University of BRISTOL

SOUTH WEST NUCLEAR HUB

Next Generation Radiation Detection Infrastructure and Algorithms for Application at Seaports: PhD Progress

Euan Connolly

#SWNuclearHub

In partnership with NRC

The **South West Nuclear Hub** incorporates the **Bristol-Oxford Nuclear Research Centre** (NRC)
www.southwestnuclearhub.ac.uk
sw-nuclearhub@bristol.ac.uk

The problem: Illicit transportation of radioactive materials

- Demand exists for illicit radioactive materials
- ~80% of world goods transported by sea
- Detection and deterrence capability needed at seaports

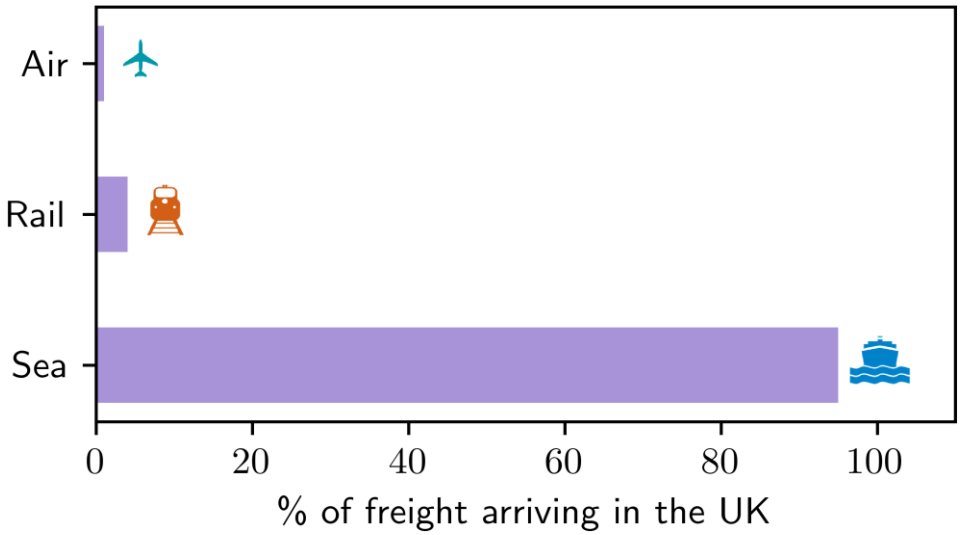


Figure 2: Great Britain's freight imports 2020[2].

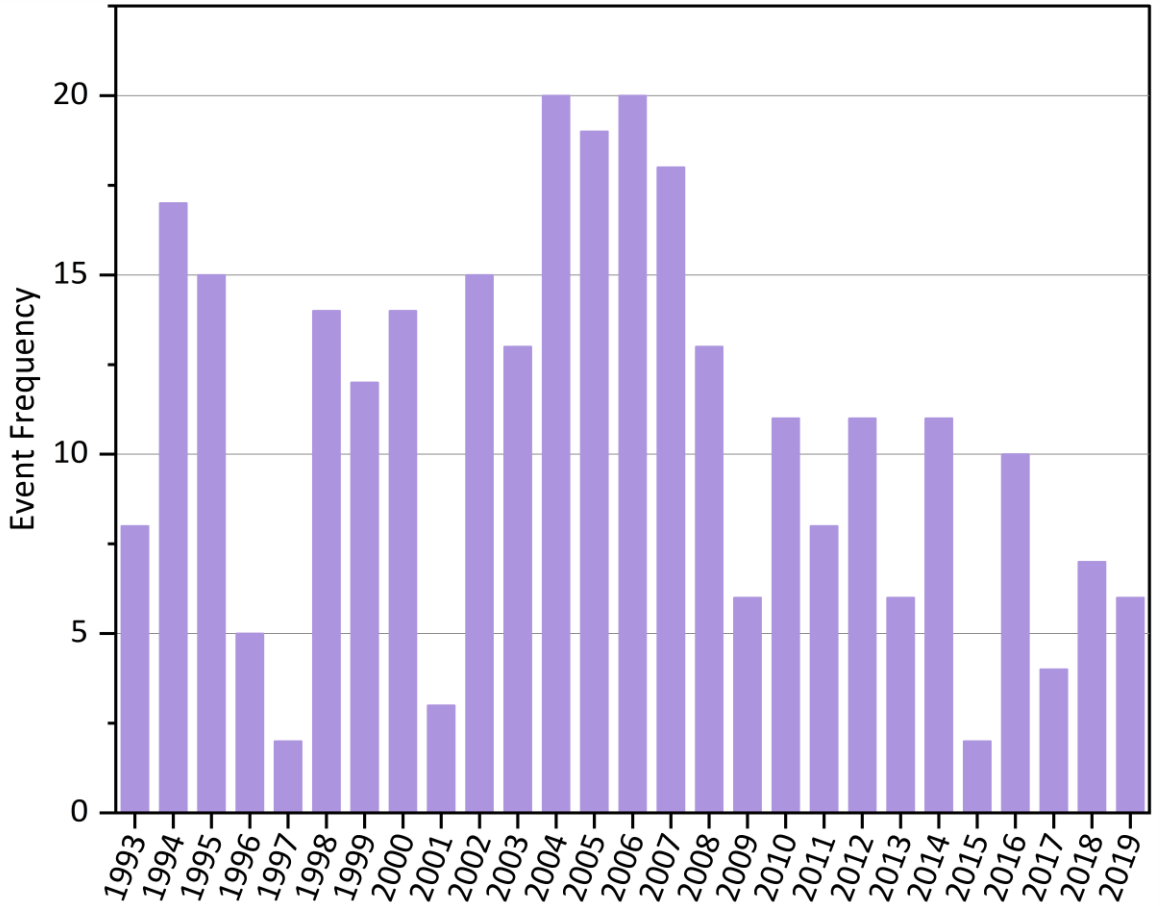


Figure 1: Incidents of trafficking or malicious use of nuclear/radioactive material reported to the IAEA Incident and Trafficking database[1].

[1] International Atomic Energy Agency, *IAEA Incident And Trafficking Database.* Available at Incident and Trafficking Database (ITDB) | IAEA
[2] Transport Statistics Great Britain 2020, *Department for Transport.* Available at Transport Statistics Great Britain 2020 (publishing.service.gov.uk)

Shipping container screening: Current systems

- Radiation Portal Monitor (RPM) based screening
- Difficult to identify false alarms

Figure 3: Shipping container mounted on flat-bed truck driven through RPM[3].

Figure 4: Cat litter, a common NORM.

Stage 1 – 'Trip-wire'

RPMs using plastic scintillators

High cross-section, cheap, low resolution

Separate n detector (^{3}He)

Stage 2 – Verification

NaI(Tl) or $LaBr_3(Ce)$ detectors

Characterise and locate

[3] Photo Truck passes through a radiation portal monitor at Port of Newark Stock Photo - Alamy

Improving RPM performance with image reconstruction

- Improve source localisation with RPM using image reconstruction techniques

1. Simulate the response function of the RPM
2. Measure (or simulate) RPM measurements with different source distributions
3. Use MLEM image reconstruction methods to determine the source distribution

- Currently using this method with different cargo types, sources and reconstruction algorithms

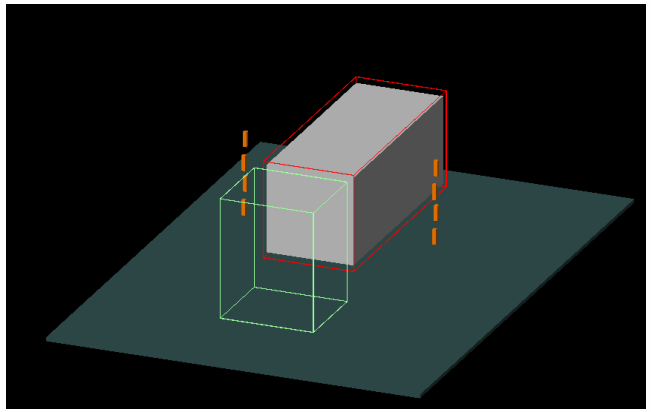


Figure 5: Shipping container (red) with cargo (silver) modelled in GEANT4. Cab (green) and NaI crystals (orange) of an RPM are shown.

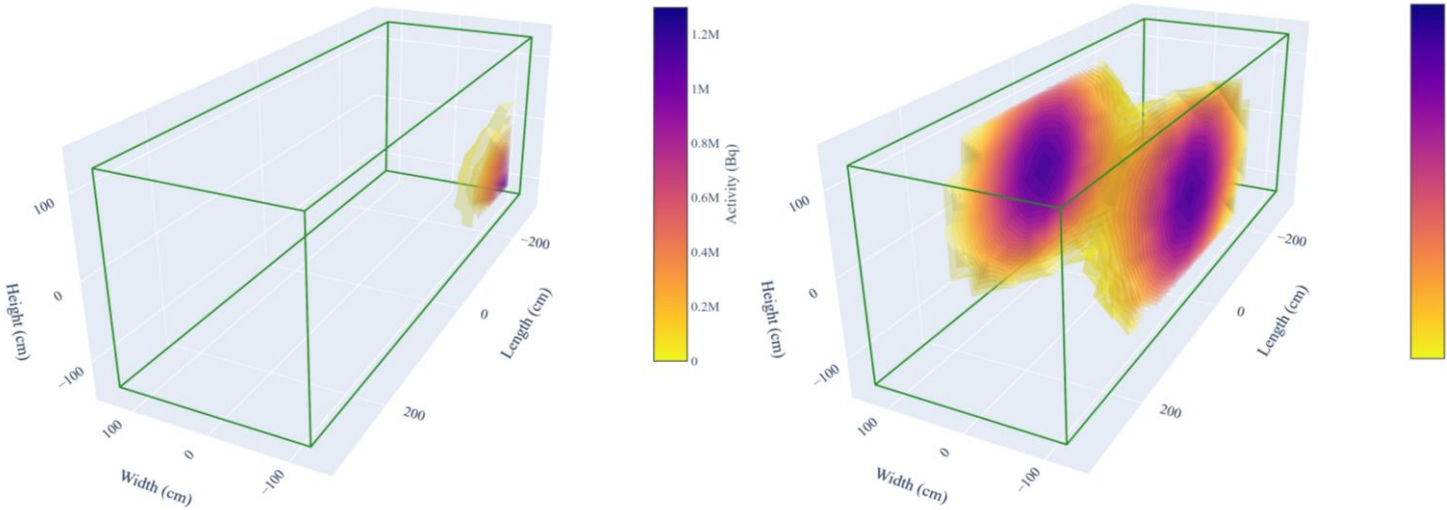
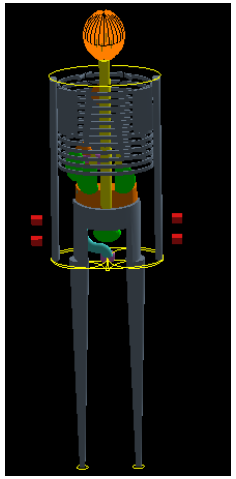


Figure 6: Reconstructed source distribution when 10 MBq 662 keV source was in the corner (left) and center (right) of the shipping container.

Image reconstruction techniques with other infrastructure

- By simulating response functions, image reconstruction techniques can be used with different detector configurations

- Scaled down proof of principle of using crane mounted detectors to localise sources



- Trailing with other detection systems, including waist or drone mounted detectors

Figure 10: GEANT4 simulation of portable waist detectors mounted on a researcher for radiation mapping.

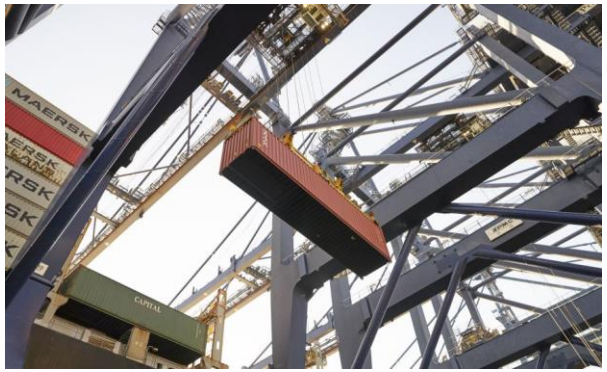


Figure 7: Port lifting equipment transporting shipping containers.

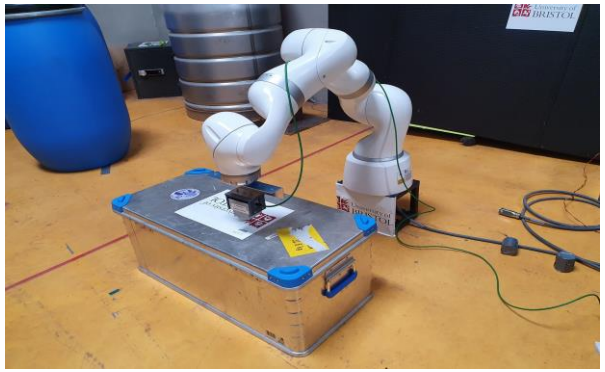


Figure 8: Scaled down version of crane mounted detectors screening a box.

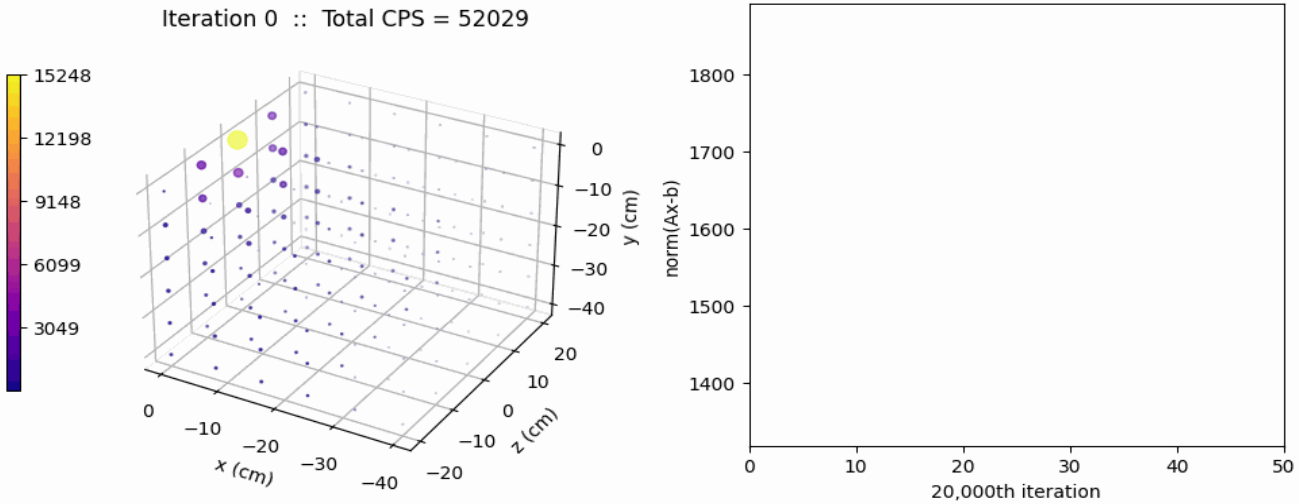


Figure 9: Reconstructed solution (left) and convergence plot (right) of source in scaled down box using ART reconstruction method. Source is halfway up the box. on the left hand side, localisation error is <6 cm.

Port-wide detector networks

- Attach detectors to port infrastructure in a distributed network
- Continuous radiation mapping & GIS integration
- Optimisation of detector size and position needed

Figure 11: Port of Felixstowe. Regular grid layout of shipping containers.

Figure 12: Small modular detectors can be used in portable mapping systems.

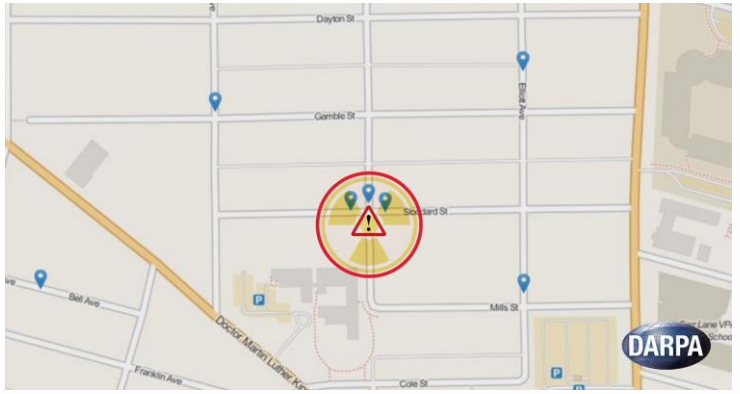


Figure 13: DARPA SIGMA project.

Bristol distributed network pilot

- Pilot project around University of Bristol precinct

Figure 14: Example modular mapping units with 3.8x3.8x2.5 cm CsI(Tl) scintillator detectors (Hamamatsu) .

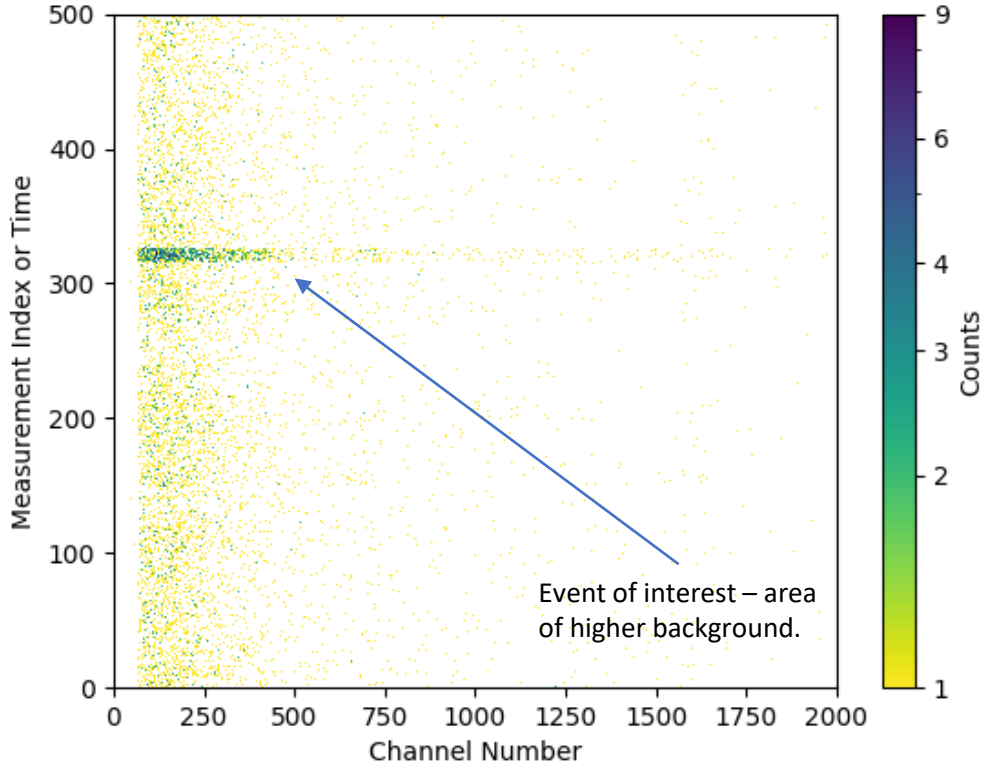


Figure 15: 1000 measurement sample of the UoB dataset from 13/06-16/06. White pixels are zeros.

- Data processing needed to identify anomalies from complex varying background signal

- Principle component analysis used to identify modes of variation in typical background spectra