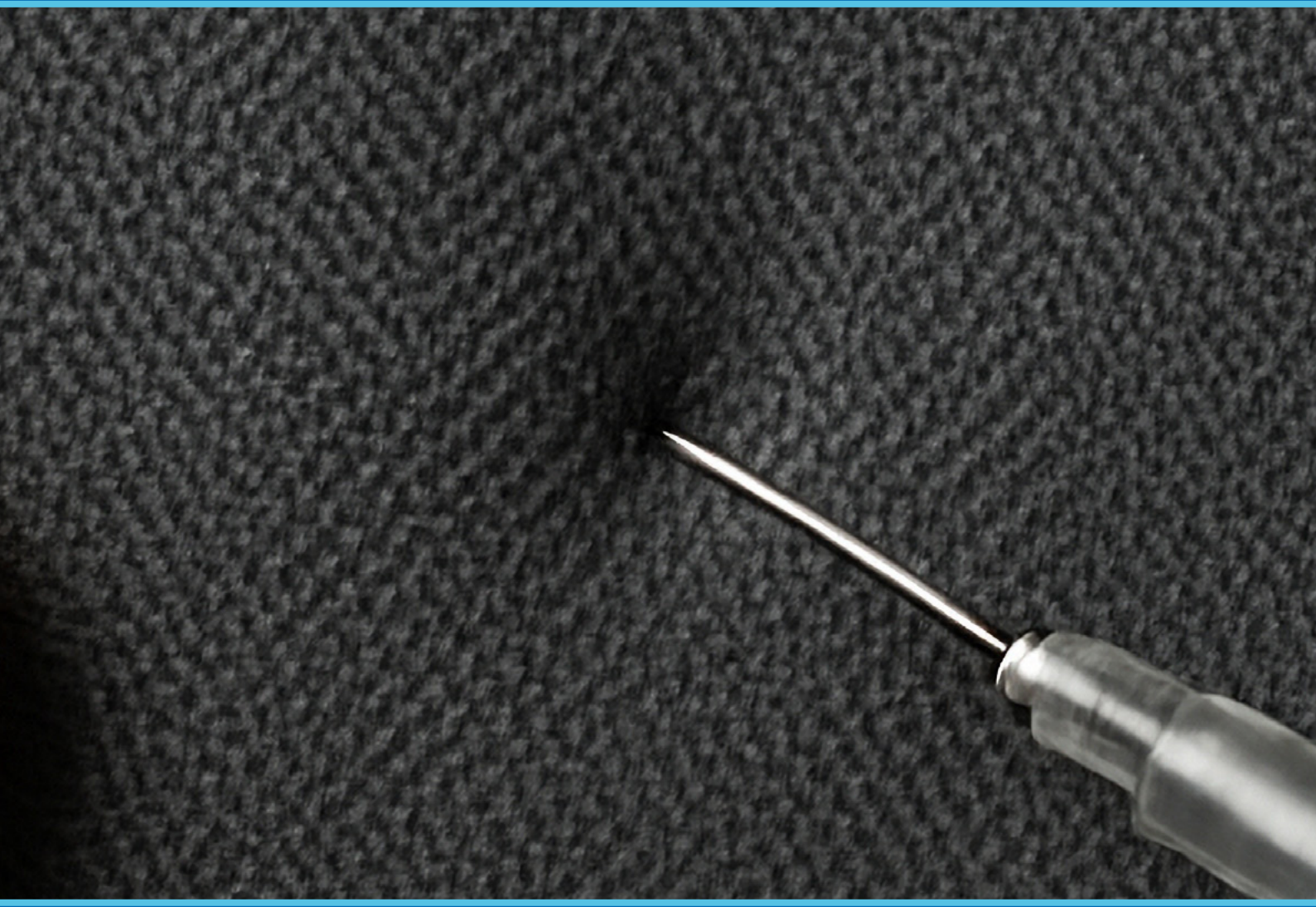
Sellafield Ltd

GAMECHANGERS
DELIVERING NUCLEAR INNOVATION



CHALLENGE:

Needlestick and puncture-resistant materials for enhanced nuclear safety

Sellafield Ltd is seeking innovative, scalable solutions for needlestick and puncture-resistant materials to improve gauntlets, containment bags, and lay-down sheets used in nuclear decommissioning. Sellafield Ltd invites proposals for advanced materials that enhance operator safety, address diverse hazards, and are suitable for large-scale production – ensuring reliable protection and improved operational efficiency.

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Introduction

The decommissioning work at Sellafield presents a range of complex safety and operational challenges. Workers are routinely required to handle hazardous materials in confined environments such as gloveboxes (sealed containment units accessed through gauntlets attached to small entry ports). These environments often contain sharp objects such as cropped cables, exposed wires, and pipework which pose significant puncture and needlestick hazards. Limited visibility, restricted access, and the requirement for strict containment compound these risks.

Current equipment and containment solutions, while effective to a degree, are increasingly strained under the demands of modern decommissioning tasks. Sellafield currently uses approximately 200–250 gauntlets per month, with requirements expected to evolve as work progresses and hazard profiles shift. In addition to gauntlets, containment bags and lay-down sheets are essential for the safe handling and transport of sharp or contaminated materials.

There is an urgent need for next-generation materials capable of providing enhanced protection in nuclear decommissioning environments. Sellafield Ltd is seeking to collaborate with innovators and suppliers developing advanced materials with the following performance characteristics:

- High resistance to punctures, cuts, and needlestick injuries
- Effective chemical barrier properties – acidic, alkali and organics
- Good ductility and user comfort for gauntlet applications
- Suitable for streamlined disposal and waste handling processes
- Feasible for scalable, efficient manufacturing

Further material properties can be found in Table 1.

These materials will be used in the development of improved gauntlets, reinforced containment bags, and lay-down sheets used across decommissioning operations.

The implementation of advanced materials in protective equipment is expected to enhance worker safety by mitigating risks of injury and contamination, while also improving operational efficiency at Sellafield and potentially across other sites within the Nuclear Decommissioning Authority (NDA) estate. These innovations may also benefit sectors like defence, law enforcement, emergency response, and healthcare, where puncture and needlestick risks are prevalent.

Table 1: Overview of required material properties, desired outcomes, and evaluation criteria

Material Properties	Desired Outcome	Measurement Criteria	Testing Standards
Chemical Permeation	Protection from chemical exposure without degradation – change in properties.	Resistance to: Nitric Acid Oils Tri Butyl Phosphate/Odourless Kerosene (TBP/OK)	ISO 37 BS EN 374-3 BS EN 16523-1
Puncture Resistance	Prevent injuries from sharps and other sharp objects.	Puncture force (N)	BS EN 388
Cut Resistance	Reduce the risk of cuts to the material during handling.	Cut resistance Tear resistance	BS EN 388
Ductility	Ensure flexibility and movement without material failure.	Elongation at break (%)	ISO 37
Weight	Maintain a lightweight, comfortable design.	Weight (g/m^2) comparison	
Disposability	Suitability for single-use applications and ensure environmentally safe disposal after use.	Waste Conditions for Acceptance (CFAs) – dependent on plant/site	

Material Properties	Desired Outcome	Measurement Criteria	Testing Standards
Manufacturability	Develop materials that can be efficiently mass-produced and are cost-effective.	Production cost per unit Lead time	
Wear	Extend the lifespan of the equipment from wear and tear over time in challenging environments.	Abrasion resistance (cycles)	BS EN 388
Thermal	Ensure operator safety and material integrity over a range of temperatures.	Thermal resistance (°C) Thermal conductivity (°C)	BS EN ISO 12127-1 (Above 100°C)
Dexterity	Ensure ease of movement and long-term comfort for the wearer.	Minnesota test (only for gauntlets) Purdue pegboard test (only for gauntlets) Flexural rigidity (N/mm)	ISO 9073-9 Operator trials
Material Strength and Integrity	Protect workers from impact forces or accidents.	Impact resistance (J) Ultimate tensile strength (MPa) Elongation to break (%) Permanent set Integrity tests: - Electrical continuity – Each gauntlet shall withstand 5000 Vd.c. for at least 15 seconds. Alternatively, each gauntlet shall withstand 2500 V a.c. for at least 15 seconds. Leakage shall not exceed 100mA throughout the complete test - Air filtration/ vacuum test	BS 7971-6 ISO 37 BS ISO 2285 BS EN 421
Needlestick Resistance	Protect workers from injuries as a result of puncture by a hypodermic needle.	Puncture force (N)	ASTM F2878-10
Fire Resistance	Ensure that the material will not ignite, propagate a flame or produce harmful products upon ignition.	Flammability – ability to sustain a flame Ignitability – ability to be ignited Edge and surface	BS 476-12 BS ISO 5660-1
Ozone Resistance	Ensure that the material does not degrade in the presence of ozone.	Mechanical properties after exposure to ozone	BS EN 421 BS ISO 1431-1
Weldability (Only for Bags)	Ensure that the material is weldable to be able to provide adequate containment.	180° T-Peel test across weld	

Sellafield Ltd seeks to accelerate the development, testing, and deployment of novel materials for use in gauntlets, containment bags and lay-down sheets. Proposals that combine material innovation with practical routes to manufacture and deployment are strongly encouraged. Enhancing safety in high-hazard environments is paramount; successful solutions will drive the development of next-generation protective equipment, contributing to a safer, more efficient, and more sustainable future for nuclear decommissioning and beyond.

Current Practice

Gauntlets (Figure 1): Used in glovebox and handling operations to protect operators from radioactive or contaminated materials. Current designs are not engineered to resist needlestick or puncture hazards, so operators often wear additional layers, such as two pairs of Marigold gloves beneath the gauntlets, particularly during posting-bag operations or in contaminated areas. This layered approach provides some contamination protection but reduces dexterity, comfort, and operational efficiency, contributing to operator fatigue over time. Gauntlets are typically a single, universal size used across the site.

Figure 1: Image of a gauntlet commonly used at Sellafield

Containment bags (Figure 2): Used in glovebox operations, similar to gauntlets but without handed access. A welded O-ring at the bag opening ensures a secure seal, while Radio Frequency (RF) welding maintains overall containment integrity. These bags are primarily used for import/export operations and are then welded off and cut into waste packages for further processing. Bag sizes vary with port dimensions (typically 8–10 inches), O-ring size, and operational requirements.

Figure 2: Images of containment bags commonly used at Sellafield

Lay-down sheets (Figure 3): Used to contain contamination from nuclear and non-nuclear sources, providing a protective barrier against dust, fibres, and radioactive particles. They are typically placed on work surfaces, floors, or around gloveboxes to prevent the spread of contamination. Supplied on rolls and cut to size as needed, lay-down sheets are primarily intended for contamination control rather than protection against penetration hazards.

Figure 3: Image of lay-down sheets commonly used at Sellafield

All operations are carefully risk assessed to ensure the safety of operators and the environment. Depending on the assessed hazards, additional precautions may be implemented beyond standard equipment, including cold- and heat-resistant gloves, cut-proof gloves, and reinforced lay-down sheets. Gloveboxes may operate under a nitrogen or argon purge rather than a vacuum, and the materials of gauntlets, containment bags, and lay-down sheets must not be adversely affected by these conditions. Despite these precautions, current protective solutions at Sellafield rely on layering and equipment combinations that compromise dexterity, comfort, and efficiency, and fall short of addressing all hazards. There is a clear need for innovative, multi-functional materials that offer comprehensive protection without sacrificing usability.

Challenge Aims

This challenge aims to enhance operator safety by identifying and developing needlestick and puncture-resistant materials for use in gauntlets, as well as other protective equipment such as containment bags and lay-down sheets. These materials must provide superior puncture resistance while maintaining dexterity in gauntlets, tear resistance and avoiding additional weight or bulk.

While Sellafield Ltd can offer guidance on sizing and manufacturing specifications, the primary focus is on materials that can be effectively transformed into functional, puncture-resistant gauntlets and related equipment. Proposals should include evidence of the materials' protective capabilities along with plans for their development into the requested items.

Benefits to Sellafield

The core benefit is improved operator safety by eliminating needlestick and puncture hazards. Depending on the solution, further advantages may include:

Gauntlets:

- Reduced weight or enhanced flexibility, leading to less operator fatigue and discomfort, potentially allowing the gloves to be worn for longer periods
- Better fit, particularly if tailored to hand size or designed with stretchable properties
- Improved dexterity compared to current gauntlets, providing greater control and ease of use
- Easier removal, including the ability to quickly take them off when necessary

Containment bags & lay-down sheets:

- Increased durability and protection against sharp objects, ensuring the safe handling and transport of hazardous materials
- Improved flexibility and reduced bulk, making it easier to manoeuvre and work in confined spaces without compromising safety
- Improved containment, i.e. reduction of risk of contamination spread to operators and the environment

Constraints

To support safe decommissioning at Sellafield, the following constraints define essential requirements for gauntlets, containment bags, and lay-down sheets. These focus on material performance, safety, and operational needs in challenging environments.

Gauntlets:

- The gauntlets must seal to the current 6-inch glove port. While most ports are circular, a few are oval, though addressing these is a lower priority
- The gauntlet length should be approximately 760mm, with a bead size ranging from 5.16mm to 7.14mm (Figure 4), which is a fixed constraint
- The wrist and hand area must be spacious enough to fit two pairs of Marigold gloves underneath without restricting the operator. Extended reach is occasionally needed, but is a lower priority
- The gauntlets must be ozone-resistant to Level 4 and preferably resistant to up to 4M nitric acid, as well as caustic (NaOH)
- The gauntlets must maintain their properties up to at least 50°C, ideally 75°C; above this, heat-resistant gloves may be necessary
- Additionally, some equipment may need to be used in areas where temperatures drop to below 10°C
- The weight of the gauntlets must not significantly exceed that of the current gauntlet (395g, range 240–395g), and their dexterity should not be substantially reduced

Containment bags & lay-down sheets:

- Must be made of materials that offer effective puncture and needlestick resistance for operator safety
- These materials should be durable enough to protect against sharp objects, while still being flexible enough to allow for ease of use and transport without compromising safety
- The design should facilitate ease of handling, especially in confined spaces; during decommissioning; and/or during inspections and condition monitoring tasks
- Cutting or puncturing the proposed material must not release powders, fibres, or any embedded substances
- The current materials used for containment bags and lay-down sheets are translucent for ease of use. While clarity is not required, it remains advantageous
- Although direct contact with water is not expected, containment bags and lay-down sheets must withstand moisture exposure without loss of integrity or performance
- Containment bags must be able to be welded so that posting bag operations for import/export of items from gloveboxes can be performed
- The material must be compatible with acrylonitrile butadiene rubber (Nitrile/NBR), as an O-ring of this type is welded into the bag opening to ensure a reliable seal on the glovebox port

- The material should be tear, wear, and abrasion resistant to prevent degradation when it is required for floor use in the case of lay-down sheets

Figure 4: Ethylene propylene diene monomer (EPDM) beaded port seal

Functional Requirements

The following requirements apply to gauntlets, containment bags and lay-down sheets:

- The solution must maintain or improve upon current dexterity, weight, and operational performance compared to existing gauntlets and bags
- Gauntlets must be ambidextrous and available in appropriate sizes, with stretch or shrink-to-fit properties if needed
- The materials must be needlestick and puncture-resistant:
    - For gauntlets this includes on the front, back, and between the fingers, ideally extending to the elbow
    - Enhanced protection maybe required for specific applications, such as heat or chemical resistance
- Operators must be able to change gauntlets quickly, especially in cases of contamination
- Gauntlets should be marked with a barcode or date stamp
- The materials must be suitable for batch production and can be manufactured into gauntlets, containment bags and lay-down sheets
- Materials must not release particles if ruptured or cut during testing or use
- Heat transfer from the environment to the operator should be minimal to improve comfort
- Low static properties are required to prevent contamination and ensure safe use in hydrogen environments
- The material's lifetime, failure modes, and impact of glovebox environments, including radiation exposure, must be understood
- The material must be resistant to wear and abrasion without compromising containment

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 3pm on Tuesday 2nd December 2025.

Delivered by

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