Innovation Action

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D1.2 – Specifications for the PLEIADES system prototype and validation tests

WP1 - Task 1.2

Date [M6]

Author(s): Dusan DANISKA (WAI), Kristina Kristofova (WAI), Tom-Robert Bryntesen (IFE), Patrice Francois (IRSN), Antoine Lasnier (L&S), Mikel Salazar (IFE), Nicolas De Bievre (CDS), Raimo Launonen (VTT)

www.pleiades-platform.eu

@pleiades-platform

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Disclaimer

Executive Summary

The scope of the task described in this deliverable was to analyse requirements collected in previous tasks of the project and to provide the following outcomes:

- Identification of functional and hardware requirements
- Specification of basic principles for communication and data exchange between software tools included in the PLEIADES ecosystem
- Development of user stories to be used as a basis for validation tests to demonstrate the capabilities of the PLEIADES prototype system
- Development of test protocols to be used as a template for documenting results from the validation tests

The work described in this document was supported by targeted discussions among the consortium partners in project work meetings, as well as with experts outside the consortium, in project workshops and international conferences. Each partner provided their expert opinion and comments in meetings and directly in this document that was developed on an on-line sheared platform. Due to unexpected COVID-19 situation, discussions, presentations and other means of scientific communication have been performed online.

Keywords

nuclear, decommissioning, software platform, software messaging, hardware requirements, functional software requirements, user requirements, software testing

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Abbreviations and acronyms

Acronym	Description
ALARA	As Low as Reasonably Achievable
API	Application Programme Interface
AR	Augmented Reality
BCOT	Base Chaude Opérationnelle du Tricastin: a nuclear installation located on the Tricastin nuclear site specializing in nuclear maintenance. It maintains and stores equipment and tools from circuits and contaminated equipment in nuclear power reactors, excluding fuel elements, and in particular guide tubes, intervention tools, equipment dedicated to dismantling and vessel covers.
BIM	Building Information Modelling/Management
D&D	Decommissioning and Dismantling
DQO	Data Quality Objectives
DWH	Data Warehouse
ERP	Expert Review Panel
HC NPP	José Cabrera Nuclear Power Station
IFC	Industry Foundation Classes, a data model intended to describe architectural, building and construction industry data
ISDC	International Structure for Decommissioning Costing of Nuclear Installations
LOD	Level of Detail

KM	Knowledge Management
KPI	Key Performance Indicator
KPIM	Knowledge Centric Plant Information Modelling/Management
MC	Monte Carlo
RFQ	Request for Quote
SAR	Safety Evaluation Report
SMG NPP	Santa María de Garoña Nuclear Power Station
SSCs	Structures, Systems and Components
TSO	Technical Support Organisation
WM	Waste Management
WP	Work Package
XR	Mixed Reality

1. Introduction

D&D operations in nuclear environments require to follow the three major steps:

1. Characterization of the initial state of the facility to be dismantled, including several in situ campaigns to collect inventory data (e.g., physical and radiological inventory).
2. Studying alternative solutions and choosing the most optimal dismantling scenario. The studies go through preliminary studies, detailed studies, and final design, including qualifying tests and training for staff.
3. Implementation, including site preparation, dismantling operations, and waste management.

3D data (point clouds, 3D models, CAD mock-ups) are being increasingly applied in the first step (characterization). The overall aim of the PLEIADES project is to provide a new digitally enhanced methodology for improving the above D&D operations, defining good practices for digitalization and facilitating higher standardization required for international application.

The specific approach is to demonstrate an innovative digitally enhanced approach for selected key tasks related to D&D in real life examples from decommissioning projects in Europe. The project will prove the feasibility of scenario simulation-based analyses and comparison of alternative decommissioning approaches, as well as BIM based digital methods for waste, radiation exposure and cost/duration estimations. The core technical concept to be applied within the project is a common interface enabled by a shared ontology, integrating cutting-edge digital support tools in a BIM technology-based software ecosystem.

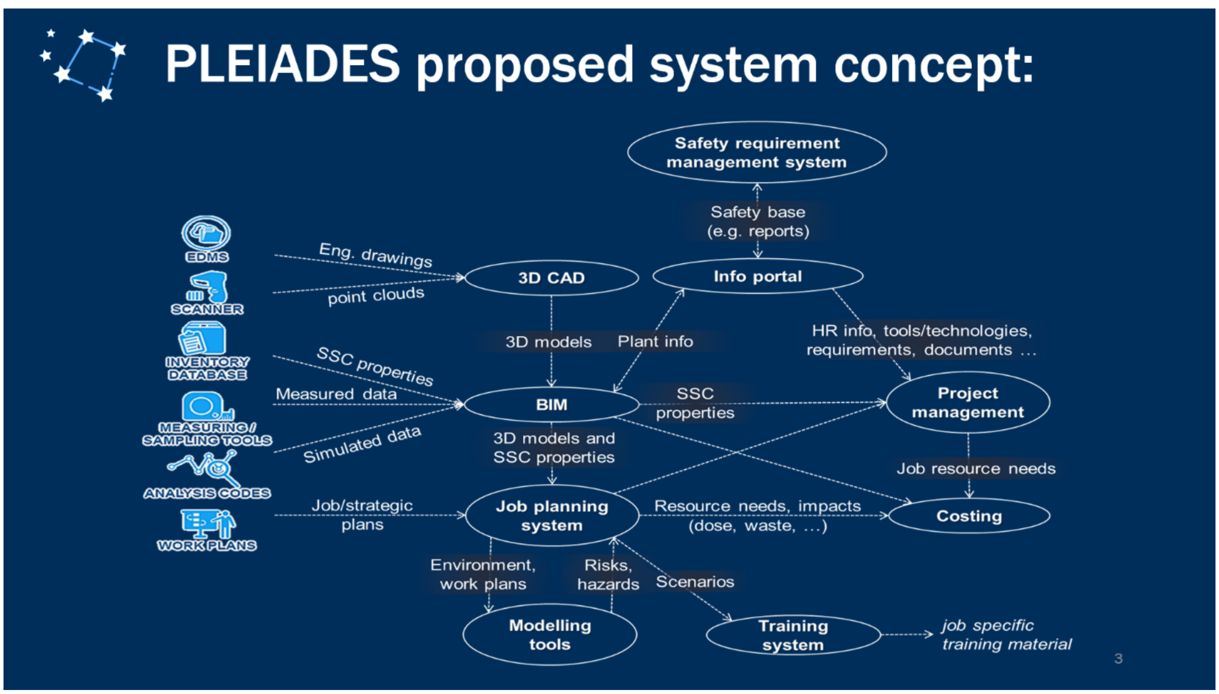

Figure 1 Illustration of the proposed PLEIADES system concept

In this project, the BIM-based integrated prototype will be adapted to practical needs of real-life D&D process and demonstrated through validation exercises aiming at proving the applicability, quantifying efficiency, as well as finding shortcomings of the concept to be solved in further research and development.

On a longer time-scale, it is envisaged that PLEIADES will enable higher coordination between the partners of this project and other European organizations for collaborating beyond the scope of this project in enabling the emergence of flexible digital support systems that, through high interoperability of existing and emerging technologies, provide comprehensive professional support for D&D operations. The project also aims at making decommissioning more attractive for the new generation of “decommissioners” by promoting the adaption of innovative digital tools by the industry.

1.1. Contributing project partners

The nature of this task and the scope of this deliverable document required that all partners contributed to the content of this document. However, given that WAI was the leader of task 1.2 and IFE was the leader of the task 1.1 which provided the main input for the work descried in this deliverable, these two partners had a higher contribution. Additionally, some results from deliverable D1.4 (led by iUS), which has been developed in parallel with this document, have also been utilized.

1.2. Goals

This deliverable is a result of joint research within Work Package 1 of the PLEIADES project. Work Package 1 focuses on definition of requirements and associated specifications for developing and demonstrating an innovative 3D BIM approach based digital decommissioning support concept (the PLEIADES concept). Tasks implemented in this work package will ensure that the planned prototype system is designed to provide improvements to actual decommissioning practitioner needs, the efficiency of the methods is measurable/comparable and a suitable input database is available for the validation exercises (test cases) to be conducted. In addition, this work package will investigate how facility characterization can support development of independent safety analyses and reviews aiming to ensure that the planed decommissioning processes will be performed with appropriate measures to protect workers, the public and the environment.

The content of this deliverable is the result of discussions among all project partners aiming at elucidating technical specifications for the development and validation tests of the PLEIADES system prototype.

The main goals of this work are summarized below:

- Functional specifications for the PLEIADES system prototype based on the requirements defined in Task 1.1.
- Determination of the results expected from the test exercises: Results expected will be determined so that they contribute to achieving the expected outcomes of this project.
- Specification of the input data/information required for achieving the results expected
- Specification of the hardware infrastructure necessary to operate the PLEIADES platform and run the test procedures

- Development of test procedures for the test cases (user stories) specified. This includes establishment of boundaries and measures to be applied for ensuring measurability and comparability of the outcomes from different use cases.
- Listing potential test environments that best satisfy the requirements determined in Task 1.1 and selection of the test environments to be used: This will include evaluation of available input for the listed test sites and needs for further input generation and refinement.
- Development of specific test protocols for the selected test environments, including description of input to be used and developed, results expected from the tests, and ways for measuring (quantifying test results)

1.3. Inputs to this document

the work descried in this document was heavily based on the results of task 1.1 documented in deliverable *D1.1 (Requirements for concept design)* listing user requirements for the PLEIADES system development and testing. Another document that influenced the content of this document was deliverable *D1.4 (Ontology describing a nuclear decommissioning project)* where a common terminology (dictionary) for some functional and technical requirements is described.

1.4. Structure of this document

Chapter 2 of this document contains functional specifications for the PLEIADES system prototype based on the requirements identified in task 1.1 and summarized in the deliverable D1.1. This part also contains a summary of results from discussions on the technical architecture of the PLEIADES system. The last section of this chapter contains specifications for the hardware infrastructure and input data required for running the validation tests.

Chapter 3 of this document contains specifications for the validation tests, test protocols and guidance for their use, a list of possible test environments and a list of test procedures necessary to perform the planned validation tests.

Appendix 1 contains the test protocol provided as a template to be completed during validation tests.

2. Functional and technical specifications

2.1. Input from deliverable D1.1

Deliverable D1.1 provided with the following classification of needs, expectations, KPIs and requirements for the PLEIADES prototype:

Class	Description
Needs	3D/BIM based inventory management with focus on risks (e.g., radiological) • Connect radiological and other inventory info to SSCs

	• Aggregate data from multiple sources • Update inventory (new data, change to facility/site) • Export for providing data to third parties • Inform communication between all stakeholders Scenario simulation for analysis/optimisation of work plans • ALARA evaluation of work plans • Planning of protection • Testing & comparison of alternatives in terms safety, cost, … • Sensitivity analysis • Benchmarking across a spectrum of similar parameter specifications Safety and risk management • Safety demonstration • Support for safety inspections • Uncertainty management Waste route planning Monitoring • Actual costs in comparison with plans • Tracing waste items from initial to final location • Quality control
Expectations	3D/BIM based inventory management with focus on risks (e.g., radiological) • Aggregate all radiological data in a 3D model based interface including historical data • Filter radiological data (in terms of SSCs, time, status, DQOs) • Improved control over data management • Mapping completeness of inventory (filter: missing / estimated / validated) Scenario simulation for analysis/optimisation of plans • Compare alternative detailed plans in terms of dose • Better understand work plans • Detect physical clashes • Estimate radiological exposure to workers • Improve training by use of 3D visualization Safety and risk management • Improve current safety demonstration practices • 3D model based facility/site overview of risks (risk register) – identify critical risks, filter risk information • Improved uncertainly estimations • Better anticipation of unforeseen • Identify parameters with highest impact onto project performance • Trace back decisions (who, why, …) Monitoring • Compare 'as planned' with 'as performed' data • Detect discrepancy between predicted ALARA estimates and data from monitoring during implementation • Benchmark cost estimates using data from completed tasks • Improve updating of cost estimates in case of deviation from assumed inventory • Regularly updated information on location of items – traceability from initial to final location

	Waste route planning Optimisation of wate streams Compare alternative waste routes (costs, time, …)
KPIs	• Cost reduction • Exposure reduction • Schedule improvement (speed) • Time/effort for regulatory/review approval (licensing) • Waste reduction/optimization • Training effectiveness • Effective use of resources (nr of people, waiting time, …?) • More flexible planning (time for update in case of deviation?)

Requirements	To the end-user:
	• Level of expertise in (e.g., radiological protection)
	• Amiability of unique identifiers for items, their segments and waste packages
	• Availability of input for modelling waste streams (waste factors, etc…)
	• Capabilities for keeping information up to date
	• Dedication (by management) of internal human and other resources
	• Timing of system implementation (earlier is better)
	To the technology provider:
	• Positive economic feasibility (investment versus benefits)
	• Acceptance by different stakeholders (regulators, TSOs, management)
	• Long term support by the system provider
	• Intuitive user-friendly interface
	• Data security (security updates, secure data transfer, security barriers between software modules, access rights/control, cloud solution versus local installation)
	• System flexibility
	    ○ Platform / operating system independent
	    ○ Configurable to various customer environments
	    ○ Compatibility with future needs and future tools (future formats - open standards) – future system updates
	• Common data environment
	• Version/revision control

Table 1 Needs, expectations, KPIs and requirements for the PLEIADES prototype (from task 1.1).

The above-mentioned classification was used as a basis for development of functional requirements for the PLEIADES system prototype and user stories to be used for validation and demonstration of the concept.

2.2. Functional requirements

2.2.1. Overview of functional requirements from deliverable D1.1

Functional requirements for the PLEIADES system prototype were specified in two ways. First, based on input from deliverable D1.1, use cases describing the required outcomes of the whole concept were identified. In the next step, a numbered list of functional requirements was derived based on these use cases. Since nuclear decommissioning projects include complex tasks spanning over many years or even decades, the list of possible use cases and derived functional requirements that could be implemented in such system is very large. Hence, the list of functional requirements in this document should not be treated as a comprehensive list of functional requirements for digital nuclear decommissioning support systems in general. The goal of the PLEIADES project is to develop a conceptual framework, based on a more standardized knowledge/data representation, for interfacing advanced nuclear decommissioning support systems, and demonstrating the concept through application of a prototype system in some selected use cases. Hence, the list of functional requirements presented in this document covers only a subset of requirements; specifically, those required to demonstrate the concept within the selected use cases.

The table below summarizes the list of expectations derived from deliverable D1.1 [1].

Area	Req #	Requirement
3D/BIM based inventory management with focus on risks (e.g., radiological)	R001	Aggregate all radiological data in a 3D model based interface including historical data
	R002	Filter radiological data (for SSCs, time, status, DQOs)
	R003	Improved control over data management
	R004	Mapping completeness of inventory (filter: missing / estimated / validated)
Scenario simulation for analysis / optimisation of plans	R005	Compare alternative detailed plans in terms of dose
	R006	Better understand work plans
	R007	Detect physical clashes
	R008	Estimate radiological exposure to workers
	R009	Improve training by use of 3D visualization
Safety and risk management	R010	Improve current safety demonstration practices
	R011	3D model-based facility/site overview of risks (risk register) – identify critical risks, filter risk info
	R012	Improved uncertainty estimations
	R013	Better anticipation of unforeseen
	R014	Identify parameters with highest impact onto project performance
	R015	Trace back decisions (who, why, …)

Monitoring	R016	Compare ‘as planned’ with ‘as performed’ data
	R017	Detect discrepancy between predicted ALARA estimates and data from monitoring during implementation
	R018	Benchmark cost estimates using data from completed tasks
	R019	Improve updating of cost estimates in case of deviation from assumed inventory
	R020	Regularly updated information on location of items – traceability from initial to final location
Waste route planning	R021	Optimize waste streams
	R022	Compare alternative waste routes (costs, time, …)

Table 2 Summary of results from analyses of expectations from D1.1.

2.2.2. Requirements for the PLEAIDES software communication protocol

The software communication protocol will be the heart of the PLEIADES system prototype connecting all the PLAIDES software modules together. Since nuclear decommissioning projects are, typically, long-term, the software communication protocol must be robust yet flexible enough to adapt to future ways of working shaped by new research and experiences from completed projects. Similarly, the capabilities of digital tools and supporting equipment (e.g., 3D scanners) will expand in the future. This is also an important aspect to be considered in ensuring flexibility of the PLEIADES software communication protocol.

‘BIM Federated Model’ was selected as the basic theoretical concept behind the PLEIADES software communication protocol. BIM Federated models refers to models consisting of linked, but distinct, component models, engineering drawings, texts and other data linked to components of the model that do not lose their identity or integrity by being so linked, so that any change to one component in a federated model does not create a change in other component models within the same model.

The basic idea behind transferring data between tools integrated within the PLEIADES system prototype relies on the concept of ‘messages. This concept is analogous to emails. The concept ensures an asynchronous communication which is necessary to be used in the PLEIADES architecture due to the nature of the concept. Asynchronous communication enables human interaction within the process. In our case, human involvement will consist of manual execution of decommissioning-related tasks by responsible persons (engineers, experts or other people involved in the decommissioning planning) between automatic processes by software tools. The idea of asynchronous communication is explained in more detail in chapter 2.2.2.2 ‘Asynchronous communication’. The other advantage of using messages is the capability for keeping track of all activities performed during the decommissioning project and allowing the user to trace-back and analyse past decisions.

2.2.2.1. Messaging framework

The messaging framework will serve as the basic communication channel between the software tools of the PLEIADES ecosystem. Therefore, there are several general functional requirements pertaining to this framework. These requirements are listed in the table below:

Requirement	Description
Open implementation	The messaging framework should be built upon mature open technologies with large community support.
Variable architecture	The messaging framework should be able to adapt to specific hardware and network infrastructures used in nuclear environments.
Compatibility with ontology	The messaging framework should be compatible with the nuclear decommissioning ontology reported in deliverable D1.4 of this project.
Asynchronous operation	The messaging framework should work asynchronously to allow manual (human) interaction within the chain of messages.
Large information payload transfer	The messaging framework should allow transfer of large information payloads like 3D/BIM models or point clouds.
Scalability	The messaging framework should be able to handle increases in information load without noticeable degradation in the Quality of service (Number of messages, Size of messages, …)
Availability	The availability of the system should be high enough to enable smooth operation. For instance, system outages should not block decommissioning planning work.
Security	The messaging framework must implement authentication mechanisms with access control rights.

Table 3 List of functional requirements for the software messaging framework

Given the large variety of software tools and operating environments, the final selection of proper messaging architecture will be done in WP2, more specifically in the *Task 2.1: PLEIADES platform architecture*.

Our preliminary results from the work documented here shows that there are two main options:

- Already existing open implementation like Apache Kafka, NATS, WAMP or MQTT
- REST API with authentication and authorization mechanisms like OAuth

In both cases, the chosen messaging architecture may impose limitations on software tools of the PLEAIDES prototype. It will be the responsibility of each partner to raise objections to chosen messaging architectures and propose alternatives solutions.

2.2.2.2. Asynchronous operation

The communication protocol must ensure that human participants can be included in the messaging loop between the software tools. Majority of the tasks performed in decommissioning projects require human intervention. At present, the consortium partners agree that the process in this project cannot be fully automated. For example, if there is a need to prepare a 3D simulation for a specific work order, a skilled engineer using a specific simulation software must perform this task manually.

This requirement can be fulfilled by enabling an asynchronous operation of the messaging framework. The figure below illustrates the foreseen data/information flow in such an asynchronous messaging framework. The figure shows an example for a data/information flow initiated by a "getCostsForWorkOrder" message. The use case in the figure demonstrates calculation of costs for a work order generated from a simulation developed in a 3D modelling software.

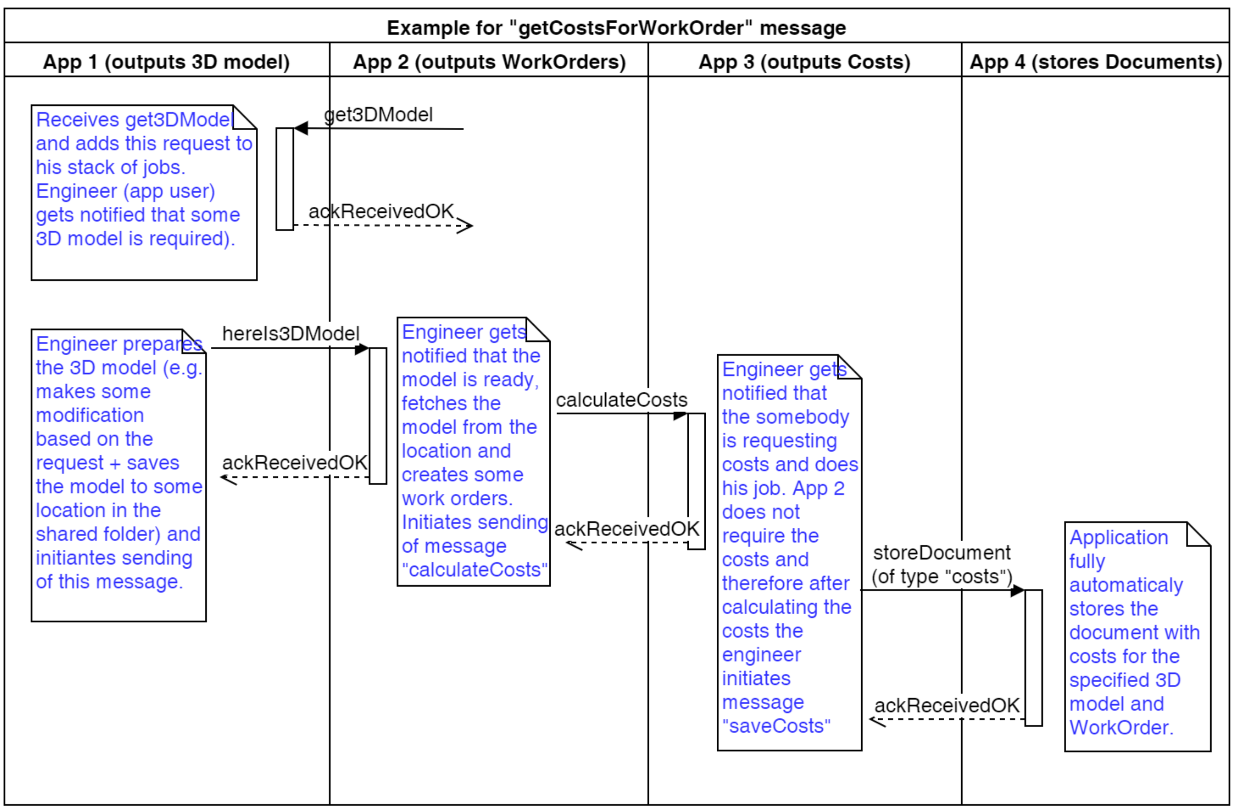

Figure 2 Messaging / data transfer concept for the PLEAIDES prototype software ecosystem

2.2.2.3. Messaging framework architecture

There are several options how the architecture of the messaging framework can be built. All options require that each software module of the ecosystem implements a communication layer (or communication API). A fundamental difference between some of the various possible architectures is centralization or de-centralization of the message flow. The figure below illustrates three types of messaging framework architectures. In case of centralized architecture (Figure 5), a message broker must be introduced into the network. The role of the broker is to check the integrity of the messages being transferred over the network and forward the messages to the correct recipients. This messaging centralization, however, does not mean that the decommissioning data is stored in a centralized manner.

The architecture using a message broker is more secure, but it may require additional efforts to configure and maintain the broker. On the other hand, a network architecture without a broker is also sufficiently robust to run the validation tests planned in this project.

It is not in the scope of this deliverable to choose the architecture that will be used in the PLEIADES concept. Future research work in the project (mostly in the Task 2.1) will lead to the final selection of a suitable architecture.

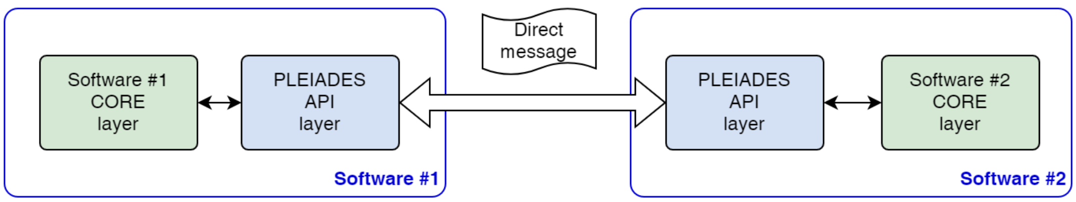

Figure 3 Messaging network architecture option #1: Direct message

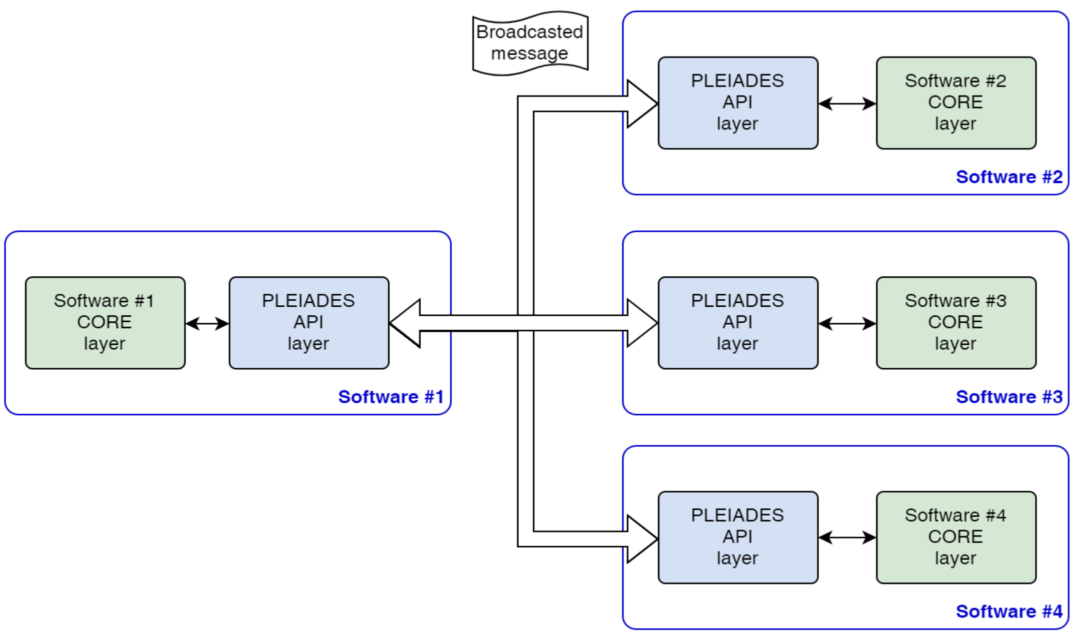

Figure 4 Messaging network architecture option #2: Broadcasted message

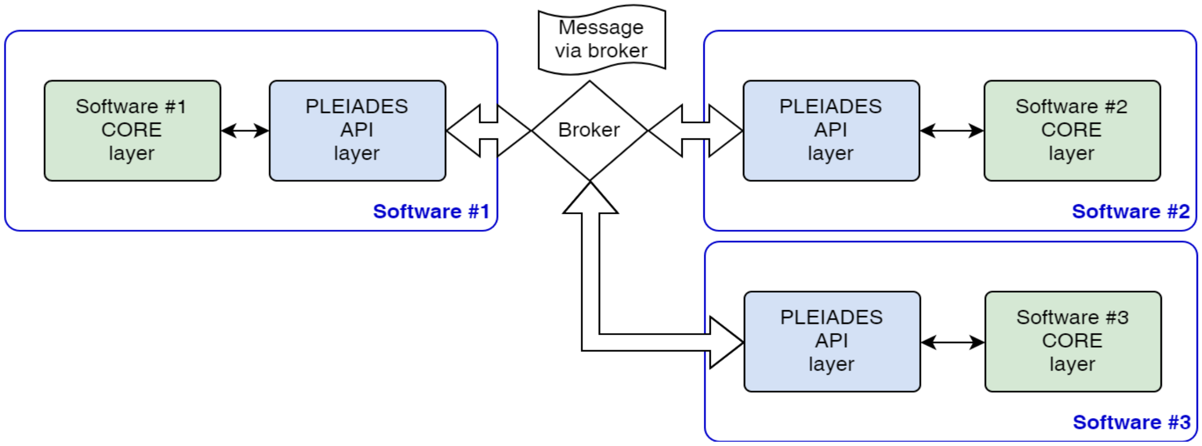

Figure 5 Messaging network architecture option #3: Message broker

2.2.2.4. Message format

While a decision on the three messaging network architectures options presented in the previous chapter has not been made yet, a message-based architecture (messaging architecture) has been selected in general as the basis for enabling mutual data/information exchange between the software modules of the PLEIADES system. It is not within the scope of this document to precisely specify the structure and content of the messages. However, some requirements can be formulated here. The final specification of the messages, their structure and content will be the scope of further work in the PLEIADES project (in WP2). The list of general requirements for software messages is summarized in the table below:

Requirement	Description
Unique identification	Each message must be uniquely identifiable across the whole PLEIADES ecosystem and during the whole lifecycle of the system.
Sender/Recipient	A message must specify its originating source (the sender) and the recipient or group of recipients. In case of broadcasting-based architecture, if applicable, and the message is dedicated to a group of recipients, it must be back-traceable who took over the responsibility of the task specified in the message.
Compatibility with ontology	Each message must be classified in terms of the ontology defined in the deliverable D1.4.
Task reference / assignment	The content of a message should clearly identify the task that should be performed. A message should not be used only for information exchange, but for assignment of certain tasks.

Data reference	The content of a message must either contain all information/inputs required by the task or, if not feasible, should clearly reference the storage or endpoint where the required data can be retrieved from.
Back traceability	Each message must be back traceable to enable identification of the responsible sender.

Table 4 Requirements for the message format and content.

2.2.2.5. Task assignment

A message should clearly specify the assignment of tasks to software tools of the PLEIADES ecosystem. Therefore, data included in messages should contain at least the following information:

- What task is to be performed?
- Who the task is assigned to?
    - Note: this information cannot be included in broadcasted messages. In that case information about who took over the responsibility of the task must be included in a dedicated separate responsibility reference table.
- Where the required input is?
- Where should the output be stored?

The main goal of including task assignments within messages is to ensure traceability of decisions. Logging all messages sent through the network in a message history allows tracing the information flow and assignment of responsibilities at any time.

2.2.2.6. Data exchange

A message should hold all input information necessary to perform a task assigned via that message. However, due to the large size of some data types required by certain tasks (mostly 3D/BIM models or point clouds), it would not be effective to include all input data directly in the content of a message.

Therefore, it is suggested to further elaborate on the following two types of data exchange architectures:

- Use shared folders for storing large files (3D/BIM models or point clouds) and include only reference to these files in the content of messages.
- For small or medium sized data payloads, it is suggested to include them directly in the content of the message.

Specification of the format for the content of the message is not in the scope of this document. However, a few basic ideas are introduced in chapter 2.4 entitled ‘Hardware infrastructure’.

2.2.2.7. Security

Security of data transfer should be ensured by using standard up-to-date mature solutions. There are two topics to be addressed here:

- Security of data transfer
- Security of data storage

As for the security of the data transfer, an authentication mechanism must be implemented. There are several open standards for such purposes, like OAuth or SAML 2.0. These solutions could include using a separate identity provider solution with configurable access permissions management. The communication flow in the process of receiving access permissions using the OAuth 2.0 standard, as an example of authentication and authorization mechanism, is illustrated in the figure below.

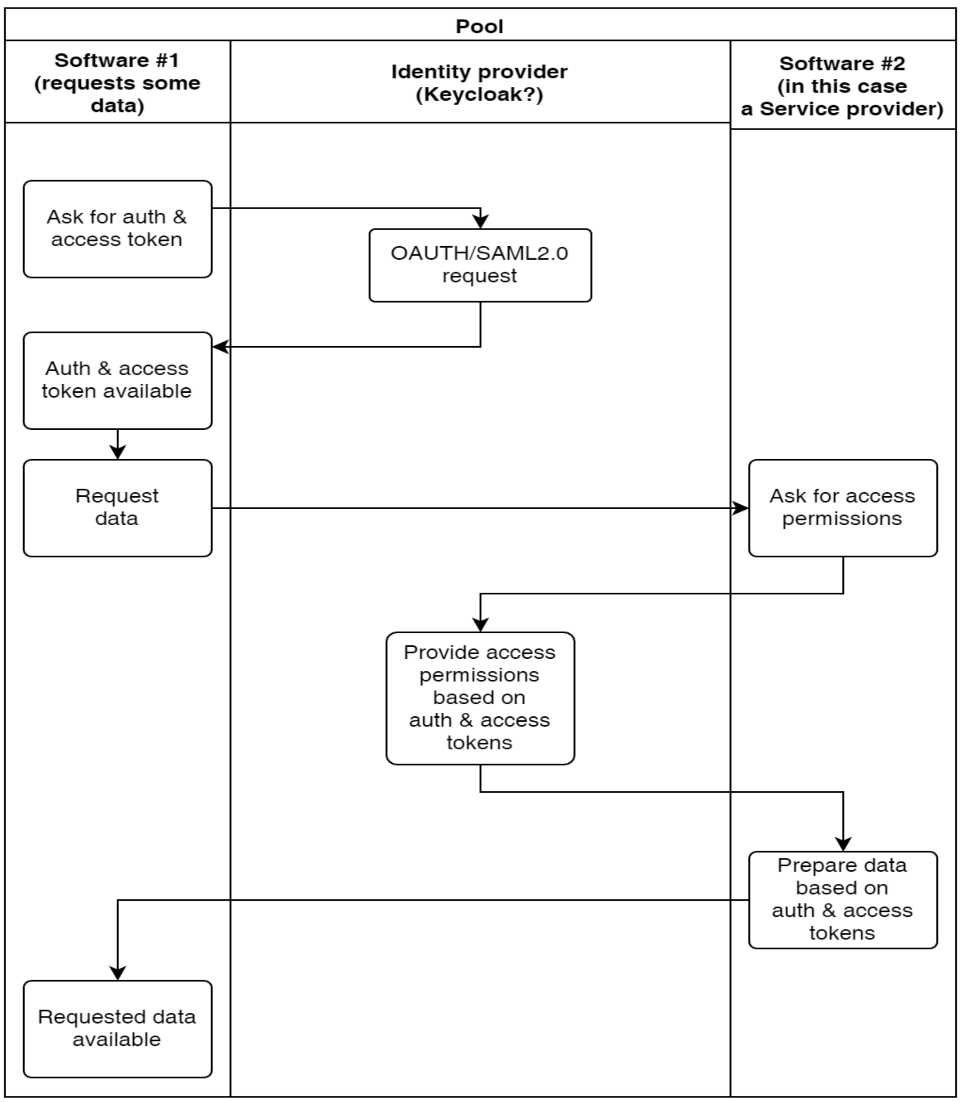

Figure 6 Illustration of authentication principles using the OAuth 2.0 standard

In addition to authentication and authorization, transfer of the data between the endpoints must also be secure. This means that the transferred data should be appropriately encrypted using hard-to-break encryption algorithms like AES256 or similar and sent over network connections using secure protocols like TLS 2.0 or similar.

As for the secure storage of the data, there were no specific requirements identified on encryption of the data on the storage infrastructure of the PLEIADES ecosystem. However, the storage infrastructure should be appropriately protected by network protection software or hardware components like firewalls, intrusion prevention systems and/or other protection systems.

2.3. Hardware infrastructure

2.3.1. General requirements

As presented in previous chapters, several technical aspects must be considered for prototype development of the PLEIADES system architecture. These aspects are summarized in the table below:

Aspect	Description
Data transfer	It must be possible to transfer data between different software tools having different software architectures. Data transfer must allow an asynchronous communication between software tools in general and specifically those within the PLEIADES ecosystem. Several possible architectures are described in the following chapters.
Data storage	The system must be able to work with large data sets like 3D/BIM models or point clouds.
Security	Security of the data transfer and data storage is of very high priority. The security level should be adequate for securing services and data / information in-transit and at-rest in the system using well known secure communication (e.g., TLS) and encryption standards (e.g., AES265). The hardware architecture must be extendable to meet the security requirements in each phase of the lifecycle of the system.
Flexibility	The PLEIADES system must be independent, e.g., any kind of application running on any kind of operating system shall be able to comply with PLEIADES standards.

Table 5 Hardware architecture requirements of the PLEAIDES system

The following diagram describes the top-level architecture of the envisaged building blocks of the hardware infrastructure of the PLEIADES system. The diagram also shows the interconnection between several other tasks in WP1 and their relationship to the blocks in the diagram. The blue middle part shows results reported in this document and future tasks building on these results (right side) specifically, tasks T1.3, T2.1 and T2.2.

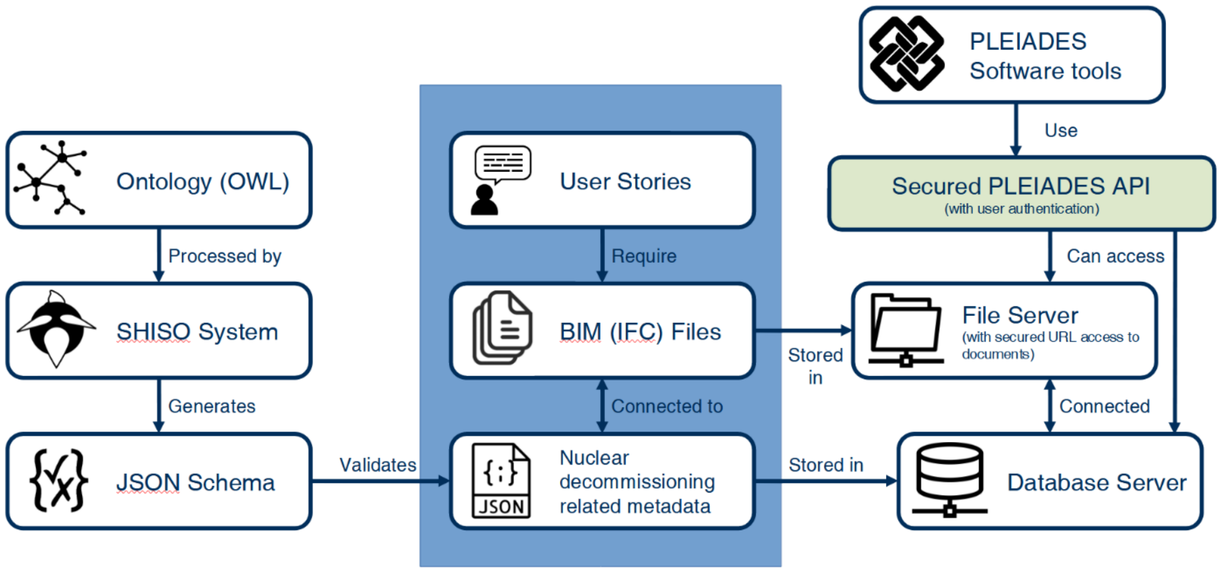

Figure 7 Top-level illustration of the envisaged building blocks of the PLEAIDES hardware infrastructure

The diagram should be understood as follows:

- The ontology and the input database must comply with the requirements identified in task 1.1.
- Compatibility of the system architecture with requirements will be ensured by the user stories described in Chapter 3. These user stories were constructed so that implementation of these stories in the PLEIADES prototype system will demonstrate compatibility of the system with most of the requirements from task 1.1.
- In a nutshell, the data formats related to the PLEIADES system include:
    - IFC files which represent the 3D model and can also store nuclear decommissioning related properties of objects (e.g., SSCs) ("BIM model" will be used to refer to such files)
    - Files containing point clouds
    - Object properties which cannot be stored in IFC files or it would be ineffective to do so. A JSON storage format is envisaged to be used for storing such data.
- Each of the above types require their own storage architecture. This architecture must be sufficiently secure and must allow URI / API access to data.

It is not in the scope of this document to precisely specify the storage formats and storage engines necessary to build the PLEIADES system. This is to be developed in further tasks, e.g., Task 1.3 'Input data/information (BIM) base design'.

2.3.2. Recommendations for hardware and/or software components

Based on the diagram in Figure 7, the following hardware and software components are envisaged for the PLEIADES system:

- A shared **network folder** for storing large files of **3D/BIM models or point clouds**. Possible solutions to consider: any document management system with API access functionality.
- **Database** storage engine for storing **nuclear** (decommissioning) **specific properties** of objects in BIM models. Possible solutions to consider: any implementation of SQL or NoSQL database engines. The current recommendation is MongoDB.
- An **authentication** and **access permissions** management solution compatible with OAuth 2.0 or OpenID standards. Possible solutions to consider: Keycloack, Okta.
- A **messaging platform** for sending and receiving messages. Possible solutions to consider: any open implementation of messaging frameworks (e.g., MQTT, Apache Kafka, WAMP, …) or a REST API developed within the project which would be made open.

All the above-mentioned possible solutions will be further investigated in *Task 2.1: PLEIADES platform architecture*.

3. Specifications for validation tests

In order to determine specifications for validation tests, user stories were developed. These user stories were developed in such a way that their implementation in the PLEIADES prototype system will demonstrate capabilities corresponding to most requirements (expectations) identified in task 1.1. The list of these capabilities was presented in Tables 1 and 2. Six user stories were developed focusing on comparison of alternatives for radiological characterization, dismantling and decontamination of building surfaces as well as, management of risks, regulatory requirements and waste management. For each user story, this document provides details on required input information, basic 3D model features, validation test procedures and expected outcomes.

The last chapter provides cross reference tables between user stories, expectations and KPIs identified in task 1.1.

Appendix 1 A provides a validation test protocol template to be used for capturing the results of validation tests and their assessments.

3.1. Input data and test environments for validation tests

The PLEIADES concept will be tested and validated using input data/information from three different nuclear sites provided by IFE, EDF and ENRESA. The input data from these sites will include 3D CAD models, physical and radiological data, BIM based database, and other input like scenario description, project scheduling, cost factors, etc. Each test model will be used in at least one of the user stories with the main focus on the following aspects:

- Scenario simulation-based comparison of alternative solutions
- Waste estimation
- Radiation exposure estimation and safety assessment
- Cost and duration estimation

Each 3D/BIM test model supplemented by a set of input data (radiological, regulatory safety related data, etc.) will serve as input data for the software tools of the PLEIADES platform in the validation tests.

3.2. User stories for validation tests

The following chapter describes six proposed user stories for validation tests. Each user story includes a description of input data and their boundaries, a test procedure and expected outcomes.

User stories #1 to #3 focus on comparison of alternative approaches to decommissioning activities such as radiological characterization, dismantling and decontamination of building surfaces. Each of these user stories will use a different 3D model and include simulations for a list of decommissioning activities.

User stories #4 to #6 depend on 3D models developed for the previous user stories and focus on management of risks, uncertainties, regulatory aspects, and waste management strategies for the selected decommissioning scenarios.

3.2.1. User Story #1 - Manual vs. remote radiological characterization

The Halden Reactor started its operation in 1958 and, for close to 60 years, hosted some of the most important fuels and materials in-core tests of the international research. The reactor has been shot down and is in the process of entering the decommissioning phase. The reactor site is located near the city centre of Halden and the reactor hall is located inside an artificial cave.

A simplified 3D model of the reactor hall was created by IFE containing no sensitive information. This model has been used as a test model for research, mainly related to digitalisation of planning and training activities. The model was created from photos, manual measurements and drawings of the reactor hall.

Due to security reasons, it will not be possible to provide laser scanned point clouds from the reactor hall. Instead, a point cloud of the boiler room of IFEs office building was created. This can be used for user stories where point clouds are needed. Other point clouds from IFE’s non security sensitive nuclear facilities will also be available.

The aim of User story #1 is to use the PLEIADES software suite for comparison of manual and remote radiological characterization plans for selected components within the Halden Reactor hall. In one scenario robots equipped with measuring devices will perform characterization. The second scenario simulates a manual characterization approach. The two scenarios will be compared in terms of different parameters like time, cost, doses and risk.

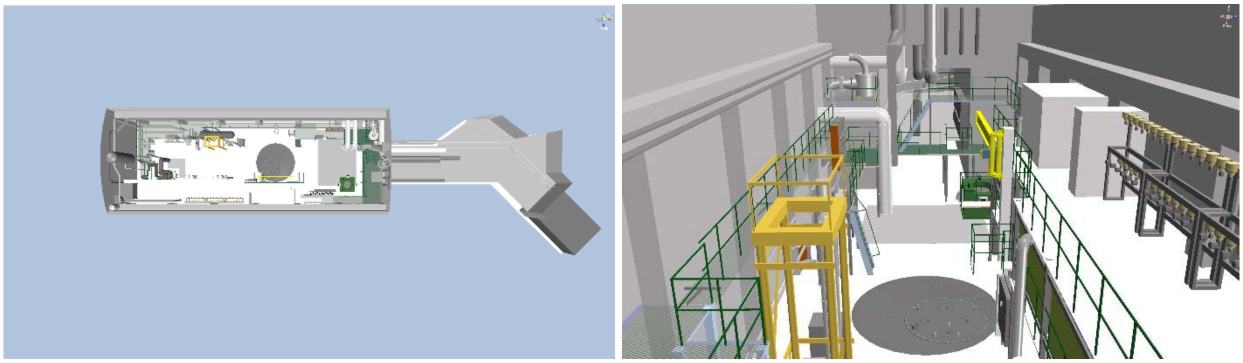

Figure 8 CAD model of the Halden Reactor hall to be used in User story #1

Figure 9 Point cloud from nuclear-like room to be used in User story #1

3.2.1.1. Input database requirements and boundaries

The input database required for the validation test must contain:

- 3D model of the reactor hall
- A point cloud of a nuclear-like room
- Radiological characterization data
- Working groups with their cost factors for both manual and remote alternatives
- A shielding plan (if applicable)
- List of radiological characterization tools and equipment for both alternatives

3.2.1.2. Test procedure

The table below lists the step-by-step sequence of actions to perform in the validation test for this user story.

#	Task/Step/Action
1	Prepare a 3D/BIM model of the area and provide at least one point cloud and information on remote measurement equipment to be used for characterization
2	Identify measuring and sampling points
3	Create a sequence of activities (a work order) both for the manual and the remote alternative
4	Develop input information for regulatory/TSO reviews and link it with the BIM model (e.g., list of SSCs important to safety, information on equipment to be regularly certified, checked…)
5	Simulate and visualize a sequence of activities in the modelled area
6	Identify missing radiological data at identified points using a dedicated software tool
7	Extend 3D model with real measured, calculated and sampled data and other relevant information
8	Verify the 3D model with point cloud model (can be performed on a different model)
9	Calculate estimated time schedule and costs for work orders
10	Calculate estimated dose exposures to workers
11	Perform sensitivity analysis on selected input parameters (identify parameter with the highest impact on costs & schedule)
12	Save all available data and test results for further analysis
13	Perform an ALARA worker safety study: assess radiological risks (e.g., identify risks related to certain SSCs important to safety)
14	Assess industrial risks (clashes, equipment overuse, heavy component transport, fire, …)
15	Identify the preferred alternative
16	Trace back and check the correctness of the decision (Browse all available data and test results and generate a relevant report.)

Table 6 Test procedure for User story #1

3.2.1.3. Expected outcomes

Comparison of two alternative options for radiological characterization activities in terms of radiological and industrial risks. Identification of parameters with the highest impact onto costs and risks (sensitivity analysis).

3.2.2. User Story #2 - 3D supported vs Digitally enhanced dismantling

Main goal of this user story is to implement a scenario and define a test procedure to compare the advantages, disadvantages, and implications that the usage of PLEIADES solution provides compared with a traditional 3D model without complementary functionalities.

ENRESA's proposal to evaluate and compare the usefulness of PLEIADES concept for dismantling purposes will be focused on the dismantling of a component located in the turbine building. The turbine building with all its components has already been modelled and it is currently being used in conjunction with a specifically designed Common Data Environment for the planning of the complete decommissioning process. The rationale behind the level of detail to which the individual components have been modelled is to provide sufficiently accurate information for the decision making, facilitate sequencing and control of the activities to be performed during the decommissioning process and provide traceability to the SSC components, waste route assignments etc.

In order to provide the required accuracy for the definition of all the individual tasks to be completed for the removal of this component a refinement in the modelling of the component will be required. The component to be removed from the plant will need to be modelled to a higher level of detail, including elements such as bolts, bindings, brackets, supports and other elements to be manipulated, either by a person or by remote controlled devices, during the process of extracting the component.

A refined model of the component to be removed will also be beneficial for training purposes of the teams assigned with the task of removing the component.

Relevant PLEIADES software tools will be used for the following purposes:

- Simulate both scenarios, identify potential risks and help in the definition of measurements to eliminate, reduce or mitigate the risks.
- Combine the 3D model of the area(s) penetrated during the work process with radiological information for enabling the modelling of contamination distribution and radiation fields. Contamination and radiation modelling will be used for deciding on the need for remote dismantling or planning protection of human workers against radiological exposure.
- Cost comparison between the two scenarios
- Schedule for the completion of the activity under both scenarios
- A multilayer 3D model will be used for training in both scenarios. The 3D model will not only show the geometry of the element(s) and the environment, but will also provide information on the radiological values of the components and a dose map of the area of interest.

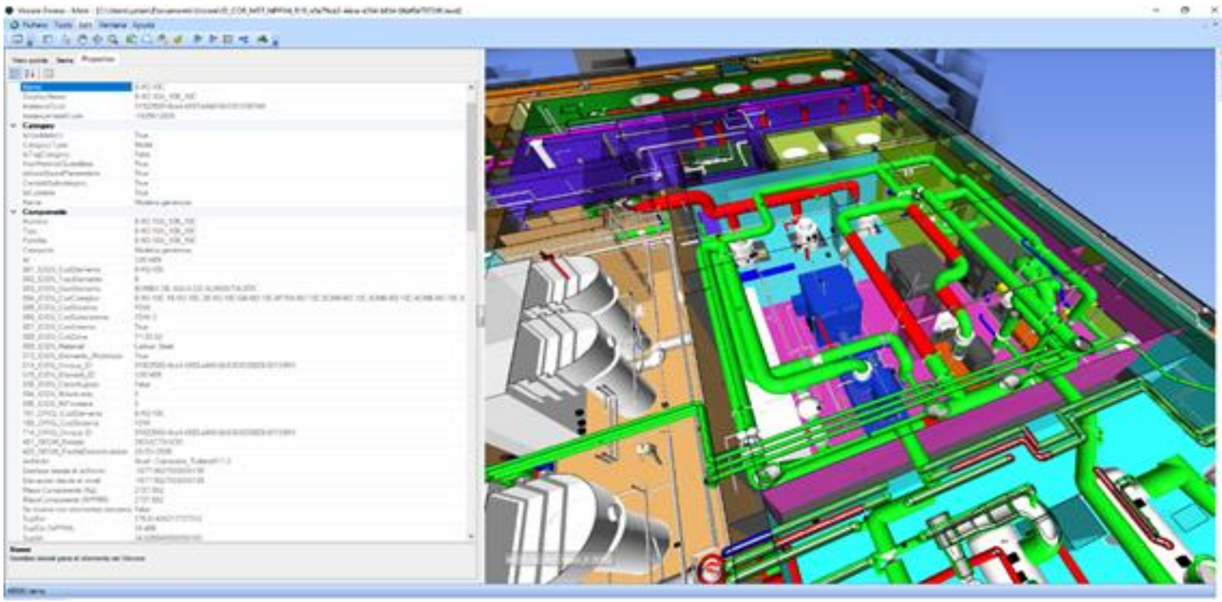

Figure 10 3D model of the environment for part 1 of User story #2

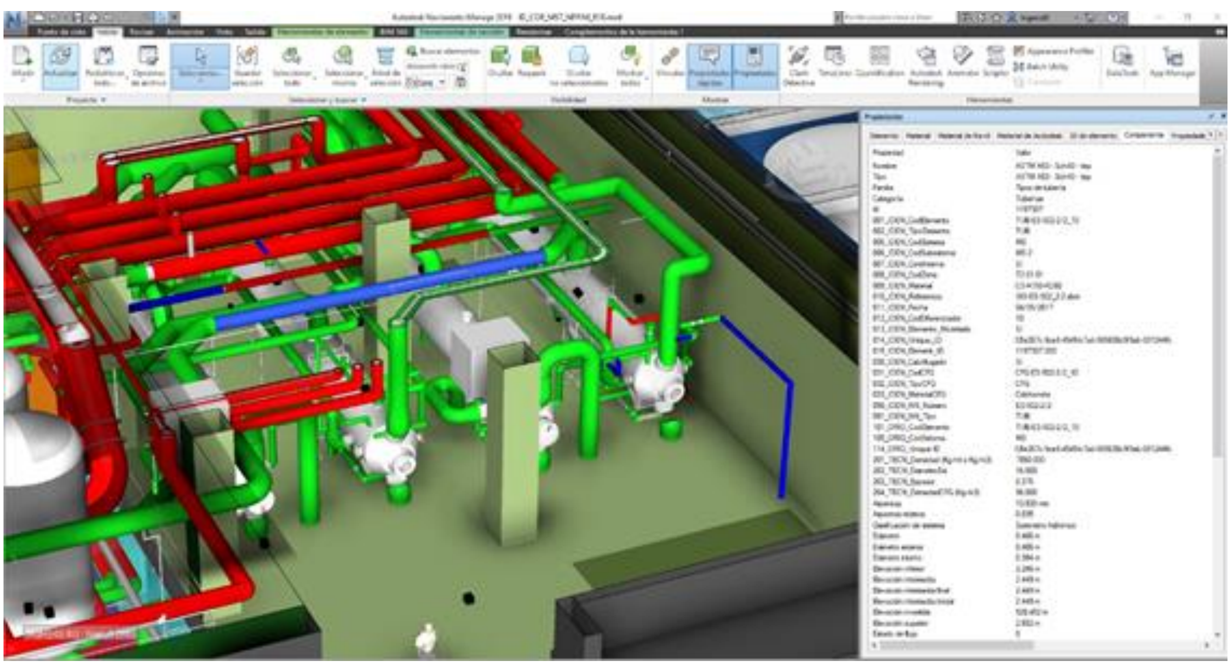

Figure 11 3D model of the environment for part 2 of User story #2

3.2.2.1. Input database requirements and boundaries

The input database necessary to run this validation test must contain:

- BIM model of the component and the surrounding area where it is installed

- BIM model of along the path to be followed by the element in its travel from its original position to the storage/treatment area
- Available design drawings and specifications of the component to be removed for its high-resolution modelling
- Available radiological characterization of the area where the component is installed
- Available radiological characterization of the transportation path to be followed by the component
- Physical parameters of the component (mass, material, thickness, density etc.)
- Information on whether the component, or the system that the component is part of, is considered relevant for safety or not
- Planning of the activities to be completed
- Resource assignments

3.2.2.2. Test procedure

The table below lists the sequence of actions for performing the validation test for this user story. When completing the procedure in the table below, performance of the PLEIADES prototype will be assessed against using more traditional methods.

#	Task/Step/Action
1	Load 3D model (optionally point cloud) of the area and models of dismantling tools to be applied
2	Increase LOD of the component to be removed in the 3D model
3	Load 3D model of the areas to be crossed by the component on its route from its original position to the final position before leaving the facility.
4	Identify and update whether the component, or the system the competent is part of, is relevant for safety or not
5	Model the dose distribution based on measurements from radiological characterization of the component and the system it is part of.
6	Model the dose distribution based on measurements from radiological characterization of the disassembly area.
7	Model the dose distribution based on measurements from radiological characterization of the transportation route.
8	Enable animation of the element in the 3D model (move, rotate)
9	Define sequence of activities (work order) with specific information for all involved disciplines
10	Estimate dose exposure of workers
11	Simulate and visualize the sequence of activities in the 3D model
12	Visualize and execute the sequence of activities in XR
13	Estimate time schedule and costs for work orders
14	Estimate waste quantities
15	Perform sensitivity analysis on selected input parameters (identify the parameter with the highest impact on waste amounts)
16	Save all available data and test results for further analysis
17	Assess the radiological risks in terms of ALARA and worker safety
18	Compare the alternative dismantling scenarios

19	Select the preferred alternative
20	Trace back and check the correctness of the decision (Browse all available data and test results and generate a relevant report)

Table 7 Test procedure for User story #2

3.2.2.3. Expected outcomes

Comparison of more conventional digital approach using 3D models against the more digitally enhanced support provided by PLEIADES for the selection of the most optimal solution for removing a large contaminated component.

Efficiency of the PLEIADES concept will be monitored in terms of dose rate, scheduling, costing and waste production, as well as safety and risk management. During the completion of this process, tasks described in the test procedure will be implemented. Including cost estimates for the activities will provide a fair comparison between simple use of a 3D models and the comprehensive digitally enhanced dismantling toolkit providing multiple functionalities. For instance, dose maps and radiological 3D models (activity/contamination maps) can be directly obtained from the set of tools included in PLEIADES, whereas producing such information using more traditional methods adds time and costs and may not provide sufficiently accurate results.

XR visualization and execution allows users to navigate and experience related work tasks in real size environments. XR visualization and execution can provide users with spatial-temporal information. This information can contain, for instance, path of workers and time spent in different stationary locations during work tasks. This output can, for instance, be used as input for estimating radiation exposure.

3.2.3. User Story #3 - Manual vs. Automated decontamination of building surfaces

The BCOT (Base Chaude Operationnelle de Tricastin) is a nuclear facility located in EDF's nuclear power plant of Tricastin. This facility was specialized in the maintenance of contaminated tools and equipment, and also served as a storage facility. Most of the tools arriving to this facility came from the nuclear power plant. The equipment treated in this facility was mostly categorized as low-level waste, and with a few exceptions of medium level wastes. Currently all waste has been removed from the facility, with the remaining contamination being restricted to walls and some support systems like ventilation and electrical systems.

This facility has been permanently closed in 2017 and will be decommissioned in the next few years. A 3D model of the facility has been created in 3 steps to support its decommissioning:

- 3D model of the facility built from 2D floor-plans
- 3D model of remaining equipment like ventilation and electrical systems
- 3D model of contamination on walls, floor and ceiling based on measurements and using a contamination propagation model

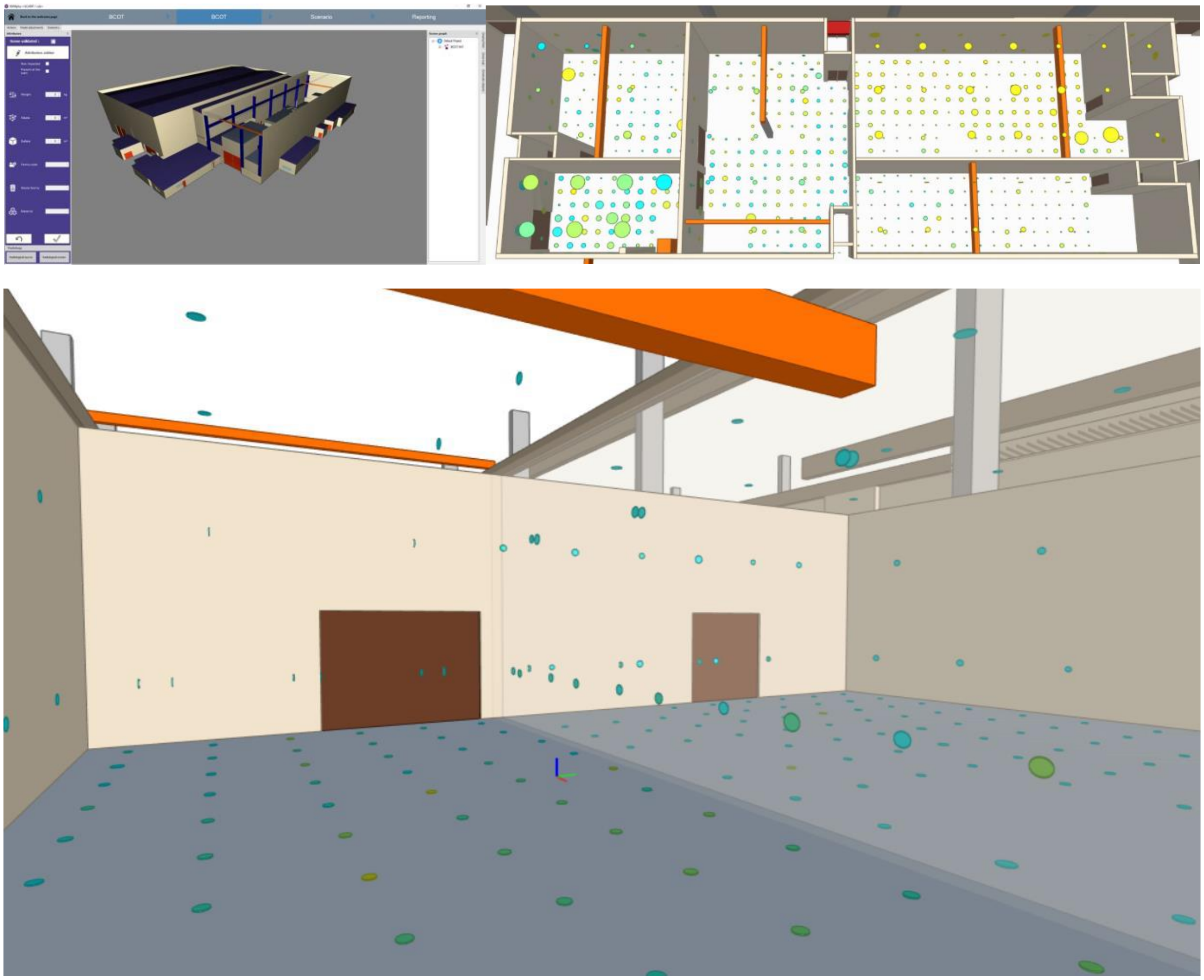

Figure 12 3D model from EDF showing surface contamination measurement results as coloured dots

Before demolition work can start, it is necessary decontaminate building surfaces in order to separate radioactive waste from the uncontaminated building structures. In user story #3 two alternatives for decontamination of building surfaces are compared (manual vs. automated).

In the scenario simulation, safety of operators is considered first priority. Thus, simulation of the work plan aims at ensuring compliance with an ALARA principle. Consequently, providing a comparison between a manual and an automated approach, both in terms of costs and dose, is required for deciding which of these two is the optimal solution.

3.2.3.1. Input database requirements and boundaries

The input database required for running the validation test must contain:

- 3D model of the room (or rooms)
- Surface contamination map
- Working groups with their cost factors for both manual and automated alternative

- List of decontamination tools and equipment for both alternatives
- 3D model of waste container(s)

3.2.3.2. Test procedure

The table below lists the sequence of actions for performing the validation test for this user story:

#	Task/Step/Action
1	Prepare a 3D/BIM model of the target area including point clouds and, optionally, models of the decontamination tools to be applied
2	Extend the BIM model with radiological maps of the area, costs, factors related to work performance and other relevant information
3	Create a sequence of activities (work order), both for the manual and the remote alternative
4	Simulate and visualize the sequence of activities using the 3D model
5	Develop input information for regulatory/TSO reviews and link it with the BIM model (e.g., list of SSCs important to safety, information related to equipment that requires regular certification and checking, …)
6	Verify the 3D model against the point cloud model (can be performed on a different model)
7	Estimate time schedule and costs for work orders (for both alternatives)
8	Estimate dose exposures to workers
9	Estimate waste quantities
10	Perform a sensitivity analysis for selected input parameters (identify the parameter with the highest impact onto dose uptake)
11	Save all available data and test results for further analysis
12	Assess radiological risks in terms of ALARA planning and worker safety (e.g., identification of risks related to certain SSCs important to safety)
13	Compare the two alternative decontamination options (manual vs. automated)
14	Identify the more optimal alternative
15	Trace back & check the correctness of the decision (Browse all available data and test results and generate a report)

Table 8 Test procedure for User story #3

3.2.3.3. Expected outcomes

Comparison of two alternative options for decontamination of building surfaces in terms of worker exposure and waste quantities. Sensitivity analysis for identification of the parameter with the highest impact on dose uptake. Optionally, evaluate alternatives for removing of the whole surface versus removing only contaminated surface areas.

3.2.4. User story #4 - Strategic risk management planning

The main purpose of this user story is to demonstrate the PLEIADES concept and its prototype installation for performing strategic planning with focus on analysis of risks and uncertainties related to the whole site (or areas targeted by upcoming decommissioning activities) in general, rather than for selected decommissioning scenarios. The focal point of this user story will be providing a risk overview using 3D models, component specific information relevant for risks impacting on upcoming work and a risk-register providing a specific risk focused overview within the site or area.

From a more general perspective, this user story will aim at demonstrating novel ways for data management using 3D models and BIM concepts, based on the related user needs and requirements from task 1.1 of this project. Some of the most important keywords related to new data management capacities include aggregation, filtering, and checking completeness of data required for strategic decision making within a site, facility or area. In this project, such capabilities will be based on exploitation of the BIM concept for providing a natural way for organizing risk related and other data, taking into account the configuration of the site or facility. Such data organization makes it possible to aggregate and filter data for a specific component, or a multitude of components that may play a major role in upcoming work or the characteristics of which may determine strategic decisions about choosing the optimal dismantling and waste management approaches.

In a timeline, this user story would proceed the other user stories listed in this chapter, as such strategic decision-making processes would, typically, be taken first, before developing details of specific scenarios after the general decommissioning approach has been decided. However, responses to our survey on user needs and requirements indicated that specific scenario simulation and analysis-based capabilities had a higher priority than more the more general capabilities demonstrated in this user story. The reason for this may simply be the pre-conditioning of the respondents, who may have primarily been exposed to demonstrations of 3D modelling enabled decommissioning support concepts that exploit scenario simulation related capabilities.

3.2.4.1. Input database requirements and boundaries

Input data required for this validation test must contain:

- All input and output data from user story #1
- Specification of the final state of the site or facility
- National waste management infrastructure and waste acceptance criteria
- List of risks associated with certain objects in the BIM model

3.2.4.2. Test procedure

The table below lists the sequence of actions to perform as part of the validation test of this user story:

#	Task/Step/Action
1	Import the 3D model of the area developed in User story #1
2	Import all available data, test results and the generated report from User story #1
3	Check the data management capabilities of the software suite, e.g., aggregation, filtering, checking completeness of 3D and BIM models
4	Develop a risk register for a specific scenario or risks associated to certain objects in the BIM model
5	Perform strategic risk analysis
6	Identify main risks and uncertainties related to, for instance, various end state decisions, availability of waste management infrastructure, etc.

7	Save all available data and create reports for further analysis

Table 9 Test procedure for User story #4

3.2.4.3. Expected outcomes

The expected outcomes of this user story can be grouped in two categories:

1. 3D modelling and simulation-based capabilities for strategic analysis of alternative decommissioning approaches (e.g., manual vs. robotic, on-site waste management vs. rip and ship, system decontamination first or not, etc.) focusing on risk and uncertainty management
2. Identifying where data may be missing or not in line with data quality objectives and hence being insufficient for taking a strategic decision

3.2.5. User story #5 - Regulatory/TSO review capabilities

This user story depends on results from User story #1 or #3 and is focused on the following tasks:

- Review process: Regulatory/TSO review related to the work plans from User story #1 or #3 regarding feasibility of the sequence of work activities, safety and conventional risks, and
- Inspection process: compliance with safety criteria, identification of SSCs important for safety.
- Possible option: Provide a virtual visit by the regulator/inspector not involved in the work

3.2.5.1. Input database requirements and boundaries

The input database for this validation test must contain:

- All input and output data from User story #1 or #3
- Regulatory criteria for nuclear/radiological and industrial safety

3.2.5.2. Test procedure

The table below lists the sequence of actions for the validation test based on this user story:

#	Task/Step/Action
1	Import the 3D model developed in User story #1 or #3
2	Import the related available radiological data developed (in User story #1 or #3)
3	Import the sequence of activities for a given task from User story #1 or #3
4	Check the source term considered for the sequence of activities
5	Check SSCs important for safety considered in the sequence of activities
6	Check techniques and related data (e.g., handling means, decontamination, cutting works, release fraction, ...)
7	Check work forces (team of workers)
8	Perform sensitivity analysis to check the feasibility of the sequence of activities, the radiological risks in terms of ALARA and worker safety (deterministic approach)
9	Check industrial risks (clashes, equipment overuse, heavy component transport, fire, ...)

10	Identify findings for safety (compliance with safety criteria, alternatives options)
11	Identify findings for inspection purposes using XR for visualization and execution (equipment important for safety, work force)
12	Save all available data and created reports for further analysis for possible virtual illustration of findings

Table 10 Test procedure for User story #5

3.2.5.3. Expected outcomes

Review of the documents related to the decommissioning scenarios in User story #1 or #3. Inspection report for the same scenario containing information on compliance with safety criteria in general related to specific SSCs important for safety. An optional outcome is a demonstration of a virtual visit by the regulator/inspector to the site.

XR visualization where the user can observe the environment and attach virtual post-it notes with information on e.g., safety issues. These notes will be attached to specific coordinates within the whole 3D model or objects of the model.

3.2.6. User story #6 – Strategic waste management planning

This user story focuses on analysis of decommissioning scenarios from a waste management strategy perspective. Material composition and radiological properties of each component of the 3D model can significantly affect decisions on waste treatment techniques and strategic waste management plans. Analysis of several alternatives assuming different material properties for SSCs allows an agile planning process with preparedness for deviations in assumed waste classes/quantities and related waste management costs.

One of user stories #1, #2 or #3 will be applied as the input for this analysis.

3.2.6.1. Input database requirements and boundaries

Input for this validation test must contain:

- All input and output data from the selected user story (user story #1, #2 or #3)
- Quantities of various waste with corresponding radiological data
- Description of the waste management strategy and available waste management infrastructure
- Provisional waste acceptance criteria to be applied

3.2.6.2. Test procedure

The table below lists the sequence of actions for the validation test based on this user story:

#	Task/Step/Action
1	Import the 3D model of the area developed in the selected user story
2	Import available radiological data and waste quantities from the selected user story

3	Extend 3D model with available radiological data and waste acceptance criteria
4	Configure two alternatives for material/waste composition of equipment in the 3D model
5	Calculate quantities of generated classified waste and corresponding ISDC costs for dismantling
6	Analyse alternatives for generated waste quantities, optionally waste treatment and disposal possibilities and identification of related risks for both alternatives (if relevant)
7	Save all available data and created reports for further analysis
8	Take the decision (select preferred waste management strategy)
9	Check the correctness of the decision (Browse all available data and test results and generate a relevant report)

Table 11 Test procedure for User story #6

3.2.6.3. Expected outcomes

Sensitivity analysis for the selected user story in terms of different possible material compositions of SSCs, resulting waste quantities and related waste management costs.

3.2.7. User story requirements coverage and KPIs

The following table shows the complete list of requirements reported in D1.1 (in rows) and, for each requirement, a list of the user stories (in columns) that address that specific requirement.

#	Requirement	User Story					
		#1	#2	#3	#4	#5	#6
R001	Aggregate all radiological data in a 3D model based interface including historical data				☺		
R002	Filter radiological data (based on SSCs, time, status, DQOs)				☺		
R003	Improve control over data management				☺		
R004	Mapping the completeness of inventory (filter: missing / estimated / validated)				☺		
R005	Comparison of alternative detailed plans in terms of dose	☺	☺	☺			
R006	Better understanding of work plans	☺	☺	☺		☺	☺
R007	Detection of physical clashes	☺	☺		☺		
R008	Estimating radiological exposure to workers	☺	☺	☺	☺		
R009	Improve training by use of 3D visualization	☺			☺		

R010	Improve current safety demonstration practices	☺	☺	☺	☺		
R011	3D model based facility/site overview of risks (risk register) – identification of critical risks, filtered risk information				☺		
R012	Improve uncertainly estimations				☺		
R013	Better anticipate unforeseen				☺		
R014	Identify parameters with highest impact onto project performance	☺	☺	☺	☺	☺	☺
R015	Trace back decisions (who, why…)	☺	☺	☺	☺	☺	☺
R016	Compare 'as planned' with 'as performed' data					☺	
R017	Detect discrepancy between predicted ALARA estimates and data from monitoring during implementation					☺	
R018	Benchmark cost estimates using data from completed tasks						
R019	Improve updating of cost estimates in case of deviation from assumed inventory	☺					
R020	Regularly update information on location of items – traceability from initial to final location						☺
R021	Optimize waste streams		☺	☺			☺
R022	Compare alternative waste routes (costs, time, …)		☺	☺			☺

Table 12 List of functional requirements and their coverage by user stories.

The list of KPIs identified in the gap analyses reported in D1.1 and the possibility of their coverage in each user story is displayed in the table below:

#	KPI Name	User Story					
		#1	#2	#3	#4	#5	#6
1	Cost reduction	☺	☺	☺			
2	Exposure reduction	☺	☺	☺	☺		
3	Schedule improvement (speed)	☺	☺	☺		☺	

4	Time/effort for regulatory/review approval (licensing)					☺	
5	Waste reduction/optimization		☺	☺			☺
6	Training effectiveness				☺		
7	Effective use of resources (nr of people, waiting time, ...?)	☺	☺	☺		☺	
8	More flexible planning (time for update in case of deviation?)	☺	☺	☺	☺	☺	☺
9	Investment (time, cost) required	☺	☺	☺			☺

Table 13 List of KPIs and their foreseen coverage in the six user stories.

3.3. Test protocols from validation tests

The protocol template prepared for the documentation of the results from the planned validation tests is provided in Appendix 1. A test protocol template will be completed for each of the six user stories, documenting a basic description of used input data, the sequence of activities (scenario) including estimated durations, software tools of PLEIADES platform used, requirements from D1.1 addressed, KPIs applied for evaluation and some final notes.

4. Conclusion

Chapters of this document provided a description of the work performed in this project, to date, providing the following outcomes:

- Functional and technical requirements for the PLEIADES system architecture have been formulated
- Basic concepts of data transfer and task assignment between the tools of the PLEIADES software ecosystem, using semi-automated mechanisms, have been proposed and/or specified (where applicable)
- User stories have been developed with specification of test procedures (sequence of tasks to be performed in each test), as well as input and output boundary conditions
- A test protocol template for the documentation of validation tests results has been developed

Results from deliverable D1.1 and deliverable D1.4 have been used as an input for the work described in this report.

The functional specifications reported in this (D1.2) document will be used as an important input to develop the platform architecture in WP2 of this project. More specifically, the functional and hardware requirements defined in this document, combined with outcomes from D1.3, will be the primary basis for the work in *Task 2.1 'PLEIADES platform architecture'* and will ensure the completeness of the developments in *Task 2.2 'PLEIADES platform interfaces design'*.

One of the validation tests will also be used as a general test case to validate the overall PLEAIDES platform and the interfaces between the software tools of the platform. This validation will be performed in *Task 2.4 'Validation tests'*. All validation tests specified in this report will be performed within WP3 of this project.

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5.3. Further reading

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Appendix 1 Template for test protocols

Excel spreadsheet: PLEIADES D1.2 Test protocol template

PLEIADES D1.2 Test protocol template

Name of the user story:	**User Story #X**
Date of validation test run:	DD/MM/YYYY
Input data description:	e.g. For this test run the input data for manual radiological characterization was used.

Tool	**Used in the test**	**Note**
3DScanPF	Yes/No	
Aquila costing		
ARWorkflow ALVAR BIM Access		
BimSync		
DEMplus		
DIM tool		
iDROP		
IMS		
Interact		
LLWAA		
RadPIM		
VRDose		

No.	**Test/Action/Step**	**Performed**	**Estimated duration (days)**	**Note**
1	*List relevant tasks from test procedure for the given user story*	Yes/No		
2		Yes/No		
3		Yes/No		
...				

Req. No.	**Requirements from D1.1 gap analyses**	**Relevant for the user story**	**Covered**	**Note**
R001	Aggregate all radiological data in a 3D model based interface incl. historical	Yes/No	Yes/No	
R002	Filter radiological data (for SSCs, time, status, DQOs)			
R003	Improved control over data management			
R004	Mapping completeness of inventory (filter: missing / estimated / validated)			
R005	Compare alternative detailed plans in terms of dose			
R006	Better understand work plans			
R007	Detect physical clashes			
R008	Estimate radiological exposure to workers			
R009	Improved training by use of 3D visualization			
R010	Improve current safety demonstration practice			

R011	3D model based facility/site overview of risks (risk register) – identify critical risks, filter risk info			
R012	Improved uncertainly estimations			
R013	Better anticipation of unforeseen			
R014	Identify parameters with highest impact onto project performance			
R015	Trace back decisions (who, why…)			
R016	Compare ‘as planned’ with ‘as performed’ data			
R017	Detect discrepancy between predicted ALARA estimates and data from monitoring during implementation			
R018	Benchmark cost estimates using data from completed tasks			
R019	Improve updating of cost estimates in case of deviation from assumed inventory			
R020	Regularly updated info on location of items – traceability from initial to final location			
R021	Optimize waste streams			
R022	Compare alternative waste routes (costs, time, …)			

KPI No.	**KPI name**	**KPI evaluation**	**Comparison of scenarios**	**Note**
1	Cost reduction	% / text answer / NA	Yes/No/NA	
2	Exposure reduction			
3	Schedule improvement (speed)			
4	Time/effort for regulatory/review approval (licensing)			
5	Waste reduction/optimization			
6	Training effectiveness			
7	Effective use of resources (nr of people, waiting time, …?)			
8	More flexible planning (time for update in case of deviation?)			
9	Investment (time, cost) required			

Final Notes
