NUCLEAR SECURITY APPLICATIONS AND DETECTION SYSTEMS

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Viareggio, July 28 – August 01, 2025

Agenda

- Radiation fundamentals
- R&N threats
- Measurement in practice
- Devices
  - PRD Personal Radiation Dosimeters
  - Handheld
  - BRD Backpack Radiation Device
  - Fixed station for environmental monitoring
  - Underwater radioactivity sensors
  - Mobile and Transportable Radiation Monitors
  - UAV radiation detection system
- scenarios

green text

Some slides contain a cocktail logo and green text.
These slides contain useful tips for the last day's mission "Mojito"

1

RADIATION FUNDAMENTALS QUICK START GUIDE

Decay modes

- α, β(+/-) : emission of particles (mass & charge)
- γ: electromagnetic emission (nuclear de-excitation)
- fission: the nucleus is broken in two similar parts plus minor fragments (prompt and delayed neutrons)
- n emission
- *p emission*

Decay Type	Radiation Emitted	Generic Equation	Model
Alpha decay	${}^{4}_{2}\alpha$	${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}X' + {}^{4}_{2}\alpha$	Parent → Daughter + Alpha Particle
Beta decay	${}^{0}_{-1}\beta$	${}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}X' + {}^{0}_{-1}\beta$	Parent → Daughter + Beta Particle
Positron emission	${}^{0}_{+1}\beta$	${}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}X' + {}^{0}_{+1}\beta$	Parent → Daughter + Positron

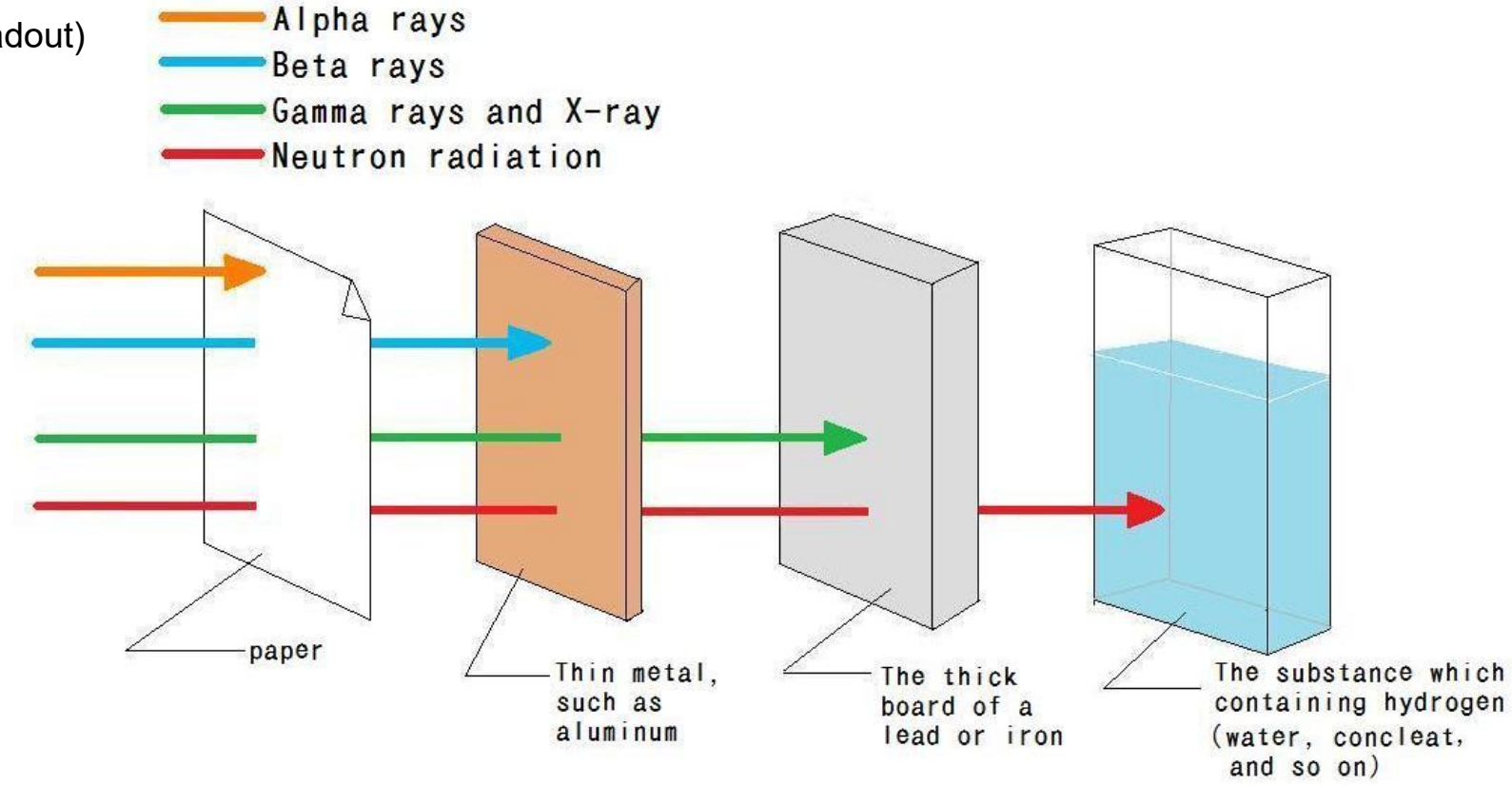
Gamma emission	${}^{0}_{0}\gamma$	${}^{A}_{Z}X^{*} \xrightarrow{\text{Relaxation}} {}^{A}_{Z}X' + {}^{0}_{0}\gamma$	Parent (excited nuclear state) → Daughter + Gamma ray
Spontaneous fission	Neutrons	${}^{A+B+C}_{Z+Y}X \longrightarrow {}^{A}_{Z}X' + {}^{B}_{Y}X' + C\,{}^{1}_{0}n$	Parent (unstable) → ENERGY + Neutrons + Daughters

Decay modes

Each decay mode has his own proprieties and different ways to interact with matter, these factors affect:

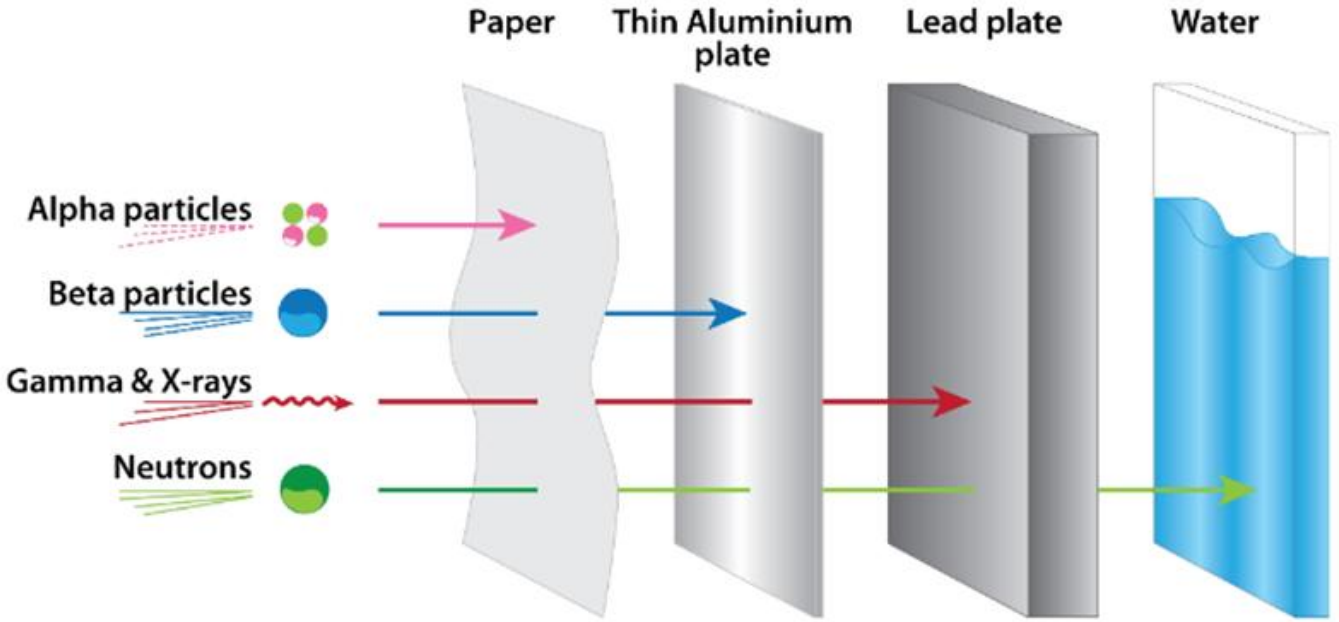
- The damage produced
- The way to detect it (detector material and readout)
- The shield needed to stop it

Each emitted particle has a lot of kinetic energy. The damage can be caused when this energy is absorbed by a human cell



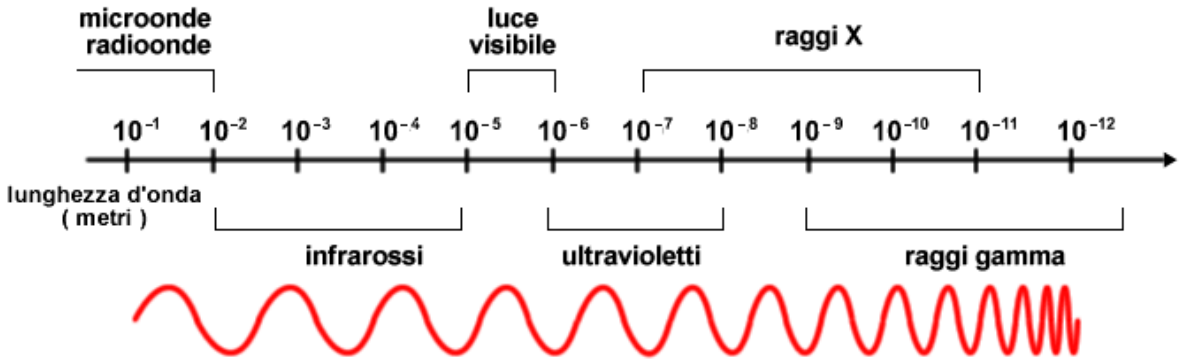
Why Neutron Detection?

- Low energy gamma rays may be easy to shield and hard to detect
- Materials such as nuclear fuels and weapons grade material are low gamma ray emitters, but emit neutrons
- Neutrons are harder to shield
- The neutron detector increases the chance of detecting radioactive materials with lower energy gamma ray

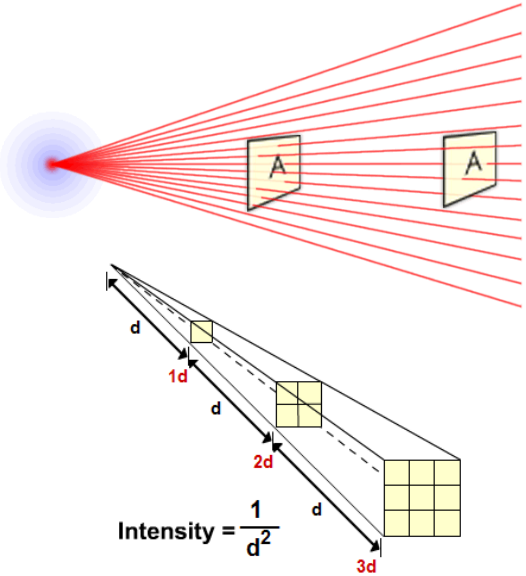


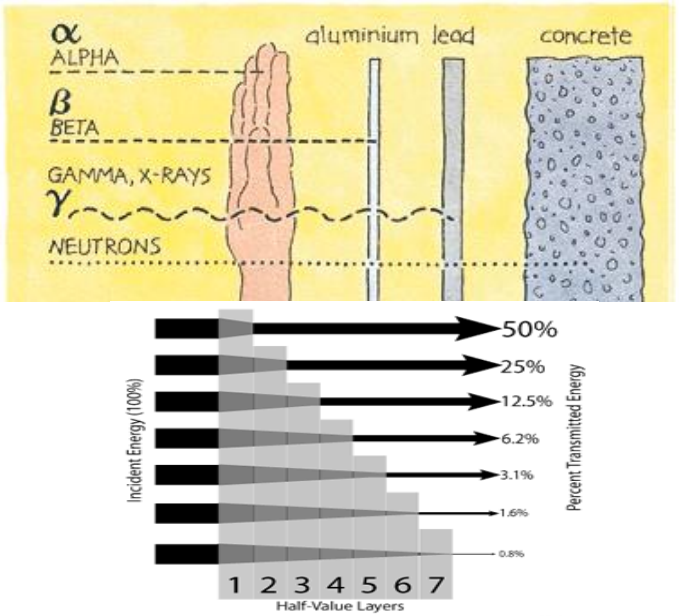
Radioactivity proprieties

	paritcle	Range En	Shielded with	Stopped in air (cm)	Damage when intaked	External damage
Alfa	He nucleus	4 – 10 MeV	Paper sheet skin	1.5	**HIGH**	**LOW**
Beta	e^{+}/e^{-}	Range MeV	Aluminum sheet to lead mm	20 - 100	**MID**	**MID**
gamma	Photons or EM radiation	10 keV – 10 MeV	Cm of lead	20 – 20.000	**LOW**	**HIGH**



ALARA principle





2

R&N THREATS

Types of emergencies

Nuclear emergencies categorized in threat category* I, II or III, depending on their on-site and off-site threats.

- Large irradiation facilities
- Nuclear reactors
- Storage facilities for large quantities of spent fuel or liquid or gaseous radioactive material
- Fuel cycle facilities
- Industrial facilities (e.g. facilities for manufacturing radiopharmaceuticals)
- Research or medical facilities with large fixed sources

Types of emergencies

Radiological emergencies. These are categorized in threat category* IV.

- They can occur anywhere
- Uncontrolled (abandoned, lost, stolen or found) dangerous sources
- Misuse of industrial and medical dangerous sources
- Public exposures and contamination from unknown origins
- Re-entry of a satellite containing radioactive material
- Serious overexposures
- Malicious threats and/or acts
- Transport emergencies

**No. GS-G-2.1 -Arrangements for Preparedness for a Nuclear or Radiological Emergency*

R and N emergencies

Nuclear emergencies categorized in threat category I, II or III, depending on their on-site and off-site threats.

Radiological emergencies: these are categorized in threat category IV (they can happen everywhere)

Incident	Warning / time to injury or illness	Magnitude	Availability
Chemicals	Seconds to hours	Localized to regional	High
Biologicals	Days to weeks	Local to global	Medium
Radiologicals	Hours to days	Local	Medium
Nuclear	Minutes to hours	City to regional	Very low
Explosives	Immediate	Local	Medium/high

Same contaminant → Radioactive material

Different size and method of dispersion

A focus on RN

Detecting SNM is critical because incidents involving unauthorized possession, loss, or trafficking of nuclear material are reported every year

The IAEA has highlighted the persistent global threat and the urgent need for effective detection capabilities

Incidents and Trafficking DataBase divides incidents in:

- Group I: incidents that are, or are likely to be, connected with trafficking or malicious use
- Group II: incidents of undetermined intent
- Group III: incidents that are not, or are unlikely to be, connected with trafficking or malicious use

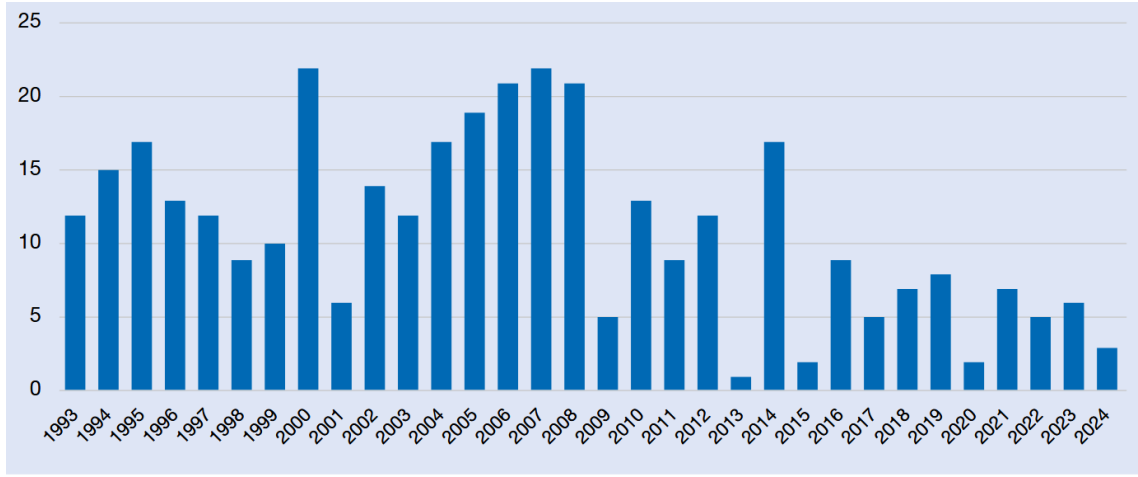
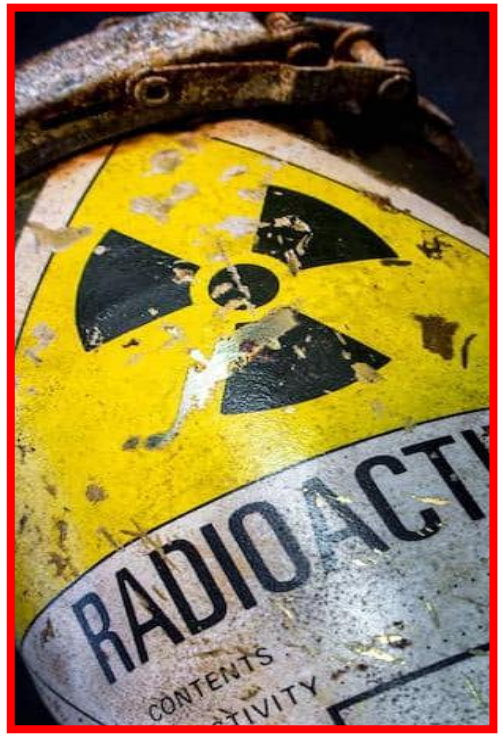


Figure 2. Incidents reported to the ITDB that are confirmed, or likely, to be connected with trafficking or malicious use, 1993–2024.

Detection of Special Nuclear Material is crucial in different contexts

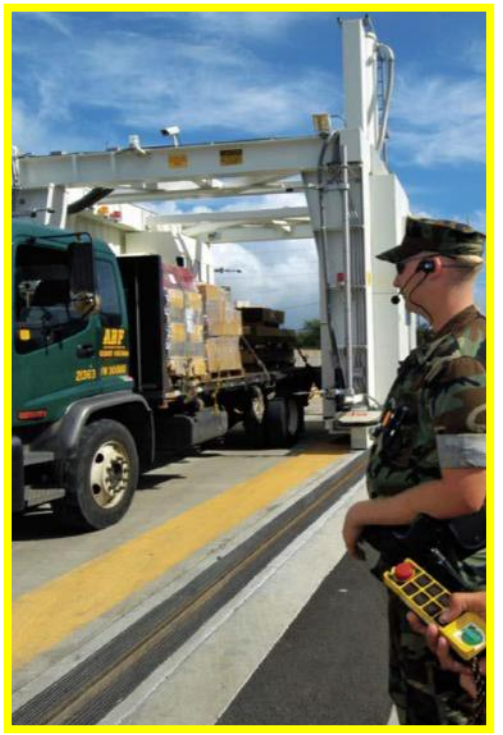
CBRN



Dirty bombs and smuggled material

Security control in airports

First responder prompt intervention



Custom border inspection

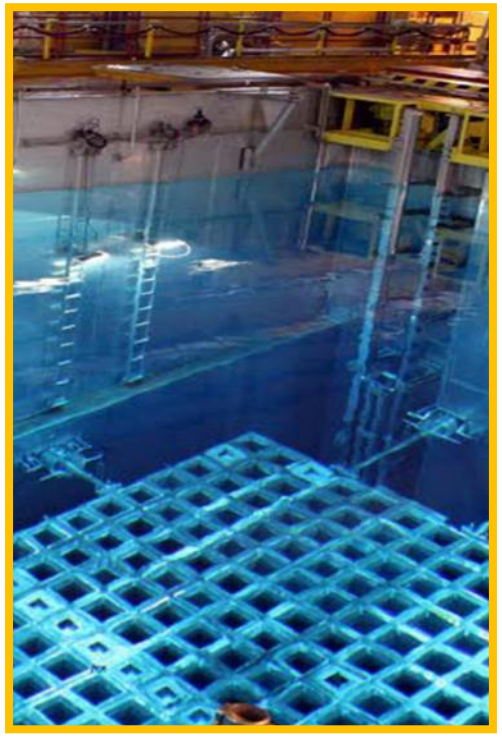
Radiological Dispersal Device detection and identification

Detection of Special Nuclear Material is crucial in different contexts

INDUSTRIAL

Critical infrastructure's perimeter monitoring

Enrichment plant survey and verification



Spent fuel safeguards

UF6 cylinder characterization

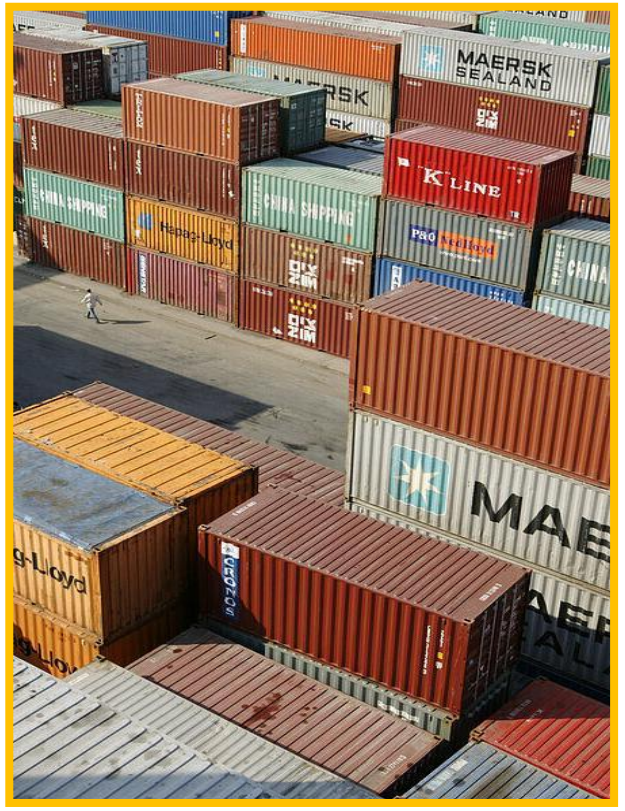
Fast waste screening

Detection of Special Nuclear Material is crucial in different contexts

CIVIL

Public events fast deployment

Parcel scanning



Harbor's container or airport's cargo areas

Preventive radiation survey in crowded areas

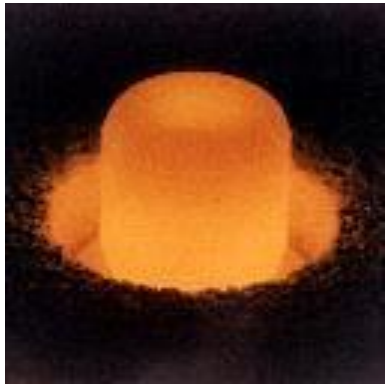
The Criticality of the SNM

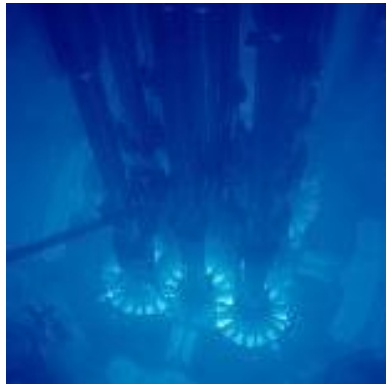
Special nuclear materials (SNM) are the Plutonium, 233U, 235U and samples of enriched uranium

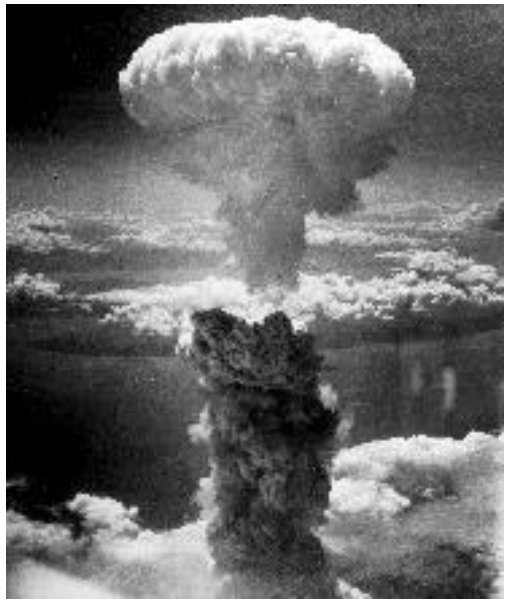
The 233U or the Pu are artificially produced using reactors or extracted using targets or via chemical separation.

There is a regulation for the production, storage and transport of these materials followed by the production facilities to ensure the safety of the population

The danger of these materials is not due to their radioactivity, that in small quantities is also mild, but that they are the primarily ingredients of nuclear explosives.



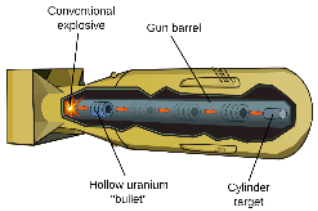


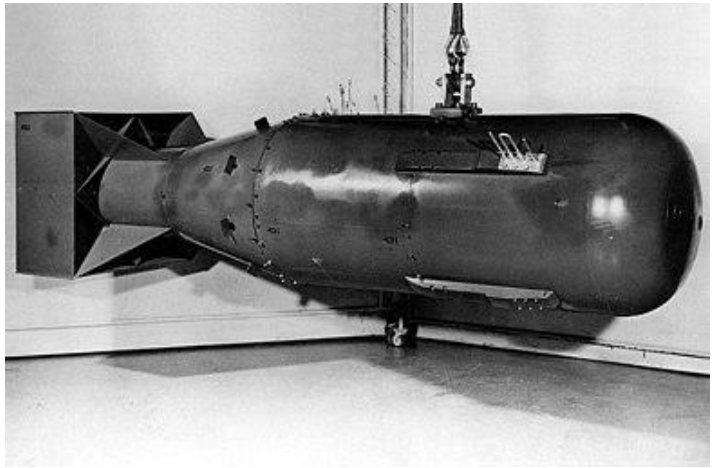


What is the SNM?

“"Special nuclear material" (SNM) is defined by Title I of the Atomic Energy Act of 1954 as plutonium, uranium-233, or uranium enriched in the isotopes uranium-233 or uranium-235...”

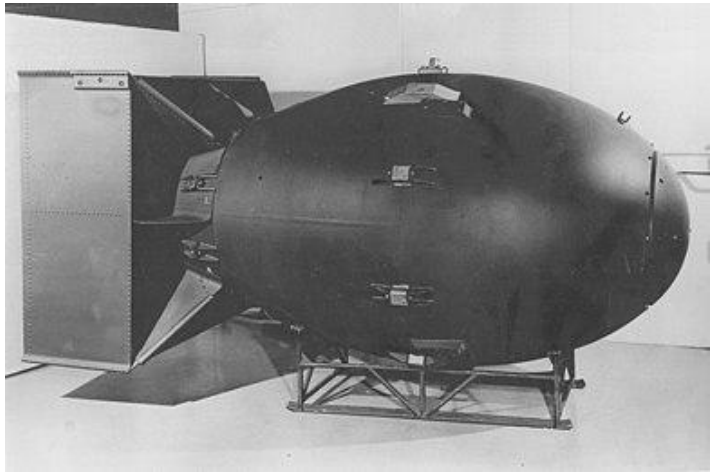
Special nuclear material is only mildly radioactive, but it includes fissile isotopes — uranium-233, uranium-235, and plutonium-239 — that, in concentrated form, could be used as the primary ingredients of nuclear explosives.





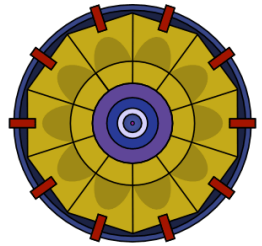
“Little Boy” Hiroshima

64,13 kg of U enriched at 80%(U-235)
0,7 kg fissioned (efficiency 1%)
Bomb type: Uranium piston



“Fat Man” Nagasaki

6,19 kg of Pu enriched at 93-95% (Pu-239)
1 kg fissioned (efficiency 17%)
Bomb type: Plutonium implosion



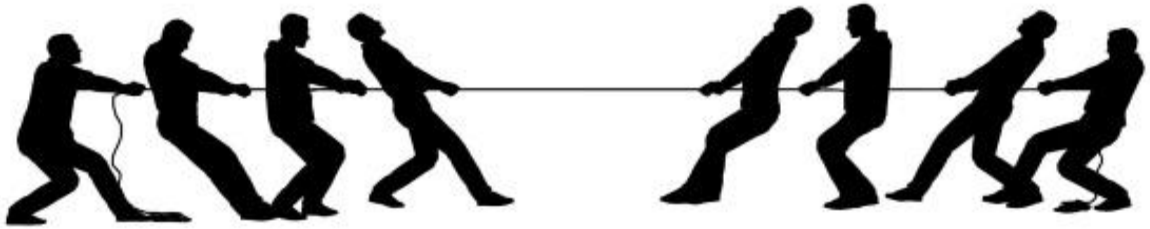
3

MEASUREMENT IN PRACTICE

The measurement quality trade-off

Amount and quality of Data

Time and speed



INSPECTION AND INVESTIGATIONS	EMERGENCY MEASUREMENTS
Scenario well defined	Unknown scenario
Known number of people involved	Unknown number of people involved
Time for sampling and lab analysis	Immediate response needed
Quantitative information required	Fast response required
Time to plan the intervention – hours to days	Time to plan the intervention – minutes to hours

! Quantitative and precise measurements are made, BUT LATER, after a site inspection and first responder prompt intervention

Data gathering for decision making

Higher data quality → better response

Faster data gathering → shorter time for first intervention

After the first emergency measurements “no further action required” is often a correct response

Radiation presence hypotesis → Cps measurements → Dose rate or radiation exposure → Radionuclide ID and activity concentration

If I know the radionuclide

Site inspection → sampling → Shipment to the lab → preparation of the sample → Lab measure

Is the sample representative of the whole environment? Many samples needed

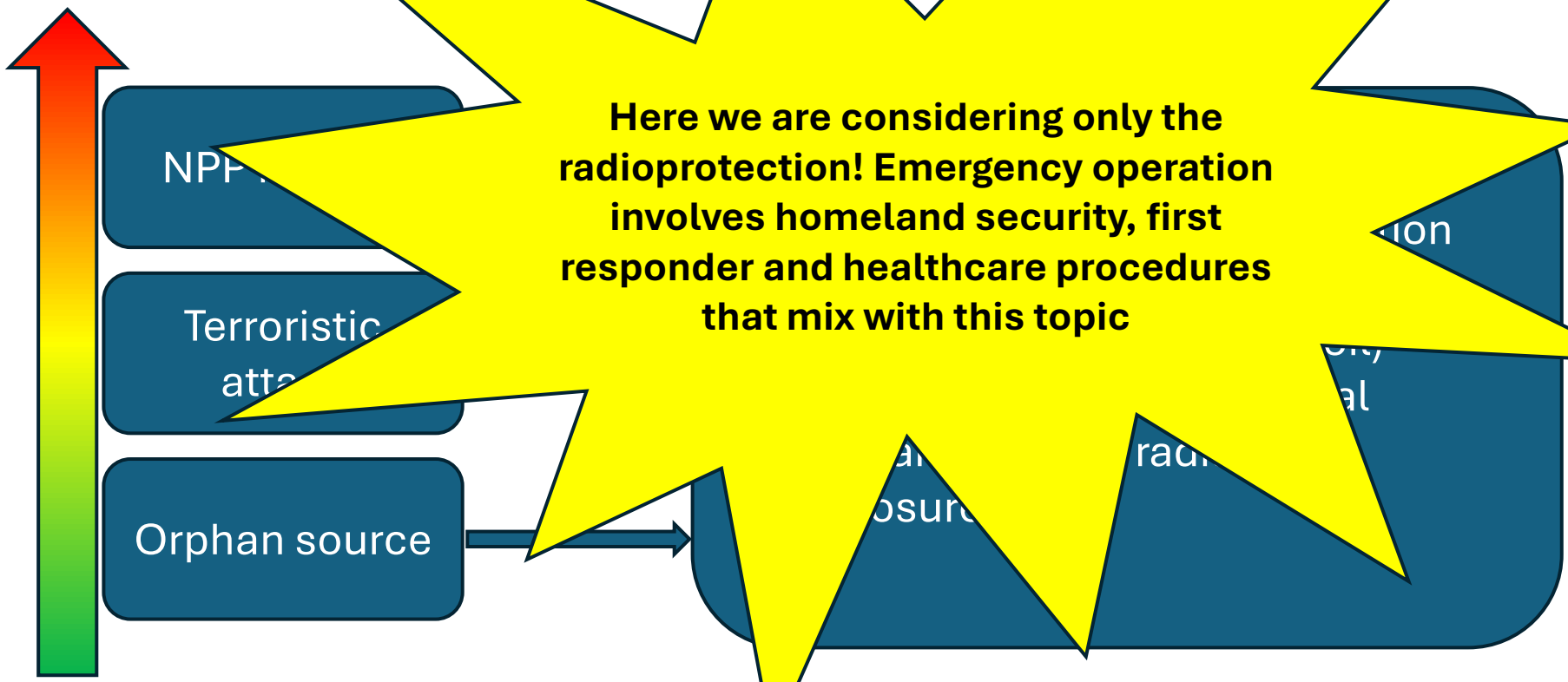
Handheld/transportable units can be used directly on site → time reduction

Emergency Measurements

Different threat categories (I, II, III or IV) : different scena → different measurement

Depending on the scenario different measurements (and inst re required

- Previous direct experiences
- Literature
- Emergency operative plans



Here we are considering only the radioprotection! Emergency operation involves homeland security, first responder and healthcare procedures that mix with this topic

New generation devices

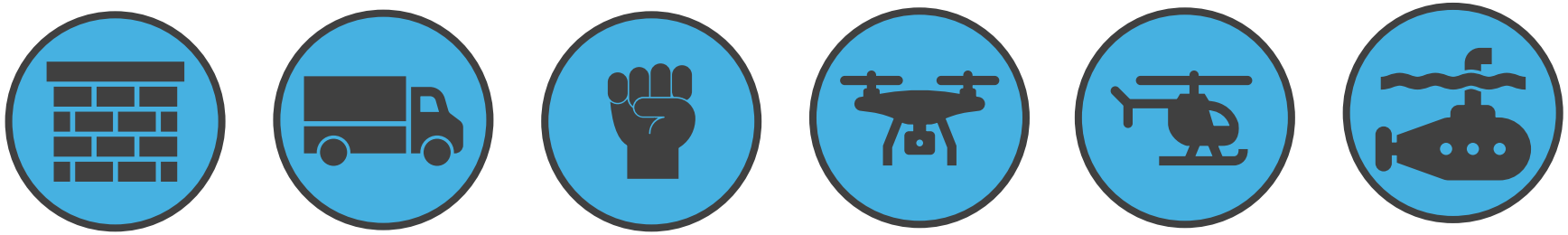
- Handheld, backpack, transportable systems
- Counting, dose-rate, spectroscopy, radionuclide ID and categorization ON SITE
- Data storage, reachback and fast communication

Site inspection → sampling → Shipment to the lab → preparation of the sample → Lab measure

On site measurements

New generation devices

- Different type of sensors (fixed, wearable, UAV, underwater, …ecc)
- Problem: they didn't work in concert (different producer, data format, type of data)→ STANDARDS (ANSI, IEC, etc.)
- Waste of time and resource for data harmonization

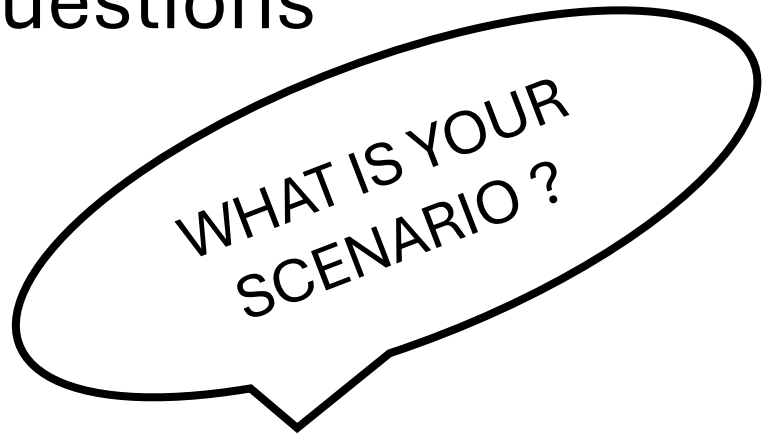


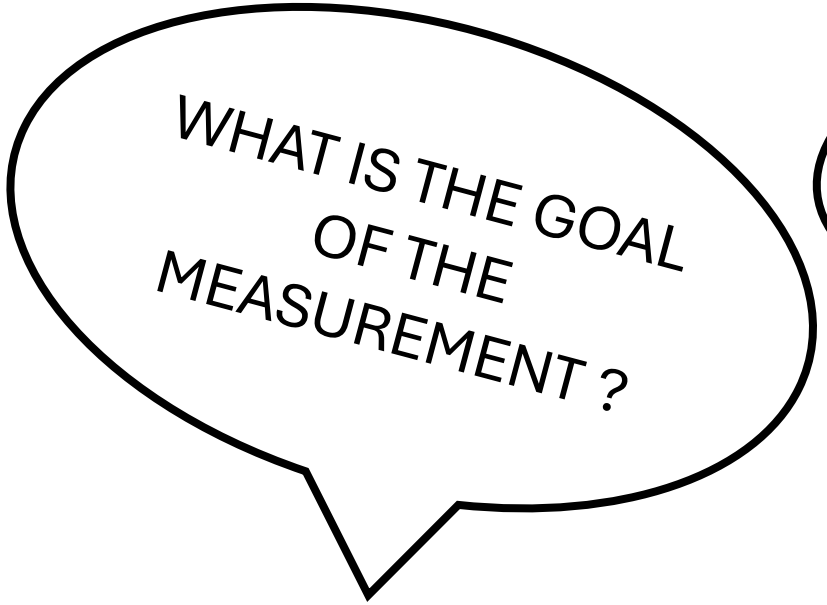
real-time data fusion

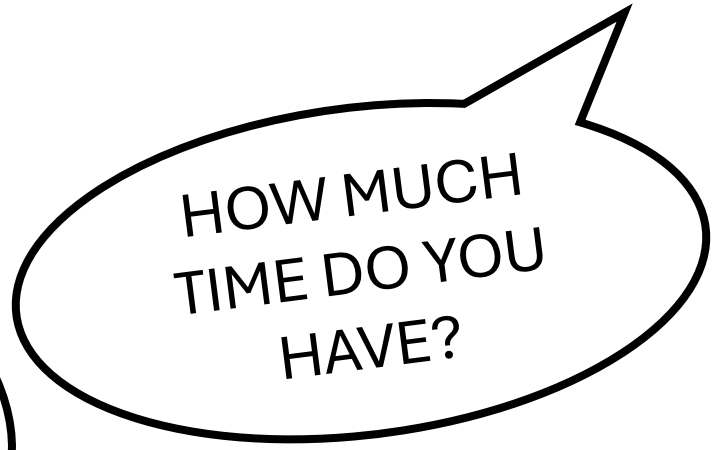
Higher accuracy in the risk assesment

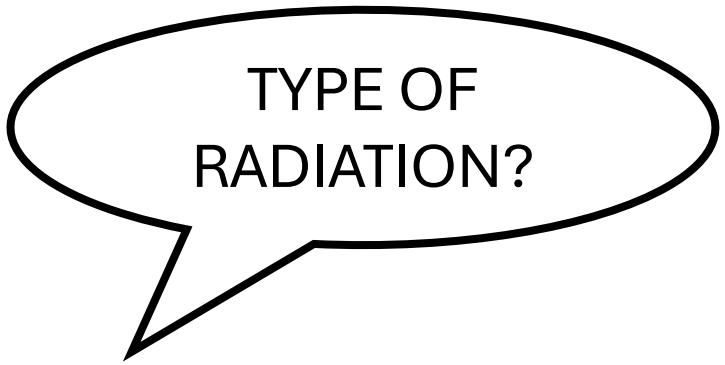
Easier decision making and higher quality in mitigation plan

Questions


WHAT IS YOUR SCENARIO ?


WHAT IS THE GOAL OF THE MEASUREMENT ?


HOW MUCH TIME DO YOU HAVE?


TYPE OF RADIATION?

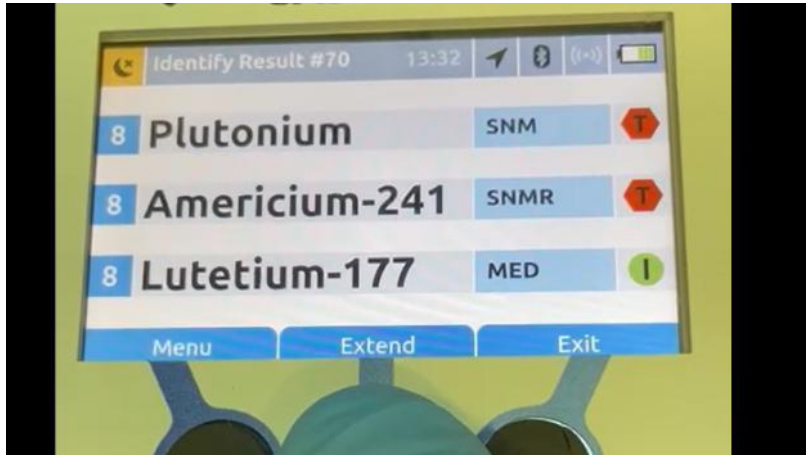

WHAT ARE YOU LOOKING FOR?

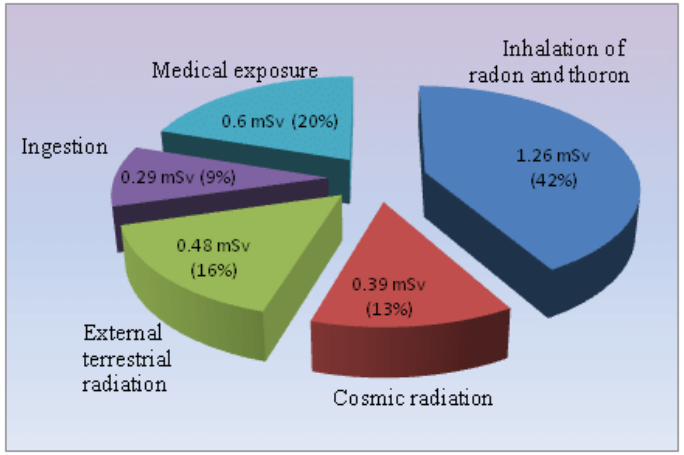

NEEDED SENSITIVITY?

Answer 1 – choose the device

	EFFICIENCY	PORTABILITY	H*(10) DOSE	ALFA	BETA	GAMMA	NEUTRON
PRD	VERY LOW	VERY HIGH	YES	SOMETIMES	SOMETIMES	COUNTING	SOMETIMES
CONTAMINA METER	MEDIUM	HIGH	NO	YES	YES	COUNTING	NO
RIID	LOW	HIGH	YES	NO	SOMETIMES	SPECTRA	SOMETIMES
BACKPACK	MEDIUM	MEDIUM	SOMETIMES	NO	NO	SPECTRA SOMETIMES	SOMETIMES
VEHICLE MOUNTABLE	HIGH	LOW	SOMETIMES	NO	NO	SPECTRA SOMETIMES	SOMETIMES
DRONES	MEDIUM	MEDIUM	SOMETIMES	SOMETIMES	SOMETIMES	SPECTRA	NO

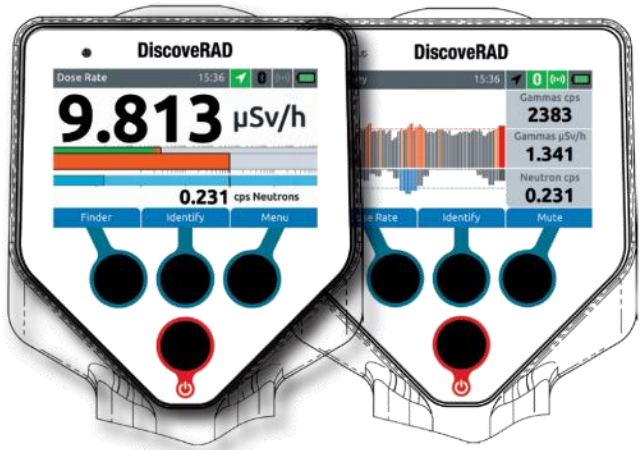
Answers 2 – choose the info needed (i.e. nuclide library)





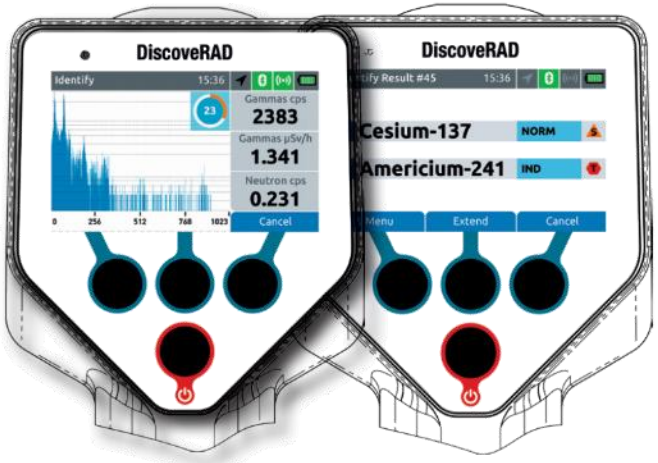
CATEGORY	EXAMPLES	WHERE /WHY
NORM	K-40, Th-232	Fertilizer, food
TENORM	Bi-214, K-40	Sludge, scales, O&G
INDUSTRIAL	Co-60, Ir-192, Cs-137, Co-57	Welding or building inspection
MEDICAL	I-131, Lu-177	Therapy, diagnostic
SNM	Pu-239, Pu-240, U-235	NPP,

Answers 3 – choose the software



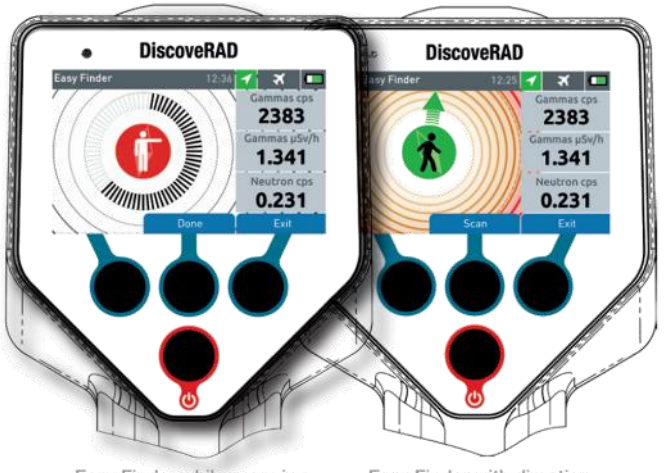
Dose rate mode

Finder mode



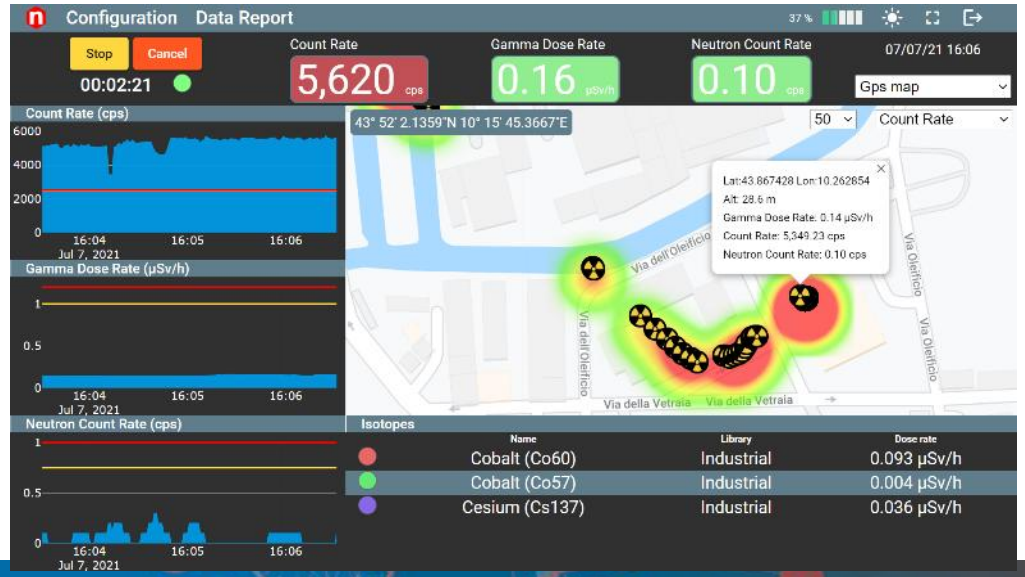
Identification mode

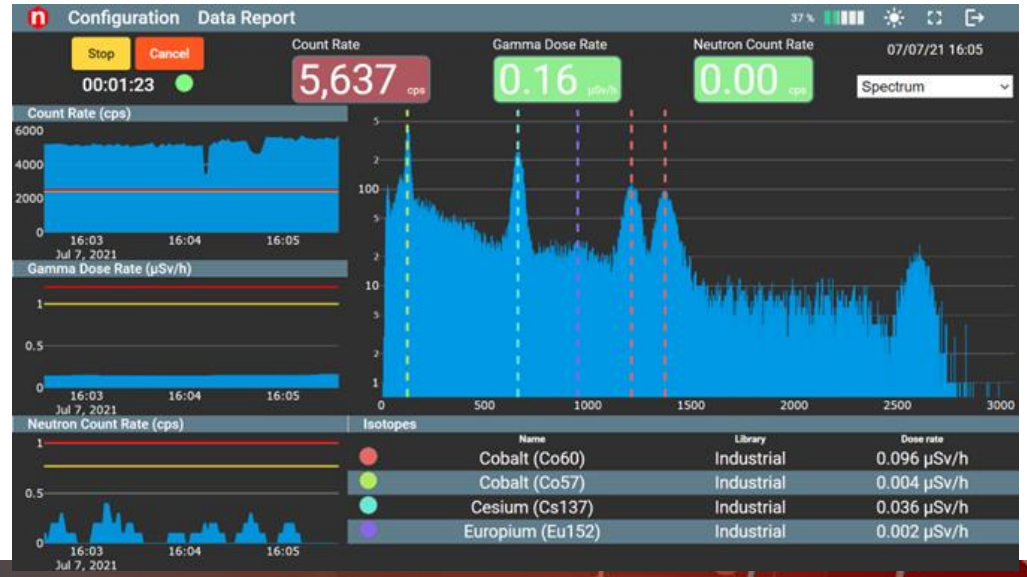
Identification results



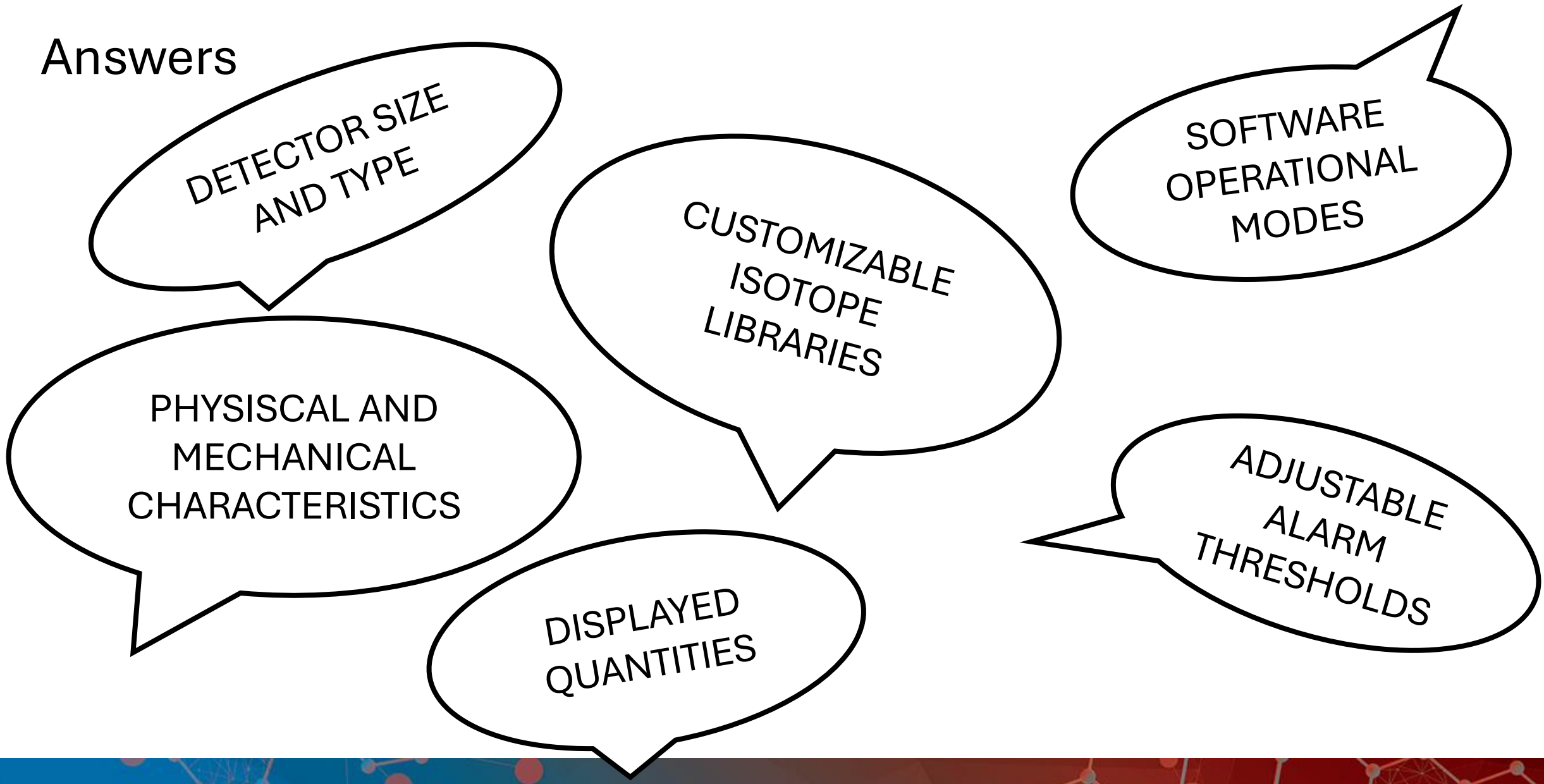
Easy Finder while scanning

Easy Finder with direction





Answers

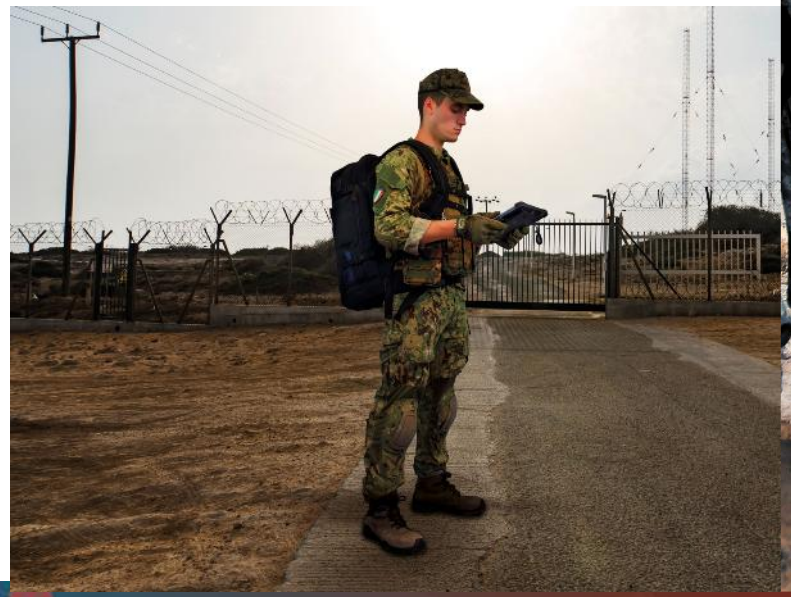

DETECTOR SIZE AND TYPE
SOFTWARE OPERATIONAL MODES
CUSTOMIZABLE ISOTOPE LIBRARIES
PHYSISCAL AND MECHANICAL CHARACTERISTICS
ADJUSTABLE ALARM THRESHOLDS
DISPLAYED QUANTITIES

4

DEVICES

CBRNe instrumentation selection

- Detection and identification of RDD
- First detection and interception of MORC
- Characterization of contaminated area
- Search and identification of gamma and neutron sources (SNM)
- Enrichment level estimation and shielding/moderator detection
- The damage produced
- The way to detect it (detector material and readout)
- The shield needed to stop it



A comprehensive suite of RN detection devices

- Environmental Monitoring Stations
- Vehicle mountable radiation device - GAMON-Mobile
- Backpack Radiation Device (BRD) -SNIPER-GN
- Handheld device RIID - Discoverad
- UAV mountable probes – GAMON Drone
- Underwater Probe –GAMON - Diver

Personal Radiation Devices

- Active or passive
- Wearable (lightweight) → low efficiency
- Personal dose equivalent
- Dose rate and integrated dose
- Mainly gamma, sometimes neutron
- Optional alfa and beta window
- “””Identification””” → very low efficiency and low resolution

GAMON-S and D

Gamma Radiation Spectroscopy or Dose System for Real-Time Radiation Monitor

MAIN FEATURES

- Gamma radiation spectroscopy system based on scintillation detector and Geiger-Mueller counter
- Internal database for summary reports and plots, easily generated by the embedded web interface
- Robust spectrum stabilization algorithms
- Designed for operating outdoor in extreme weather conditions from -40 to +60 °C
- Robust case, designed to guarantee IP68, including the power and the communication connectors
- Design for easy wall and pole mounting
- Wired and Wireless communication interfaces: USB 2.0, Ethernet, WiFi and 3G/4G LTE
- Autonomous delivery of email and SMS on alarm to a configurable list of recipients

GAMON-S and D

Gamma Radiation Spectroscopy or Dose System for Real-Time Radiation Monitor

USE CASE

Environmental gamma radiation monitoring, early environmental warning and emergency response, first responder emergency network, accelerator/NPP ring monitoring,

END USERS

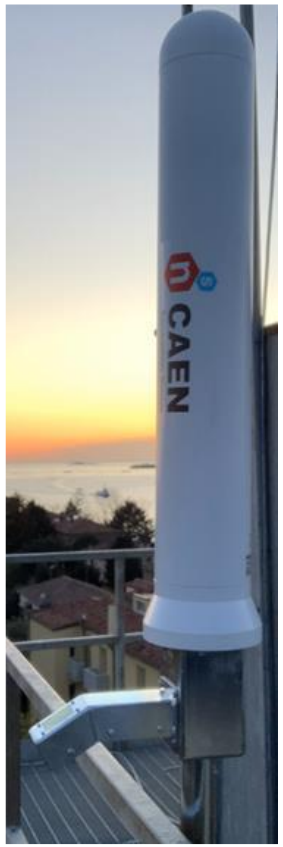
Environmental protection agencies, firefighters and first responders, nuclear regulatory commissions, DOD, nuclear power plants or accelerators

REFERENCES

ITA ISIN network, IAEA tech cooperation, Italian regional protection agencies, National Institute of physics, Research accelerator

GAMON-S and D

Gamma Radiation Spectroscopy or Dose System for Real-Time Radiation Monitor



CAEN
Tools for Discovery

GAMON Mobile

Vehicle Mountable Gamma Spectrometric Mapping System

MAIN FEATURES

- High efficiency gamma spectroscopic and dosimetry probes for the identification of radionuclide gamma emitters
- n option available,
- Georeferenced measurement map for real time data visualization
- Nato stock number
- Extended operation with rechargeable for more than 8-hour continuous acquisition
- Web interface for fast and easy system and isotope-based alarm configurations

GAMON Mobile

Vehicle Mountable Gamma Spectrometric Mapping System

USE CASE

RN wide area threat search by ground air and water vehicles, emergency and first-response sensitive area scan, georeferenced measurements for radioactive mapping

END USERS

CBRNe army department, Firefighter/Police with RN competences, geological radiation characterization laboratories, environmental department, DNDO

REFERENCES

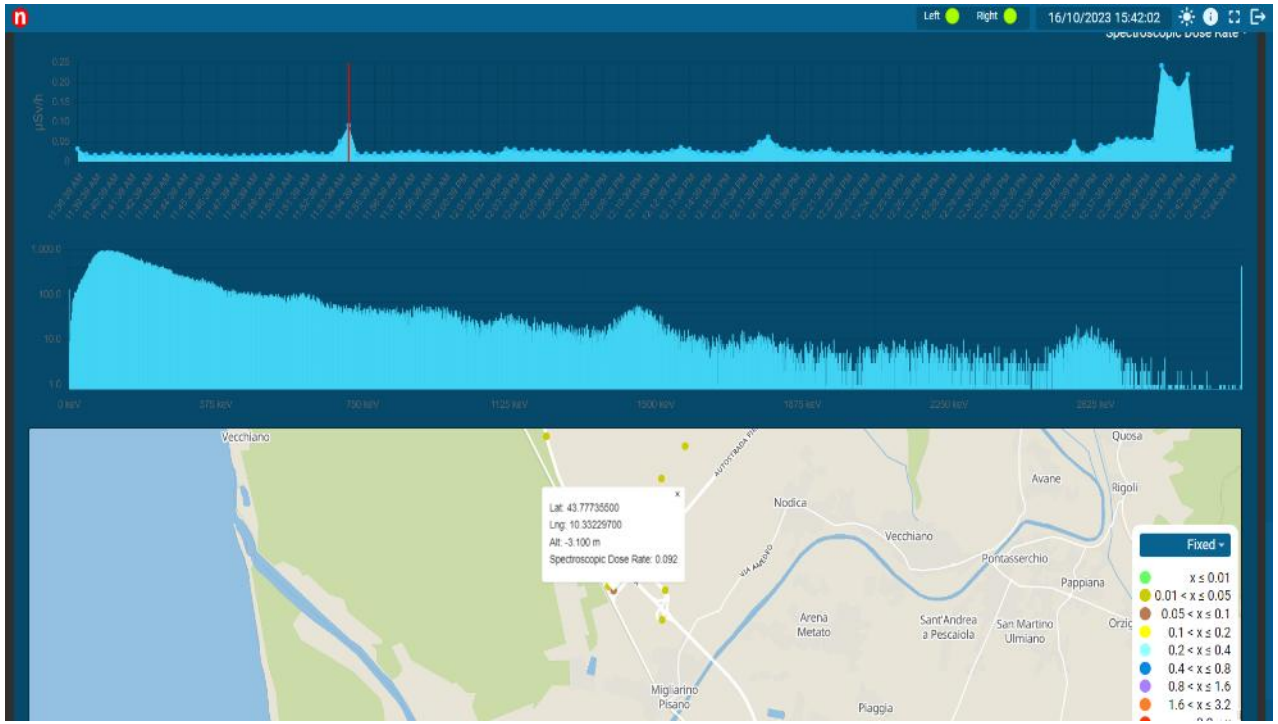
IAEA, ITA Navy, ITA Army, Radiation Safety Center RCS Lithuania, Lokmis UAB

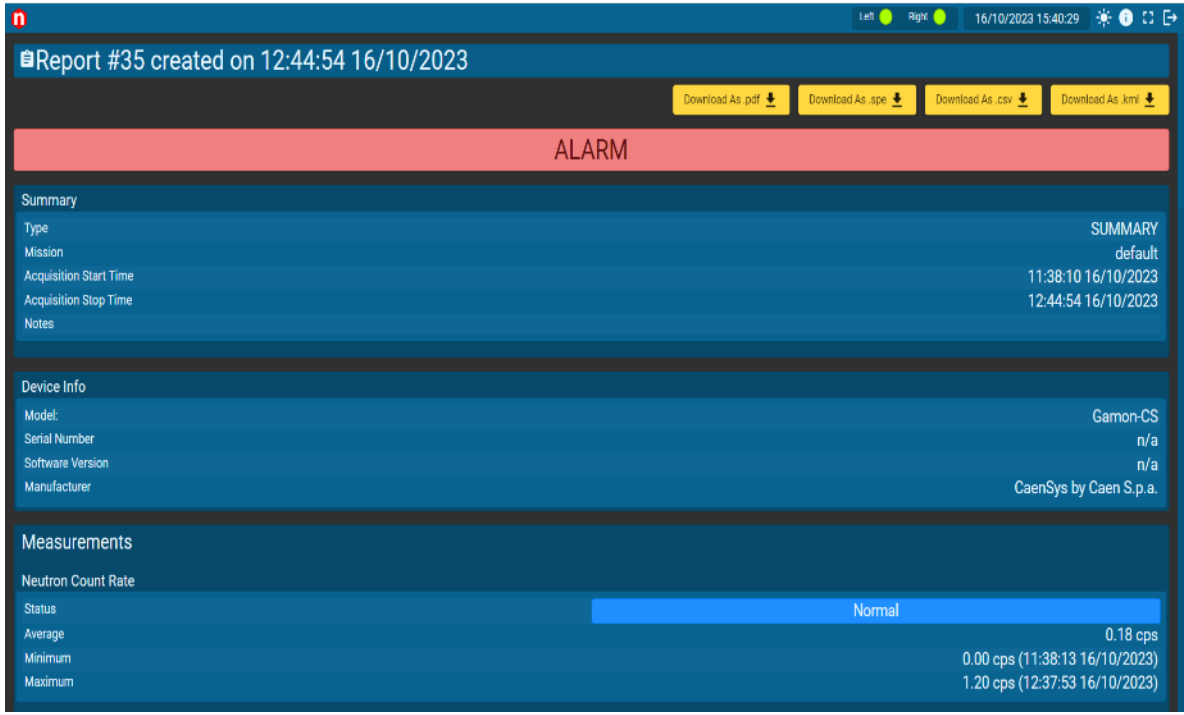
GAMON Mobile

Vehicle Mountable Gamma Spectrometric Mapping System

GAMON Mobile

Vehicle Mountable Gamma Spectrometric Mapping System





SNIPER-GN

Special Nuclear Material portable identifier – Backpack radiation device

MAIN FEATURES

- Detection and localization of radioactive materials such as Special Nuclear Material (SNM) and Radiological Dispersal Devices (RDD) even when moderated, shielded or masked.
- Neutron ID patented algorithm (U.S. Patent No. 11835477)
- Discrimination between fissile material, alpha-n source, Plutonium and Uranium (enrichment estimation level in 1 min).
- Real-time gamma/neutron discrimination using algorithms implemented by CAEN for the IAEA Safeguards for fresh fuel
- 8 kg backpack IP67,
- nato stock number (6650150265712),
- smear test and filter function

NATO OTAN
NATO Stock Numbers

SNIPER-GN

Special Nuclear Material portable identifier – Backpack radiation device

USE CASE

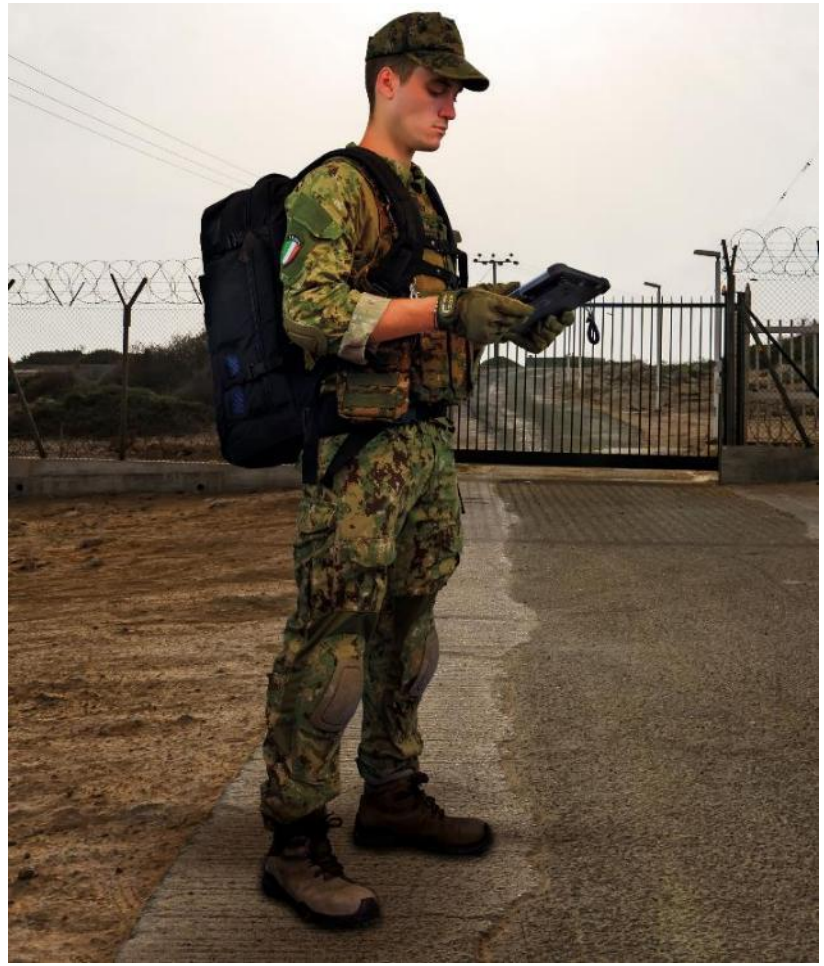
CBRNe scenario, Nuclear security application, Nuclear emergency, Parcel scanning, Military application, Border control, SNM measurement related application

END USERS

CBRNe army department, Firefighter/Police with RN competences, HAZMAT inspector, DOD, Los Alamos and SNM material labs, DNDO

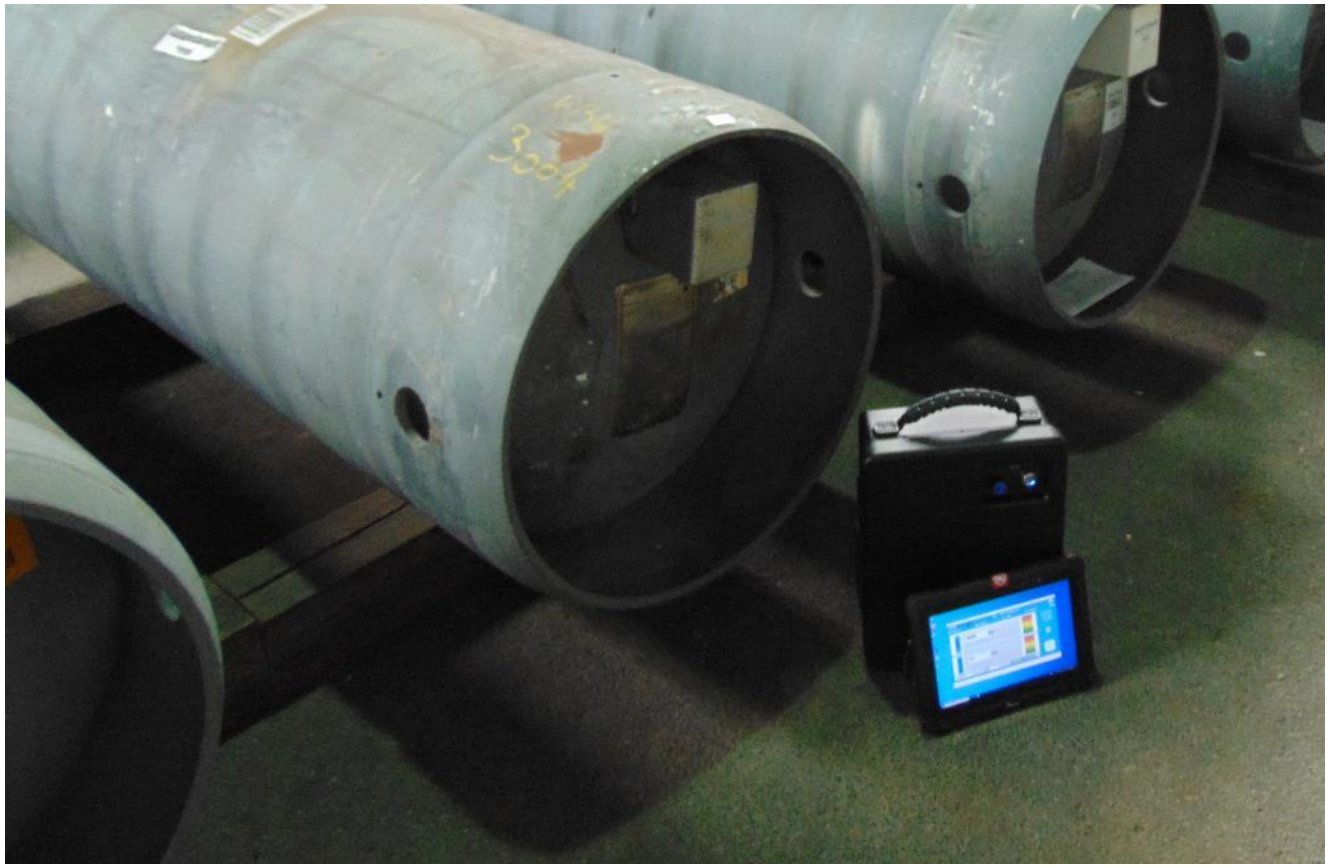
REFERENCES

IAEA, SAFE Veolia, Italian Navy, ITA Army, Fraunhofer, CAEN India, Beijing phyclover



SNIPER-GN

Special Nuclear Material portable identifier – Backpack radiation device



Security and Safeguards

Passive detection systems used for security control in safety conditions

GAMMA detection/counting is the minimum requirement

GAMMA Spectroscopy identification is an added value

NEUTRON detection/counting is a plus

NEUTRONS identification (FAST NEUTRONS)
was not implemented until today

SI

GA

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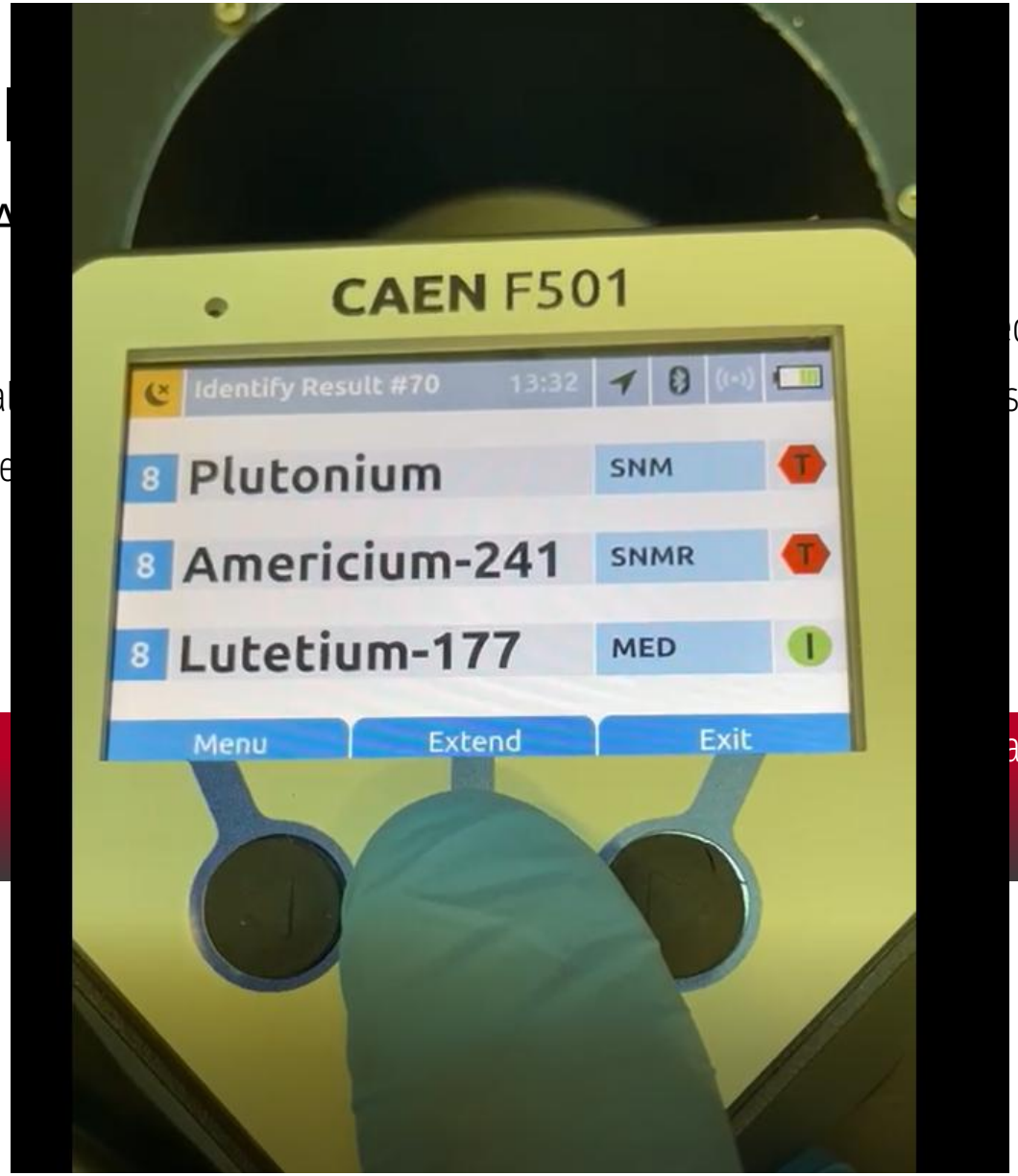
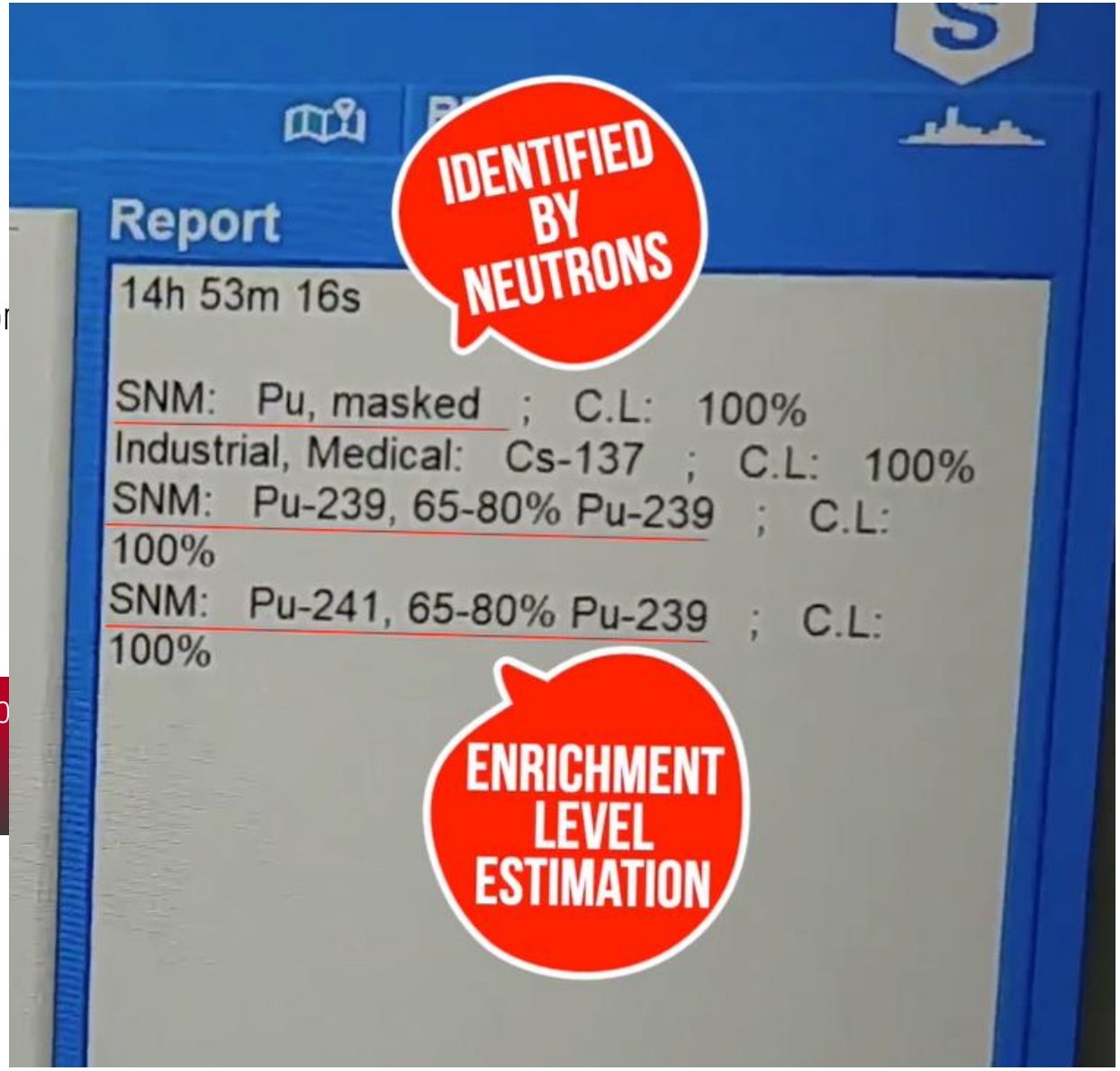


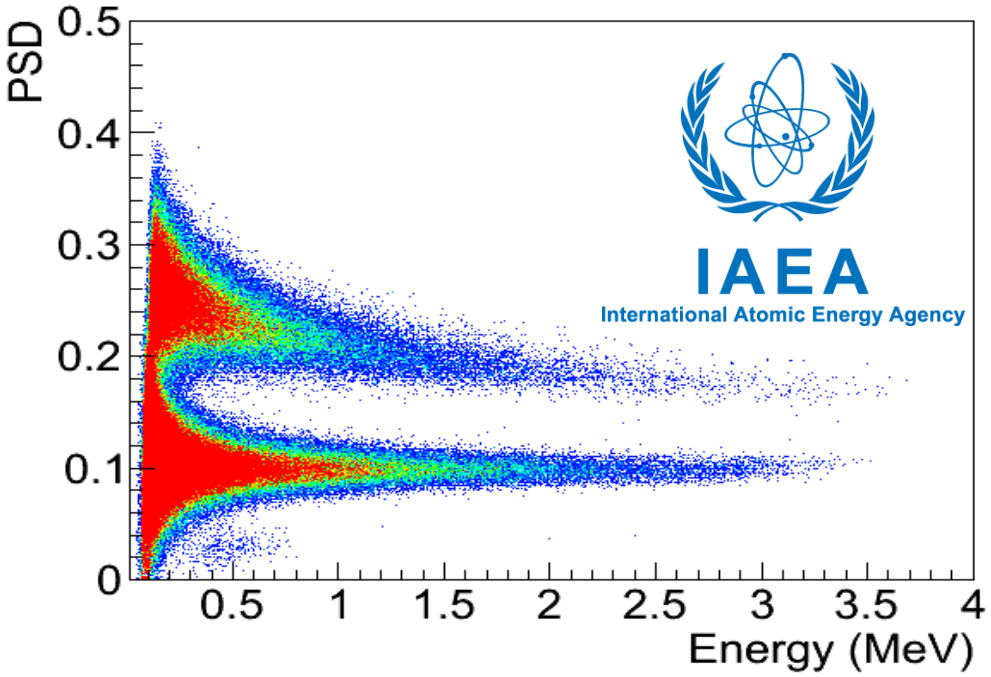


SNIPER-GN detection

GAMMA/NEUTRON COUNTING

High-efficiency gamma/neutron detector enhances the detection distance

Real time gamma/neutron discrimination**



** based on the same Pulse Shape Discrimination (PSD) algorithm tested and implemented by CAEN for the IAEA Fast Neutron Collar Monitor (fresh fuel verificationlevel estimation

SNIPER-GN Military Certification

TESTS PERFORMED @ ENEA Reference Laboratory

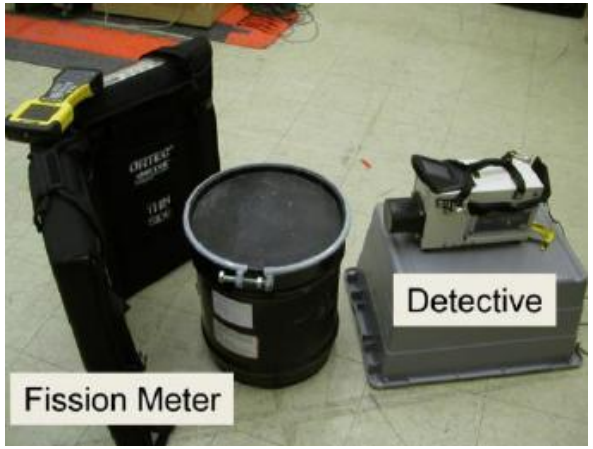
In presence of Ministry of Defence (ARMY and NAVY) for NATO approval

NATO STOCK NUMBER
6650150265712

If you want to execute simultaneous gamma and Neutron Identification today you need 3 different measuring systems

From publication P. Kerr, D. Decman, M. Prasad - February 23, 2018.

"Fission Meter Information Barrier Attribute Measurement System: FY2018 Office of Nuclear Verification FNI/UKC Task 2 Documentation Package"



- 100.3 x 67.3 x 7.9 cm
- 26.8 kg
- 0 – 40 °C
- Id in 15-20 min
- "designed to identify slightly elevated count rates"
- "several hours to obtain an accurate partitioning"
- "the intent is that the data will be provided to experts for later analysis"
- "Threshold mass detection for WGPu is 25 g"
- "the cost of fission meter is 320 k$"

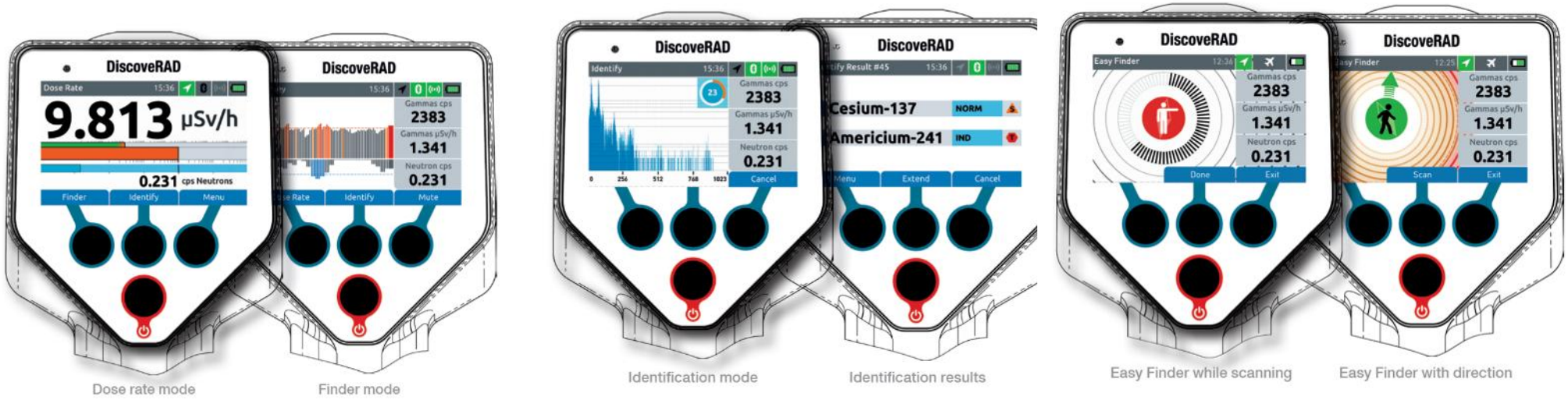
- 39.4 x 16.3 x 34.9 cm
- 11.1 kg
- <12 hours for cooling
- 2-10 min for identification

DiscoveRAD

MAIN FEATURES

- Detects and identifies nuclides in mixed, shielded, and heavily masked configurations including Special Nuclear Material
- Weight < 1,25 Kg in IP68 (underwater to 10 m),
- quantum gain stabilization (no source or led) and autocalibration
- Doserate, search mode, ID and directionality,
- ID up to 200 uSv/h (20mrem/h) or 1 million cps
- Spectra view and analysis with data storage (30 GB) for reach back
- User Interface with day and night view
- High accuracy dose measurement
- Finder mode with directionality
- Replaceable batteries

DiscoveRAD



Dose rate mode | Finder mode | Identification mode | Identification results | Easy Finder while scanning | Easy Finder with direction

Spectrometry at up to 1 million cps between 10 KeV to 10 MeV

- DOSE-RATE
- Gamma ISOTOPE Identification
- Neutron Counting

DiscoveRAD

GAMMA/NEUTRON COUNTING

USE CASE

CBRNe scenario, Second level detection, Nuclear security application, Nuclear emergency, Parcel scanning, Border controls, Military application, Law enforcement, customs, Radiological emergency personnel,

END USERS

CBRNe army department, Firefighter/Police with RN competences, NRC, DOD, DHS, custom and border, Transport authority, Emergency responder, DOE, NRC, EPA, Coast guard, Fire Departments, State and Local Police Departments

REFERENCES

ZATCA (border control Saudi Arabia), SORIM (ITA), Japan security agency, Hospital ITA, BeiJin Phyclover, CAEN India, Qatar defense

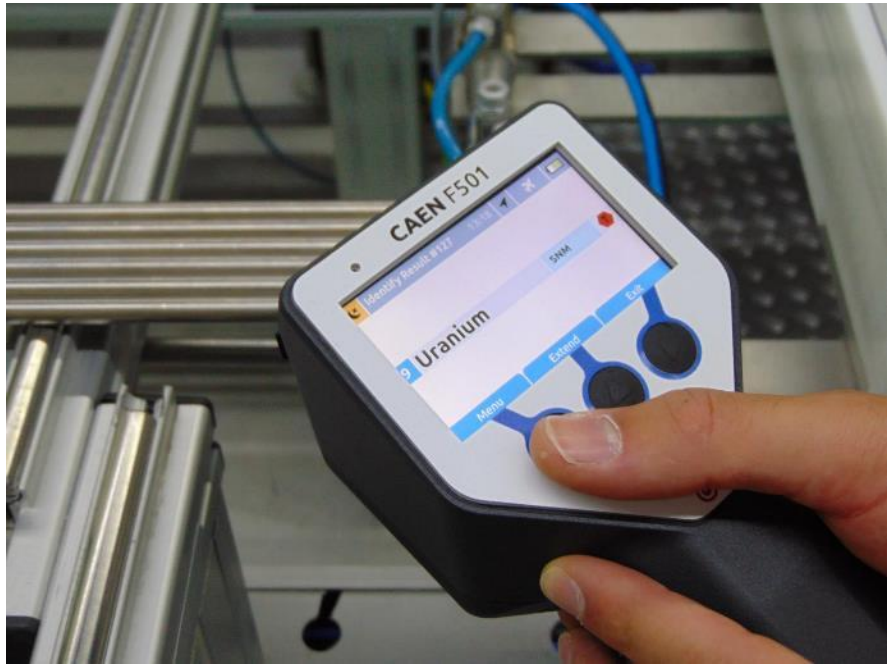

CBRN Applications

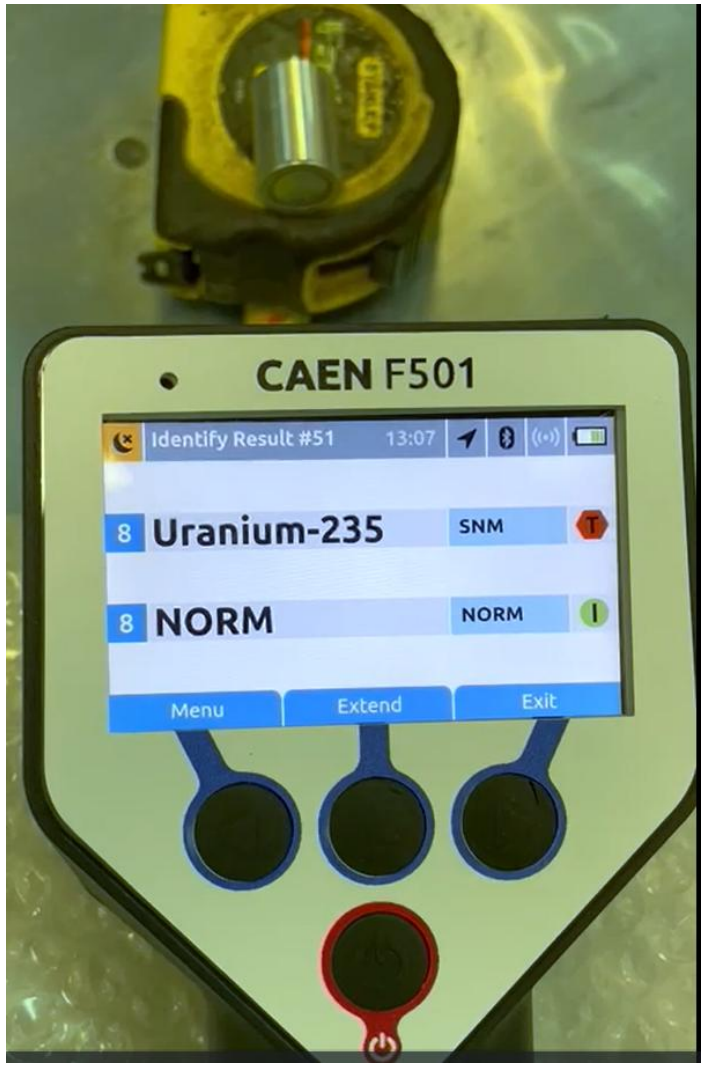

Civil Applications


Industrial Applications

DiscoveRAD

GAMMA/NEUTRON COUNTING





GAMON Drone

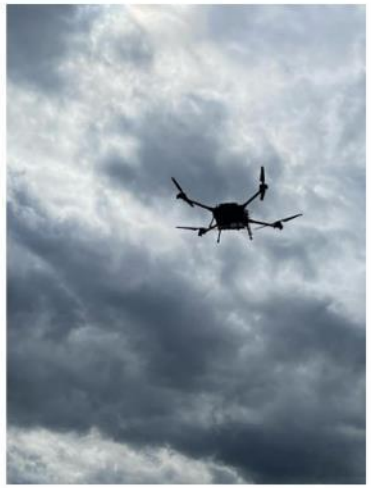
Dose and Spectrometric Detection Unit, Light Weight

MAIN FEATURES

- Mobile system for radiological search and monitoring purposes
- Automatic radionuclides analysis with configurable library,
- Detachable unit for handheld operations
- software for radionuclides activity concentration quantification,
- Embedded gamma dose rate and spectrometry measurement units,
- Programmable isotope based and dose rate alarms,
- Georeferenced and real time data visualized by the operator
- Flight plan program and automatic flight execution

GAMON Drone

Dose and Spectrometric Detection Unit, Light Weight



USE CASE

UAV environmental radiation protection, inspection, site remediation, exploration of hazardous areas, radio-geological evaluation of areas/sites (NORM quantification)

END USERS

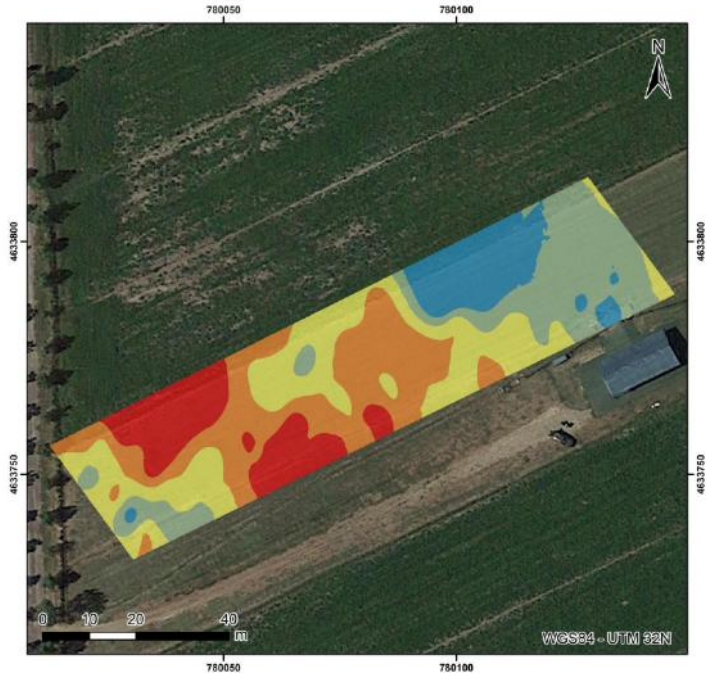
CBRNe army department, Firefighter/Police with RN competences, DOD, DHS, EPA,

REFERENCES

CBRNe protection GmbH, IAEA support program, IAEA seibersdorf security lab, UniBari, Galway uni, Salento uni

IAEA

Dose [nSv/h]

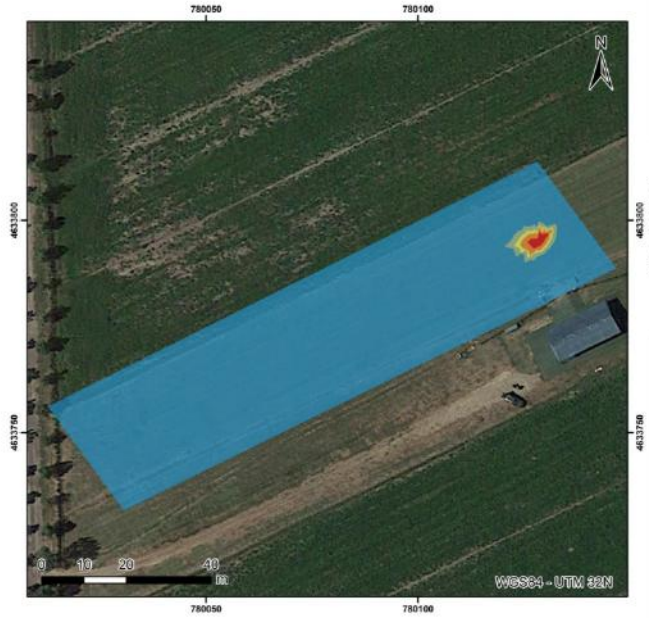


D_{tot} [nSv/h]

- 54 - 60
- 61 - 62
- 63 - 64
- 65 - 66
- 67 - 71

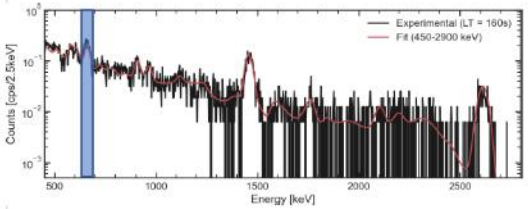
	D_{tot} [nSv/h]
Min	54
Max	70
Media	62
Dev. St.	3

^{137}Cs [Bq/m^2]



Cs [Bq/m^2]

- < MDA
- 1250 - 2173
- 2174 - 2383
- 2384 - 2638
- 2639 - 2948



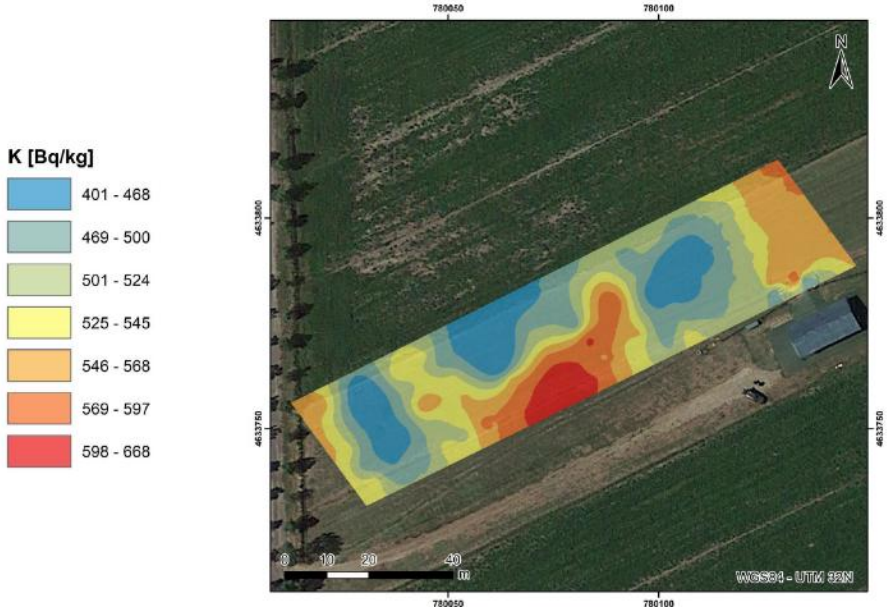
	Cs [kBq]
Sorgente calibrata	370
Valore stimato	285 ± 75
MDA	1.25

CAEN
Tools for Discovery

Spaziatura [m]	10
Lunghezza traccia [m]	507
Durata survey [min]	12
Area investigata [m^2]	3928
Numero di spettri	140

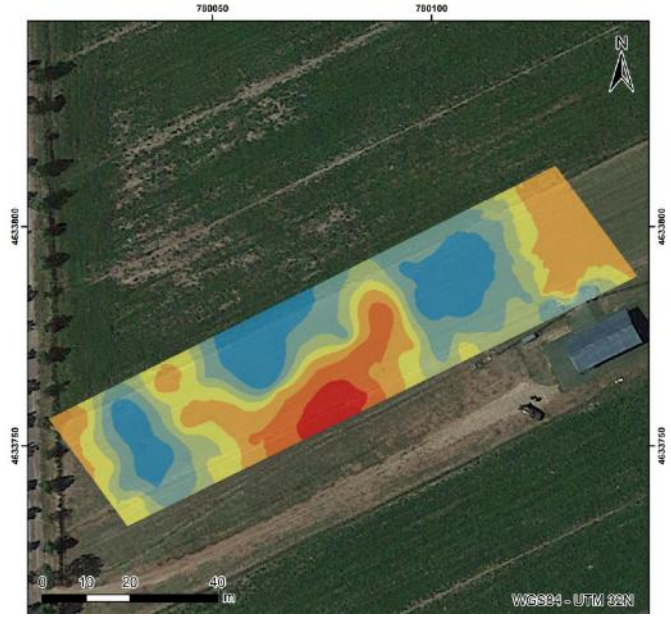
	Min	Max	Media	Dev. St.
Velocità [m/s]	0	1.5	0.7	0.4
Quota [m]	0	5.9	4.2	1.2

^{40}K [Bq/kg]



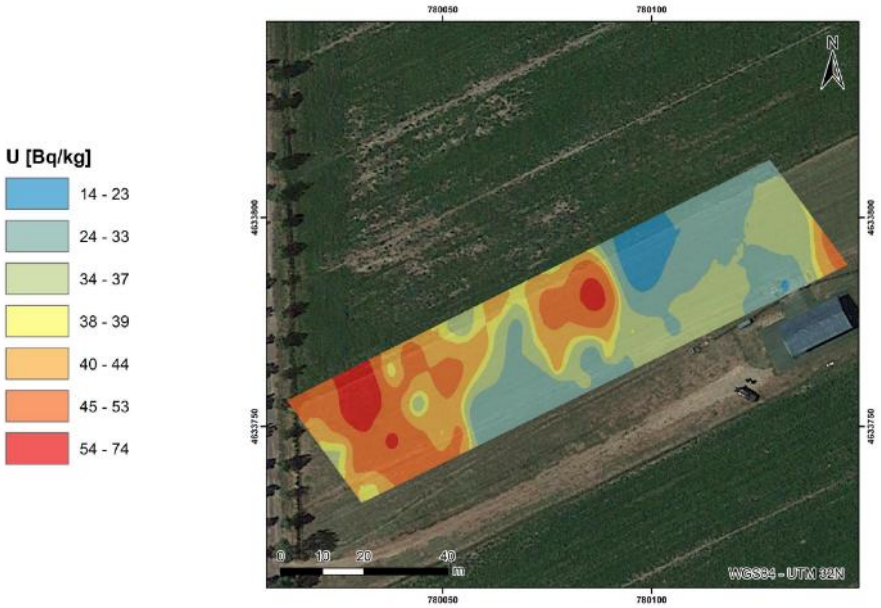
	K [Bq/kg]
Min	397
Max	670
Media	537
Dev. St.	50
MDA	36

Attività totale [Bq/kg]



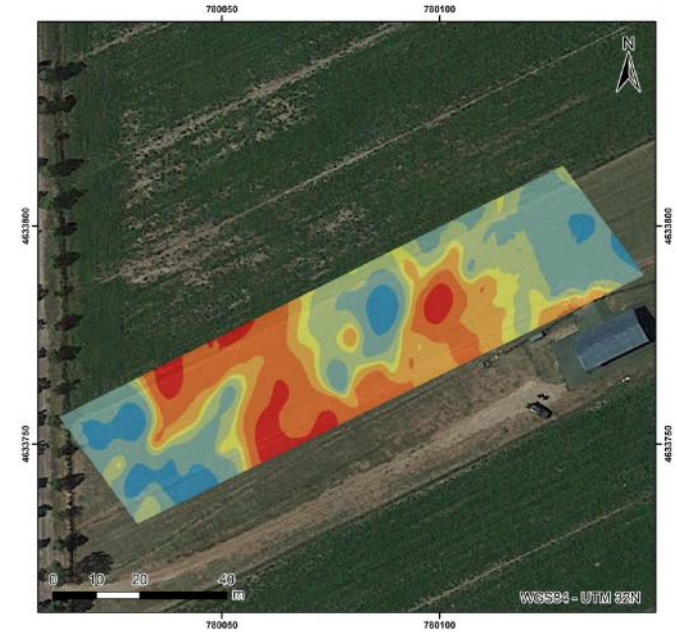
	Att_{tot} [Bq/kg]
Min	529
Max	805
Media	678
Dev. St.	49

^{238}U [Bq/kg]



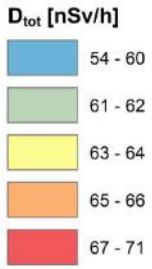
	U [Bq/kg]
Min	14
Max	73
Media	36
Dev. St.	9
MDA	14

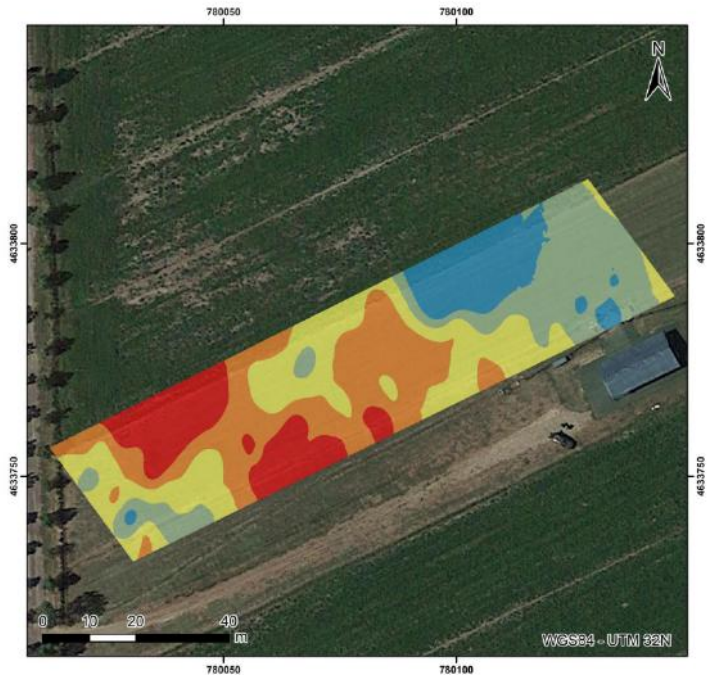
^{232}Th [Bq/kg]



	Th [Bq/kg]
Min	66
Max	103
Media	82
Dev. St.	7
MDA	9

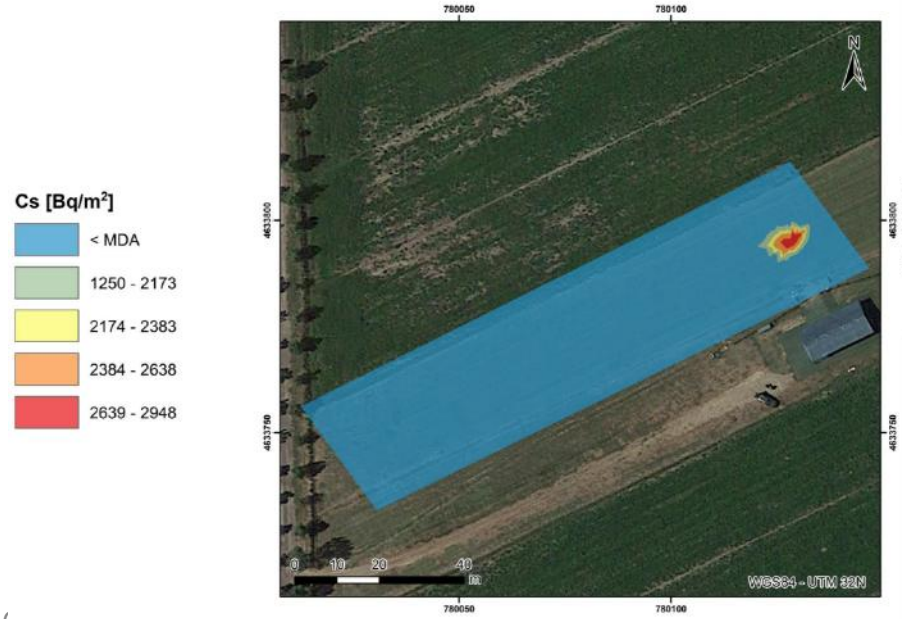
Dose [nSv/h]

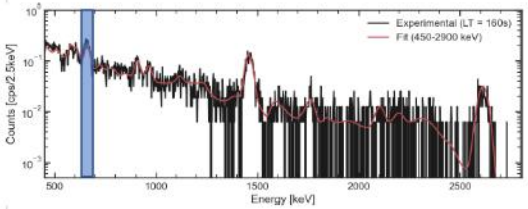




	D_{tot} [nSv/h]
Min	54
Max	70
Media	62
Dev. St.	3

^{137}Cs [Bq/m^2]





	Cs [kBq]
Sorgente calibrata	370
Valore stimato	285 ± 75
MDA	1.25

GAMON-Diver

Compact Underwater System for Radionuclides Identification

MAIN FEATURES

- Gamma dose rate, and gamma activity concentration (Bq/l) calculation in realtime,
- radiological search by diver operator or in static conditions
- gamma count rate and isotope identification (+76 nuclide library),
- 450 m depth operation (45 ATM) salt and freshwater,
- decontaminative material
- Integrated GPS used for easy mapping of the measurements
- Wired communication during the measurement session and also wireless capability for the configuration of the system

GAMON-Diver

Compact Underwater System for Radionuclides Identification

USE CASE

Underwater application, O&G scenario, spilling of radioactive material, search of MORC in basins or water, permanent installation for long term monitoring of sensitive underwater locations

END USERS

CBRNe army department, Firefighter/Police with RN competences, DOD, Navy

REFERENCES

Navy seals incursion team Italy, IAEA

GAMON-Diver

Compact Underwater System for Radionuclides Identification

THANK YOU!

SCAN ME

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