IAEA Activities in Support of Radiological Site Characterization

Emerging Technologies

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Nuclear Science and Instrumentation Laboratory

International Atomic Energy Agency

International Atomic Energy Agency

An autonomous international organization within the United Nations system

The Department of Nuclear Science and Applications (NA)

NA Department

- Human Health
- Physical & Chemical Sciences (NAPC)
- IAEA Environmental Laboratories

NAPC Division

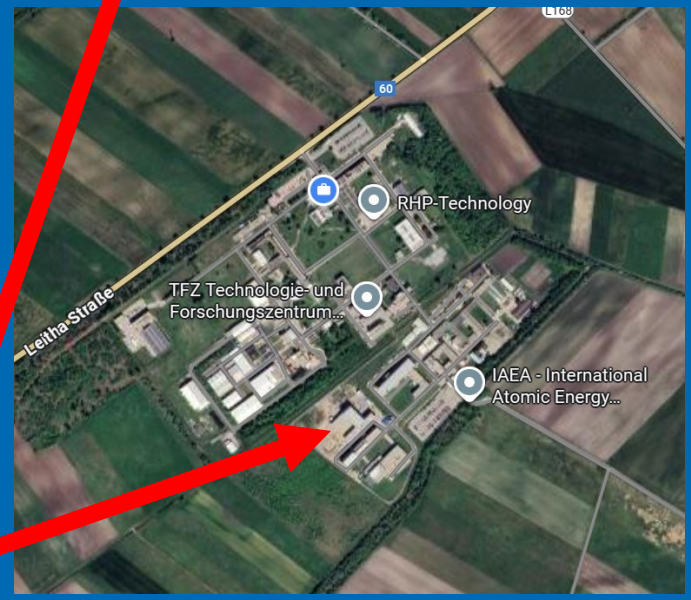
- Radioisotopes and Radiation Technology Section
- Physics Section
- Nuclear Data Section
- Isotope Hydrology Section

Physics Section

- Research Reactors
- Fusion
- Nuclear Instrumentation
- Accelerators

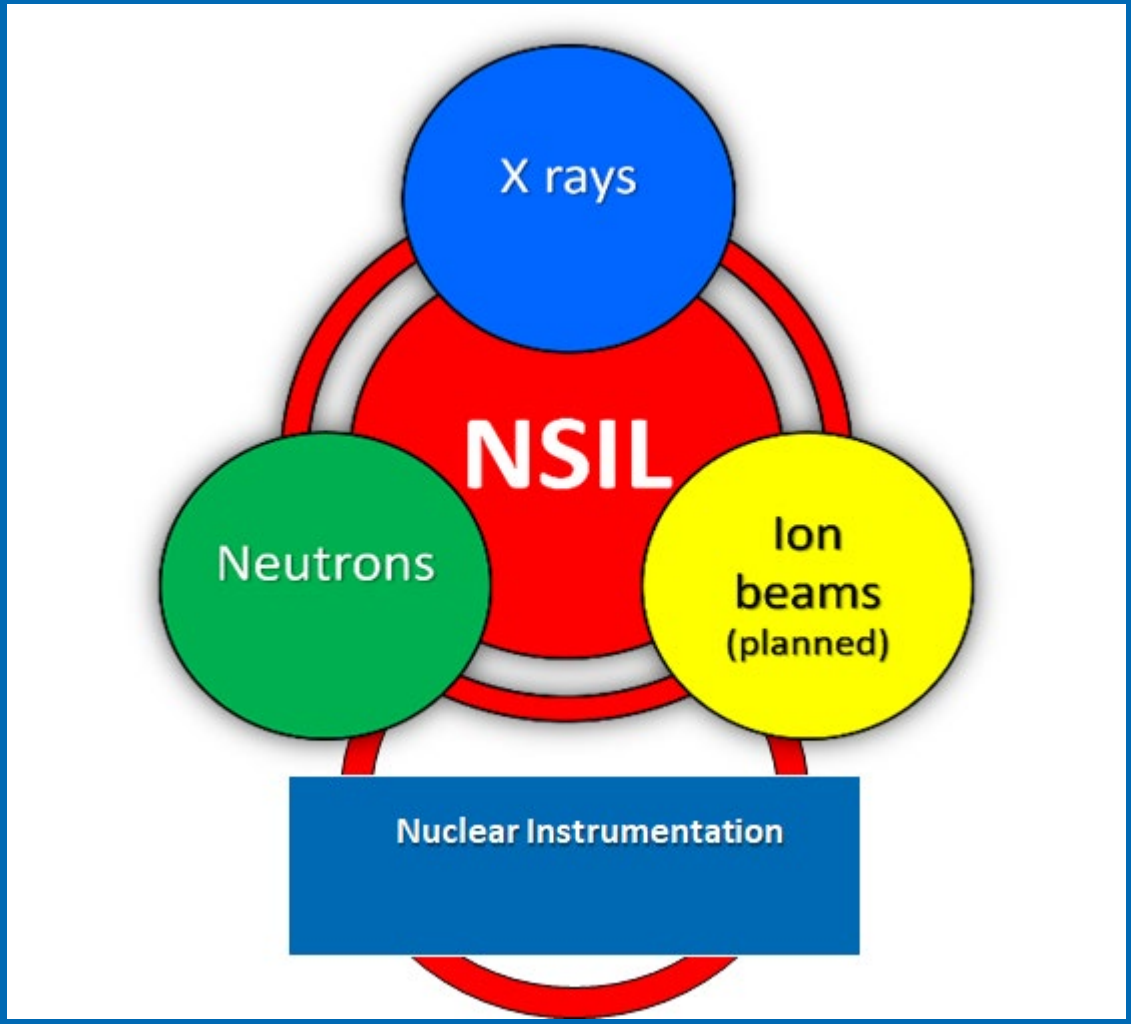
NSIL Lab Seibersdorf

- **Staff:** 21 positions, 11@HQ & 10@Seibersdorf,
- + consultants, interns, fellows; TOTAL: ~30-35
- **Budget:** ~4M Euros RB under 4 sub-programmes



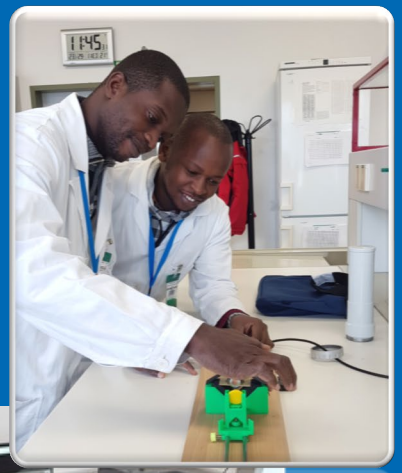
Nuclear Science & Instrumentation Laboratory - NSIL

Mission:
assisting Member States in introducing and extending the use of nuclear instrumentation and radiation measurement techniques, including related capacity building

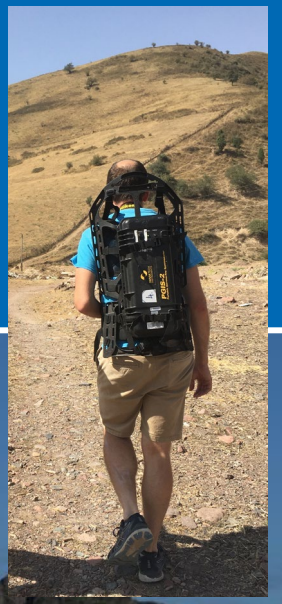


Nuclear Instrumentation

Laboratory Techniques



Portable Measurement



NSIL has long-standing experience in development and application of instrumentation techniques for in-situ measurements

Portable HPGe Detectors

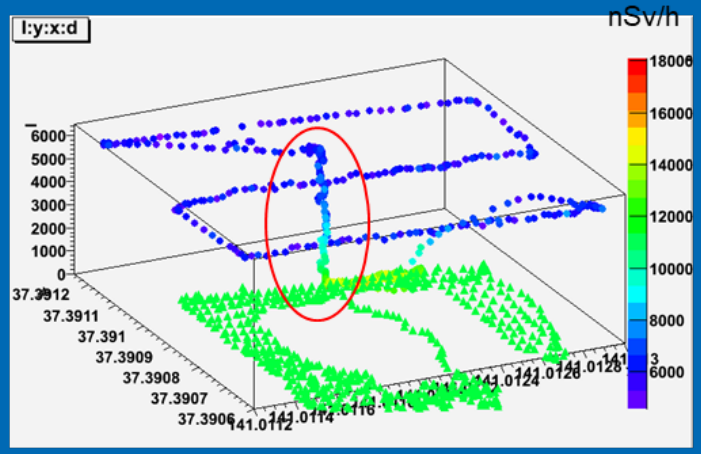
Backpack Detectors

Uncrewed Aerial Systems

Support to Fukushima Prefecture (Japan)

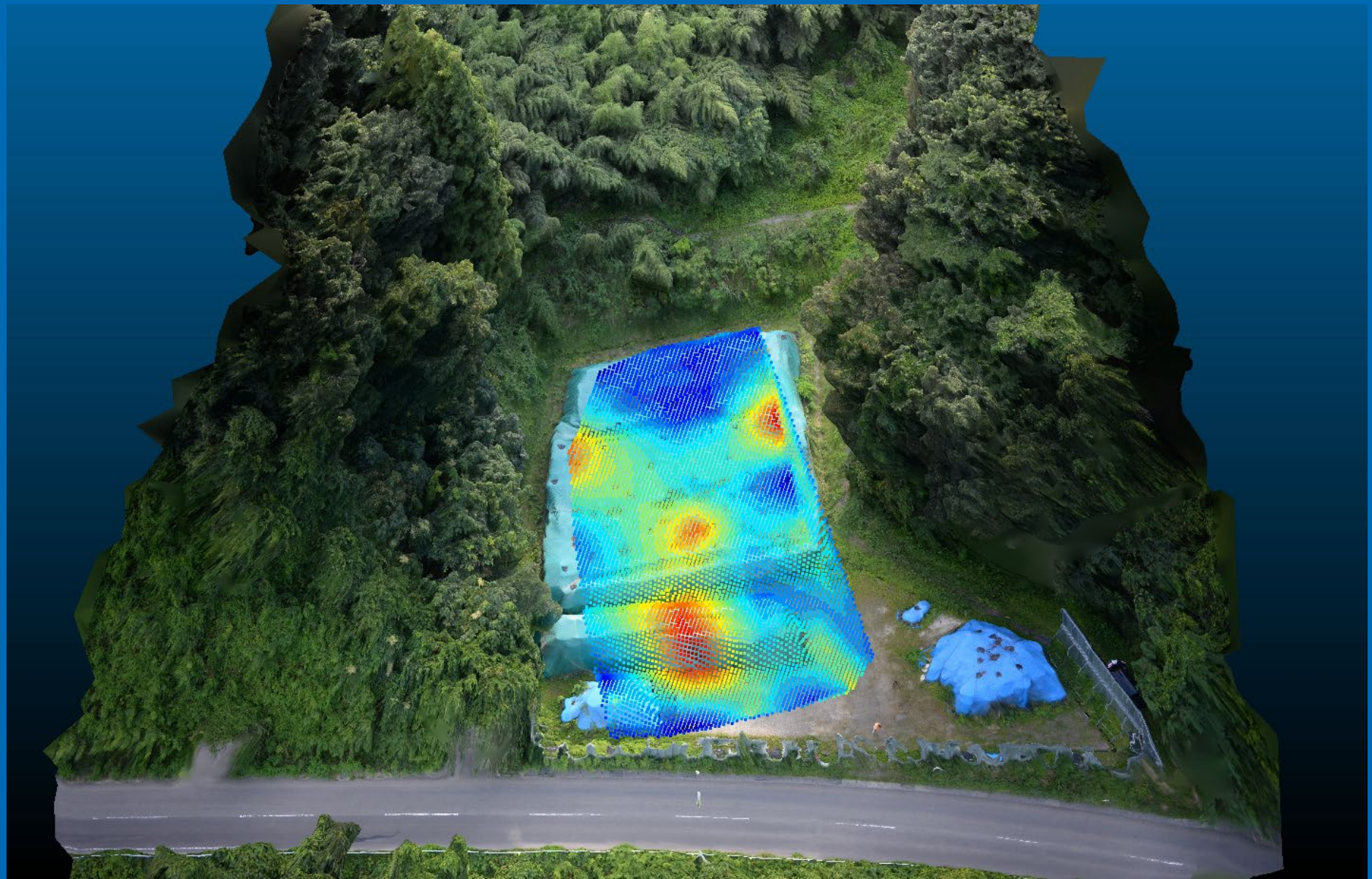
Developed/adapted hardware/software

Developed methodology



A number of trial measurements completed

Photogrammetry



Full 3D aerial photogrammetry superimposed with a radiological map was obtained using the same UAV in two consecutive flights

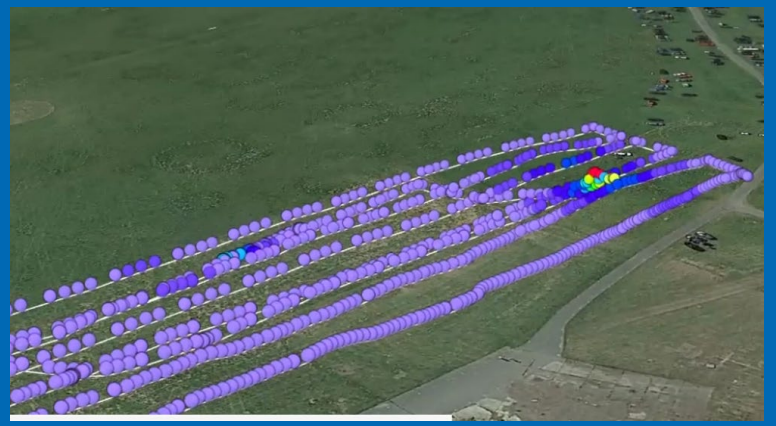
Technical Meeting on the Use of Uncrewed Aerial Systems for Radiation Detection and Surveillance

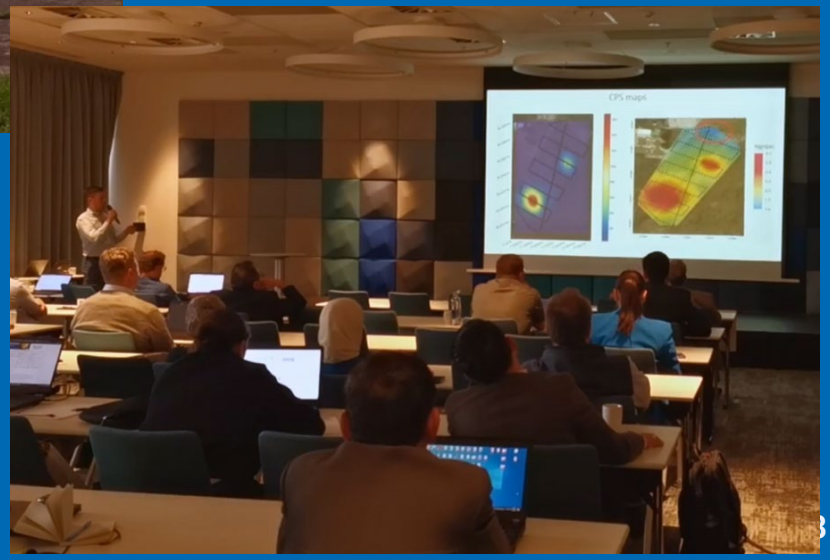
Brno, Czech Republic
26 -30 September, 2022

~120 participants from >50 countries
~ 40 presentations
1 day with practical
demonstrations at the local airport

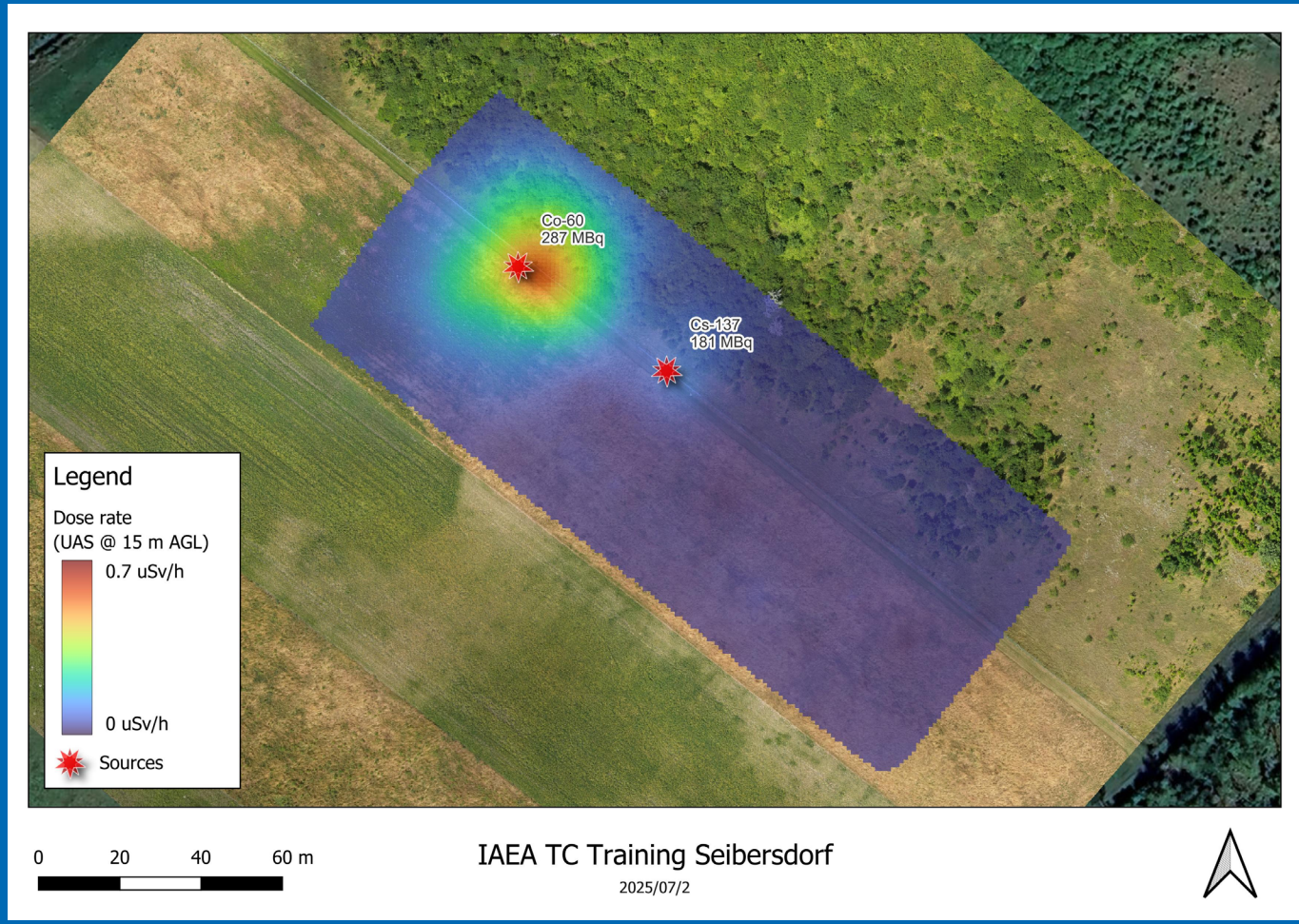
Topics included:

- Radiation Sensors
- Processing and Data Transmission
- Development & Experiences
- Operational, Legal, and Policy Considerations
- Lessons Learned
- Supplementary Sensors





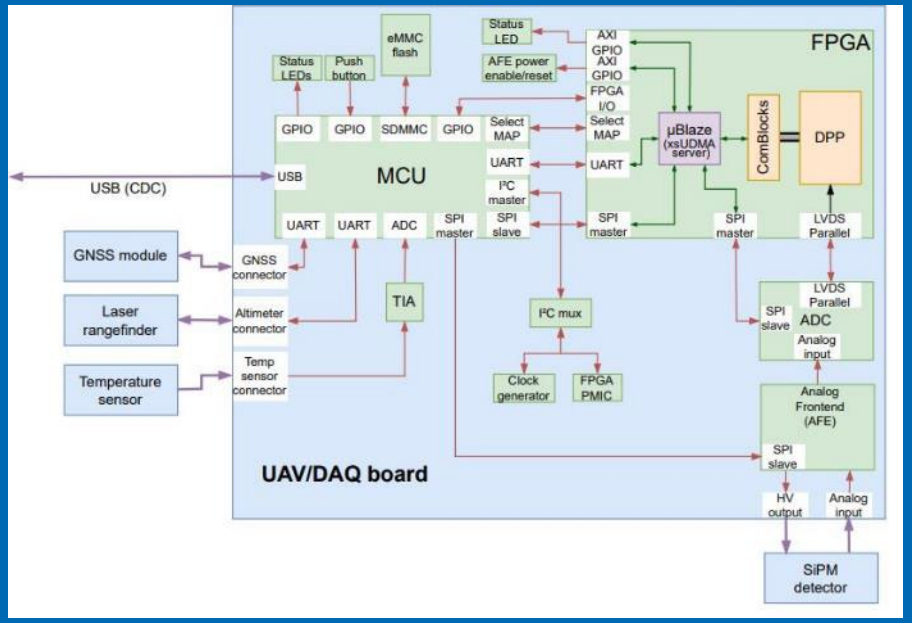
NSIL Trainings on Radiological Monitoring with Uncrewed Aerial Systems (UAS)

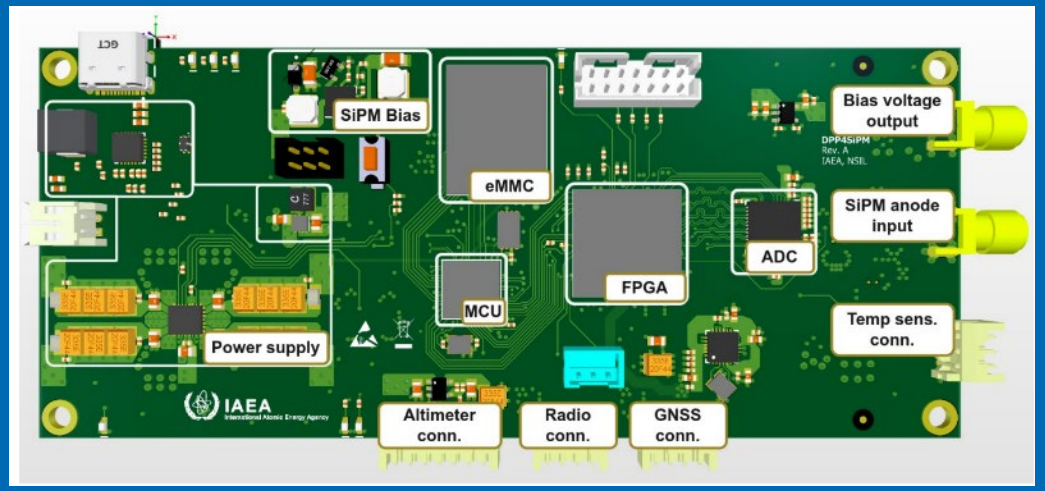


Hardware Platform for SiPM/Scintillator Detectors with a Custom Processing Board

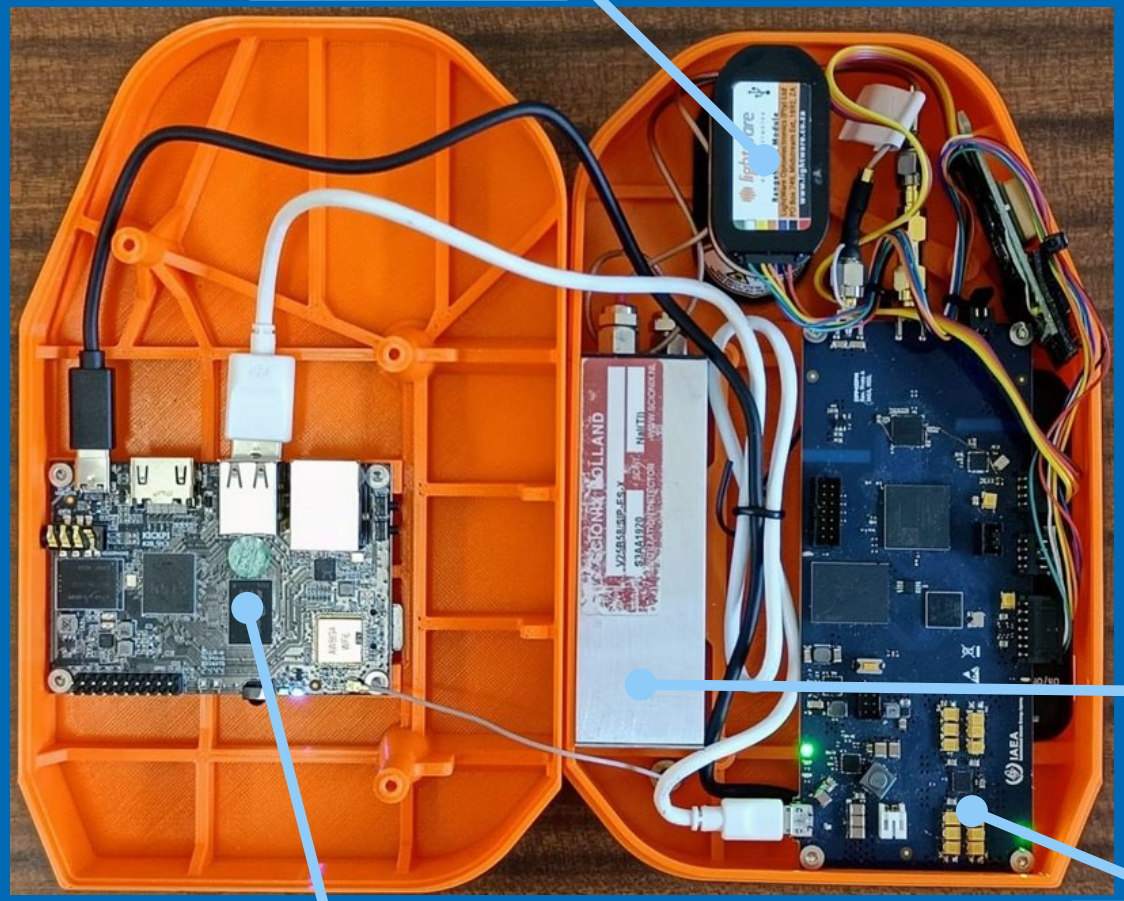
Board Integration

- FPGA for digital signal processing, and micro-controller for communications and telemetry
- Analog front-end with transimpedance amplifier and digitally-controlled bias for SiPM
- eMMC flash for data storage
- Integrated with GNSS, laser altimeter, temperature sensor
- Low SWaP (size, weight and power): suitable for UAV radiation monitoring systems

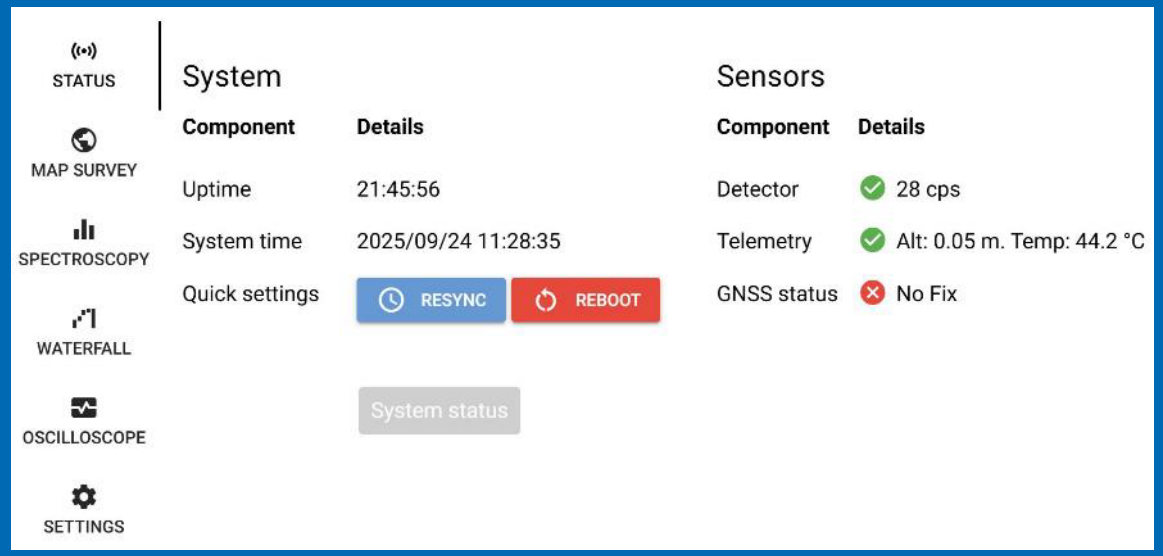


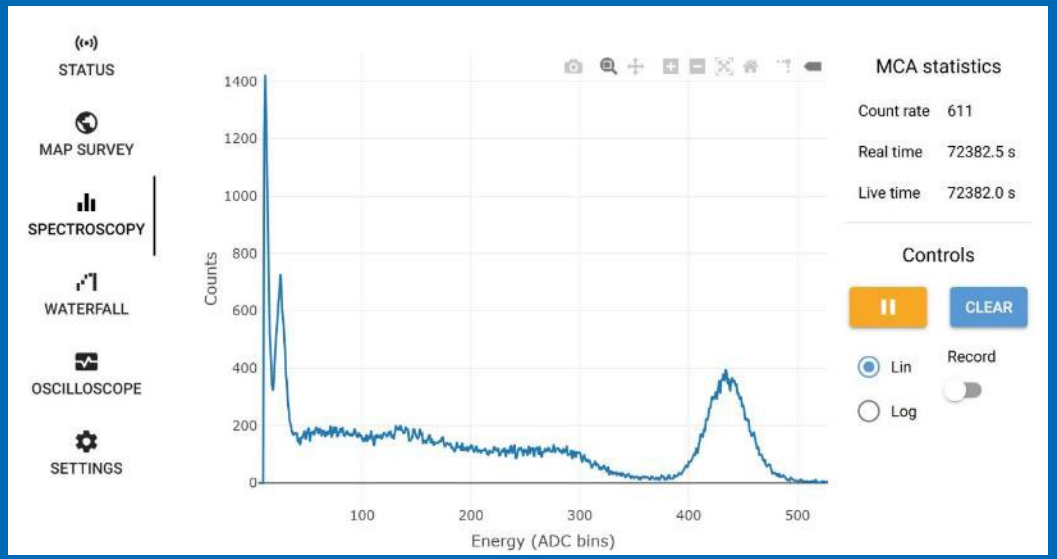


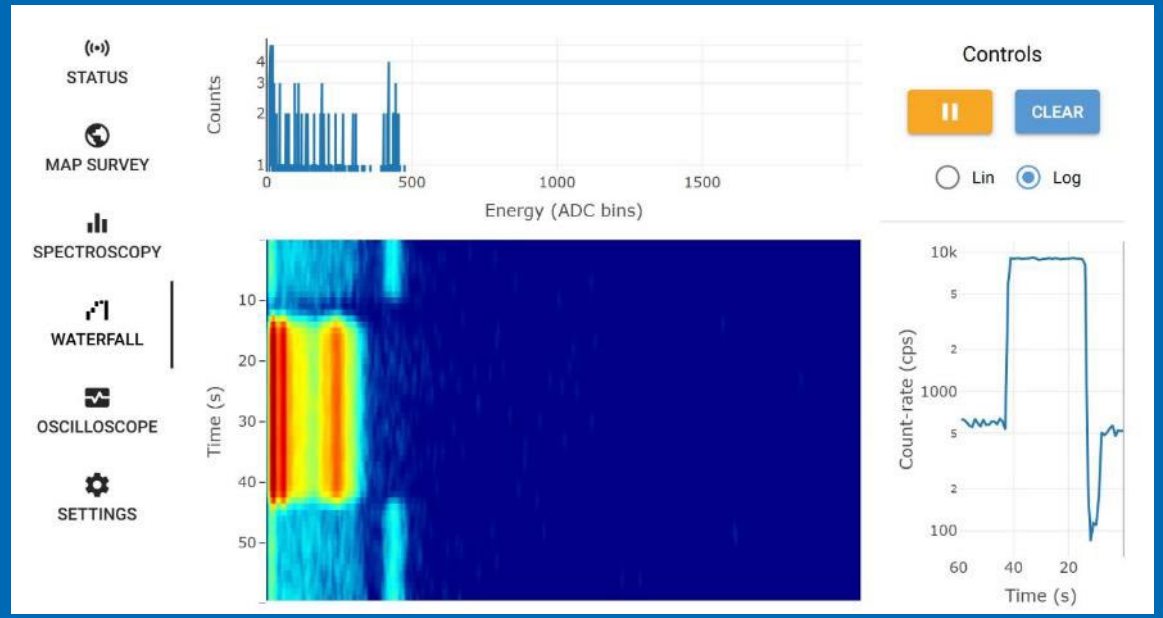
Radiation Monitoring System Deployment

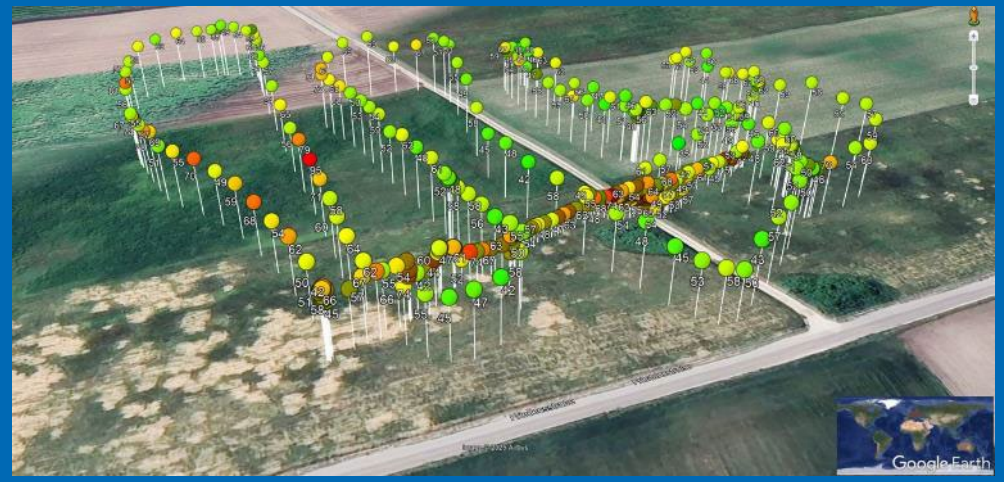


Airborne Radiation Surveying



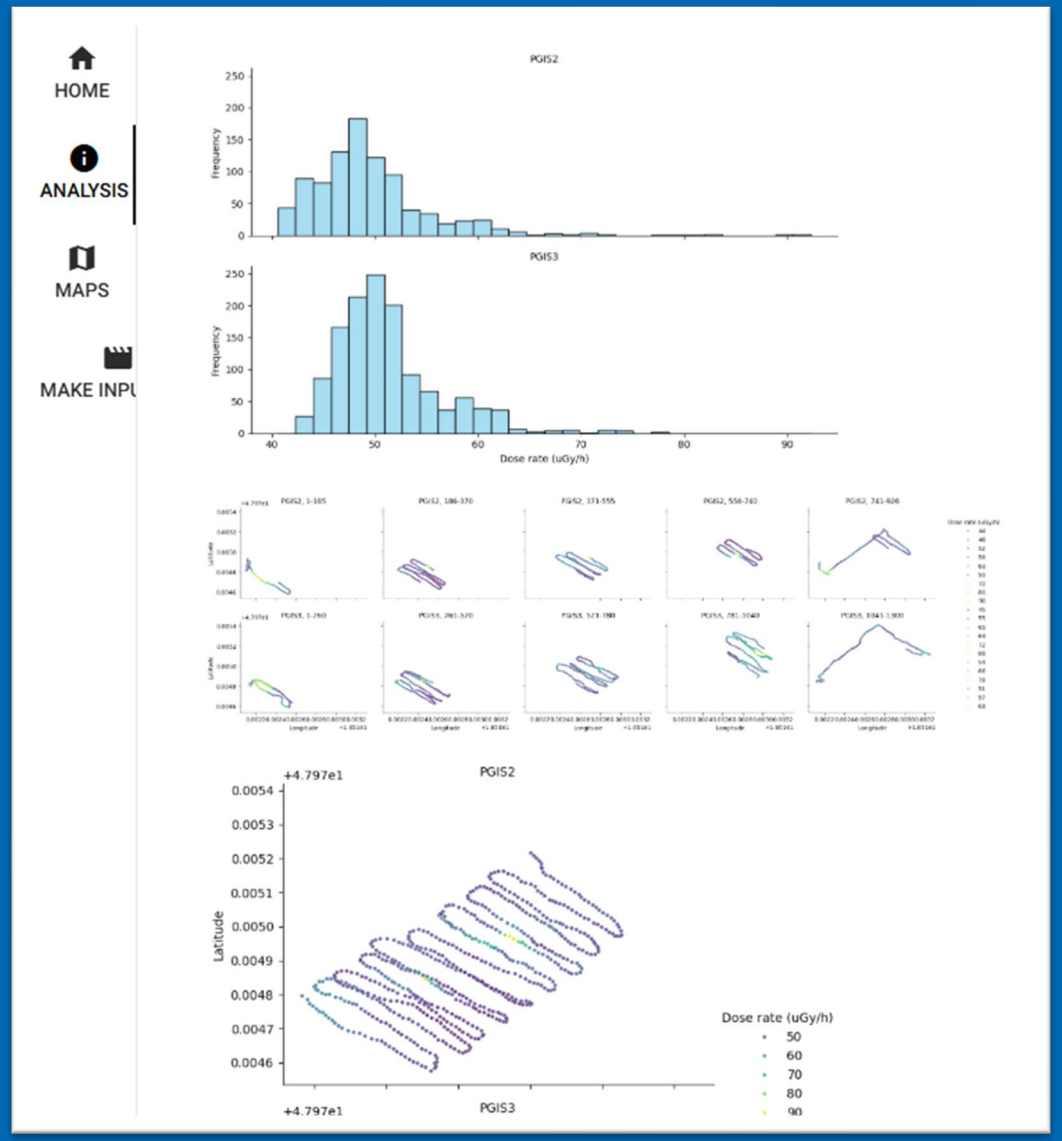


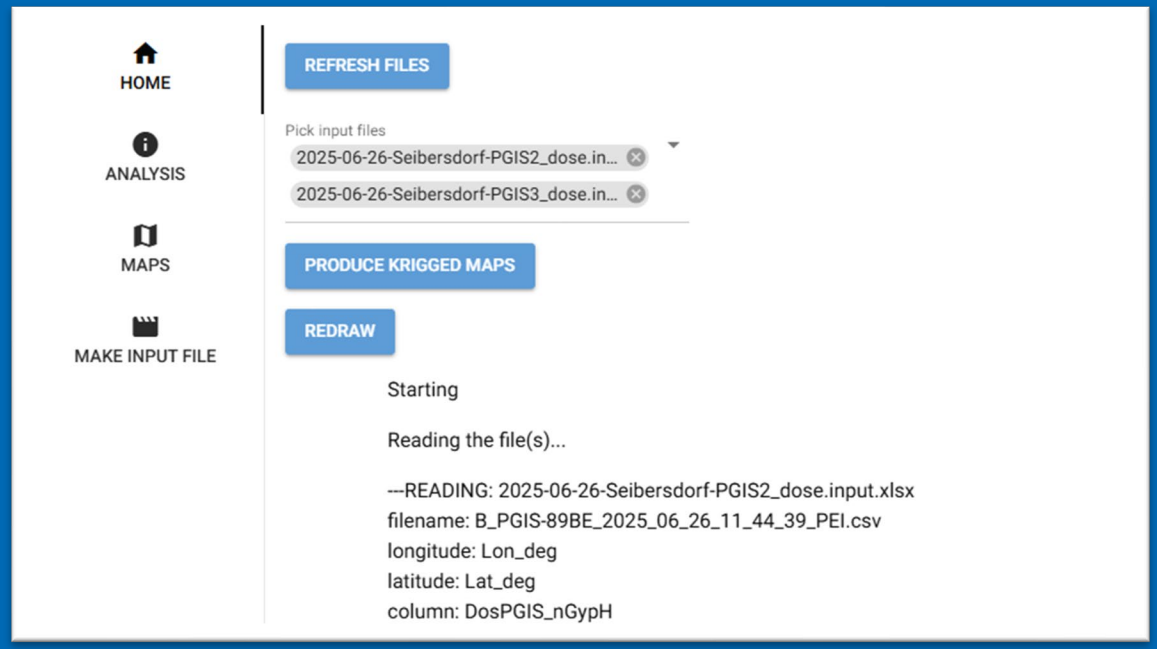




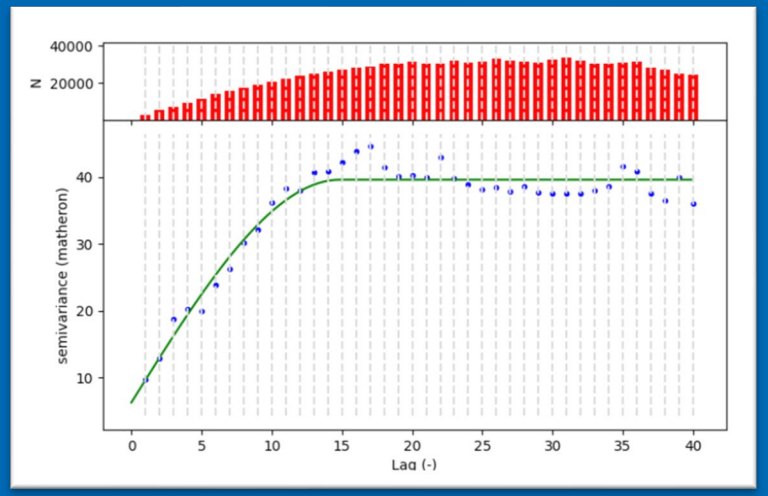
User Friendly Interpolation using Kriging

Survey Data Processing





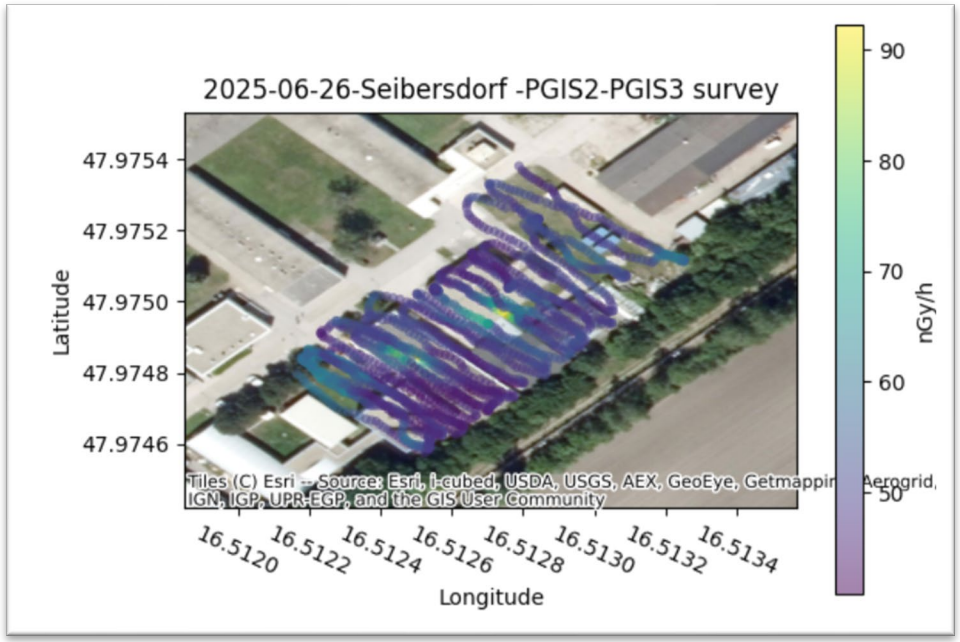
Variogram:



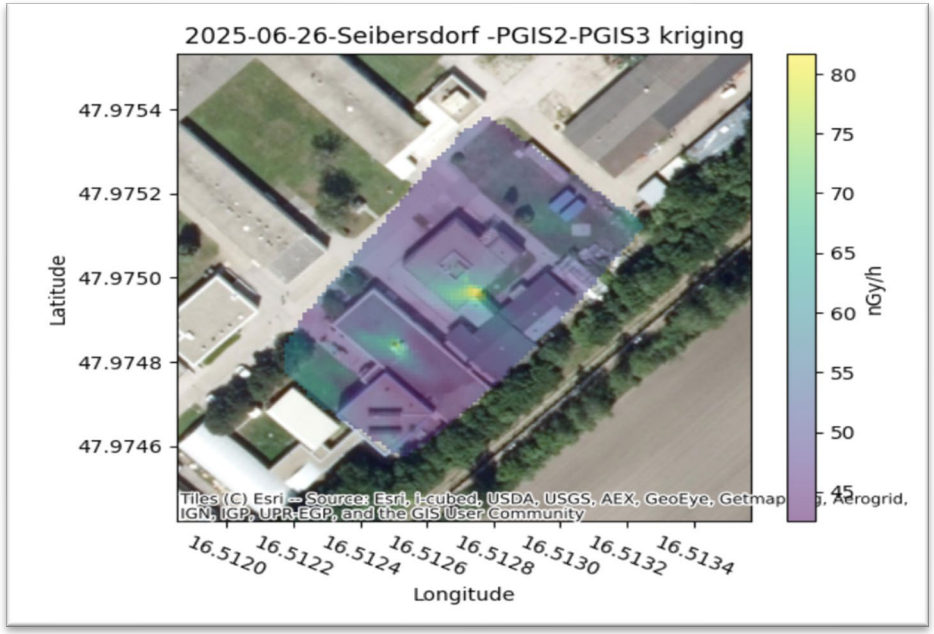
Maps produced

Three maps are produced and stored

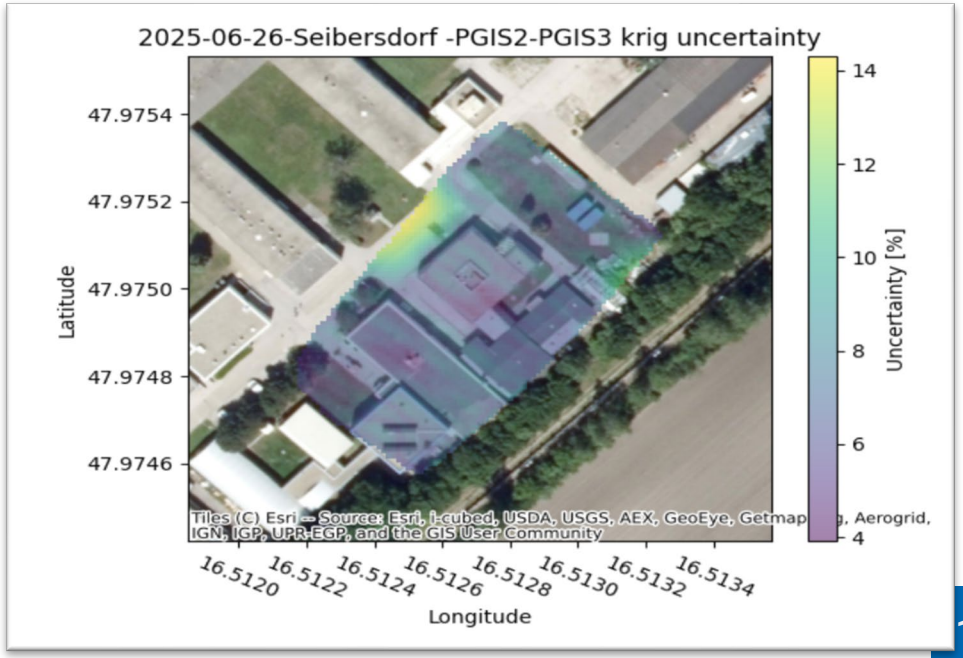
Survey map



Interpolated (kriged) map

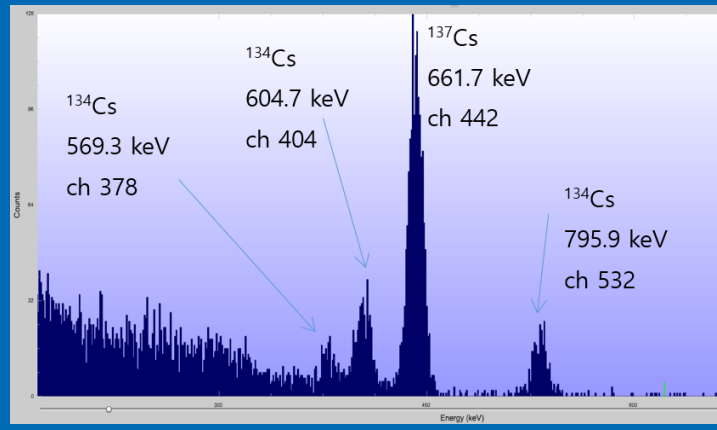


kriging uncertainties



Nuclide Identification Based on the Gamma Spectrum and Artificial Intelligence

Nuclide Identification Based on the Gamma Spectrum – Commercial Devices



- Patented QCC algorithm for fastest isotope ID
- Patented and field-proven Discovery Technology
- RadEAGLET advanced algorithms
- Automatic identification on dose-rate warning
- Advanced identification algorithmes (DU, LEU, HEU)

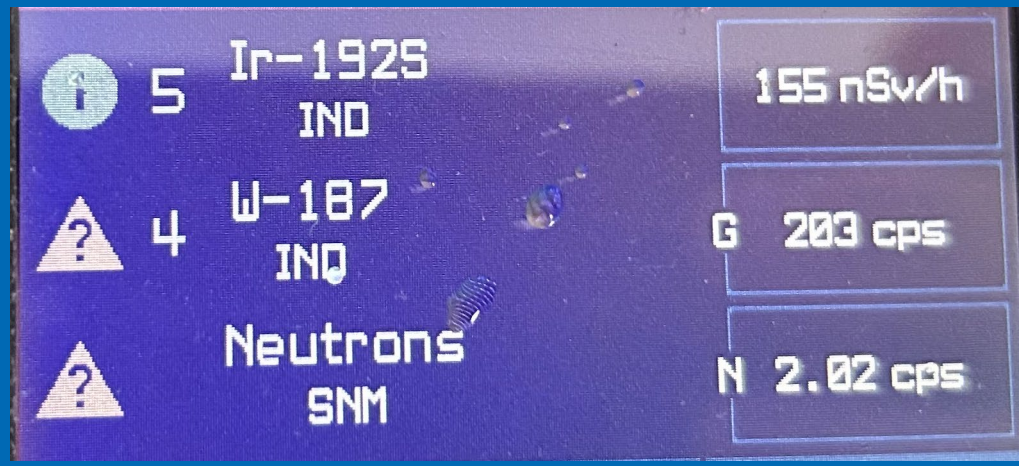
AmBe source

Results:

Unknown, other sources -> explanation

(not found in library, two possibilities, …)

More possible identification results



Nuclide Identification Based on the Gamma Spectrum

Two goals:

- Identify the nuclides (isotopes)
- Automated process + portability

  - to respond quickly (security)

  - large amount of data (site characterisation)

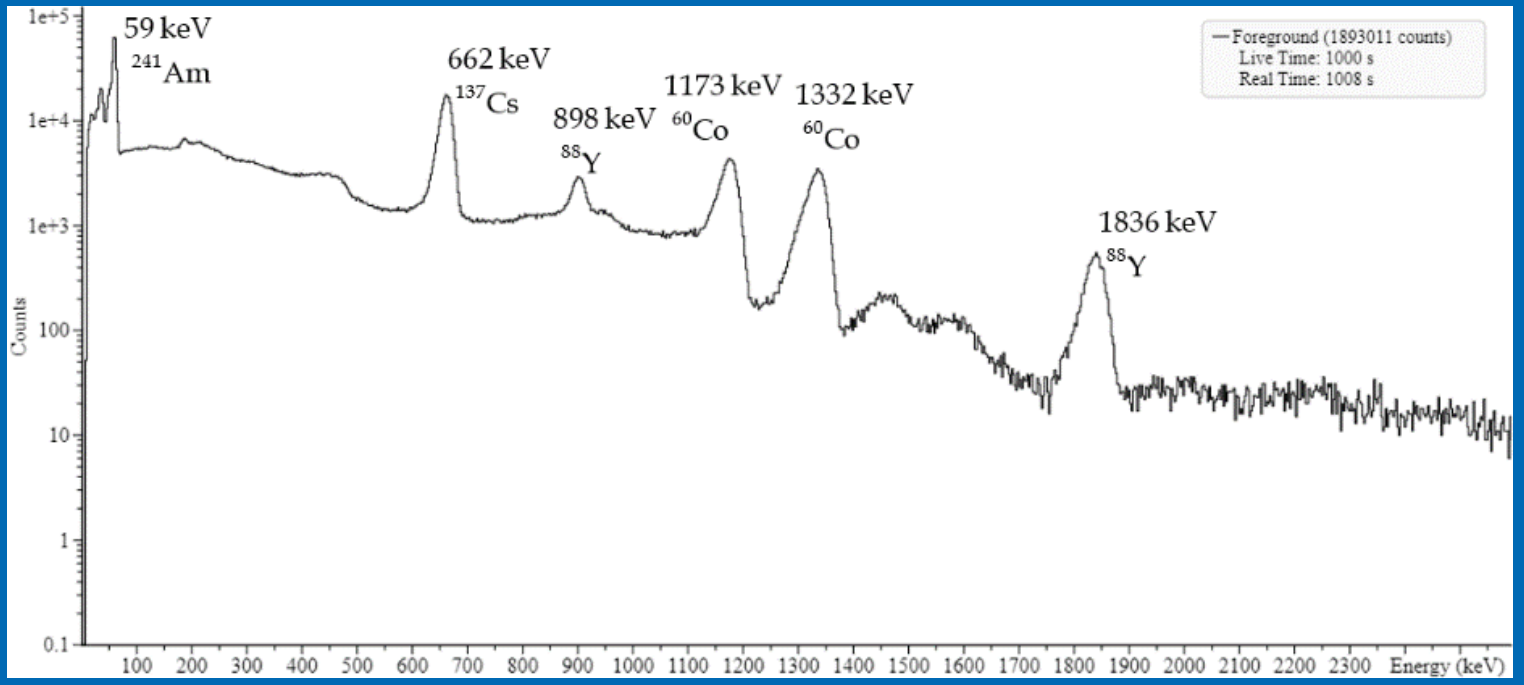
Artificial Neural Networks!

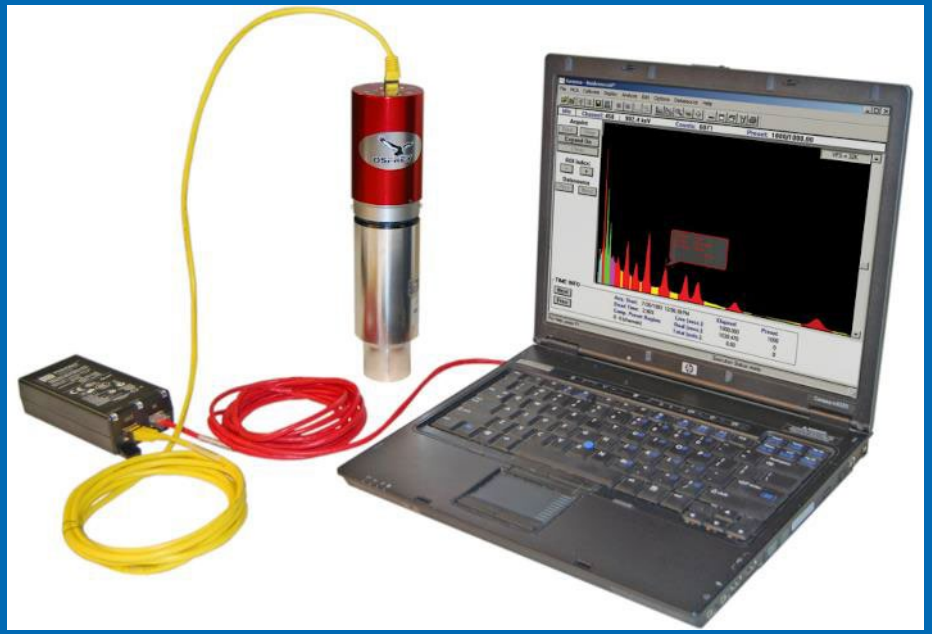
Artificial Neural Networks (ANNs)

- superior pattern recognition capabilities
- particularly suited to the analysis of complex data

Most previous machine learning methods

- synthetic data without testing on experimental data
- conducted on single source

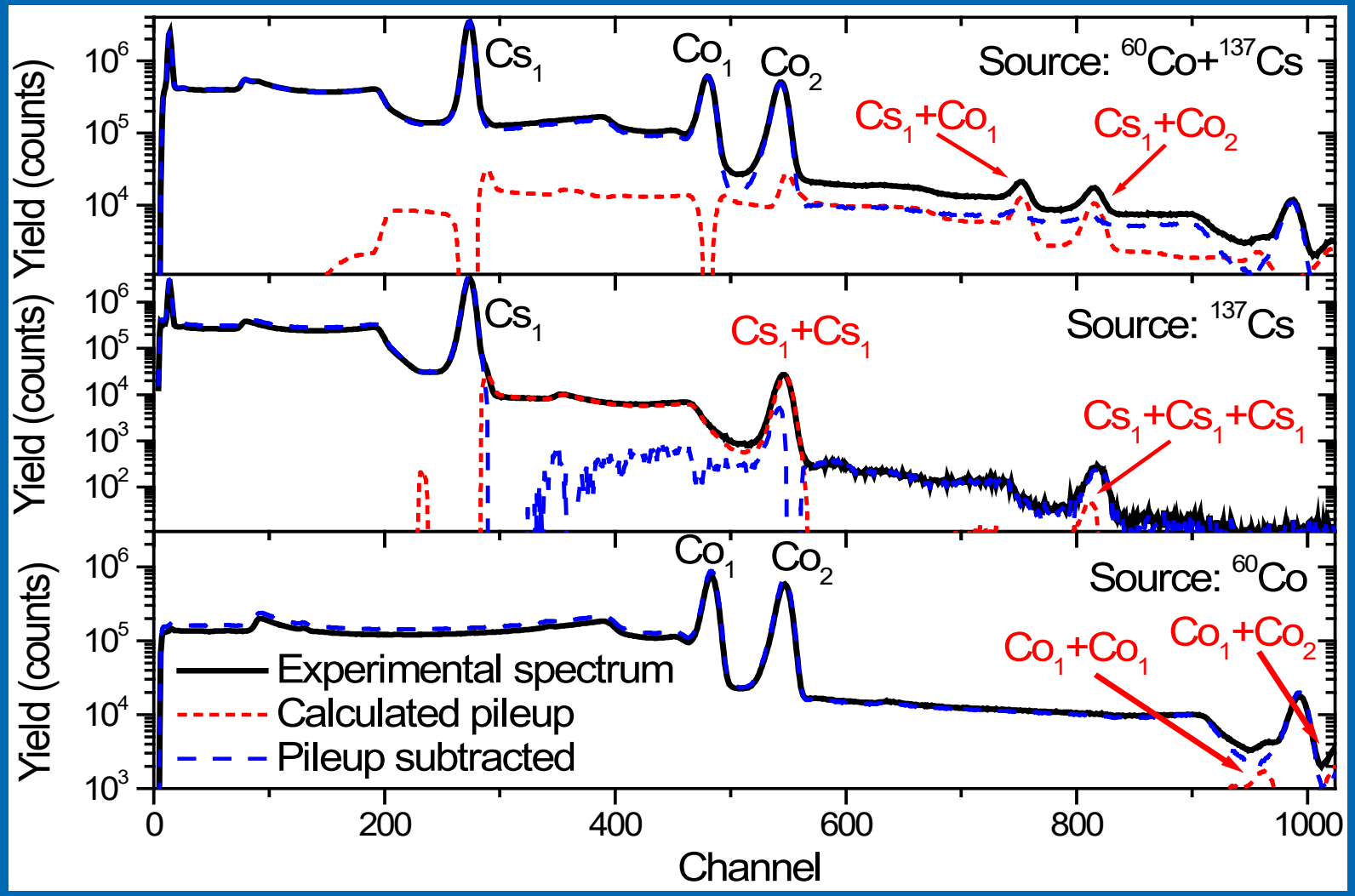




$LaBr_3(Ce)$

110 spectra were recorded over several months with various combinations of 10 sources

Synthetic Learning Data



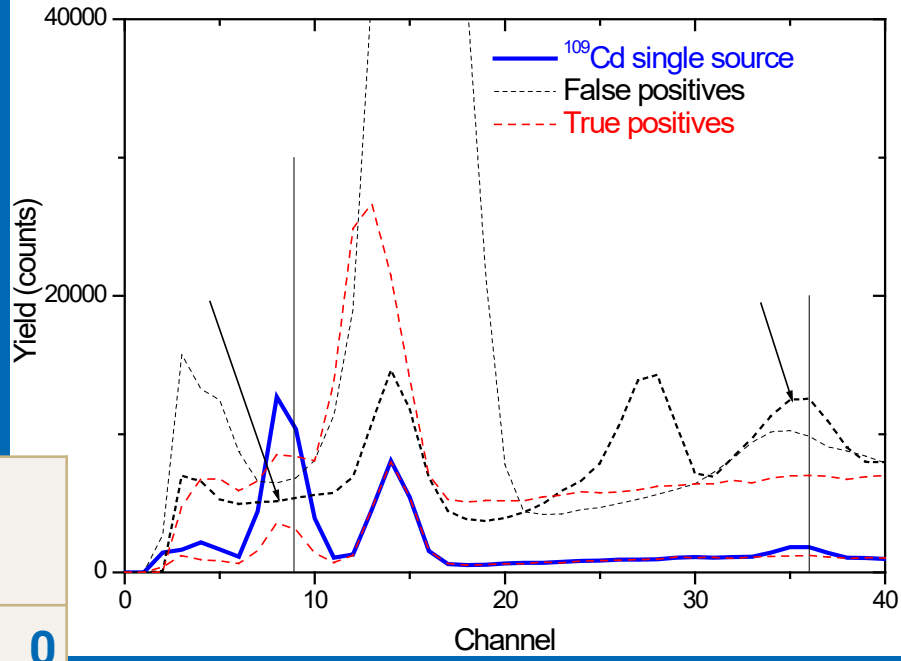
50000 synthetic spectra

- Random factor for each source from 10^{-2} to 10^{2}
- Pileup
- Limit of detection in the linear combination

Results

- used Convolutional Neural Networks (CNNs)
- tested on the 70 multiple-source spectra

nuclide	positives in set	negatives in set	FP (ANN)	FN (ANN)	FN (IS)	"True" FP (ANN)	"True" FN (ANN)
Co-60	25	45	0	0	0	**0**	**0**
Cs-137	26	44	0	0	0	**0**	**0**
Am-241	18	52	0	6	7	**0**	**0**
Y-88	21	49	0	4	4	**0**	**0**
Eu-152	21	49	1	0	0	**1**	**0**
Ba-133	15	55	0	0	0	**0**	**0**
Na-22	11	59	0	0	0	**0**	**0**
Co-57	11	59	4	4	4	**4**	**3**
Tl-204	10	60	4	3	3	**4**	**1**
Cd-109	29	41	2	13	16	**0**	**1**



- ANN performed at least as good as conventional methods
- Limit of detection considered

Conclusions:

- Successful first attempt to involve AI in Radioisotope Identification for Gamma Spectra
- Paper published *https://doi.org/10.1016/j.radphyschem.2025.112692*
- Expand the experimental data set to include uranium isotopes (and plutonium).
- Serve as hub on topics related to AI in gamma spectroscopy:
  - Training data databases
  - Consultancy and Technical Meetings
  - Coordinated Research Projects

Summary

The Nuclear Science and Instrumentation Laboratory (NSIL) provides expertise, training and support in the effective utilization of nuclear instrumentation

- focus on EMERGING TECHNOLOGIES