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PREPAREDNESS

Metrology for mobile detection of ionising radiation following a nuclear or radiological incident.

WP 1. Unmanned aerial detection of radiological data

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Objective

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The aim of this work package is to:

develop, **test** and **validate metrologically-traceable systems and methods** for remote measurements of **ambient dose** equivalent rates and **radionuclide ground concentrations** using rotary-wing unmanned aircraft systems (**RWUAS**), commonly named 'drones', **with spectrometry systems** mounted on them.

Tasks

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Development: airborne detectors and software

i) **Airborne detectors mounted in RWUAS**

- **Semiconductors detectors:**
  - Small size Cadmium Telluride 1.5 cm^3 (CZT)
  - Big High Purity Germanium detector with electrocooler (HPGe)
- **Scintillator detectors**
  - Sodium Iodine 50 mm x 50 mm (NaI)
  - Cerium Bromide 38 mm x 38 mm (CeBr3)
  - Caesium Iodine 25 mm x 50 mm (CsI)
  - "Localizator" system

ii) **Development and optimization of software**

- Merge drone data with data from detectors and send to ground station
- On-line visualization of count rates and dose rates
- Off-line calculation of $H^*(10)$ rate, man-made count rates and activity concentrations
- Program to control the "localizator" system

Tasks

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Measurements campaigns

i) Calibration using a reference ^{137}Cs source.
  - Threshold limits for artificial source detection using man-made counted rate and *H**(10) rates
  - Capability to detect the source at different heights, determine the *H**(10) rates and calculation of the activity
  - Source localization using "classical" detectors and with the "localizator" detector.

ii) Calibration using extended source in former Uranium mines
  - Mapping *H**(10) rates and ground activity concentrations
  - Identification of hidden point source detection in elevated ground activities

iii) Response of detectors to Ar-41 plume from an experimental reactor

iv) Air-show postpone to spring 2021

Outcomes

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Outcomes

i) Different airborne detectors mounted in drones and tested
ii) Software for sending, analysing spectra and visualizing calculated parameter such as *H**(10) rates, artificial count rates, activity concentrations and source localizations
iii) Reports of results
iv) Calibration procedures
v) Good practices guidelines
vi) Recommendations
vii) Papers in peer review journals

Developed systems: HPGe

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HPGe detector ~ 21 kg
Ortec IDM 200-V

SDO 50 v2
Patrol engine
payload ~45 kg

Developed systems: small and medium size

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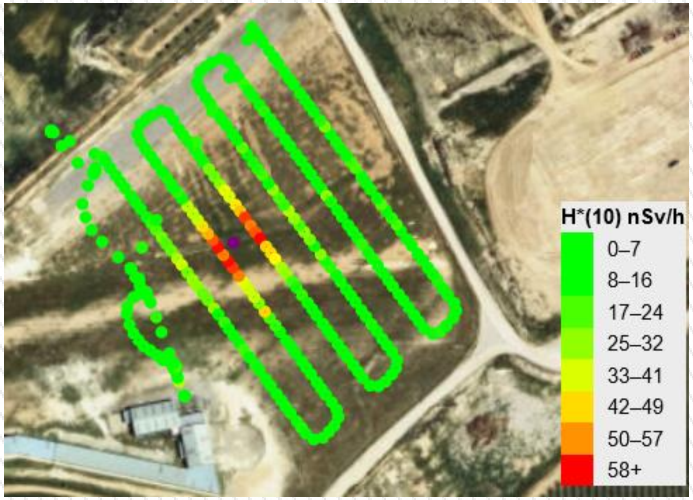
Table: main characteristics of participant in Mollerussa comparison

Detector	MCA	Total size/ weigh	Communication to ground	Resolution at 662 keV (%)	Efficiency per unit fluence at 662 keV (cm^{-2})	Position/ altitude
NaI 50 m x 50 mm from BridgePort Instruments (BPI)	USB-base from BPI 4096 ch 512 ch used in the campaign	82 x 82 x 242 mm / 1.4 kg (power supply by drone batteries)	radio modem peer-to-peer communication 433 MHz or Wi-Fi or 3G/4G	7.3 %	7.58	D-RTK GNSS included in the UAV/ LightWare SF11/C laser
$CeBr_3$ 30 mm x 38 mm from Scionix	USB-base from BPI 4096 ch 2046 ch used in the campaign	230 mm height x 200 mm diameter / 1.5 kg including batteries	radio modem peer-to-peer communication 2.4 GHz XBee Pro transceiver	4.1 %	3.60	RasPiGNSS / LightWare SF11/C laser altimeter and MS5607 barometer
CZT uSpec 1.5 cm^3 from Ritec	MicroMCA527 from Ritec 4096 ch	100 x 200 x 80 mm / 0. 5 kg including batteries	local Wi-Fi network about 100 m	< 3.5 %	1.4	Blox NEO-7M GPS / BMP180 digital barometer

Developed systems: small and medium size

Drone: DJI Matrice 600 Pro
$CeBr_3$ detector



Drone: DJI Matrice 600 Pro
NaI detector detector

Drone: DJI F550
CZT detector detector

Developed systems: Localizator

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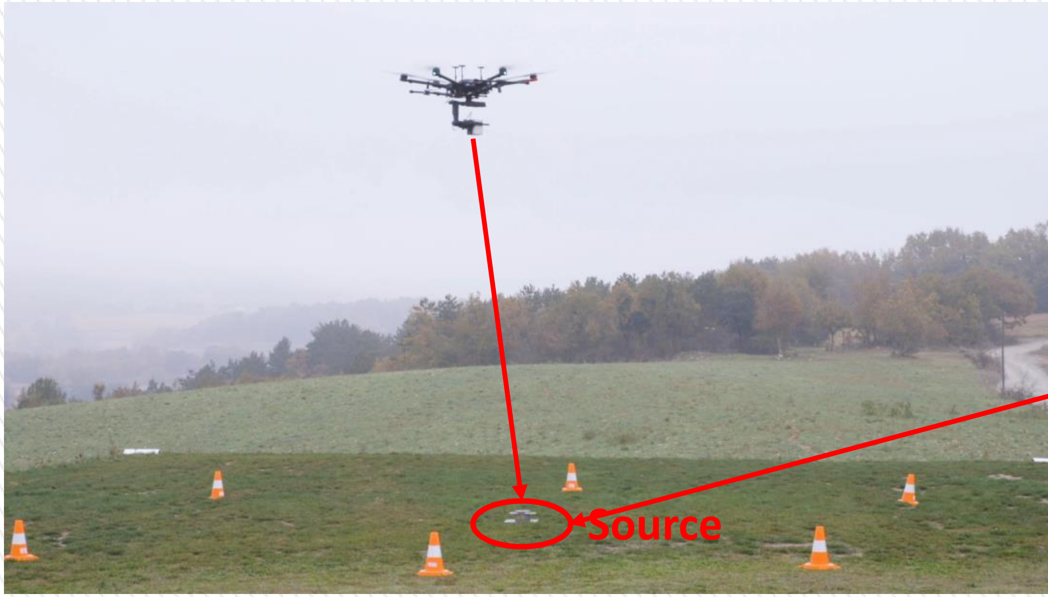


The drone goes to the detected source

Gimbal and detector mounted in the DJI Matrice 600 Pro

Airborne Spectra Analisys

Development of gamma spectrum analysis software, methods to calculate *H**(10) and activity concentrations

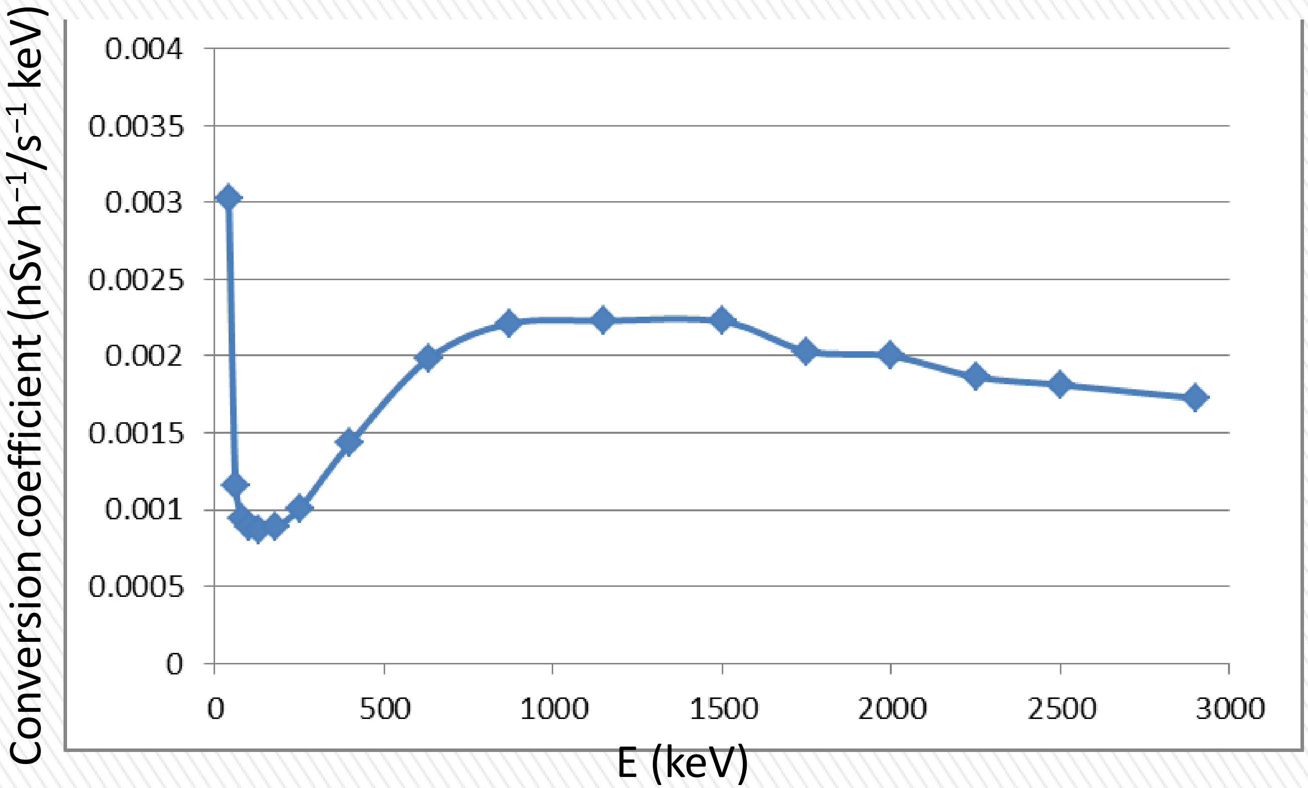
Main **Recommended methods** to implement in the calculations:

- For ***H**(10) calculation, conversion coefficient** method is recommended because is accurate, precise and robust.
- Man Made Count Rate (**MMCR**) is a robust and fast method to detect artificial radioactivity.
- Full Spectra Analysis **(FSA)** is one of the most promising methodology to calculate **activity concentration**
- **Decision Thresholds** for artificial radionuclide detection is also recommended to be calculated according to the actual background.
- **Anisotropy** is applied to the “localizator” system.

Conversion coefficient method

$$\dot{H}^*(10) = \sum_{i=1}^{j} w_i\, n_i\, E_i$$

Where w_i is the conversion coefficient for energy band i (nSv h^{-1}/s^{-1} keV) , n_i is the count rate in s^{-1} in the band i, E_i is the mean energy of the energy band i in keV and j is the number of energy bands.



Man-Made Count Rate (MMCR)

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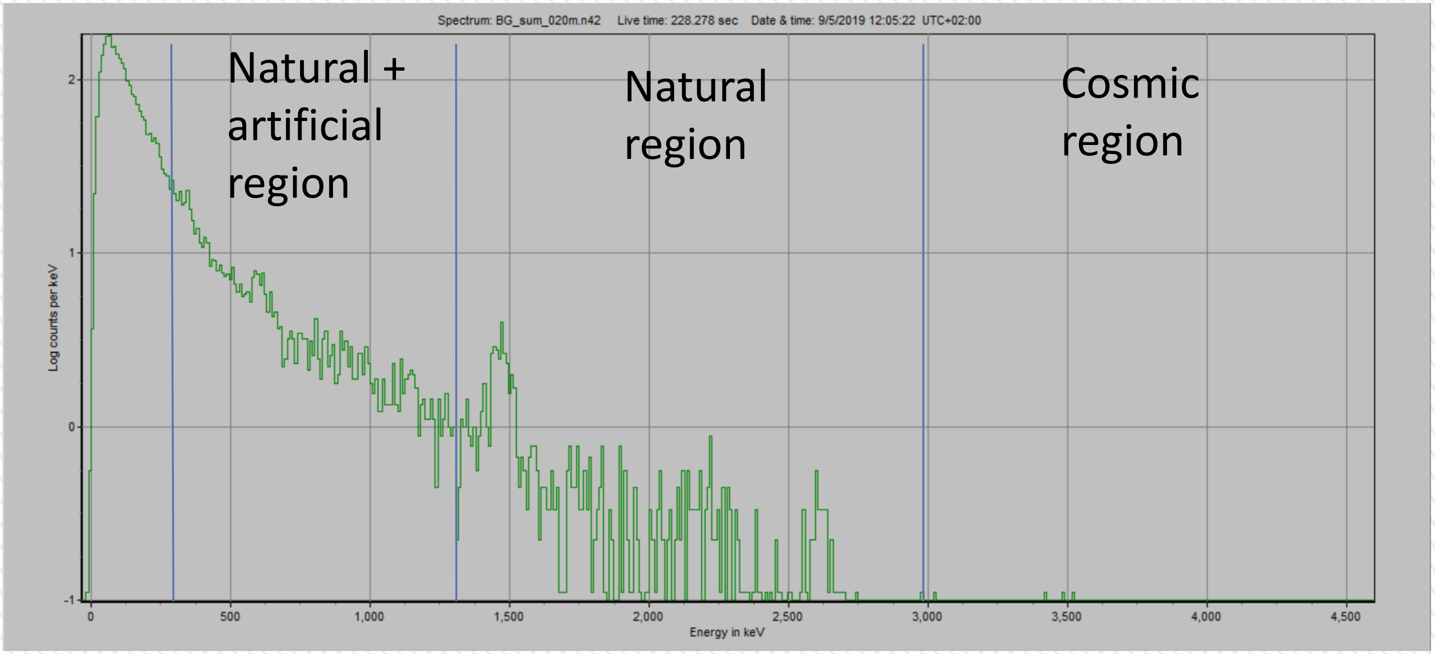
Background NaI spectrum at 20 m height (acquisition time close to 4 min)



$$\text{MMCR} = \sum_{320}^{1360} n(E) - ratio \sum_{1360}^{3000} n(E)$$

The ***ratio*** is of the low-energy counts to high-energy counts when no artificial source is present and Is almost no dependent to natural radioactivity variations

$$\text{ratio} = \frac{\sum_{320}^{1360} n\,(E)}{\sum_{1360}^{3000} n\,(E)} = 7.11 + 0.0018\ * h\ (m)$$

NaI 50mm x 50 mm

Airborne data analysis

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Spectra analyses using “γ-aerospec” software applied to flights at Wismut former Uranium mines

Full Spectra Analysis (FSA)

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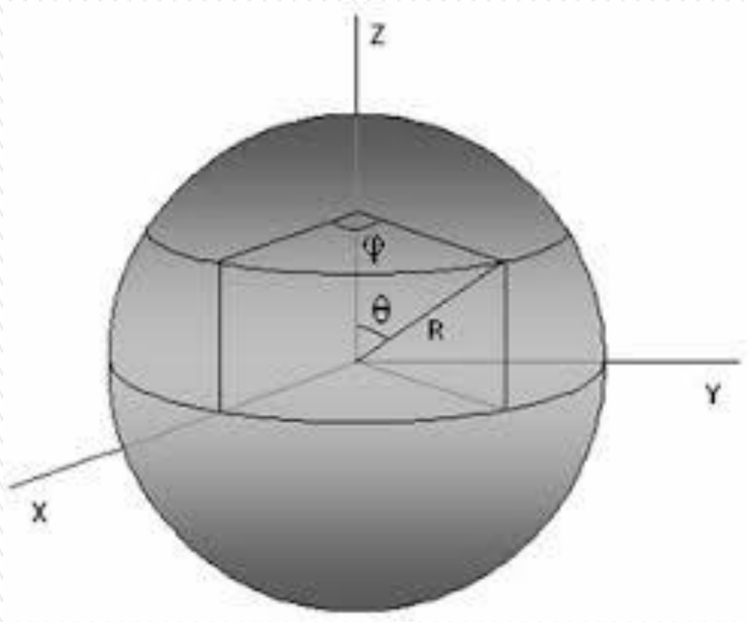
FSA tool included in γ-aerospec software to calculate ground activity

Localizator Anisotropy

Basic methodology description

$\vec{R}$ is the vector that indicates the source direction and has and Euclidean Norm equal 1



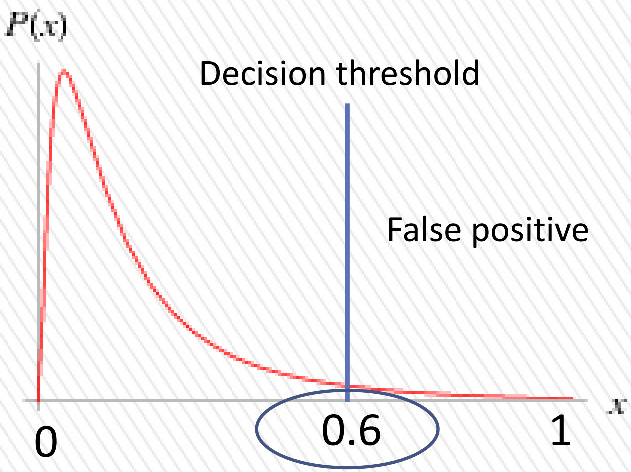
NO SOURCE:

$$x = \frac{1}{n}\left\|\sum_{1}^{n}\vec{R}\right\|$$ is close to 0

SOURCE

$$x = \frac{1}{n}\left\|\sum_{1}^{n}\vec{R}\right\|$$ is close to 1

NO SOURCE measurements:



Localizator

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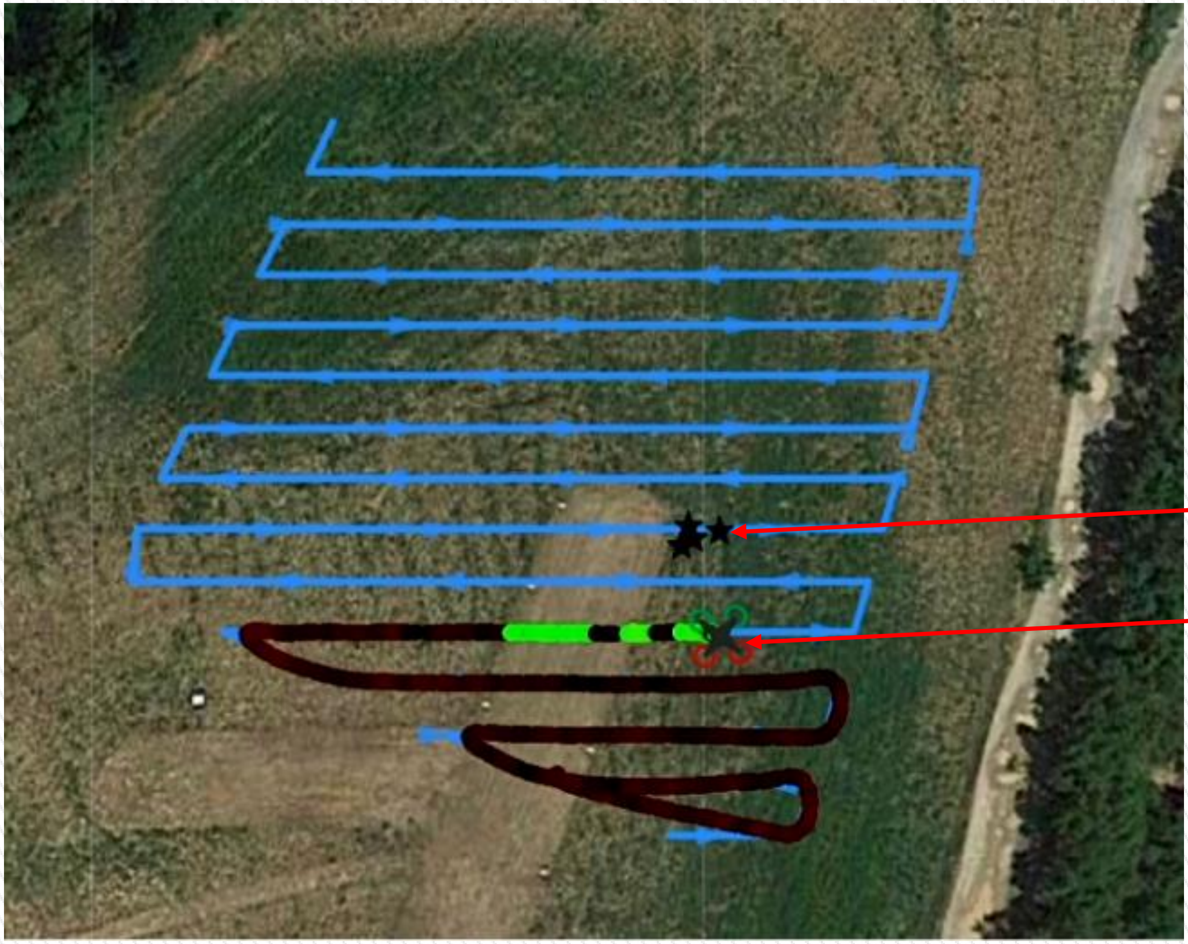
The flight plan could be classical parallel lines or random path
The drone stops when the source is detect (black stars)
The drone goes to the source position to determine a better position

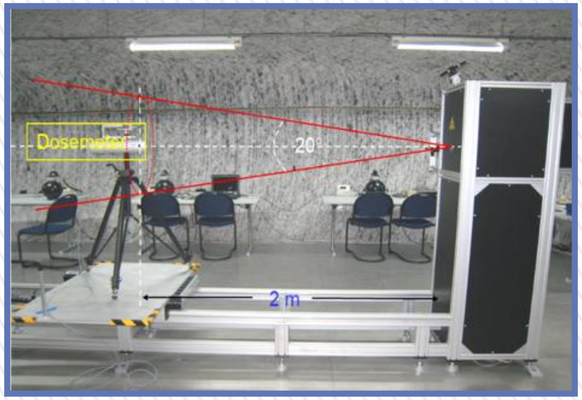


Source: estimated position

Drone stops

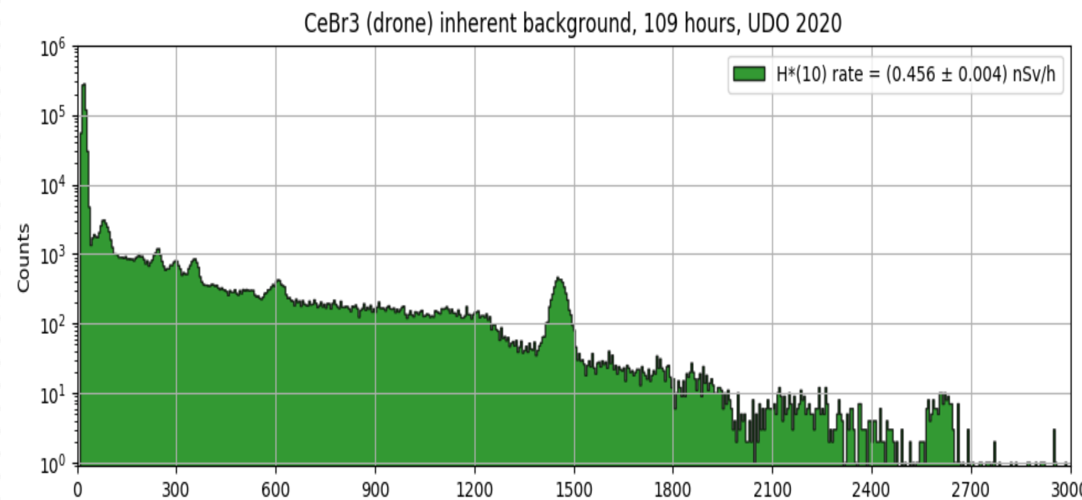
Calibration procedures

PTB UDO II underground laboratory
490 m, salt mine
No cosmic radiation!

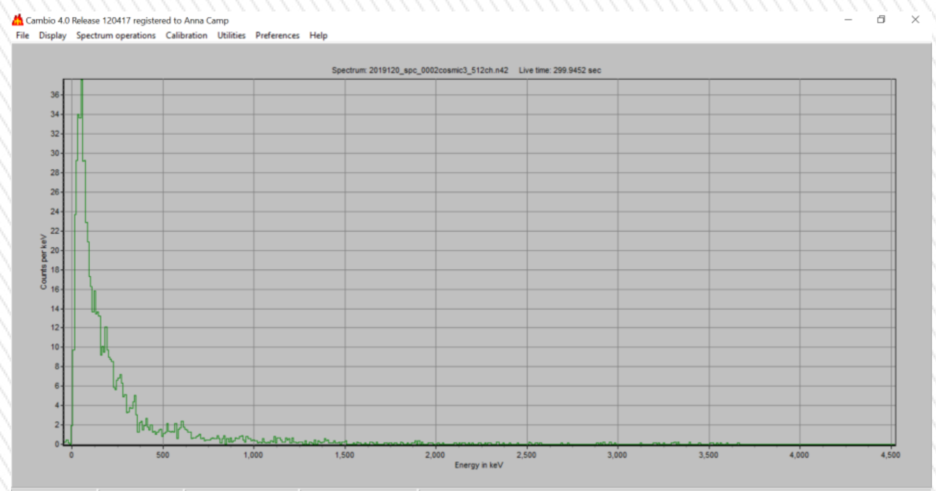


Reference measuring site for cosmic radiation
Almost no terrestrial radiation.

Inherent background $CeBr_3$ detector
H*(10) ~ 0.5 nSv/h



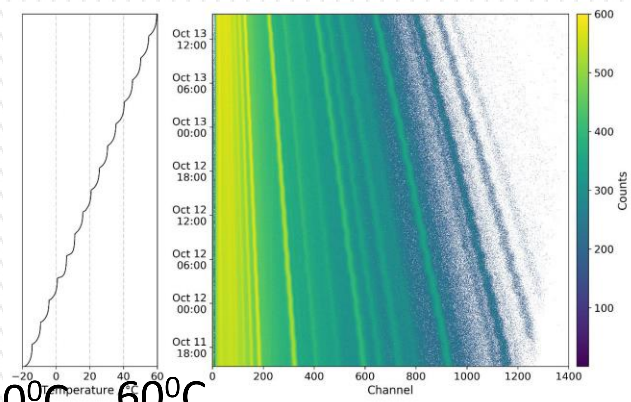
Cosmic spectrum NaI detector in Banyoles lake
H*(10) ~ 7 nSv/h



Calibration procedures

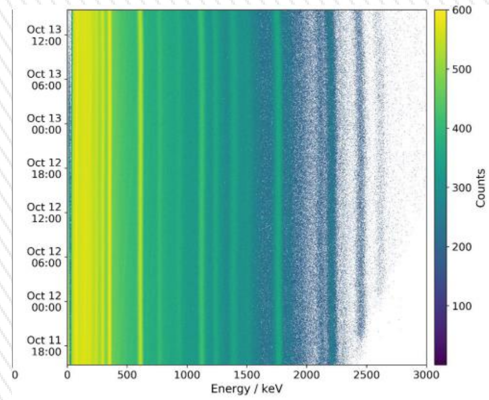
Temperature stabilization ((climate chamber with Ra-226 source)

Raw Sepctra



-20^0C 60^0C

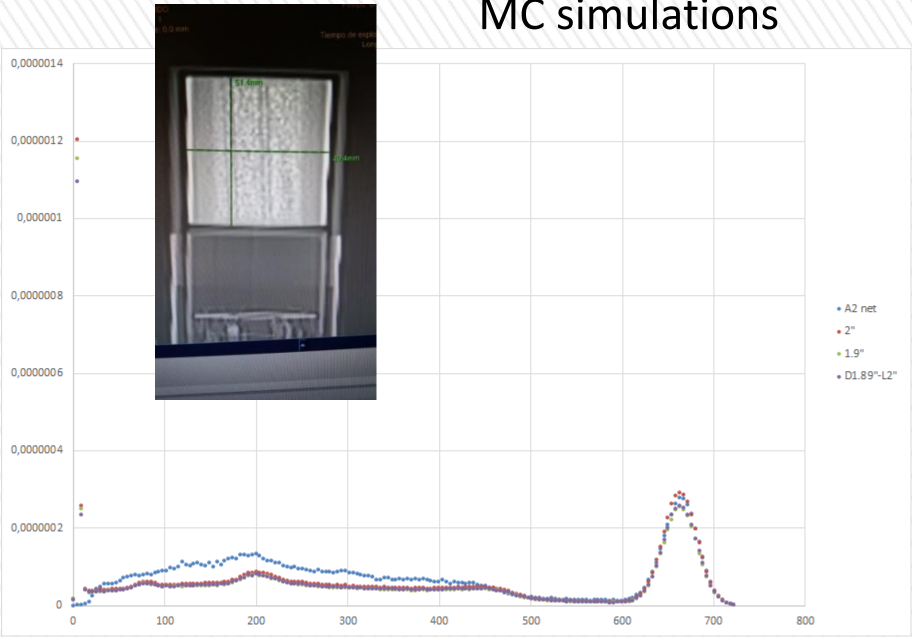
Calibrated Sepctra



Reference facility irradiations

Radiography of the detector

MC simulations



Calibration procedures: MMCR

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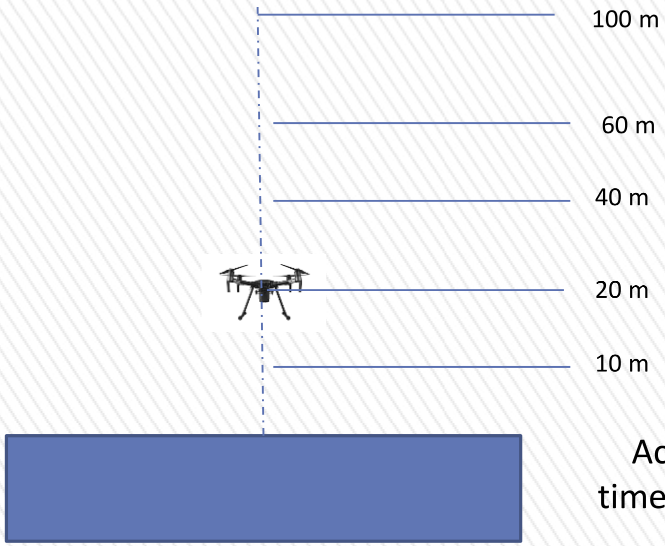
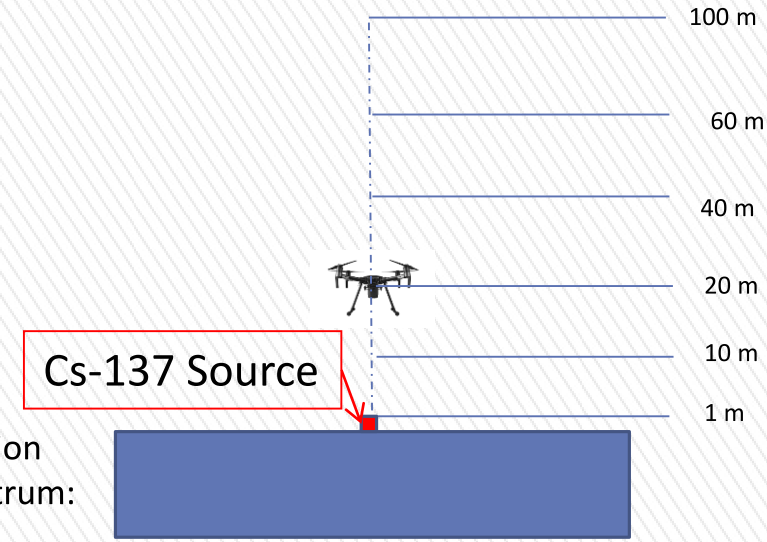
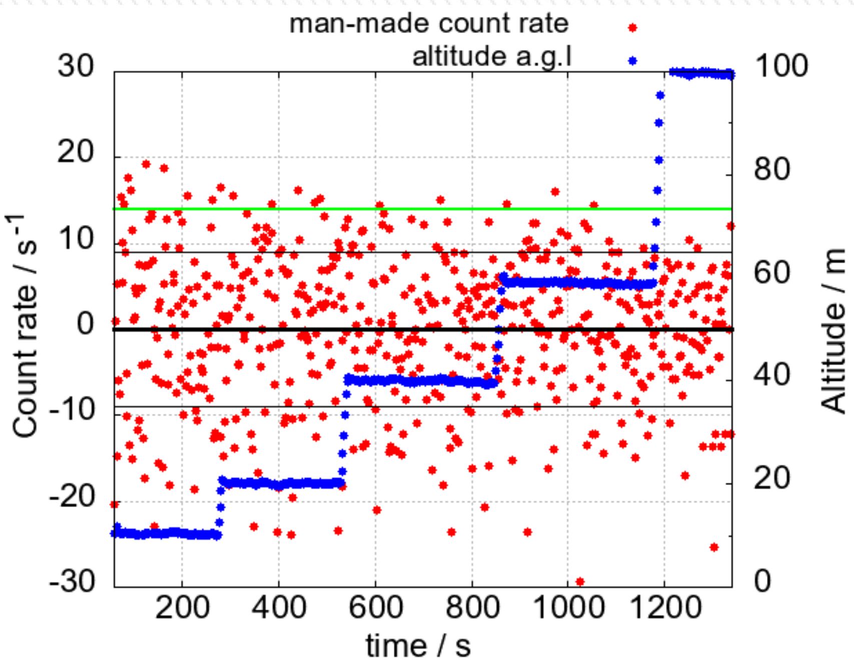
1. Background characterization

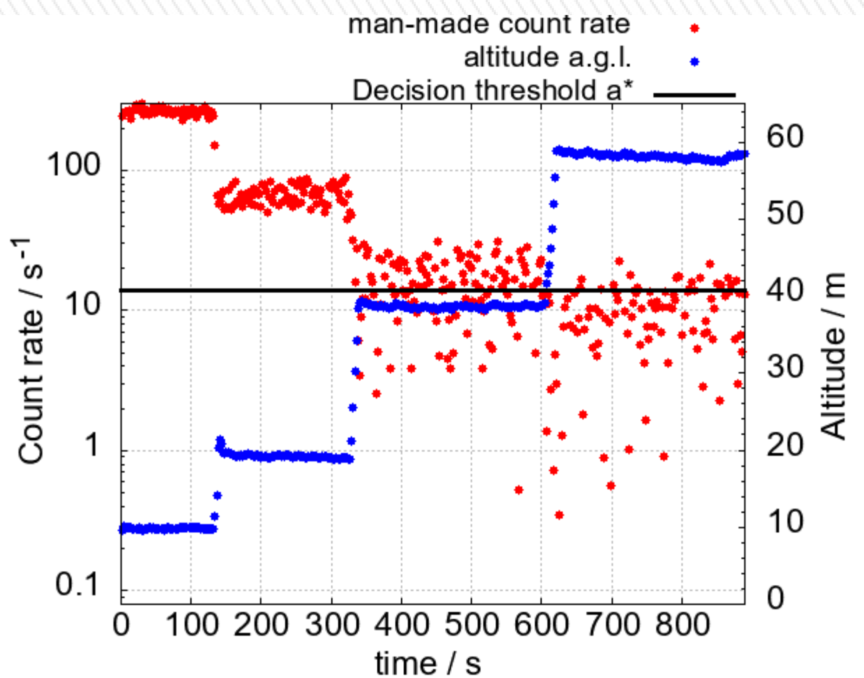


2. Vertical flights over point source



Acquisition time/spectrum: 2 s





Calibration procedures: *H**(10) rates

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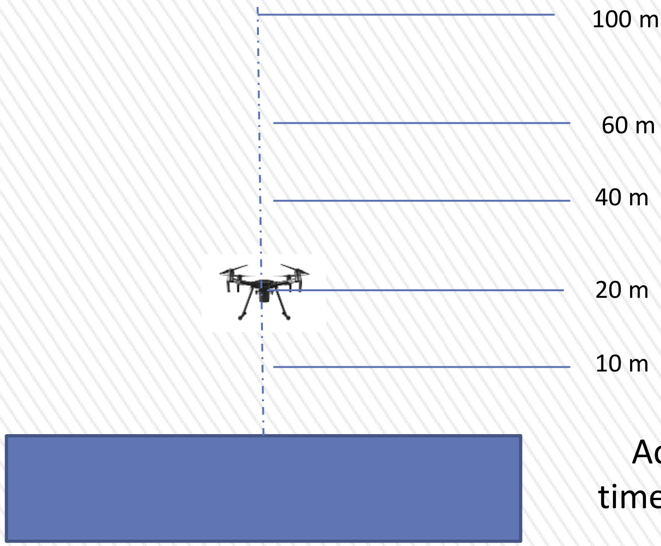
1. Background characterization



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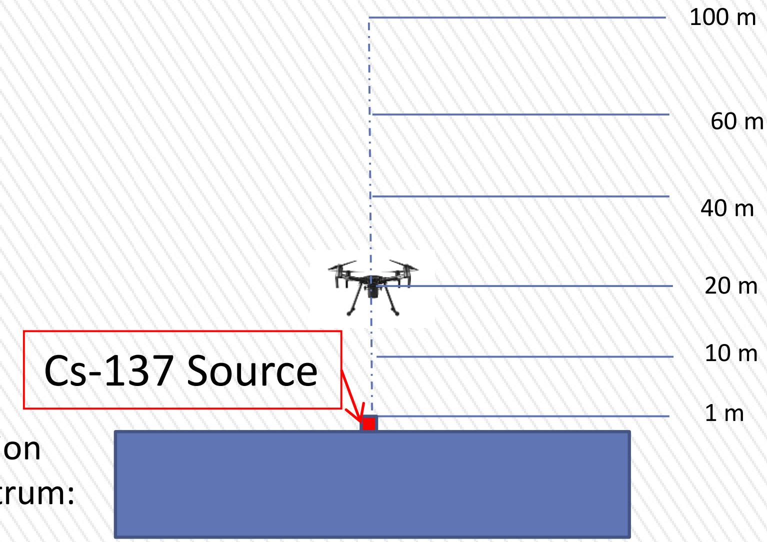
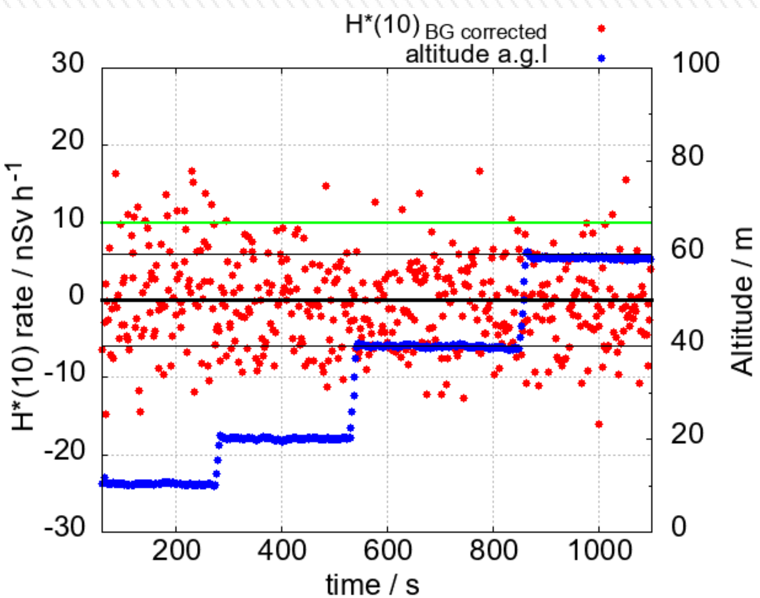
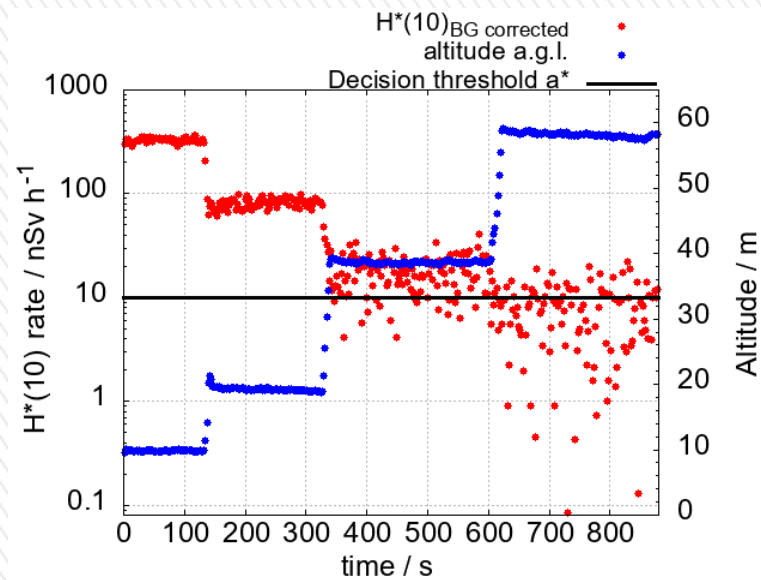


$$H^*(10)_{BG} = 57.0 * \exp(-0.0077 * h)$$





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Publications

Pablo Royo, Enric Pastor, Miquel Macias, Raul Cuadrado, Cristina Barrado and Arturo Vargas. AN UNMANNED AIRCRAFT SYSTEM TO DETECT A RADIOLOGICAL POINT SOURCE USING RIMA SOFTWARE ARCHITECTURE. Remote Sens. 2018, 10, 1712; doi:10.3390/rs10111712

A. Vargas, D. Costa, M. Macias, P. Royo, E. Pastor, M. Luchkov, S. Neumaier, U. Stöhlker, R. Luff COMPARISON OF AIRBORNE RADIATION DETECTORS CARRIED BY ROTARY-WING UNMANNED AERIAL SYSTEMS PERFORMED IN SPAIN. Radiation Measurements. In preparation.

T. Petrovic, M. Vencelj, A. Vargas, D. Costa, P. Royo, M. Macias. LOCALIZATOR DETECTOR MOUNTED ON AN UNMMANED AERIAL SYSTEM. In preparation fro Radiation Measurements.

N. Kržanović, A. Röttger, V. Morosh, M. Luchkov, S. Neumaier CADMIUM ZINC TELLURIDE SOLID-STATE DETECTOR CHARACTERISATION FOR ITS USE AS A SPECTRO-DOSEMETER. RAP Conference Proceedings 4, 148-151 (2019) DOI: 10.37392/RapProc.2019.30

Reports and documents

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Reports and documents

D1 report: "Summary Report on Unmanned Aerial Spectrometric Systems Developed for Monitoring in the Aftermath of a Radiological Event". **What have been develop ?**

D2 report: "Recommendations on the measurement of dose rates and radioactivity ground concentrations using UAV based spectrometric systems including dedicated calibration procedures". **How to use including calibration ?**

Good practice guide. "Good practice guide on measurement of dose rates and radioactivity concentrations using rotary-wing unmanned aerial detection systems (RWUAS)"

Report. "Report of the Wismut campaign results." In preparation.

Report. "Spectro-Dosemeter-based gamma dose rate network in Germany"

User manual. "User Manual for γ-aerospec software"

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EMPIR 16ENV04 „Preparedness“ Kick-off meeting

WISMUT CAMPAIGN

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Former Uranium mines and hidden Cs-137 and Co-60 point sources

WISMUT CAMPAIGN

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