In-Situ Monitoring and Characterisation of the Radioactive Sludge in the Legacy Ponds and Silos at Sellafield

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Highlight of Presentation

- The Problem Definition
- The Available Solutions
- The Proposed Solution
- Further Works
- Conclusion
- References

The Problem: Definition

- The legacy silo is a one-metre thick wall enclosure of radioactive sludge and is to be evacuated by a mechanical equipment.

Figure 1: Magnox Swarf Storage Silos at Sellafield [1]

- Every volume of sludge in the region to be evacuated needs to first be scanned for the presence of gas pockets, metals, concrete materials, temperature and potential hazards.

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The Problem: Task

- To obtain a 3D characterisation map of density distribution, temperature and material identification of the sludge volume to a depth >15 cm and 3 mm resolution.

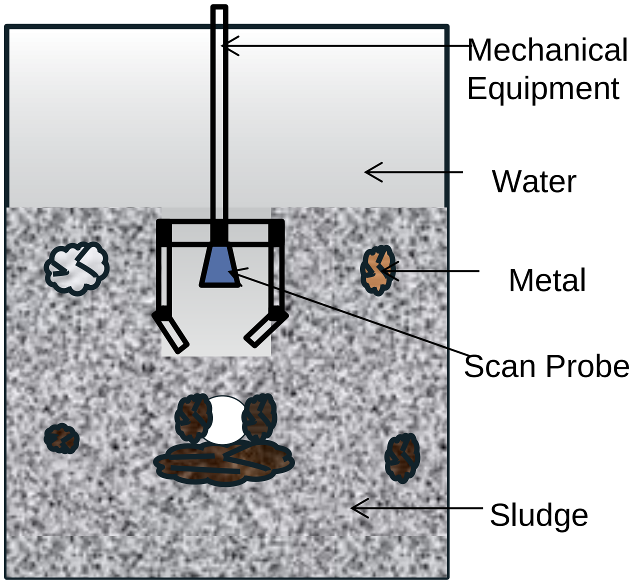


Figure 2: Schematic diagram showing deployment

- To design an invasive tomographic imaging system that will be attached to the mechanical equipment and operate from one side of the investigated volume.

Available Solutions: Overview

- Tomographic imaging involves illuminating an object by an energy source, and obtaining information from the energy projections [2].

Transmission	Reflection	Emission
Muon	Acoustic Backscattering	Positron
Ultrasonic		SPECT

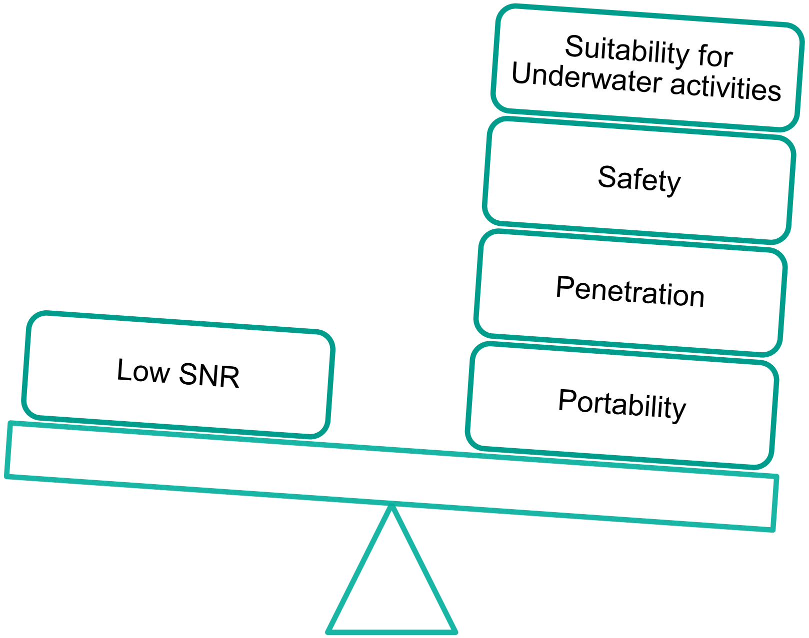
Available Solutions: Techniques

Table 1: Comparison of some Tomographic techniques

	Principle of Operation	Example of Applications	Limitation
X-Ray Backscattering Tomography	Compton scattering at interactions	underwater naval dome inspection [3]	Penetration is limited by thickness and inhomogeneity
Ground Penetrating Radar	Reflections at dielectric boundaries	Detection of landmine and underground water leakages [6]	Accuracy depends on dielectric contrast at boundaries
Vibrational Spectroscopy and LIDAR systems	Light absorption and scattering	detection and identification of underwater submarines [5]	High light scattering and absorption affect penetration [4]
Magnetic Field Technology Systems	Electromagnetic Induction and Interference	Two-phase flow process imaging and for metallic mine detection [8].	Preferred for detection than identification.
Acoustic Backscattering Systems	Sound scattering at acoustic boundaries	Settling suspension and velocity profile inspection in ponds [7]	Low Signal to Noise Ratio due to Multiple Scattering

The Proposed Solution

- **Acoustic Backscattering Tomography** is considered most viable, and will be investigated further



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The Proposed Solution: Operation?

$$R = \left(\frac{z_1 - z_2}{z_1 + z_2}\right)^2 \quad (1)$$

$$T = 1 - R \quad (2)$$

Where; R – sound power reflection coefficient; T – sound power transmission coefficient; z_1 – Acoustic impedance of medium I; z_2 – Acoustic impedance of medium II

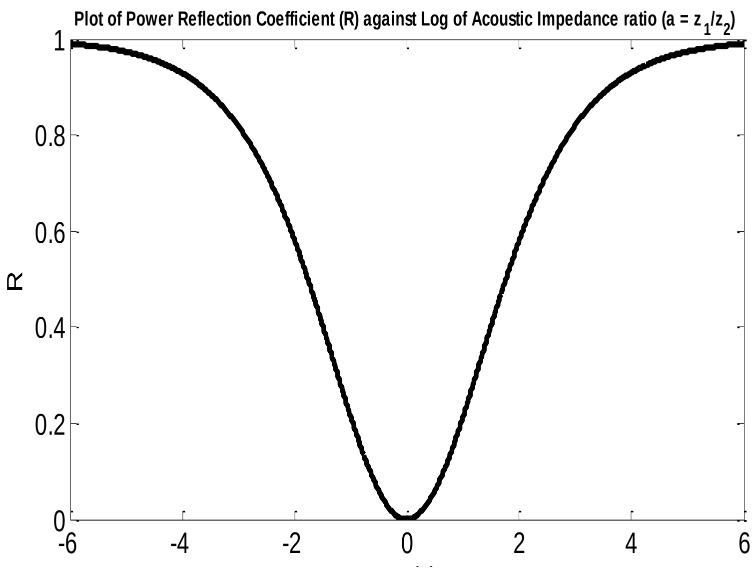

Fig 4:Plot of R against Log (a) where $a=z_1/z_2$

Table 2: R values for various Acoustic Boundary cases

Power Reflection Coefficient at Acoustic Boundaries	Magnesium Sludge (z=21.5MRayl)	Concrete (z=8 MRayls)	Steel (z=45.7 MRayls)	Water (z=1.48 MRayls)
Air (z=0.0004)	0.9999	0.9998	1.0000	0.9989
Water	0.7590	0.4730	0.8785	
Steel	0.1297	0.4929		
Concrete	0.2094			

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The Proposed Solution: Operation?

Given z_1 = 5.58286, z_2 = 8.2626, z_3 = 46.13 and z_4 = 8.2626 MRayls

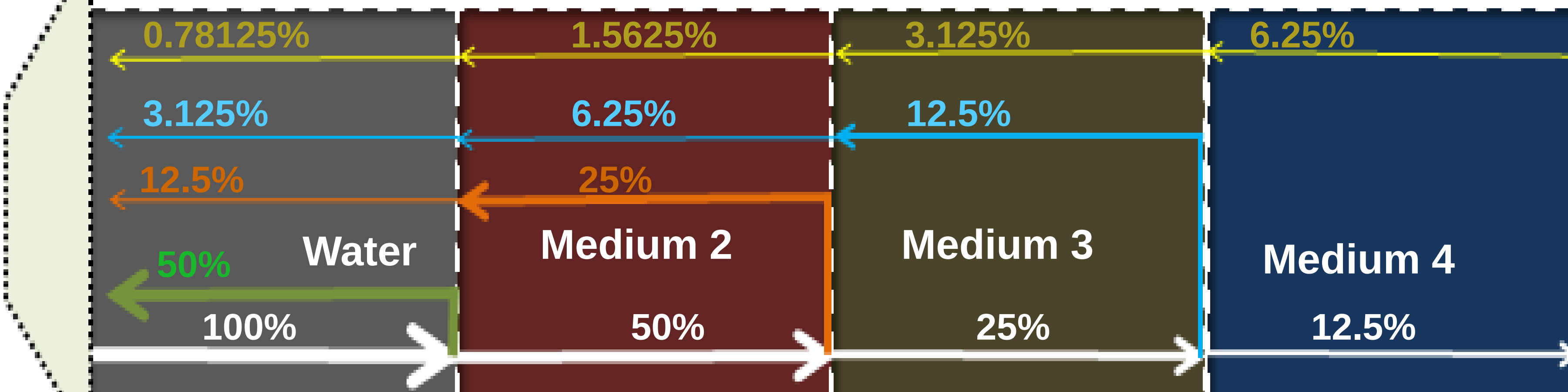
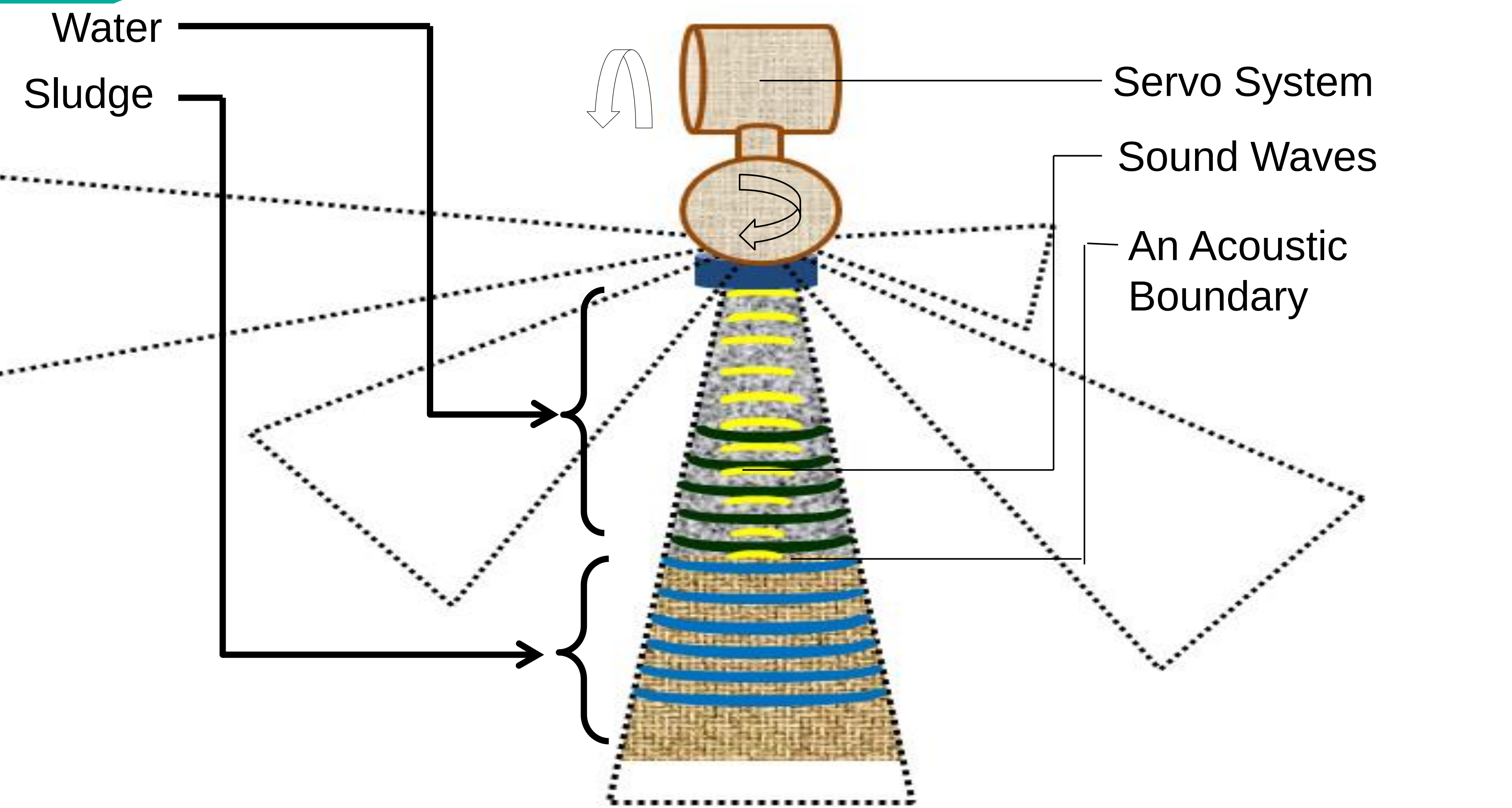
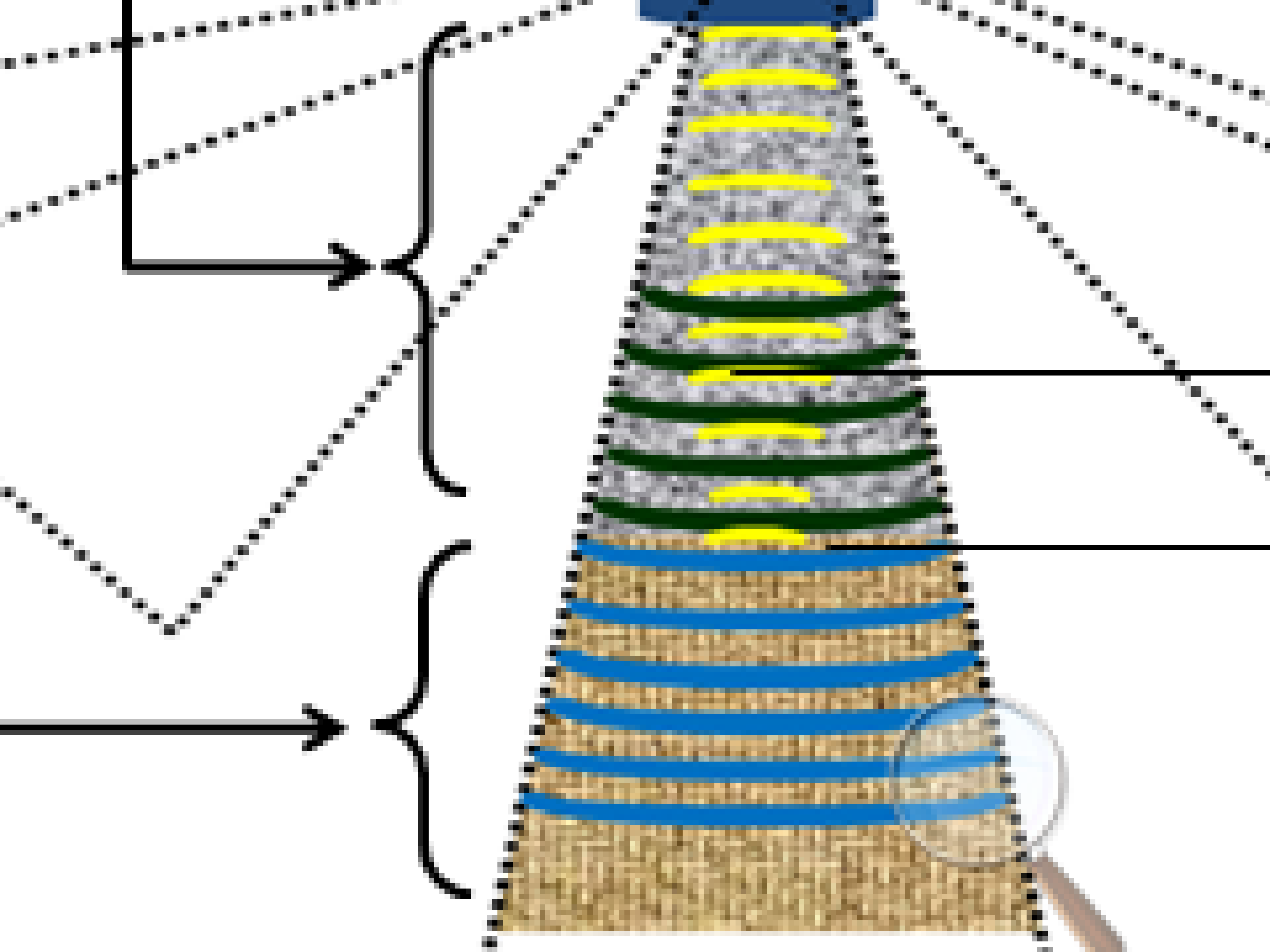


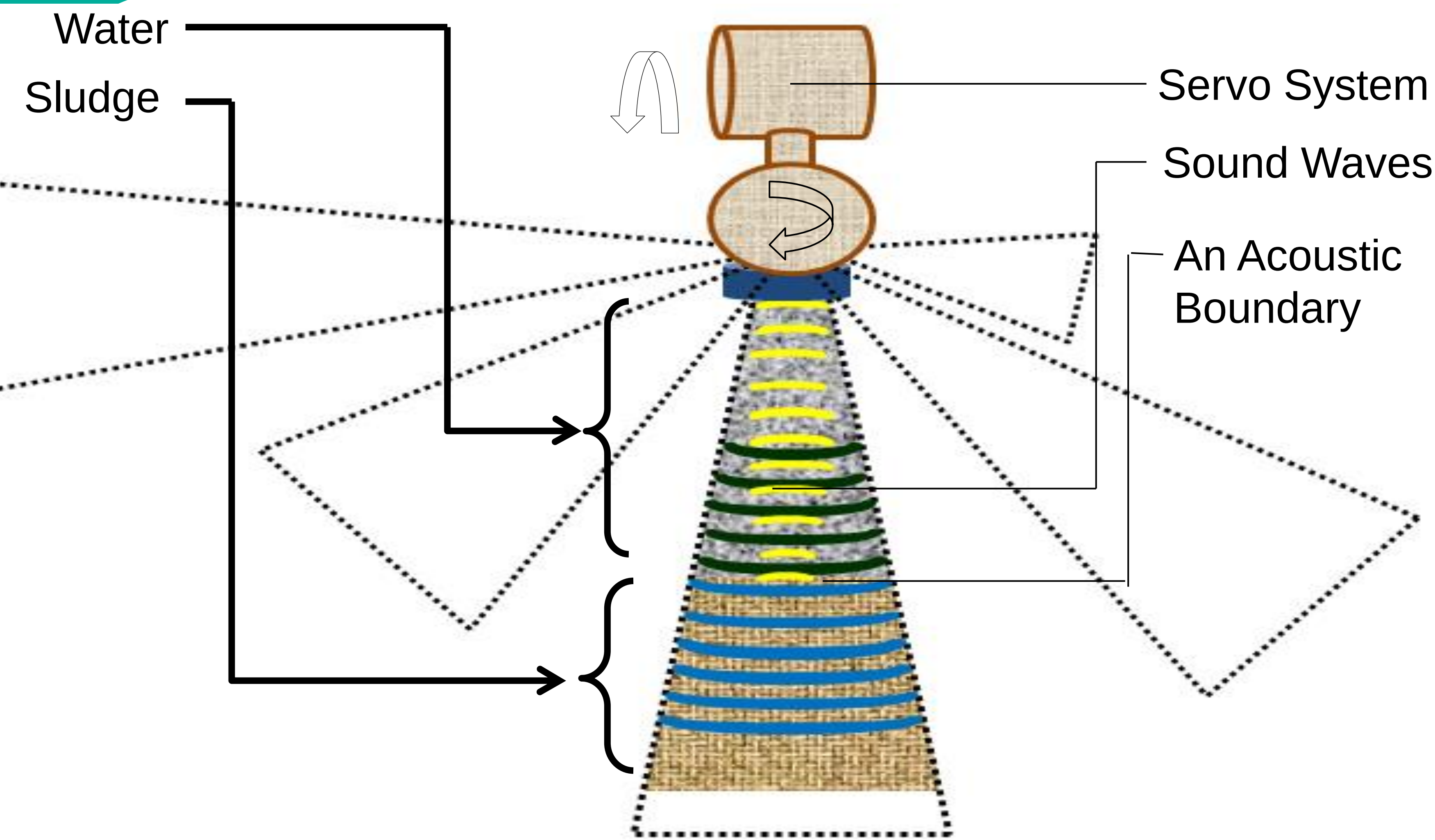
Figure 5: Schematics showing scattering at acoustic boundaries

The Proposed Solution: Deployment?





The Proposed Solution: Deployment?



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The Proposed Solution: Challenges?

- Improving the Signal to Noise Ratio (SNR)
- Attaining about 3 mm spatial resolution
- Understanding the worst case scenario
- Ensuring radiation tolerance

Further Works

- Laboratory experiments on:
  - Understanding the acoustic attenuation in water, sludge, metal, gas and concrete samples.
  - Understanding the acoustic backscattering profile for boundary samples.
- Development of a:
  - servo motor control circuit to coordinate scanning,
  - sound transducer circuit to transmit and receive signals
  - reconstruction algorithm to interpret the data.

Conclusion

It will be great to have a device inside the silo that provides us with sufficient information about the radioactive sludge before and during evacuation.

We are working to make this happen.

Thank You

References

[1] Magnox Swarf Storage Silos http://www.sellafieldsites.com/solution/risk-hazard-reduction/magnox-swarf-storage-silos/, Date accessed: 18/03/2015 10:37pm.

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