
Digital twins and Ontology for Robot Assisted Decommissioning Operations - DORADO

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Abstract

Nuclear Decommissioning Projects (NDPs) are increasing in the next decades, especially in Europe and the U.S.A., that have the oldest nuclear fleet (38.7 and 43.7 years on average, respectively, in 2025) [1]. As nuclear decommissioning activities are very challenging, the Euratom (European Atomic Energy Community) has been funding programmes for research projects in this area to strengthen European collaborations. Special emphasis is placed on the use of digital technologies and robotics to assist and optimize these tasks. The project PLEIADES (PLatform based on Emerging and Interoperable Applications for enhanced Decommissioning processES) [2], completed in 2023, provided a platform connecting different digital tools together to improve the efficiency of decommissioning activities. Following its success, the European Commission (EC) decided to fund DORADO (Digital twins and Ontology for Robot Assisted Decommissioning Operations) [3] in 2024. This project is being carried out by a consortium including 7 of the former PLEIADES participants among others and is continuing the work by extending the integrated technological tools, the ontology, and data transfer. DORADO aims to improve safety and efficiency in NDPs using AI (Artificial Intelligence), BIM (Building Information Modelling), robotics, voice recognition, and sensor data visualization. The following functionalities are being developed and integrated: sensor data mapping with temporal dimension; environment data comparison against BIM; point-cloud and 3D model change detection; dynamic modelling of digital twins for ALARA (As Low As Reasonably Achievable) dose estimation and planning; server-based integration with IFC (Industry Foundation Classes) file format and extended data queries; mission planning and robot route optimization; human-to-system smart voice assistant interface; and standardization using the common ontology.

Four real use cases are currently being used to demonstrate the platform, and the first 3D models have been reconstructed. Once completed, DORADO will be used for: cost estimation; on-site waste characterization and sampling; remote segregation and packaging planning; risk identification and knowledge management; robotics and remote handling systems; or surface and structure cleaning, among others.

KEYWORDS: Artificial intelligence (AI), building information modelling (BIM), decommissioning, digital twins, dismantling, nuclear, ontology, robotics, safety.

1. INTRODUCTION

Nuclear facilities reaching the end of their lifecycle face partial or total dismantling. Simultaneously, building materials and the energy to produce them become scarce resources. Nuclear Decommissioning Projects (NDPs) were not foreseen during the design, planning and construction of the current facilities. In addition to the challenges associated to any conventional demolition (safety, budgetary constraints, long-term frames, specific logistical requirements...), NDPs present additional challenges characteristic of the nuclear sector like handling of irradiated or contaminated materials, radiological inventory, specific regulations, involvement of further stakeholders, etc.

Building Information Modeling (BIM) is a methodology that has proven effective for buildings and infrastructure, particularly in new construction. It is also being implemented for decommissioning, though an up-to-date model is required. In the case of nuclear facilities built several decades ago, there is little or no digital information available. Consequently, data collection is necessary. This data collection – geometrical, radiological, etc – can be carried out directly by operators or by tele-operated robots. This is done particularly in more contaminated areas where the aim is to minimize worker exposure. Therefore, all the information collected through these various channels must be managed and consolidated into a single platform where all involved stakeholders have access to it.

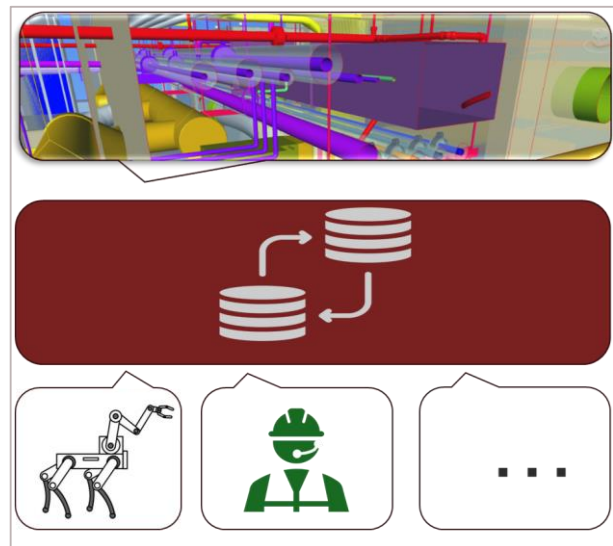


Figure 1. Data management in BIM [4]

2. DIGITAL TWINS AND ONTOLOGY FOR ROBOT ASSISTED DECOMMISSIONING OPERATIONS

Started in 2024 and funded by Euratom (HORIZON-EURATOM-2023-NRT-01, Grant agreement ID: 101165990) until 2027, the project DORADO (Digital twins and Ontology for Robot Assisted Decommissioning Operations), brings together 12 Partners from 8 European countries for 36 months. The Consortium aims to demonstrate the utilization of emerging digital technologies in decommissioning activities. Thus, the DORADO platform aims to incorporate essential compatibilities, like:

- Sensor data mapping with temporal dimension;
- Environment data comparison against BIM;
- Point-cloud and 3D model change detection;
- ALARA (As Low as Reasonably Achievable) dose estimation based on DT (Digital Twins);
- Server-based integration with IFC (Industry Foundation Classes) file format and extended data queries;
- Mission control, robot route optimization;
- Human-to-System smart voice assistant interface;
- Standardization using the common ontology.

The decommissioning core ontology, created in the previous EU-funded project PLEIADES (Platform based on Emerging and Interoperable Applications for enhanced Decommissioning processES), is the basis for the data structure development in DORADO, helping to find common definitions and wording.

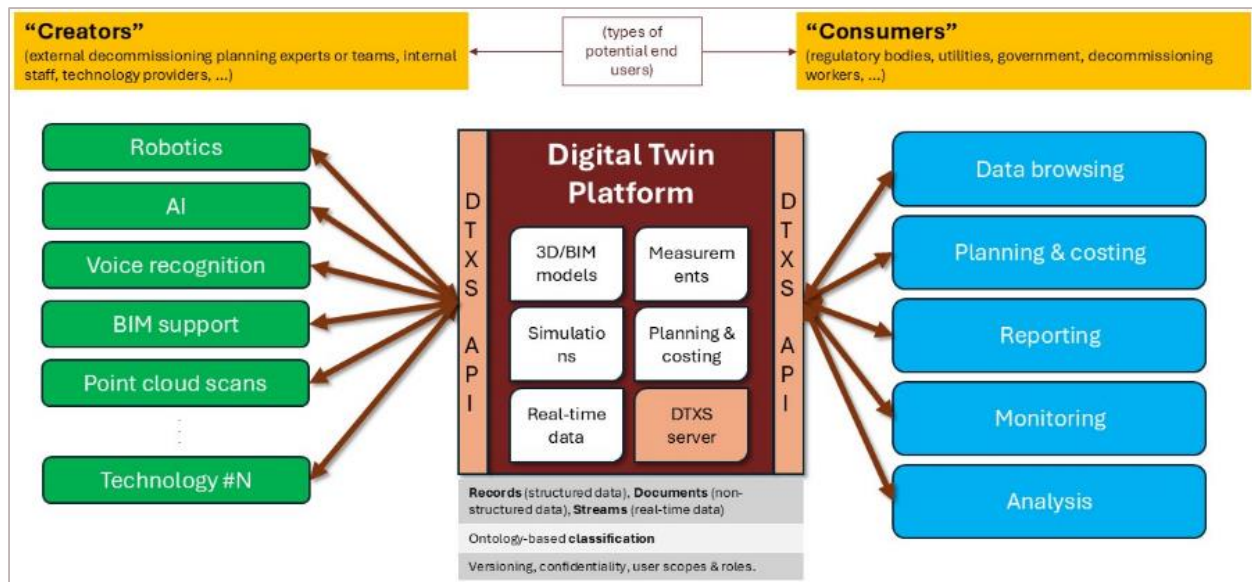
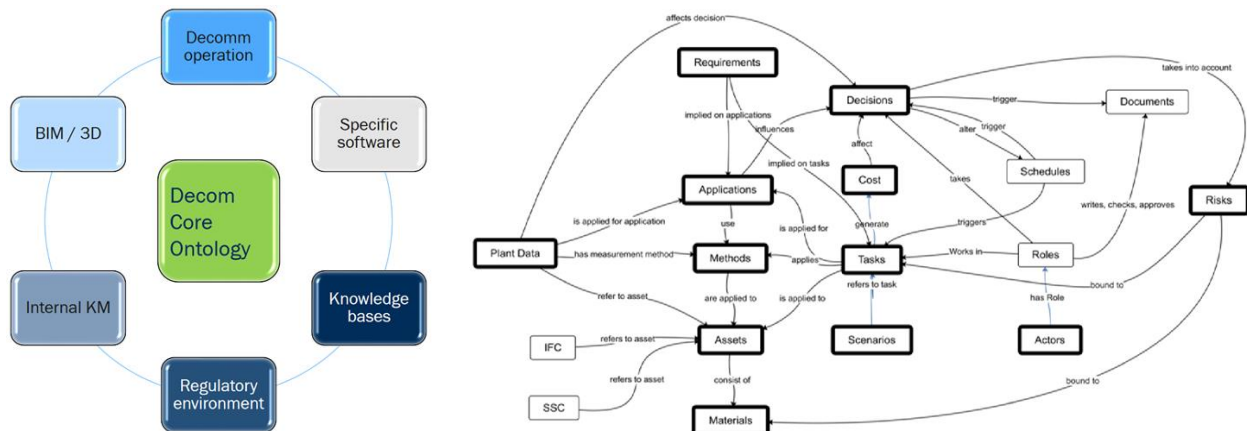


Figure 2. Illustration of the DORADO architecture [5]

2.1. Dedicated Decommissioning Ontology

The information collected in a NDP has different origin as is stored in different formats – point clouds, historical photogrammetry, dose rate survey, inventory data, etc. As each software has its own implicit ontology – history, terms and concepts – direct interfaces are difficult to generate and maintain. Therefore, a common understanding is necessary between data scientists and subject matter experts. DORADO is extending the core ontology from PLEIADES, introducing new classes and relations for robotics, sensor data, and mission planning. The ontology is being expressed in different language formats: OWL (Ontology Web Language), RDF (Resource Description Framework), SKOS (Simple Knowledge Organization System) ...

As indicated, the development approach is to reuse what is available, established and suitable, and not “reinvent the wheel”. The consortium is developing an ontology which is compatible with the IAEA (International Atomic Energy Agency) IDN (International Decommissioning Network) Wiki (<https://nucleus.iaea.org/sites/connect/IDNpublic/Pages/IDN-Wiki-Introduction.aspx>), the NEA (Nuclear Energy Agency), and the JRC (Joint Research Centre) ontology research. The alignment is being verified through term mapping, review by subject matter experts, and validation workshops, among other methods.



Figures 3- 4. Overview of the decommissioning core ontology [6] [7]

3. DEMONSTRATIONS ON REAL USE CASES

After having defined the user needs and the conceptual design of the platform (Work Package 2), as well as having implemented the system and the modules (Work Package 3) in the first half of the project, the Work Package 4 (WP4) aims to demonstrate the implementation of DORADO in real use cases. For that, the consortium is using data coming from real facilities. Some of this data was made available by some of the project partners, and some data was provided by facility owners, allowing the consortium to carry out data collection campaigns in their facilities – together with the team of the EU-project XS-Ability (Accessing hard-to-reach areas with Advanced and Breakthrough Innovation for reLIable In-situ characterization of a faciLiTY). These real facilities are:

- The Halden Research Reactor (HRR) in Norway, provided by IFE (Institute for Energy Technology);
- The Finnish Research Reactor 1 (FIR1) in Finland, provided by VTT (Research Centre of Finland);
- The Belgian Reactor 3 (BR3) in Belgium, provided by SCK-CEN (Belgian Nuclear Research Centre);
- The Ignalina Nuclear Power Plant (INPP), provided by Altra (<https://altra.lt/en/>)

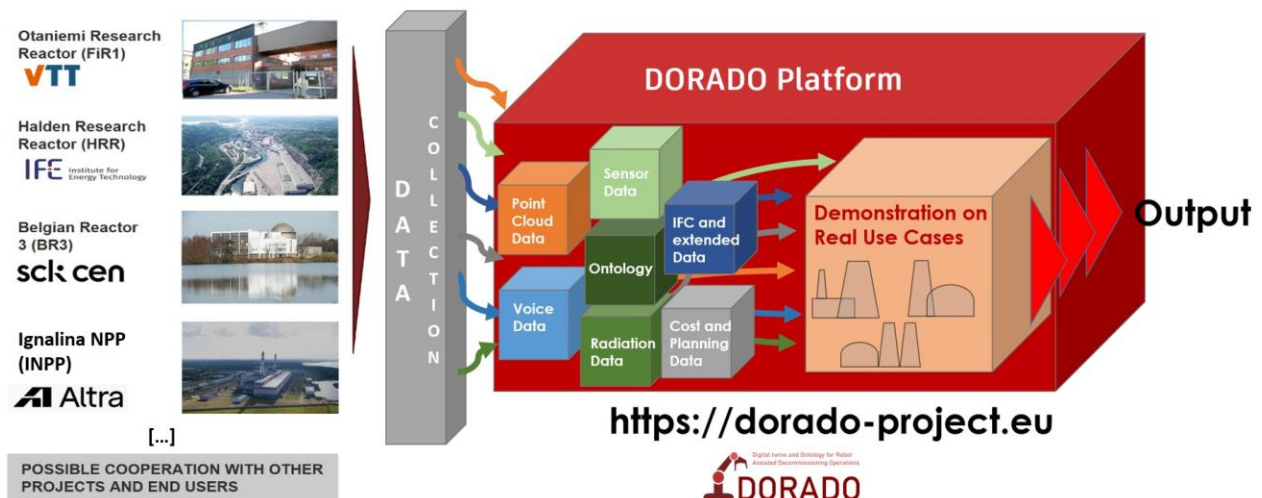


Figure 5. Demonstrations on four real use cases: FIR1, HRR, BR3, and INPP [8]

3.1. From Point Cloud to 3D Model

In the Task 4.1 – creation of a parametric 3D model – point cloud data is subsequently converted into parametric 3D models using semi-automated reconstruction workflow (3DScanPF, KIT). By creating geometries using accurate primitives, simple base models are generated that can be further enriched with additional data. The level of detail can be further increased – depending on the requirements and the simulations to be performed – through an iterative process.

The Scan-to-BIM process comprises the following main stages:

- Segmentation and extraction of various elements with easily identifiable shapes like walls, columns, beams, pipes, etc.;
- Semi-automatic reconstruction of the basic geometries, looking for primitives – like planes, cylinders, cones, spheres – that form these elements;
- Review – and completion, if needed – of the geometries;
- Exporting geometries as models suitable for use in the BIM methodology; this means they must contain minimum attributes such as dimensions, volume, material, cost, density...

Next figure gives an overview of the process with a model of the Finnish Research Reactor 1 (FIR1). Thus, a point cloud is used to create the 3D model. As agreed in the previous Work Packages, priority is given to

the E57 extension for point cloud data, and the IFC (Industry Foundation Classes) extension for the output. OBJ (Object) files are also created during the process, as they are more easily compatible with robotic platforms. The generated models can also be compared with historical datasets to identify spatial or structural changes.

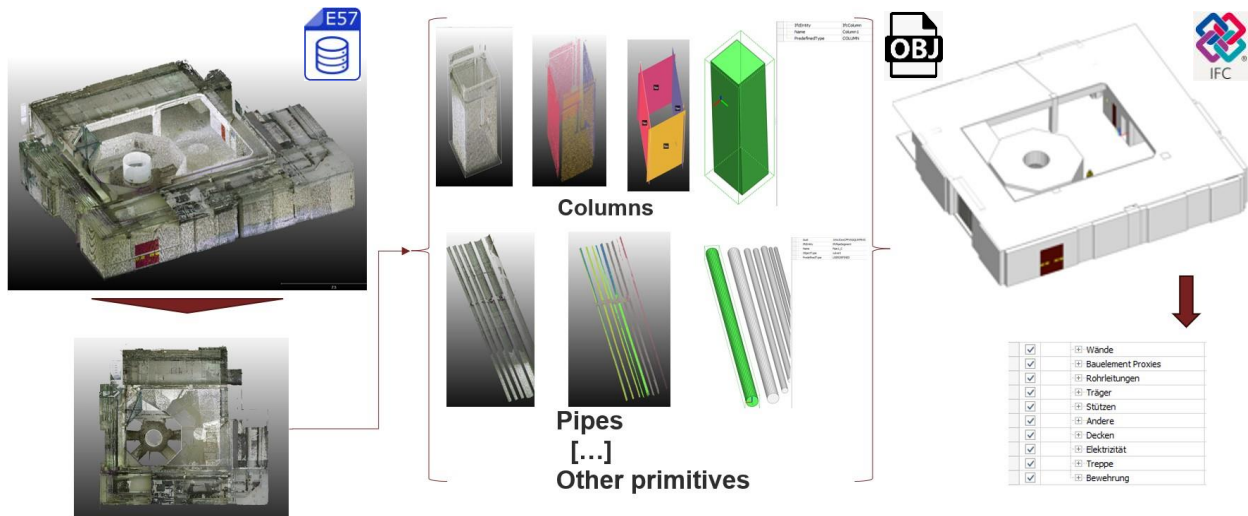


Figure 6. Scan-to-BIM process performed from an existing point cloud of the FiR1 (3DScanPF, KIT) [9]

3.2. Scan campaigns in Belgium and Lithuania

In 2026, the DORADO consortium has organized – together with the consortium of the project XS-Ability – two scan campaigns:

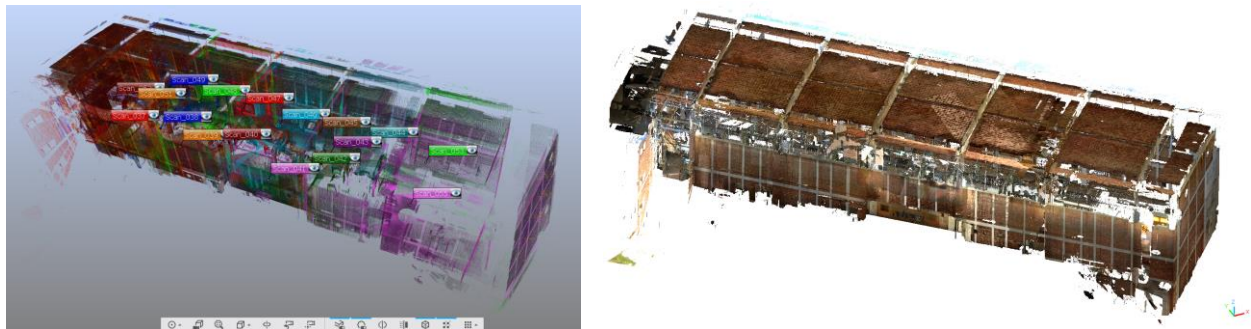


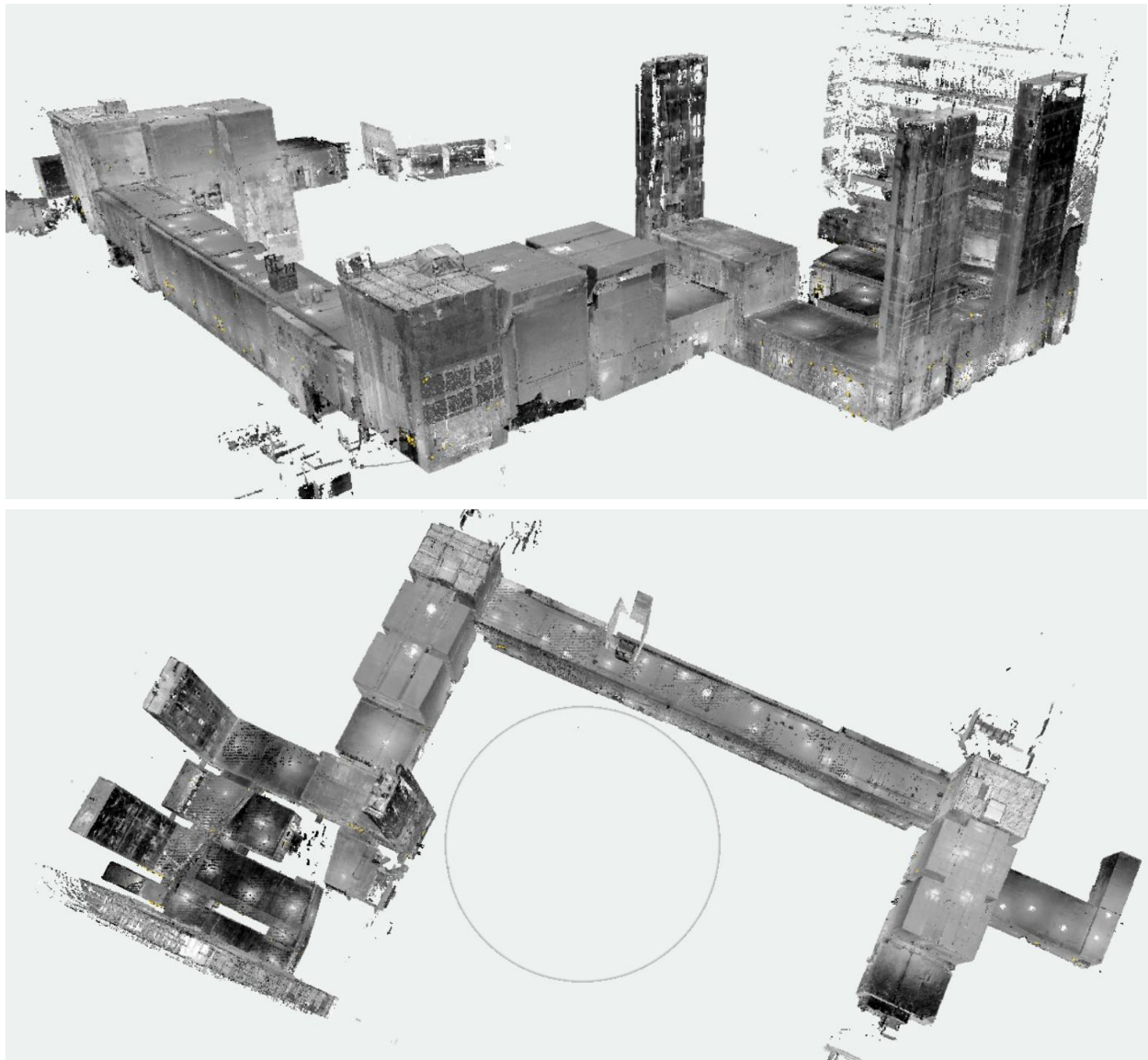
Figure 7. Point cloud of a part of the Belgian Reactor 1 (BR1) [10]



Figure 8. Point cloud of a part of the Belgian Reactor 3 (BR3), showing the different levels (BR3) [11]

In April 2026, the team visited the Belgian Reactor (BR1 and BR3) in Mol, in order to perform a geometrical and radiological data acquisition of some areas. Some results were presented on June 25th in the online webinar “Robots and Drones in Nuclear Decommissioning” (<https://dorado-project.eu/events/webinar-robots-and-drones-in-decommissioning-jul-2026>).

In September 2026, after Altra showed interest in the DORADO project, the consortium was allowed to visit the Ignalina Power Plant (INPP). Some lessons learned from the previous campaign in Belgium were applied. Although the team had to manage an environment that differed to the previous campaign in Belgium, the visit was a success – thanks to the excellent INPP team present at the facility – and a vast amount of data was collected. This data is currently being validated and analysed to determine how it can be utilized in the project, and how the facility owner can benefit from it.



Figures 9- 10. Overview of the point cloud containing the geometric information of a part of the INPP (KIT) [12]

As the WP4 of the DORADO project is being carried out until 2027, the basic 3D models of the FiR1 and the BR3 – reconstructed from point clouds – will be ready before the end of 2026 for running the various simulations performed within the platform.

3.3. The Use of Digital Models for Simulations

The Digital Models in the different formats exchanged in the DORADO platform are being used by the consortium members to perform different simulations. Some of these simulations are:

- Robot mission control and route optimization;
- ALARA dose estimation;
- Voice assistant interfaces;
- Sensor data fusion with visual location.

4. END-USERS GROUP INTERACTION

An End-Users group has been created. This group is made up of different stakeholders, mainly from the nuclear sector like regulators, Technical/Scientific Support Organizations (TSOs), Small or Medium Enterprises (SMEs). The value the end-user derives from following the project lies in the opportunity to gain deeper insight into each technology, reinforce their understanding of its advantages, and – consequently – better grasp how it can be applied to their own business. The end-users are committed to the changes and mutations in companies brought about by the industry 4.0, and aim to focus on following questions:

- What is the technology and how it is used?
- What are the benefits of using the technology? Examples presented.
- How can the technology be applied? Examples presented.
- How does the technology support nuclear decommissioning and dismantling projects?



Figure 10. Join the End-Users' Group [13]

5. CONCLUSIONS AND FUTURE WORK

DORADO continues the work started in PLEIADES by integrating more technologies to the server and extending the ontology for new applications. A holistic approach for data compatibility is the key; the aim is not to “reinvent the wheel” and leave room for future applications, so that the development work can benefit from experiences in other fields (and vice-versa).

After the project DORADO is implemented, the consortium aims for commercial cooperation in a very flexible way to tailor the applied methods according to the needs of the market. This will be carried out in several sequential phases: cross-functional team, infrastructure assessment, pilot projects with performance metrics, scale successful technologies, continuous monitoring for adaptation, and management support, which will be critical for success and adoption.

6. ACKNOWLEDGEMENTS

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