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Digital twins and Ontology for Robot Assisted Decommissioning Operations – DORADO

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**The Research
Council of Norway**

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2. The European Project DORADO
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1. Introduction

- In 2025, only 23 of 218 closed power reactors in the World have been fully decommissioned;
 - In the European Union (EU27), only Germany and Spain have carried out complete dismantling of Nuclear Reactors;
- By 2040, the number of Nuclear Decommissioning Projects (NDPs) in the World will increase from 50 today to over 400 [26];
 - The average closure age of Nuclear Reactors between 2019 and 2025 was 43.2 years;
 - Considering the mean age of the European fleet, 38.7 years, decommissioning is a growing market in the EU;
 - Collaborations between European countries is necessary.

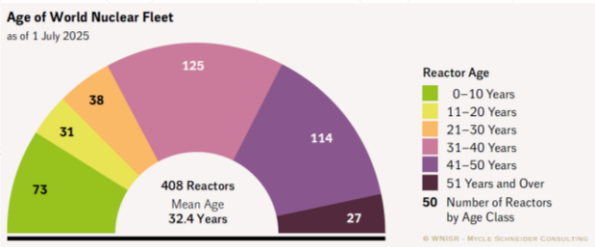


Figure 1. Age of Closed Nuclear Reactors in the World [23]

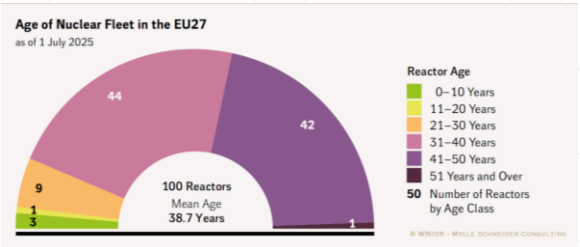


Figure 2. Age of Closed Nuclear Reactors in the EU27 [23]

Progress and Status of Reactor Decommissioning in Selected Countries

in Units, June 2018 – June 2024

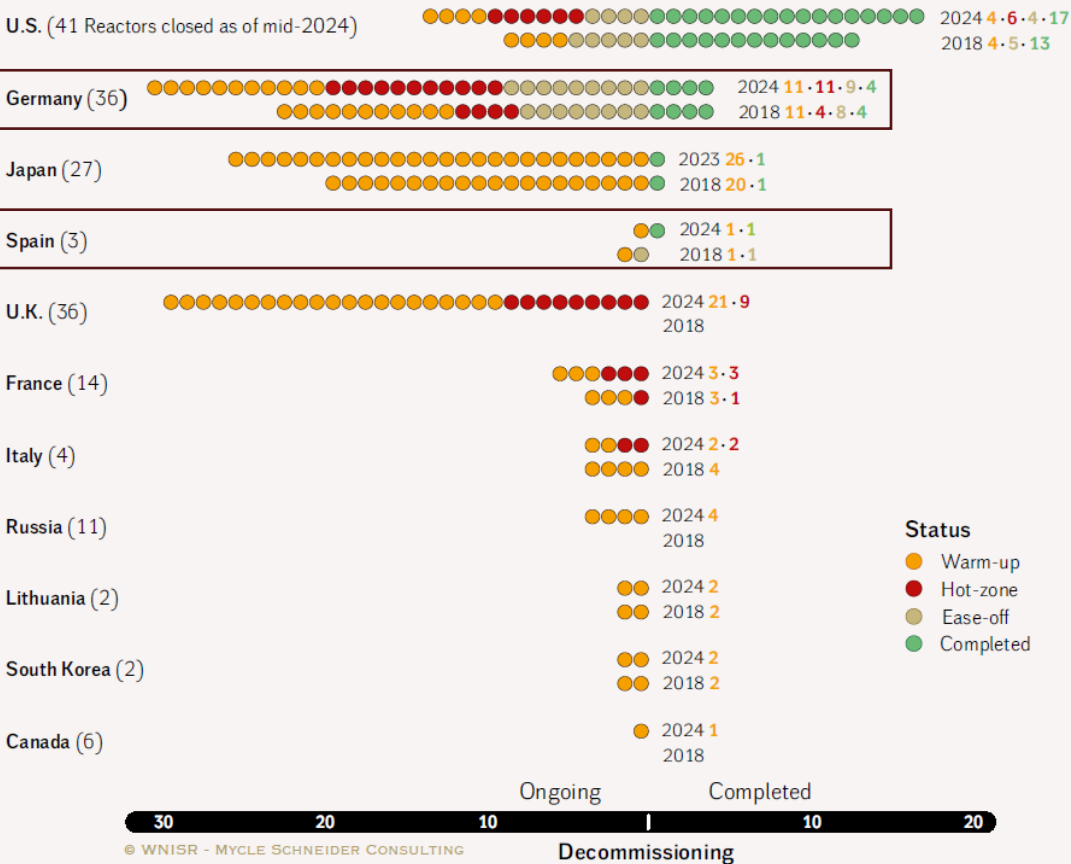


Figure 3. Progress and Status of Reactor Decommissioning [23]

2. The European Project **DORADO**: **D**igital twins and **O**ntology for **R**obot **A**ssisted **D**ecommissioning **O**perations

DORADO Partners



Key facts	Research goals	Work packages in brief
36 months 12 partners 8 countries 5 work packages		WP1 Prepare and manage project WP2 Finetune research goals WP3 Implement technologies WP4 Demonstrate on real use cases WP5 Train, exploit & standardize
Technologies		
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

Figure 4. Antti Rätty & DORADO consortium. Euratom project DORADO. Digidecom2024 conference, November 2024. Halden, Norway [2]

2. The European Project DORADO

2.1. Motivation

The Problem to Solve

- Legacy nuclear sites suffer from missing data, unknown radiological conditions, hazardous access, and poor spatial information.

The Proposal from DORADO

- BIM and Digital Twins are used at all steps of large projects;
 - Not just simulations; they help planning, remote operations, training, AI validation, etc.
- 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.

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

Sample technologies / situations

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

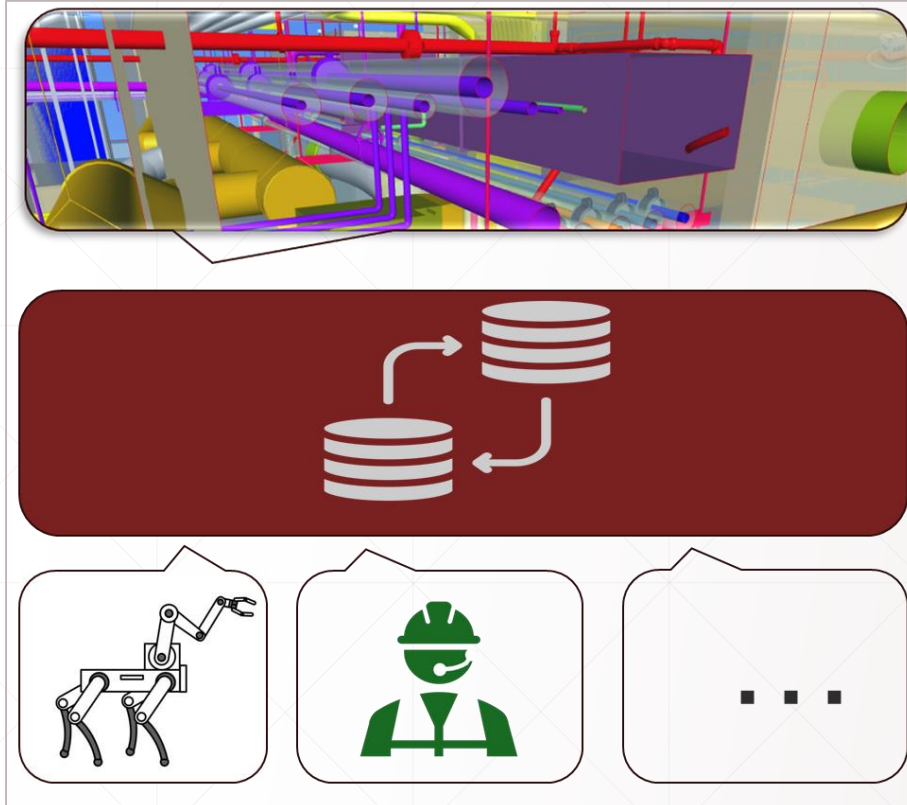


Figure 5. A. Rätty, M. Becker, F. Borrmann, J. Ridao & DORADO consortium. Digital technologies in DORADO project. 3rd webinar, April 8, 2025 [3]

2. The European Project DORADO

2.2. Technological Applications in DORADO System Architecture

- Extensible, modular structure based on ontology, clearly specified interfaces and standardized conventions between modules;
- Designed to support various data types/sources, accommodate different applications and integrate various user interface types;
- Possibility to extend or even change individual implementations without disturbing the functionality of the whole system;
- It aims to ensure compatibility and flexibility.

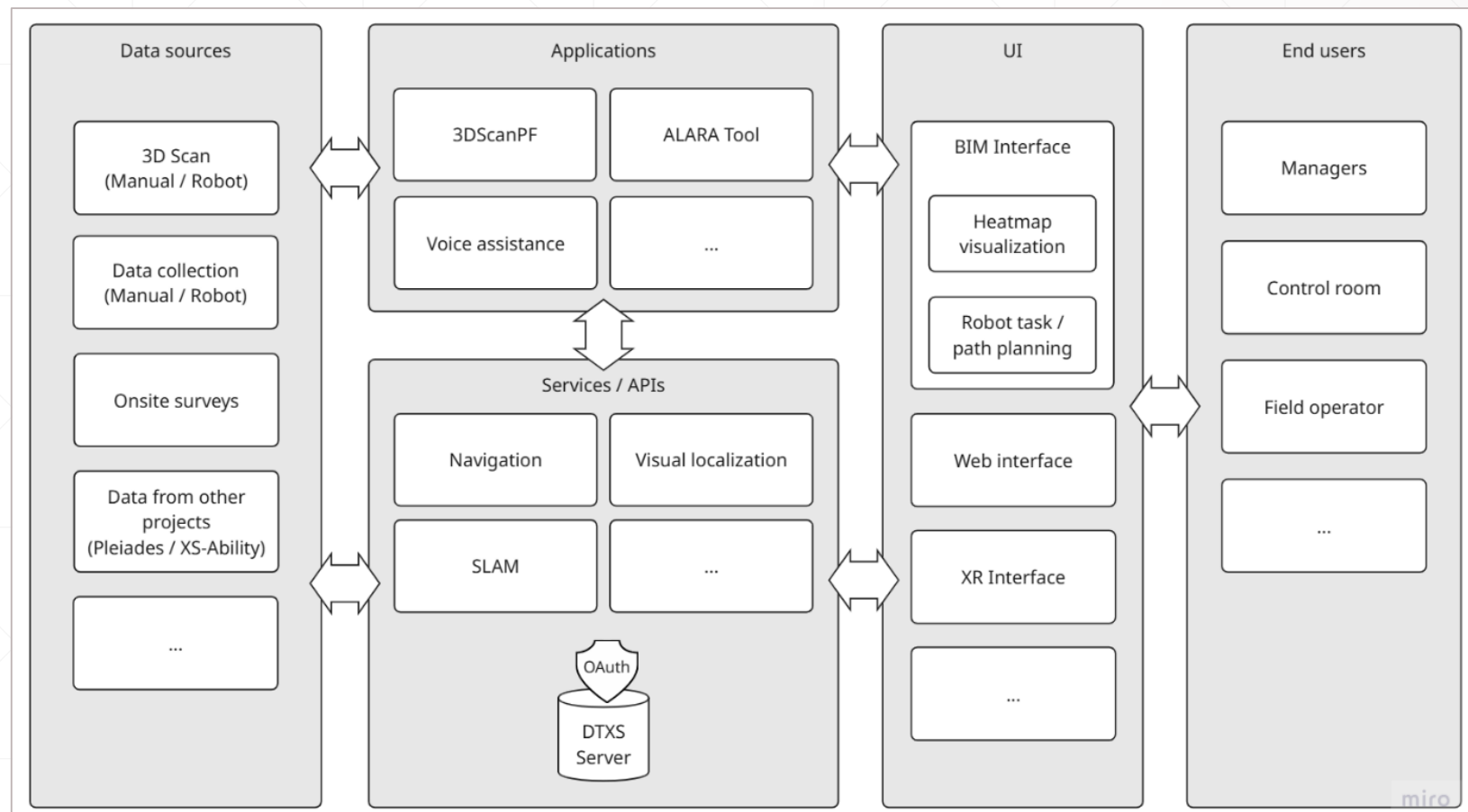


Figure 6. DORADO System Architecture. A. Rätty, O. Zahra, P. Honkamäa, J. Ridao, D. Daniska. EURATOM PROJECT DORADO. APPLYING DIGITAL TWINS AND DEDICATED ONTOLOGY FOR ROBOT ASSISTED DECOMMISSIONING OPERATIONS. DigiDECOM's NuclearNEXT 2025 international nuclear summit. Halden, November 2025 [4]

2. The European Project DORADO

2.3. DORADO Project Organization

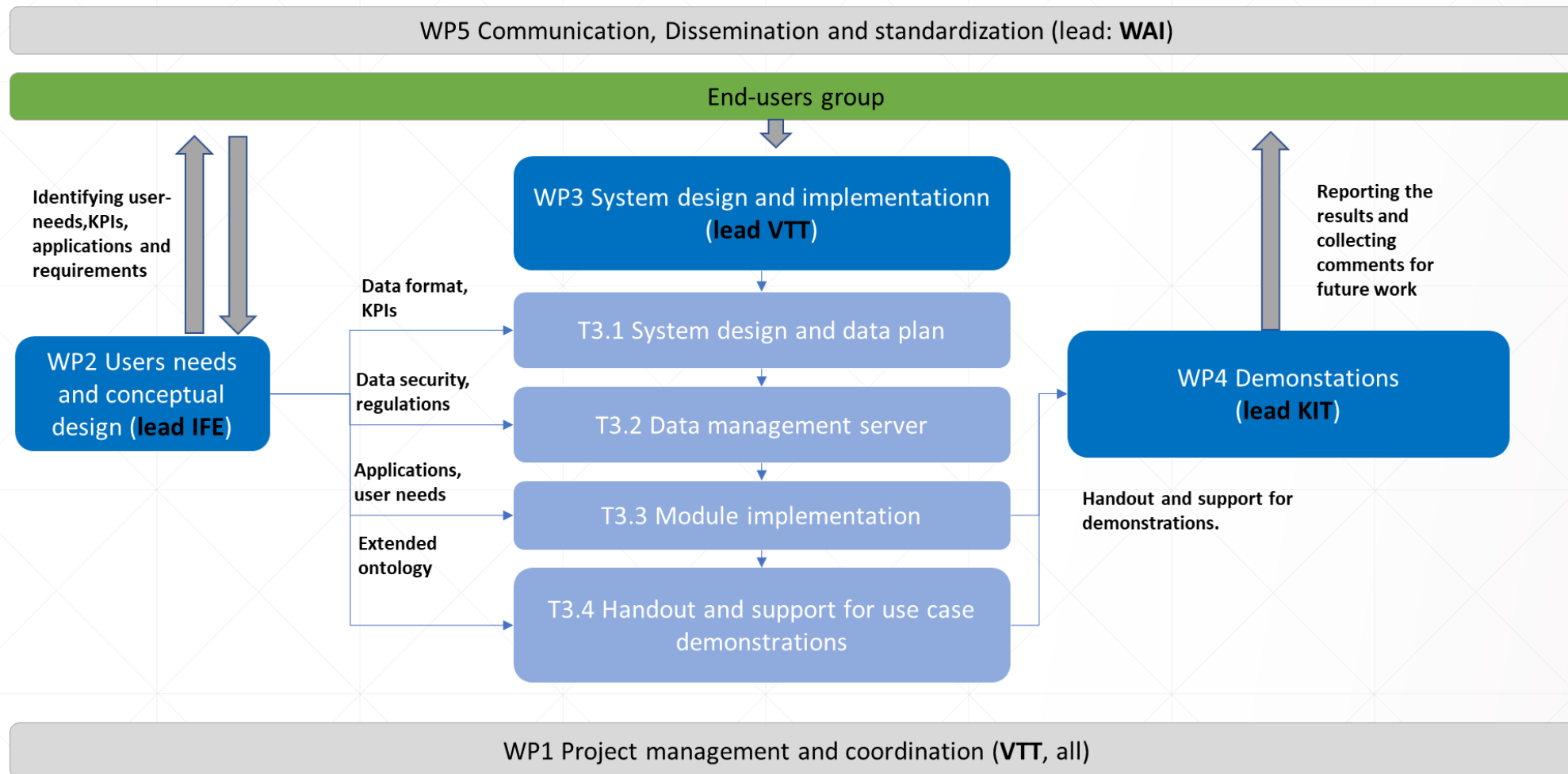


Figure 7. DORADO Project Flow [5]

3. Demonstrations on Real Use Cases

3.1. Use of Data from Real Facilities

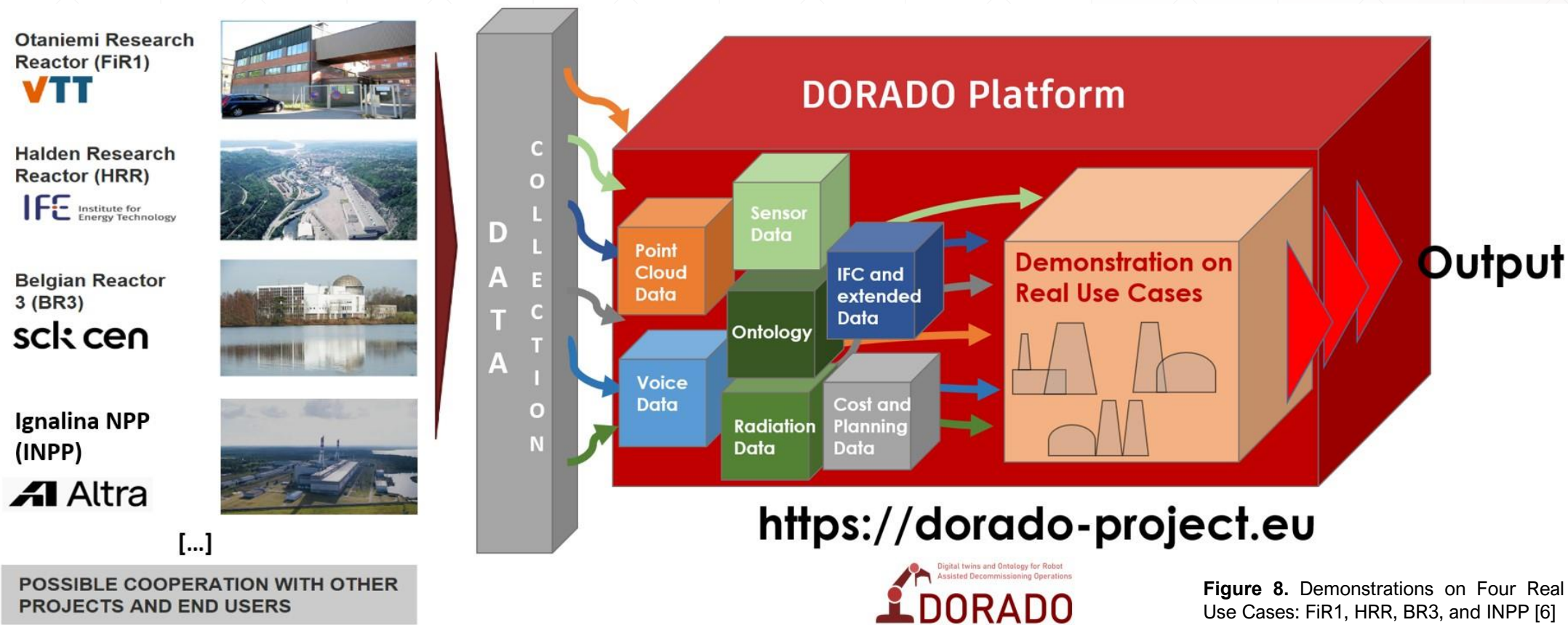


Figure 8. Demonstrations on Four Real Use Cases: FiR1, HRR, BR3, and INPP [6]

Use of different data from real facilities, like:

- Point Cloud Data, historical photogrammetry, dose rate surveys, 3D models, robot data (LiDAR and RGBD), Lidar SLAM and Visual SLAM, inventory data, dose rate mapping and spectrometry, etc.

3. Demonstrations on Real Use Cases

3.2. From Point Clouds to 3D Model

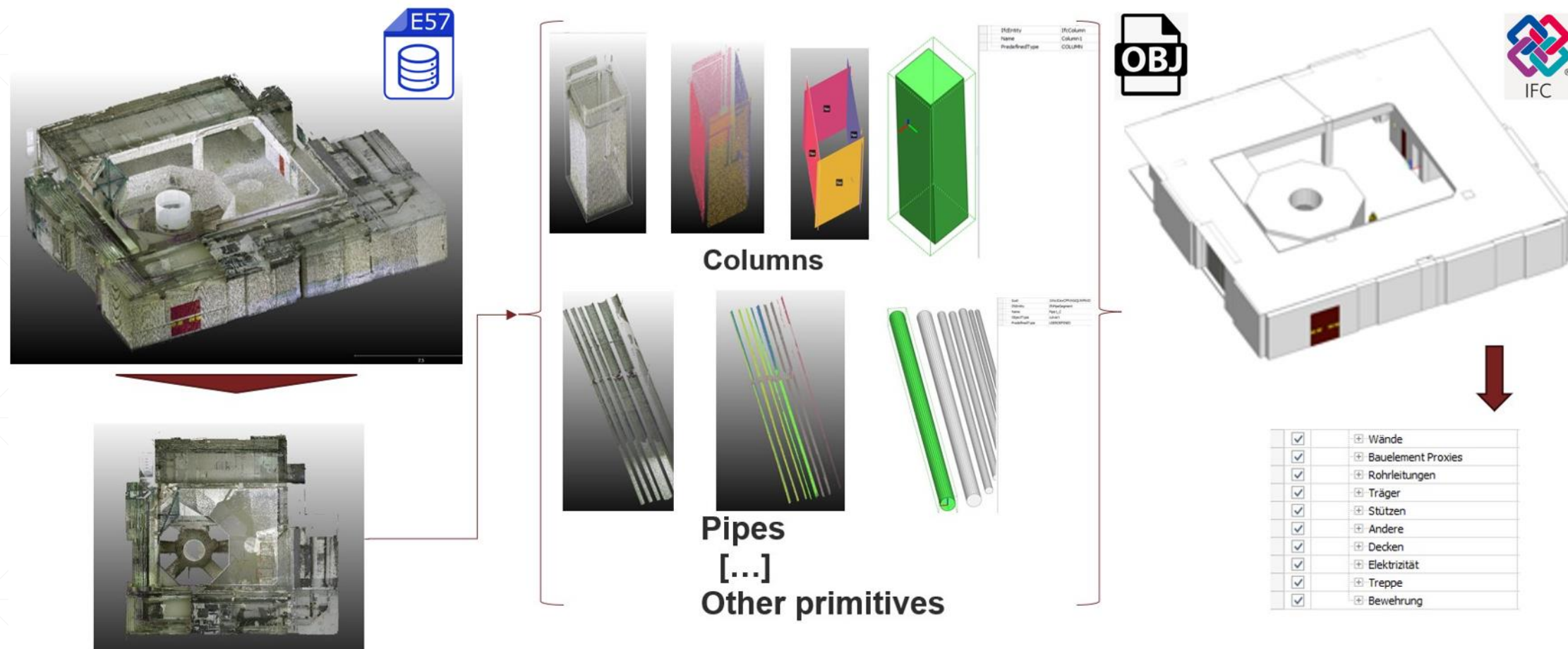


Figure 9. Illustration of Scan-to-BIM Process Workflow with 3DScanPF (KIT) Using the Point Cloud Model of the Finland Reactor 1 (FIR 1)
J. Ridao. Point Clouds and Panorama Captured by TLS (Terrestrial Laser Scanner). 'DORADO – 4th Webinar: Robots and drones in nuclear decommissioning (Online, 25.06.2026).
www.dorado-project.eu/events/webinar-robots-and-drones-in-decommissioning-jul-2026 [7]

3. Demonstrations on Real Use Cases

3.3. Scan-to-BIM of the FiR1

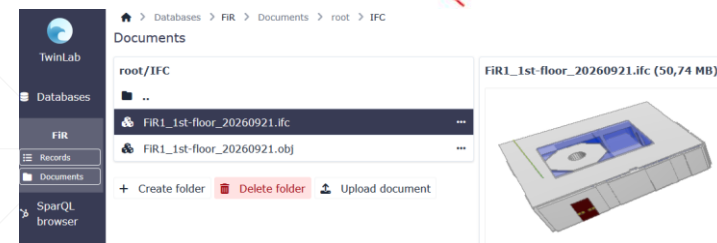
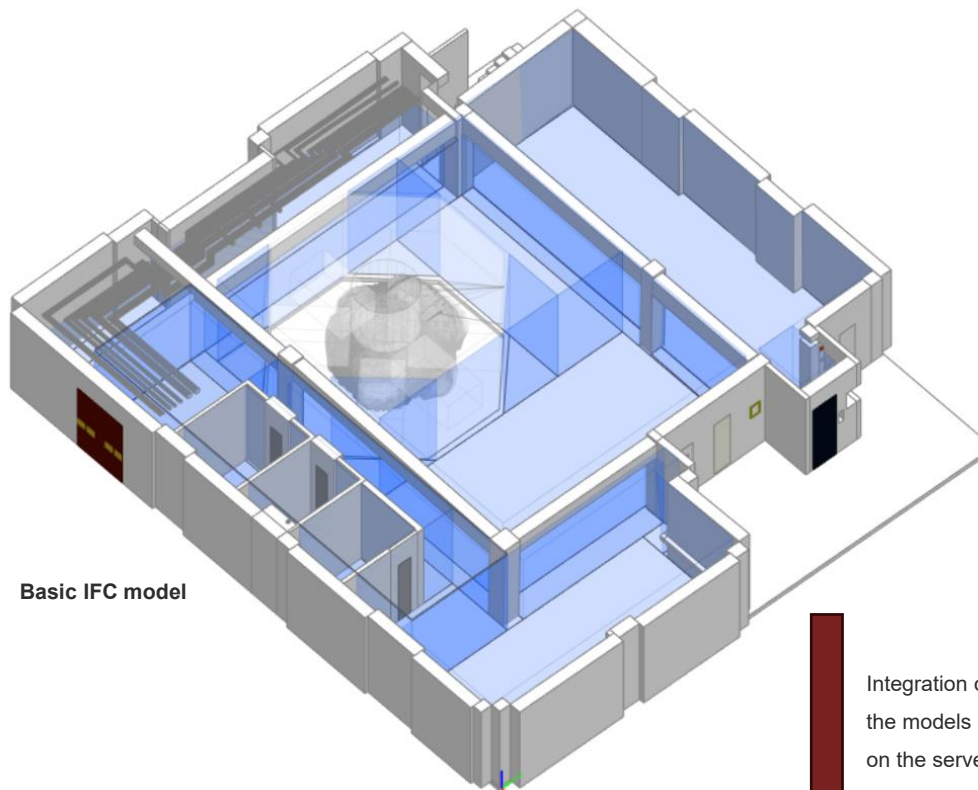
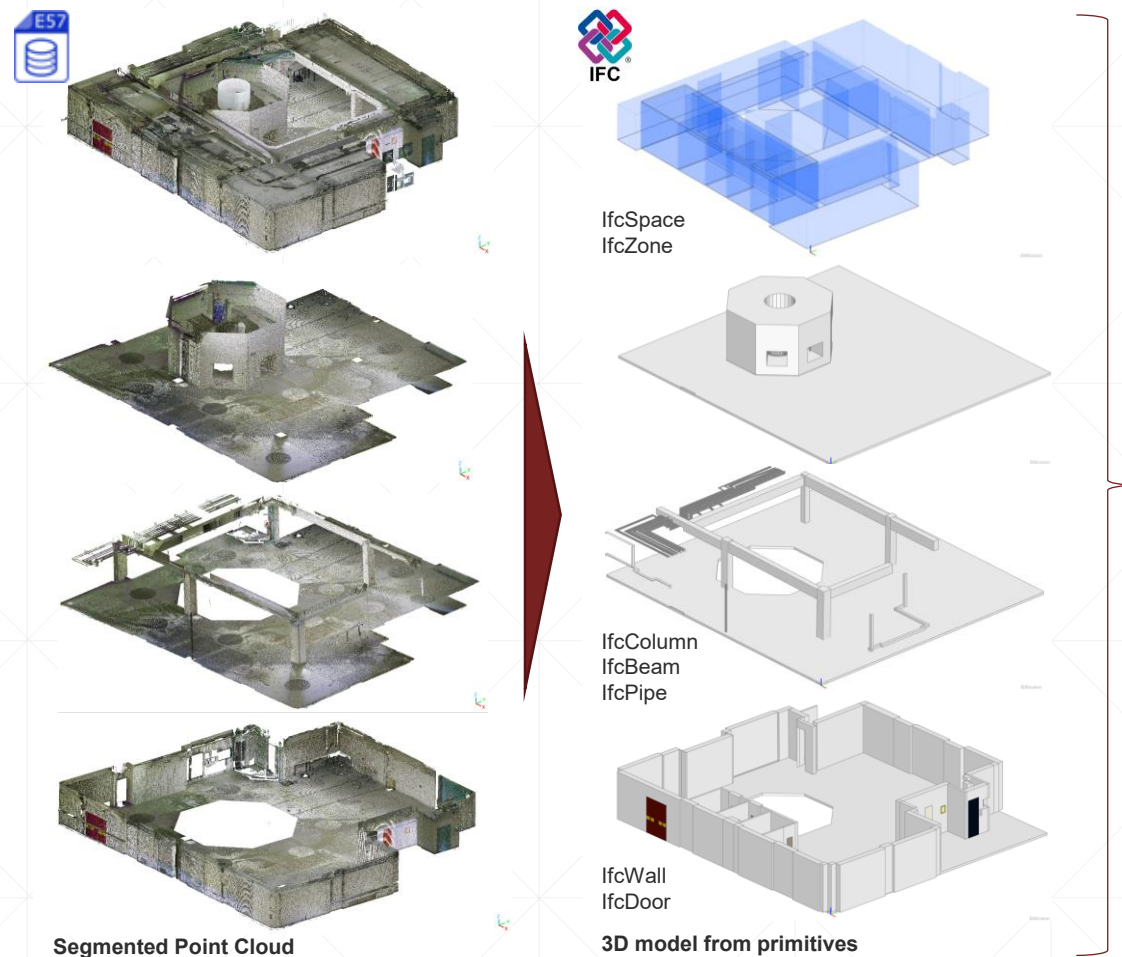


Figure 11. Integration to the Server [9]

Figure 10. Illustration of Scan-to-BIM Process Workflow with 3DScanPF (KIT) Using the Point Cloud Model of the Finland Reactor 1 (FiR 1)
J. Ridao, KIT. Task 4.1: Creation of a Parametric 3D Model [8]

4. Scan Campaigns

4.1. BR1 and BR3

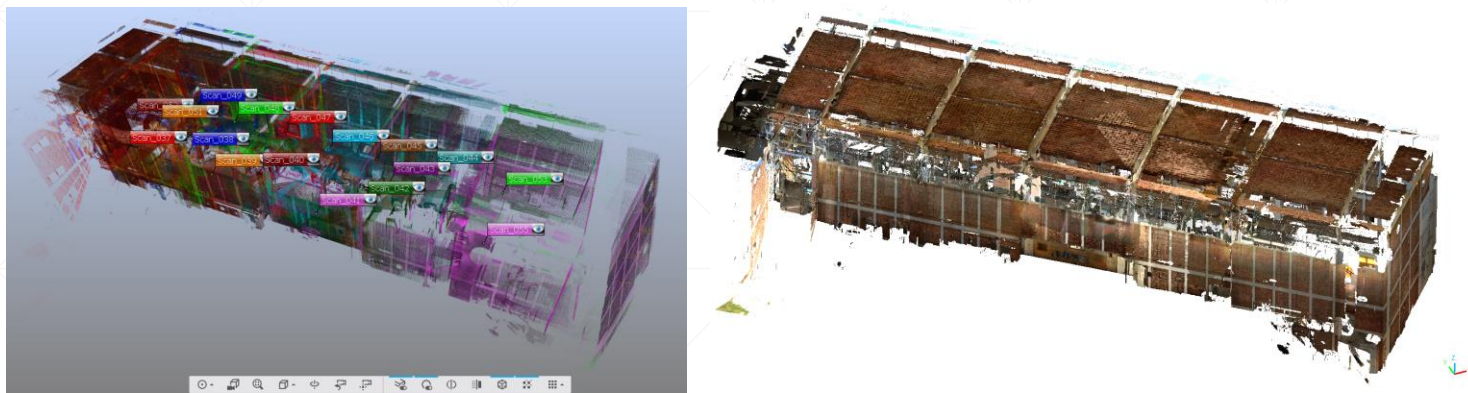


Figure 12. Processing of Scans with SCENE Software (left) and Point Cloud of a Part of the BR1 (right) [10]



Figure 13. Processing of scans with SCENE Software (left) and point cloud of a part of the BR3, showing different levels (right) [11]



Picture 1. Members of DORADO and XS-Ability during the scan campaign in Mol, Belgium [12]



Picture 2. Members of DORADO and XS-Ability during the scan campaign in Mol, Belgium [13]

4. Scan Campaigns

4.1. BR1 and BR3: Scan-to-BIM

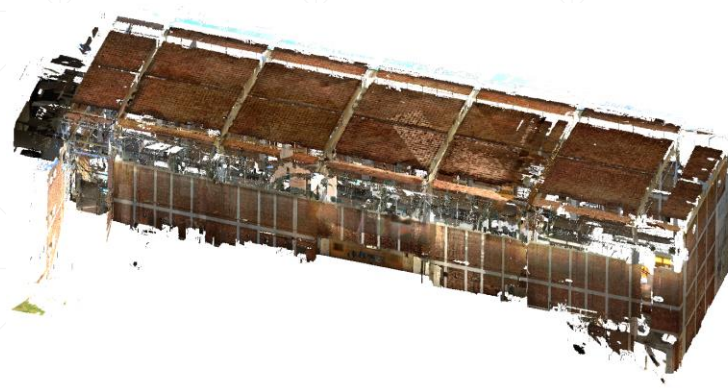
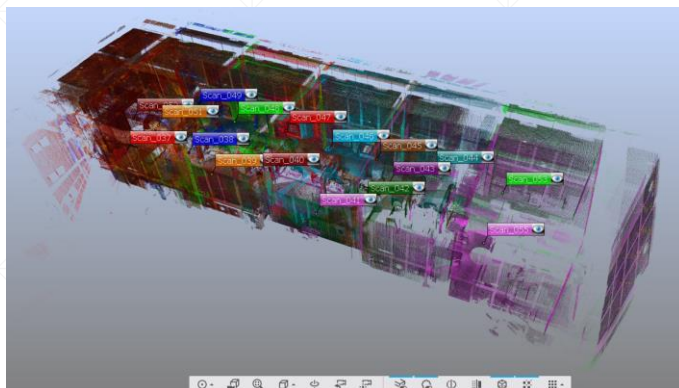


Figure 12. Processing of Scans with SCENE Software (left) and Point Cloud of a Part of the BR1 (right) [10]

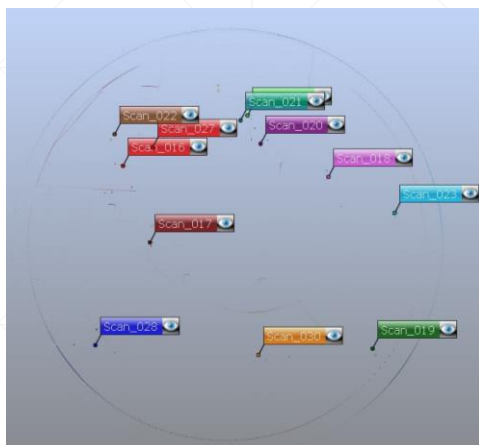


Figure 13. Processing of scans with SCENE Software (left) and point cloud of a part of the BR3, showing different levels (right) [11]

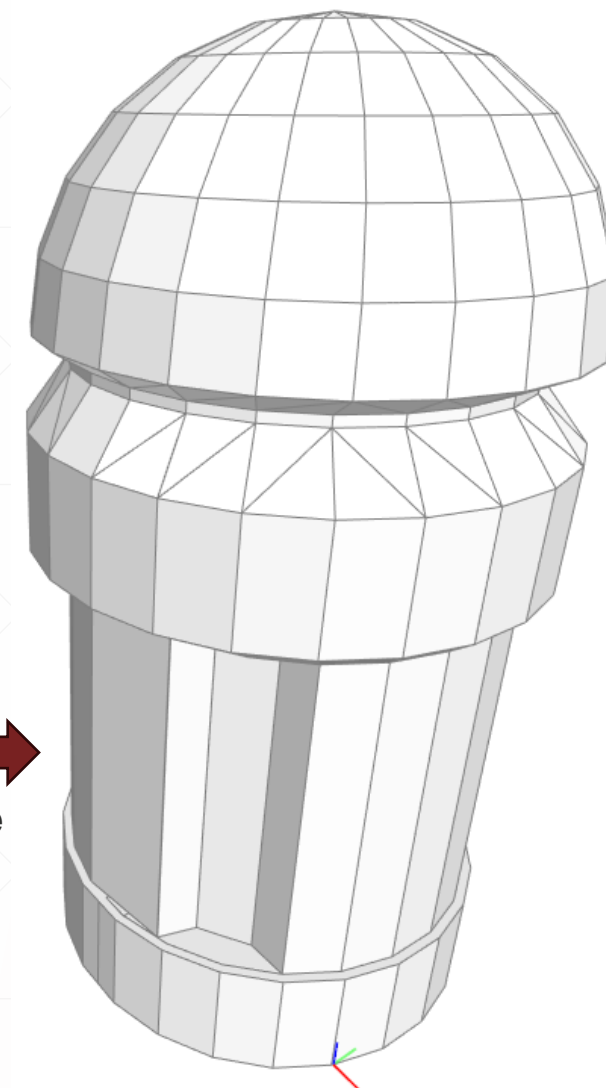


Figure 14. Overview of the BR3 3D model (3DScanPF, KIT) using the point cloud [14]

4. Scan Campaigns

4.2. Ignalina Nuclear Power Plant (INPP)

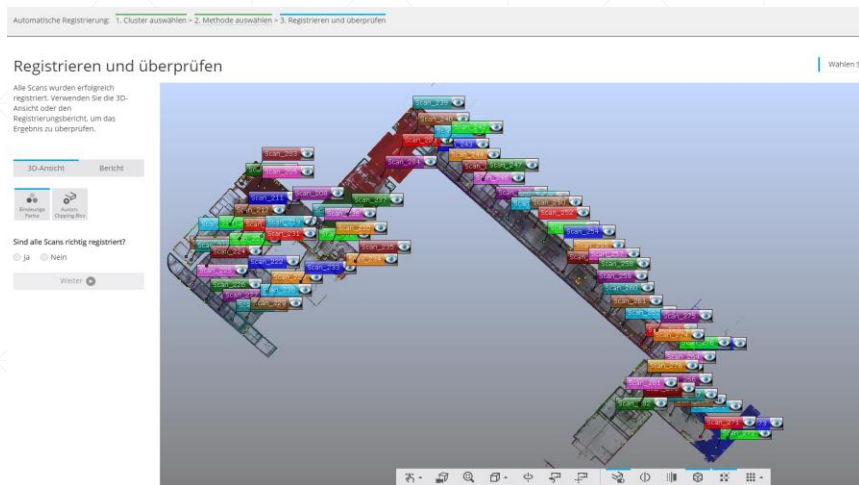


Figure 15. Processing of scans with SCENE Software [15]



Picture 3. Members of DORADO and XS-Ability during the scan campaign in Lithuania [18]



Picture 4. Scan campaign in the INPP [19]

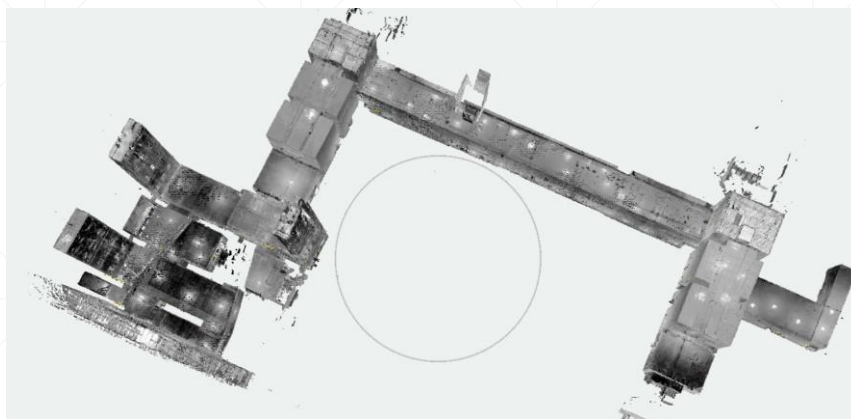


Figure 16. Point Cloud of a Part of the INPP [16]

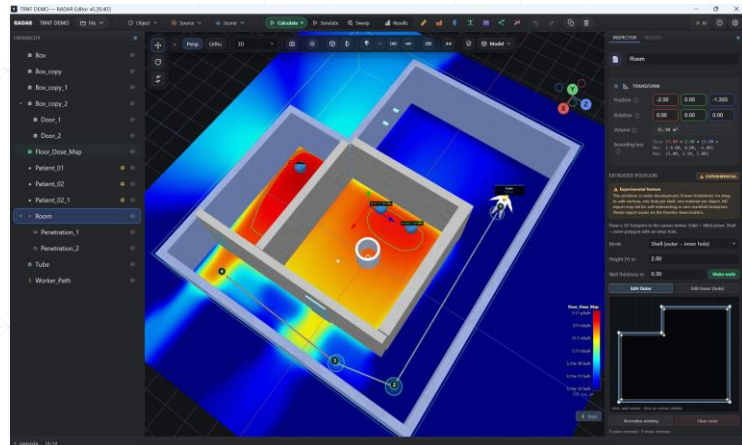


Figure 17. Point Cloud of a Part of the INPP [17]

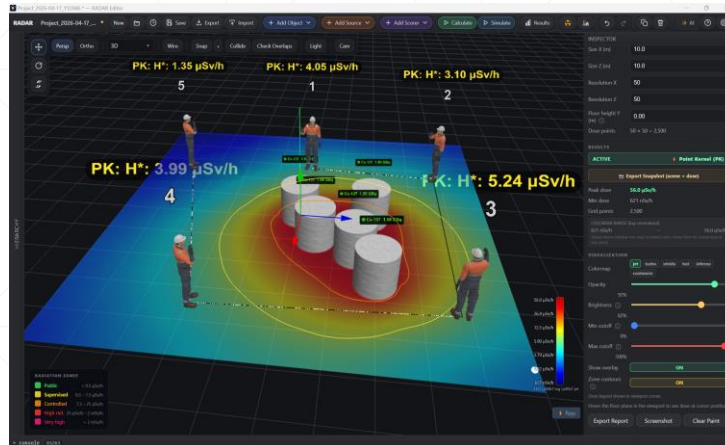
5. The Use of Digital Models for Simulations

5.1. ALARA Dose Estimation

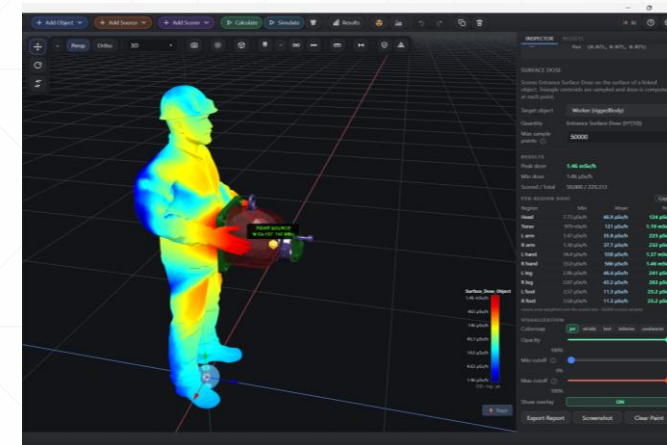
Shielding calculation and ALARA planning



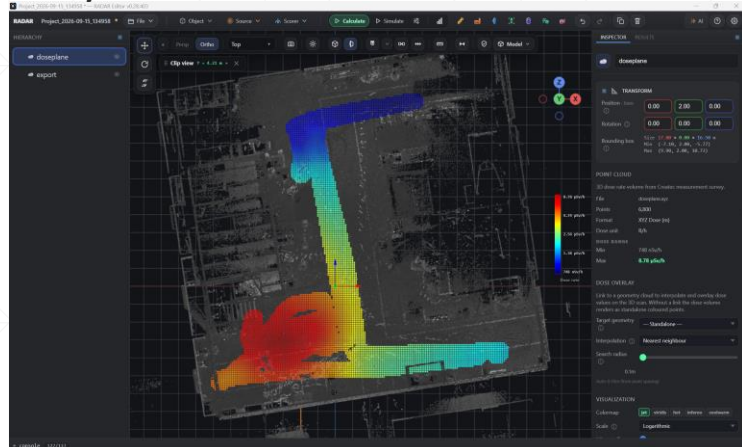
Worker dose at multiple positions



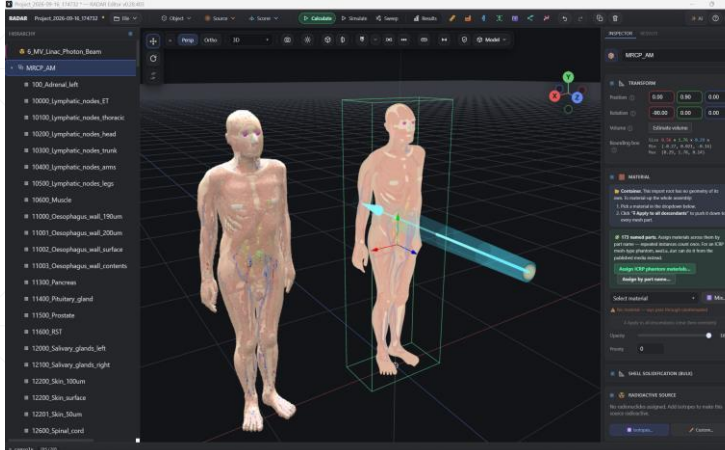
Hands-on source handling



Survey data on 3D scans



Organ dose in ICRP mesh phantoms



Detector response simulation

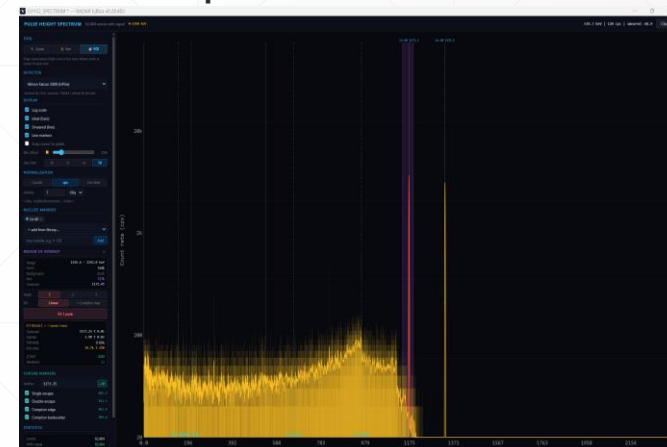


Figure 18. ALARA Use Cases with RADAR (SCK CEN) [20]

5. The Use of Digital Models for Simulations

5.2. Robot Mission Control and Route Optimization

- **State-of-the-Art:** Existing mission control and robot route optimization methods lack ontology-based planning;
- **Ontological Planning:** Introduce semantic modeling of spatial interdependencies, enabling context-aware mission planning;
- **Heterogeneous Robot Fleet:** The system dynamically assigns tasks to a diverse set of robotic agents with varying mobility, sensors, and payloads;
- **Integrated Safety Monitoring:** Real-time worker safety and risk assessment are supported through sensory data, semantic mapping, and AI-driven hazard detection;
- **Visual BIM-Based Planning:** High-level mission planning in a BIM interface allows intuitive waypoint and scanpoint definition, which feeds into detailed technical planning.
- DORADO mission planning tool integrates IFC-based facility model to support semantic mission definition, survey planning, waypoint selection, and target-surface specification within a unified digital-twin environment.

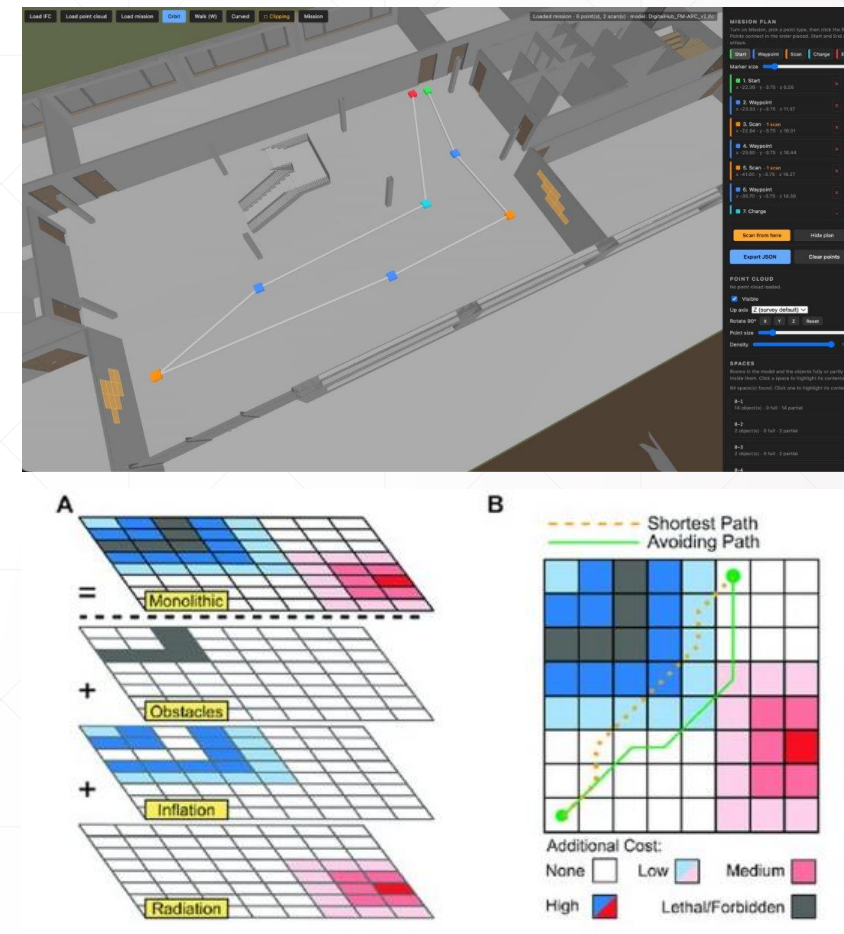
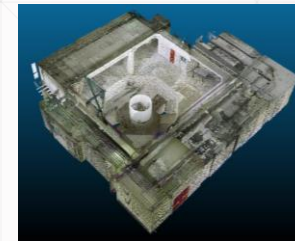


Figure 19. Robot Mission Control and Route Optimization [21]

5. The Use of Digital Models for Simulations

5.3. Sensor Data Fusion with Visual Localization



- Nuclear facilities require unified coordinate systems for consistent environmental and radiological data.
- Data fusion integrates multiple sensor types with support for temporal (time-series) analysis.
- Approach builds on aligned LiDAR point clouds and automatic alignment of previously mapped areas.
- Camera pose is estimated from images relative to a known 3D scene to localize different sensor measurements.
- The first demonstration included allocating thermal image data to the to the BIM model at the FiR1 research reactor in Finland
- Visual localization enhances robot and device tracking, supporting AR interfaces and manual data input.
- Current performance (~3 s query time) already enables real-time alignment of local and global coordinate frames.
- The only input for the visual positioning is the laser-scanned point cloud of the environment.



Figure 20. Visual Localization [22]

5. 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>

6. Conclusions and Future Work

- 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!
 - Don't re-invent the wheel and leave room for future applications
 - The development work can benefit from experiences in other fields of industry (and vice versa)
- Technical implementation work is approaching completion and last year will be used for demonstrations.
- After the project, the consortium aims for commercial cooperation and is very flexible to tailor methods for the market needs. This will be made in several phases:
 - Phase 1: Form cross-functional team, assess infrastructure
 - Phase 2: Pilot projects with performance metrics
 - Phase 3: Training, cybersecurity, regulatory engagement
 - Phase 4: Scale successful technologies
 - Phase 5: Continuous monitoring and adaptation
- **Management support is critical for success and adoption!**

References

- [1] [11] [12] www.dorado-project.eu
- [2] [5] Antti Rätty & DORADO consortium. Euratom project DORADO. Digidecom2024 conference, November 2024. Halden, Norway
- [3] A. Rätty, M. Becker, F. Borrmann, J. Ridao & DORADO consortium. Digital technologies in DORADO project. 3rd webinar, April 8, 2025
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- [6] A. Rätty, O. Zahra, P. Honkamaa, J. Ridao, D. Daniska. Euratom Project DORADO: Applying Digital Twins and Dedicated Ontology for Robot Assisted Decommissioning Operations. Digidecom Conference, 21.- 25. September 2026, Halden, Norway
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- [20] ALARA Use Cases with RADAR (SCK CEN)
- [21] [22] A. Rätty et al. (2026). Euratom Project DORADO: Applying Digital Twins and Dedicated Ontology for Robot Assisted Decommissioning Operations. Digidecom Conference, 21.- 25. September 2026, Halden, Norway.
- [23] Schneider, M., Froggatt, A., 2025. The World Nuclear Industry Status Report 2025. https://doi.org/10.1142/9789811213953_0021

Thank you for your attention!

Any questions?



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