Box Encapsulation
Robotics Project
Stephen Shackleford
Dr. Jeffrey A. Kuo, C.Eng. MIMechE
Jim Harken  BEng (Hons) CEng FIMechE

NIST Conference, 2-4 Feb 2016
Contents

• Overview of Sellafield site and Operations
• Why Remote Intervention?
• Box Encapsulation Plant Project
• Step Change Box Encapsulation Robotic Project
• Waste Treatment Cell and Robot Operations
• Robot Selection Criteria
• BEP Robot Trial Results
• Future Robotic Project Work
• Supporting Research
Sellafield – One of The World’s Most Challenging Nuclear Sites

| THE CHALLENGE | • 1200 buildings in 6 sq km:  
|               |   • 200 hold nuclear inventory  
|               |   • 100 equivalent or greater than a nuclear reactor in terms of hazards and security  
|               | • Ageing infrastructure, 60+ years  
|               | • Poor historical record keeping  
| LARGEST UK CONSTRUCTION SITE | • Multi-billion facilities being built for clean-up  
|                             | • 450 engineering and construction projects  
|                             | • 17 valued over £100 million  

Source data: Nuclear Management Partners Performance and Progress at Sellafield (http://nuclearmanagementpartners.com)
Why Remote Intervention?

- Decommissioning the UK’s current nuclear facilities including waste storage will cost £115 billion over the next 100 years.
- The cost of a UK geological disposal facility is circa £12 billion.
- UK investment in new nuclear build before 2030 is circa £60 billion.

- Clearly a step change is required to make improvements in risk reduction, safety, reliability, efficiency and cost across the entire UK nuclear cycle.

- Robotics has the potential to make that step change for deployment in harsh environments.
Box Encapsulation Plant Project

Box Encapsulation Plant is being constructed to accelerate the Sellafield High Hazard and Risk Reduction legacy Beta/Gamma waste programme.

BEP expectations:
- Accelerate delivery: BEP commissioned 2018 and operate for 50 years.
- Receive waste from numerous donor plants in differing import skips.
- Recover, identify and flood grout the processed waste.
- Transfer the encapsulated waste for interim storage before GDF disposal.
BEP Robotic project involves the development of a robotic system that operates in both the tele-operation and automated modes.

Capable of handling legacy nuclear waste in a new plant at Sellafield to be commissioned by 2018.

The project will run for 5 years and is being delivered in a collaborative approach between Sellafield Limited, NNL & KUKA on behalf of the NDA.
1. Skips containing waste received and moved to the skip buffer station.

2. Skips are placed in the unloading station and the liquor is decanted to allow operators to view the waste inside.

3. The decanted liquor is moved to a buffer storage position and particulates are allowed to settle.

4. Following settling the supernatant is decanted off and stored before being consigned for effluent treatment.

5. The decanted liner, containing a heel of sludge is transferred to the loading station.

6. Solid waste items from imported skips are placed on top of the sludge layer by robots.

7. Once the waste liner is full the anti floatation plate is fitted.

8. The filled liner is moved to the grouting station.

9. The fluid grouted liner is moved to the curing station and cured.

10. Following curing the liner will have bleed water removed and a cap applied.

11. When the cap has cured the liner will be transferred to the Box Operations Cell.
Project Significant Features and Robot Operations

- Develop BEP robots designed for structured environments, to operate in unstructured environments.
- Minimise development and trials, and utilise LFE from elsewhere.
- Adopted systematic approach to technical development separate to project delivery.
- Utilise and nuclearise proven commercial ‘off the shelf’ technology.
- Very high reliability of robots and ancillary equipment required.
- No man access is possible:
  - Use CCTV cameras to identify the waste items
  - Process the waste by disruption of items to release trapped liquors and ensure full grout infiltration to minimise voidage
Robots had to demonstrate operability in a high radiation and contaminated environment. They must meet the following criteria:

- Demonstrable history of proven, technology, high reliability, service provision and prior nuclear applications.
- High payload (0.5 tonne), but robot weighs less than 3 tonnes.
- Use of resolvers rather than encoders.
- Operate in both tele-operation and programme mode with Force feedback, zoning and collision avoidance features.
- High accuracy and repeatability e.g. 0.08mm.
- IP67/65 rating for wet and sludgy environment.
- 3D live simulation of robots and environment.
- Good supplier support.

- Supplier of choice KUKA.
BEP Robot: Waste Recovery Trials

• All of the test materials trialled have been successfully recovered, handled, disrupted and deposited in export liner, remotely using cameras, and at acceptable throughput rates, using 2 robots.
• Graphite blocks, Magnox swarf, Aluminium doughnuts
• Sludge carryover
• Zeolite skips, Ionsiv cartridges, swarf bins, Filters
• Drums, cans, boxes and containers (tins and fuel bottles)
• Plant equipment valves, motors, gearboxes, pumps etc.)
• Generic scrap: Pipes, hoses, tubing, plastic bags and sheeting, wire rope, reels, cables, slings, chains etc.
BEP Robot: Disruption Trials

- A very high degree of dexterity & control, both in manual tele-operation & automated modes.
- A high waste consolidation & packing efficiency and enables packing of lightweight waste into new cans.
• Automated programmed sequences have reduced operator workload and stress especially for routine operations, housekeeping, waste/liquor management and tool change
BEP Robot: Tooling
BEP Robot Future Project Work

• Current test rig will be modified to be a complete inactive demonstrator of the BEP cell.
• Trials to investigate remote installation/removal and failure recovery equipment.
• Completion of radiation and environmental tolerance assessments.
• Nuclearisation modifications on the robot implemented
• Continued trials to investigate robot reliability, redundancy, human factors, waste identification and inventory etc.
EU Horizon 2020 RoMaNS: Robotic Manipulation for Nuclear Sort and Segregation

- €6.4 million 3 year R&D project
- Applied to nuclear waste sort and segregate processes
- Cross-sector applications for asset care, maintenance and decommissioning

ROBOT WASTE PROCESSING

- Visual tracking and visual robot servoing
- Autonomous trajectory planning for robots and grasping
- Autonomous learning for reactive robot grasping
- Novel haptic master hands and slave robots
- State of the art waste and object identification

Co-funded by the European Union
Eu Grant No: 645582
Robot Laser Cutting

• Deploy industrial robot and laser at Sellafield
• Increase throughput, safety and reliability
• Proven and innovative technology for robot paths and collision detection
• Applied to welding, plasma cutting
• Easy operator interfaces

Automated robot paths
Collision detection and avoidance
Optimal laser cutting
Remote extraction of plant geometry
Real and virtual worlds
Summary

- Robots have been chosen as the technology to deliver the SL risk reduction programme for the next 50 year.
- Box Encapsulation Plant will be commissioned in 2018 with installed robots.
- Robot trials will continue for the next 5 years supporting:
  - Nuclearisation of the robots
  - Continuous Training and education platform for employees
  - Hot spares for operational robots
  - Inactive test rig supporting active operations
  - Testing for future robot and tooling development.
- Research is undertaken in parallel to delivery of the BEP Robot project thereby minimising schedule and scope creep.
BEP Robot Project: Any questions?

Thanks to:

Sellafield Ltd  Nuclear Technologies  NSG  KUKA