Institut de Tècniques Energètiques
UNIVERSITAT POLITÈCNICA DE CATALUNYA

EURADOS

WG3 – Environmental dosimetry
7th EURADOS/NERIS webinar, 23rd Sept. 2021

Unmanned aerial detection of radiological data - Results of the EMPIR "Preparedness" project

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

EMPIR EURAMET
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

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Content

1) **Overview of the Preparedness project**
2) **Developed airborne detectors installed in UAVs, software control and data analysis: γ-spectrometric detectors and locator detector**
3) **Results of flight campaigns for radiological maps and source detection. Calibration of the developed aerial systems.**
4) **Video**
5) **On-going and future activities in EMPIR calls**

The “Preparedness“ EMPIR project

EMPIR is an European Metrology Research Programme within **EURAMET (European Association of National Metrology Institutes)** that has been developed as an integrated part of **Horizon 2020.** It s co-funded by Horizon 2020 and the EMPIR participating states.

https://www.euramet.org/research-innovation/research-empir/about-empir/

The **Preparedness Project** has been developed in the framework of **the Environment challenge call of 2016.**

http://www.preparedness-empir.eu/?page_id=1019

The **consortium** is composed by **17 participants**: 3 National Metrology Institutes (NMI), 3 Designated Institutes (DI), 10 external funded partners and 1 external unfunded partner.

Project started **1st August 2017**, lasting **3-years + 6 months extension due Coronavirus.**

The **specific objec**tives of the project are grouped in **4 Technical WP**, and **WP1** are related to **UAV**:

WP1 - Develop **unmanned aerial detection systems** installed on aerial vehicles.

γ-spectrometry systems

Drone: DJI Matrice 600 Pro
(max. payload: 6 kg)
$CeBr_3$ detector. Total weight: 1.5 kg

Drone: DJI Matrice 600 Pro
(max. payload: 6 kg)
NaI detector detector Total weight: 1.4 kg

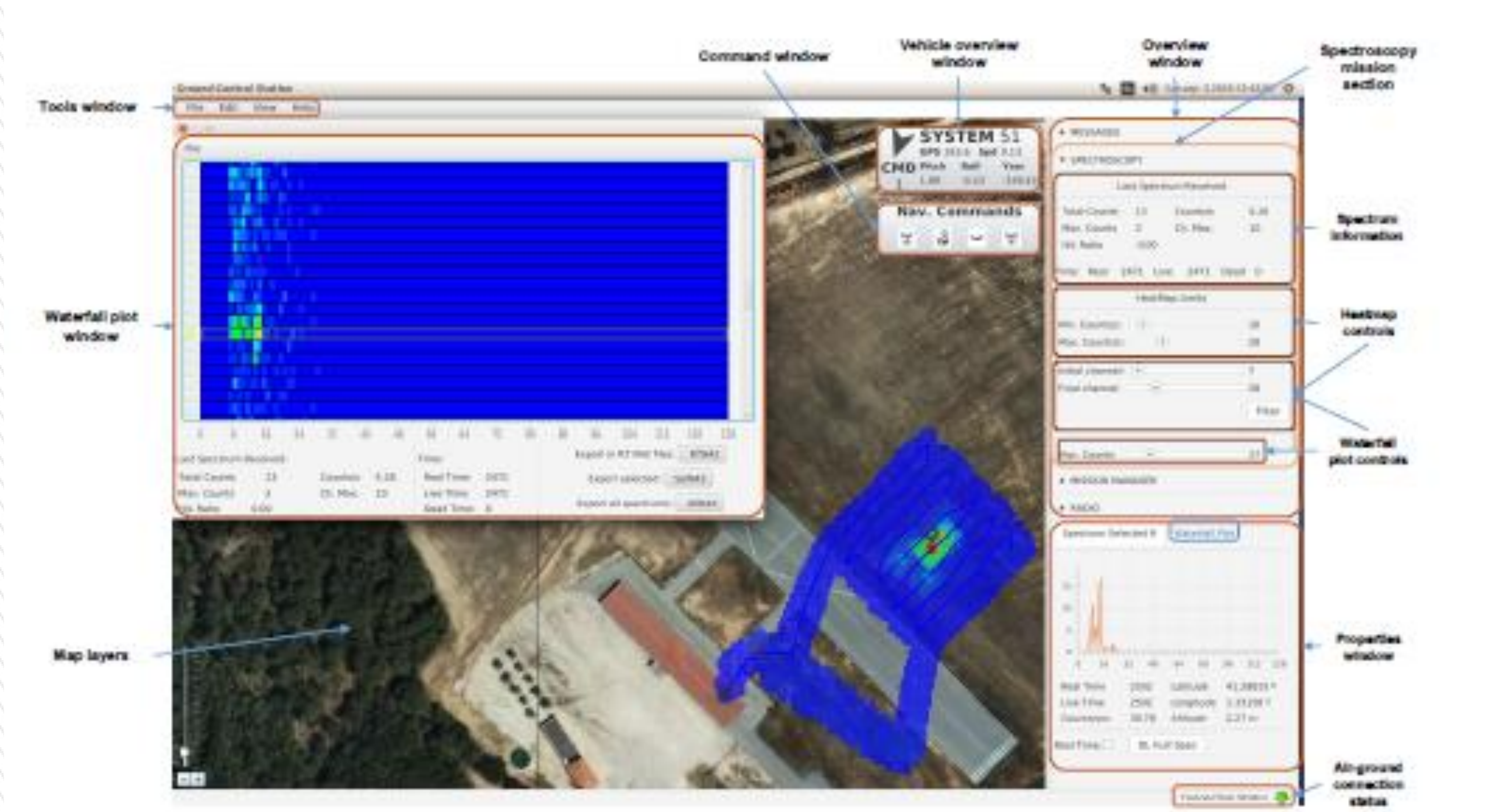
Drone: SWISSDRONE SDO 50 v2
Patrol engine Max. payload ~45 kg
HPGe detector: total weight: 25 kg

Drone: DJI F550 (max. payload: 0.6 kg)
CZT detector. Total weight: 0.4 kg

Control software

The ground station (control) software displays real-time telemetry, dose rates, count rates, detector spectra and waterfall plots (i.e. time series of gamma-ray spectra). The different teams developed their own control software.

As an example, the RIMA-spec software is shown



Royo , P. et al. Using Unmanned Aircraft System for Detecting a Radiological Point Source. *Remote Sens.* **2018**, *10*(11), 1712

https://doi.org/10.3390/rs10111712

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

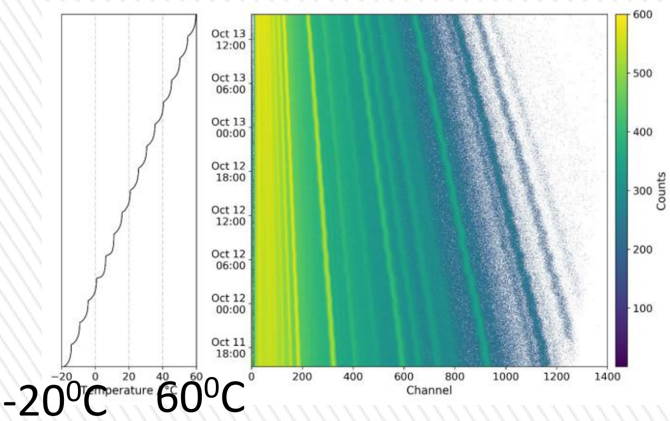
Main **Recommended methods** to implement in the calculations:

- 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.

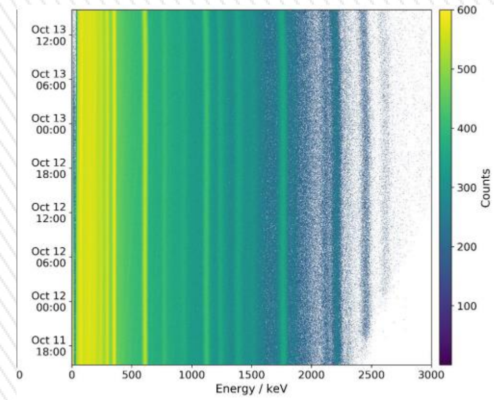
Calibration procedures

Temperature stabilization (climate chamber with Ra-226 source)

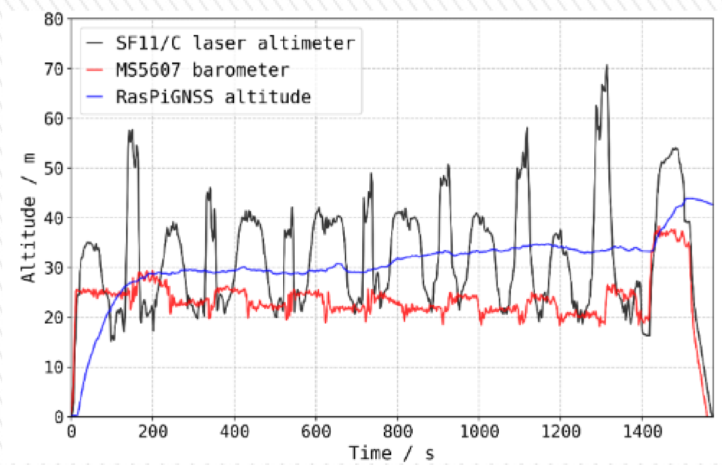
Raw Sepctra



Calibrated Sepctra



Altitude measurements (to calculated doses at 1 m, activity concentrations,….)

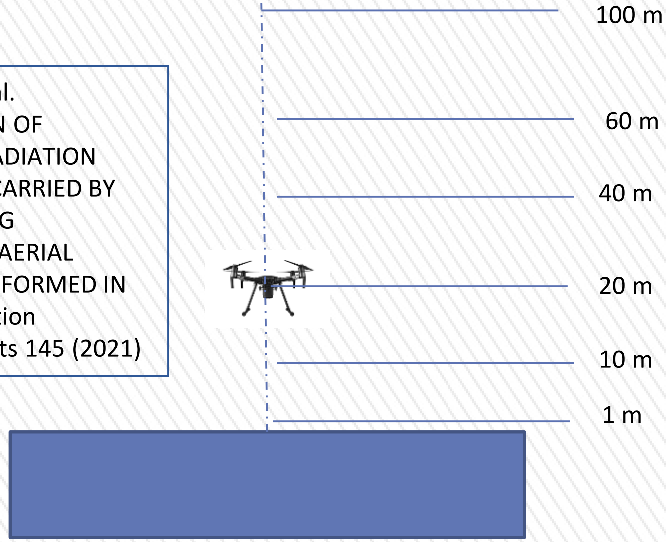


- the GPS and barometer measurements do not give information about the local terrain profile (hills and valleys cause height variations)
- The laser will be influenced by trees and brushes
- Humid grass can cause the laser to fail

Calibration procedures

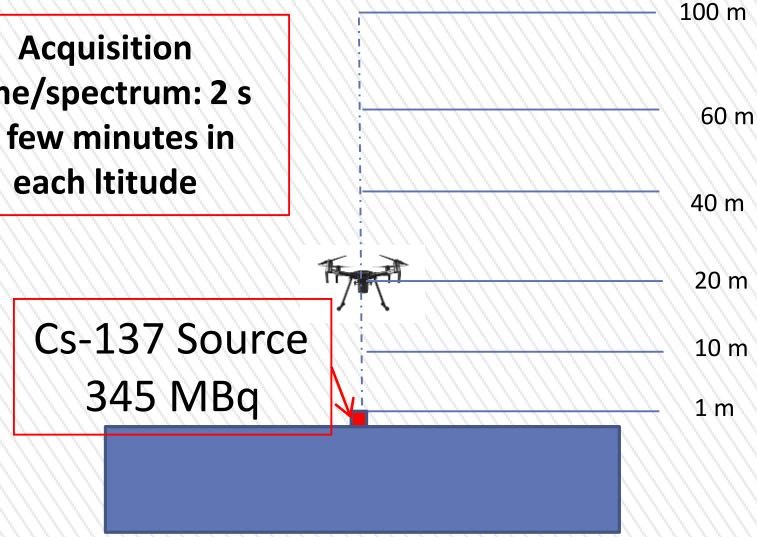
1. Background characterization

A. Vargas et al. COMPARISON OF AIRBORNE RADIATION DETECTORS CARRIED BY ROTARY-WING UNMANNED AERIAL SYSTEMS PERFORMED IN SPAIN. Radiation Measurements 145 (2021)

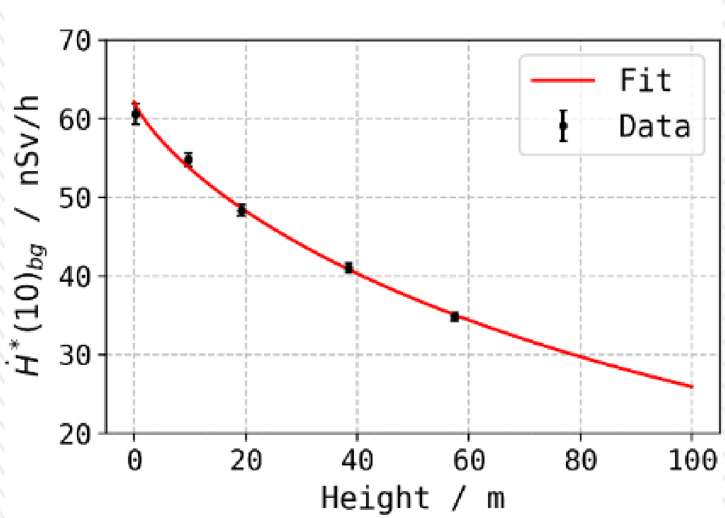


2. Vertical flights over point source

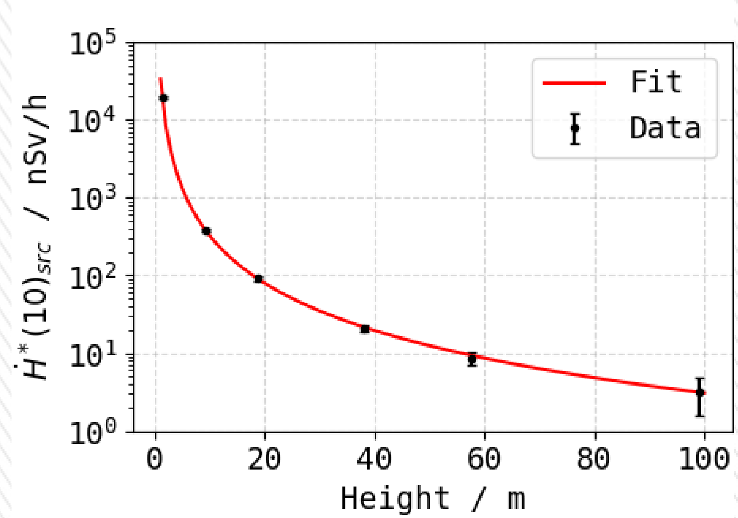
Acquisition time/spectrum: 2 s
A few minutes in each ltitude



Exponencial integral profile

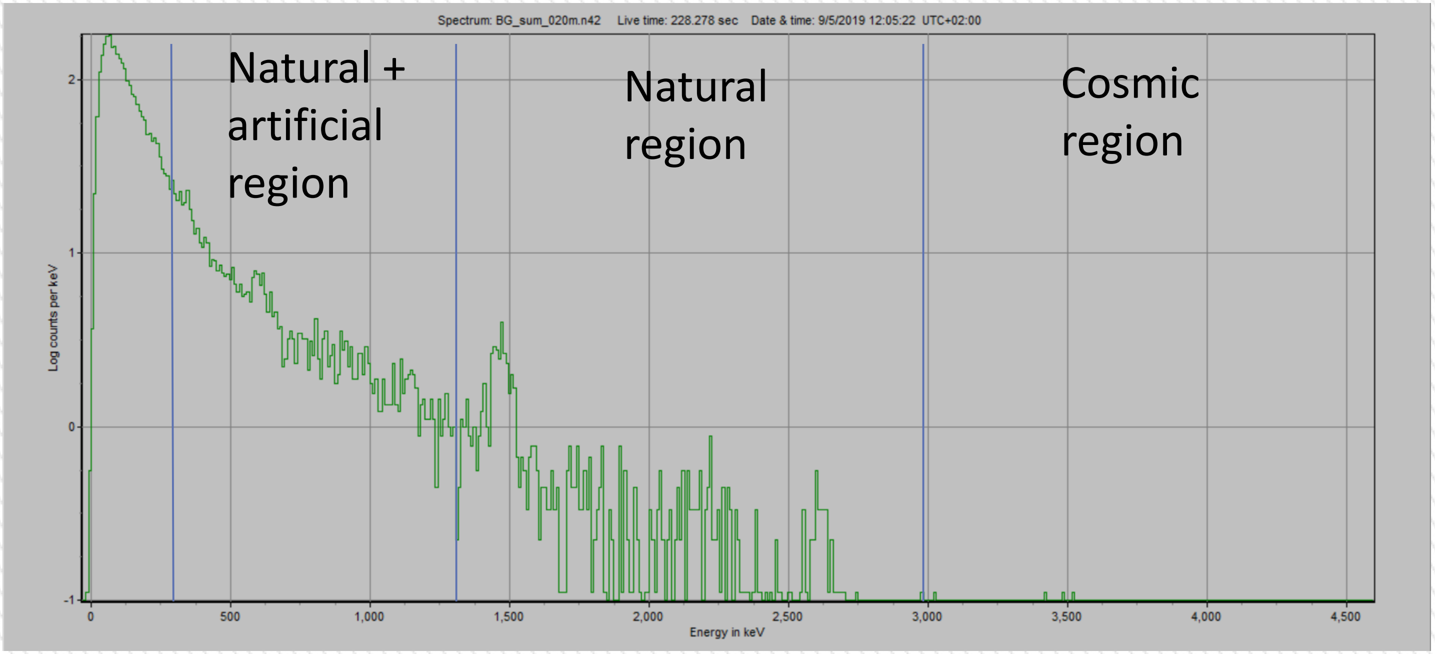


Inverse of the square distance profile



Man-Made Count Rate (MMCR)

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



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

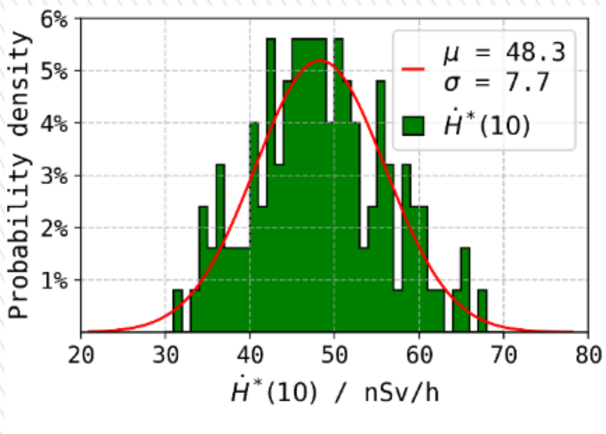
The ***ratio*** is calculates **when no artificial source is present** , i.e., MMCR= 0.

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

NaI 50mm x 50 mm

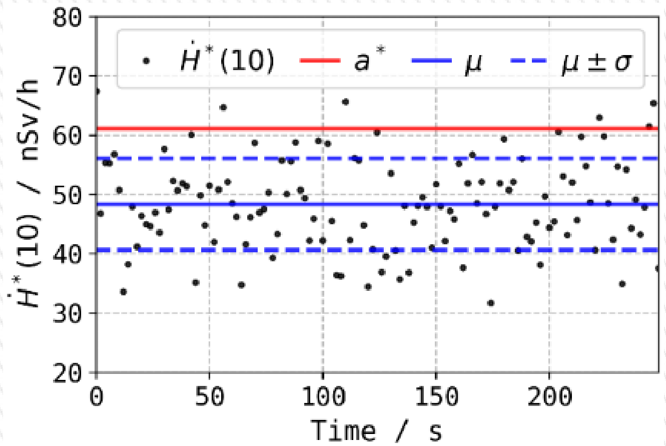
Calibration: decision thresholds

Background $CeBr_3$ $H^*(10)$ at 20 m height (acquisition time 2 s)



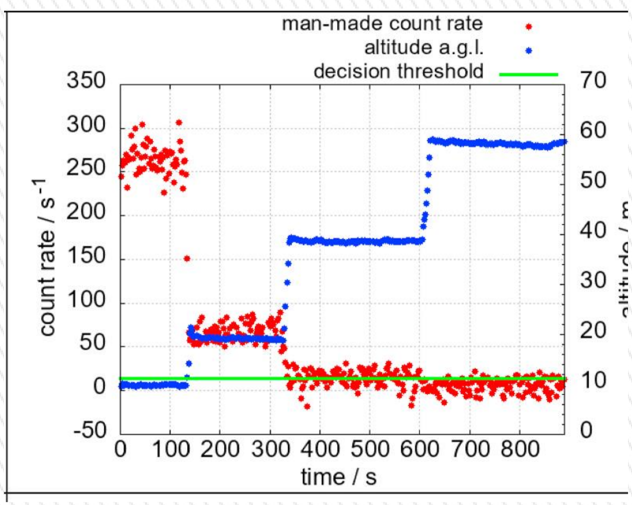
Decision threshold (ISO11929-4)

a^*=1.645 σ

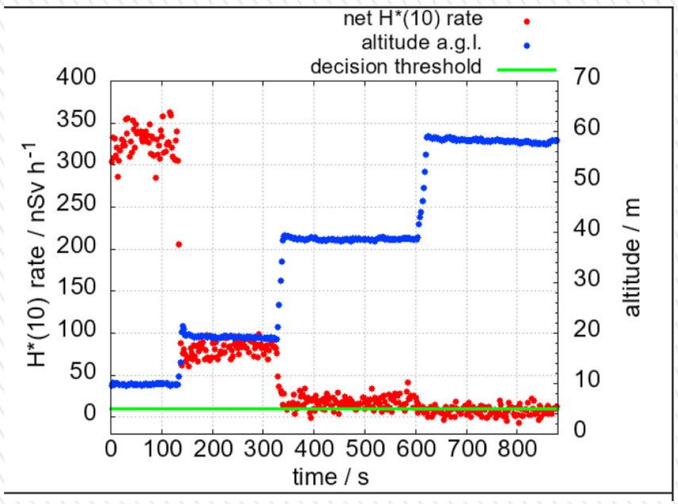


Response $CeBr_3$ $H^*(10)$ to a Cs-137 point source of 345 MBq at different heights (acquisition time 2 s)

MMCR



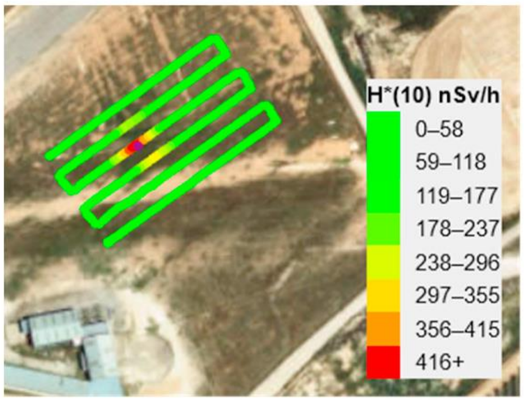
$H^*(10)$ rates



Calibration: source location

Measurements carried out in a flat homogeneous terrain in an aerial site (Spain) using a Cs-137 point source of 345 MBq

NaI 50 mm x 50 mm



$CeBr_3$ 38 mm x 38 mm

CZT 1500 mm^3

Source coordinates and corresponding uncertainties as measured with the NaI detector (top values) and the $CeBr_3$ detector (bottom values). Actual position is 41.612430 ± 1.6E-5 N, 0.854505 ± 1.6E-5 E.

Nominal altitude (m)	Longitude		Latitude	
	Measured	abs. difference (m)	Measured	abs. difference (m)
10	0.854505 ± 6E-6	0.0 ± 1.4	41.612420 ± 5E-6	1.1 ± 1.9
	0.854505 ± 1E-5	0.0 ± 1.5	41.612444 ± 8E-6	1.6 ± 1.6
20	0.854513 ± 1.6E-5	0.7 ± 1.8	41.612434 ± 1.3E-5	0.4 ± 2.3
	0.854503 ± 3.2E-5	0 ± 3	41.612411 ± 2.4E-5	2 ± 3
40	0.85451 ± 9E-5	0 ± 8	41.61245 ± 6E-5	2 ± 7
	0.85434 ± 2.0E-4	14 ± 17	41.61237 ± 9E-5	7 ± 10

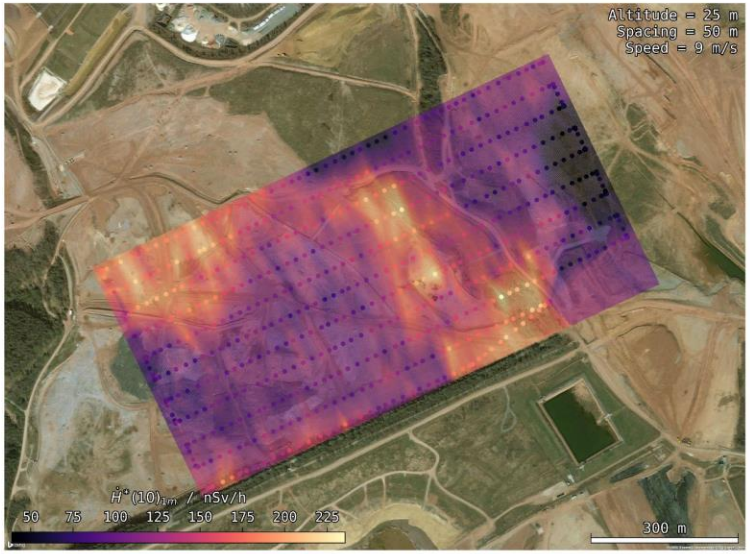
Results of the decision thresholds and source location are published in:

Vargas , A. et al. **Comparison of airborne radiation detectors carried by rotary-wing unmanned aerial systems.** *Rad. Meas. 145 (2021)*

https://doi.org/10.1016/j.radmeas.2021.106595

Calibration: WISMUT CAMPAIGN

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



Wismut: H*(10) and MMCR

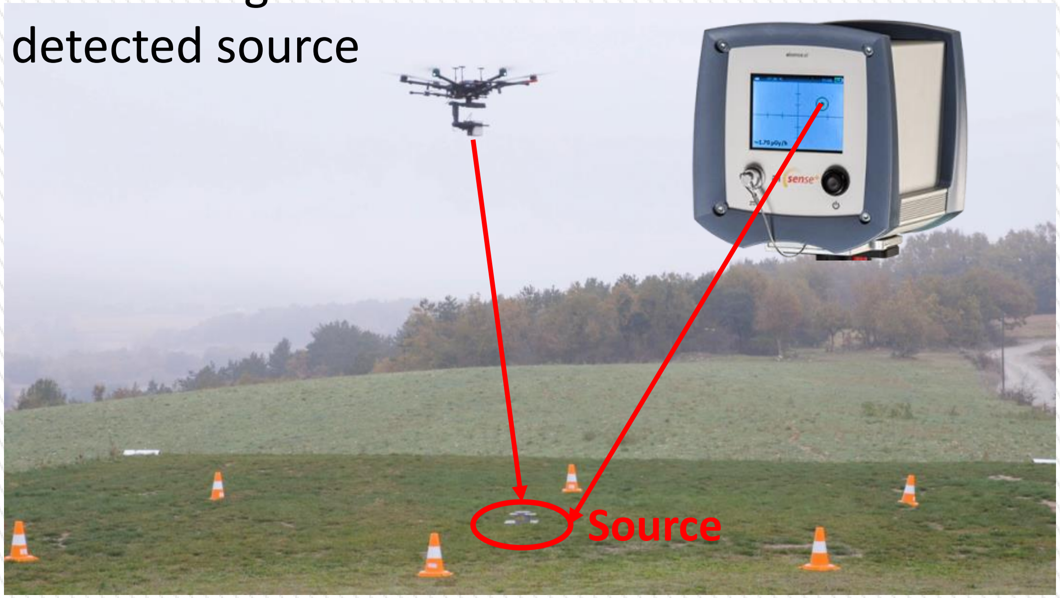
Increases on the *H(10) rates are due to variation in the natural activity concentration and to the presence of Cs-137 and Co-60 sources, but cannot be distinguished. However, *MMCR* can identify the presence of artificial sources.**

Full Spectra Analysis (FSA)

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

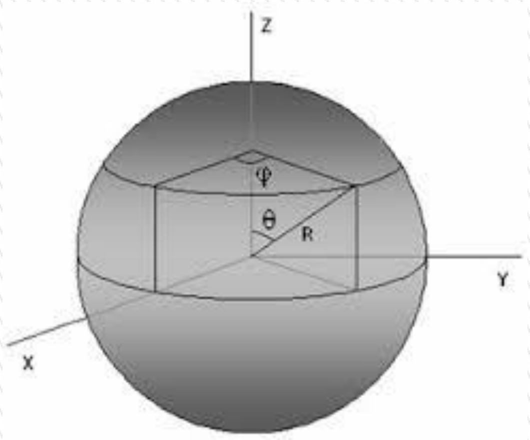
Locator system

The drone goes to the detected source

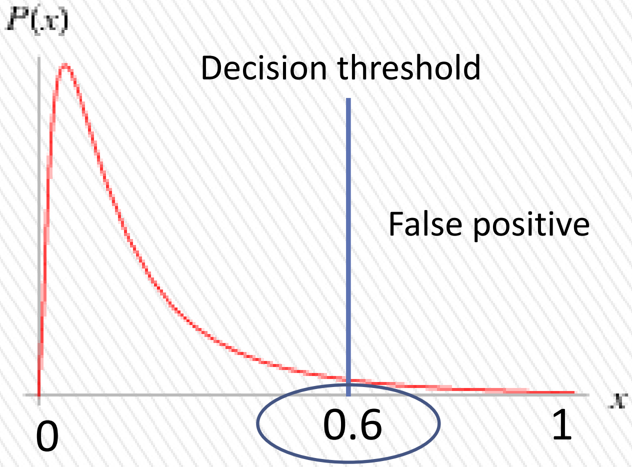


Gimbal and detector mounted in the DJI Matrice 600 Pro

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

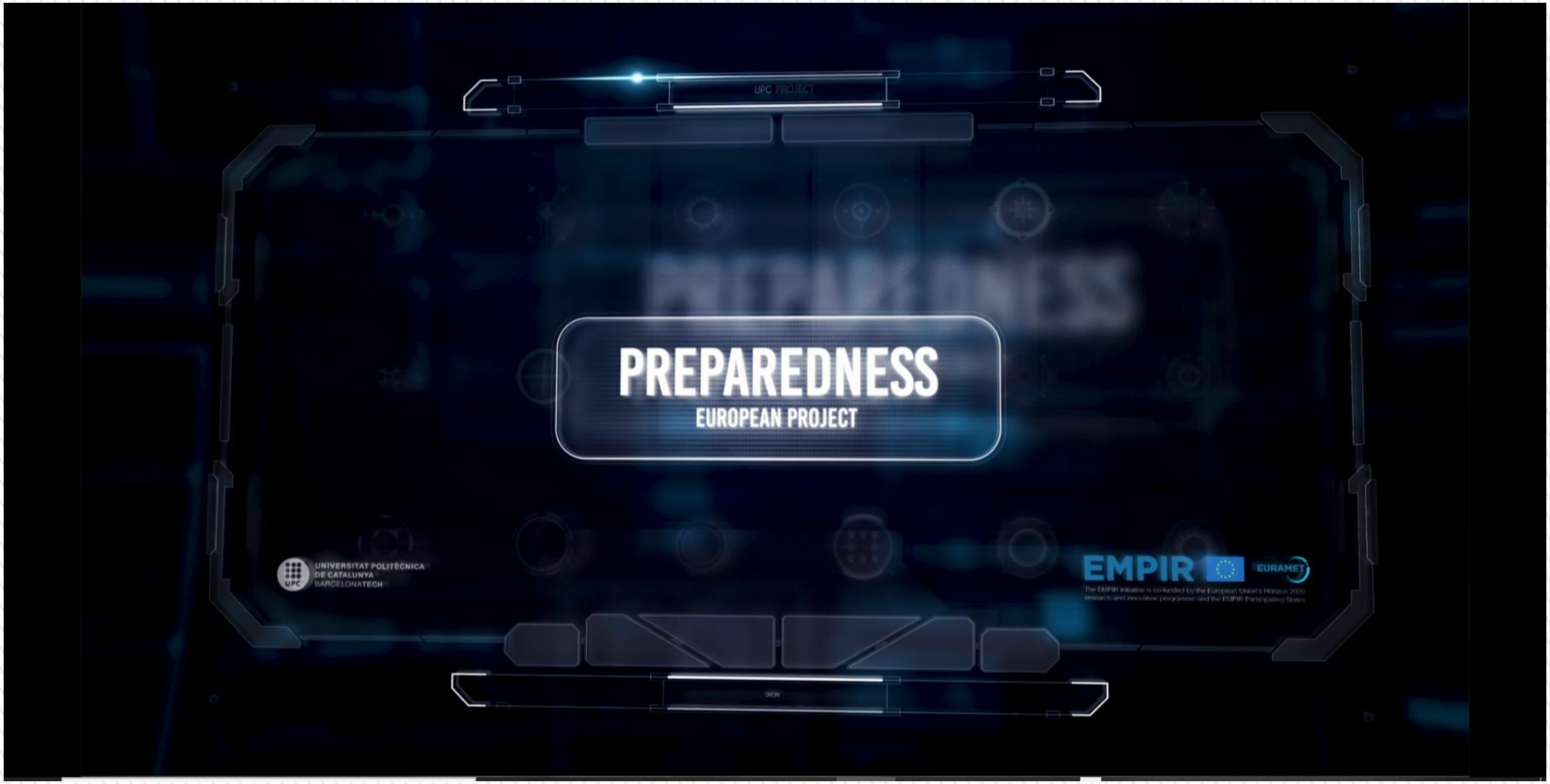


$$x = \frac{1}{n}\left\|\sum_{1}^{n} \vec{R}\right\|$$



Video

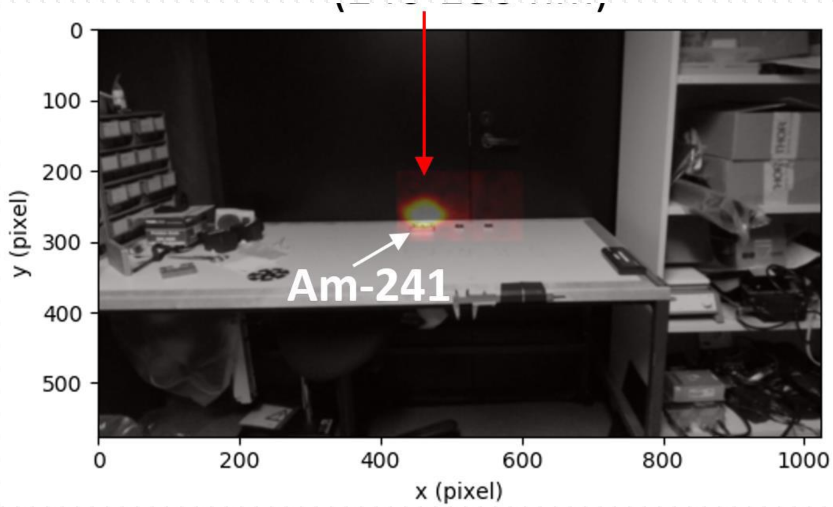
https://www.youtube.com/watch?v=IV45uvionKI&t=46s.



On-going and Future activities

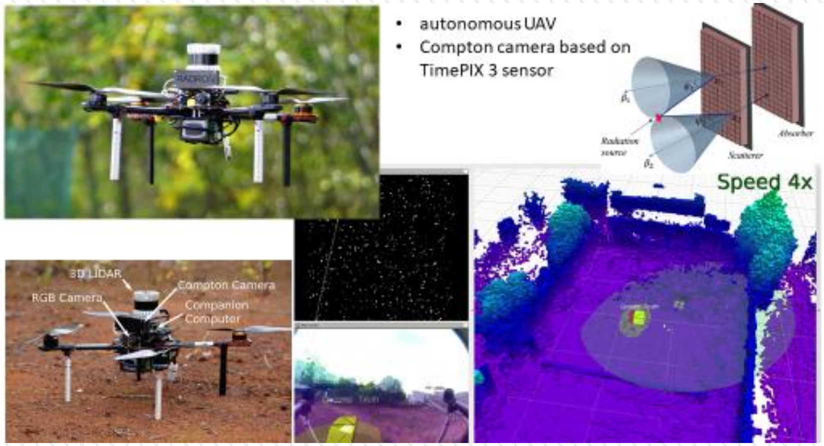
UAV's for **remote alpha measurements (remoteAlpha EMPIR project)**

Radioluminescense signal



Autonomous, AI-controlled UAV, specially for indoor accidents (METOXA EMPIR project in preparation)

"Compton camera" (METOXA)



3D maps for radiological clouds (**METOXA**)

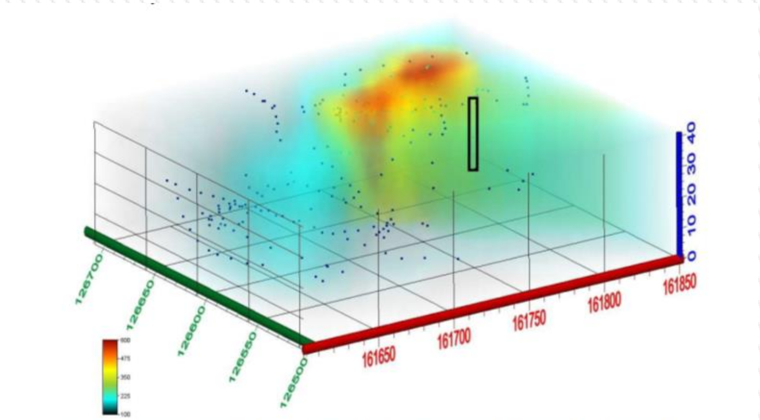


Figure 13 : 3D impression of release plume xe-133 signal , the stack is approximately indicated with black rectangle

METOXA → https://msu.euramet.org/current_calls/greendeal_2021/index.html