Demonstration of a Non-Invasive Radiation Measurement Technique to Support the Decommissioning of Nuclear Power Plants

NUCLEAR

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Background

- Nuclear facility decommissioning involves a large amount of concrete waste disposition.
- Radiological characterization of concrete contamination must be performed to estimate the amount of materials that must be remediated and disposed of as radioactive waste (cost factor).
- However, characterization of cementitious waste is time intensive and expensive leading to conservative characterization.
- Improved methods of quickly and accurately characterizing concrete could offer significant savings in labor, resource allocation, disposal and thus, overall cost reduction.

Waste Stream	Mass of cementitious material [metric tonnes]	Proportion of total material in waste stream
ILW	66,000	21%
LLW	800,000	40%
VLLW	2,000,000	71%

Source: UK Concrete Waste By Waste Class based on UK-NDA "UK Radioactive Waste Inventory 2022", published 2023

Advanced Characterization Technologies Could Save Costs

Problem Statement
Characterisation is Key

Image: concrete dust sampling, EPRI 3002005412

- To develop and improve decommissioning strategy
- Reduce decommissioning uncertainties and resulting liabilities
- Support more precise material segregation based on radiological inventory
- Improved utilization of the waste hierarchy to reduce disposal costs
- Combination of new and state of the art technologies can further increase characterization efficiency

Non-Invasive Characterization can Support State of the Art Technologies.

Current Solution?
Core&Drilling Sampling

Image: courtesy of ENRESA of direct drilling characterization, EPRI 3002005412

Image: courtesy of EDF UK core sampling technology

<u>Challenges:</u>

- Estimating the entrained contamination are **challenging** (i.e. slow/time consuming).
- Depth is typically estimated with a **sparse** grid of core or drill samples, resulting in:
  - **Hazardous** work generating airborne contamination.
  - **Damages** fabric of facility.

Objective

- Emerging non-destructive characterization technology D:EEP developed by Createc out of the United Kingdon.
- Principle is to characterize internal contamination in-situ using changes to the gamma energy spectrum due to attenuation/scattering.
- Technology has been previously demonstrated by Createc in a legacy UK facilities.

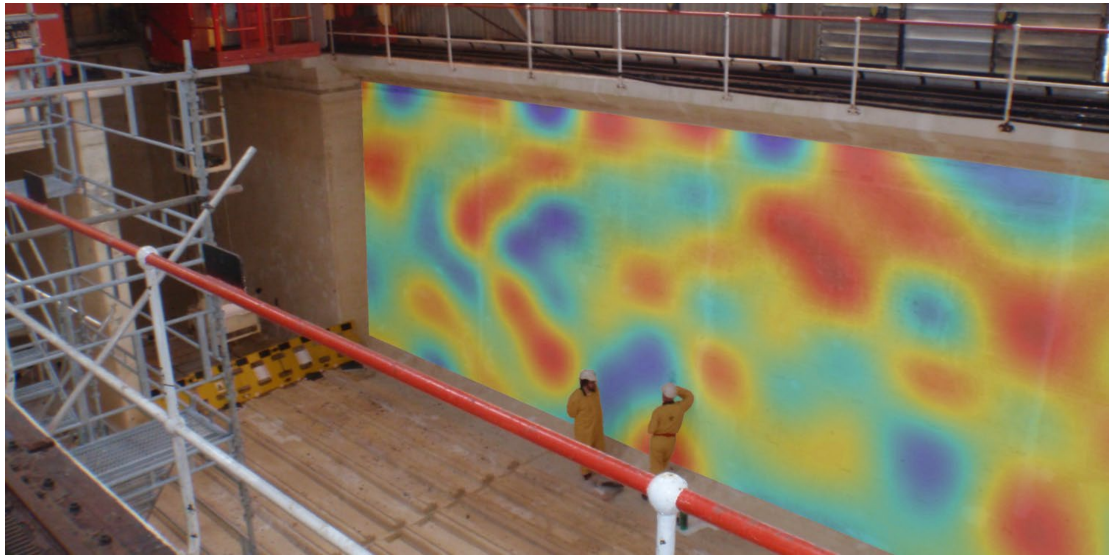


Image: resulting contamination profile through D:EEP application

Objective: EPRI co-sponsored proof of concept of deploying the DEE:P sensor to characterize Spent Fuel Pool (SFP) concrete at the decommissioning Dungeness B site in the UK, to:

- **Demonstrate** the ability to make **measurements below and above water** (i.e. providing a proof of concept of physical capability of the technology)
- **Provide better understanding of the technology**, noting that the project was **not** able to evaluate the technique efficacy

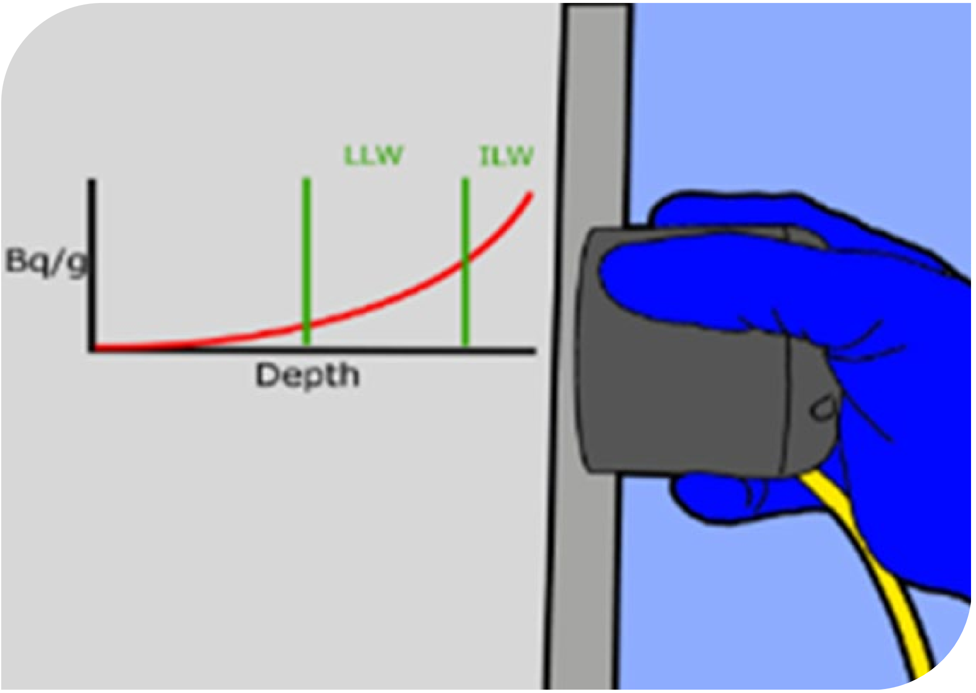
Proposed Technology?
D:EEP

- D:EEP is a **spectral analysis technique** combining specially designed hardware and software to interrogate concrete structures on nuclear sites.

- Provide a **non-intrusive** picture of the penetration of contamination within a concrete surface.

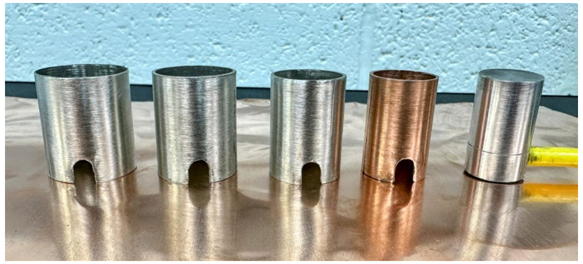
- **Ascertain contamination depth** of multiple gamma emitting isotopes up to a depth of ~ 150 mm (~ 60 in).

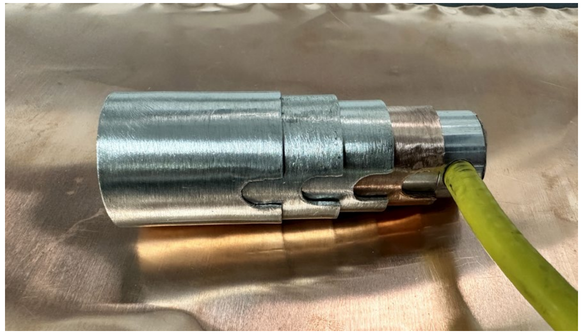
- Measure a **single position** or **map entire surfaces** through rastered measurements and interpolation of results.

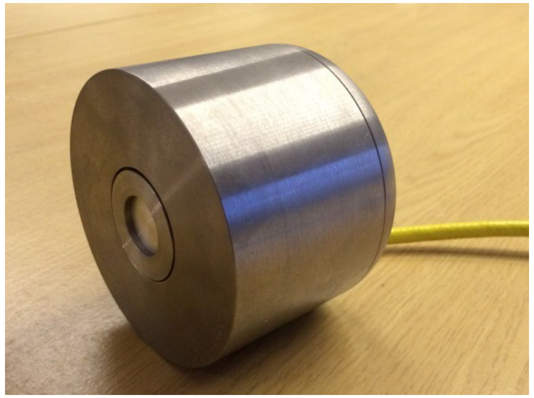


What is D:EEP?
Hardware - Overview

Component	Description
Cadmium Zinc Telluride (CZT) Spectrometer	Collects gamma spectra from the sample of interest. Connected to a suitable counting chain (pre-amp, MCA, laptop).
Tungsten Shield	Isolates the sample of interest, reducing background radiation from the sides and rear of the detector.
Copper & Tin Graded Shield	Reduces contributions from x-rays scattering from the tungsten shield into the detector.
Waterproof Housing	Waterproof deployment housing with hydraulically controlled background shield
Deployment Mechanism	D:EEP is deployment agnostic, providing flexibility for deployments into varying nuclear environments.



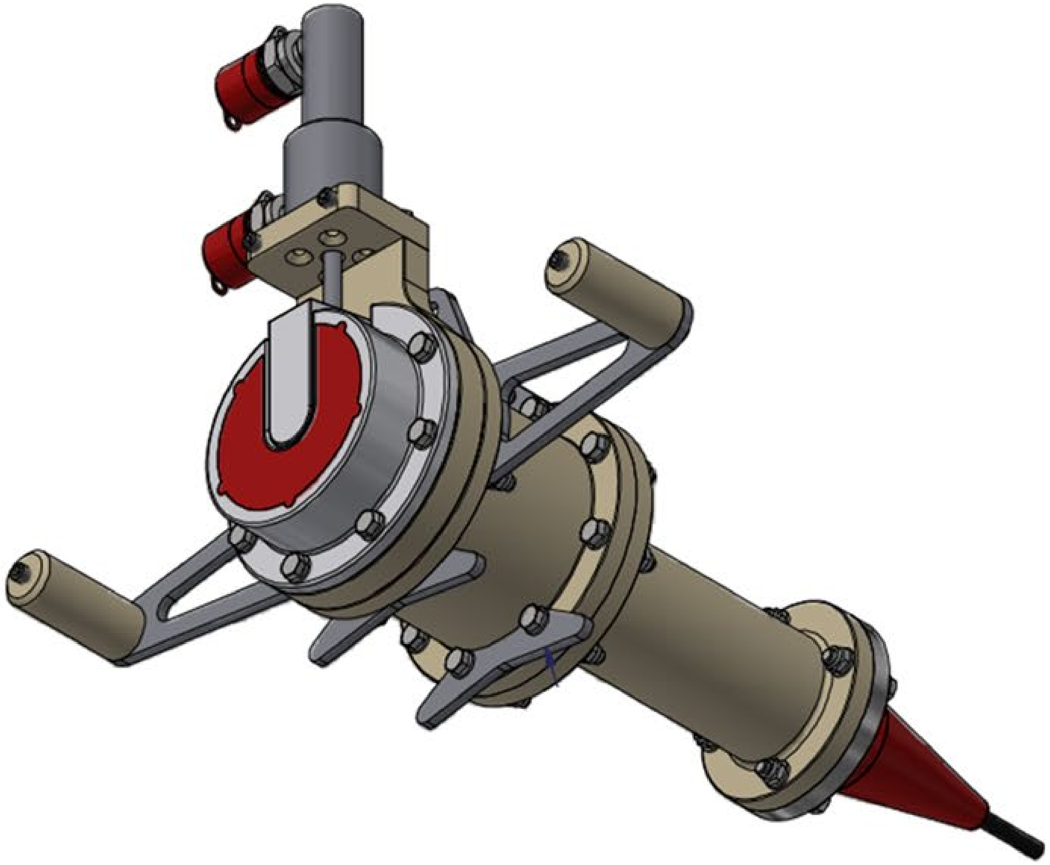




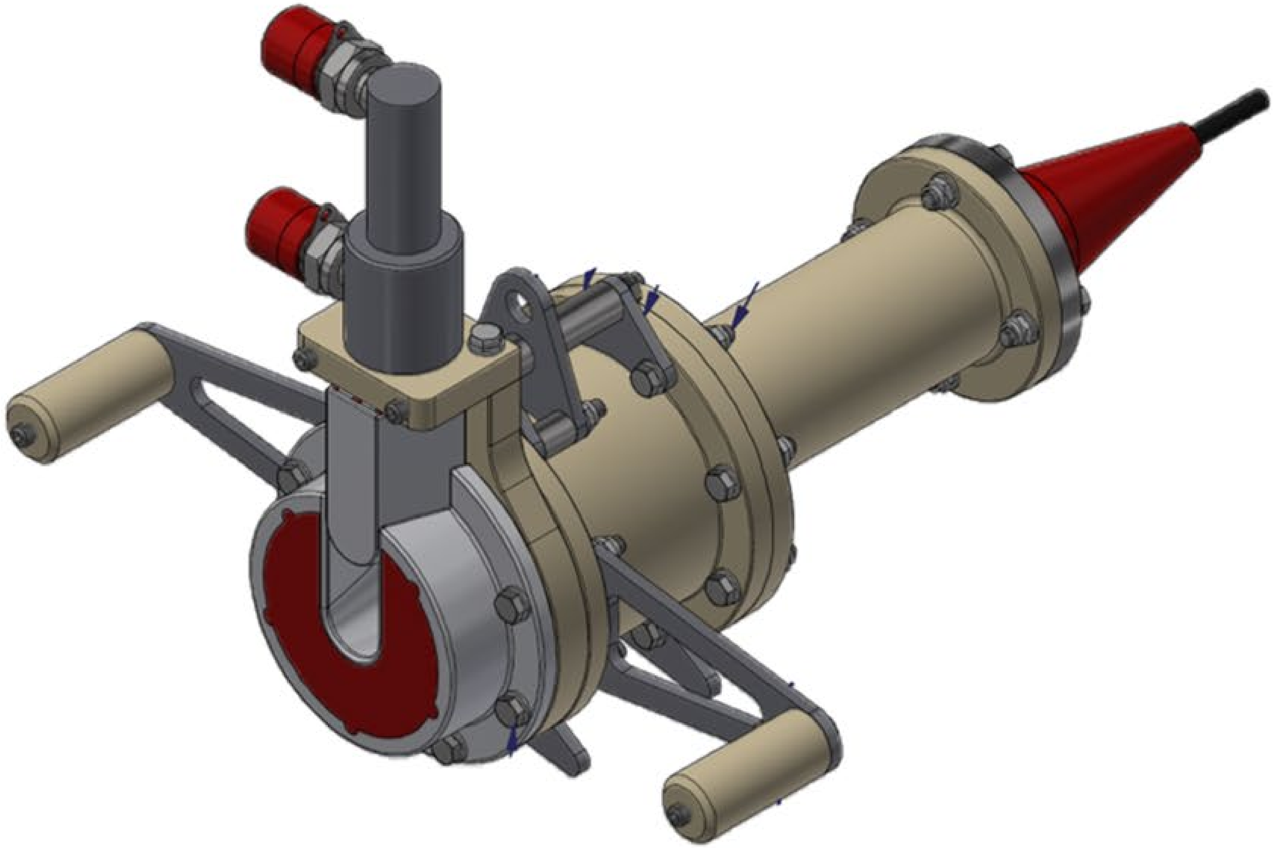
Standalone Detector

What is D:EEP?
Hardware – Underwater Housing

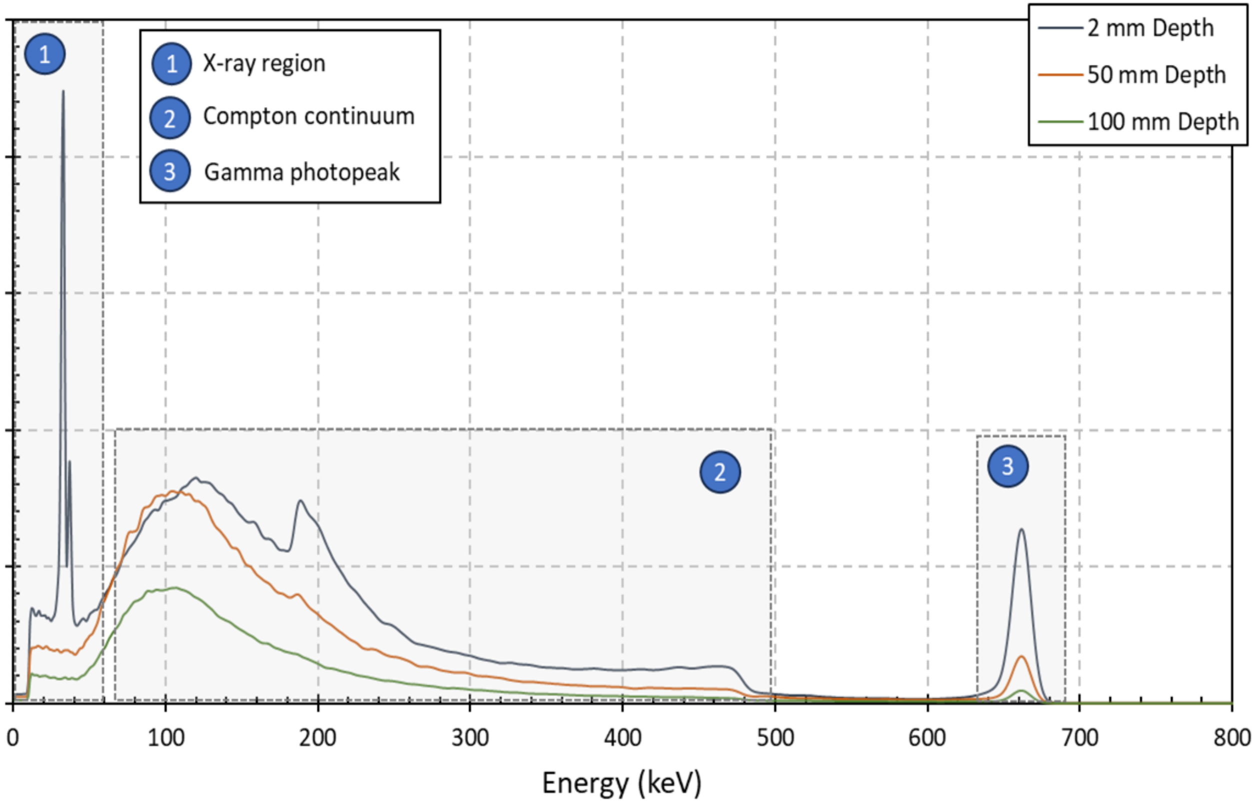
Background Mode
“Shield Closed”



Signal Mode
“Shield Open”



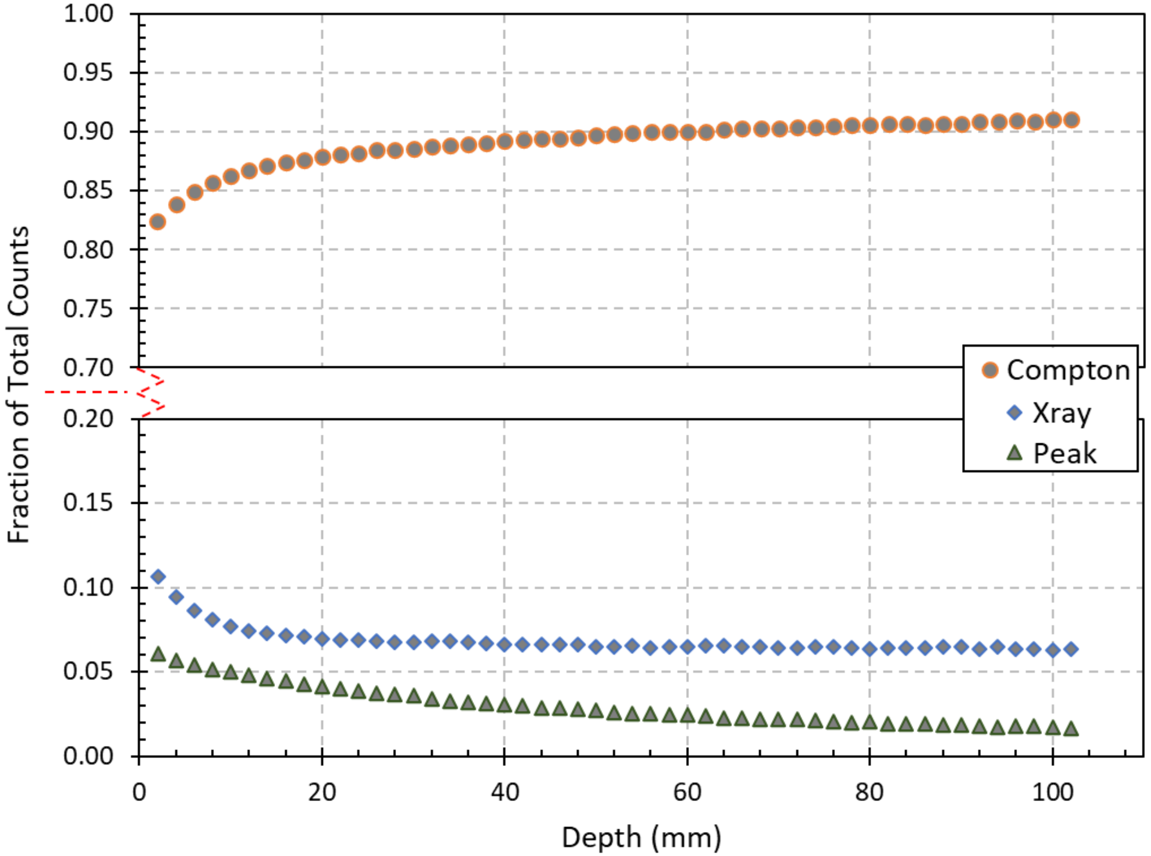
What is D:EEP?
Software - Theory



- ❑ Characteristic spectral features vary as a function of depth.
- ❑ Geant4 used to generate theoretical response at depth.
- ❑ Models generated every 1 mm up to 150 mm depth.
- ❑ Measurement spectra compared to simulation to obtain best fit.
- ❑ Individual contributions used to generate depth profile.

Theory of Operation

What is D:EEP?
Software - Theory



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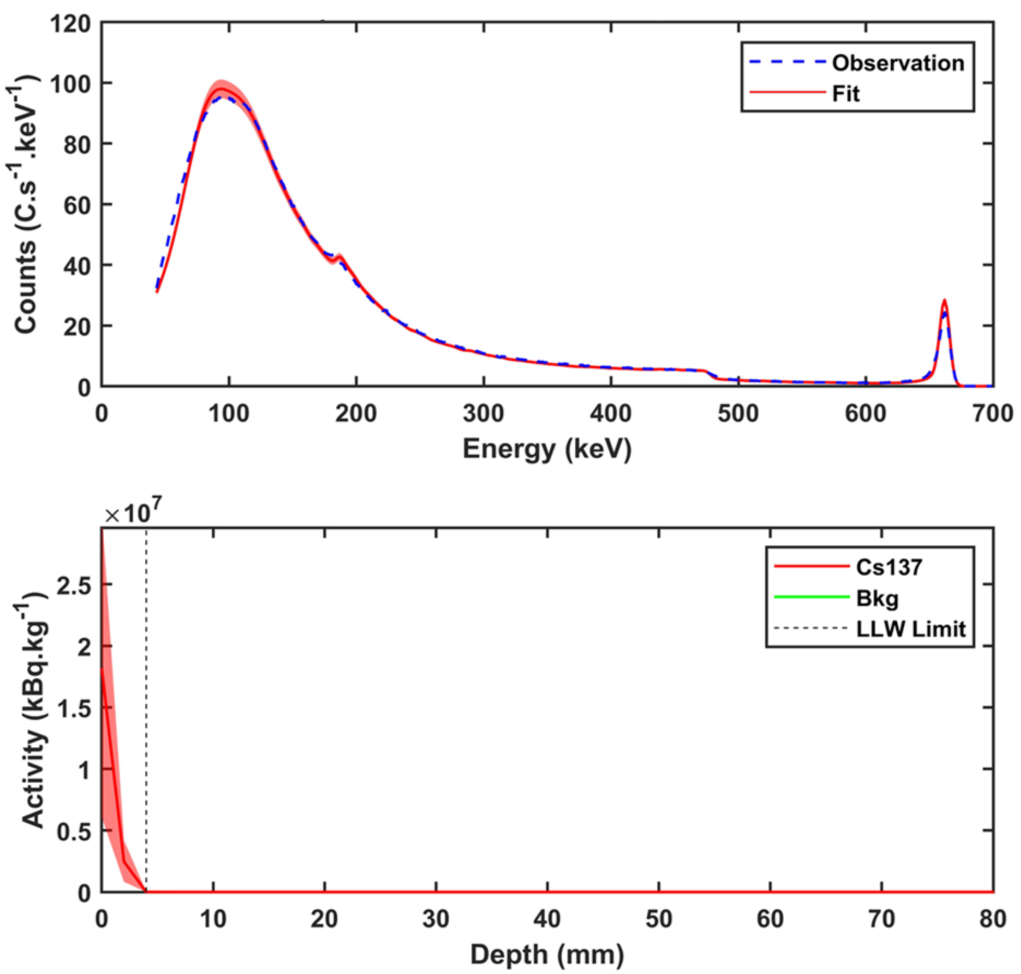
Theory of Operation

What is D:EEP?
Software - Output



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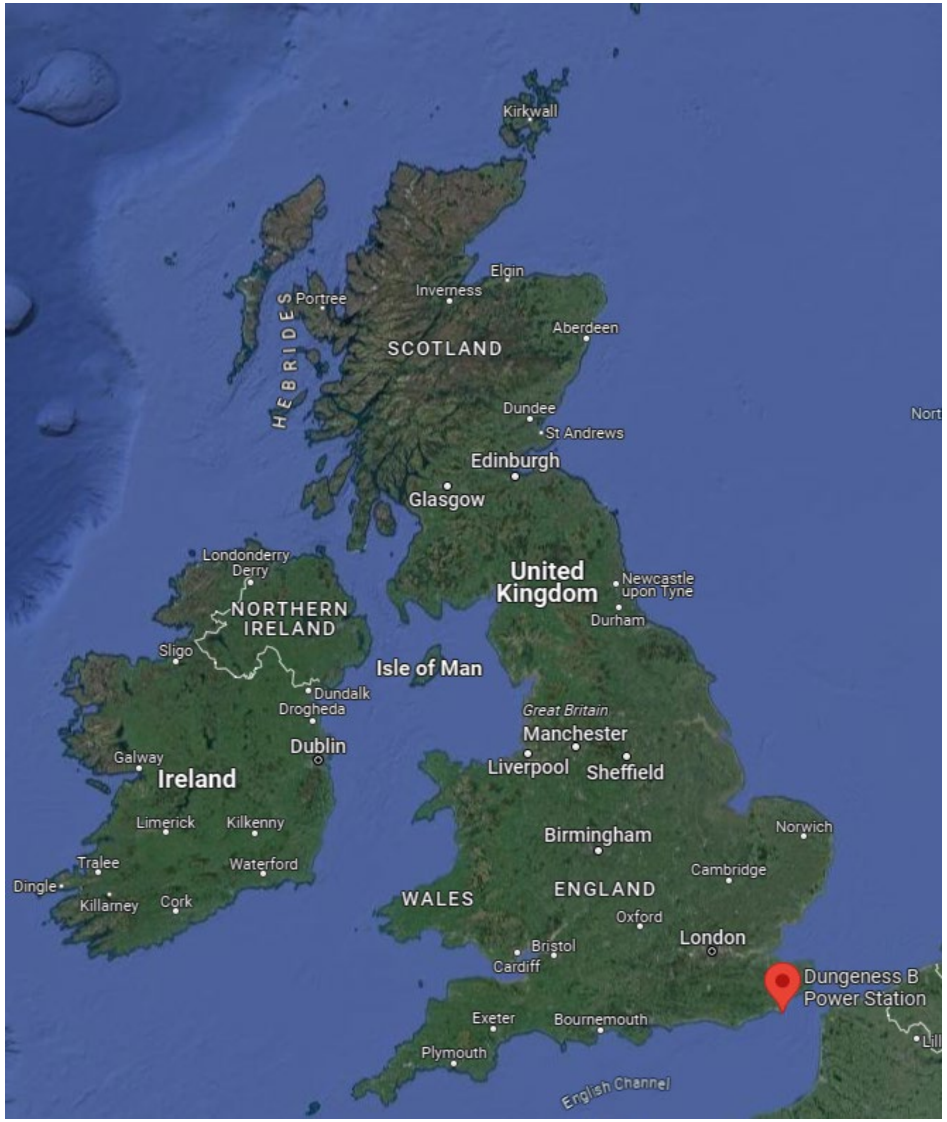
Theory of Operation

EPRI

Case Study - DNB
EDF Dungeness B Ponds Trial



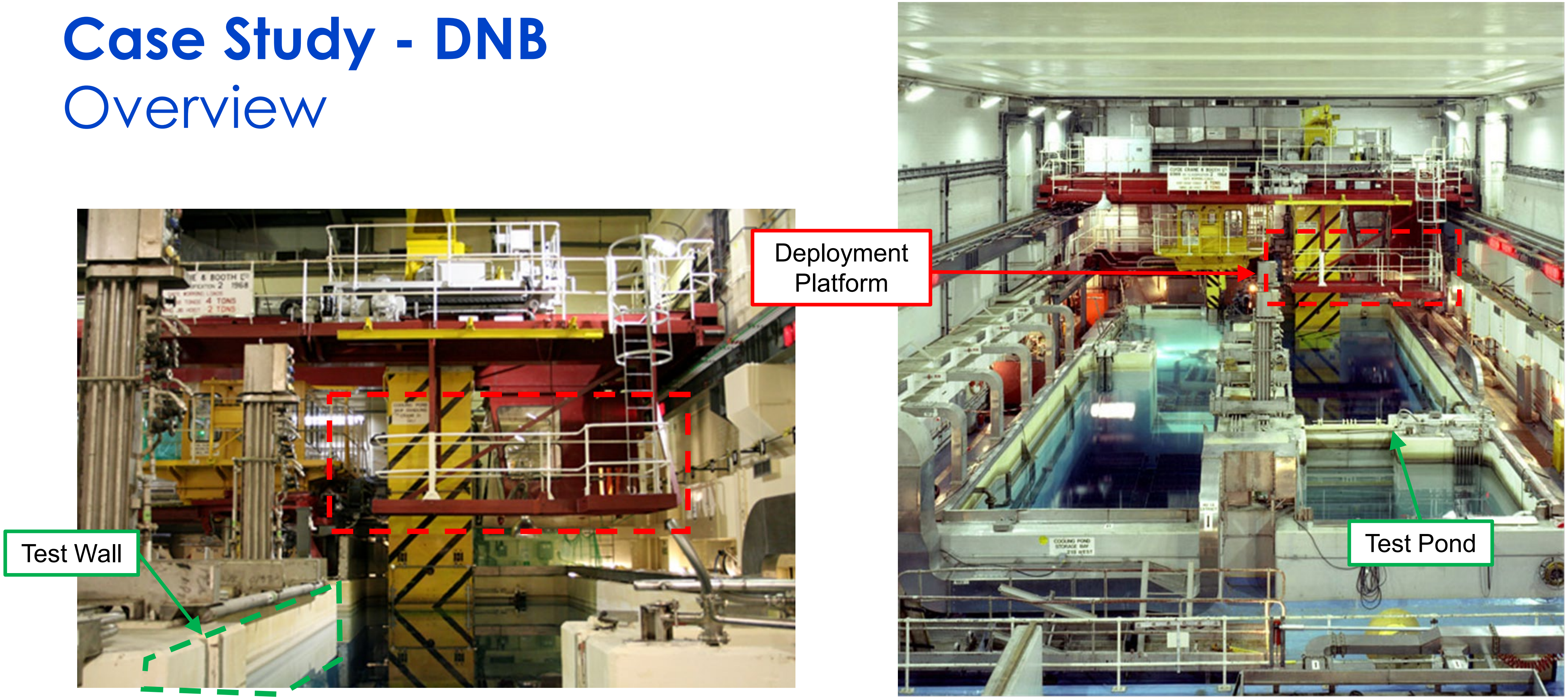
Dungeness Site:

- ❑ EDF owned, Advanced Gas Reactor, currently undergoing defueling.
- ❑ Operational from 1983 to 2021.
- ❑ Located in Dungeness, England.
- ❑ EDF need to estimate waste before hand over to NDA
- ❑ Cannot do destructive core sampling as the pond is in use

Project Details:

- ❑ Requirement to characterise contamination ingress in the concrete walls of a fuel storage pond.
- ❑ Pond will be active during measurements, with potential for fuel to be present.
- ❑ New design required for the D:EEP housing to enable wet deployment with remotely operated background shield.

Case Study - DNB
Overview



The EDF Dungeness B Fuel Storage Pond showing the wall of interest in the red dotted area and the platform used to deploy the D:EEP sensor.

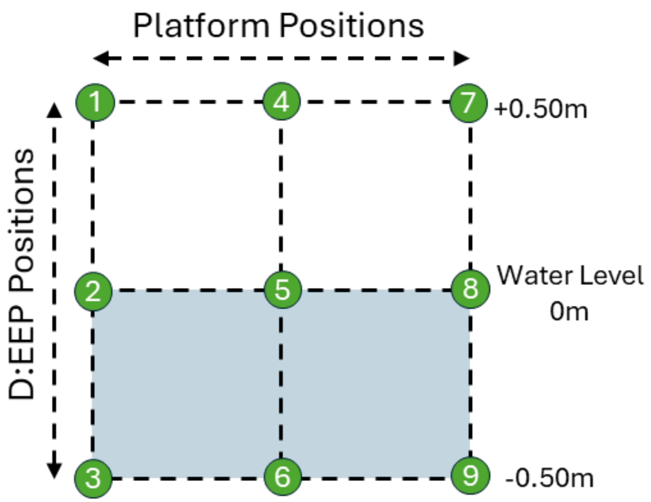
Deployment Area

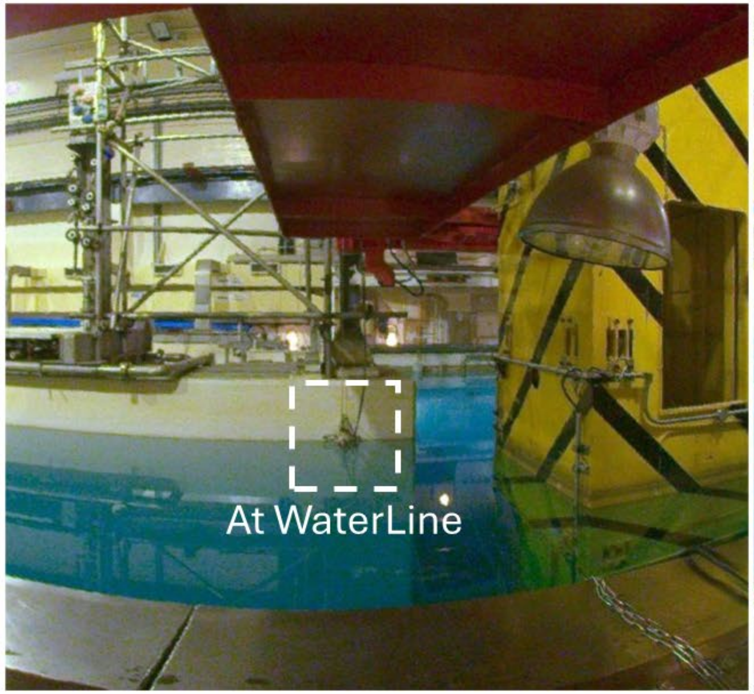
Case Study - DNB
Overview

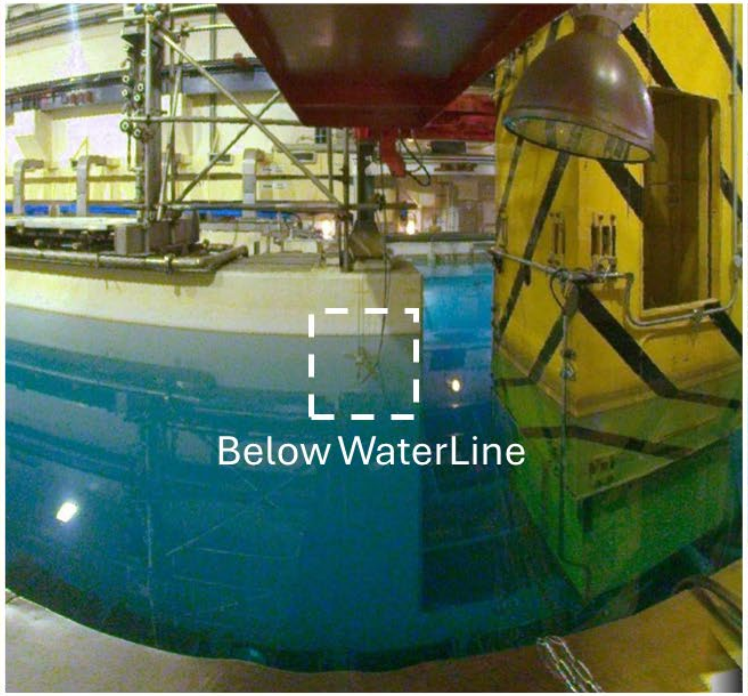
The EDF Dungeness B Fuel Storage Pond showing the wall of interest in the red dotted area and the platform used to deploy the D:EEP sensor.

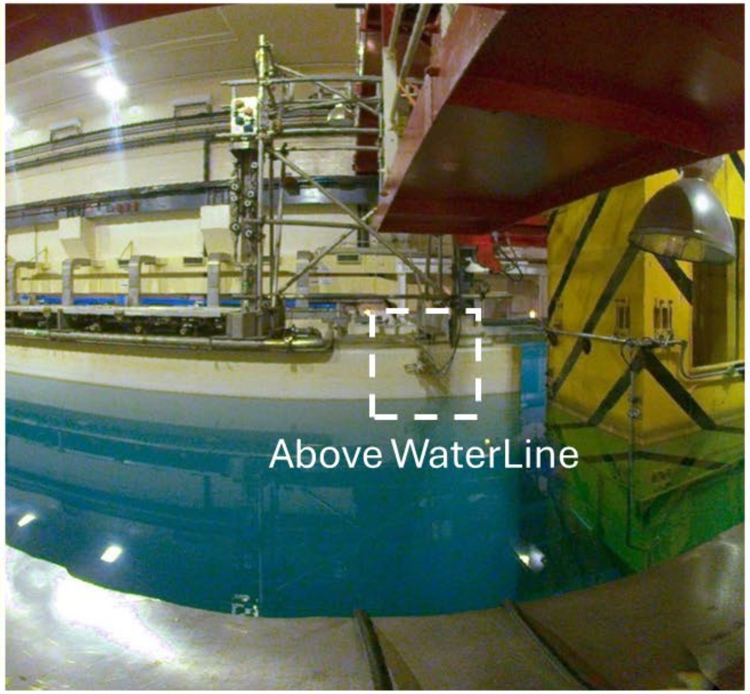
Case Study - DNB
Measurements

- ❑ D:EEP sensor deployed above, at, and below the waterline.
- ❑ Background + signal measurements taken at 9 locations.
- ❑ LiDAR scans performed to map the environment.









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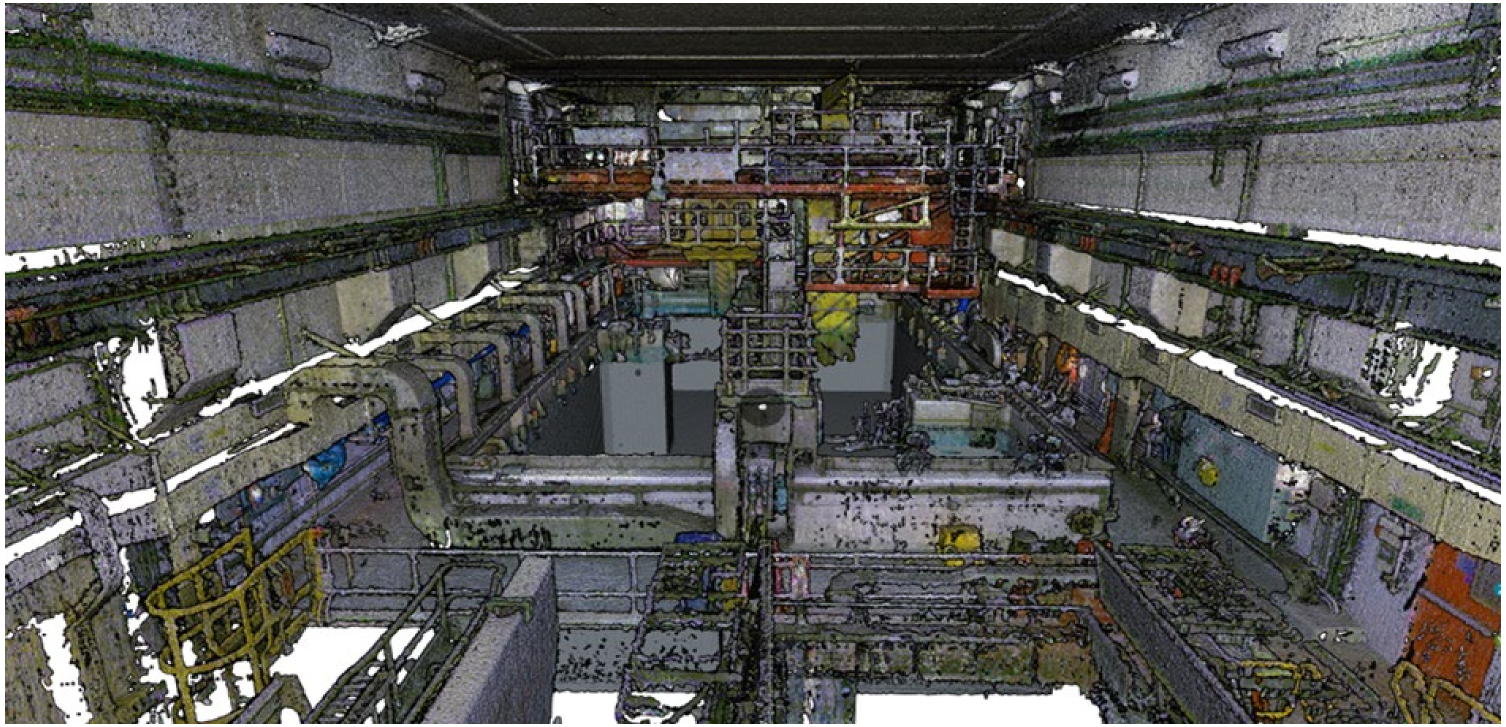
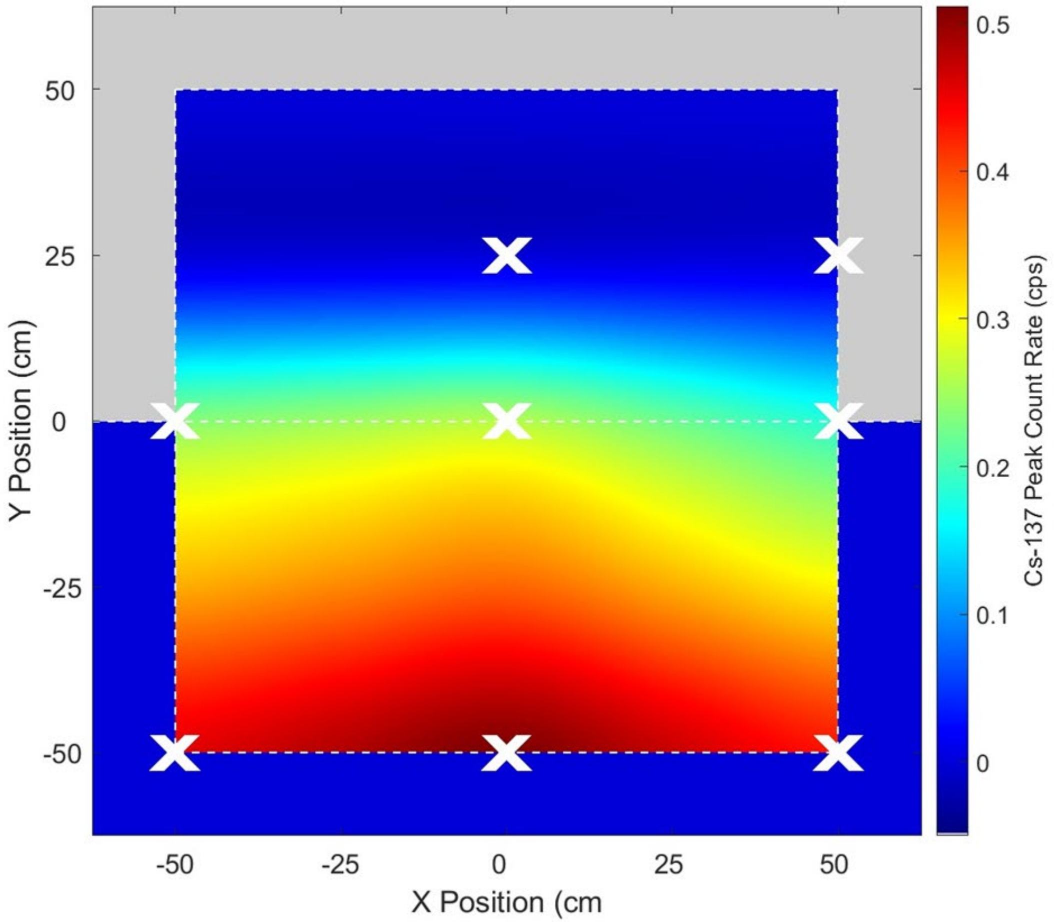


Case Study - DNB
Results

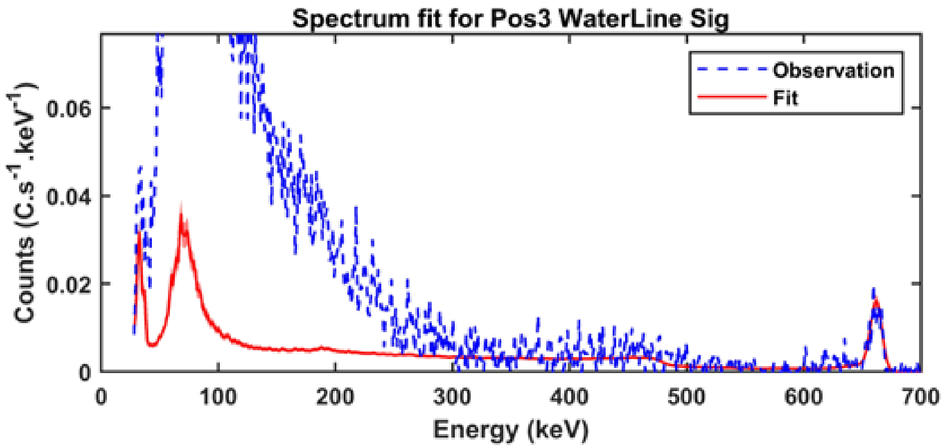
- ❑ Minimal activity present in the pond walls.
- ❑ Activity elevated below the surface relative to above.
- ❑ Lateral uniformity in count rates.
- ❑ Limited contamination ingress.
- ❑ Contamination restricted to the surface paint layer.

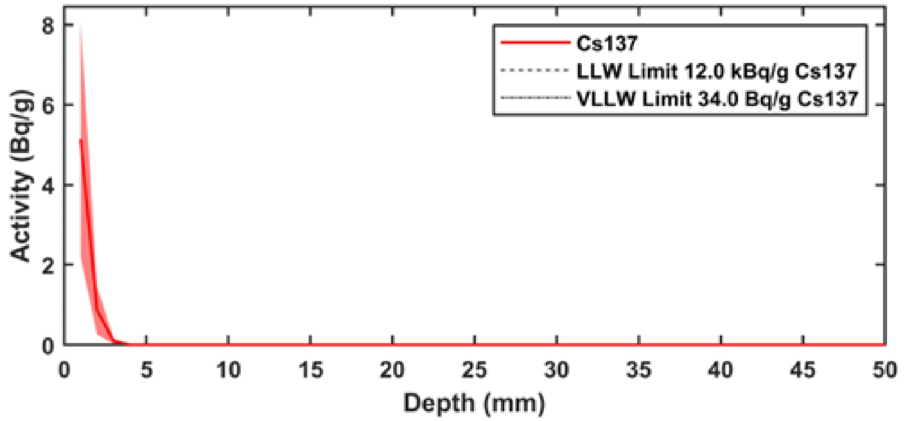


Results allow Interpolation of Data to Provide Potential Contamination Maps

Case Study - DNB
Results

- ❑ Minimal activity present in the pond walls.
- ❑ Activity elevated below the surface relative to above.
- ❑ Lateral uniformity in count rates.
- ❑ Limited contamination ingress observed.
- ❑ Contamination restricted to the surface paint layer.

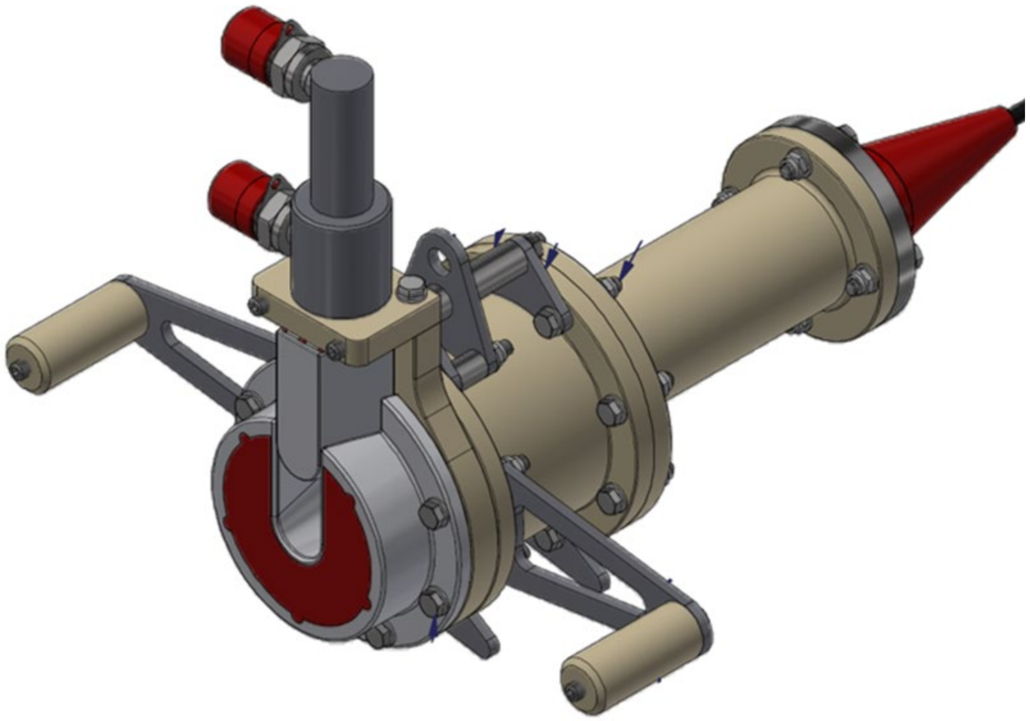




No Contamination Ingress Detected Supporting the Assumption of Paint Layer Integrity

Conclusion
D:EEP

- D:EEP offers a potentially novel approach to non-destructive depth profiling of cementitious materials, supplementing existing sampling technologies.
- Conducted proof of concept demonstration of physical deployment in a Spent Fuel Pool (SFP) above and below the waterline.
- LiDAR represents a novel method of data evaluation and visualization for future projects.
- Through proper characterization, D:EEP may enable cheaper, faster, and safer decommissioning.
- **Further work required to determine efficacy of approach as a measurement method.**



Thank You
Any Questions?

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