# Robotic Inspection for the Nuclear Industry

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ROBOTICS AND AI IN NUCLEAR

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# Overview

- What are the inspection challenges in the nuclear industry?
- Where do they occur?
  - Legacy facilities
  - New build and plant life extension
- What is the state-of-the-art in robotic inspection?

# The role of inspection

- **Legacy**: Characterising facilities and waste stores for decommissioning
- **Non-legacy**: characterising and monitoring facilities for waste disposal and safety purposes.

- Low-, intermediate- and high-level waste must be handled and stored differently.
  - Major cost implications for storing intermediate and high level waste
  - Safety cases are different for different waste types

- We also need to know what other materials are present for decommissioning purposes

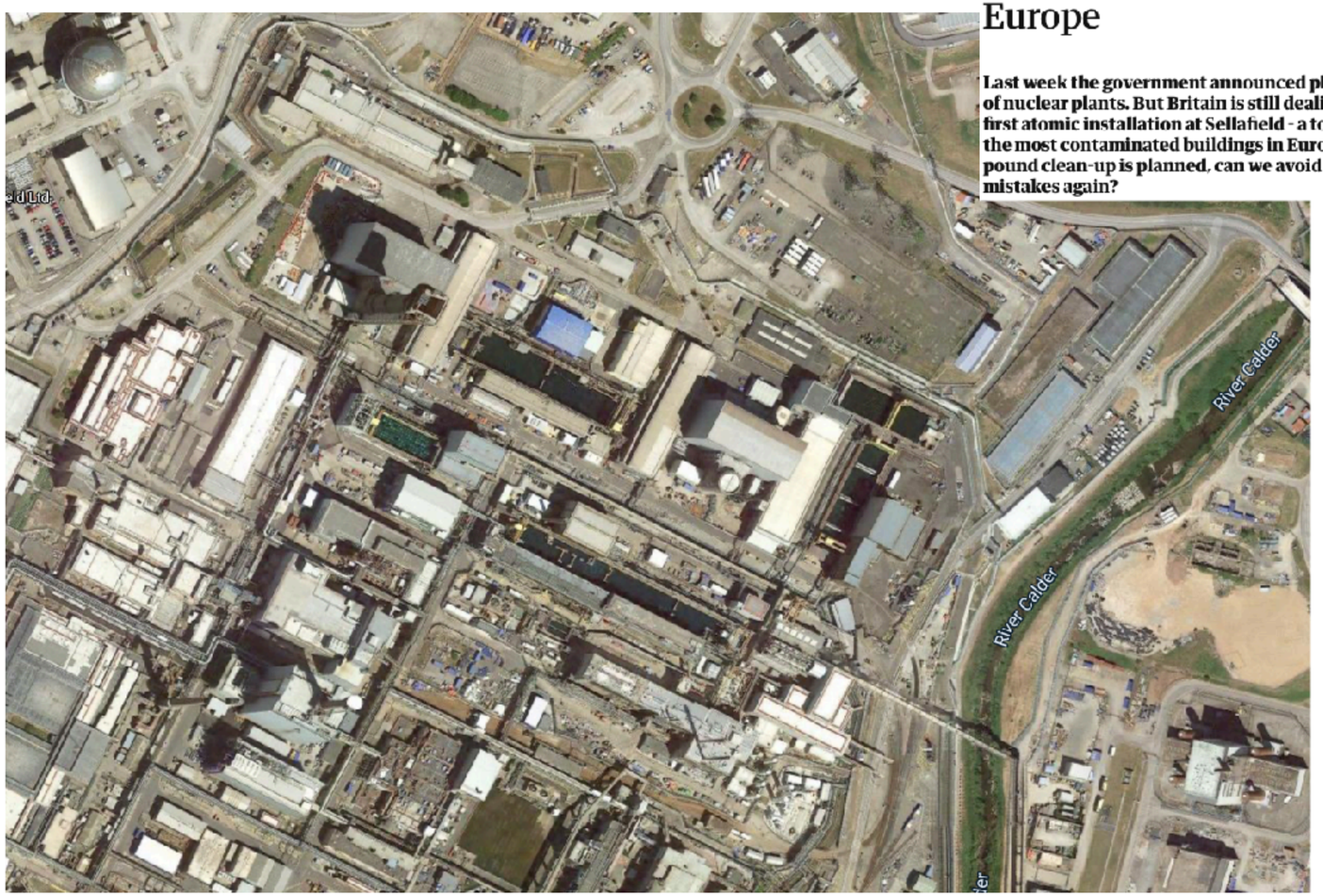
- Longer-term monitoring is necessary to determine how sites, stores and waste are changing.
  - This is for safety and for planning of decommissioning over time

# The role of robotics

Risk from nuclear operations should be:

**ALARP**: As low as reasonably practicable

# Sellafield Site




The Observer
Nuclear power

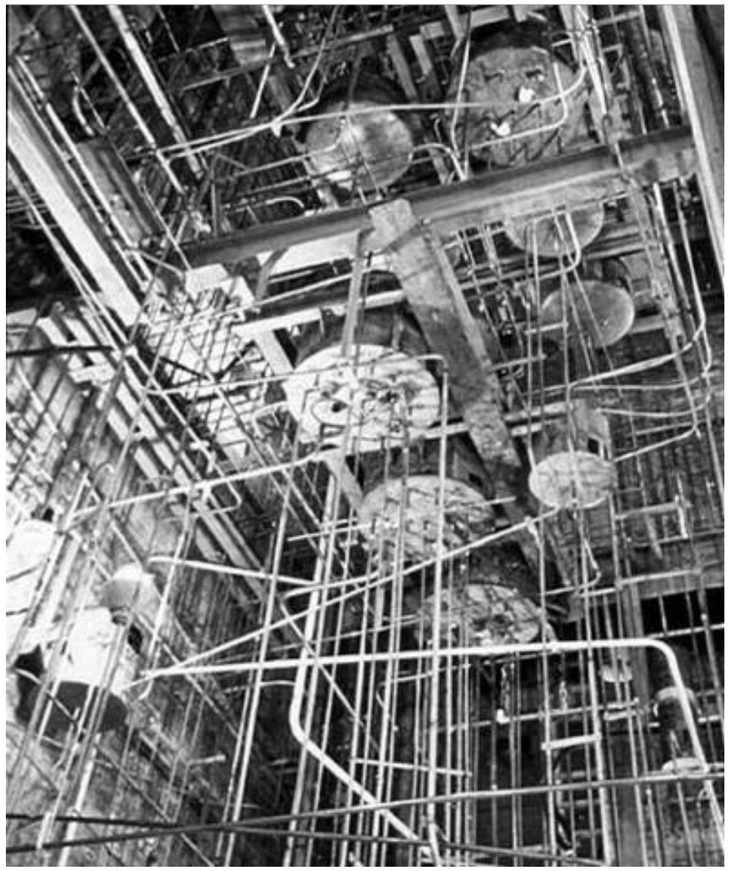
## Sellafield: the most hazardous place in Europe

**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 (NDA) and operated by Sellafield Ltd.
  - NDA describes some of the legacy waste at Sellafield as '***intolerable risks***'.
- 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

# Characterisation Challenges



How can we identify radiation hot-spots?

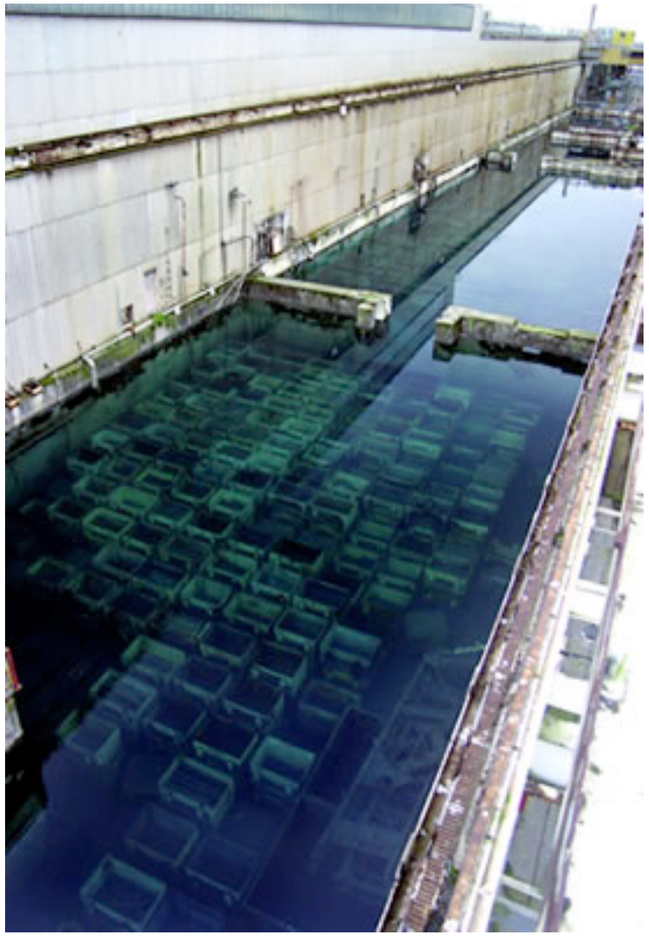
How can we determine when POCO is complete?

How can we generate 3D drawings overlaid with radiometric information?

How can we cut and retrieve waste?

http://sellafieldsites.com
http://gamechangers.technology

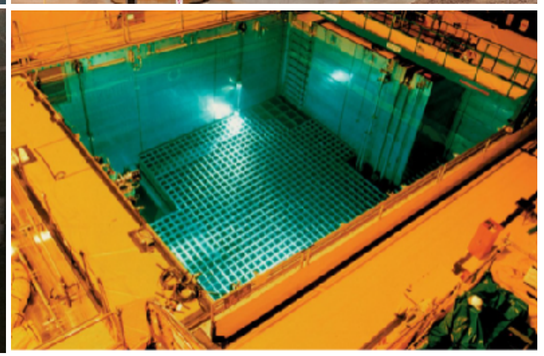
# First Generation Magnox Storage Pond



# New Build / Plant Life Extension / Storage

- Important to remove plant operators away from hazardous environments.
- Significant benefits in utilising autonomous robots to inspect facilities on a routine basis.

IAEA Inspection Challenge



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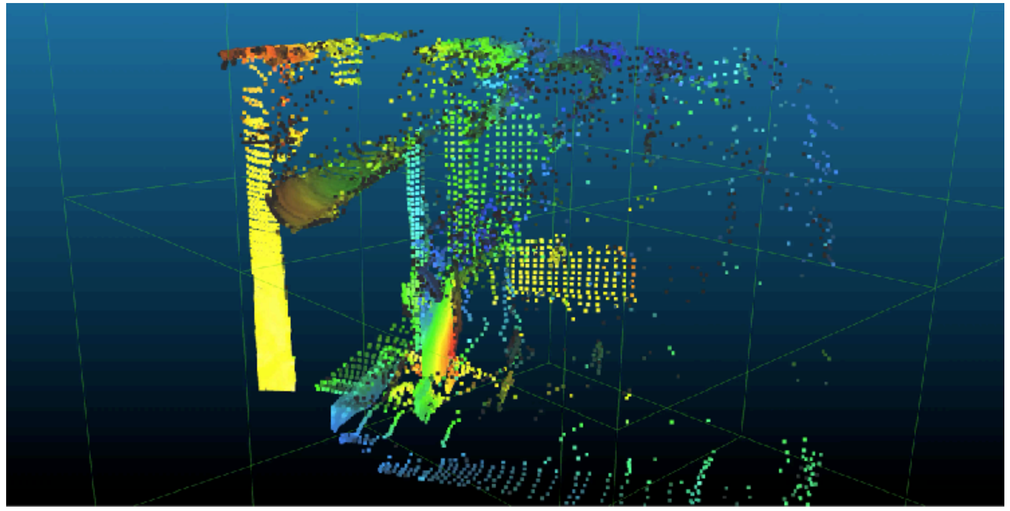
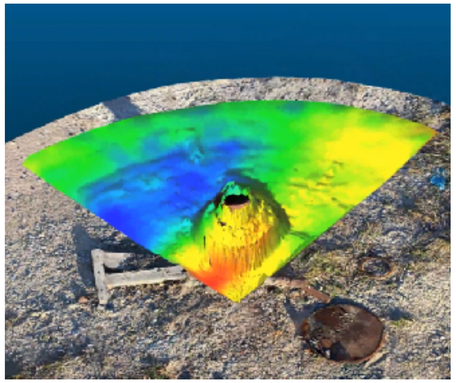
# Radiation Imaging



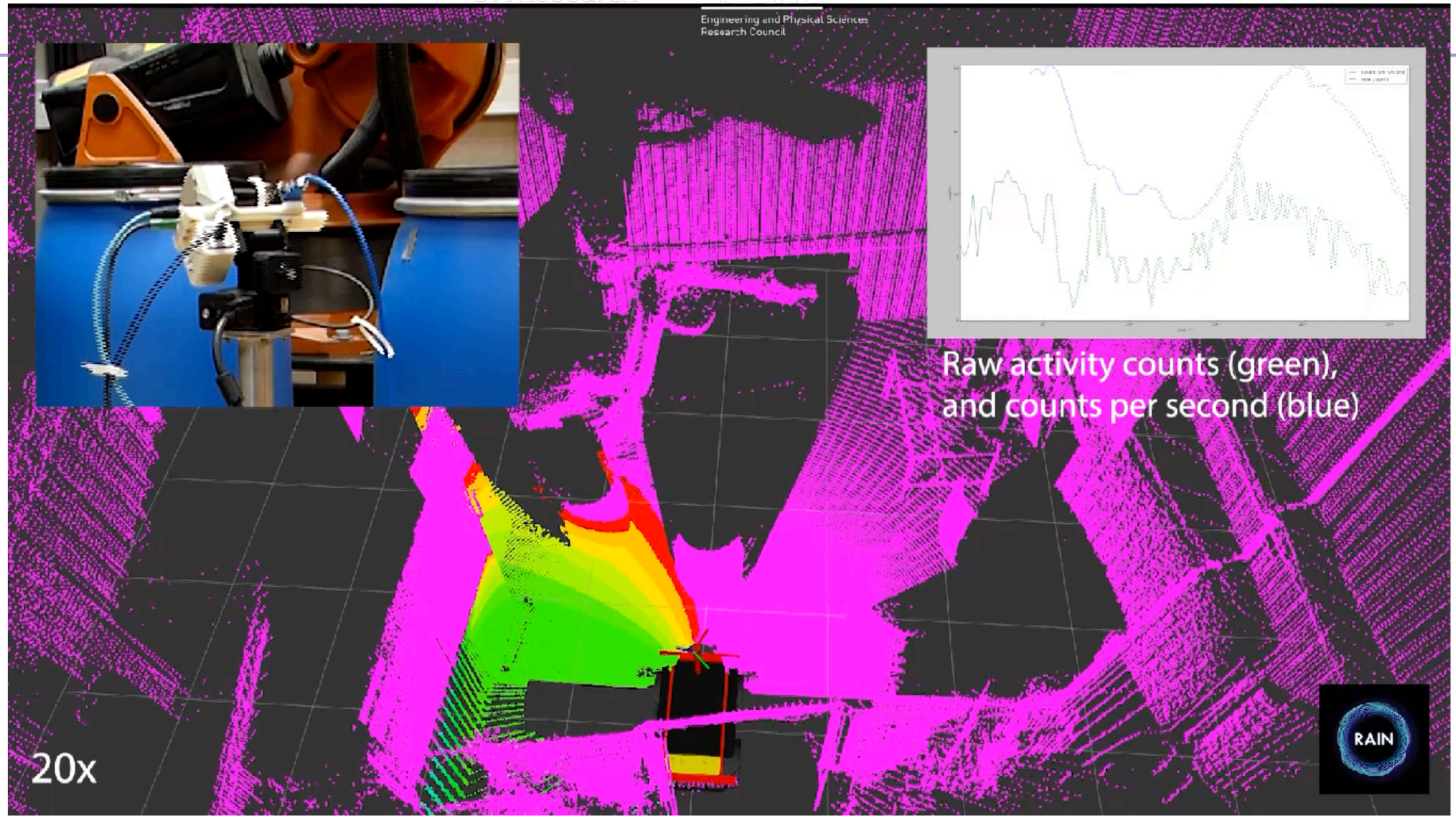
Coincident LiDAR and collimated gamma spectrometry used to produce 3D radiation maps from a fixed-point.

Data was collected from PChP, an active site in Ukraine

A contaminated container producing a localised radiation hot-spot. The 3D model was produced using the LiDAR data combined with photogrammetry

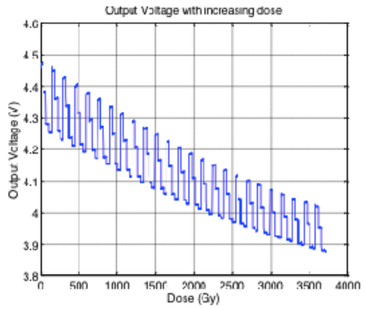


# Radiation Imaging



# Radiation Resilience

- Materials and electronics will be affected by radiation, particularly gamma.
- Co-60 irradiator is used to measure the resilience and effects that gamma has on the robotic systems and materials.
- Test results below for a Raspberry Pi



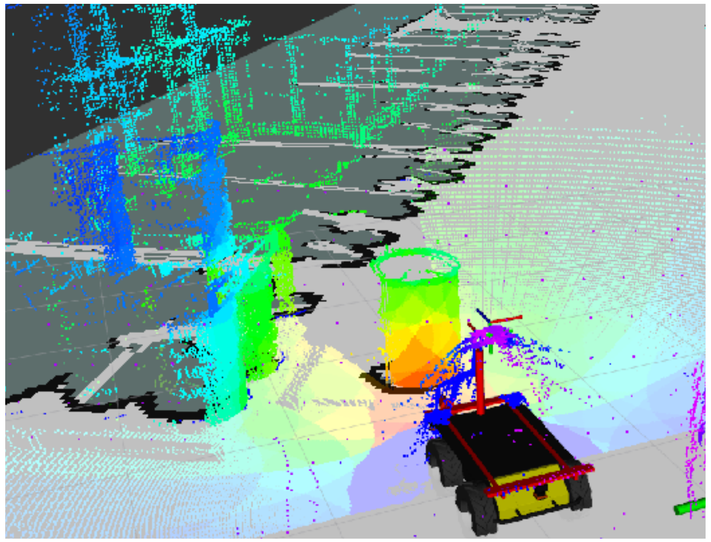

# Routine Radiation Surveys

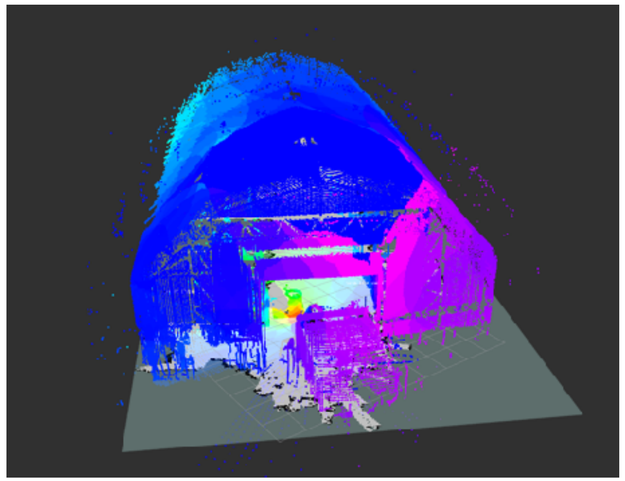
- CARMA is a fully autonomous radiation surveying robot (here detecting alpha contamination).
- Deployed into several active facilities on Sellafield site.
- First fully autonomous robot to be deployed on Sellafield site.

CARMA deployed in active area on Sellafield site, May 2019

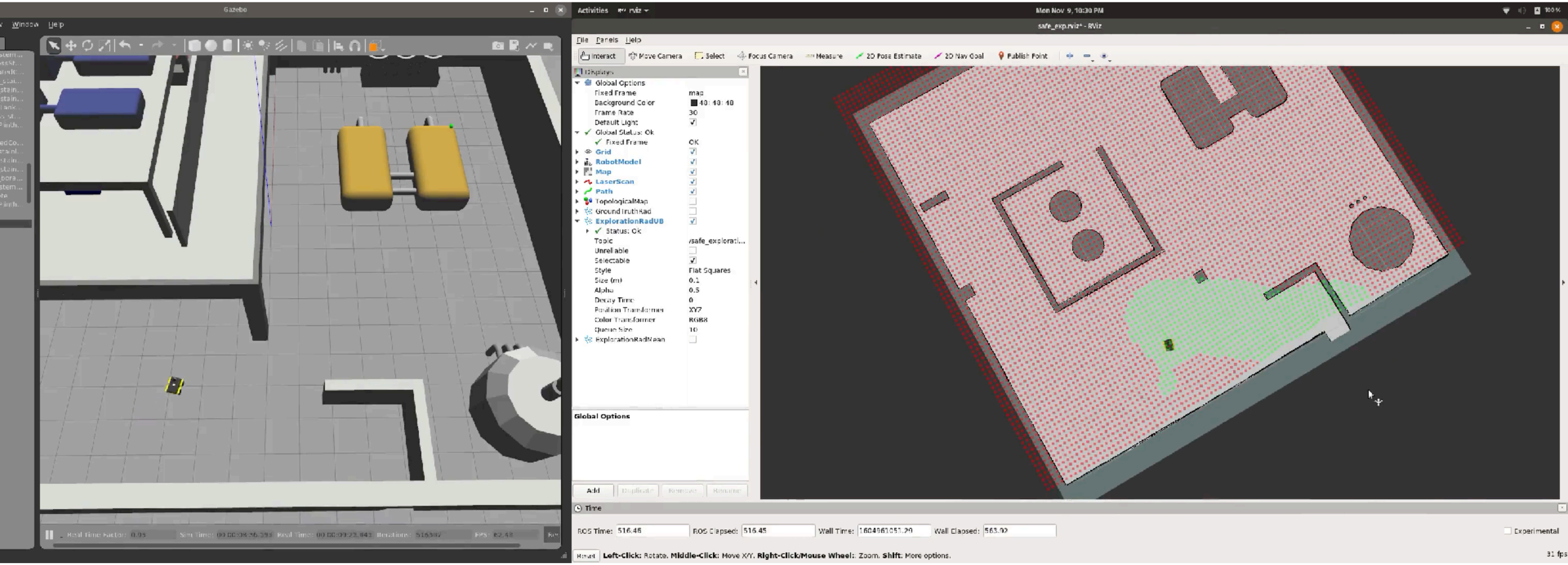
# Inspection of Waste Stores

- Robot used to inspect waste store at Culham.
- Identified raised levels of waste in drum.





# Safe Exploration of Nuclear Facilities

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The University of Manchester

# RAIN Expansion + Innovate UK w/ createc

Maurice Fallon

Ioannis Havoutis


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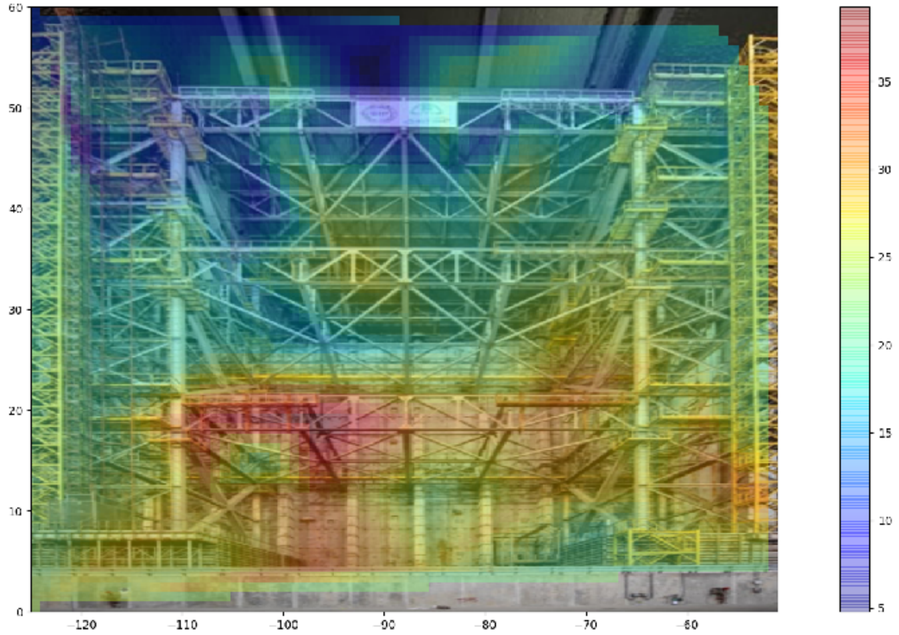
# Chernobyl NPP Results

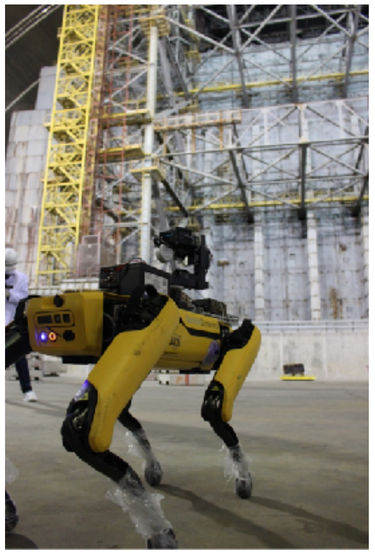


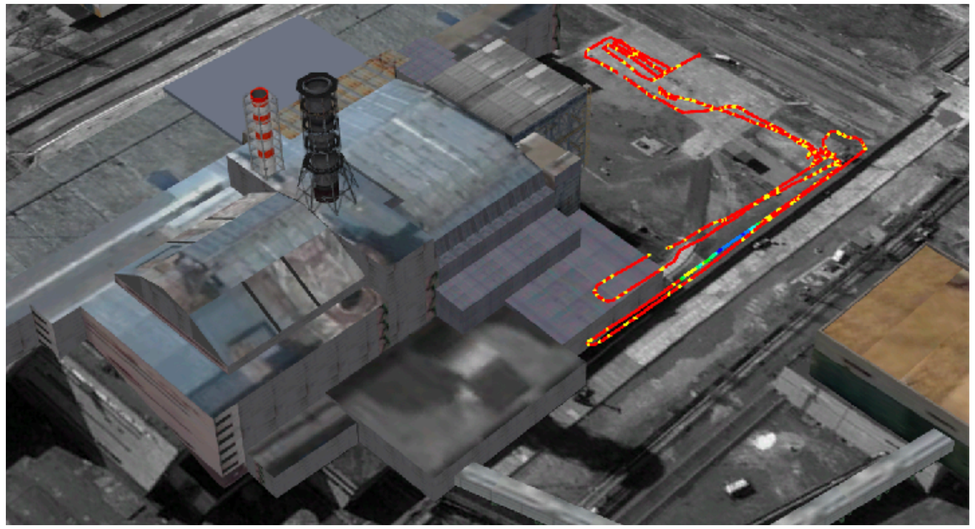

(Above): Radiation survey of the western wall of the Shelter Object, (a.k.a. the Sarcophagus).

- Was intended as temporary structure but...
- Structural integrity questionable
- Dismantled soon prior to reactor decommissioning

(Right): Spot conducting radiation survey of survey of western wall.

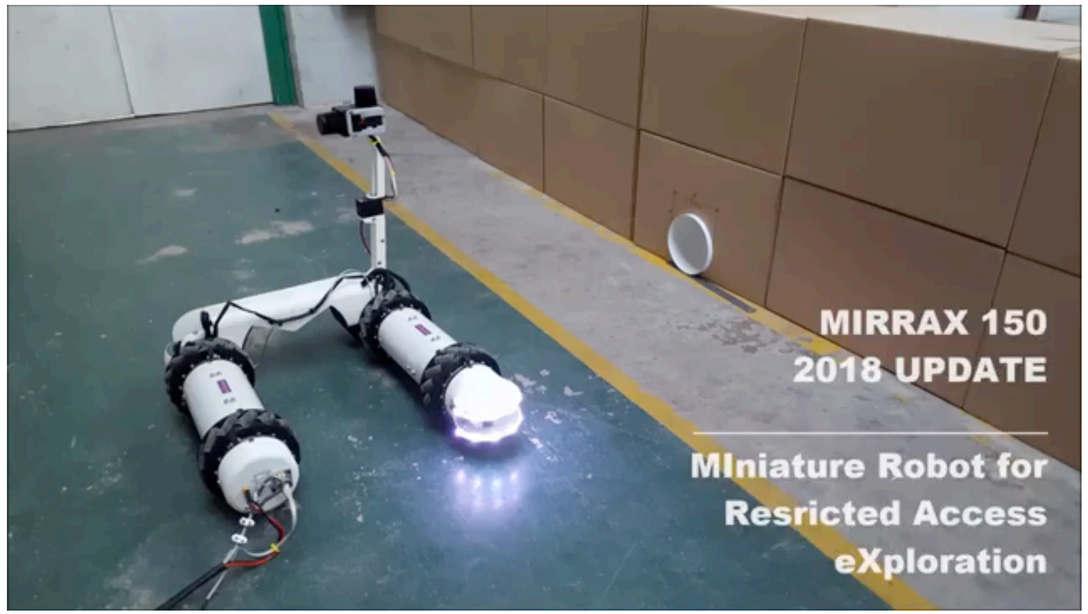
(Below): Radiation measurements inside the Shelter. Positions obtained from odometry





# Restricted Access Vehicle

- MIRRAX was first robot deployed into Magnox reprocessing facility on Sellafield site
- Used to generate 3D image of the facility to aid with decommissioning plans.
- Designed to be deployed through 120 mm access port




# Visual Inspection of Sellafield Silos

AVEXIS Robot was the first robot deployed into Magnox Silos on the Sellafield site. Robot deployments in this facility are now routine.

# Conclusion

- Robotics has a major role to play in inspection in the nuclear industry in removing operators from high risk settings
- A huge range of applications and environments:
  - Ground, water, air / Indoor and outdoor
  - Legacy sites, disaster zones, new reactors, storage facilities
- Some major challenges:
  - Retrievability of robotic platforms (can't make more waste)
  - Reuse of robotic platforms (they should be built for decontamination)
  - Access to locations to be inspected
  - Communications to the running robot
  - Control of running robot: teleoperation, human-in-the-loop, autonomy
  - Confidence of site operators in robotics and AI

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