

Drone mapping radioactivity in emergency situation

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Liberté
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SFRP
Société Française de Radioprotection

IRSN
INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

DRONE MAPPING RADIOACTIVITY IN EMERGENCY SITUATION

Caroline SIMONUCCI, Fabien PANZA, Elise CROSLAND, Vincent FAURE, Xavier AMET

IRPA - BUDAPEST 05/31/2022

IRSN/PSE-ENV/SIRSE/LER-NORD

IRPA INTERNATIONAL RADIATION PROTECTION ASSOCIATION

IRSN/FRM-296 ind. 06

MEMBRE DE ETSON

OUTLINE

- Context
- IRSN UAV fleet
- IRSN engagement scenarii
  - type of scenarii
  - data integration system
  - example of scenarii
- Conclusion & Perspectives







IRSN AREAS OF INTERVENTION

IRSN IS THE FRENCH PUBLIC EXPERT ON NUCLEAR AND RADIOLOGICAL RISKS

NUCLEAR SAFETY AND SECURITY

Reactors, fuel cycle, waste management, transport of radioactive materials, radioactive sources

PROTECTION OF THE POPULATION AND THE ENVIRONMENT

Against the risks associated with ionizing radiation

NUCLEAR AND RADIOLOGICAL EMERGENCY RESPONSE

Operational support capacity

SIRSE activities



ENVIRONMENTAL MONITORING



RADIOLOGICAL CHARACTERIZATION/ INTERVENTION

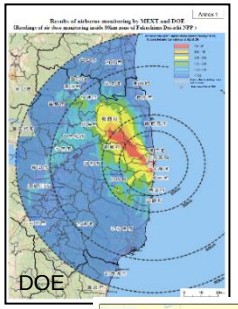


EMERGENCY PREPAREDNESS

Systems dedicated to measure radioactivity at different scales



National/region area





Territory

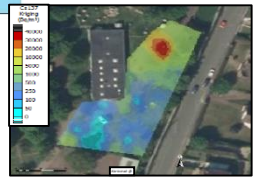




Roads



Lot/Field





Ponctual measure







IRSN DRONE FLEET

PHANTOM 4 by DJI (x2)

- Flight duration: 25 mn
- Visualization : 4K full HD camera





Radioactivity detector:

- ISYFlighter sensor (ISYMAP)
- γ dose rate meter: CsI(Tl)
- Dose rate only
- Dose rate: 1 $\mu Sv.h^{-1}$ to 10 $mSv.h^{-1}$ (*)
- Energy range: 59 keV to 2 MeV

Drone + sensor deployment:
2 people – ~10 mn

UAV dedicated to visualization and dose rate estimation



IRSN video credit 2022

IRSN DRONE FLEET

DRONESTAR 850V2 by INNOVADRONE

MADE IN FRANCE

INNOVADRONE

- Flight duration: 20 mn
- Weight: 8.5 kg (payload capacity of 3.3 kg)
- RTK GPS
- Map a soccer field size during 1 flight



Radioactivity detector:

- SPIR-EXPLORER sensor (MIRION Technologies)
- γ spectrometer NaI + 2 GM tubes
- Dose rate: 0,1 µSv.h^{-1} to 10 Sv.h^{-1}
- Energy range: 50 keV to 3 MeV
- Identification: 100 nSv.h^{-1} of ^{137}Cs in 1s

Drone+sensor deployment:
3 people – 30 mn

UAV dedicated to radioactivity measurement



IRSN video credit 2021

IRSN DRONE FLEET

SURVEYOR by INNOVADRONE

MADE IN FRANCE

- Weight: 8 kg (payload capacity of 3.5 kg)
- Flight duration: 35 mn



Radioactivity detector:

- SPIR-EXPLORER sensor (MIRION Technologies)
- γ spectrometer NaI + 2 GM tubes
- Dose rate: 0,1 $\mu Sv.h^{-1}$ to 10 $Sv.h^{-1}$
- Energy: 50 keV to 3 MeV
- Odometry system
- Range finder

It will be dedicated to radioactivity measurement

NOT YET DELIVERED, BUT COMING SOON !

IRSN ENGAGEMENT SCENARII

RADIOACTIVE MATERIAL TRANSPORT ACCIDENT (RMTA)

ORPHAN SOURCE & MALEVOLENT ACT (OSMA)

NUCLEAR FALLOUT (NF)

POLLUTED SITE & SOILS (PSS) R&D



IRSN photo credit 2022



Skynews photo credit 2011



IRSN photo credit 2021

1- IRSN ENGAGEMENT SCENARIO :

RADIOACTIVE MATERIAL TRANSPORT ACCIDENT (RMTA)



SCENARIO A

- RMTA with or without package spillage outside the vehicle, no visible degradation of the package
- Source term: irradiation
- Needed for: intervention preparation, zoning, intervention estimated dosimetry
- Equipment: DJI PHANTOM 4 + ISYFlighter sensor, DRONESTAR + SPIR-EXPLORER sensor
- Results: visualization and dose rate estimation at the closest, dose rate mapping at 1 m from the soil surface

Scenario A



SCENARIO B

- RMTA with package spillage outside the vehicle, with visible degradation
- Source term: dispersion of radioactive material, radioactive contamination of the environnement
- Needed for: no material spillage evidence, quantify spreading for remediation
- Equipment: DJI PHANTOM 4 + ISYFlighter sensor, DRONESTAR + SPIR-EXPLORER sensor
- Results: visualization, dose rate mapping or relative counting rate, map of the integrated activity per unit area in Bq/m² (naturals & artificials)

Scenario B



2- IRSN ENGAGEMENT SCENARIO :

ORPHAN SOURCE & MALEVOLENT ACT (OSMA)

SCENARIO A

Scenario A

- OSMA: hidden irradiating source in an outdoor crowded area
- Source term: irradiation
- Needed for: accurate source localization, identification of the radionuclide(s), intervention preparation, zoning, intervention estimated dosimetry
- Equipment: DJI PHANTOM 4 + ISYFlighter sensor, DRONESTAR + SPIR-EXPLORER sensor
- Results: visualization and dose rate estimation at the closest, dose rate mapping or relative counting rate, gamma spectrometry in hover flight from afar and radionuclide id. (no quantification), dose rate mapping at 1 m from the soil surface

SCENARIO B

Scenario B

- OSMA: hidden irradiating source plus radioactive material spreading in an outdoor crowded area
- Source term: dispersion of radioactive material
- Needed for: accurate source localization, identification of the radionuclide(s), intervention preparation, quantify spreading for remediation
- Equipment: DJI PHANTOM 4 + ISYFlighter sensor, DRONESTAR + SPIR-EXPLORER sensor
- Results: visualization, dose rate mapping or relative counting rate, gamma spectrometry in hover flight from afar and radionuclide id. (no quantification), map of the ground surface activity per unit area in Bq/m² (artificials)

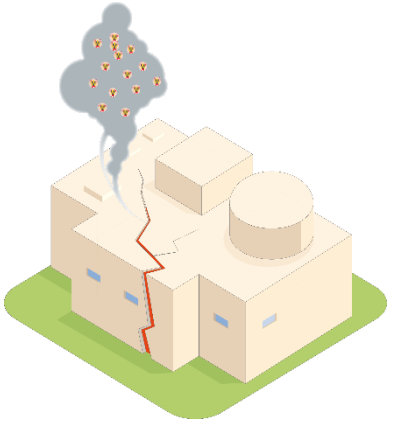
3- IRSN ENGAGEMENT SCENARIO :

NUCLEAR FALLOUT (NF)



SCENARIO

- NF: massive release (according to measurement strategy), evaluate localy the level of pollution in the soils, usually deployment of airborne or manborne equipments
- Source term: irradiation of nuclear fallout, radioactive pollution or deposits (mines, industries, etc.)
- Needed for: quantification of dose rate level, quantification of the ground surface activity per unit area
- Equipment: DRONESTAR + SPIR-EXPLORER sensor
- Results: dose rate mapping at 1 m from the soil surface, map of the ground surface activity per unit area in Bq/m² (naturals & artificials)



IRSN R&D SITE:

POLLUTED SITE & SOILS (PSS) R&D



SCENARIO

- PSS (R&D): Expertise of polluted site, usually deployment of airborne or manborne devices
- R&D site: testing of equipment, flight procedures and data treatment methods
- Source term: irradiation of nuclear fallout
- Needed for: identify areas of interest, estimate ground surface activity and potentially the activity per unit mass massic of the soil (hypothesis)
- Equipment: DRONESTAR + SPIR-EXPLORER sensor
- Results: dose rate mapping at 1 m from the soil surface, map of ground surface activity per unit area in Bq/m² (naturals & artificials) or map of the activity per unit mass at the soil surface in Bq/kg (naturals and artificials)

IRSN DATA INTEGRATION SYSTEM

IN SITU



acquisition

analysis

DB

visualization

IRSN scripts

Drone data transfer in real-time on IRSN data base

IRSN BACK OFFICE

Spectra DB

storage

WEB

extraction
visualization
calculation

- ARCGIS
- AVID
- KARTOTRAK
- INTERWINNER
- EXCEL
- MIRION/SMI
- MIRION/REPLAY

Results can be processed *in situ* or by IRSN back office

WORK IN PROGRESS

EXAMPLE: MEASUREMENT ON A CONTAMINATED SITE WITH NATURAL RADIONUCLIDE (FRANCE)

Site description

- Former mining site: contamination with Radium-226
- High and dense vegetation with rugged topography
- Harsh flying conditions

Challenges

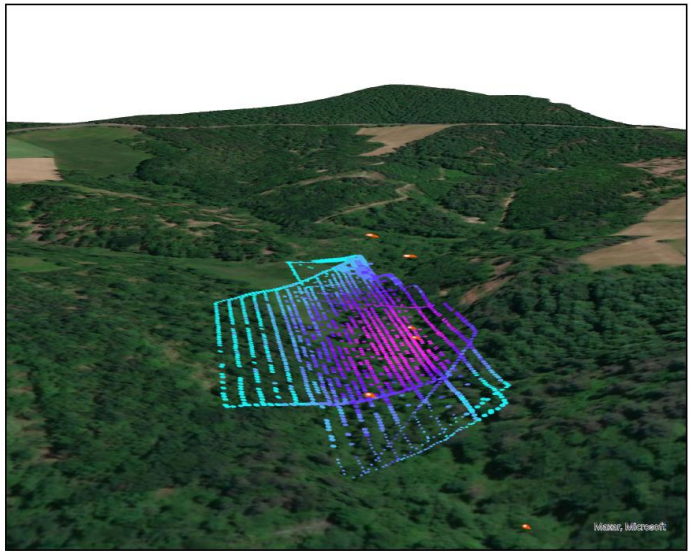
- How to determine the height above the ground with a good accuracy:
  - ➢ UAV range finder measurement is influenced by the forest canopy
  - ➢ Low precision of free Global Digital Elevation Model data sources (SRTM)

Development in progress

- Access to the Global Digital Elevation Model with good accuracy that can be used for
  - ➢ Autopilot and height control (flight parameters)
  - ➢ Data treatment

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Résultats de mesures aériennes par drone
14 Octobre 2021



CONCLUSION

- IRSN purchased UAV to minimize intervention team dose, to visualize scenery and to collect radioactive data in the environment. It has many advantages in terms of deployment time, intervention preparation/organization and minimization of collective dose to the intervention team on field.
- IRSN defined different engagement scenarii hence different type of results.
- Data treatment methodologies are in progress to deliver relevant results.

PERSPECTIVES

- Development of a methodology to calculate dose rate at 1 m from the soil surface: comparison of drone hovering at different heights over a patch without contamination (background level) and over a contaminated patch. Collaboration with JAEA
- Indoor/outdoor mapping using odometry technique
- Optimization of flight parameters: enhancement of sensor data accuracy vs. sensor deployment time (drone flight)

THANKS FOR YOUR ATTENTION !

WORK IN PROGRESS

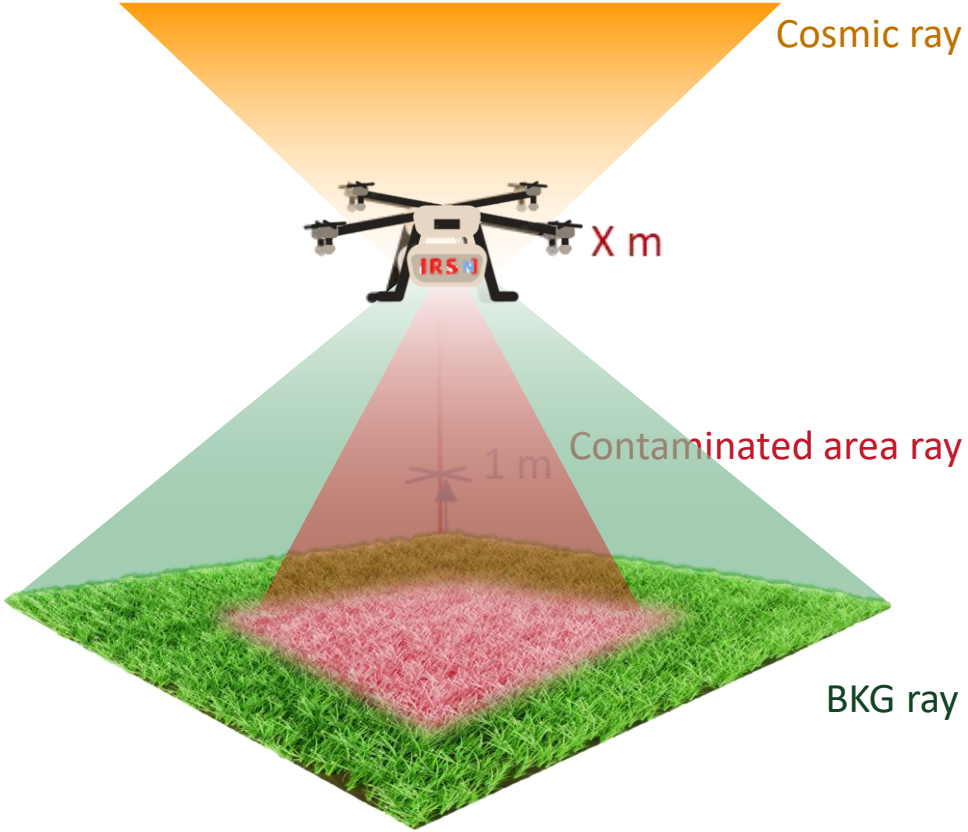
NORMALIZATION OF DATA AT 1 M ABOVE GROUND

Composition

At 1 m height, dose rate is function of :
- Cosmic ray
- BKG ray
- Contaminated area ray

Each component is different in type, energy, geometry and is related to the flying height

Each component of the signal is analyzed independently

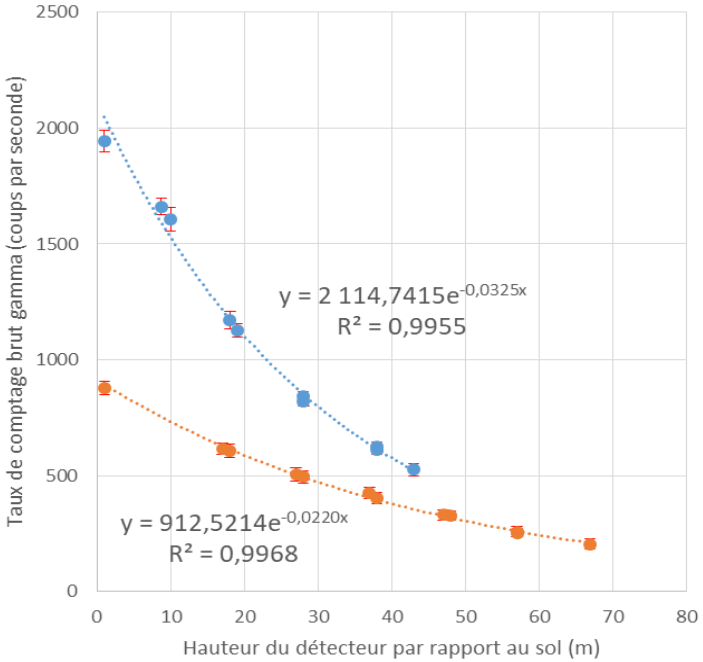


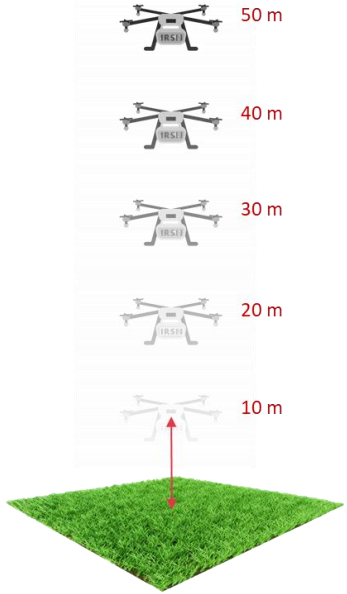
WORK IN PROGRESS!!

WORK IN PROGRESS

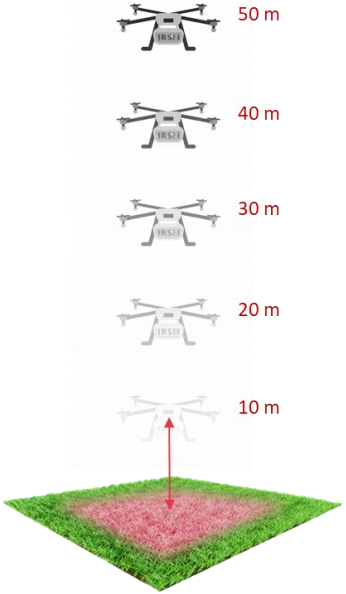
NORMALIZATION OF DATA AT 1 M ABOVE GROUND

- Patch 1: BKG dose rate attenuation
- Patch 2: Contaminated area dose rate attenuation





Patch 1



Patch 2

WORK IN PROGRESS



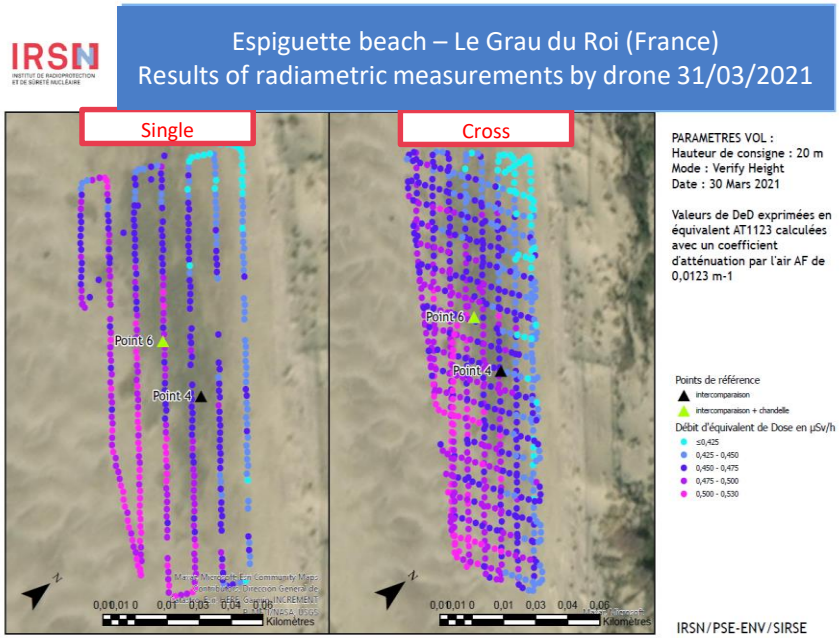
Dronestar 850V2 – Autopilot Flight parameters

- Flight height above ground: 10 – 30 meters depending on the flight security
- Height control:
  - Constant height above ground measured with the UAV range finder

    → recommended for sites without vegetation or buildings
  - Correction of the height above ground at each waypoint (change point direction) with Digital terrestrial Elevation Model (DEM) from NASA

    → recommended for sites with vegetation or buildings

    → development in progress to use Digital Elevation Model throughout the flight
- Speed: 1 to 3 $m.s^{-1}$ depending on the size of de site, the composition of the source and its extent
- Track mode: cross in order to offset few losses of data
- Interval: around 5 m depending on the flight height



NEW DEVELOPMENT: INDOOR GEO POSITIONING

- Radiological mapping indoor or when bad GPS positioning
  - Allowing drone flight stabilization and automatic drone piloting
  - Recovering radiological measurement data with geo positioning and GIS exploitation

- Integration of an additional module of indoor geo positioning using inertial visual odometry

