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PLEIADES, the Smarter Plant Decommissioning SZÖKE, I.^{1*}, JACQUES, M-B.², BORRMANN, F.³

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Abstract

CEA coordinates PLEIADES, an international project within the framework of the European H2020 NRFP2019-09 call for projects, which aims at fostering innovation in the decommissioning of nuclear facilities, by developing a digital decommissioning approach.

The idea is to inspire from the BIM (Building Information Modelling) concept, which enables all the information related to the construction of a new building to be managed in a single 3D model. Adapted to the dismantling of a nuclear installation, PLEIADES will gather in a BIM-like model all the data useful for defining scenarios, improving safety, minimising radiation exposure, optimising costs and schedules and carrying out the work. PLEIADES will develop a platform including a set of innovative modules, developed by most of the partners, based on simulation technologies.

For such purpose, the PLEIADES project aims first at defining the requirements and specifications, and to specifying a common ontology for nuclear decommissioning. Based on these specifications, a platform will then be developed and will enable the software modules to exchange data thus providing customers a better use of existing data by multiple tools.

Next, the platform will be implemented on three real cases of nuclear facilities, a research reactor, a nuclear power plant and a maintenance facility. The implementation on these different kinds of facilities will enable to highlight strengths and weaknesses of such a digital approach.

In parallel, an associated methodology will be developed to help capitalize data generated and knowledge during the decommissioning process. PLEIADES will indeed establish a standardised process to organise the data collected throughout the project in datasets. It will also use codebooks to accompany datasets, providing authoritative and quotable information, as well as instructions on how to read, analyse, interpret, and verify data for accuracy and replication purposes.

Last, the PLEIADES project aims at defining the exploitation strategy of the project outcomes. It deals with assess the market potential and prepares exploitation scenarios with organisations involved in the project and end-users activated through the Stakeholders group. A comprehensive exploitation strategy with preliminary business plan will be delivered, a baseline scenario via an EEIG (European Economic Interest Grouping) has been sketched before. A focus will also be given to launch a strategy that will promote trainings for the application of 3D models in decommissioning, interact and coordinate with existing initiatives and raise awareness towards young generation of scientists and engineers.

Introduction

In the next decades, more than 400 nuclear facilities, hundreds of fossil power stations and an unnamed number of chemical plants will face decommissioning. While the nuclear power station decommissioning is mainly based on national decisions (such as the phase out in Germany) and on the technological obsolescence (such as the low power rated graphite moderated, gas cooled reactors in France and UK), the overall decarbonization strategy is set by the Paris Climate Agreement. Thus, it will be inevitable to find ways of decommissioning and deconstruction of various facilities in an efficient and cost-oriented manner. PLEIADES aims at the reuse of data generated by the application of 3D modelling and BIM applications and at cost-saving measures and digitalization also of the deconstruction phase of a building and plant lifecycle. Fleet approaches, digitalisation of the overall decommissioning process also relies on the application of modern and appropriate planning and controlling tools. BIM applications and 3D modelling (i.e., for radiation protection calculations) offer added value in all phases of decommissioning. It is also an aim of PLEIADES to provide evidence for such added value and cost saving through the exemplar application in different facility types.

The main aim of the PLEIADES project is to demonstrate a modular software ecosystem based on the connection of front-line support tools through an interface built on decommissioning specific ontology that integrates OpenBIM.

The expected results of the project are foreseen to:

- Improve safety, specifically by providing improvements in radiological protection, communication between stakeholders and training of workers.
- Reduce costs by enabling better and more standardized costing, as well as higher optimization of the waste management process.

There are three central ideas / motivations behind the PLEIADES project:

1. Support for holistic approach

The use of 3D modelling and simulation based innovative concepts are increasingly emerging, but most examples are for specific use cases. More general adoption is, however, hindered by the lack of clear evidence proving cost efficiency (the business case) for using such advanced 3D techniques. At the same time, it seems quite clear that the business case for the use of 3D concepts can be much improved simply by thinking about the use of 3D models as an asset in various tasks including information management, costing, planning, communication, etc. Hence, one of the core ideas behind the PLEIADES project is demonstrating the use of 3D models in a holistic approach as a general project implementation tool, rather than a specific solution for a specific task. In this approach, 3D models and associated data provides input for an ecosystem of more general and purpose-built tools providing capabilities for key decommissioning tasks. Figure 1 visualizes a high-level system design for such an ecosystem of support tool types that can benefit from information stored in information rich 3D models.

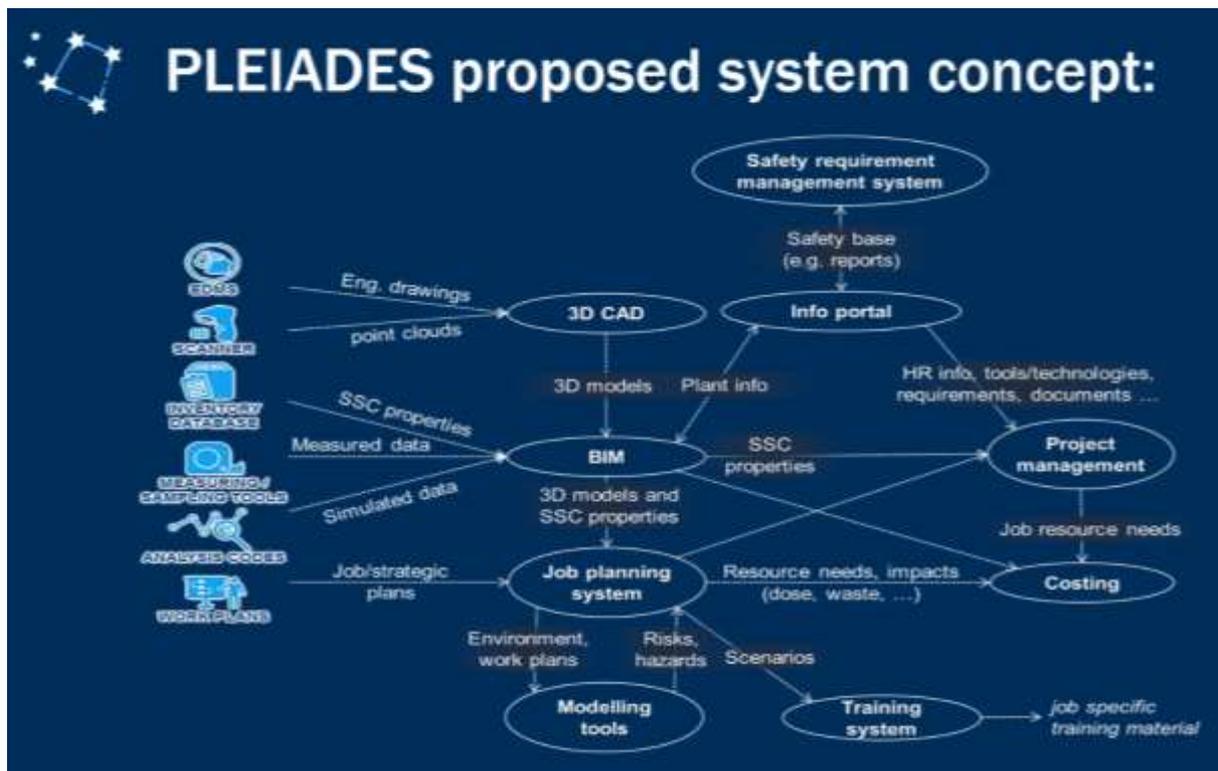


Figure 1 PLEIADES concept – software ecosystem for holistic, safety focused, support

2. Higher independence from vendors

As mentioned above, modern techniques based on the use of 3D models are emerging. Due to the lack of standardization in the nuclear industry for the use of 3D modelling and simulation-based techniques

users are typically constrained by the offerings of a specific technology provider. Vendors providing various 3D modelling and simulation based innovative solutions are emerging and it is foreseen that solutions offered by such vendors will, in the near future, cover most of the tasks where 3D models can provide benefits. However, the use of several such tools typically requires extensive manual efforts for data/information transfer between the tools or massive in-house system integration efforts. Hence, another core strategic aim of PLEIADES is demonstrating how systems/solutions from various vendors (in this project those represented by the project consortium members) can be semantically integrated into a software ecosystem using a nuclear decommissioning specific *ontology*. Figure 2 shows how the 12 modules of the PLEIADES ecosystem can cover the whole value chain ranging from data acquisition, through decision making and up to training.

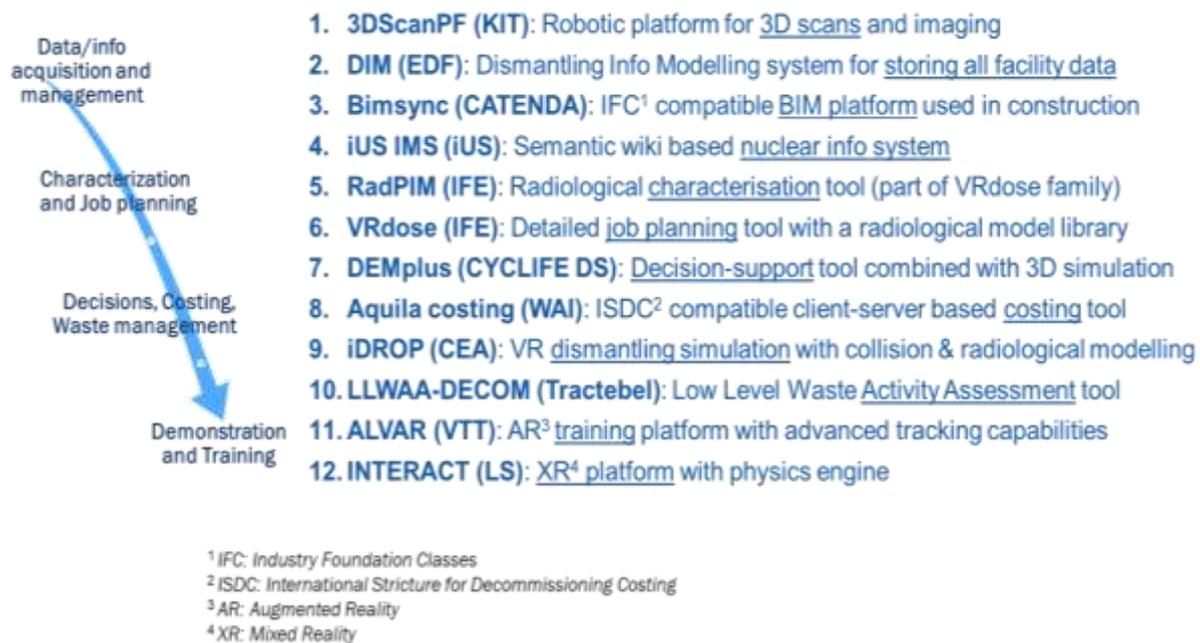


Figure 2 PLEIADES software modules provided by the project consortium members

3. Advanced tech support

The third core idea behind PLEIADES is to demonstrate integration of advanced tools representing the cutting-edge technology available in a modular concept. This modular approach is in contrast to some other solutions offered, typically by large vendors that integrate all functionalities in one single multi-purpose tool. In the PLEIADES concept, the user can apply each module independently or in parallel as required by the goal / discipline of the user and according to the current needs of the project.

Project developments started, primarily, with the project focusing on analysing requirements and eliciting specifications to be used for designing the PLEIADES software architecture and planning the final validation tests aiming at demonstrating the concept and the prototype system through realistic user stories. This was divided into 4 sub-tasks:

- Task 1.1 Requirements set-up for the design of the PLEIADES concept
- Task 1.2 Specifications development for the PLEIADES system prototype & validation tests
- Task 1.3 Input data/information (BIM) base design
- Task 1.4 Ontology generation

Tasks 1.1, 1.2 and 1.4 are just, at the time this paper was prepared, being concluded. Summaries from the results from these tasks are provided later in this paper.

Most of the results of this stage will be used as key input for the main technical developments and demonstration tests. Detailed identification of requirements, expectations, key performance indicators

(KPIs), barriers and enablers in task 1.1 will ensure that all software developments and demonstrations will be in line with actual needs of the industry, the effectiveness of concept can be measured against KPIs defined by practitioners, and important foreseen blockers are considered in an early system design phase. *Figure 3* illustrates how outcomes will be utilized as input for further developments in other work packages of the project. *Figure 3* also shows that some of the results, in addition to being used as input for further developments, will be reported as independent results that can be taken advantage of in other national and international developments. The most important results to be mentioned here are:

1. Conclusions from the gap analysis resulting in general knowledge about user requirements related to more holistic application of digital support concept in nuclear decommissioning, and
2. A nuclear decommissioning specific ontology that goes beyond the scope of this project and will provide an important input to international developments towards harmonization of knowledge management within nuclear decommissioning

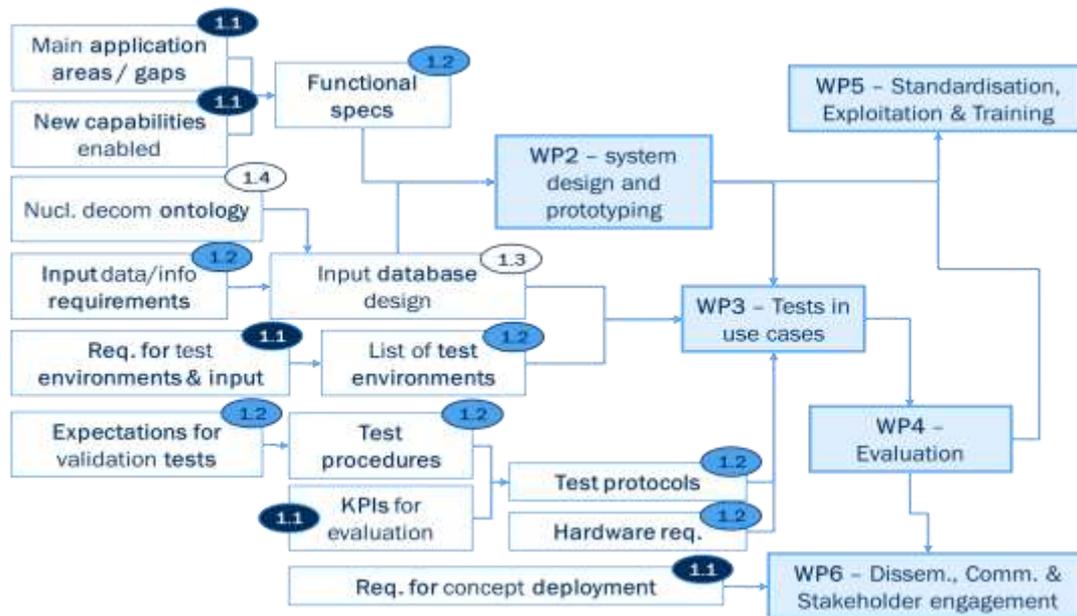


Figure 3 Relation of the tasks described in this paper and their relation to on-going and future work in the Project

Achievements

Requirements set-up for the design of the PLEIADES concept:

The need and requirement analysis activities performed in the project resulted in detailed information about user needs, expectations (of potential users towards emerging digital support concepts like the one developed in PLEIADES), requirements (both of the foreseen users towards the technology provider and vice versa), key performance indicators, as well as blockers and enablers (impacting on possibilities for adoption of the digital support systems proposed by PLEIADES). This gap analysis started with the consortium partners launching an online questionnaire based survey for gathering input from a large international audience and concluded with a short summary providing a list of high priority common (re-occurring) needs, expectations, KPIs and requirements. This summary is prepared by summarizing (and grouping) the input that received at least three votes at the group session dedicated to PLEIADES on the DigiDecom 2021 workshop. Since the summarized and prioritized results of the questionnaire survey was provided as a base for informing the group discussions, these conclusions also integrate results from the questionnaire survey and direct inputs provided by the project consortium partners.

Below is a stepwise description of how the final conclusions were obtained starting from the questionnaire analysis results:

1. Gathering responses through a detailed on-line questionnaire: Project consortium partners were also allowed to complete the questionnaire.

2. Summarizing the questionnaire results in interactive sessions with the consortium partners: Project partners provided direct input through complementing or interpreting responses to the questionnaire.
3. Using the summarized questionnaire results for identifying high priority needs and requirement, as well as KPIs, blockers and enablers through topical interactive on-line group sessions at DigiDecom 2021. These sessions took advantage of an online collaboration tool that allowed the participants to provide input (in the form of digital sticky notes) and to vote on all the notes provided by all the participants within an online voting session.
4. Preparing conclusions: Input that received three or more votes was summarized by the consortium partners and reported in the 'Requirements for concept design' deliverable document, that is foreseen to be published via the on-line EU project portal by the time of the DEM 2021 conference.

Below we are providing a short summary from the conclusions of the gap analyses described above.

Identified needs mostly focused on:

- 3D/BIM based inventory management with focus on risks (e.g., radiological)
- Scenario simulation for analysis/optimisation of work plans
- Safety and risk management
- Waste route planning
- Monitoring

Expectations of the respondents towards the foreseen PLIADES concept and prototype implementation can be summarized under the same topical areas.

Recommended KPIs are related to benefits in terms of: 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, and 8. More flexible planning VERSUS Investment (time, cost) required

Requirements towards the foreseen end users of the PLEIADES system:

- Level of expertise in (e.g., rad. protection)
- Unique identifiers for items structures systems and components (SSCs), their segments and waste packages
- Availability of input for modelling waste streams (waste factors, etc...)
- Capabilities for keeping information up to date
- Dedication of internal human and other resources
- Timing of system implementation (earlier is better)

Requirements towards the technology provider:

- Positive economic feasibility (investment vs. benefits)
- Acceptance by different stakeholders (regulators, technical support organisations, management)
- Long term support by the system provider
- Intuitive user-friendly interface
- Data security (security updates, secure data transfer, barriers between software modules, access rights/control, cloud solution vs. local installation)
- System flexibility (Platform / op. 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

Specifications development for the PLEIADES system prototype & validation tests:

The work 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.

The scope 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 above-mentioned user stories were developed in order to determine streamlined specifications for validation tests to be completed toward the end of this project. 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 previously. 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, required input information, basic 3D model features, validation test procedures and expected outcomes were specified in this task. 3D models and other facility information to be used as input for the validation tests were provided by three partners of the PLEIADES consortiums (IFE-Norway, ENRESA-Spain and EDF-France) (Figure 4). Three demonstration sites have been preselected for the PLEIADES platform implementation tests:

- Base Chaude Opérationnelle du Tricastin (BCOT), a nuclear maintenance facility in France (Bollène)
- The Halden Research Reactor, a nuclear research facility in Norway (Halden)
- Santa María de Garoña (SMG), a nuclear power plant in Spain (Burgos)



Figure 4 3D models of the nuclear facilities provided by IFE (left panel), ENRESA (middle panel) and EDF (right panel)

In addition to providing the six user stories, task 1.2 also supported the future work in PLEIADES by laying the groundwork for the technical developments towards a detailed software system architecture. Figure 5 provides an easy-to-understand overview of the current top-level vision of the PLEIADES system architecture. The figure also illustrates the connection of task 1.2 to the two most important outcomes from other tasks: 1. user requirements from task 1.1 that were used as a base of the user stories and 2. nuclear decommissioning specific ontology from task 1.4. Figure 5 clearly depicts that the ontology and the input database will comply with the requirements identified in task 1.1. Compatibility of the system architecture with requirements will be ensured through the user stories. 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 (Industry Foundation Classes) 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 (JavaScript Object Notation) 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 (Uniform Resource Identifier) / API (Application Programming Interface) access to data.

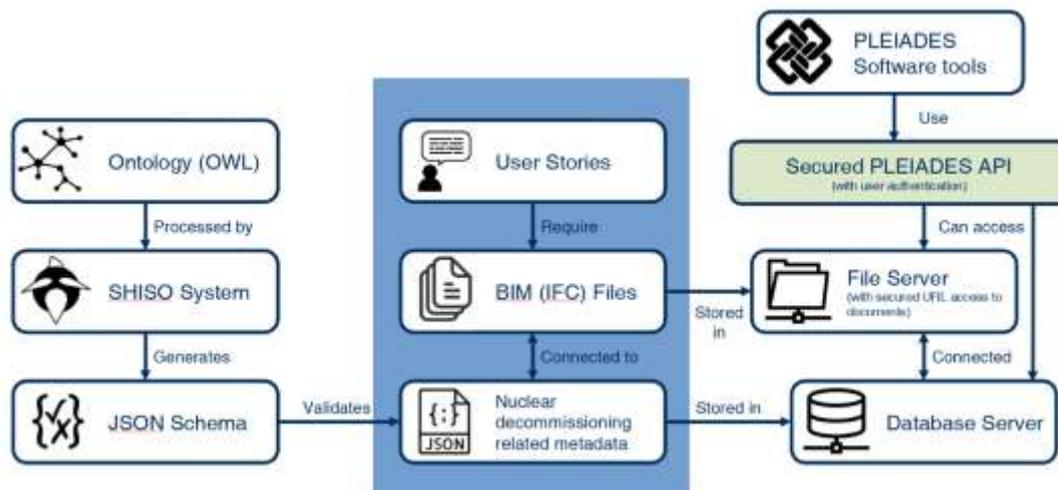


Figure 5 Top-level illustration of the envisaged building blocks of the PLEIADES hardware infrastructure

Generation of a Core Decom Ontology

As many of the software packages exist de facto and bring along their own history of terms and concepts, it was concluded, that a pure terminology-based approach has good chances to fail. This is why the application for such a grant already contained the idea of a common ontology. An ontology is a collection of concepts and the underlying properties that connect the concept. More of this is to hear in an additional presentation on the ontology generation.

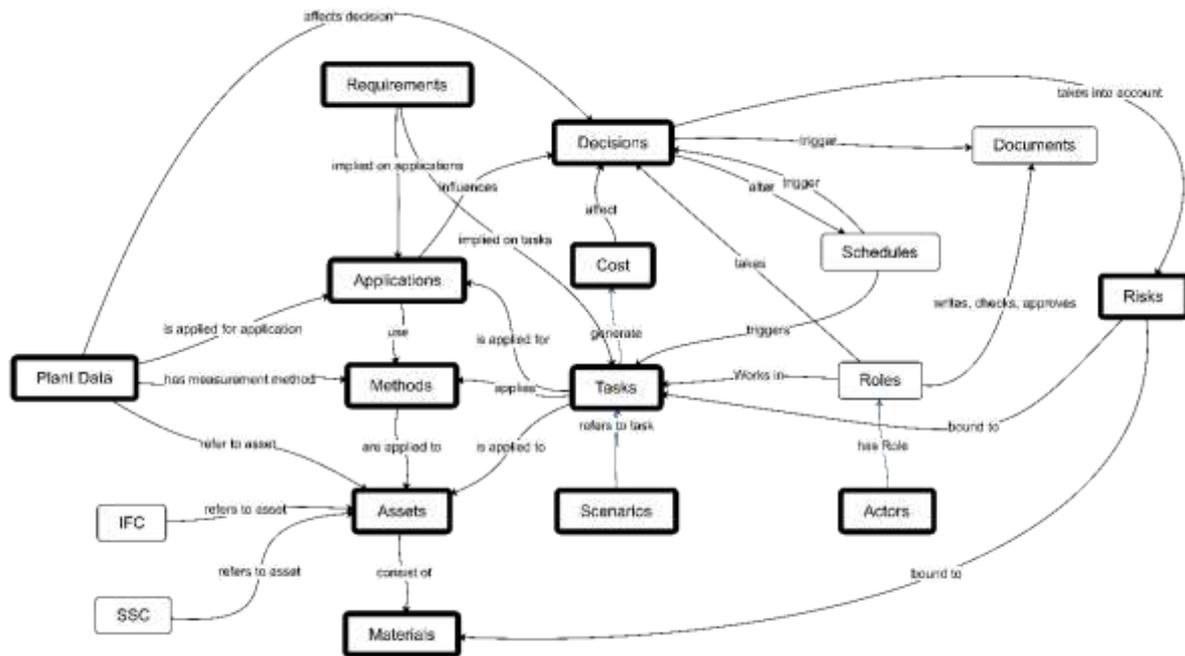


Figure 6 Core decommissioning ontology

This ontology has been in parallel aligned with similar approaches in international organizations, ensuring a basic compatibility to international knowledge resources (such as communities of practice or databases).

Next steps

Based on the requirements identified (so far) and the specifications elaborated based on these requirements, the next steps of the project will focus on

- development of the PLEIADES software architecture,
- prototyping of the PLEIADES software platform and
- demonstration/validation of the platform in the 6 user stories mentioned before.

Development of the PLEIADES platform is based on the specifications identified so far and summarized previously in this paper. The focus will be on developing the data exchange protocols and the software interfaces between the innovative support tools provided by the consortium partners. Hence, the software suite will, primarily, include the tools listed earlier in this document (Figure 2).

In addition to the harmonisation and interoperability efforts, the PLEIADES project partners will also develop some new software modules: most importantly software interface modules (APIs), and also modules providing some key functionalities that may be missing in the existing tools, including “point cloud modules” for management of data (3D models) coming from laser scanning, new modules for optimization of simulated work processes in terms of dose, modules allowing the consideration and assessment of body posture and ergonomics, further developments related to project management functionalities and developments related to semantic ontology.

The main goal is to assure efficient and safe/secure communication between the existing standalone software tools providing an efficient information/knowledge process through the PLEIADES platform. The integrated platform will help to achieve better working conditions and the prevent accidents through, for instance, optimization of work plans in terms of ergonomics, technology feasibility, costs, waste, duration, radiation exposure, as well as knowledge, process and HR management issues. The PLEIADES platform will cover the entire work cycle from investigation, through studies (preliminary, detailed and final design) and final implementation (training and assistance) for decommissioning

projects, and can also be utilized in any operation (maintenance, modification) during the earlier life cycle phases of nuclear facilities.

Three demonstration sites have been preselected for the PLEIADES platform implementation tests:

- Base Chaude Opérationnelle du Tricastin (BCOT), a nuclear maintenance facility in France (Bollène)
- The Halden Research Reactor, a nuclear research facility in Norway (Halden)
- Santa María de Garoña (SMG), a nuclear power plant in Spain (Burgos)

The PLEIADES project partners will demonstrate a prototype software platform in the six selected case studies using inputs from the three selected test sites (Figure 4). The six decommissioning scenarios (user stories) will demonstrate the interaction of the different building blocks (modules) of the PLEIADES platform. These user stories were developed to cover various aspects of decommissioning aiming to validate the capabilities of the PLEIADES system. Three of the six user stories focus on comparing alternatives for radiological characterization, dismantling and decontamination of building surfaces. The other three user stories address risks, regulatory and waste management issues. These tests will, among others, provide results in terms of collective dose, time, waste and cost of each task.

Exploitation strategy

The exploitation strategy of the PLEIADES project aims at assessing the market potential and prepare exploitation scenarios with the organisations involved in the project and end-users linked with the project through the Stakeholders group.

The exploitation strategy of the project will be reviewed by two high level groups, the Stakeholders Group (SG) representing interested end-users and the Advisory Board (AB), composed of persons that are not involved in the Project. The first group will assess the relevance of the Project from an industrial perspective, while the second one will evaluate the quality of its scientific approach. Both groups will issue comments and recommendations.

Overall, the PLEIADES project aims at the establishment of a standard interface, that is licensable by third parties and allows to use and re-use the 3D data gained by the decommissioning project. To the understanding of the project partners, this will be beneficial for the customer, but also for parties involved in the project or joining the initiative at a later stage.

Invitation to connect

As mentioned in the previous chapters, the developments in the PLEIADES project started with the consortium launching an on-line survey for identifying needs and requirements of the foreseen end-users within the international community. While the primary analysis of the responses to this questionnaire has been concluded, the consortium is still open to receiving further input. Respondents of the questionnaire had the option of providing contact information so that the consortium can reach out to these persons for getting further input, specifications/clarifications on already provided input and, most importantly, to get feedback from these experts at the stage when preliminary demonstrable results (e.g., early prototypes) are available. Guided interview discussions will be held with for gathering such further feedback from experts representing the foreseen end-user community.

The PLEIADES consortium is very interested in extending the list of experts who provide contact information through the questionnaire. The questionnaire is still active, and hence, input can be provided, as well as contact information for further discussions. Since the primary questionnaire analysis is now concluded, contact information for connecting to the project can be provided via the questionnaire without providing input, or directly to the email address of the first author of this paper. The questionnaire can be reached via this link: <http://pleiades-platform.eu/2021/01/13/pleiades-survey/>

For more information about developments in the PLEIADES projects and results from completed work, the reader is invited to visit the on-line the project portal here: <http://pleiades-platform.eu>

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