



The Euratom project MICADO and its innovative characterization process of the Nuclear Waste Packages

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On behalf of the MICADO collaboration

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Measurement and Instrumentation for Cleaning And Decommissioning **O**perations CAEN cea Tools for Discovery ENE INFŃ orano sck cen SOGIN This project has received funding from the European Union's Horizon 2020 research and innovation SMEs. programme under grant agreement No 847641



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.

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The gap



 Missing of a comprehensive procedure able to address different type of Waste Packages (WP) providing a unique and digital information easily accessible within the Nuclear Waste characterization field



From IRSN RWM

- The Dismantling & Decommissioning (D&D) process of nuclear infrastructures increasingly demands methods for a full traceability of waste material to improve quality management and operational safety
- 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
- Missing of a harmonized definition of the waste categories and of the characterization procedures to be used

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The MICADO idea



Development of a Radiological Characterisation & Monitoring System (RCMS) DigiWaste Platform that could become a referenced standard, facilitating and harmonizing the methodology used for the in-field Waste Management and D&D operations

The RCMS DigiWaste Platform focuses on precise waste management, minimization procedures and a full digitalization process in order 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. Have a cost reduction in terms of number of operators needed, measurement time, better characterization results and be flexible with the possibility to use the same technologies in different locations
- 5. Reduce working time digitizing all the information available for the logistics and the Waste Package (WP) characterization process

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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 ...



- An automatize characterization step procedure to maximize the impact. It is based on a software process combining radiological 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



Investigation techniques

- Hot spot search and gamma spectroscopy & spectrometry techniques for the identification of the energy spectra and quantification of the gamma emitters (⁶⁰Co, ¹³⁷Cs...), detection of fissile materials (U, Pu), and define isotopic compositions and activities;
- Neutron active and passive measurements based on ³He 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;



Interim Storage of Radioactive Waste Packages

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1998

- 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.
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The technologies

- The gamma characterization station
 - Hot spot & spectroscopy characterization
 - Gamma spectrometry technique & Al
- **Passive and active neutron measurements**
- **Photofission Station**
- Waste Monitoring Grid
- **Uncertainty assessment**



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The gamma characterization station

Develop an integrated & automatic multi-technologies system for gamma characterization of the wastes

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The gamma characterization procedure



The Nanopix gamma camera performs:

- hot spot search of the WP in open geometry
- radionuclide identification of the detected sources

The RadHand performs:

- first spectroscopy radionuclide search in open geometry of the rotating WP in fixed configuration
- dose rate @contact

Characterization procedure defined for the NDA gamma characterization station. It foresees the integration of the measurements from the 3 devices.

The procedure is used to identify the spectrometric measurement(s) to be performed based on results from spectroscopic and dosimetry measurements.

The TSGS determines the WP gamma content and distributions withing the package with different measurement techniques:

- Emission and transmission measurements
- Tomography image reconstruction
- Angular and segmented gamma

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Passive and active neutron measurements micado

Development of a transportable detection system:

- Passive neutron counting is a nonintrusive characterisation method providing information on the quantity of actinides present in WP, especially Pu
- The neutron active measurement allows characterizing the fissile and fertile nuclei content of the WP



Expected neutron signal (c.s⁻¹.g⁻¹235U)

Design of MICADO passive and active neutron measurement system for radioactive waste drums Ducasse Ouentin - 23 June 2021

https://www.sciencedirect.com/science/article/pii/S016890022100382X













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Photofission station



- Active non-destructive technique based on photon-induced fission



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list

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- Simulation study using two Monte Carlo codes (MCNP6.2 & PHITS v.3.16) for the
 - Characterization and optimization of the photon beam delivered by a 7 or 9 MeV linac
 - Assessment of the performances of the photofission technique at 7 and 9 MeV
- Photofission measurements at 7 MeV linac: a new challenge
 - Energy threshold of the photofission reactions: 6 MeV for most actinides
 - Designing for the conceptual design of a mobile linac-based system



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- Conceptual design of shielding for the mobile system
- Experimental campaign aiming at evaluating performances of the photofission technique at 9 MeV on 220 liter-nuclear waste mock-up drums

https://www.sciencedirect.com/science/article/abs/pii/ S0168583X20304134



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Waste Monitoring Grid

- Low cost, compact and easily deployable detection systems for gamma and neutron detection
- Modular structure can be used for the radiological monitoring of the waste during storage or long-term disposal
- Long term monitoring of the radiological content and evaluation of possible incidents for the historical trend
- Gamma (SCIFI) & Neutron (SiLiF) detectors characterized in laboratory with AmBe source #08-16 The Gamma and Neutron Monitor Counters for the MICADO Project

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Paolo Finocchiaro – 23 June 2021





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Uncertainty assessment

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Uncertainty evaluation for all detection technique to verify the uncertainty reduction due to the combination of multiple measurements

- Identified, tracked and quantified all sources of uncertainty for all measurement techniques
- Monte Carlo error propagation used to evaluate the probability distributions for all relevant parameters
- Perform global sensitivity analysis allowing further optimization





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Digital waste platform

The software infrastructure of the RCMS DigiWaste Platform is under development to collect, elaborate and store data from all technologies described before

The RCMS software is:

- 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
- Allow the access to data based on permission





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Final demonstration



The full RCMS DigiWaste Platform will be tested to verify the feasibility and its performances:

- RCMS DigiWaste hardware integration tests
- RCMS DigiWaste software integration test
- Final demonstration and workshop to demonstrate the procedure feasibility

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- Gamma spectrometry station and hot spot characterization
- Passive neutron
 measurement system
- Waste monitoring grid

CEA DEN Cadarache TOTEM facility

• Active & passive neutron measurements



CEA LIST Saclay SAPHIR facility

• LINAC technologies





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The benefits



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The MICADO project goal is to provide a proof of concept system, the RCMS DigiWaste Platform based on stakeholders and end-users' requirements and necessities, for a complete NWP characterization. An expert system integrating hardware and software technologies to offer the opportunity to enhance the ALARA concept reducing the operational exposure.

- 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.



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Thanks for your attention

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