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## Update on the cleandem project

Maugan Michel, Guillaume Amoyal, Vincent Schoepff

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**<https://cea.hal.science/cea-04487975v1>**

Submitted on 4 Mar 2024

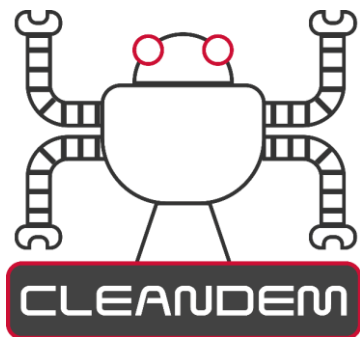
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# Mr Maugan MICHEL

**Job/Position:** Researcher

**Organization, Country:** Alternative Energies and Atomic Energy Commission, France

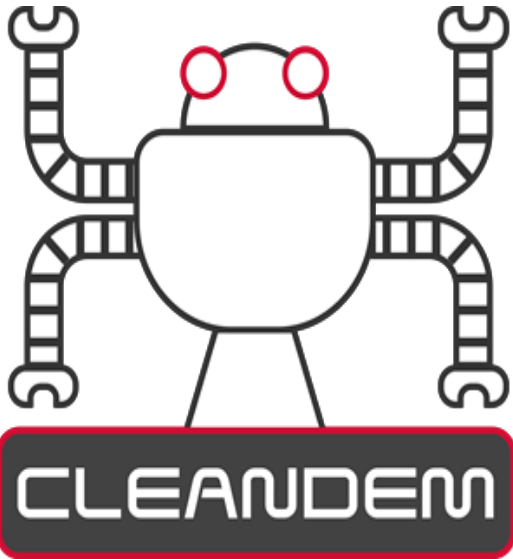


- Background in **radiation physics, radiation protection and nuclear instrumentation**, with a PhD thesis in fundamental nuclear physics in 2014, on non-linear optics phenomena applications for ionizing radiation detection.
- Worked at the **La Hague** nuclear fuel reprocessing plant with Framatome, then joined VINCI Group's nuclear division, **NUVIA**, as a **field-operating project manager**.
- Late 2019: joined the Instrumentation and Nuclear Measurement group at CEA-List, where in charge of the development of **D&D and RN threats-dedicated measurement systems**, combined or not with **SLAM and robotics**.





This project has received funding from the European Union's Horizon 2020 research and innovation programme under agreement No 945335.



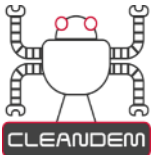
## **CLEANDEM**

A CYBER PHYSICAL EQUIPMENT FOR  
UNMANNED NUCLEAR  
DECOMMISSIONING MEASUREMENTS

International Conference on Nuclear Decommissioning:  
Addressing the Past and Ensuring the Future  
15–19 May 2023, Vienna, Austria

**Dr Maugan MICHEL, CEA**  
**French Alternative Energies and Atomic Energy Commission**  
Project Director, on behalf of the CLEANDEM Consortium





# Key items

**C**yper physical **L** Equipment for un**m**anned  
**N**uclear **DE**commissioning **M**easurements

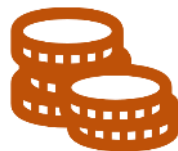


Bring **technological breakthrough** at different steps of the D&D operations:

- Initial** radiological status
- During** operations (continuous monitoring)
- Final** characterization



3 years  
(Started 03/2021)



2.8 M€  
(100 % EC)





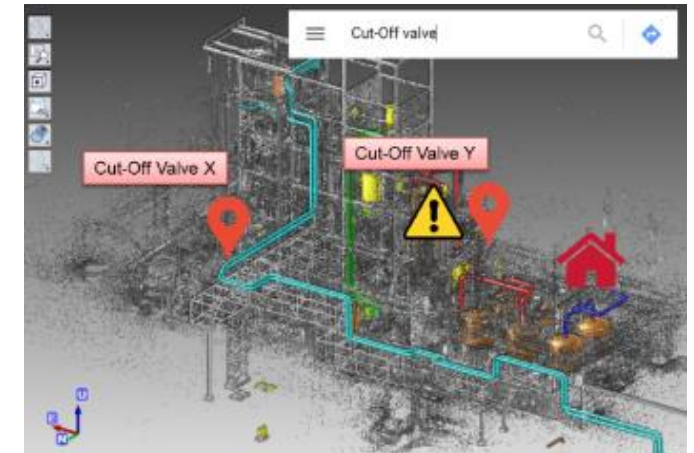
# Approach and main goals

## ❑ Different D&D steps → different expectations:

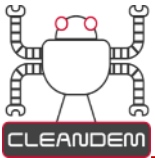
- **Initial** characterization  
↔ harsh environments
- **During** D&D operations:  
↔ need **real time information** on facility status
- **Final** characterization:  
↔ **very low contamination level**

## ❑ Main goals related to CLEANDEM

- **UGV platform** for remote operations
- **Advanced dose rate** measurements
- **Hot spot** localization
- **Neutron/gamma** detection
- Air and soil **contamination** monitoring
- **Data fusion** and full **digitalization** of the plant



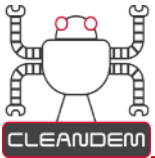
## Cost, Time, Dose



# The CLEANDEM Consortium

11 Partners





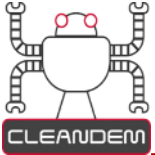
# The CLEANDEM Consortium

11 Partners

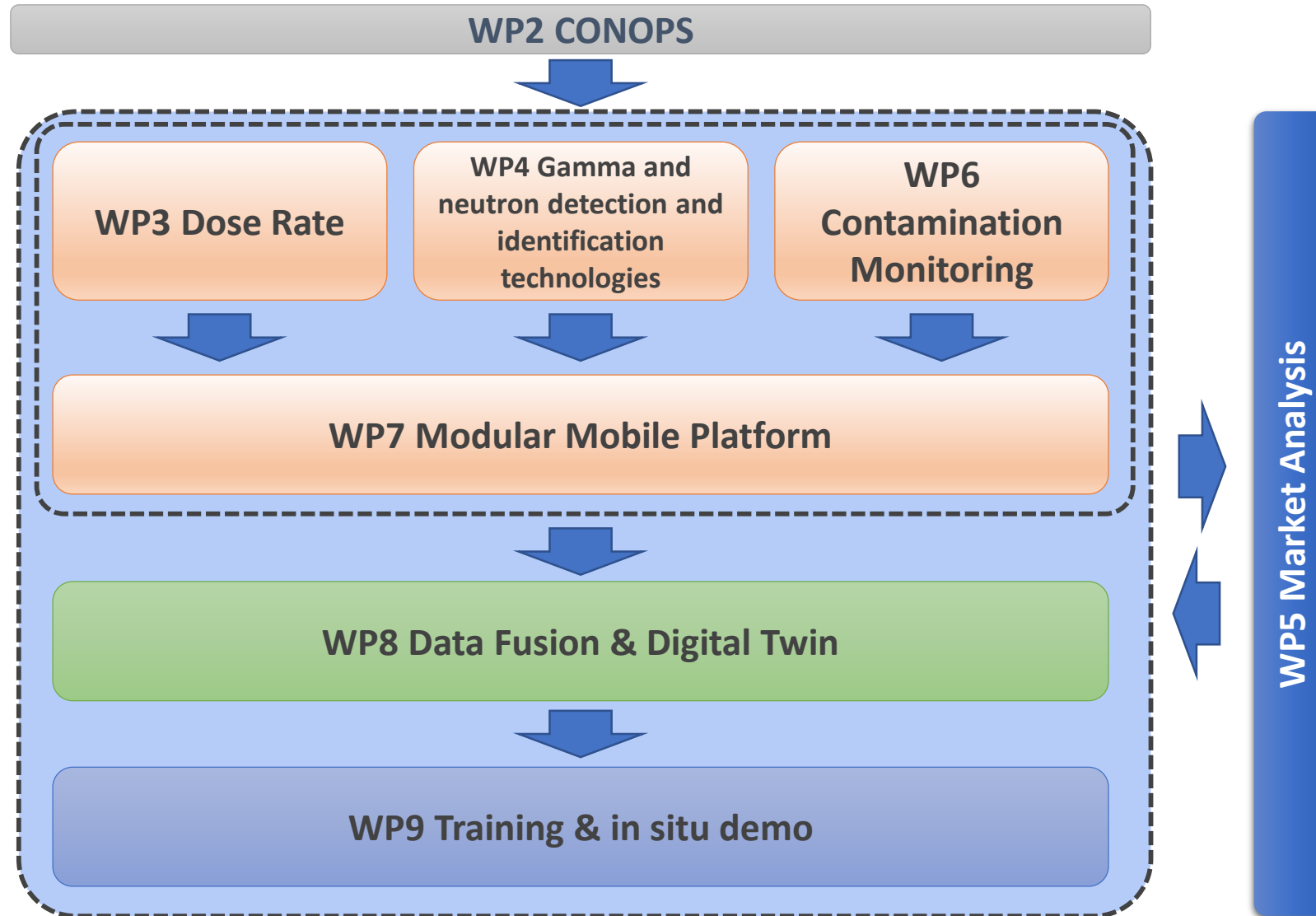


4 Countries

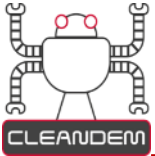




# Work packages







## ✔ Definition of **Technical specifications**

For all tools, robotics elements, measuring instruments or software

- Identifying needs & requests of **End-Users**;
- Expected functions and **performances**;
- Desired **interaction** between developments;
- Thinking on post-project opportunities.

## ✔ Definition of **Concepts of Operations**

- Environment in which systems will be deployed;
- Constraints they will be exposed to;
- Issues to be solved.

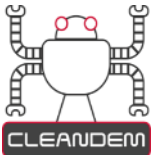
Experience & specific know-how of ORANO, SOGIN & ANSALDO to

- ambitious but realistic scenario;
- trials and final demonstration site.

Description of proposed system with generic operating conditions.

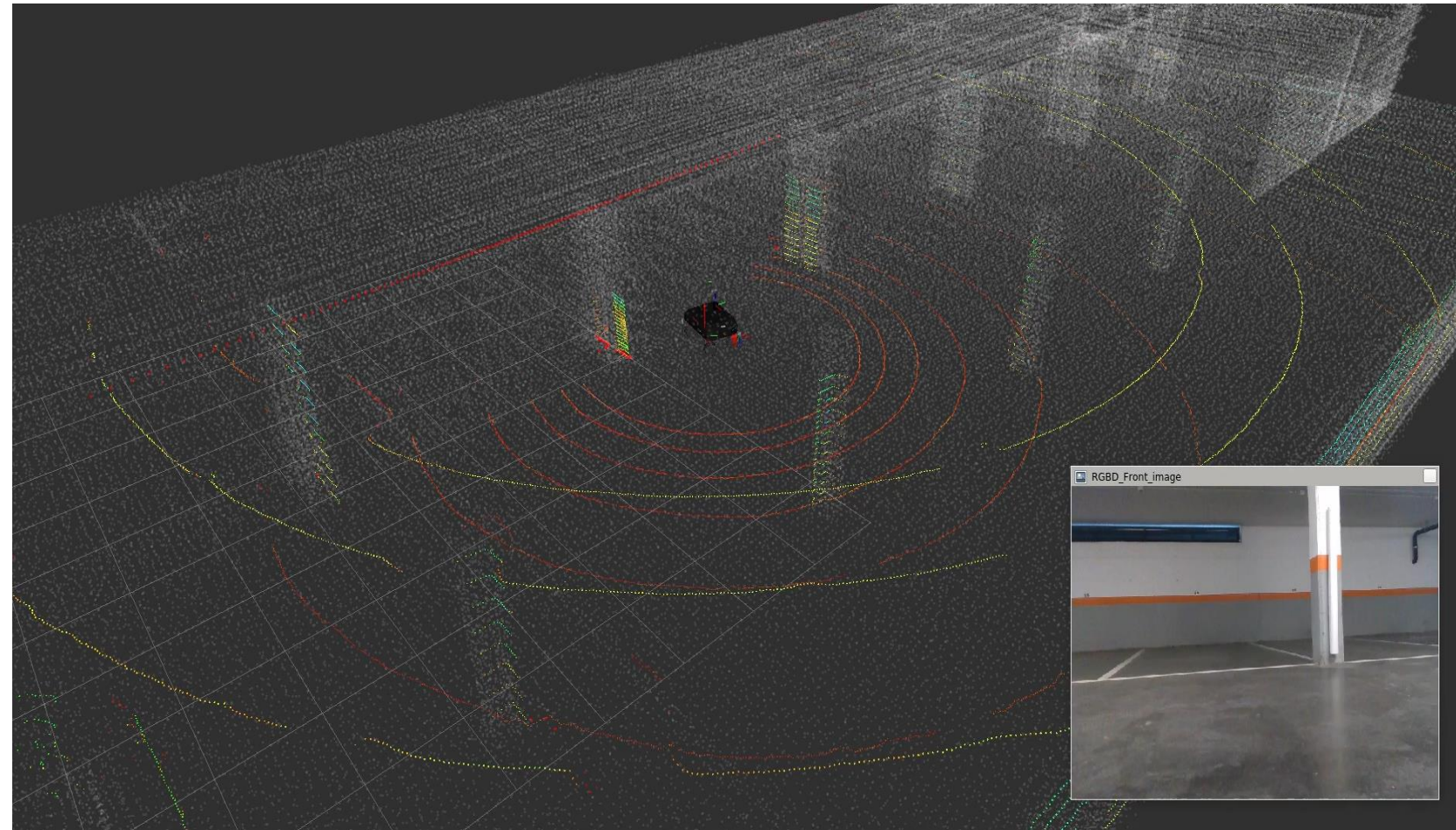
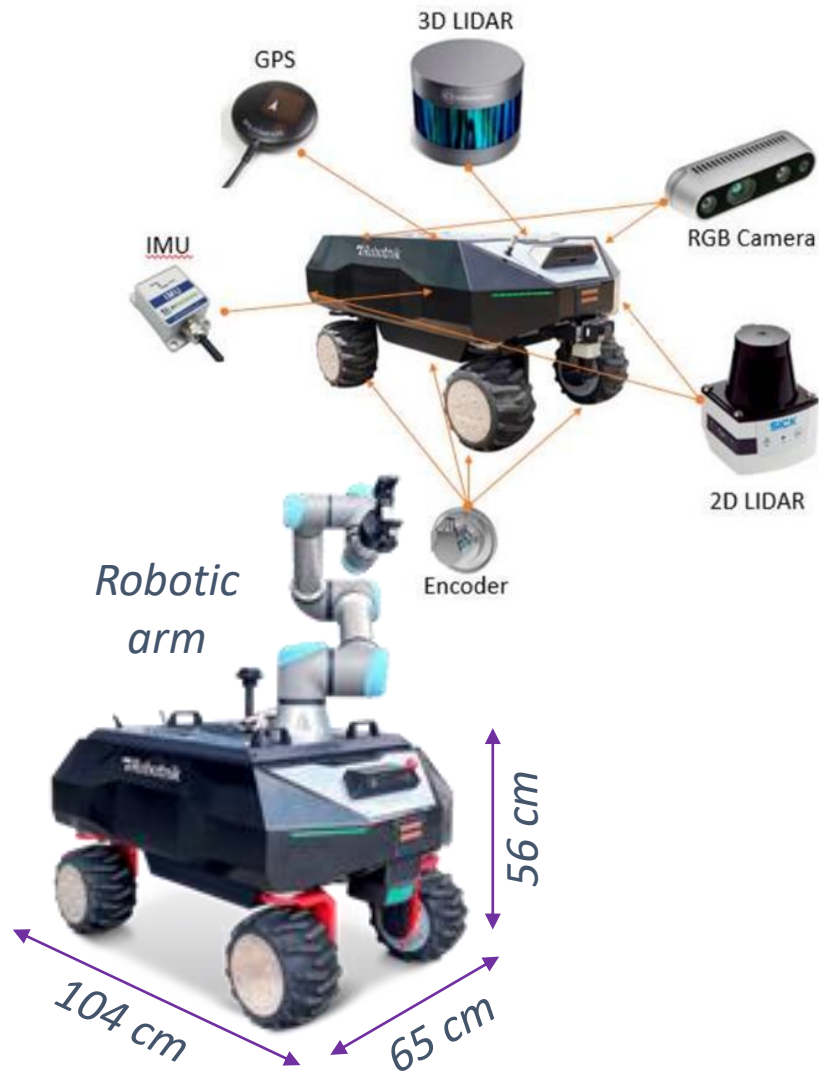
## ➔ Roadmap for technical developments

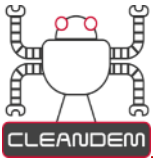
❑ **European Guideline for D&D Operation:** Delayed to M30 to benefit from Project's experience.



# WP7 | Modular Mobile Platform

## 3D Localization & Navigation





# WP3 | Dose rate

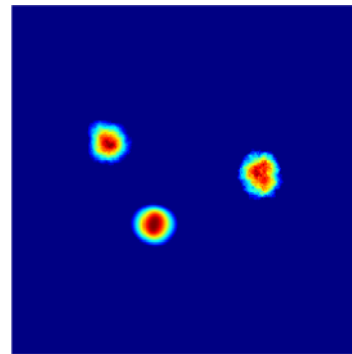
## Nanopix, the smallest coded-aperture gamma imager



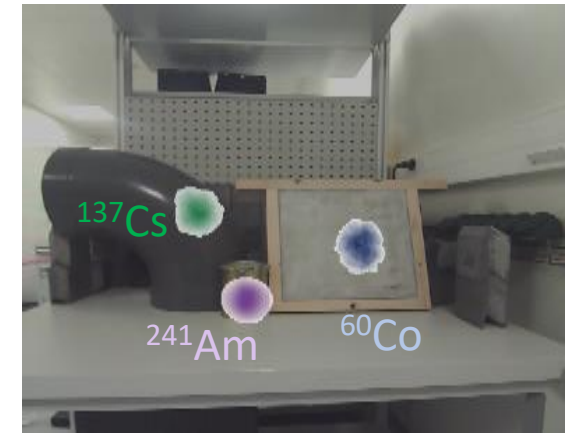
Visible image



Gamma image

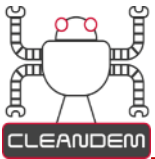


Visible + Gamma  
(spectro-imaging)



**TERRIFFIC**  
ACCELERATED CBRNE RESPONSE

**aeraccess**<sup>®</sup>  
airborne engineering research



# WP3 | Dose rate

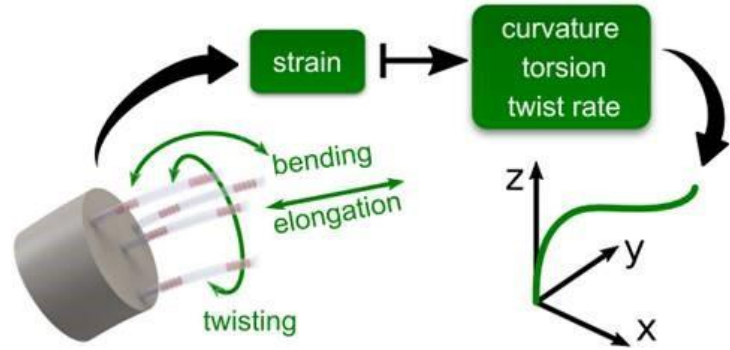
## Fiber optics OSL 1D dosimetry + 3D Shape sensing

### 3D localization (shape sensing)

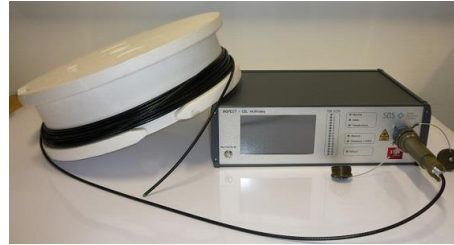


### 1D Dose data (INSPECT)

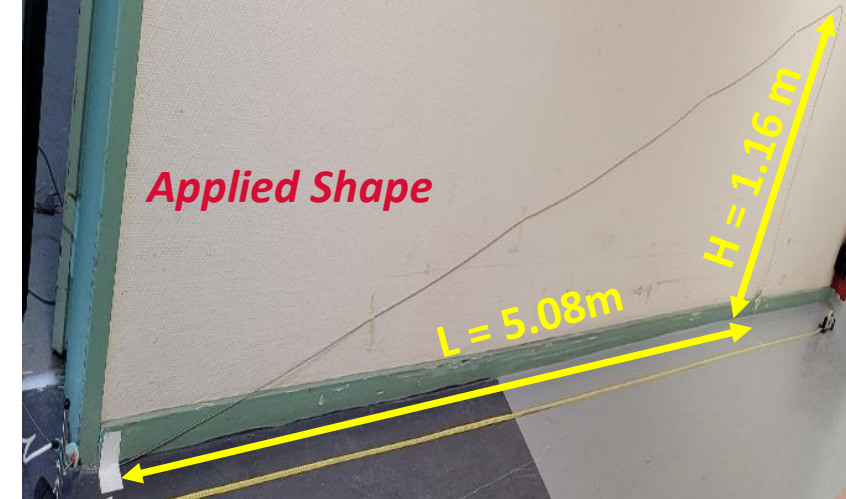
### 2D Shape reconstruction @6.2m



Optically Stimulated Luminescence

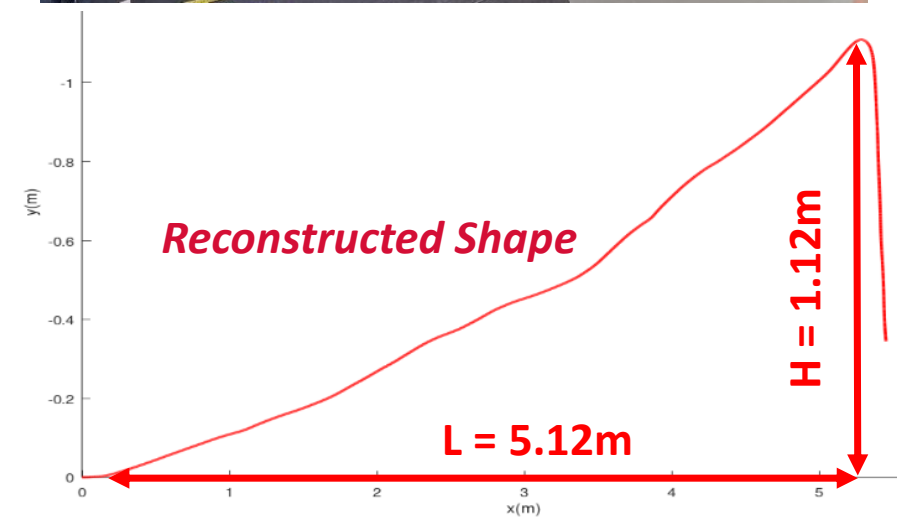
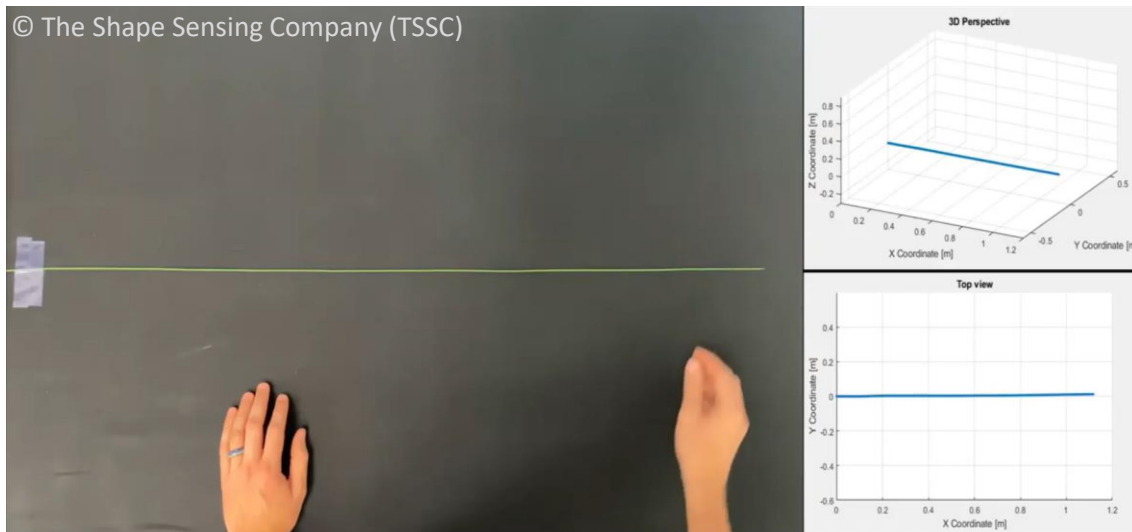


Accurate 3D dose reconstruction within hidden/out-of-reach volumes



V. Modes *et al.*, "Shape Sensing Based on Longitudinal Strain Measurements Considering Elongation, Bending, & Twisting" in *IEEE Sensors Journal*, vol. 21, no. 5, pp. 6712-6723, 1 March, 2021, doi: 10.1109/JSEN.2020.3043999.

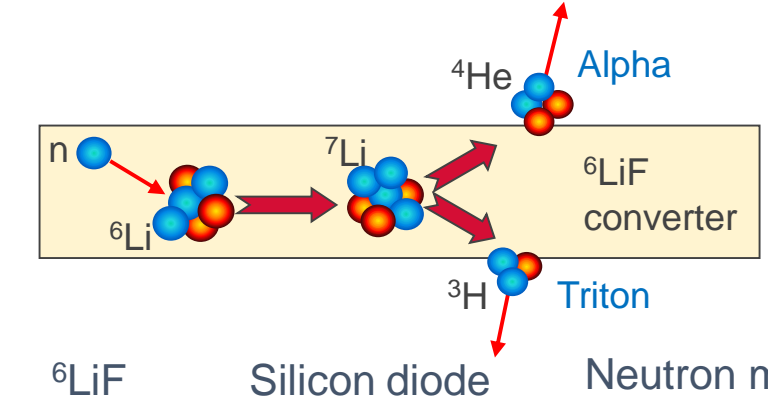
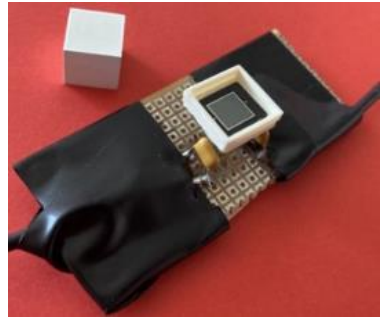
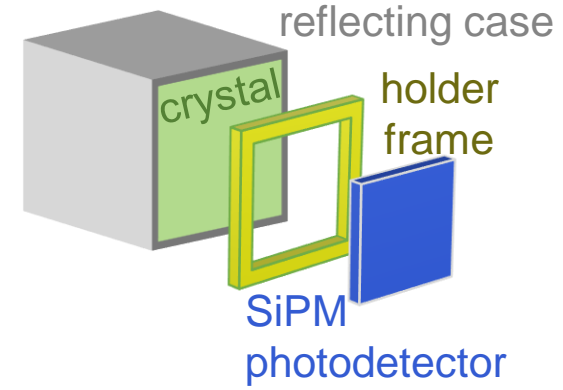
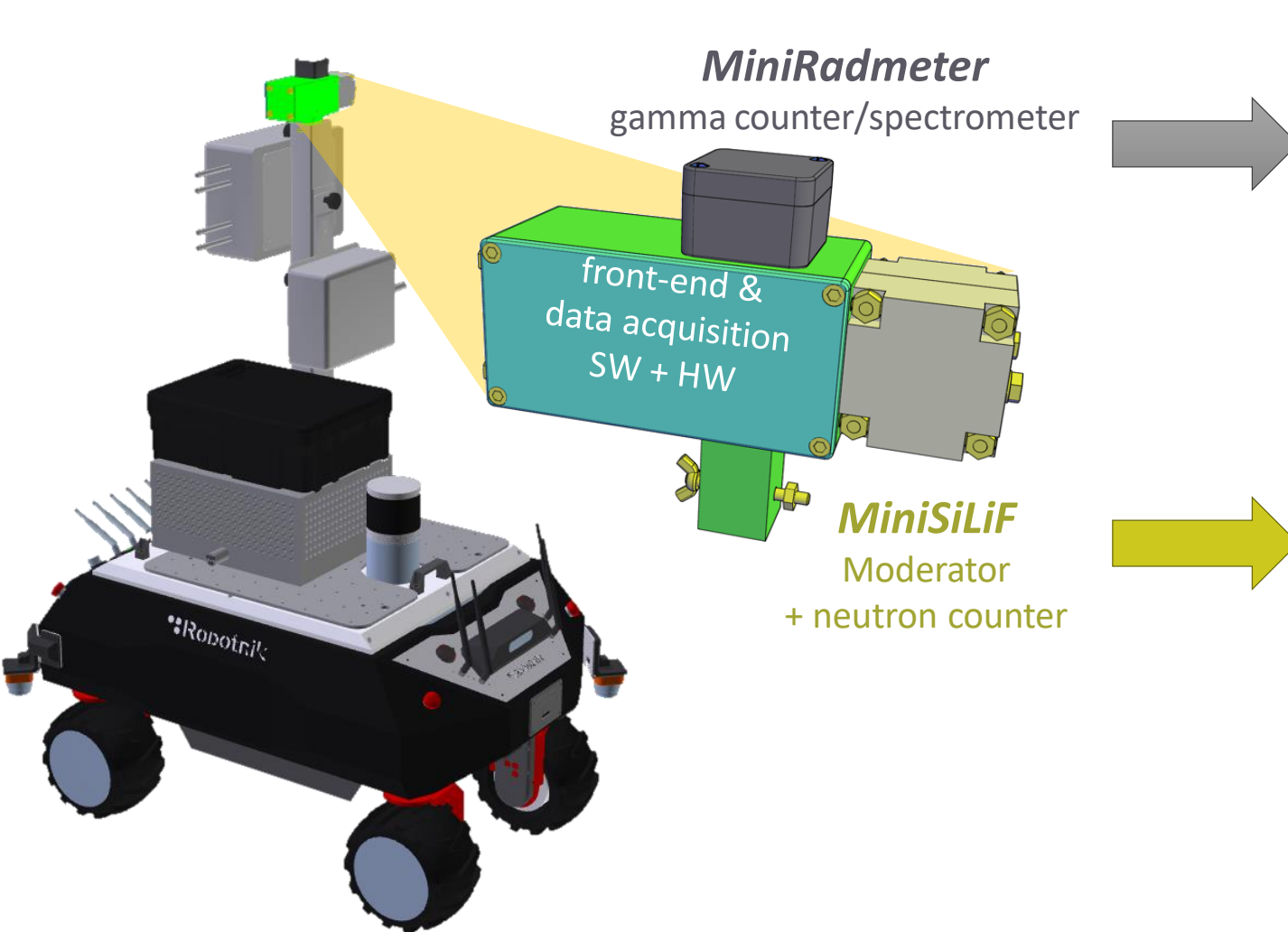
© The Shape Sensing Company (TSSC)





# WP3 | Dose rate

## Low cost miniature $\gamma$ counter/spectrometer and n counter

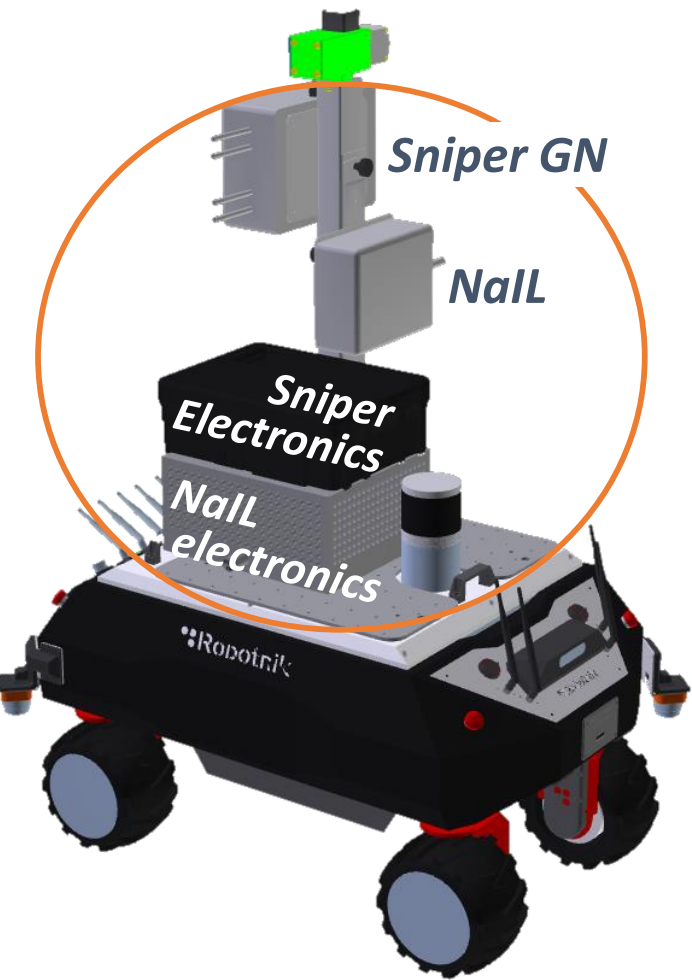


Rossi F *et al.* The Gamma and Neutron Sensor System for Rapid Dose Rate Mapping in the CLEANDEM Project. *Sensors*. 2023; 23(9):4210. DOI: 10.3390/s23094210



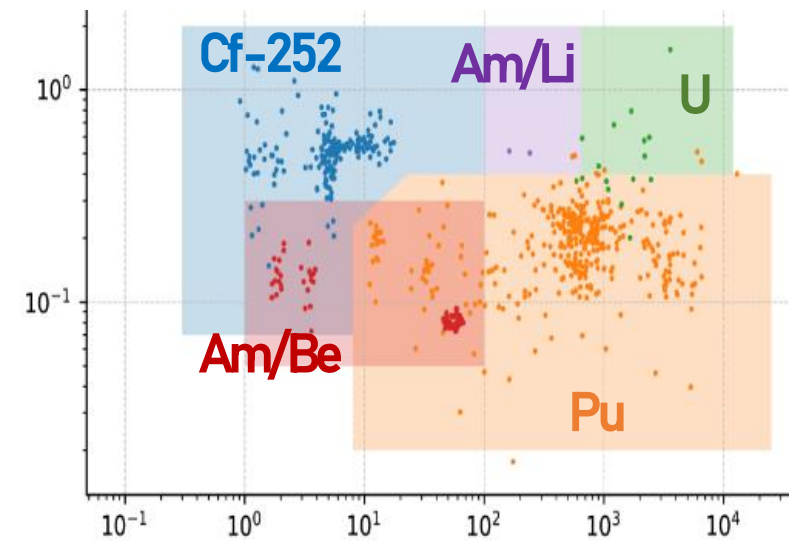
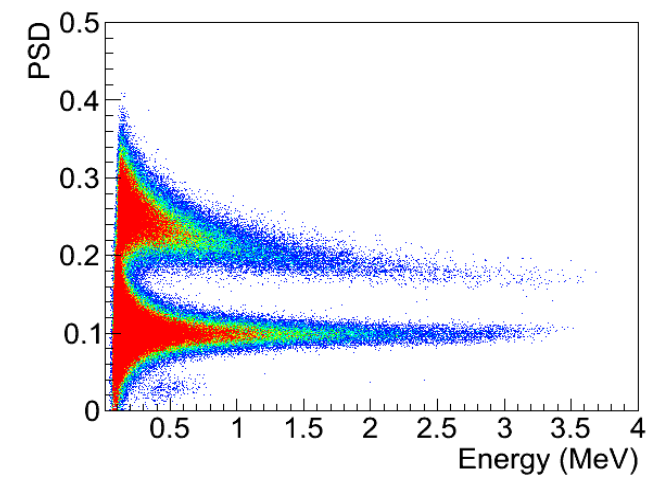
# WP4 | $\gamma/n$ detection and identification technologies

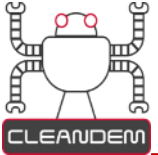
## Sniper + Gamon



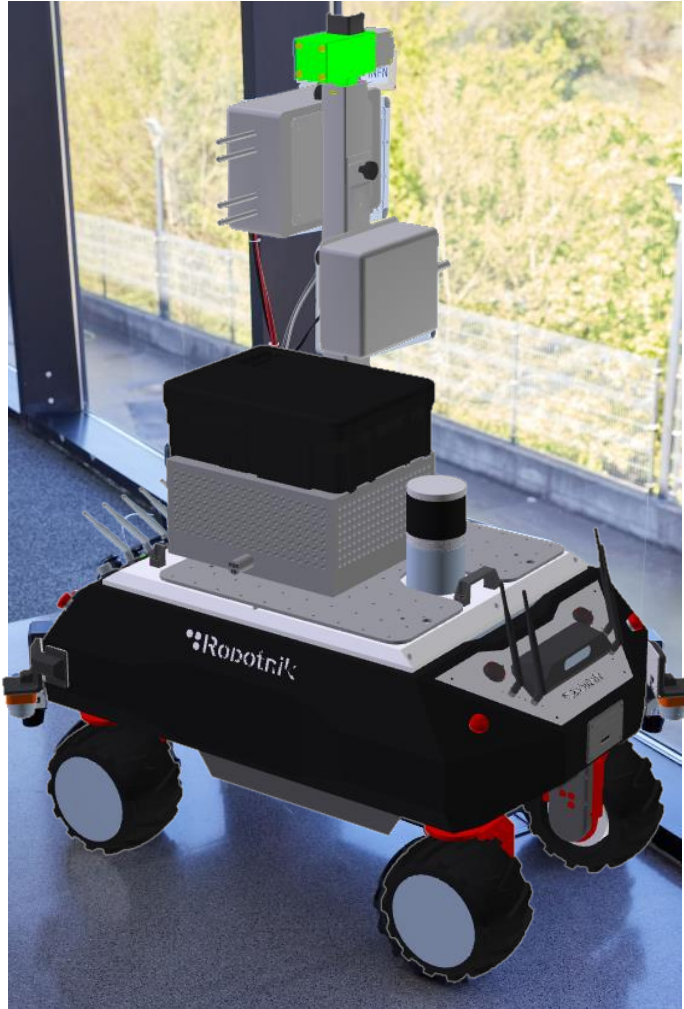
❑ **Sniper GN: Stilbene and CeBr<sub>3</sub>**  
→ detection & identification of gamma and neutron sources

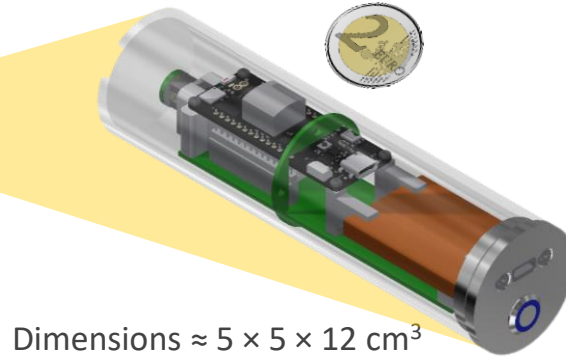
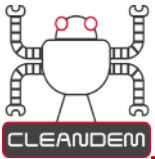
❑ **NaIL (NaI + Li)**  
→ gamma spectrometry  
+ neutron detection ( ${}^6\text{Li} + n_{\text{slow}} \rightarrow {}^7\text{Li} \rightarrow \alpha + {}^3\text{H}$ )





# Integration test week, April 17<sup>th</sup>–20<sup>th</sup>

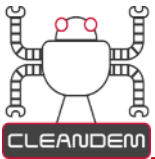




### Compact gamma semiconductor device, for:

- Deeper inspection of hot spots found out during the first step of the survey
- Checks of difficult to access zones for larger sensors
- Pipe or tube inspection Large Volume Hemispheric CZT Detector to be mounted on the UGV arm



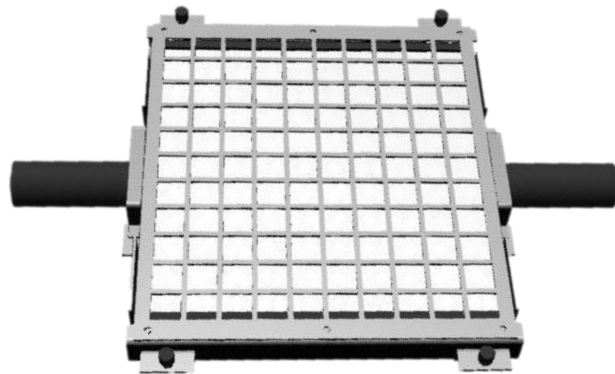


# WP6 | Contamination Monitoring

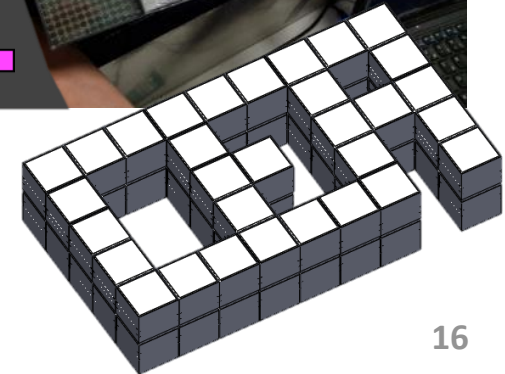
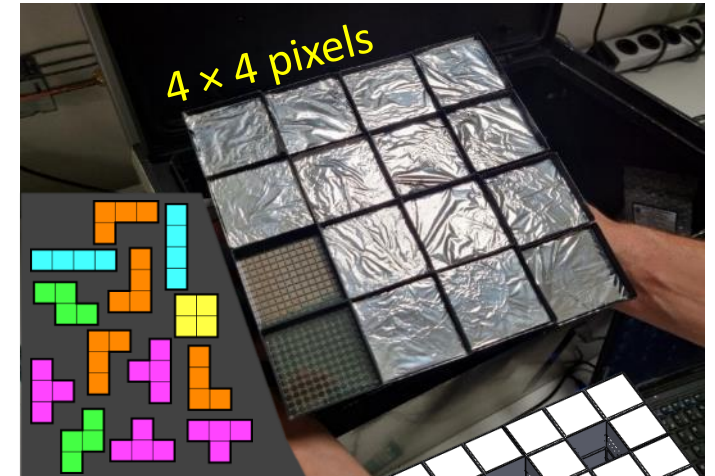
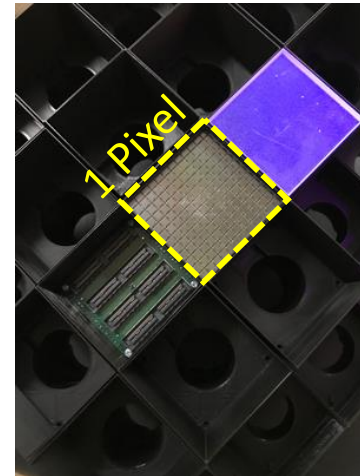
## Surface contamination monitoring



Large Area  $\alpha/\beta$  PSD phoswich



Pixellated  $\beta/\gamma$  plastic scintillators





# WP6 | Contamination Monitoring

## Air contamination monitoring

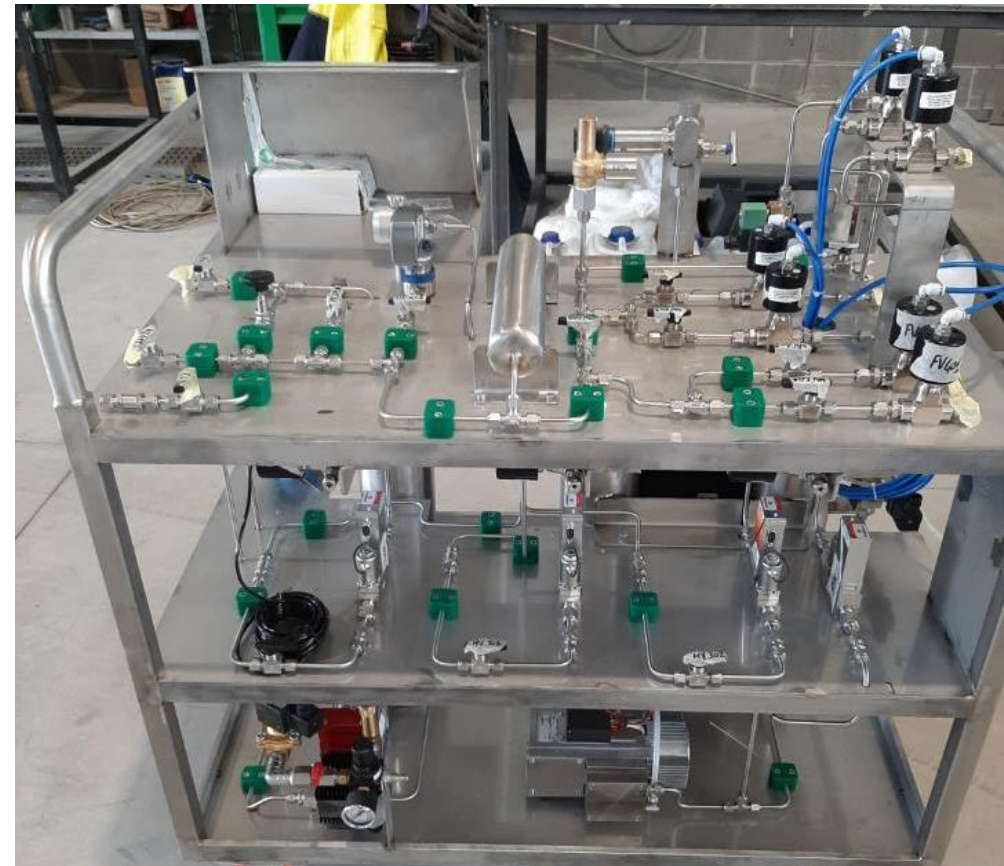


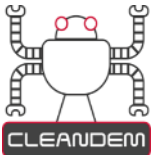
### Cryogenic system for $^{14}\text{CO}_2$ monitoring

First ENEA-INMRI prototype for gas trapping



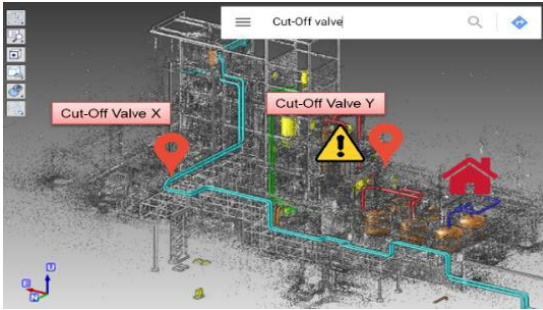
Early design of the atmospheric  $^{14}\text{CO}_2$  monitoring system.





# WP8 | Data Fusion & Digital Twin

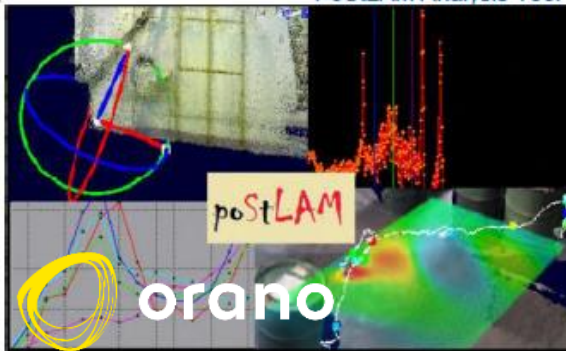
## DT Qpro<sup>2</sup> Platform with PoStLAM tools



BIM based data Visualization



PoStLAM Analysis Tool

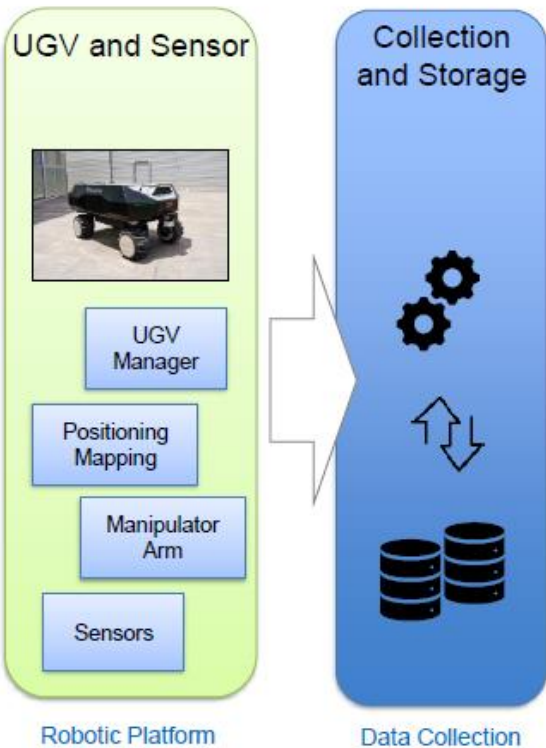


### Qpro<sup>2</sup> Multiplatform (RINA)

- Based on WEB (HTML 5)
- Safe
- Widely configurable
- 3D representation based on BIM (Building Information Modeling)

### PoStLAM software (ORANO)

designed to exploit 3D point clouds and positioned radiological data to prepare interventions



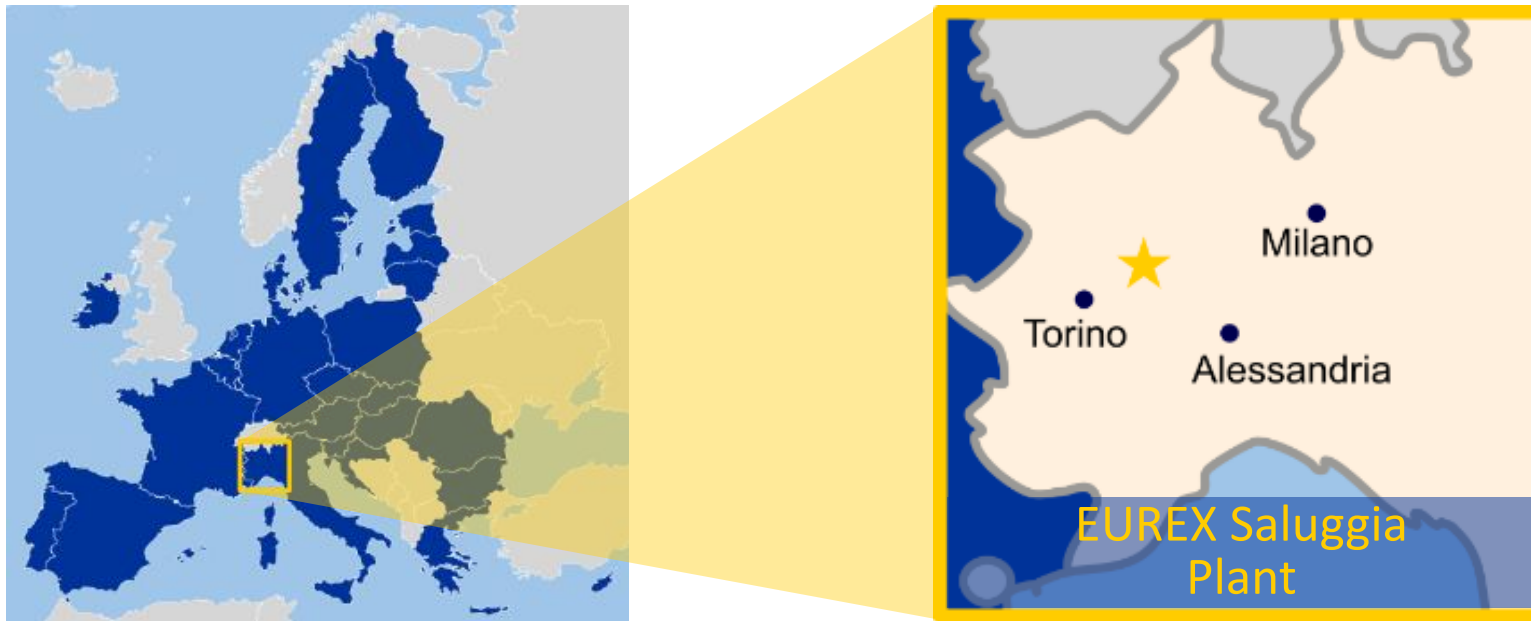
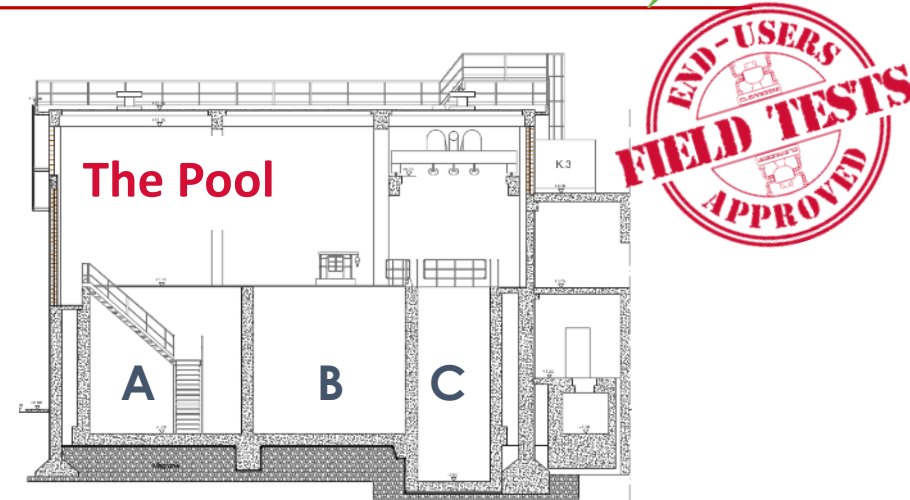


# WP9 | Training & in situ demonstration

## In-Situ demonstration



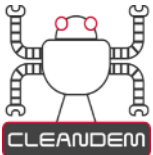
- 1) Ability to measure in hard to access areas with remote solutions
- 2) Real time information on the facility status
- 3) Ability to perform the **initial radiological characterization** of an area (in presence of **hot spots** and **very low contamination level**)



- A: Completely empty
- B: 6 vessels with sludges
- C: 3 big vessels with sludges (from remediation activities)

Expected in case of contamination:  
 $^{137}\text{Cs}$ ,  $^{90}\text{Sr}$ ,  $^{238}\text{U}$ ,  $^{239,240,241}\text{Pu}$ ,  $^{241}\text{Am}$

Expected dose rate < 10  $\mu\text{Sv}$ .



- Feedback from End-Users  
Different requirements will need training content with different focus

**1st CLEANDEM Webinar**

*You are Invited to Join*

*A Robotic Toolbox for Radiological Mapping in D&D of Nuclear Facilities*

**Free Register**

FRI DAY | SEP 16 | TIME 10am

**2nd CLEANDEM Webinar**

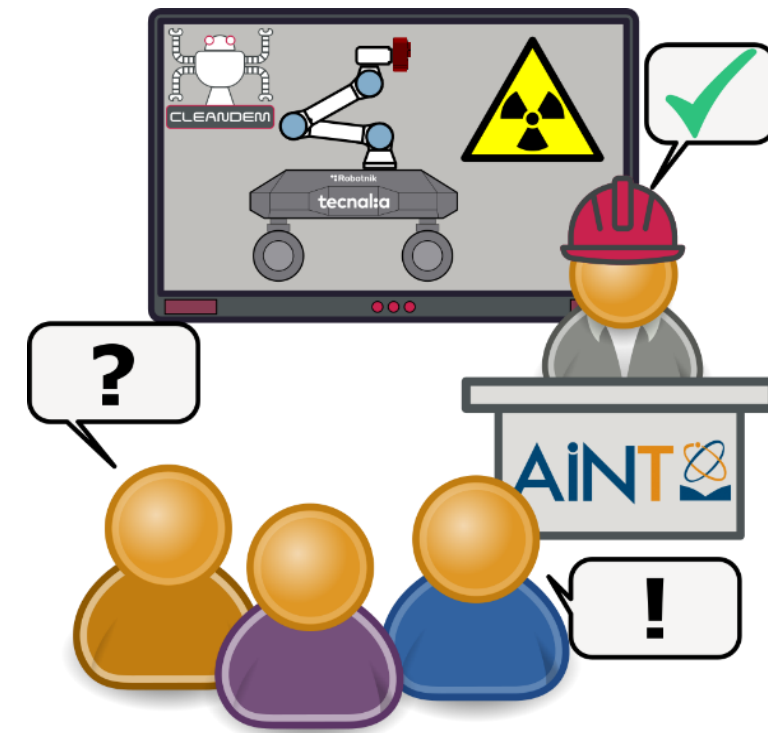
*You are Invited to Join*

*A Robotic Toolbox for Radiological Mapping in D&D of Nuclear Facilities*

**Save the date!**

THURS DAY | FEB 09 | TIME 10am

9<sup>th</sup> February 2023, 10:00 – 11:30 am

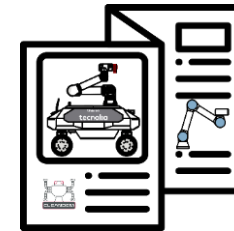




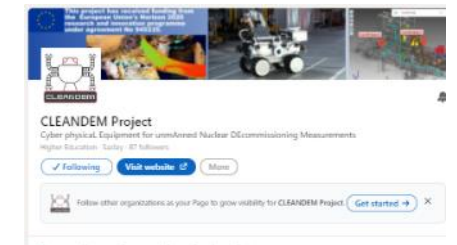
# WP10 | Dissemination and Discussions

<b>INNO4GRAPH H2020 Project</b>	Mar 21
<b>LD-SAFE H2020 Project</b>	Apr 21
<b>UK National Nuclear Laboratory</b>	May 21
<b>iCOND Conference, Aachen</b>	Oct 21
<b>World Nuclear Exhibition, Paris</b>	Nov 21
<b>MICADO H2020 Project 2nd GA</b>	Jan 22
<b>UK NNL E-U Network</b>	Mar 22
<b>INNO4GRAPH Project End-Users Workshop</b>	Jun 22

<b>CLEANDEM's EUN Webinar #1</b>	Sep 22
<b>MICADO H2020 Project Final demo</b>	Jan 22
<b>CLEANDEM's EUN Webinar #2</b>	Apr 22
<b>INNO4GRAPH H2020 Project</b>	Apr 23
<b>IAEA's DECOM 2023</b>	May 23
<b>ANIMMA Conference, Lucca</b>	Jun 23
<b>iCOND Conference, Aachen</b>	Oct 23
<b>World Nuclear Exhibition, Paris</b>	Nov 23





[cleandem-h2020.eu](http://cleandem-h2020.eu)





# Call for participants to the CLEANDEM End-Users Network

- To join the CLEANDEM end-users network:  
Please send us an e-mail at [cleandem-wp9@eurtd.com](mailto:cleandem-wp9@eurtd.com) with:
- Your intentions to participate
  - Your company details
  - Your background expertise
  - Your expectations



## Sign up for CLEANDEM Updates

CLEANDEM is Co-funded by the Horizon 2020 programme of the European Union  
Grant Agreement N° 945335

The aim of the CLEANDEM project is to deliver an Unmanned Ground Vehicle for radiological survey to support D&D operations. The project runs from 2021 – 2024, and it is planned to engage with stakeholders via various channels and activities (Webinar, Training & In-situ demonstration).

Interested? Sign-up here to stay up to date!

Follow CLEANDEM at LinkedIn:  
<https://www.linkedin.com/company/cleandem-project/>

Fill out the fields below and insert in box!

E-Mail:

Name*:	
Company*:	Position*:

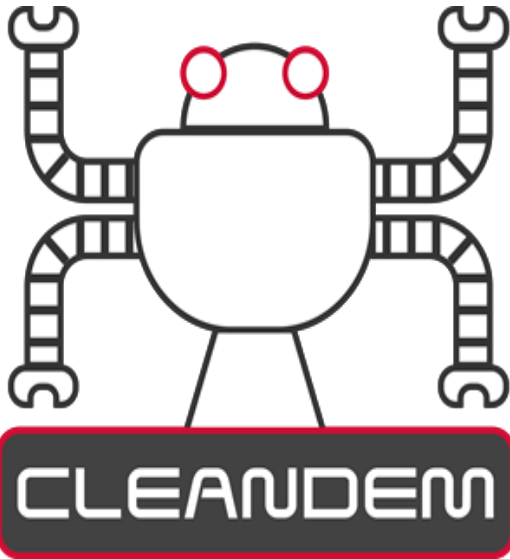
I am interested in D&D operation for following type of facility\*  
(NPP, Hot Cell, Nuclear Fuel Cycle, ...)

Any other detail, you want to share with us? \*

I hereby declare I accept to be contacted to be part of the CLEANDEM end-users group, and understand that all data here detailed will only be used in accordance with the Privacy Policy described on the back-side of the present page.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under agreement No 945335.



# Thank you for your attention

Maugan MICHEL,  
*on behalf of the CLEANDEM consortium*



[cleandem-coord@eurtd.com](mailto:cleandem-coord@eurtd.com)



[cleandem-h2020.eu](http://cleandem-h2020.eu)



**CAEN**

Tools for Discovery



orano



INFN

ansaldo

nucleare



**tecna:a**

MEMBER OF BASQUE RESEARCH  
& TECHNOLOGY ALLIANCE



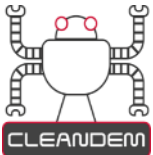
**AiNT**

**ENEA**



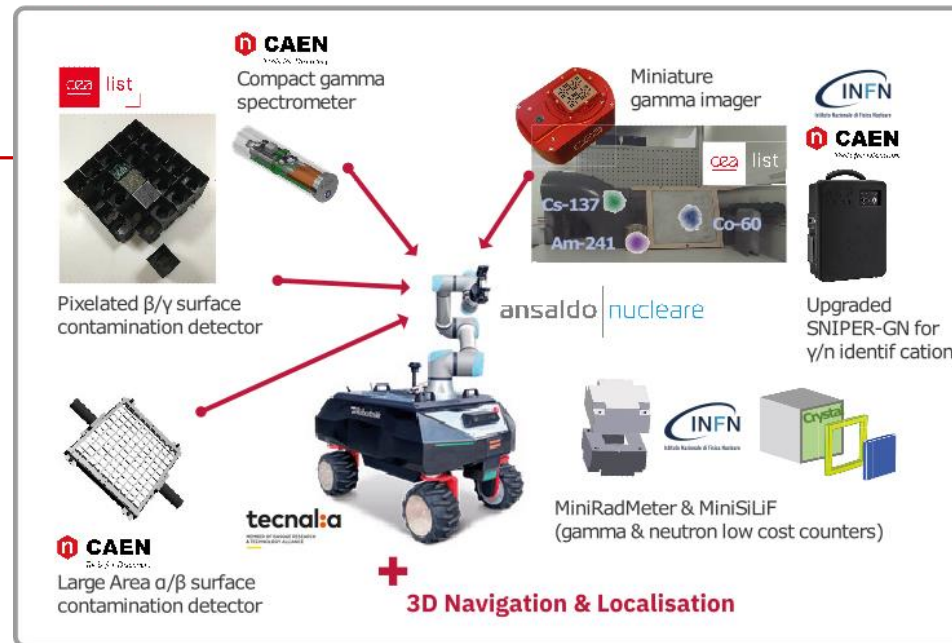
a PNO international management services company





# Project diagram

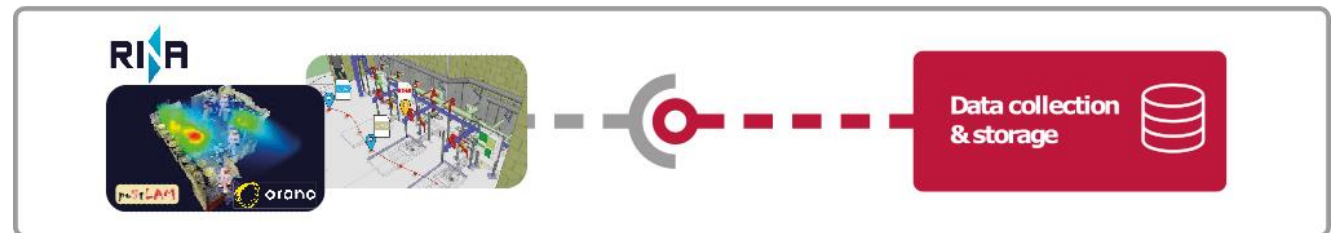
## SENSORS ON PLATFORM



## OTHER SENSORS

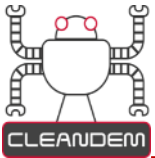


## DIGITAL TWIN

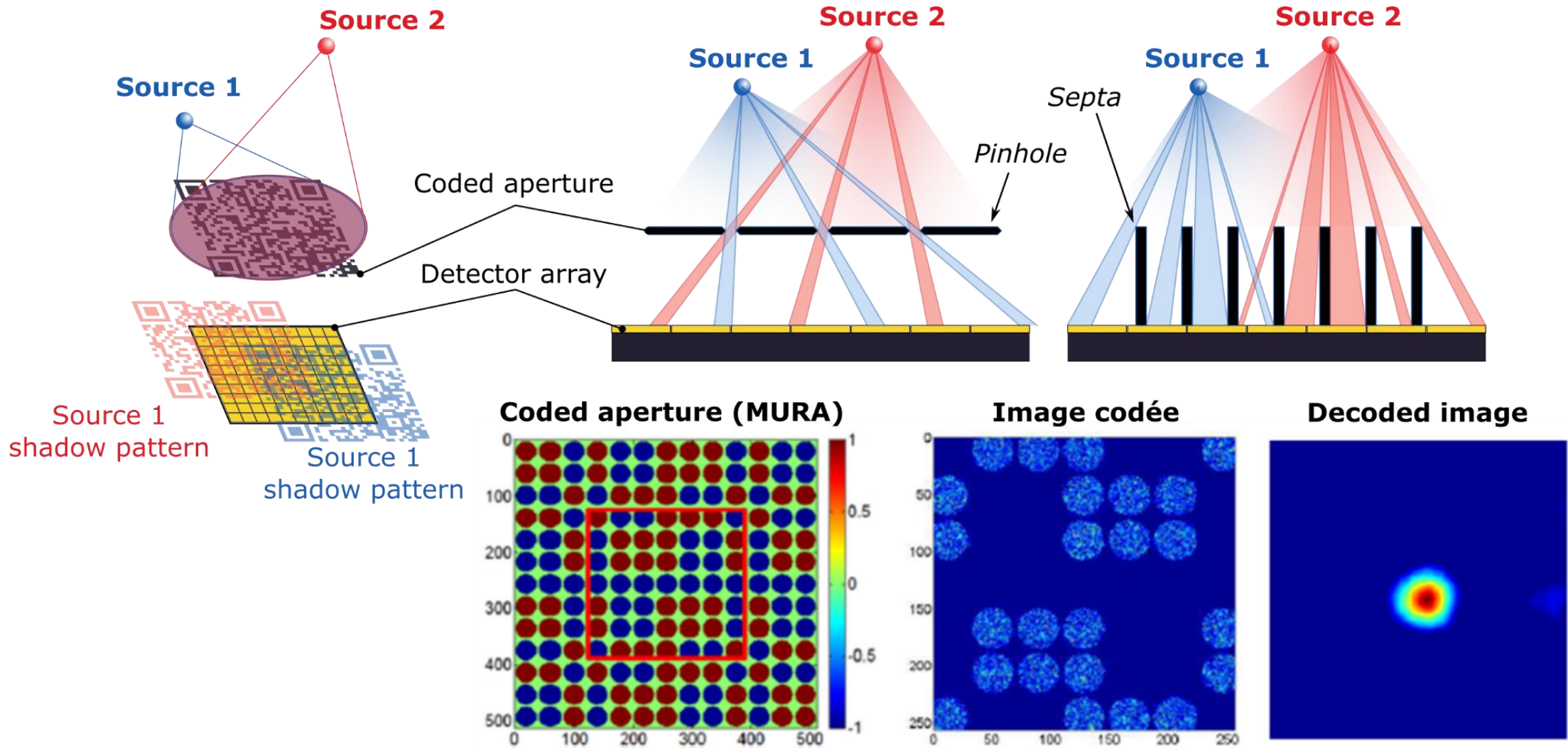


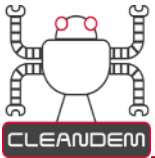
## TRAINING & DEMONSTRATION





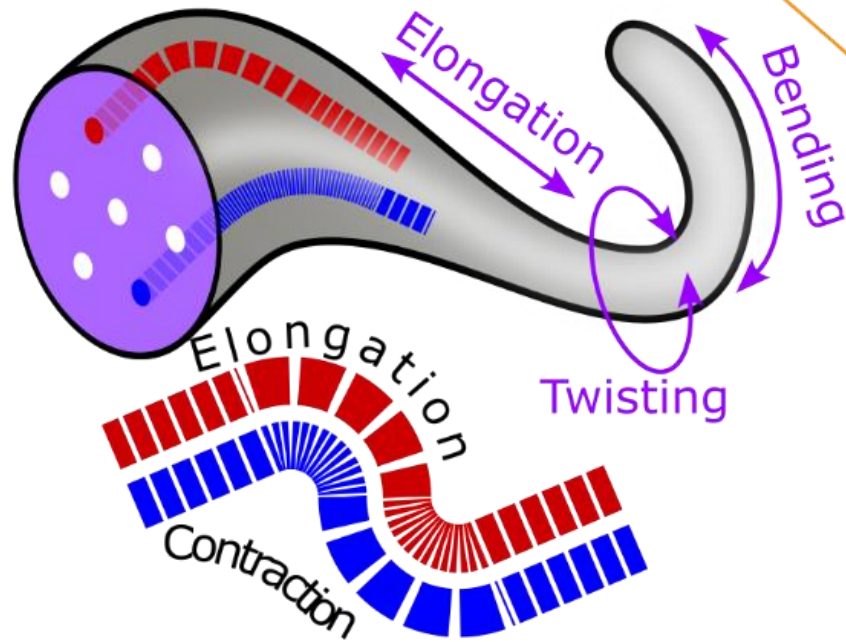
# Coded aperture gamma imaging



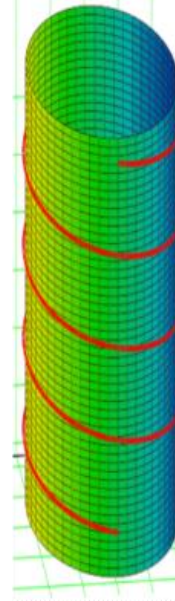


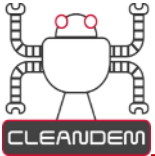
# Shape sensing

## Bended Multicore fibre (MCF)

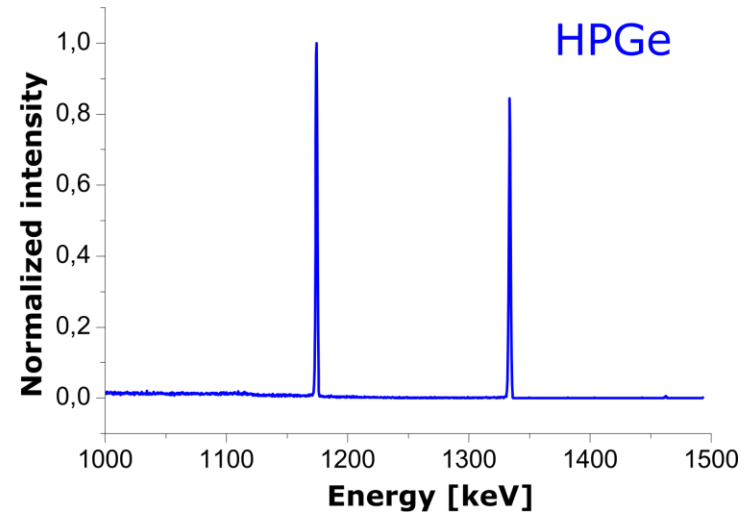
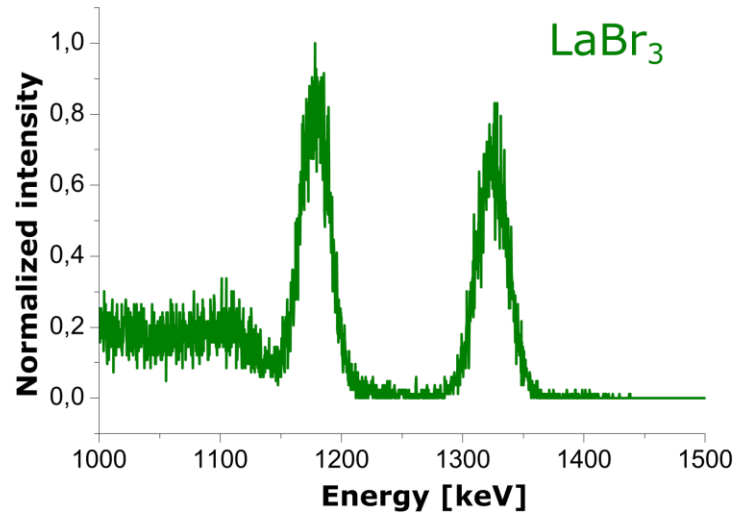
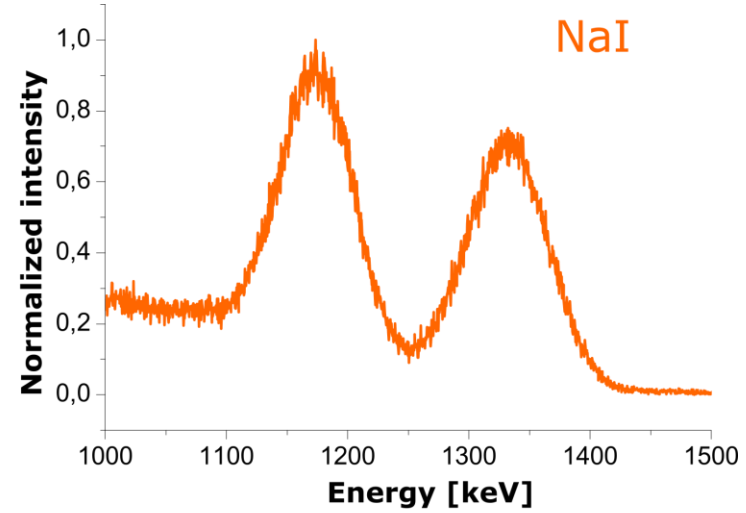
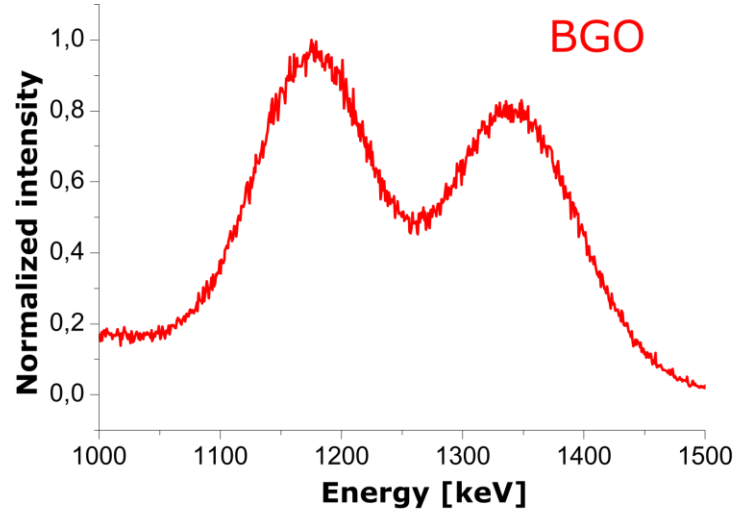


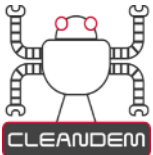
## 3D Reconstruction





# Why is detector resolution important ?





# Different interactions $\rightarrow$ different pulse shapes

