Digital twins and Ontology for Robot Assisted Decommissioning Operations

DORADO

Ontology-based BIM data exchange for decommissioning in the DORADO project

Technical Meeting on Innovations in Data Analysis and Retrieval for Nuclear Decommissioning of the IAEA (EVT2404267)

Joseph Ridao, Antti Räty, Dusan Daniska, Franz Borrmann, Omar Zahra, Petri Honkamaa – on behalf of the DORADO consortium

August 20th, 2025

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Digital twins and Ontology for Robot Assisted Decommissioning Operations

DORADO Partners

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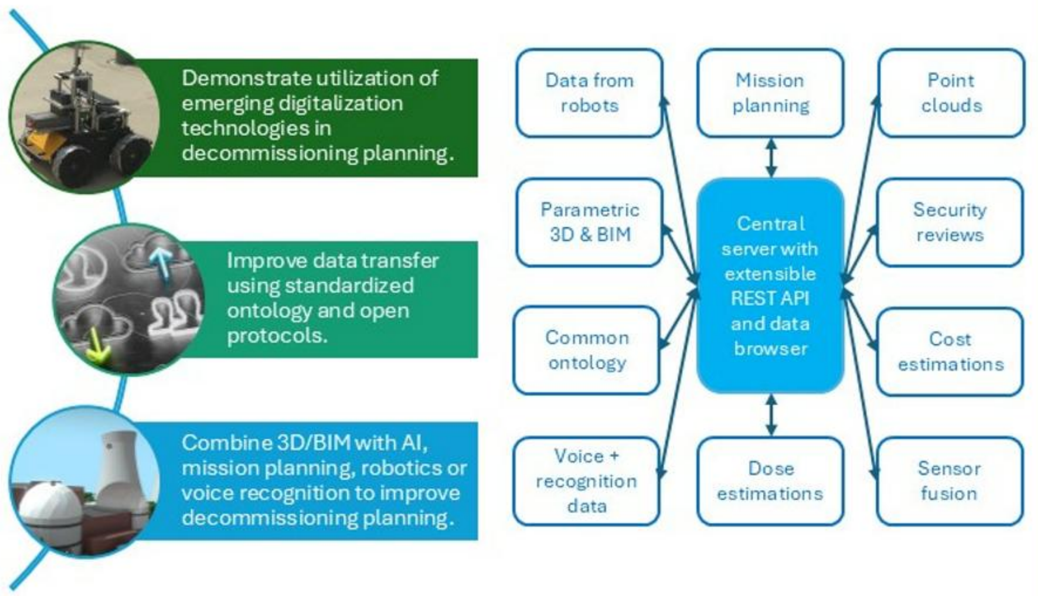
Key facts

36 months
12 partners
8 countries
5 work packages

Technologies

Robotics
Sensor fusion
Data management
Voice recognition
Ontology
BIM / 3D
Artificial intelligence
Dose estimation
Mission planning

Research goals



Work packages in brief

WP1
Prepare and manage project

WP2
Finetune research goals

WP3
Implement technologies

WP4
Demonstrate on real use cases

WP5
Train, exploit & standardize

Final expectations

1) Integrate emerging digital technologies into one coherent platform to support decommissioning planning.
2) Extend decommissioning ontology and data transfer protocols to cover new use cases.
3) Describe extensible API to provide standardized data exchange between tools used in decommissioning planning.

[1] www.dorado-project.eu

[2] Antti Räty & DORADO consortium. Euratom project DORADO. Digidecom2024 conference, November 2024. Halden, Norway

The objective of DORADO

The problem to solve

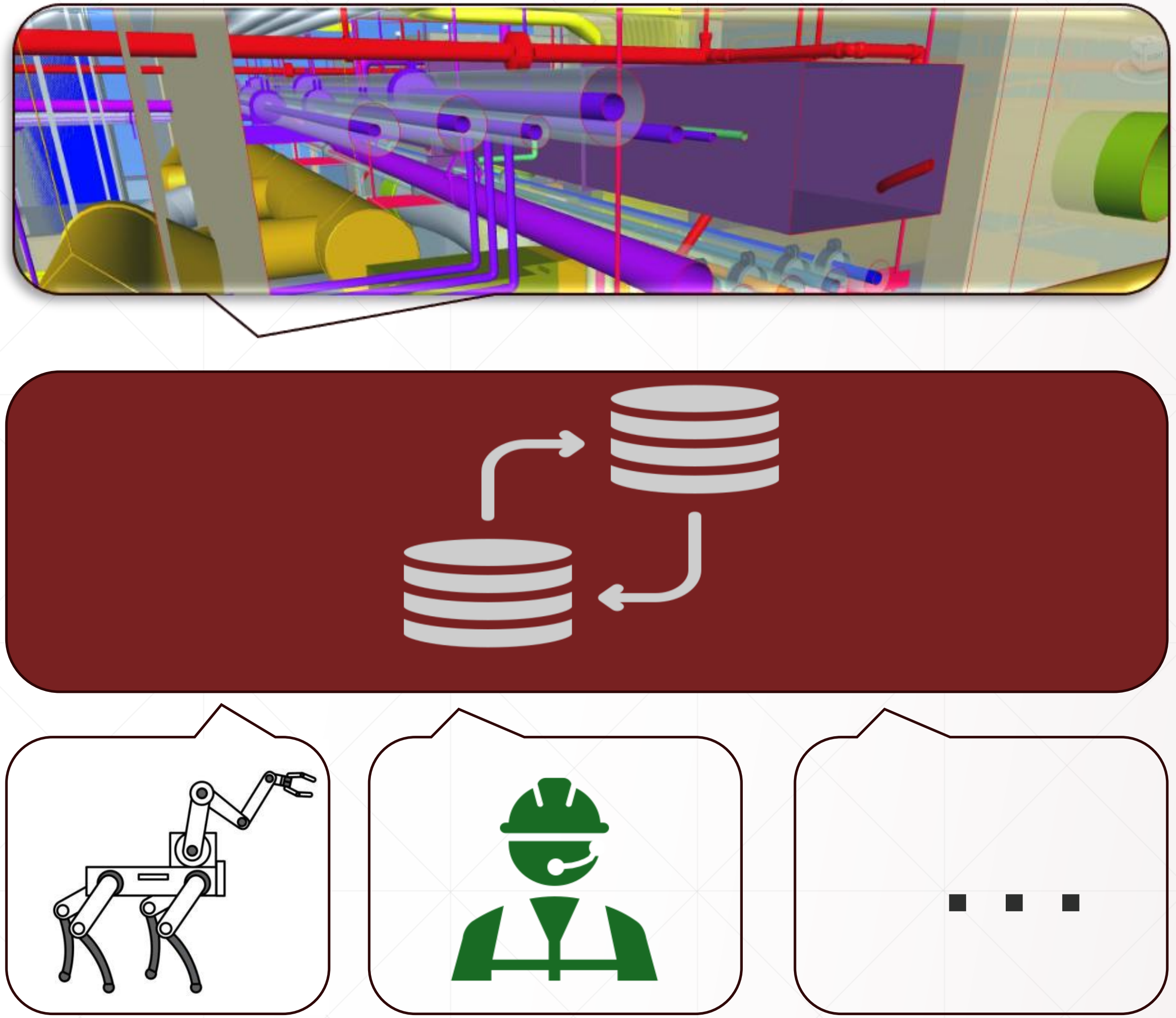
- BIM and Digital Twins are used at all steps of large projects;
- Such data needs to be up-to-date and accessible by many actors;
- Common language and protocols are needed to insure the coherence of the data.

Sample technologies / situations

- Data for *robot planning;*
- *Field operators*' data generation.

The proposal from DORADO

- A platform to share/consume data across a wide variety of actors.



[3] A. Räty, M. Becker, F. Borrmann, J. Ridao & DORADO consortium. Digital technologies in DORADO project. 3rd webinar, April 8, 2025

Previous steps in PLEIADES

PLatform based on Emerging and Interoperable Applications for enhanced Decommissioning processES

[4] PLEIADES partners

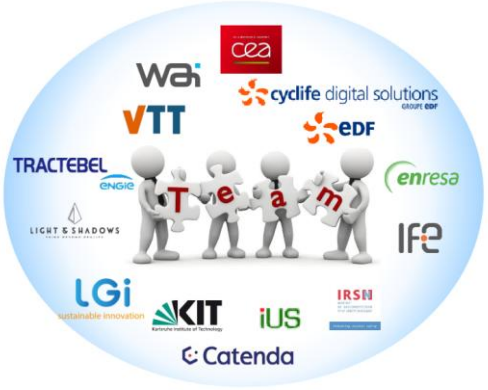
[5]

[6] Implementation of PLEIADES on real use cases (Fig. 2)

- **Call**: H2020 NFRP-2019-09 "Fostering innovation in decommissioning of nuclear facilities"
- **Duration:** 3 years (1/10/2020 - 30/09/2023)
- **Consortium:** 14 partners
  - Countries: FR (6), DE (2), NO (2), ES (1), FI(1), BE (1), SK (1)
  - 4 academic/research organisations, 1 TSO, 4 industrial companies, 5 SMEs
- **Objectives:**
  - Demonstrate a modular software ecosystem based on interconnection of front-line support tools through a decommissioning specific ontology building upon open BIM (Building Information Modeling);
  - Propose an ontology for an international standard of decommissioning with specific terminology/ vocabulary definition for a common understanding and common knowledge modeling;
  - Validation of the platform in the 6 user stories from 3 case studies in different European countries

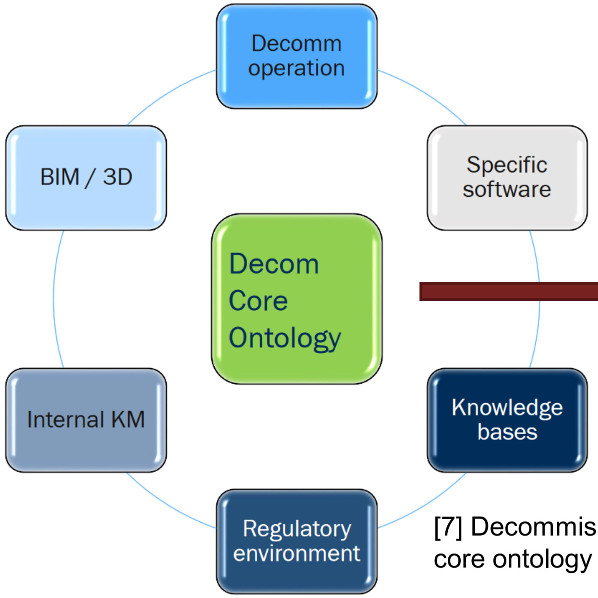
Previous steps in PLEIADES

Achievements in PLEIADES

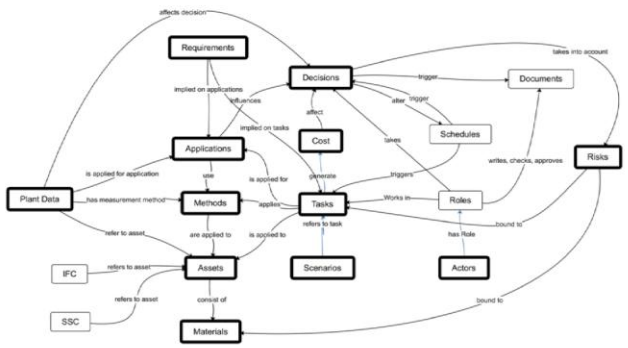


[4] PLEIADES partners

[5]

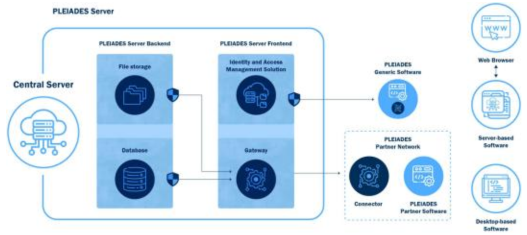


[7] Decommissioning core ontology

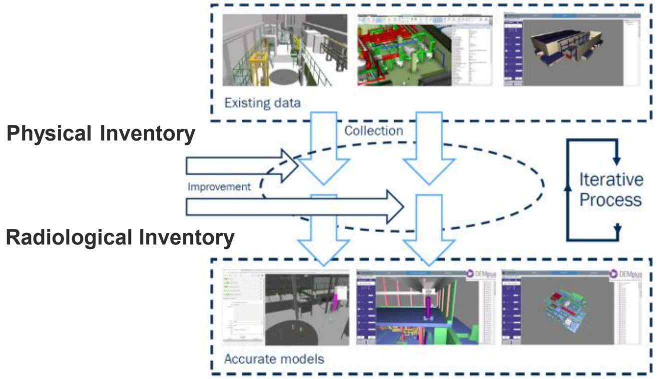


[8] Decommissioning core ontology

[6] Implementation of PLEIADES on real use cases (Fig. 2)



[6] Server architecture in PLEIADES (Fig. 4)



[6] Use cases 3D models and data in PLEIADES (Fig. 3)

Further development in DORADO

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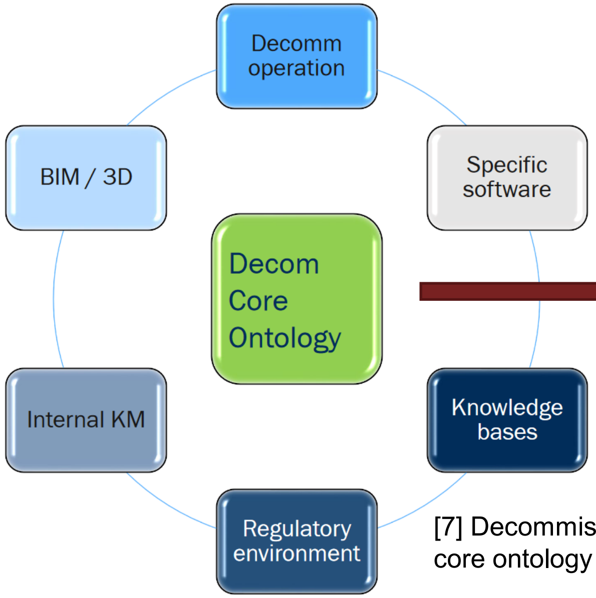
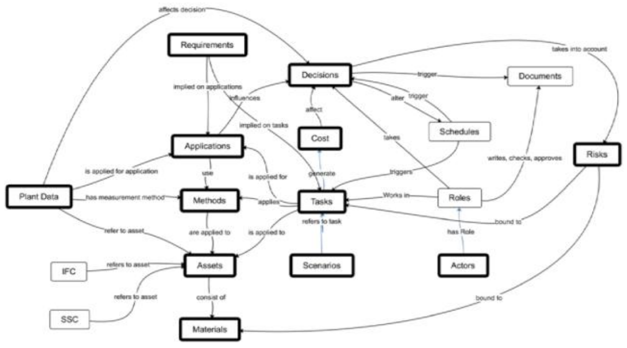
PLEIADES
Smarter Plant Decommissioning

Continuation in DORADO

- In PLEIADES, a platform was developed, but software integration just started. Recommended next steps:
  - Extension of the coverage of the supported ontology and supported decommissioning planning activities;
  - Continuation in the development of the ontology and the API (Application Programming Interface)
  - Integration of further technologies such Artificial Intelligence (AI), Robotics and sensor networks;
  - Promotion of the concept for wider use.



[7] Decommissioning core ontology



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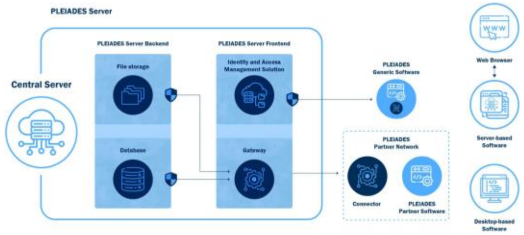

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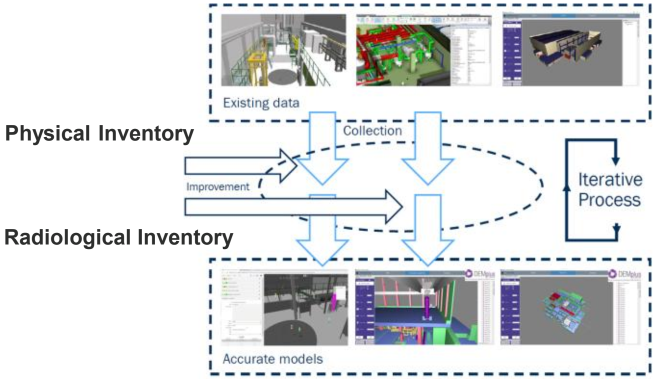
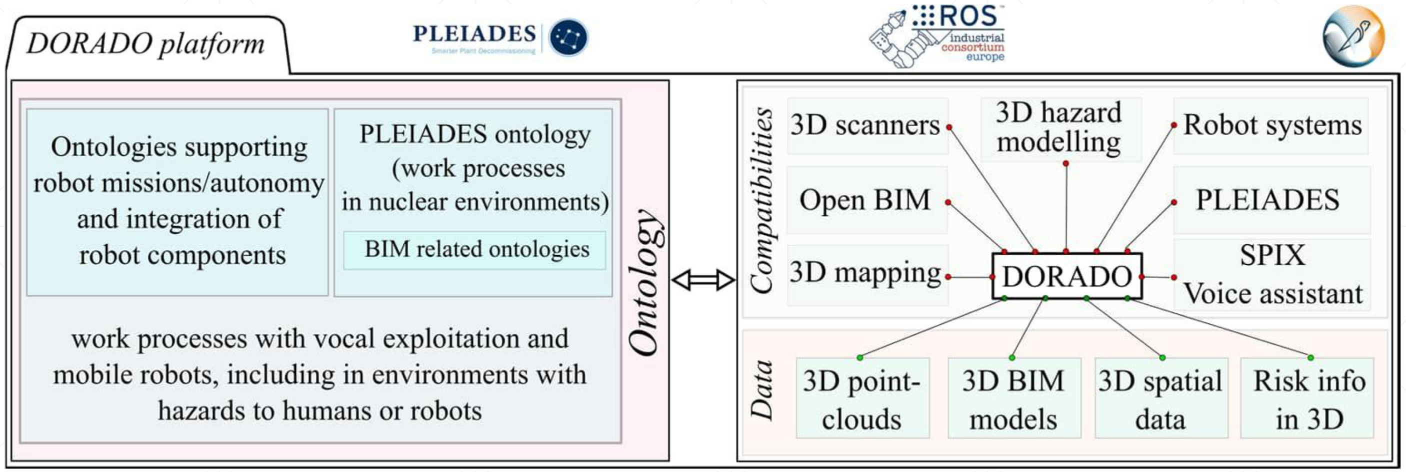


[6] Use cases 3D models and data in PLEIADES (Fig. 3)

Implementation in DORADO

Data compatibility and ontology



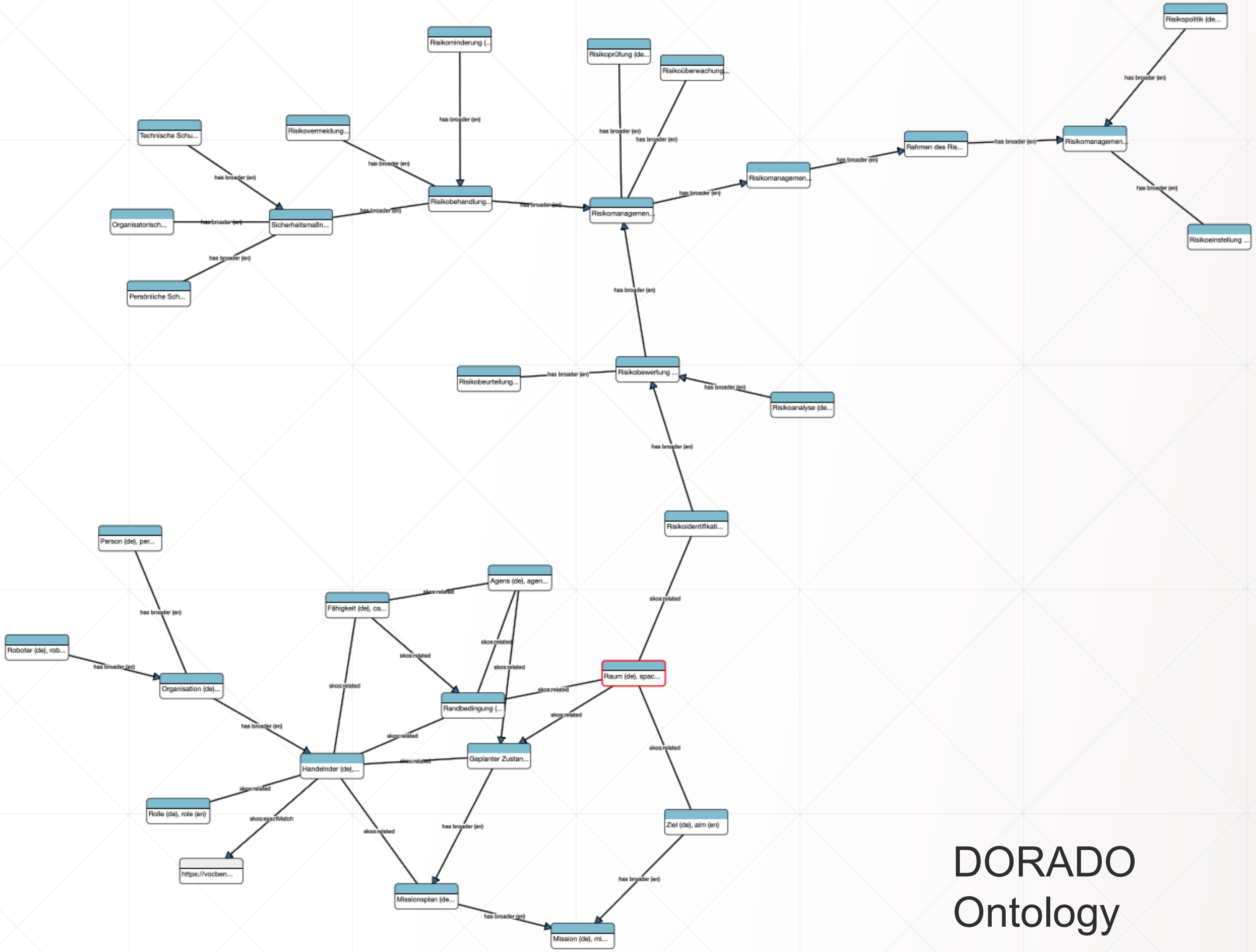
[9] Existing taxonomies and ontologies related to the project

- In a NDP, the interconnected and overlapping roles of active agents (workers, software entities, robots, etc.) are crucial for safety and productivity;
- Necessity to maintain a common knowledge representation and standardised data storage and exchange among agents;

- DORADO aims to incorporate essential compatibilities, like:
  - Sensor data mapping with temporal dimension;
  - Environment data comparison against BIM;
  - Point-cloud and 3D model change detection;
  - Digital twins based ALARA dose estimation;
  - Server-based integration with IFC file format and extended data queries;
  - Mission control, robot route optimization;
  - Human to System smart voice assistant interface;
  - Standardization using the common ontology;

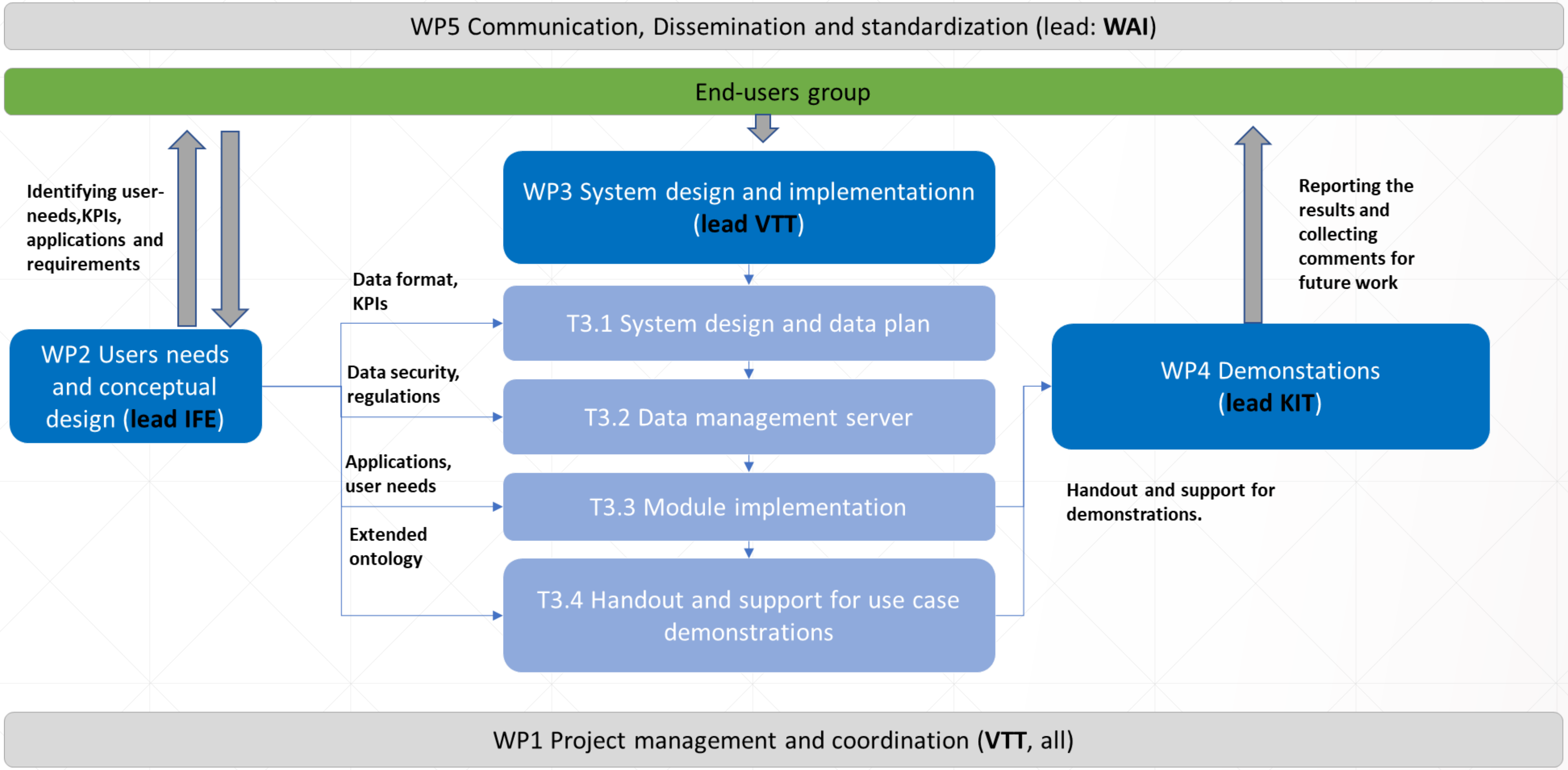
Ontology based approach

- Ontology helps to find common definitions and wording
- Ontology defines basis for data structure development
- Shown DORADO ontology has common members with the DECOM CORE ontology from the PLEIADES project
    - Actor
    - Room (as part of IFC)
    - Risk
- While the DECOM CORE ontology is focusing on the project, DORADO is adding the mission planing and feedback part



DORADO Ontology

DORADO project organization



[10] DORADO project flow

Implementation in DORADO

Linking technologies to demonstrations

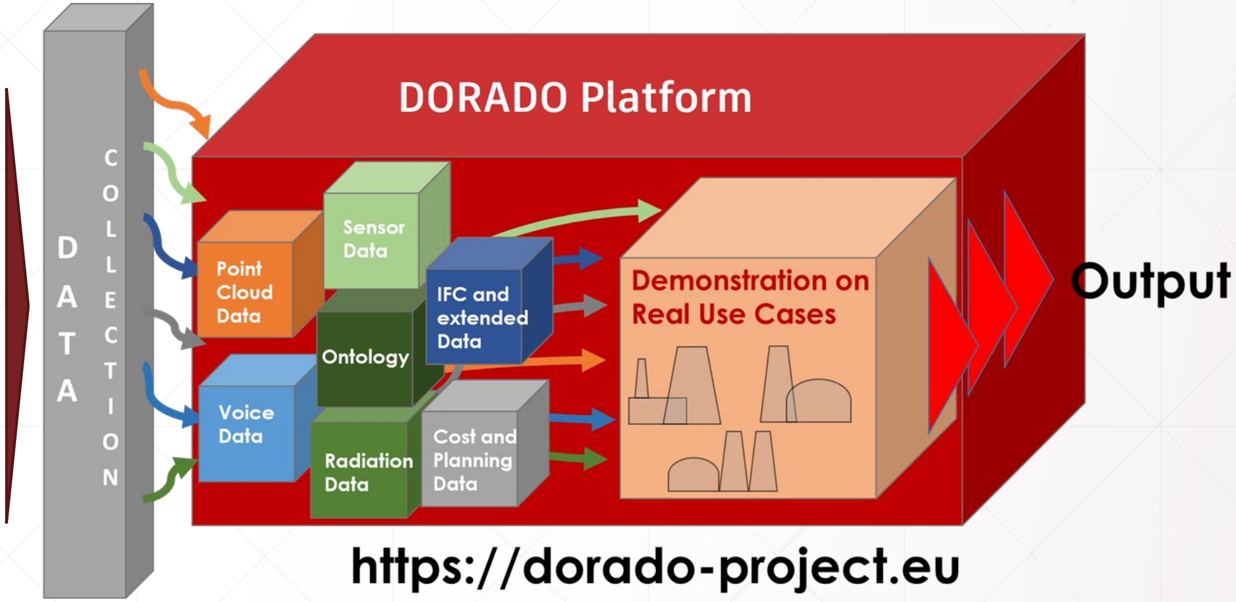
- DORADO will use data based on information from real facilities, like:
  - Point clouds;
  - Historical photogrammetry;
  - Dose rate survey;
  - 3D models;
  - Robot data (LiDAR and RGBD);
  - LiDAR SLAM and Visual SLAM;
  - Inventory data;
  - Etc.

Otaniemi Research Reactor (FiR1)

Halden Research Reactor (HRR)

Belgian Reactor 3 (BR3)

POSSIBLE COOPERATION WITH OTHER PROJECTS AND END USERS

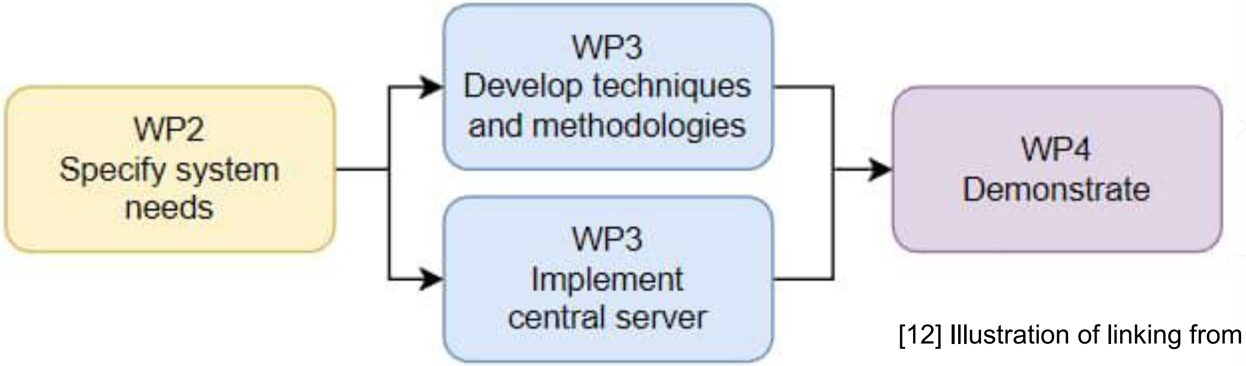


[11] Demonstrations on real use cases

- Further data is being collected or completed, like:
  - Dose rate mapping and spectrometry, in particular from the **XS-Ability project** [24], aiming at extending robotics and radiological sensors integration;
  - Etc.

WP4: Demonstration on real use cases

- **Main objective**: to demonstrate that the implementation of DORADO is possible in real use cases:



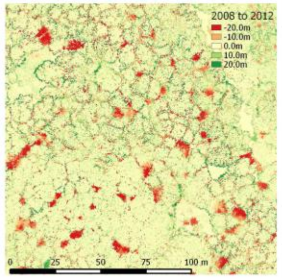
[12] Illustration of linking from techniques to demonstrations

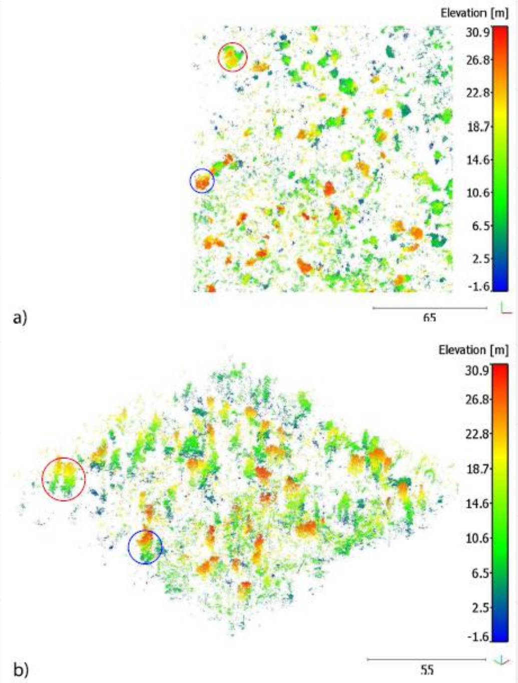
  - Data from different facilities will be used;
  - The different demonstrations are defined separately and independently;
  - However, they can partially benefit from the data from other demonstration cases.

1) Creation of a parametric 3D model;
2) Detecting the changes in the 3D models over time;
3) Comparison of plans vs. reality;
4) Decommissioning safety and risk/hazards assessment.

Change Detection: State-of-the-Art (I)

- Used in a variety of areas:
  - Traffic monitoring;
  - Documentation of urban development;
  - Damage assessment (e.g. following natural disasters);
  - Etc.
- Change detection depend on spatial dimension [13]
  - Vertical changes
    - Referred to as a one-dimensional (1D) method
  - Changes in all possible directions
    - Referred to as a three-dimensional (3D) method





[13] Lindenbergh, R., & Pietrzyk, P. (2015)

Change Detection: State-of-the-Art (II)

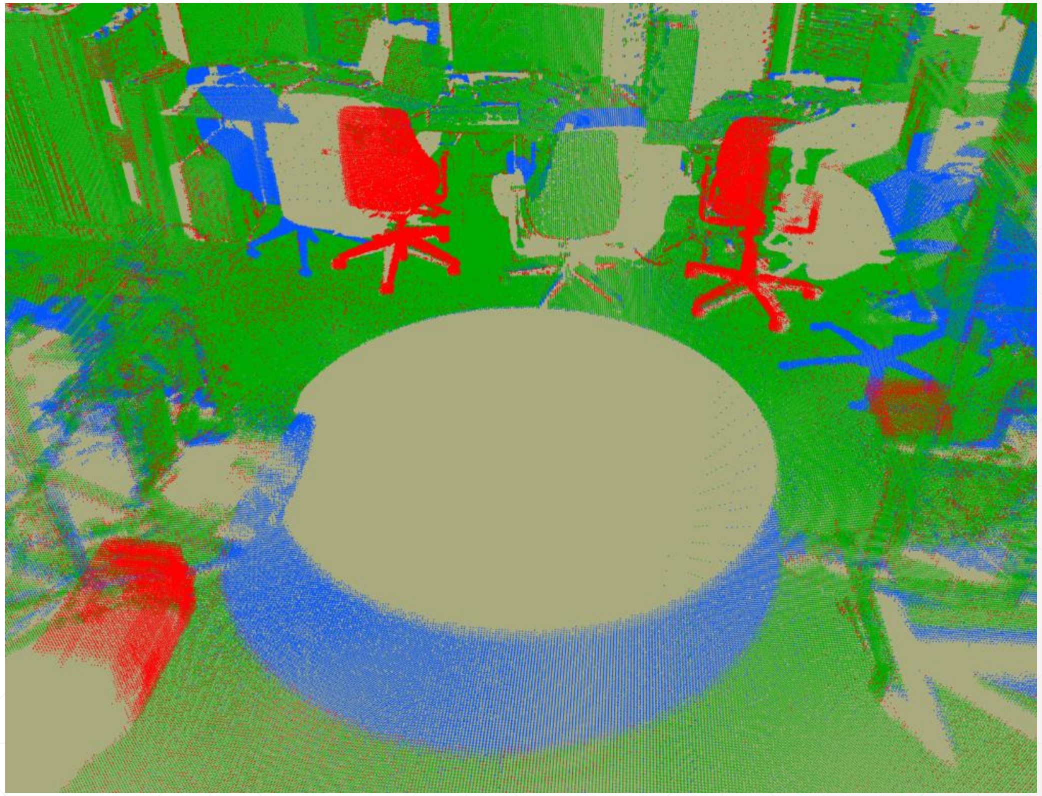
- In the AEC (Architecture, Engineering and Construction) field:
  - Significant role in documenting construction progress
    - Not used as much in demolition and dismantling tasks
  - Traditionally performed manually (visual inspections and measurements)
    - Improvement of measuring devices and creation of digital information
    - Development of robotics for better and automated data collection
- Checking the geometry with the help of point cloud data
  - Generation of point cloud data using scanners
    - Laser scanners (e.g. Terrestrial Laser Scanner, TLS)
  - Generation of point cloud data using photogrammetry
    - Reconstruction (e.g. Structure from Motion, SfM)

The process is becoming increasingly automated

[14] KIT-TMB-RKKB

Point Clouds Generation and Processing: State-of-the-Art

- Use of two or more point clouds from a same environment in two different periods of time
- Aspects to be taken into account [16]
  - Geometry and surface properties
    - Dimensions
    - Position in global coordinate system
  - Point Cloud Generation
    - Noise behavior
    - Point cloud density
    - Shadow effects
- Processing of the Information
  - Data Cleaning
  - Efficient handling and presentation of Data
  - Segmentation of Point Clouds



[15] A. Räty & DORADO consortium (2024)

Point Clouds Segmentation: State-of-the-Art

- Different methods for the segmentation of point clouds [17]

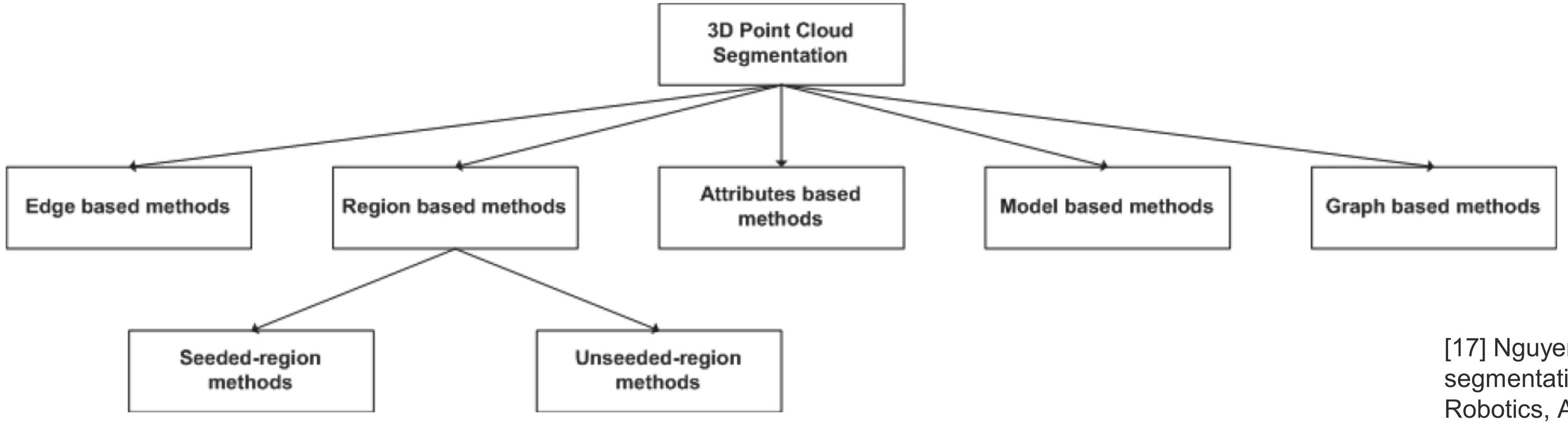


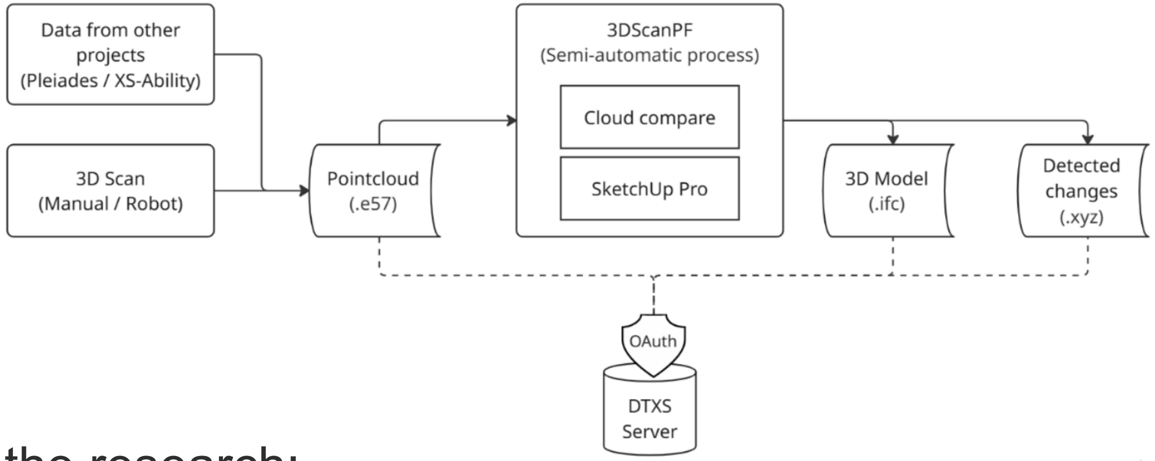
Fig. 2. Taxonomy of 3D point cloud segmentation methods.

[17] Nguyen, A., & Le, B. (2013). 3D point cloud segmentation: A survey. 2013 6th IEEE Conference on Robotics, Automation and Mechatronics (RAM), 225–230. https://doi.org/10.1109/RAM.2013.6758588

- Different methods for the automation of change detection with point clouds
  - Voxel-based analysis [16] [18]
  - Point-based approach [19]
  - Change detection using Machine Learning (ML) [20]

Implementation in DORADO

- A workflow has been defined in the WP3 – System design and implementation



[21] 3D scans can be transferred with a well-defined semi-automatic process into IFC models. Here we can also detect changes compared to previous LiDAR scans.

- Next steps in the research:
  - Automated segmentation of complex objects / geometries in a Point Cloud
  - Automated modelling of complex objects from (segmented) Point Clouds
  - Detection of materials in point clouds
  - Dealing with gaps / holes / hidden areas in a Point Cloud
  - Dealing with loss of accuracy due to voxel information

End-users group interaction

End-users are invited to follow our project via webinars, newsletters and other publications.

- Technological experts and DORADO tools users
- Business management (how tools connect to business value chain and enable new services)

What will be the value for end-users to participate?

The end-user's value in following the project is built on the opportunity to increase their understanding of each technology, strengthen their own understanding of the benefits of using each technology and hence, gain a better understanding of how the technologies can be utilized in their own business. We aim to focus on following questions:

- **What is the technology and how is it 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?**

https://www.dorado-project.eu/join-us

Summary

- DORADO continues the previous PLEAIDES project by integrating more technologies to the server and extending the ontology for new applications.
- Eight new technologies are handled. Emphasis on utilizing BIM and AI.
- Holistic approach and data compatibility is the key!
- Developed technologies will be demonstarted with data from real environments
- The development work can benefit from experiences in other fields of industry (and vice versa)
- We welcome new members to the end users group!

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Sources

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[14] KIT-TMB-RKKB. https://www.tmb.kit.edu/RKKB.php

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Thank you for your attention!

Any questions?

This project has received funding from the Nuclear Research and Training (HORIZON-EURATOM-2023-NRT-01), project #101165990.

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