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PLEIADES - SMARTER PLANT DECOMMISSIONING

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Abstract

PLEIADES (Platform based on Emerging and Interoperable Applications for enhanced Decommissioning processES), is an international project that receives funding from the Euratom research and training program 2014-2018 under grant agreement No 899990. PLEIADES aims at making the decommissioning of nuclear facilities more efficient, through demonstrating an innovative digital decommissioning approach inspired by the BIM (Building Information Modelling) concept. BIM provides a digital twin and enables all the information related to a building to be managed through a central 3D model, enhancing information exchanges between different jobs and enabling scenario simulations for work on the building. PLEIADES applies this concept to the dismantling domain and will demonstrate how a BIM-like models (containing data required for decommissioning planning) can be used for scenario simulations improving safety, minimizing radiation exposure, optimizing costs, schedules and communication. To achieve this, PLEIADES has developed an interoperable platform including a set of innovative modules, developed by most of the partners, based on simulation technologies. Currently, PLEIADES will implement this platform on three real cases of nuclear facilities: a research reactor (Halden Research Reactor in Norway), a nuclear power plant (Santa Maria de Garona in Spain), and a maintenance facility (Base Chaude Opérationnelle de Tricastin in France). The implementation on these different kinds of facilities will enable to highlight strengths and weaknesses of such a digital twin and simulation approach.

1. INTRODUCTION

Due to energetic choices and the nuclear plants end of design life, economic considerations and political decisions, an increasing number of nuclear installations and power reactors is to be dismantled in the coming decades. The nuclear market is a matter of country-specific legal regulations and requirements. More than 300 NPPs are estimated to be shut down between now and 2047, as estimated by a study conducted by the PLEIADES consortium. Within the European Union alone, estimations indicate that 80 NPPs will be shut down until 2047. France shutting down 40 NPPs and Ukraine 13 NPPs, will be the most affected countries, to the current knowledge. This large number of dismantling sites in the next decades combined with the mandatory reliability and safety requirements impose to make the dismantling operations more efficient, safer and more cost-effective.

The PLEIADES project aims at making the decommissioning of nuclear facilities more efficient, through demonstrating an innovative digital decommissioning approach inspired by the BIM (Building Information Modelling) concept. BIM provides a digital twin and enables all the information related to a building to be managed through a central 3D model, enhancing information exchanges between different jobs and enabling scenario simulations for work on the building. PLEIADES applies this concept to the dismantling domain and will demonstrate how a BIM-like models (containing data required for decommissioning planning) can be used for scenario simulations improving safety, minimizing radiation exposure, optimizing costs, schedules and communication.

Main PLEIADES achievements are presented hereafter: the decommissioning ontology that structures the useful data and concepts useful for decommissioning management, the interoperable platform including the server, its efficient programming interface (API) and the associated tools.

Then the implementation of this platform on 6 user stories based on 3 real cases of nuclear facilities is presented: a research reactor (Halden Research Reactor in Norway), a nuclear power plant (Santa Maria de Garona in Spain), and a maintenance facility (Base Chaude Opérationnelle de Tricastin in France).

2. PROJECT ACHIEVEMENTS

2.1. Platform

The goal of the PLEIADES platform is to provide the basement for a holistic digital ecosystem to support the decommissioning planning. To achieve this, following challenges were addressed when designing the architecture of the PLEIADES platform:

- complexity and security of the data structures for the decommissioning planning.
- variability of the software tools connected and technologies used.
- interoperability with 3D/BIM modelling approaches and formats.
- maintainability for future development and extensions based on lessons learnt from production usage.
- the technical aspects of the platform's architecture.
- the technical specification of the required APIs.

The platform architecture shown in FIG.1 was developed. The main building block of the platform is the application server containing the database and several programming interfaces (APIs) for authentication and data manipulation. Any software tool with the compatible, so-called, "PLEIADES connector" can connect to these interfaces, using the APIs provided by the implemented PLEIADES application server.

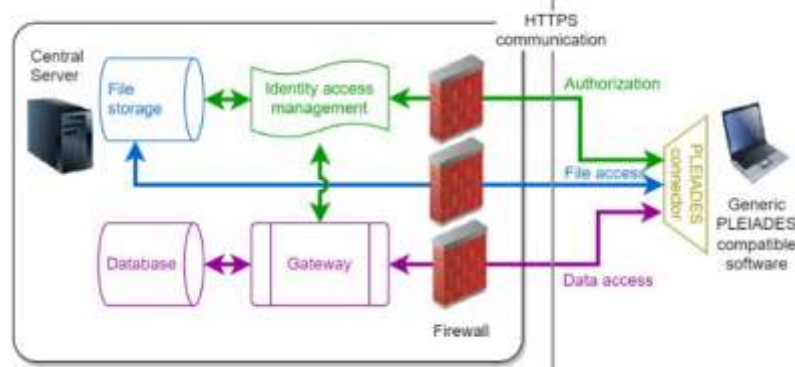


FIG. 1. Overall illustration of PLEIADES's application server [1]

To digitalize the decommissioning planning, two types of data must be considered:

- the 3D/BIM model for a facility, building, room or any other spatial context for which the planning is to be performed.
- the structured data specific for the nuclear decommissioning planning, describing the whole environment for which the planning is to be performed and providing relevant inputs for simulations or estimations.

As for 3D/BIM models, an IFC file format has been used as a standard used in PLEIADES. This format has been chosen because it is an open format, regularly updated by a centralized institution and, it has already well-established with a broad community of users. Some other details of this decision are described in [2].

The platform interoperability properties essentially rely on the custom "PLEIADES" API. The development of this API was split into two phases:

- Specification of the API, its transfer protocols, data-package format, and the classification of the data stored in the database.
- Implementation of the specified API, based on the decommissioning ontology described in [3].

The structure of specific "PLEIADES classes" was developed. A "class" contains a definition of properties of database records for use in certain situations. As an example, a class "Task" contains properties that hold the information about a decommissioning task to be performed. The sample content of a record in a class "Task" is shown in FIG.2 JSON format is used to encapsulate the content of a record makes the implementation of the PLEIADES connectors at the side of the client software tool easy and intuitive.

```

"Name": "any-string-value-random-6209",
"Number": "any-string-value-random-8718",
"Definition": "any-string-value-random-7137",
"ParentTaskId": "802219be-4dca-b347-8aa9-eddd7e19288a",
"DependsOnTaskIds": [
  "51181925-3c20-04dc-1345-7ad56fda51f0",
  "6d0a2735-50b1-c827-0a0e-0de4248c8e95",
],
"Start": "2023-01-20T12:05:18",
"Duration": 65.78,
"TeamId": "8278f776-2053-9998-8667-b5388ec5b3d4",
"ApplicationId": "dac8fc56-9898-0500-232b-051da8904e9d",
"WorkplaceId": "c413b8c5-f0bb-0332-b7b3-5b58e38679a0",
"InputAssetIds": [
  { "Class": "Assets.Tangibles.Parts", "RecordId": "2ba907f6-289e-c411-7403-20623ee0584a" },
  { "Class": "Assets.Tangibles.Tools", "RecordId": "8f65e3ea-d453-ccfd-9acf-e4c940cc1cf0" }
],
"UnitCostFactors": {
  "HourlyInvestments": 1234,
  "HourlyExpenses": 1234,
  "Contingency": 20
}

```

FIG. 2.: Sample content of a record in a class "Task"

Moreover, classes have a hierarchical structure. At the top level, following classes are defined: PlantData, Events, Applications, Tasks, Methods, Workplaces, Assets, Materials, Actors, Safety, Wastes and Costs. Each of these top-level classes is further structured into more detailed class names. An example can be seen in FIG.2, above in which the property "InputAssetIds" of the class "Task" uses a reference to records of a class "Assets.Tangibles.Parts" or "Assets.Tangibles.Tools".

From the technical perspective, the application server is built using:

- Linux-based operating system with MongoDB database engine;
- REST transfer protocol for the custom API for data manipulation;
- Support of the IFC file format for the 3D/BIM models;
- OAuth 2.0 protocol for the authentication API
- Amazon S3 protocol for transferring the files (3D/BIM models).
- JSON format for encapsulation of the data in records.

2.2. Connected tools

Different software tools have been connected to the server through a dedicated connector. This assembly allows to simulate decommissioning scenarios to verify decommissioning parameters and as a consequence improving safety, minimizing radiation exposure, optimizing costs, schedules, ...

Currently the following tool are integrated to the platform thanks to the development of PLEIADES-connector:

- DEMplus (CyclifeDS – Decision-support combined with 3D simulation);
- iDROP (CEA – VR dismantling simulation including radiological modelling);
- RadPIM (IFE – Radiological characterization);
- VRDose (IFE – Job planning including a radiological model);
- Interact (Light&Shadows - XR platform with physics engine);
- XRWorkflow (VTT – AR training platform);
- Wastream (Tractebel – Dismantling waste cost and planning management);
- AquilaCosting (WAI – costing tool).

The platform specification makes it easy to develop a connector for any other tool that could be interesting for the simulations. The only requirement for the additional tool is to implement a PLEIADES connector compatible with the API. There is no limitation for technologies or platforms on which the software tool is built.

2.3. Use case and User story

Three uses cases have been selected to simulate and test the platforms at different condition and context:

- Base Chaude Opérationnelle du Tricastin (BCOT) in France. BCOT, a nuclear maintenance facility of EDF, has been created in 1993, and dedicated to nuclear maintenance, and equipment / tools from contaminated circuits and equipment of EDF nuclear power reactors. In June 2017, EDF decided to shut down this facility in 2020.
- Santa María de Garoña (SMG) in Spain. SMG is a boiling Water Reactor (BWR-3) of 466 megawatts (MWe) of NUCLENOR with ENRESA in charge of D&D. This reactor has been shut down in 2012 after 41 years of operation and is in D&D process since 2017.
- The Halden Research Reactor in Norway. The Halden Reactor, operated by IFE, was a key asset in the research within the Halden Reactor Project (sponsored by 19 countries with a jointly financed program under the auspices of the OECD Nuclear Energy Agency). IFE's board of directors of has decided to close the Halden Reactor permanently and to start its decommissioning.

Six user stories have been defined to demonstrate the PLEIADES platform capabilities. The first 3 user stories will allow to obtain the main results usually used in the framework of nuclear projects: dosimetry, duration, cost and waste generated. The last 3 user stories aim to test and provide more specific analyses concerning risks, compliance with safety criteria and waste management.

User Story #1: Manual vs. remote radiological characterization

This user story is focused on radiological measurements. Dose received are calculated during a nuclear intervention simulation in an irradiating environment simulate with both a "contact intervention team", and a "remote operation team". The aim is to evaluate and compare the obtained results, in particular the doses received by the operators.

User Story #2: 3D supported vs Digitally enhanced dismantling

This user story involves the cutting and evacuation of a large mechanical equipment. Specific issues to study are the relevance of detailed 3D data, the contribution of metadata associated with 3D objects (BIM methodology) and the scenario feasibility (detection of collision, clashes).

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

In this user story remediation operations, of contaminated concrete surfaces, are simulated (remediation category 1, 2 and 3), carried out in contact and in remote operation. Thanks to precise surface contamination measurements an estimate of the atmospheric contamination generated by the operations can be provided by the simulation.

User story #4: Strategic risk management planning

The main objective is the analysis of risks and uncertainties related to the areas covered by the simulated activities. The aim is to assess the feasibility of making strategic decisions within a facility based on the BIM concept.

User story #5: Regulatory/TSO review capabilities

This user story depends on the results of the first 3 user stories. It provides a regulatory/TSO review process of the simulated scenarios in terms of work activities feasibility, nuclear safety and radiation protection, conventional risks, and compliance with safety criteria.

User story #6: Strategic waste management planning

The material composition and radiological properties of each component of the 3D model can significantly affect decisions on waste treatment techniques. This user story focuses on the analysis of the waste management strategy. One of the first 3 user stories will be used as input for this analysis.

3. DEMONSTRATION PROGRESS AND PERSPECTIVES

The 6 user stories should allow the evaluation of the platform and its interest. The "classical" results obtained, which are: forecast dosimetry - planning - cost - waste estimation, should allow us to compare the PLEIADES approach, i.e. the interoperability of a BIM database with several calculation and simulation tools, with a more traditional approach (use of spreadsheets or a single specialised software package for example).

The data collection phase was mainly carried out with the use case owners, i.e. IFE, ENRESA and EDF, in order to have as much realistic data as possible. Nevertheless, to have all the required data to carry out the user

stories and test the PLEIADES platform functionalities, some data were produced arbitrarily. The central points that led to the collection of data, in terms of typology, format and quantity, were:

- The hierarchical structure of the API presented above, which allows, thanks to the different classes and sub-classes, to store the input data of a nuclear decommissioning project.
- The different test steps of the 6 user stories, and through them the anticipation of the needed data.

As an example, here are the main data collected: 3D models, point clouds, scenario to be simulated step by step, equipment and tools used, intervention teams and their composition, working methods, various cost data, waste management processes and packages used, radiological data allowing the simulation of the working environment, main risks and safety-relevant equipment...

All this data is hosted in platform databases, one per use case. The files, such as 3D models, are hosted in the file storage server.



FIG. 3. Images of database and file storage browsers

In addition, within the framework of the user stories, we plan to test new applications, such as the use of BIM models to assist in decision-making concerning the conventional risks but also safety aspects associated with the installations and the decommissioning operations envisaged. We also plan to evaluate the interest of the platform to assist in the performance of advanced ALARA studies.

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