Project overview and Gap Analysis

22/10/2020

Massimo Morichi (CAEN)

The TEAM

Kickoff Meeting,
Viareggio – 11th June 2019

9 partners over 5 countries (IT, FR, BE, DE, CZ); a good mix of universities, research centers, one large company ad SMEs.

Measurement and Instrumentation for Cleaning And Decommissioning Operations

- Development of a system that could become a referenced standard facilitating and harmonizing the methodology used for the in-field Waste Management and Dismantling & Decommissioning (D&D) operations
- The D&D process of nuclear infrastructures increasingly demands methods for a full traceability of waste material to improve quality management and operational safety. Precise waste management and minimization procedures provide two-fold benefits; the optimization of costs, associated with D&D, and the minimization of the dose exposure to operators and personnel
- The absence of a consistent, straightforward solution for fully characterize all types of materials, with the absence of an integrated solution for digitizing the enormous amount of data produced, is a critical issue. One challenge lies in the operator's ability to maintain high operational skills and quality assurance with precision measurements

Gap analysis

One of the most relevant aspects within the Nuclear Waste Characterization field is the missing of a comprehensive procedure able to address different type of waste packages providing a unique and digital information easily accessible.

From IRSN RWM

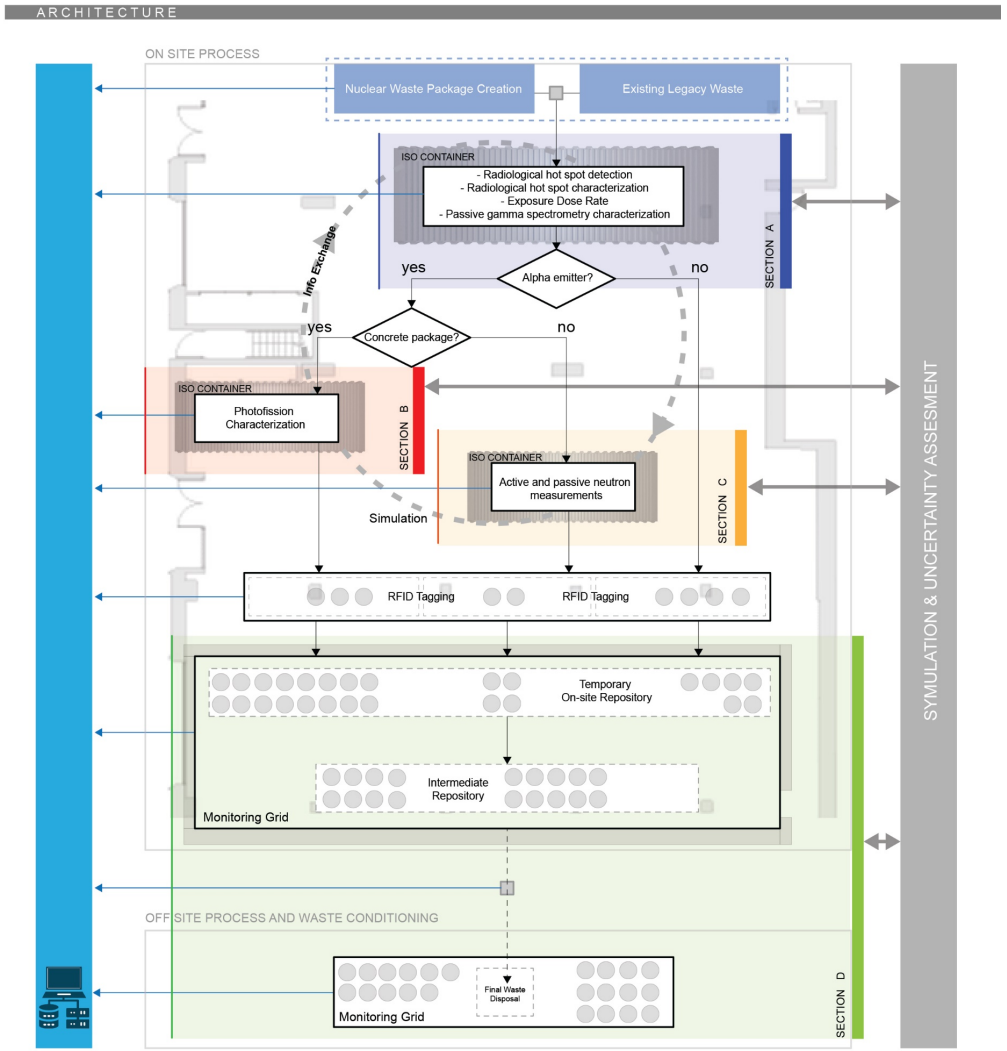
MICADO will be able to:

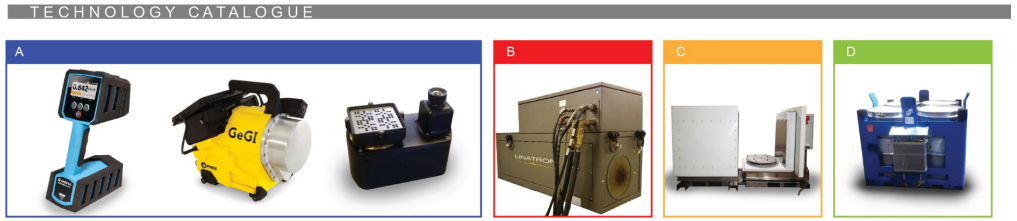
1. Improve the ALARA for the workers reducing the working time closer to the WP and the measurement time.
2. Reduce the on & off-line data analysis and management.
3. Improve the characterization and the quantification of fissile and fertile materials.
4. Cost reduction in terms of reduction of operators needed, reduction of the measurement time, better characterization results and be flexible with the possibility to use the same technologies in different locations.

How to

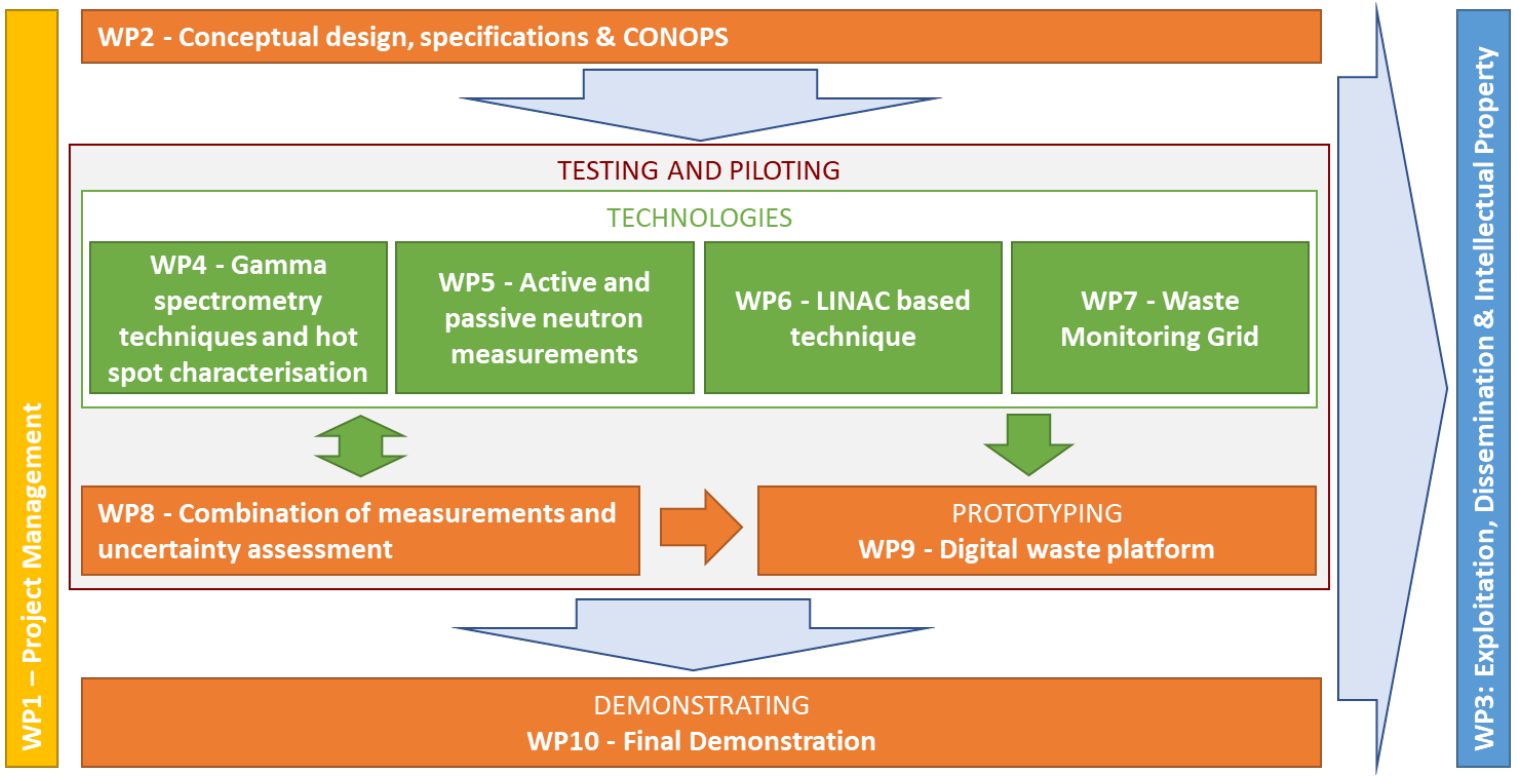
MICADO bridges this gap integrating:

- different and innovative technologies to cope multiple NWP:
  - Gamma spectroscopy & spectrometry, hot spot search, neutron detection and active interrogation & neutron detection
  - VLLW, LLW, MLW, ILW & Legacy waste
  - Concrete, variable density, inorganic, compacted … WP
- an automatize characterization step procedure to optimize the full procedure and to maximize the impact based on a software procedure for the combination of measurements and uncertainty assessment
- A software infrastructure to manage results from individual technologies, providing historical information and location of the characterized elements for the logistics





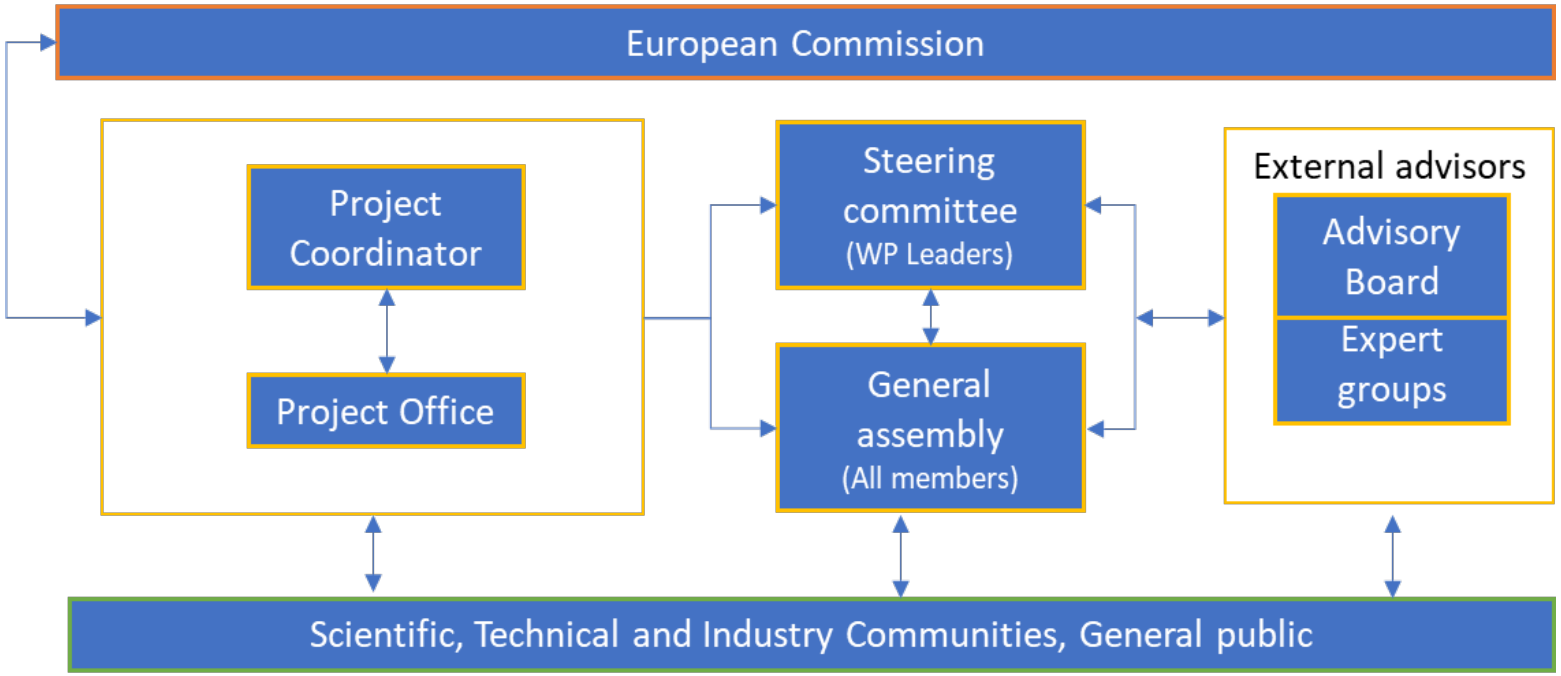
The Workplan



- Starting Date: June 2019
- Kick-off meeting June 2019
- 3 years project
- Last general meeting 4-5 February 2020 Paris (Orano Headquarter)
- Next general meeting hopefully in Prague next year.

WP	WP Leader / EB member	WP	WP Leader / EB member
WP1	Massimo Morichi (CAEN)	WP6	Adrien Sari (CEA-LIST)
WP2	Roger Abou Khalil (ORANO)	WP7	Paolo Finocchiaro (INFN)
WP3	Alessandro Iovene (CAEN)	WP8	Sven Boden (SCK•CEN)
WP4	Vincent Schoepff (CEA-LIST)	WP9	Claudio Raffo (CAEN)
WP5	Cyrille ELEON (CEA-DEN)	WP10	Nadia Cherubini (ENEA)

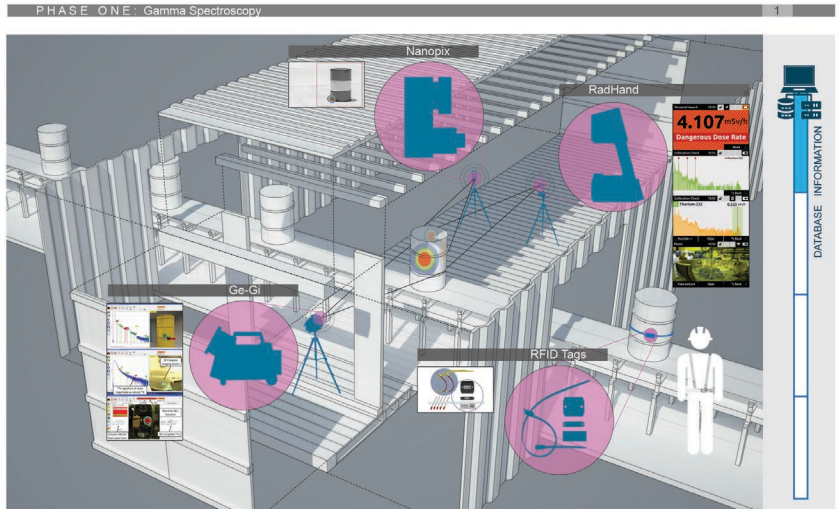
Organizational Structure

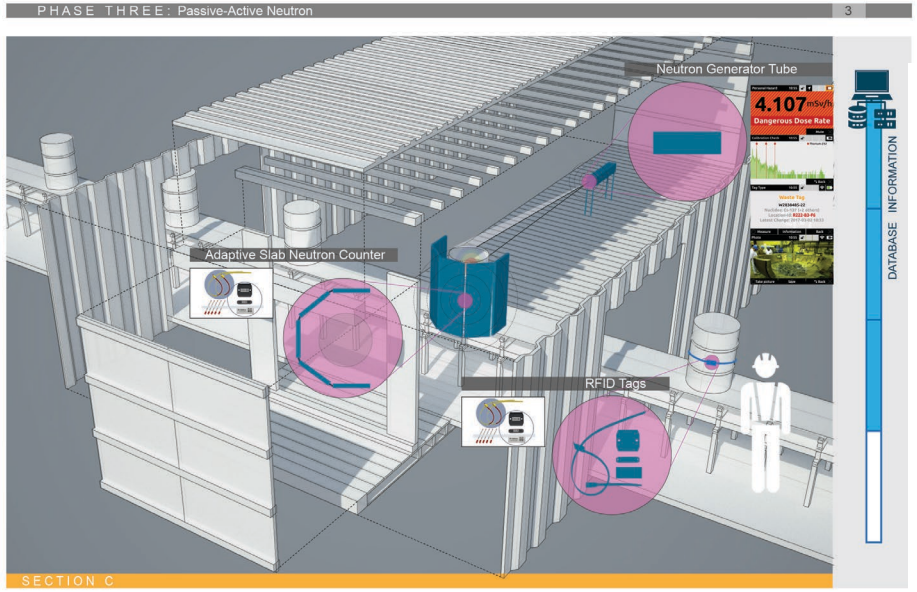


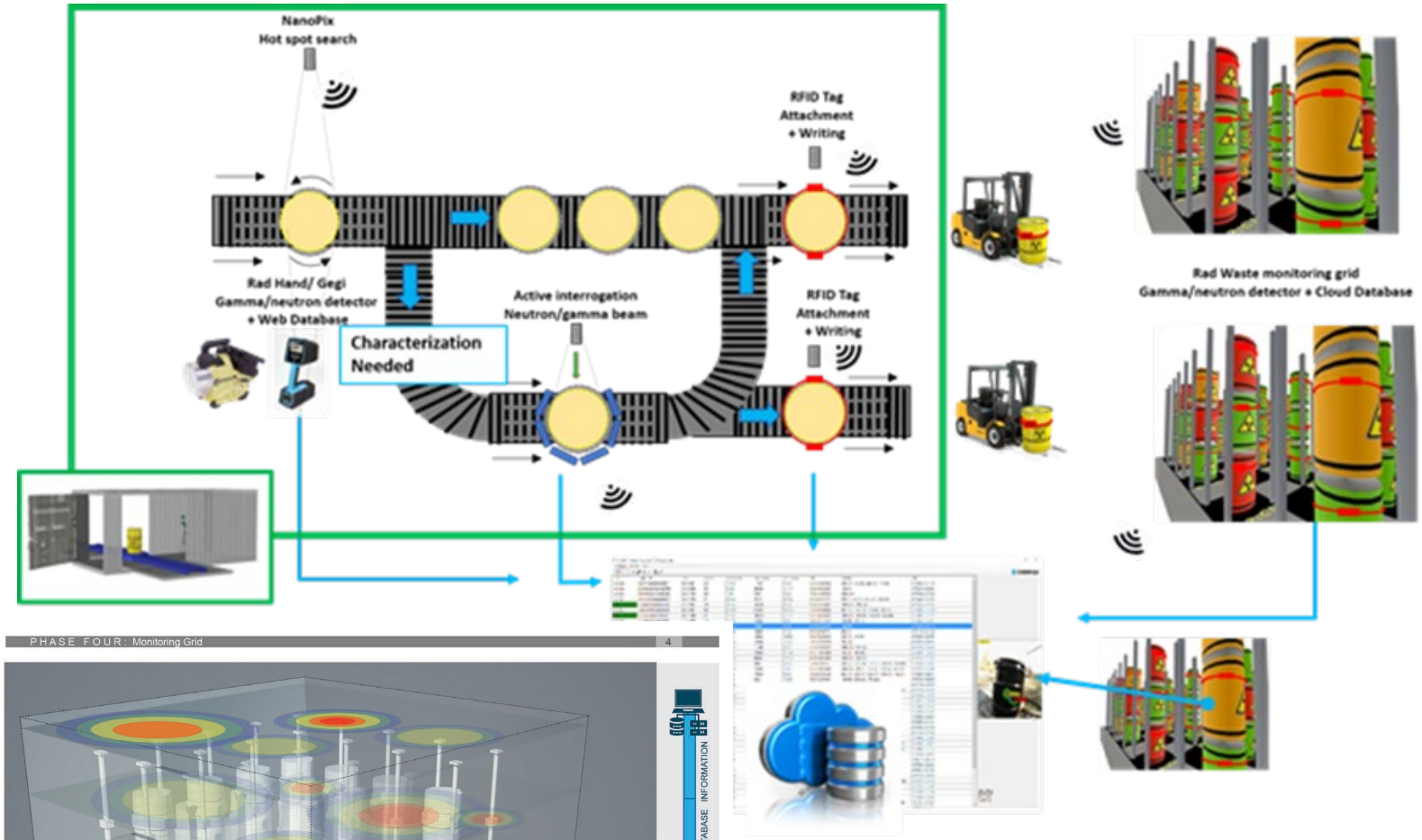
The External Advisory Board

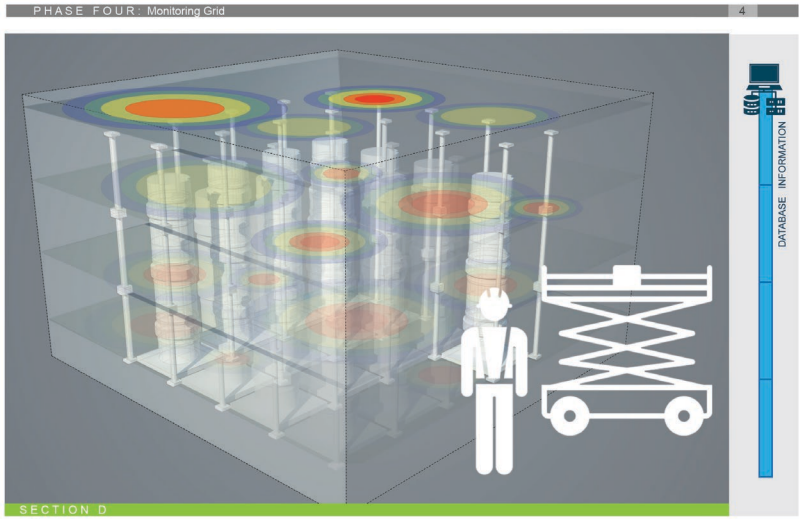
EAB member	Affiliation	Position
Paolo Peerani	JRC – Joint Research Centre	Unit head nuclear decommissioning unit
Marco Ripani	INFN – Istituto Nazionale di Fisica Nucleare	Senior researcher
Alessandro Dodaro	NUCLECO	President
Abdallah Lyoussi	CEA	Professor
Frédéric Plas	ANDRA	Head of R&D division
Philippe Renault	SWISSNUCLEAR	General Manager
Gianni Bruna	Private	Nuclear Expert

The system


PHASE ONE: Gamma Spectroscopy
1
Nanopix
RadHand
4.107 mSv/h
Dangerous Dose Rate
Ge-Gi
RFID Tags
DATABASE INFORMATION


PHASE THREE: Passive-Active Neutron
3
Neutron Generator Tube
4.107 mSv/h
Dangerous Dose Rate
Adaptive Slab Neutron Counter
RFID Tags
DATABASE INFORMATION
SECTION C


NanoPix
Hot spot search
RFID Tag
Attachment
+ Writing
Rad Hand/ Gegi
Gamma/neutron detector
+ Web Database
Characterization
Needed
Active interrogation
Neutron/gamma beam
RFID Tag
Attachment
+ Writing
Rad Waste monitoring grid
Gamma/neutron detector + Cloud Database


PHASE FOUR: Monitoring Grid
4
DATABASE INFORMATION
SECTION D

Investigation techniques

- ***Hot spot search and gamma spectroscopy*** for the identification of the energy spectra and quantification of the gamma emitters (^{60}Co, ^{137}Cs…), detection of fissile materials (U, Pu), and define isotopic compositions and activities. The identification of hot spots of a higher activity will help on the material handling or repackaging;
- ***Neutron active and passive measurements*** based on ^{3}He detectors to evaluate the Pu activity, combined to gamma measurements. Neutron coincidence techniques are also used to measure the spontaneous fission (Pu and Cm) or measure the U and Pu fissile mass and their activities using neutron induced fissions;
- ***Photofission measurements*** to evaluate the U and Pu activities for high-density waste packages;
- ***Long term monitoring system*** based on scintillating optical fibers and SiLi6Fi technology to have a low cost and distributed grid of sensors surrounding the waste packages in the storage repository.

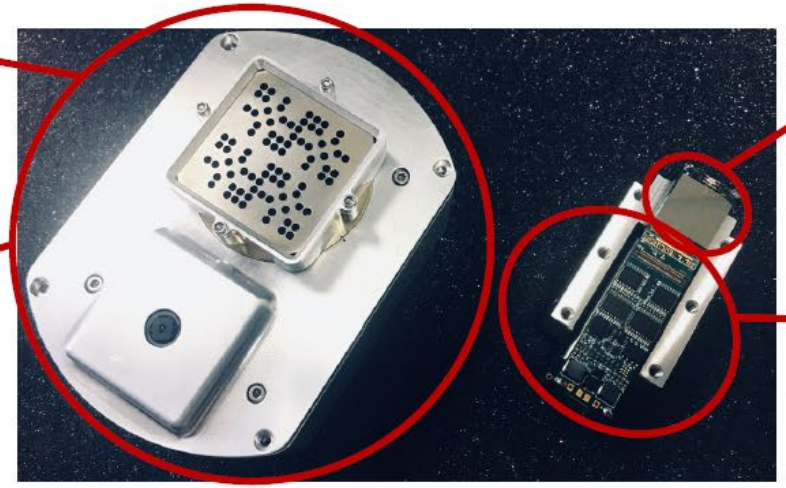
Gamma spectrometry techniques and hot spot characterization

- 5 main tasks:
  - 2 on Hot spot characterization upgrading and optimization
  - 2 on gamma spectrometry upgrading and data processing improvement
  - 1 on integration of gamma spectrometry and hot spot characterization followed by full laboratory test

Nanopix Gamma Camera

Expertise in dev. of imaging systems (Physics, electronics & algorithms)

Expertise in use of gamma imaging systems for D&D



Expertise CdTe crystals and related technologies

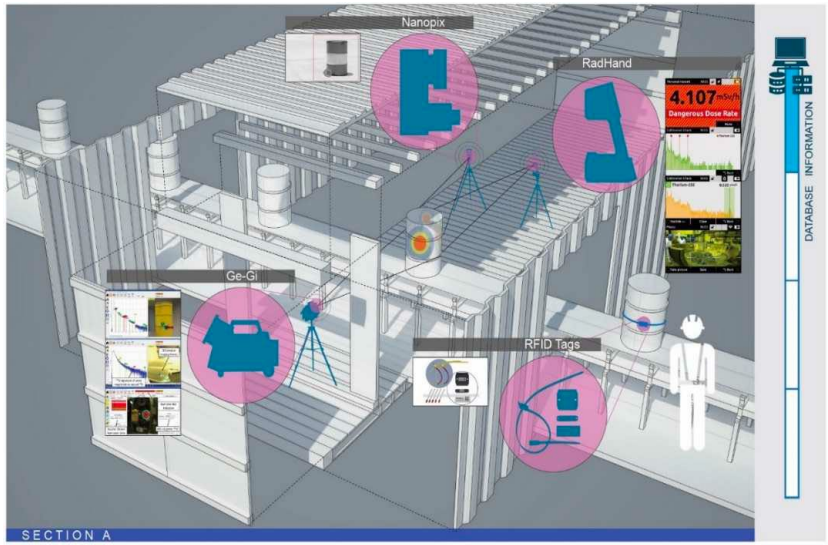
Expertise in dev. of compact embedded readout electronics

Gamma spectrometry techniques and hot spot characterization

- Gamma spectroscopy technologies

  - **Complete set of technologies** to be associated

    - Characterize the state-of-the-art technologies for gamma spectro.
    - Integrate these technologies along with density measurement in RCMS DigiWaste Plateform
    - Adapt gamma spect. and segmented gamma scanner to different geometry

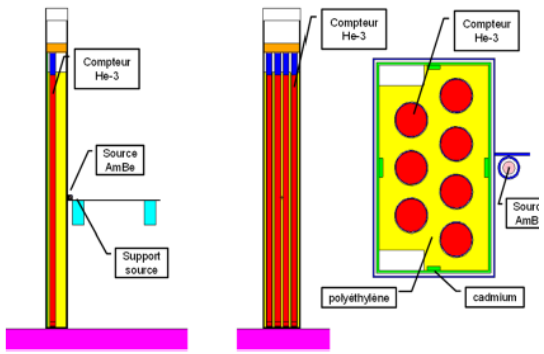


  - **AI improvements** allowing application to spectroscopy

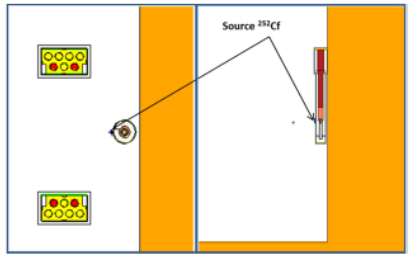
    - Apply ExpressIF ™ to gamma-ray spectrometry data for peak identification
    - Model the knowledge of physicists in a data base
    - Upgrade ExpressIF to reason on peaks (imprecise data modelled as gaussians on a first approach)
    - Characterize the AI on real gamma-ray spectra

Passive and active neutron measurements

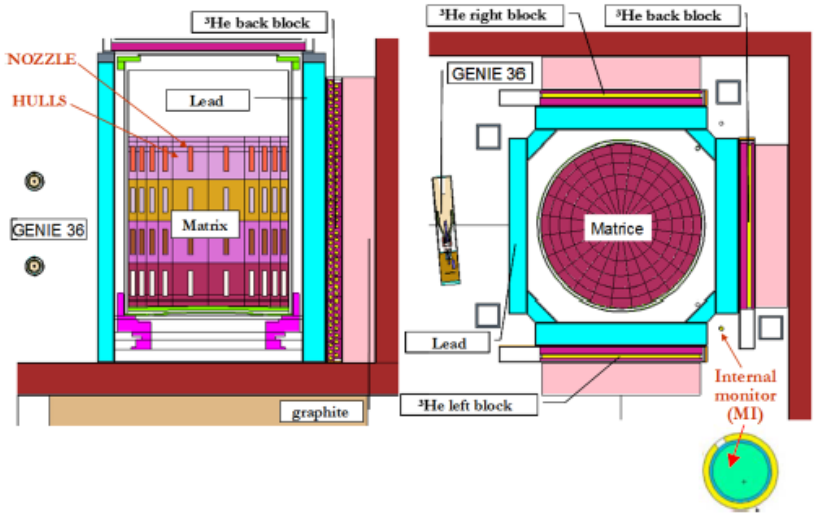
- 3 main tasks:
  - Design of the modular neutron measurement system (MCNP-based)
  - Realization of neutron measurement system
  - Commissioning and calibration of the system



DANAIDES irradiation casemate

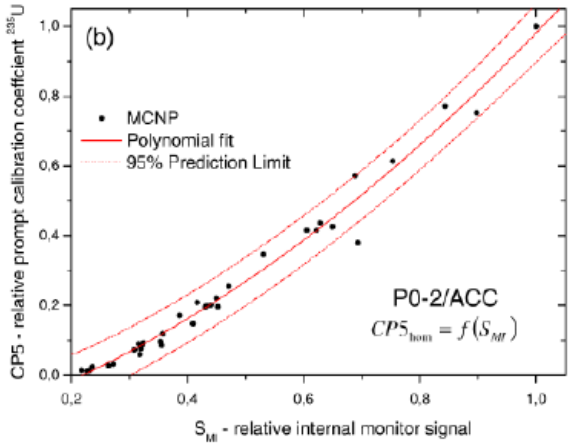


MCNP calculations for several matrix configurations
Example of an active neutron measurement set-up
(ORANO/La Hague)



^{3}He detector sensitive to matrix materials

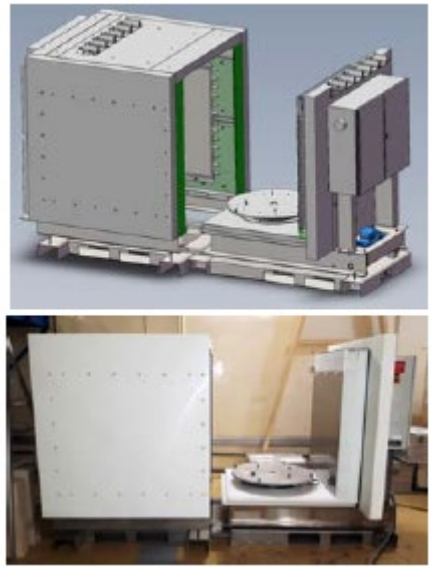
Correlation between the calibration coefficient of fission prompt neutrons ($c.s^{-1}.g_U^{-1}$) and the internal monitor ($c.s^{-1}$) using a multi-linear regression



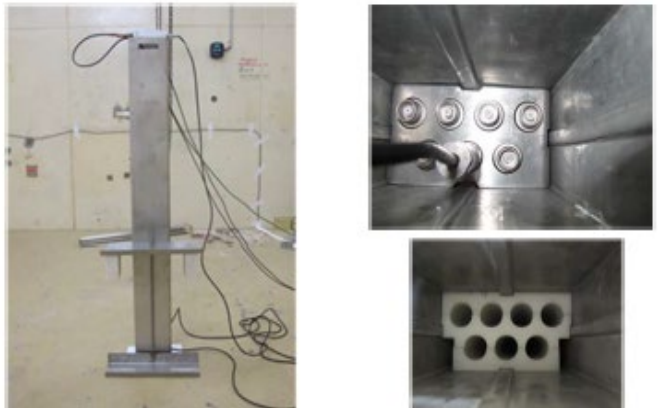
R. Antoni et al., Matrix effect correction with internal flux monitor in radiation waste characterization with the Differential Die-away Technique, IEEE Transactions on Nuclear Science, Vol. 61, No. 4 (2014)

Passive and active neutron measurements

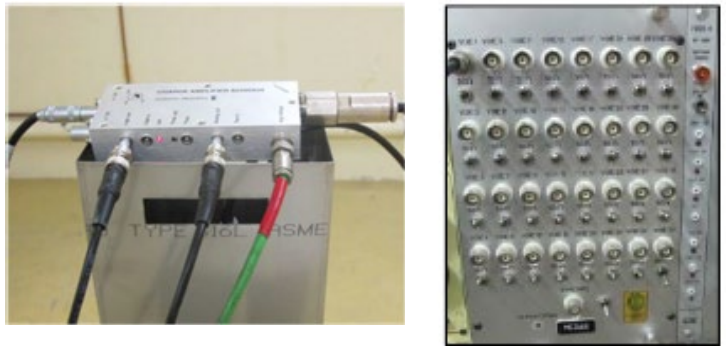
Realization of the modular system



Example of relocatable passive neutron system for D&D sites

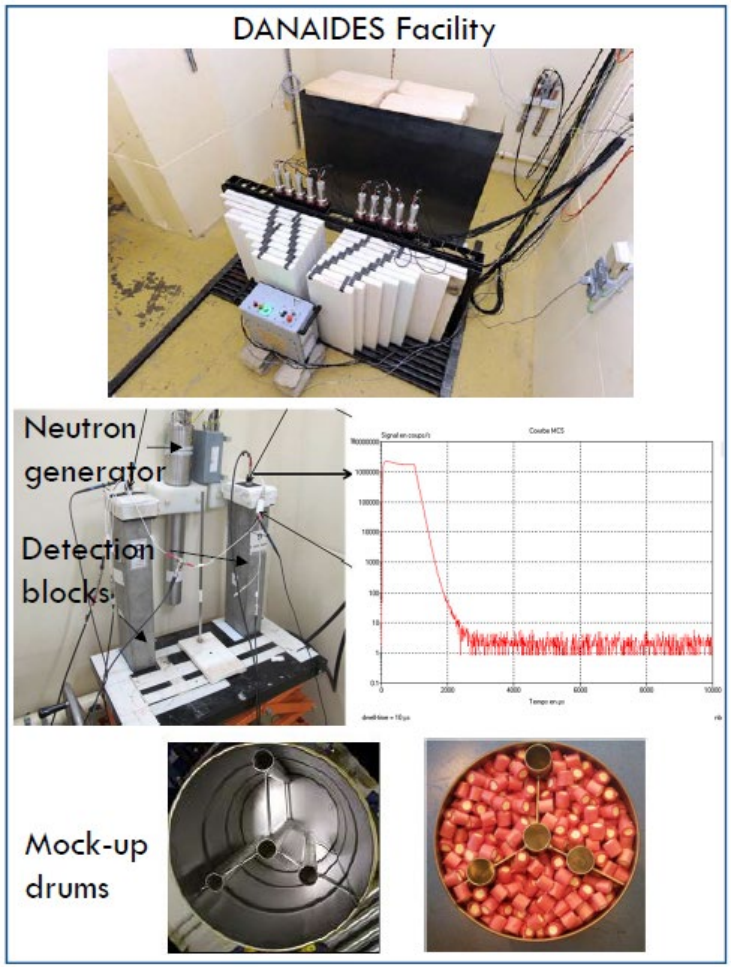


Example of 25 ^{3}He tube assembly embedding detection blocks (polyethylene + Cd)



Example of charge amplifiers & data acquisition board to record TTL pulse times

Commission & calibration of the modular system



Linac based techniques

- 3 main tasks:
  - Photofission simulation step for performance evaluation on reference cases
  - Experimental step for optimizing photofission instrumentation and associated algorithms
  - Commissioning and validation at the SAPHIR platform

The SAPHIR platform

- The Linatron® M9 manufactured by VARIAN (now Varex Imaging)
  - Either 6 or 9 MeV électrons (high-energy photons produced by Bremsstrahlung)

X-ray Head and RF Unit

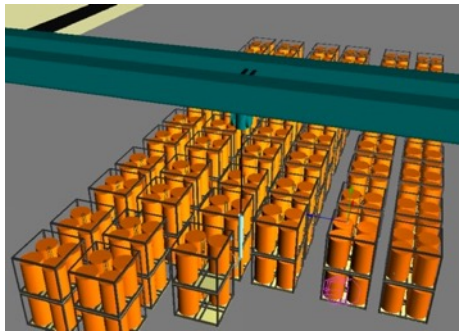
Modulator

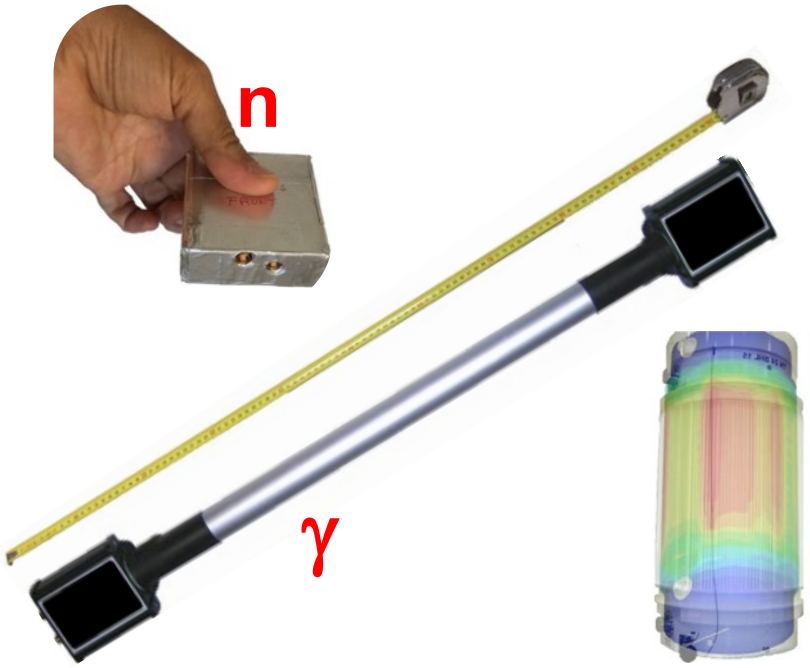
Cooling system

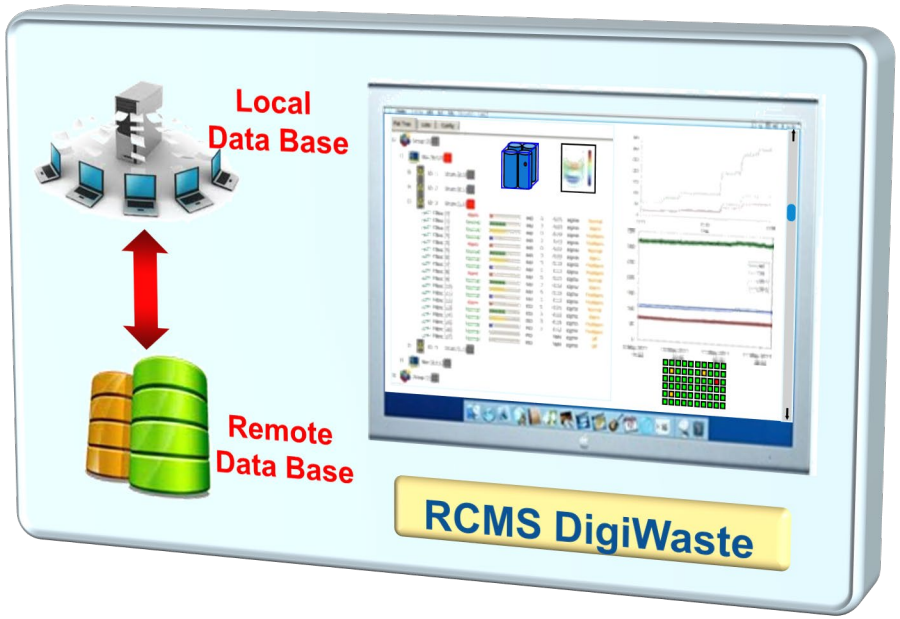
Touchscreen Controle Console

Waste Monitoring Grid

- 4 main tasks:
  - Assess the feasibility of the SiLiF (neutron) and SciFi (gamma) detectors to monitor the different types of nuclear waste
  - Build, test and characterize the detectors' behavior with respect to different types of nuclear waste and containers
  - Characterization of the system with laboratory tests in order to prepare the final demonstration
  - Performance evaluation of alternative technologies (Timepix network)

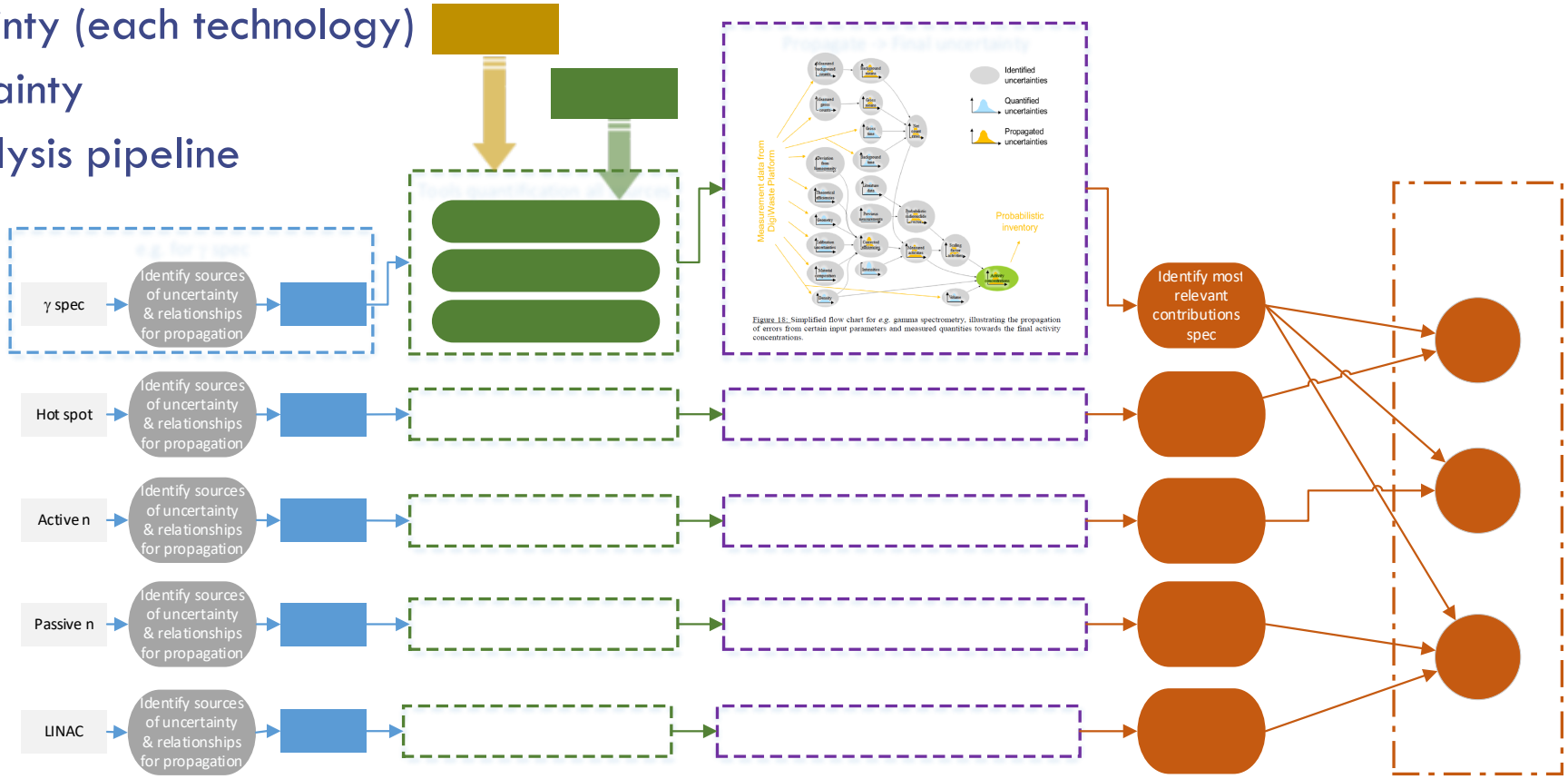






Combination of measurements and uncertainty assessment

- 3 main tasks:
  - Identify all sources of uncertainty (each technology)
  - Quantify all sources of uncertainty
  - Development of the data analysis pipeline



Final Demonstration

- 4 main tasks:
  - RCMS DigiWaste Integration Tests
  - Deployment of the monitoring grid in nuclear waste repositories
  - Demo preparation and final meeting preparation
  - Final demonstration and final workshop

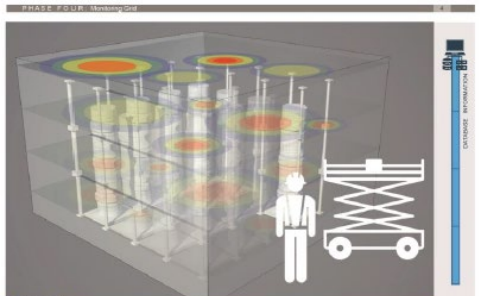
Gamma spectrometry station and hot spot characterization at ENEA - Casaccia

Active & passive neutron measurements at CEA DEN Cadarache TOTEM facility

DANAIDES cell

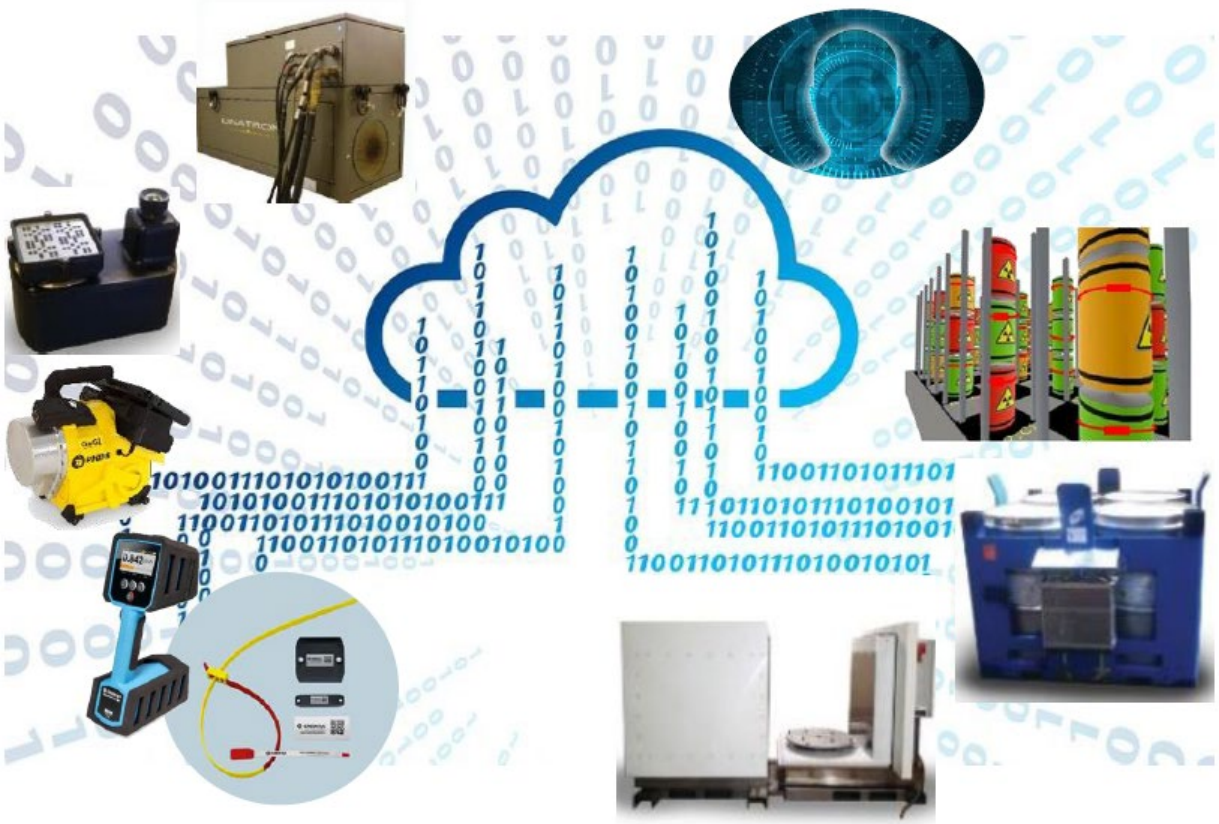
LINAC technologies at CEA LIST Saclay SAPHIR facility

Waste monitoring grid at ORANO TRIADE facility and La Hague reprocessing plant



Digital Waste Platform

- 7 main tasks:
  - Defining the data transfer protocols and the software structure
  - Integrating and securely transferring external inputs, analyzing and combining them
  - Associating a digital ID of the waste
  - Providing a unique digital traceability of the output of the waste
  - Controlling the localization of the drums during the full process
  - Controlling the monitoring grid and the status of all technologies
  - Test the full structure to guarantee the operationalities



The benefits

An expert system platform integrating hardware (HW) and software (SW) technologies to offer the opportunity to enhance the ALARA concept reducing the operational exposure.

The platform performs non-destructive analysis capable to define the characterization procedure for the waste package under investigation, determining the best measurement geometry and waste category, providing a complete integrated waste management solution and the full traceability of the waste:

- ***Flexibility***: it assures the complete characterization of many types of waste addressing geometry, package, volume/density with gamma/neutron passive and active measurement;
- ***Transportability***: different technologies embedded in ISO containers. This solution make the systems easily relocatable without moving waste. The containers will be designed to be connected in sequence to make a full characterization line of the nuclear waste;
- ***Digitization***: real time the digitization of the waste package under measurement with a direct real-time data storage on a customizable database and integration of all information from the producer to the data of the measurements just performed;
- ***Quantification***: final quantification of fissile, fertile mass and the content of the actinides to fully characterize the nuclear waste using an artificial intelligent SW solution that could support the "expert analysis";
- ***Traceability***: a database with a complete tracking of the waste movements using the RFID technology as well as the waste disposal monitoring technology for long term verification of the good status of the containment.

Future steps

The MICADO project goal is to provide a proof of concept system, based on stakeholders and end-users' requirements and necessities, for a complete NWP characterization

Within the 3 years project, the challenging is to demonstrate the feasibility and the characterization improvement provides by the established procedure and infrastructure

At the end MICADO would become a standard or a reference for an optimized characterization procedure helping to level out EU WP criteria, their treatment and management.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 847641.
This text reflects only the author's views and the Commission is not liable for any use that may be made of the information contained therein.

micado

Thanks for your attention

CAEN Tools for Discovery
cea
CTU Czech Technical University in Prague
ENEA
INFN
orano
sck cen
SOGIN
X-RAY IMAGING EUROPE

BACKUP SLIDES

The GANTT chart

MICADO	Year 1												Year 2												Year 3											
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36
WP1-Project management (CAEN)	MS 1		MS 2																																	
T1.1-Contractual mgt and financial admin. (CAEN)																																				
T1.2-Project management (CAEN)																																				
WP2-Conceptual design, specifications & CONOPS (Orano)						MS 3							MS 4																							
T2.1-Def. of technical specifications (Orano)																																				
T2.2-Def. of concepts of operations (CONOPS) (Orano)																																				
T2.3-Def. of virtual cases for assessing RCMS DigiWaste impact (Orano)																																				
T2.4-Procedure definition and conceptual design (Orano)																																				
WP3-Exploitation, dissemination and IP (CAEN)						MS 5																														
T3.1-Commercial exploitation (CAEN)																																				
T3.2-Dissemination (CAEN)																																				
T3.3-Mgt of IP and Data Mgt Plan (CEA-LIST)																																				
WP4-Gamma spectrometry tech.and hot spot characterization (CEA LIST)																										MS 6				MS 7						
T4.1-Performance upgrade of the Nanopix prototype (CTU)																																				
T4.2-Optimization of the Nanopix prototype (CAEN)																																				
T4.3-Upgrade of gamma spectroscopy technologies (CAEN)																																				
T4.4-Full lab. characteriz. & apps related to nuclear waste package monit. (CEA LIST)																																				
T4.5-Integration of gamma spectroscopy and hot spot technologies (CAEN)																																				
WP5-Active and passive neutron measurements (CEA DEN)																										MS 8				MS 9						
T5.1-Design of the modular neutron measurement system based on simul. (CEA DEN)																																				
T5.2-Realization of the neutron system (CAEN)																																				
T5.3-Commissioning and calibration (CEA DEN)																																				
WP6-LINAC based techniques (CEA LIST)																										MS 10				MS 11						
T6.1-Photofission simul. step for perf. evaluation on reference cases (CEA LIST)																																				
T6.2-Experim. step for optimizing photofission instrument. and assoc. algor. (CEA LIST)																																				
T6.3-Commissioning and validation in the SAPHIR facility (CEA)																																				
WP7-Waste Monitoring Grid (INFN)												MS 12						MS 13									MS 14									
T7.1-The addressable nuclear waste and config. of the network (INFN)																																				
T7.2-Optimization of the monitoring systems for gamma and neutron detection (CAEN)																																				
T7.3-Lab. characterisation of SciFi and SiLiF detectors (INFN)																																				
T7.4-Study of alternative solutions for long-term monitoring system (CTU)																																				
WP8-Combination of measurements and uncertainty assessment (SCK-CEN)												MS 15												MS 16						MS 17						
T8.1-Identify all sources of uncertainty (SCK-CEN)																																				
T8.2-Quantify all sources of uncertainty (SCK-CEN)																																				
T8.3-Development of the data analysis pipeline (SCK-CEN)																																				
WP9-Digital waste platform (CAEN)								MS 18				MS 19													MS 20					MS 21						
T9.1-Def. of the communication protocols and data format (CAEN)																																				
T9.2-Dataflow and software structure (CAEN)																																				
T9.3-Software dvpt and technologies integration (CAEN)																																				
T9.4-Data security assessment (CAEN)																																				
T9.5-Geolocalisation control (CEA LIST)																																				
T9.6-Status monitoring algorithm (CEA LIST)																																				
T9.7-Platform tests (CAEN)																																				
WP10-Final Demonstration (ENEA)																																		MS 22		MS 23
T10.1-RCMS DigiWaste integration tests (CAEN)																																				
T10.2-Demo preparation (ENEA)																																				
T10.3-Final demonstration (ENEA)																																				