Remote Characterisation of Wet Storage Facilities using AVEXIS

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Overview

• Background to Sellafield and some of its challenges

• Robotic research at the University of Manchester:
  – AVEXIS: small scale ROV
  – Large scale spider
Sellafield Site

Last week the government announced plans for a new generation of nuclear plants. But Britain is still dealing with the legacy of its first atomic installation at Sellafield - a toxic waste dump in one of the most contaminated buildings in Europe. As a multi-billion-pound clean-up is planned, can we avoid making the same mistakes again?
Legacy Waste - Sellafield

- Owned by the Nuclear Decommissioning Authority and operated by Sellafield Ltd.

- Contains the THORP and MAGNOX reprocessing plants and home to considerable amounts of legacy nuclear waste (170 major nuclear facilities; 2200 buildings).

- Clean-up cost of Sellafield estimated to be £67bn and programme of decommissioning extends more than 100 years.

- Waste includes:
  - Floc storage tanks
  - Legacy ponds: FGMSP, PFSP
  - Storage silos: Magnox and Pile Fuel
  - Windscale
  - 1 million m$^3$ of concrete waste above ground and 1 million m$^3$ of concrete waste below ground
  - 37 km road, 7 km pipe bridges, 16 km ducts and trenches

- NDA describes some of the legacy waste at Sellafield as ‘intolerable risks’.

- More information: http://www.sellafieldsites.com
Sellafield Challenges

Alpha Decommissioning (Sellafield):
- Minimise airborne contamination.
- Minimise waste volumes.

Diverse range of glove boxes require decommissioning.

Alpha Decontamination

- Alpha contaminated gloveboxes are a significant problem on the Sellafield site
  - There are several hundred onsite
  - Cost approximately £100k per glovebox for decommissioning & waste storage.

- Alphabot has been developed to remotely clean the insides of the gloveboxes to reduce the contamination level
Characterisation Challenges

How can we determine when POCO is complete?
How can we generate 3D drawings overlaid with radiometric information?
How can we cut and retrieve waste?
...

Legacy pond inspection: AVEXIS

- Autonomous Vehicle for Exploration and In-situ Sensing (AVEXIS) has been developed

- Two versions exist
  - AVEXIS MiniROV for restricted access deployment
  - AVEXIS Prime for collaborative monitoring

- An acoustic communications and positioning system has also been developed
The Purpose of AVEXIS

• To generate a map of radiation levels and location and geometry of the waste within the pond.

• To monitor the conditions in the pond during movement and retrieval of waste.

• To perform camera inspections of difficult to access areas.

• To possibly take samples of sludge and take in-situ measurements (psd, temperature etc).
AVEXIS

- Vehicle must fit through a 150 mm access port.

- Vehicle is 3D printed to reduce development time and construction cost (it can be disposable).

- 3D print material is porous:
  - Dual hull design is used to ensure vehicle is waterproof.
  - Thickness of outer shell is minimised to avoid contamination.

- Underwater, wireless positioning and comms system required
AVEXIS – first trials

https://www.youtube.com/watch?v=CHINXX8mOjE
Communications and Positioning

• The AVEXIS miniROV will be tethered, AVEXIS Prime will be untethered. Communication must therefore be wireless.

• RF communications is unsuitable in the water based environment. Acoustics used instead.

• Long range acoustic communications under water are well understood (> 1 km) but not for short-range (100 m).

• Clutter within the environment results in multi-path propagation leading to significant signal processing and interpretation challenges.
Basic Set-Up

- C&P is achieved using base-stations (or anchors) mounted on the edge of the ponds

- The anchors transmit mission data and positioning signals and receive measurements from the vehicles
Communication in Cluttered Environments

Drawing Scale: 2 cm = 1 m (1 : 50)

Clutter

Ladder
Mobile Positioning - Trials

Accuracy of positioning system has been demonstrated to be approx. +/- 1 m.
Underwater Spider Robot: Design

Robot will be deployed within a storage pond.

It will cut, sort and retrieve waste.

Vehicle will have grasping and cutting capabilities.
Design of one leg

**Electric components:** (a) servo motor, (b) high ratio gearhead, and (c) stepper motor.

**Hydraulics:** (d) rotary, (d) cylinder, and (e) power pack.
Radiation Science

- How will radiation affect the robotic equipment (electronics and materials)?

- Irradiation equipment used for testing

- Large scale irradiation facilities:
  - Self-contained high dose rate $^{60}$Co gamma irradiator
    - 15kCi in dual source rod assemblies (equivalent to central chamber dose rate ~16.5kRAD)
    - 9 litre (8” wide x 10” deep x 12” high) sample chamber
    - Flexible experimental configuration
  - Fully equipped sample preparation, analytical and post-irradiation examination laboratories
Radiation Science

- **Large scale irradiation facilities:**
  - 5MV ion accelerator $M^{2+}$ ions with energy $5(Z+1)$ MeV:
    - High current TORVIS source providing 10MeV $^1H^+$ at 100µamps, 15MeV $^4He^{2+}$ at 15µamps
    - Low current SNICS source providing partially and fully stripped heavy ions e.g. 35MeV $^{12}C^{6+}$ at 150namps
    - Six beam lines with two high precision raster scanners
    - Two irradiation vaults to enable parallel working and minimize downtime
  - Second 2.5MV light ion accelerator on order – creating the world’s highest energy dual beam accelerator system at DCF
Electronic Component Testing

- Work has focused on identifying susceptible components within embedded systems.

- Raspberry Pi, for example, was tested and found to fail after receiving a total dose of 1700 Gy.
  - Recovered after annealing.

Individual components tested during irradiation.
Summary

- Sellafield has a variety of complex decommissioning challenges.
- Many challenges require the use of remote operational systems:
  - robotic vehicles transporting sensors / inspection equipment;
  - remote cutting;
  - waste retrieval
- University of Manchester has several robotics projects:
  - Design of submersible vehicles: AVEXIS
  - Design of a spider robot
  - Pipe inspection robot
  - Glovebox cleaning robot
  - Augmented reality systems