PLEIADES

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Interoperability and standardisation report

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Summary

This document presents an overview of the PLEIADES project contribution in the definition of a standardized process and data model to launch targeted processes in future decommissioning projects in a standardized way. A focus has been made on the analysis of the existing guidelines, and a description of the available data based on IAEA nuclear standards and ISO standards. Then, this description has been completed with proposed contribution based on the PLEIADES platform activities performed during the project: ? development, ? data listing, collection, and validation, ? implementation on real use cases. The objective is to propose an input data standardisation and describe how PLEIADES could be a support in standardization process

Approval

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PLEIADES project

WP5: Standardisation effort, Exploitation & Training

D5.3 Report on Interoperability and Standardization

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Keywords

Nuclear, Decommissioning, Platform, Digital Tools, Data, Data structure, Data format, Standardisation.

Glossary

Abbreviation / acronym	Description
ALARA	As Low as Reasonably Achievable
API	Application Programming Interface
BCOT	EDF facility “Base Chaude Opérationnelle du Tricastin”
BIM	Building Information Modelling/Management
D	Deliverable
D&D	Decommissioning and Dismantling
HRR	IFE facility “Halden Research Reactor”
IFC	Industry Foundation Classes, a data model intended to describe architectural, building and construction industry data
IT	Information Technology
LOD	Level of Detail
NPP	Nuclear Power Plant
SMG	ENRESA facility “Santa Maria de Garoña”
SSCs	Structures, Systems and Components
SW	Software
T	Task
TSO	Technical Support Organisation
WP	Work Package

Table 1. Glossary

Executive Summary

This document presents an overview of the PLEIADES project contribution in the definition of a standardized process and data model to launch targeted processes in future decommissioning projects in a standardized way.

A focus has been made on the analysis of the existing guidelines, and a description of the available data based on IAEA nuclear standards and ISO standards.

Then, this description has been completed with proposed contribution based on the PLEIADES platform activities performed during the project:

- development,
- data listing, collection, and validation,
- implementation on real use cases.

The objective is to propose an input data standardisation and describe how PLEIADES could be a support in standardization process.

1. Introduction

1.1. Purpose

The aim of this deliverable is to contribute to definition of a standardized process and data model to launch targeted processes in future decommissioning projects in a standardized way.

The work of the different partners will focus on recommending processes, an ontology base, and data models. Recommendations will concern how to:

- identify the necessary data according to the specifications of scenarios to be simulated and considering the regulatory safety review,
- standardize input data for each actor of a D&D project (including the BIM model),
- integrate data on the PLEIADES platform.

Each country may have different national strategies, whether in terms of decommissioning or regulatory limits (intervention, waste, etc.). Thus, any contribution to this standard must take account of these specificities.

1.2. Methodology

An overview of existing guidelines has been realized, with a focus on nuclear decommissioning, safety and data management. The aim is to highlight the existing gap and how the PLEIADES project can contribute to complete the current standard.

The main contribution is related to the input data standardization: through the ontology development, to the data integration. Thanks to the work performed all along the project, in collaboration with each partner, some guidelines have been developed and collected in this report.

1.3. Contributing partners

The list of partners involved in task 5.2 is provided in Table 2.

Partner	Activity
IRSN	Assurance that the draft standard considers targeted safety issues. State of the art in terms of existing standards.
Cyclife DS	Managing task 5.2's progress and deliverable writing.
IUS, CEA, IFE, TRACTEBEL, ENRESA	Participation in task 5.3 (meetings, discussions, analyses) and in drafting the deliverable.

Table 2. Partners contribution to task 5.2

1.4. Connections with other activities in the project

<u>Input:</u>

A decommissioning ontology has been defined in WP1.

The data needed to feed the main decommissioning processes are specified through the PLEIADES database architecture achieved in task 2.2.

The data collection and formatting planned in WP3 will allow the specification of input data requirements: which data is important? Which data is difficult to obtain? What level of detail is sufficient? etc.

The realization of the user stories planned in WP3 should make it possible to evaluate which data types have been well defined, and which difficulties are encountered when using certain data types.

Finally, WP4, which foresees the analysis of the results of the scenarios tested in WP3, will allow us to make the link between the data specified as necessary and the results obtained by using these data.

In addition to the activities carried out in the framework of the PLEIADES project, this deliverable allows us to exploit the feedback from the partners outside the project, concerning the decommissioning processes and the necessary data.

<u>Output:</u>

This document is not a necessary input for any other task of the PLEIADES project.

Nevertheless, this deliverable has been established as a potential input to a project that plans to create a data model standard for D&D project processes.

2. Standard: state of the art

This part proposes to present an overview of existing guides and in addition highlight the identified gaps.

2.1. Overview of existing guides

2.1.1. International safety standards on decommissioning and waste management

A set of safety standards have been developed and published by IAEA with Member States contribution to promote consensus aspects regarding safety and radiation protection. A set of these safety standards (including requirements and recommendations) concern radiation protection, decommissioning safety and radioactive waste safety. These safety standards concern the following aspects:

- "Decommissioning of facilities",
- "Radiation protection and safety of radiation Sources IBSSs",
- "Safety Assessment for facilities and activities",
- "Predisposal management of radioactive waste",
- "Disposal of radioactive waste",
- "Classification of radioactive waste",
- "Safety Assessment for decommissioning",
- "Classification of structures, systems and components in NPPs",
- "Application of the concepts of exclusion, exemption and clearance",
- "Release of sites from regulatory controls on termination of practices".

On the basis of these International Safety Standards, at the European level, a set of EU directives have been published requiring the EU Member States to implement those requirements into national regulations:

- basic Safety Standards for protection against the dangers arising from exposure to ionizing radiation,
- community framework for the responsible and safe management of spent fuel and radioactive waste,
- community framework for the nuclear safety of nuclear installations.

These sets of international requirements and recommendations (IAEA, EU) form the framework for developing regulations on decommissioning and radioactive waste in national regulations and guides.

2.1.2. ISO Standards on nuclear safety and radiation protection

A set of normalization initiatives have been undertaken by the International Standard Organization (ISO) to address specific issues in the field of:

- nuclear installations, processes, and technologies,
- radiation protection.

Some of them are particularly developed to address decommissioning and radioactive waste management issues, such as:

- management of radioactive waste from nuclear facilities,
- criteria for design and operation of confinement systems for nuclear worksite and for nuclear installations under decommissioning.

Regarding the reliability of data exchange, the **ISO 6527:1982,** developed for Nuclear Power Plants, identifies the typical parameters of a component that permit it to be characterized unequivocally. It also allows the corresponding reliability data to be associated with those of other components having equivalent typical parameters. This International Standard deals in particular with exchange of reliability data collected on field.

This standard uses the following set of definitions:

- System: integral part of a nuclear power unit comprising electrical, electronic, or mechanical components (or combinations of them) that may be operated as a separate entity to perform a particular process function,
- Sub-system: part of a system which participates in the operation of the entire system (for example, electric power supply, controls, mechanical devices, etc.),
- Component: element of a sub-system, having its own defined performance characteristics and forming a whole that can be removed from the process and replaced with a spare,
- Reliability: ability of a component or a system expressed as the probability to perform a required function under stated conditions for a stated period of time.

The purpose of these sets of norms developed by ISO is to promote good practices in the field of nuclear safety and radiation protection.

Regarding decommissioning, the ISO related standard concerns only the ISO 16647:2018 *Nuclear facilities — Criteria for design and operation of confinement systems for nuclear worksite and for nuclear installations under decommissioning.*

Regarding radioactive waste management, the ISO/DIS 24389-1 provides general principles, objectives and practical approaches concerning the management of radioactive waste from nuclear facilities.

2.1.3. Applicable national regulations – examples

2.1.3.1. Legal and regulatory framework in application in France

In consistency with International Safety Standards, requirements and recommendations are implemented to national regulations which may contains additional specific requirements to be considered. For example, in France, the following set of safety standards have been developed:

- ASN policy concerning the decommissioning and delicensing of basic nuclear installations (BNIs) in France Revision 0.v3 – April 2009,
- order of 7 February 2012 setting the general rules relative to basic nuclear installations,
- decree No 2014-DC-0417 of January 28 2014 about incendiary risks,
- decree No 2014-DC-0462 of October 07 2014 about how to deals with criticity risks inside Nuclear facilities,
- decree No 2017-DC-0587 of March 23 2014 about conditioning radioactive wastes,
- decree No. 2019-190 of March 14, 2019 on the provisions applicable to nuclear installations, the transport of radioactive substances and transparency in nuclear matters,
- decree No. 2018-437 of June 4, 2018 relating to the protection of workers against the risks due to ionizing radiation.

These set of regulations address specific aspects and risks, such as:

- decommissioning,
- nuclear safety,
- safety demonstration,
- safety criticality,
- fire safety,
- explosion,
- lightning,
- airplane crash,
- seismic event,
- radioprotection,
- spread of contamination,
- ventilation systems,
- transport.

In addition, specific guidance documents have been developed by the French regulatory body addressing the following issues:

- clean-up of soils,
- waste management,

- waste surveys and zoning,
- transport of radioactive materials.

These sets of regulations and guides form the basis for nuclear operators/licensees for submitting nuclear applications and to provide supporting safety demonstration.

2.1.3.2. Legal and regulatory framework in application in Spain

Spanish legislation is organised into five levels, the first four of which must be complied with.

Level 1 comprises constitutional regulations, Community regulations (EURATOM), international agreements ratified by Spain, Community directives and other international conventions.

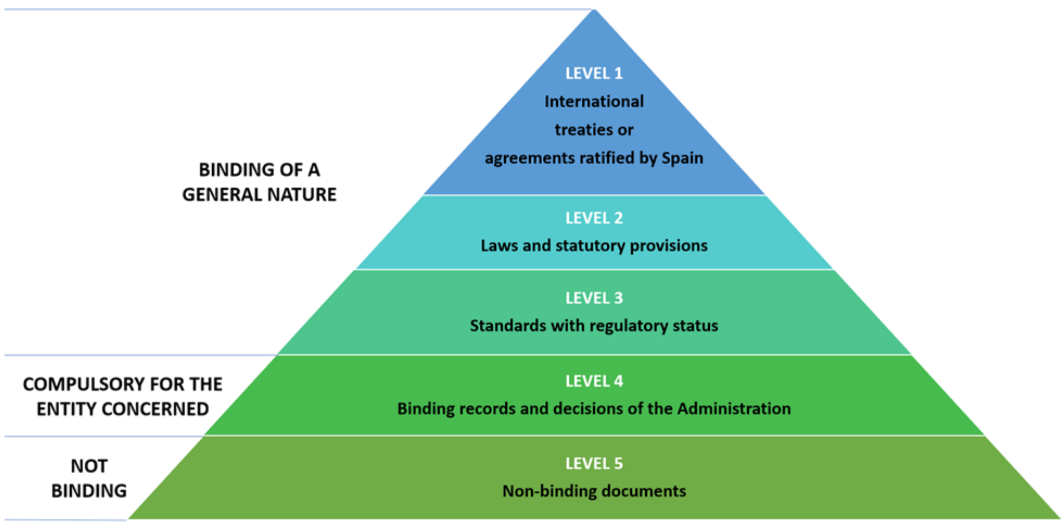

Figure 1: Spanish regulatory pyramid

Level 2 includes state laws such as the Nuclear Energy Act 25/64, which establishes the obligations of the administration and licensees of nuclear and radioactive facilities, environmental laws or laws relating to nuclear damage.

Level 3 includes regulations, ministerial orders in different fields such as radiation protection, spent fuel and radioactive waste management, security, and emergency plans. In addition, it includes safety instructions of the Nuclear Safety Council which are included in the following subject areas:

- decommissioning,
- nuclear safety,
- radiation protection,
- waste management,
- environmental monitoring,
- transport of radioactive materials,
- physical security,

- quality assurance,
- worker training,
- life management,
- fire protection,
- emergency management.

Level 4 includes those standards applicable to a specific entity and compliance with which is mandatory for that entity concerned. In many cases they are developed solely for that operator, such as complementary technical instructions.

Level 5 includes documents that are neither mandatory nor binding but are recommended. In this case, the safety guides are grouped as follows:

- power reactors and nuclear power plants,
- research reactors and sub-critical assemblies,
- fuel cycle facilities,
- environmental radiological monitoring,
- radioactive facilities and equipment,
- transport of radioactive materials,
- radiation protection,
- safety,
- waste management,
- miscellaneous (Quality assurance, qualification and certification of personnel, radiological control of activities),
- natural radiation.

2.1.4. ISO standards on lifecycle data management, BIM and visualization

The management of industrial data has been addressed by the technical committee 184 of ISO (Sub-committee 4). This representation supports the information requirements of the process industries in all phases of a plant's life cycle and the sharing and integration of information amongst all parties involved in the plant's life cycle. The standards developed within ISO/TC 184/SC 4 are based on the premise that:

- there are fundamental commonalities between different industries,
- industrial data can be considered as a product of some industrial process and subject to generalized life-cycle activities.

Models enable to structure and organize concepts for meaningful use. In this context, two models to define the use of Industrial Data are used. These are informative models, which describe the industrial environment and show the commonality between types of information in the environment. These are the industry structure model, which describes the hierarchical structure of the customer supply chain, and the Life-Cycle Activities (LCA) model, which defines a generalized set of life-cycle activities.

This framework covers the following key topics:

- interoperability of product data definitions (ISO 10303 and ISO 15926),
- manufacturing (ISO 15531, ISO 18629, ISO 18828 and ISO 18876),
- visualization (ISO 14306 and ISO/PAS 17506).

2.1.4.1. Lifecycle data management: ISO 10303 and 15926

ISO 10303 provides a representation of product information along with the necessary mechanisms and definitions to enable product data to be exchanged. The exchange is among different computer systems and environments associated with the complete product life cycle, including product design, manufacture, use, maintenance, and final disposition of the product.

ISO 15926 specifies a representation of information associated with engineering, construction and operation of process plants. This representation supports the information requirements of the process industries in all phases of a plant's life cycle and the sharing and integration of information amongst all parties involved in the plant's life cycle. ISO 15926 has thirteen parts (as of February 2022):

- Part 1 - Overview and fundamental principles,
- Part 2 - Data model [2],
- Part 3 - Reference data for geometry and topology,
- Part 4 - Reference Data, the terms used within facilities for the process industry,
- Part 6 - Methodology for the development and validation of reference data (under development),
- Part 7 - Template methodology,
- Part 8 - OWL/RDF implementation,
- Part 9 - Implementation standards, with the focus on standard web servers, web services, and security (under development),
- Part 10 - Conformance testing,
- Part 11 - Methodology for simplified industrial usage of reference data (under development),
- Part 12 - Life cycle integration ontology in Web Ontology Language (OWL2),
- Part 13 - Integrated lifecycle asset planning,
- Part 14 - Data model adapted for OWL2 Direct Semantics (under development).

One of the main ISO Standard regarding lifecycle data management is the "ISO 15926” which specifies a representation of information associated with engineering, construction and operation of process plants. The ISO 15926 concerns industry standards (like oil&gas industry). **Currently, there are no comparable standard available in the nuclear industry.**

2.1.4.2. ISO standards on BIM

The organization and digitization of information about buildings and civil engineering works, including building information modelling (Technical committee 59) is addressed by the technical committee 59 of ISO (Sub- committee 13).

ISO 19650 outlines the concepts and principles for information management at a stage of maturity described as "building information modelling" (BIM). It provides recommendations for a framework to manage information including exchanging, recording, versioning and organizing for all actors. This document is applicable to the whole life cycle of any built asset, including strategic planning, initial design, engineering, development, documentation and construction, day-to-day operation, maintenance, refurbishment, repair and end-of-life. This document can be adapted to assets or projects of any scale and complexity, so as not to hamper the flexibility and versatility that characterize the large range of potential procurement strategies and so as to address the cost of implementing this document.

Refences could be made also to the two followings ISO standards:

- ISO 16739 about Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries. ISO 16739 contains the industry foundation classes (IFC) schema, a file format that describes components of a building and that facilitates interoperability in the construction industry,
- ISO 29381 which defines a methodology to formalize an information delivery manual (IDM), which, for example, model the processes of information exchange including the interactions between stakeholders,
- ISO 12006 which specifies a language-independent taxonomy data model that can be used to store or provide information about construction works based on dictionaries.

One of the main ISO standards is the ISO 19650 - *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM)*.

2.1.5. BIM model

2.1.5.1. ISO standards on Visualization

ISO 14306:2017 has been adopted as a 3D visualization capability in addition to the ISO 10303 series.

The file format supports the following information:

- facet information (triangles), stored with geometry compression techniques,
- visual attributes such as lights, textures and materials,
- product manufacturing information, such as dimensions, tolerances and other attributes,
- boundary representation (b-rep) solid model shape representations. Several alternatives are available, including a representation based on the geometry standard defined in ISO 10303 configuration representations,

- delivery methods such as asynchronous streaming of content.

ISO 14306:2017 does not specify the implementation of, or definition of a run-time architecture for viewing or processing of the file format.

ISO/PAS 17506:2012 describes the COLLADA schema. COLLADA is a COLLAborative Design Activity that defines an XML-based schema to enable 3D authoring applications to freely exchange digital assets without loss of information, enabling multiple software packages to be combined into extremely powerful tool chains.

The purpose of ISO/PAS 17506:2012 is to provide a specification for the COLLADA schema in sufficient detail to enable software developers to create tools to process COLLADA resources. In particular, it is relevant to those who import to or export from digital content creation (DCC) applications, 3D interactive applications and tool chains, prototyping tools, real-time visualization applications such as those used in the video game and movie industries, and CAD tools.

ISO/PAS 17506:2012 covers the initial design and specifications of the COLLADA schema, as well as a minimal set of requirements for COLLADA exporters.

2.1.5.2. 3D model

Apart from the representation of BIM models in a virtual space, there are a plethora of file formats to represent 3D data: OBJ and STL for basic triangle meshes, STEP (ISO 10303) and IGES(NBSIR 80-1978) for product manufacturing, netCDF and DICOM (ISO 12052:2017) for volumetric data...

Fortunately, in recent years, several standards organizations and industrial consortiums have presented several frameworks for interchange of 3D data that aim to reduce the large number of incompatible file formats. Most notably, the COLLADA (ISO/PAS 17506) interchange file format and glTF(ISO/IEC 12113:2022) transmission formats proposed by the Khronos group have been adopted by most vendors, greatly increasing the interoperability between 3D graphics software tools.

Yet, with the recent resurgence of the “Metaverse” concept, many companies are adopting a more advanced framework called Universal Scene Description for the interchange of 3D data. An open-source framework developed by Pixar Animation Studios that has rapidly been adopted by many key players in the industry (including NVidia, who is looking for a way to encode the IFC schema in this new format).

2.1.5.3. Data quality

In addition to the data content, ISO/TC 184/SC 4 addresses with the quality of the data. A data quality framework is used as a foundation for ensuring that data meets expectations and is fit for use. The framework used to describe the context is covered by the ISO 8000 on Data Quality.

ISO 8000-100:2016 describes fundamentals of master data quality and specifies requirements on both data and organizations to enable master data quality.

The following are within the scope of ISO 8000-100:2016:

- specification of the scope of the master data quality series of parts of ISO 8000,
- introduction to master data,
- description of the data architecture,

- overview of the content of the other parts of the series.

The following are outside the scope of ISO 8000-100:2016:

- aspects of data quality that apply to all data regardless of whether they are master data,
- aspects of data quality that apply to data that are not master data.

2.2. Gaps identified in existing standards

2.2.1. IAEA Nuclear Standards

2.2.1.1. Nuclear Safety Standards

A comprehensive set of International Safety Standards cover the field of decommissioning and related radioactive waste management. Requirements are established to provide a clear framework about safety demonstration including the development of safety assessment for decommissioning, independent review and regulatory review.

These set of requirements are implemented into national regulations as well (see example of France and Spain).

Regarding Nuclear safety related to decommissioning safety and management of radioactive waste, there is clear legal and regulatory framework forming the basis for the development and the review of safety assessment.

2.2.1.2. Plant Information Model

An IAEA TECDOC – 1919 – has been developed in 2020. This document provides the basis for developing "Plant Information Model" (PIM). This document introduces the PIM as a "*set of interlinked information about plant structures, systems and components, incorporating plant data, relationships and rules used to integrate, represent, and describe nuclear facility processes and data for each phase of the facility life cycle.*"

PIM values are identified as follows:

- designing phase,
- NPP construction and start-up,
- Operation,
- decommissioning.

Regarding decommissioning, the possible added values concern:

- to provide all decommissioning project stakeholders with the required design, engineering, production, operation and other relevant engineering and technical information through a single repository,

- to facilitate development of integrated 5D or 6D simulation models based on PIM for disassembling high-level equipment and structures of NPP with concurrent calculation of radiation dose rates, generated radwaste amount, required activities, schedules, resources, and cost evaluation,
- to calculate generated radwaste amount based on data about NPP radiation condition, contamination and geometry accumulated in PIM,
- to ensure effective and safe decommissioning performance pursuant to a design with the aim to reach specified final state by means of developing and further using a PIM that consolidates all required engineering data, comprehensive engineering and radiation survey (CERS) data, as well as visual representing of decommissioning works in progress on simulating models.

As recalled in this document, the principal concept of PIM modelling is the information interoperability. The chapter 3 of the IAEA TECDOC 1919 introduces the knowledge centric Plant Information Model (K-PIM). "*A K-PIM is a semantically organized set of information describing plant structures, systems and components, incorporating relationships and rules within a knowledge framework that collectively forms enriched representations of the plant that provide shared knowledge services and resources over its life cycle*."

The TECDOC 1919 is not part of the Safety Standards developed by IAEA. The concept of Plant Information Model and in particular its implementation to decommissioning and waste management is not covered by any Standards.

2.2.2. ISO standards

2.2.2.1. Nuclear field

Regarding Nuclear Power Plants under operation, the **ISO 6527:1982** addresses the reliability of data exchange and identifies the typical parameters of a component that permit it to be characterized unequivocally and to allow the corresponding reliability data to be associated with those of other components having equivalent typical parameters. This International Standard deals in particular with exchange of reliability data collected on field.

Regarding decommissioning, the ISO related standard concerns only the ISO 16647:2018 *Nuclear facilities — Criteria for design and operation of confinement systems for nuclear worksite and for nuclear installations under decommissioning*. This standard is limited to the confinement systems.

Regarding radioactive waste management, the ISO/DIS 24389-1 *Management of radioactive waste from nuclear facilities* provides general principles, objectives and practical approaches.

Currently, there is no ISO standards addressing the full scope of decommissioning activities and the management of related radioactive waste and materials.

2.2.2.2. Industrial field

One of the main ISO Standard regarding life cycle data management is the "ISO 15926" which specifies a representation of information associated with engineering, construction and operation of process plants. The ISO 15926 concerns industry standards (like oil&gas industry). A set of additional ISO standards exist and cover the field related to life cycle data management, BIM, visualization and data quality.

Currently, there are no comparable standard available in the nuclear industry.

Current BIM standards present several limitations for decommissioning projects, often requiring the inclusion of other standards or the development of custom solutions to be able to overcome them. Most notably, the Industry Foundation Classes (IFC, ISO 16739-1:2018) does not provide a comprehensive enough way to describe the terrain where the site is located and, thus, software companies are forced to integrate Geographic Information Systems into their solutions (making them more difficult to program and operate with). Furthermore, since these data models do not provide a common mechanism to specify temporal/mobile elements such as scaffolding or cranes, a great deal of useful knowledge is not registered in an interoperable way and, ultimately, is lost during import-export operations.

3. Input data standardization for PLEIADES platform

This chapter highlights the standardising nature of the platform through the input data that can be hosted in a PLEIADES database.

3.1. Ontology and API classes

An important part of the standardisation supported by the PLEIADES platform concept comes from the ontology defined at the start of the project in collaboration with all the partners. During WP1, the platform desired final functions had been listed, and each partner was able to submit the data that seemed essential to ultimately enable the calculations and analyses underpinning these functions.

A visual and global representation of the ontology defined as part of task 1.4 is presented in the Figure 2 below.

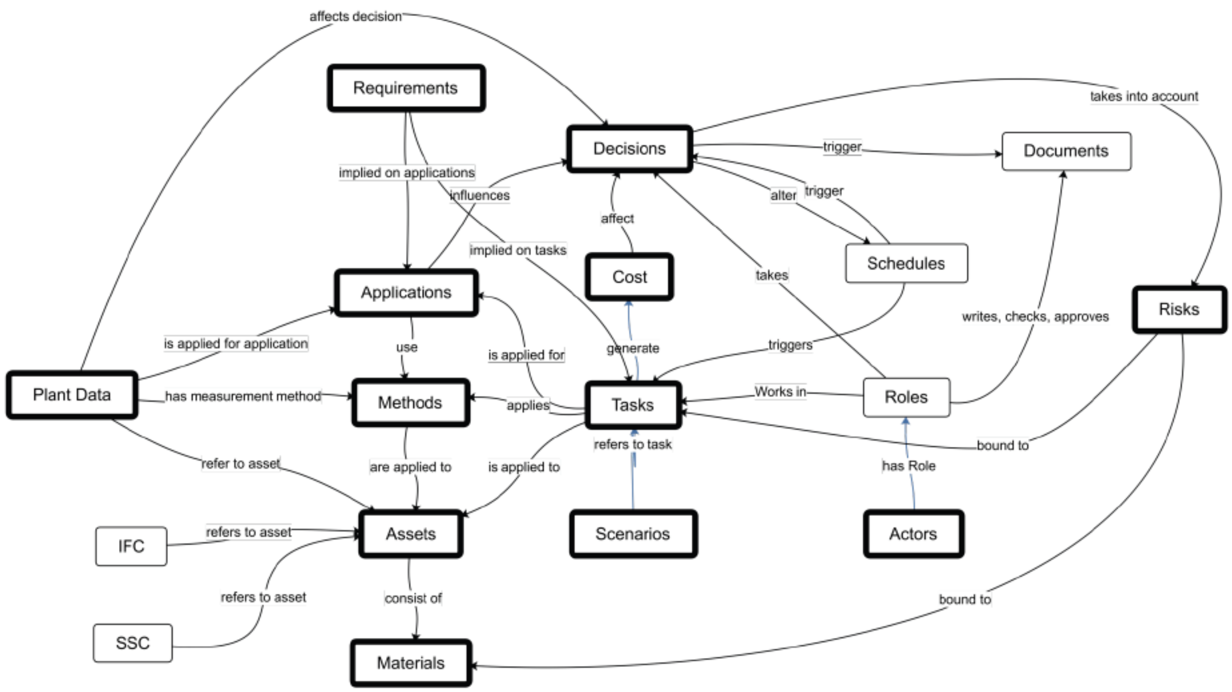

Figure 2: Final Decom Core Ontology from WP1

Input data that can be recorded in the PLEIADES database of a project is regulated by the PLEIADES API classes. This data tree is initially derived from a transcription of the ontology.

This architecture may seem both tedious and restrictive:

- tedious, because of the large number of classes and sub-classes (see Figure 3 below),
- constraining because if user wants to load a type of data into the PLEIADES database for his project, he has to find the class that corresponds to this data.

Nevertheless, it is these criteria that enable the PLEIADES platform, on the one hand, to cover all the data needed to carry out studies linked to dismantling projects, and on the other hand, to move towards standardisation for these project data.

- PlantData
  - Space
    - Cartesian
  - SiteStructure
    - Buildings
    - Floors
    - Rooms
  - NuclideVectors
  - RadiationSources
- Events
- Applications
- Tasks
- Methods
- Workplaces
- Assets
  - Tangibles
    - Parts
    - Tools
    - Equipments
    - Consumables
  - Intangibles
    - Documents
    - Measurements
      - CartesianMeasurements
      - CartesianMeasurementSets
      - PartMeasurements
    - VirtualPostIts
    - SpatialTemporals
    - Calculations
      - DoseUptake
- Materials
- Actors
  - Persons
  - Robots
  - Roles
  - Teams
- Safety
  - States
  - Regulatory
    - Frameworks
    - WasteCategories
    - ClearanceLimits
    - WorkSchedule
  - Risks
    - Register
- Wastes
  - WasteAcceptanceCriterias
  - PackageTypes
  - ManagementProcesses
  - Sorters
- Costs
  - ISDC
- Scenarios
  - Runs
- $defs
  - CartesianPoint
  - MeasuredQuantity
  - MeasuredValue
  - IFCObjectReference
  - RelatedRecord
  - TeamMember
  - Measurements
  - Costs
  - UnitCostFactors
  - NuclideVector
  - Shape
  - ClassName
  - RecordInfo
  - PartHistory

Figure 3 : PLEIADES API classes

As part of the project, standardisation was not an end in itself, but rather a means to guarantee interoperability between the platform and the tools connected to it, and between the tools themselves.

With the benefit of hindsight on the use of the platform, mainly linked to user story testing during workpackage 3, this standardisation quickly led to greater ease of use. Indeed, it was easier to communicate with the other partners about the data to be collected, thanks to the common API architecture. Thus, the different classes participate to identify data not yet collected.

In addition, in a PLEIADES database, several data items are linked together, as many data items contain a "reference" property that refers to one or more other data items. For example:

- roles (of members) records are referenced in team record to define its composition,
- ambient dose rate is referenced to a room in a 3D model, which in turn is referenced to a building level in this 3D model, which in turn is referenced to this 3D model.

This functional interconnection, which is specific to the platform's API, also adds a layer of standardisation since these references between data are common to all PLEIADES users.

Finally, it should be noted that it is not necessarily necessary to declare all types of data in a PLEIADES database for it to be functional/operational. In fact, the data must be collected using the API, but above all with a view to the expected results. For example:

- for a study that does not envisage a dosimetry estimate for the personnel or the production of a 3D dose map, then the RP data is not necessary,
- if we want to carry out a study focusing on total operation duration and waste produced, then the various cost ratios that can be set in the database can be left empty,
- if we want to carry out a study that focuses on the radiological aspect, then the physical inventory, the radiological inventory and the schedule of tasks to be simulated are important data, but in this case the different classes of data relating to waste can be left empty.

3.2. Properties and format

To declare each data type using the PLEIADES platform, that require not only finding an API class, but also complying with the formats and usage rules for the properties that make up each data type.

As shown in Figure 4 below, each class or sub-class is made up of one or many properties in general.

Name String	Description	Part's full name
	ChangeLog	2022-09-29: Added.
	Example	any-string-value-random-8090
ParentPartId Reference	ReferencedClass	Assets.Tangibles.Parts
	Description	In case of more complex systems, this is the way to define hierarchical structure of parts.
	Example	a70b9cdf-1da2-52ef-99fe-f860f1985e03
ParentWasteId Reference	ReferencedClass	Assets.Tangibles.Parts
	Description	If this Part is already a waste, using this Id we can reference to a waste package.
	Example	4a314875-cec5-153c-08c6-d935358d9741
Type String	Description	Type of the part.
	ValidValues	["System", "Structure", "Component", "Fragment", "Waste", "Waste package"]
	Example	Structure
SiteStructureId Reference	ReferencedClass	PlantData.SiteStructure.Buildings PlantData.SiteStructure.Floors PlantData.SiteStructure.Rooms
	Description	In which building/floor/room is the part (or the whole object) located
	Example	2d1381ec-3104-2bc2-3284-80ccb2f418fc
IFCObject Def Optional	Definition	$defs.IFCObjectReference
	Description	reference to a model of the part
	Example	{ "Model": "da67277a-e79a-cbe4-b68e-e3acdb8ce917", "IfcGUID": "1W_HslFTT2WwXj91DxSWxH" }

Figure 4: Properties of “Assets.Tangibles.Parts” classe

Currently, a significant proportion of the formats of certain properties are free. In fact, a format ratio of 80% fixed and 20% free has been chosen ; so as not to overly constrain the first users during the user story tests.

However, it is entirely possible, in the future of the platform, to reduce the proportion of properties with a free format. This would have the effect of increasing the level of standardisation of the declarations to be made in order to create a PLEIADES database, and therefore increasing the difficulty of data collection. But in terms of connecting tools to the platform, it would, on the contrary, reduce the effort required to develop a connector.

Here are some examples of properties with a fixed declaration format:

- properties “Name” or “Message” or “Definition” or “SafetyStateNotes” necessarily call a character string,

- property “ReferencedClass” necessarily calls a "RecordId", i.e. another data from the platform,
- property “IFCObject” necessarily calls a "RecordId" of a 3D model registered in the platform, as well as the ifcGUID of the 3D object concerned. Example:


```
{
    "Model": "8039f7cc-5f9e-eb03-5b69-4d0be535eff3",
    "IfcGUID": "1W_HslFTT2WwXj91DxSWxH"
}
```


- property “MeasurementIds” necessarily calls a list of RP measurement results. Each result is associated with a "MeasurementType" type and a identifier "MeasurementId",
- distance properties that must be declared in [m]: “Width”, “Height” and “Length”,
- surface and volume properties that must be declared in m^2 and m3: “Volume”, “InnerSurface” and “OuterSurface”,
- “Mass” and “VolumicMass”: [kg] and [g/cm^3],
- property “NuclideVector” calls a unit ("Bq/kg" or "Bq/m2" or "µSv/y" or "relative amount") as well as a list of isotopes with their distribution in the spectrum. Example:


```
{
    "Co-60": 0.15,
    "Cs-137": 0.85
}
```


- properties “Location” and “Coordinate” call the coordinates of a point in X, Y and Z, i.e. a "CartesianPoint" in the database. Example:


```
[
    -803.43,
    540.7,
    -438.926
]
```


- property “File”calls up a path in a MinIO server bucket pointing to a file,
- property “HourlySalary” in €/h.

Here are some examples of properties with a free declaration format:

- property “TechnicalParameters” is used to supply technical data, for example to define the work rate for a work method,
- property “UnitCostFactors” calls a cost ratio. Example:

```
{
    "DeprecationCostsPerHour": 1234,
    "CostPerTonne": 888,
    "TransportationUnitCostFactor": 567
}
```

- property “Costs” calls cost data. Example:

```
{
    "FixedInvestments": 1234,
    "FixedExpenses": 1234
}
```

3.3. Specific data and results

Data are specified as necessary because involved in the calculation of at least one of the outcomes expected by the main stakeholders of nuclear decommissioning projects. Therefore, it seemed judicious, before talking about specifics data, to recall the main families of expected standard results:

- estimation of project duration,
- estimated overall project cost,
- estimated waste generation,
- dosimetry assessment.

WP3 of the project demonstrated that the PLEIADES platform can be used to create project databases that can be used to carry out studies giving this type of result.

However, certain more specific data, which could potentially lead to new or more precise results, were also considered during the project, and classes were inserted into the platform API. Some of these data are described below.

3.3.1. Kinematic data

In order to study the space and accessibility aspects of handling equipment or moving a mobile tool such as a gantry crane or an intervention robot, kinematic data are essential input data.

Indeed, this data allows the different axes of movement and degrees of freedom of a 3D object to be parameterised so that they correspond to reality.

Kinematic data in the PLEIADES platform:

1. For an “Assets.Tangibles.Tools” record, for example, we will find the "URDFKinematicDocumentId" property, in which the document record reference is requested.

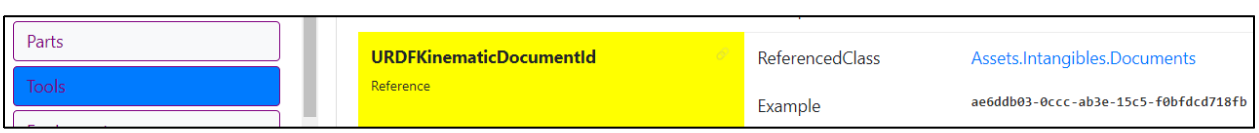

Figure 5: API property “URDFKinematicDocumentId”

2. It is therefore necessary to first declare an "Assets.Intangibles.Documents". To do this, we indicate the type of document (in this case "URDF"), then we must indicate the access path in the MinIO server pointing to our document containing data in URDF format.

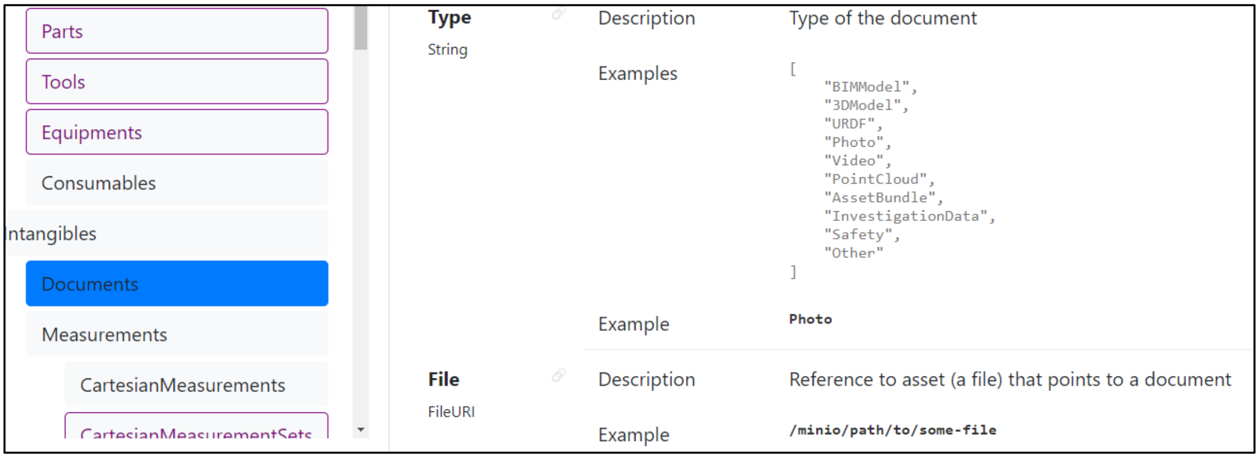

Figure 6: API property "Assets.Intangibles.Documents"

3. Before declaring a document in the database, it is therefore necessary to enter the data in a file (a text document for example), then upload this file to the bucket of the project concerned. We can then use the path indicated in the MinIO console to declare our document.

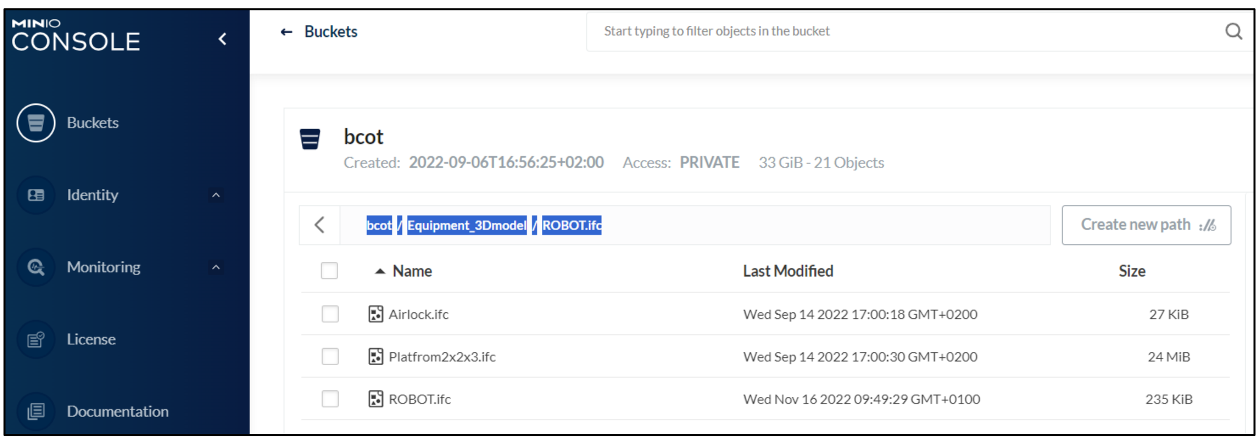

Figure 7: MinIO path to use for a "Assets.Intangibles.Documents" record

The URDF format (Unified Robot Description Format) is a standard file for storing this data. If the client does not have the kinematic data of the equipment, either because it is an old equipment or because the project's level of progress (feasibility, preliminary draft) does not allow to benefit from these data, it is possible to define the kinematic data. To produce the URDF file for a piece of equipment, such as a bridge, you need to have at least:

- the 3D model of the bridge, in order to identify the moving parts and integrate the equipment into the 3D model,
- all available manufacturer data, such as angular limits.

3.3.2.Safety-Security data

One of the functions required for the platform is to enable a person responsible for safety or security to be able to understand/verify the various safety and security issues inherent in all nuclear decommissioning projects.

In the frame of the task 1, the deliverable D1.3 “Input BIM data base” has been delivered. The section 2.5 of this deliverable addresses “Safety related data” aspects. It recalls that the regulatory review is the task performed by a regulator or a technical support organization (TSO) to review safety documents submitted by a licensee to support a decommissioning application. To facilitate the regulatory review performed in the frame of a licensing process for decommissioning, benefits can be taken from the set of data associated to a 3D model. This section proposes to identify the safety related data to be attached to each Structures, Systems and Components (SSCs) of a nuclear facility supporting the regulatory review process. The Safety data families to support regulatory review is providing in the following figure:

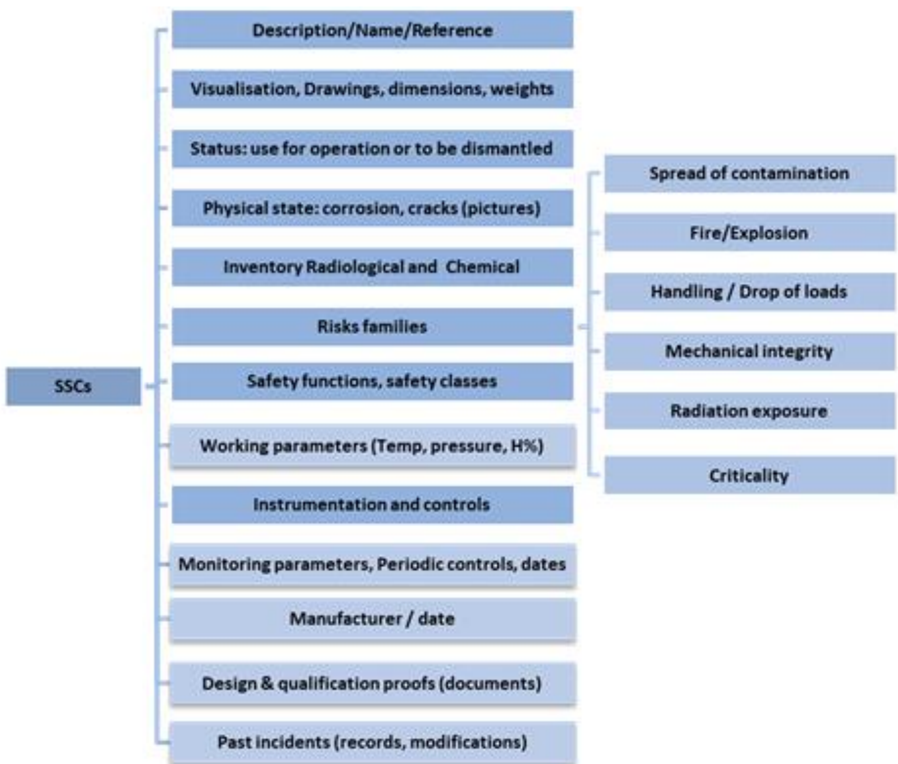

Figure 8: Safety data families to support regulatory review

For Systems, Structures and Components (SSCs) the following data and information are considered relevant:

- description of SSCs (Name, reference, dimensions, weights),
- visual aspect and 3D representation of the SSC: all components participating to a safety system should be identified in an integrated view (example: visual illustration of all the components participating to the same the ventilation network with a specific colour or visual effect), drawings, pictures,

- status: use for operation, to be dismantled,
- physical status (corrosion for metallic components, cracks for concrete),
- radiological and chemical inventory, when applicable,
- risks associated to SSCs (loss of containment, fire, handling, etc),
- safety functions the SSC participates with (spread of contamination, heat removal, criticality),
- safety class, if any,
- working parameters (min/max temperature, pressure),
- instrumentation and controls: Systems and components participating to I&C, Control rooms (location, premises) and thresholds associated with safety automatic actions Manufacturing date, manufacturer, model (if applicable),
- pictures for a better understanding of the type of equipment and its integration in its environment (if applicable, they should also show corrosion effects for metallic components, cracks for concrete),
- maintenance procedure (document in pdf format for example), monitoring and surveillance parameters, if any,
- qualification of SSCs (document establishing the proof of qualification),
- list of past incidents (document describing any event and corrective actions implemented).

Initially a property and a format for each of these points has been defined. Then, all properties into the 'Safety' class have been added. But at the end, as a conclusion this list represented a lot of important information for SSCs, but not exhaustive. So, it has been decided to include the following 3 properties in "Assets.Tangibles.Parts" class, to indicate on the one hand that the 3D object in question is an SSC, and on the other the various useful safety and security data available:

1. "SafetyStateId" property, where you can indicate the safety state of the SSC by name, and a description of this state. Examples of safety states:

```
[
    "Ready for use for operation",
    "To be upgraded before utilization",
    "Ready to be dismantled",
    "To be dismantled after"
]
```

2. "SafetyStateNotes" property to indicate any note describing the current part's safety state.

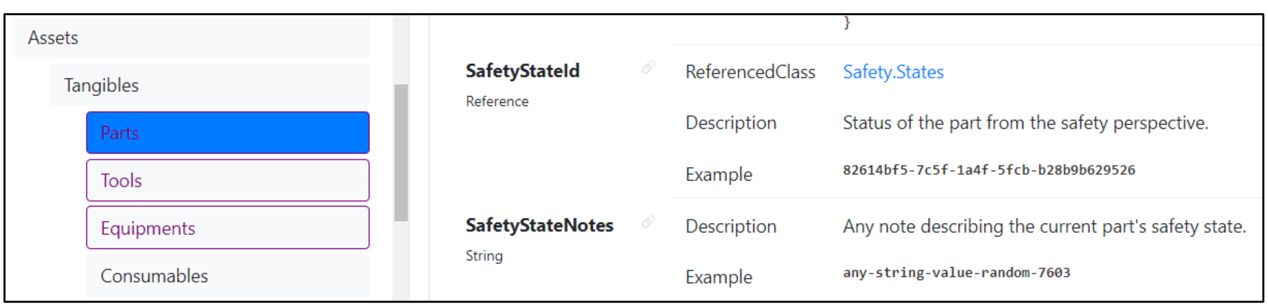

Figure 9: Properties "SafetyStateId" and "SafetyStateNotes" in "Assets.Tangibles.Parts" class

3. "DocumentIds" property, which allows any type of data or document to be saved, including those listed above.

4. PLEIADES support in standardisation

This part proposes the PLEIADES contribution and support in standardization process; mainly in data standardization and management.

4.1. Supporting of existing standards

As presented in 2.1, several guides, in nuclear decommissioning field, are currently available. They provide guidance for regulatory bodies, licensees, technical support organizations and other interested parties on planning for decommissioning, conducting decommissioning actions, demonstrating completion of decommissioning and terminating the authorization for decommissioning of facilities.

PLEIADES project aims to support these existing standards by proposed guideline in data standardisation and management.

4.2. Best practices: user story performance evaluation

4.2.1. Data Collection and Integration on PLEIADES Platform

As presented in 3, several types of data have been listed and required for perform nuclear decommissioning studies. In this part the methodology employed for data collection and integration is presented, more detailed are available in the D3.1.

The input data collected can be divided in several types:

- Data for the development of 3D CAD modelling and for the selected target sites and areas
- Data for the development of the BIM model
    - Physical inventory
    - Radiological inventory
    - Kinematic data to animate the different mechanical equipment such as cranes, remote handling systems, etc.
    - Waste streams and waste management associated
    - Contextual information, such as the equipment, tools to be used during the D&D operations, schedule and team definition, etc.
    - Data related to safety as characteristics of fire protection systems, electricity network, utilities (air, steam, decontamination fluids…) etc.
- Input information required for scenario analyses, e.g. development of scripts for the scenario simulations to be implemented

Data collection has been performed along two “campaigns” :

- First, to highlight the main data required to perform digital decommissioning studies, a data collection table has been developed. This table list the main input data and the associated the unit / format / file type needed.
- Then a second campaign of data collection has been realized in order to define more precisely the input data to collect. In this each main data is described more precisely.

To complete perform the second data collection, the decommissioning scenario must be considered, and define precisely in terms of examples of:

- Steps: allowing the scenario realization (example: Team that performs each step, people who make up these teams, necessary tools, implemented methods, etc.).
- Objects of the 3D model concerned by operations must be identified.

To collect data with the scenario associated, a dedicated excel file has been developed, composed by several sheets:

- 3D model data
- Radiological data
- Resource definition
- Parts
- Applications methods costs
- Scenario
- Waste management and data
- Safety regulatory

The methodology employed for the data collection allows to consider all the input data to perform decommissioning scenario simulations and to select the required data as function of a specific scenario. These data collection are based on the development of the data collection table and the use case detailed data table.

This methodology in two steps could be a base for the data standardization and management.

Then the data integration in PLEIADES platform proposes currently two standards:

- Using the PLEIADES platform database interface. This solution is based on the final structure of the standard database of the final platform. Interface allows the end-user to enter data in different classes and sub-classes and to select already filled-in properties to create references. Then, an internal API will automatically transfer data entered in this interface to the MongoDB database, which is the final hosting solution.

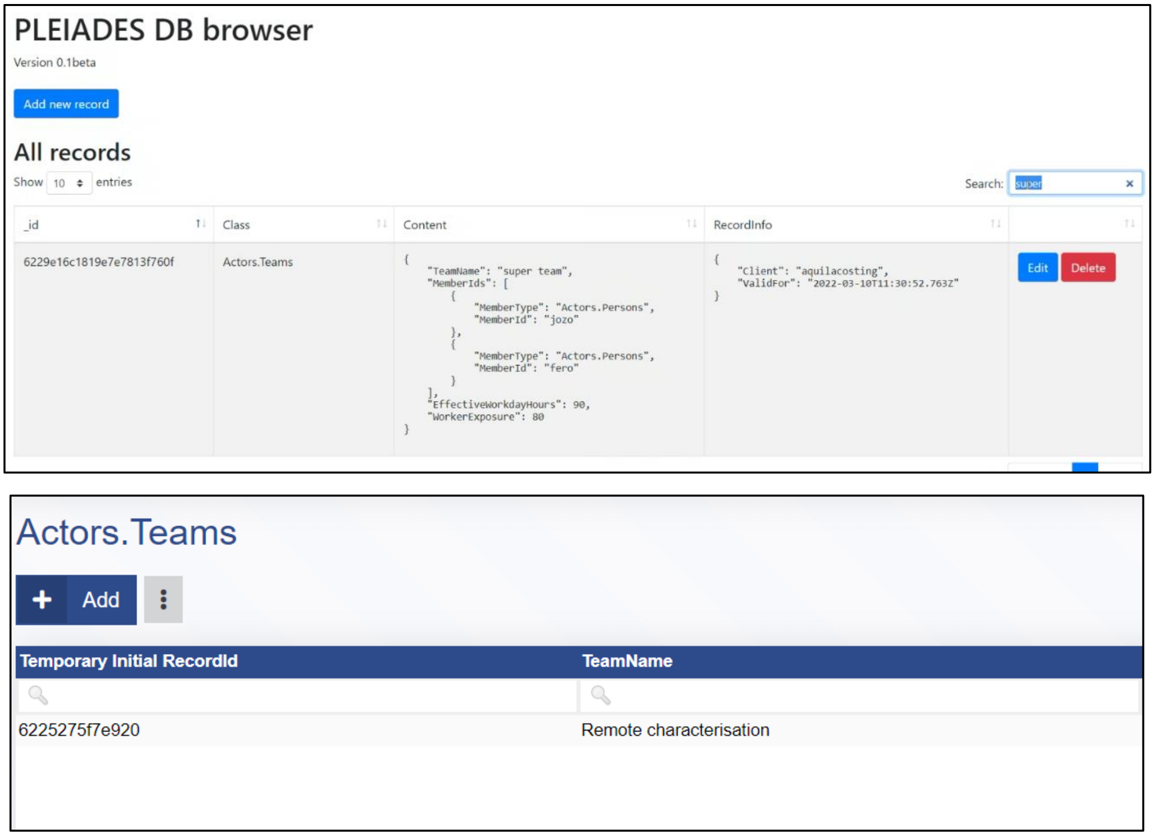

Figure 10: Visuals of the current PLEIADES database interface

- Using a graphical interface to produce a JSON file. This integration is based on the final platform standard database structure, the database structure is transcribed into a JSON file. Interface allows data integration and automatically inserted into the JSON file of the database structure. Then a single JSON file containing the PLEIADES database structure is generated and can converted to transfer data to the project's MongoDB database.

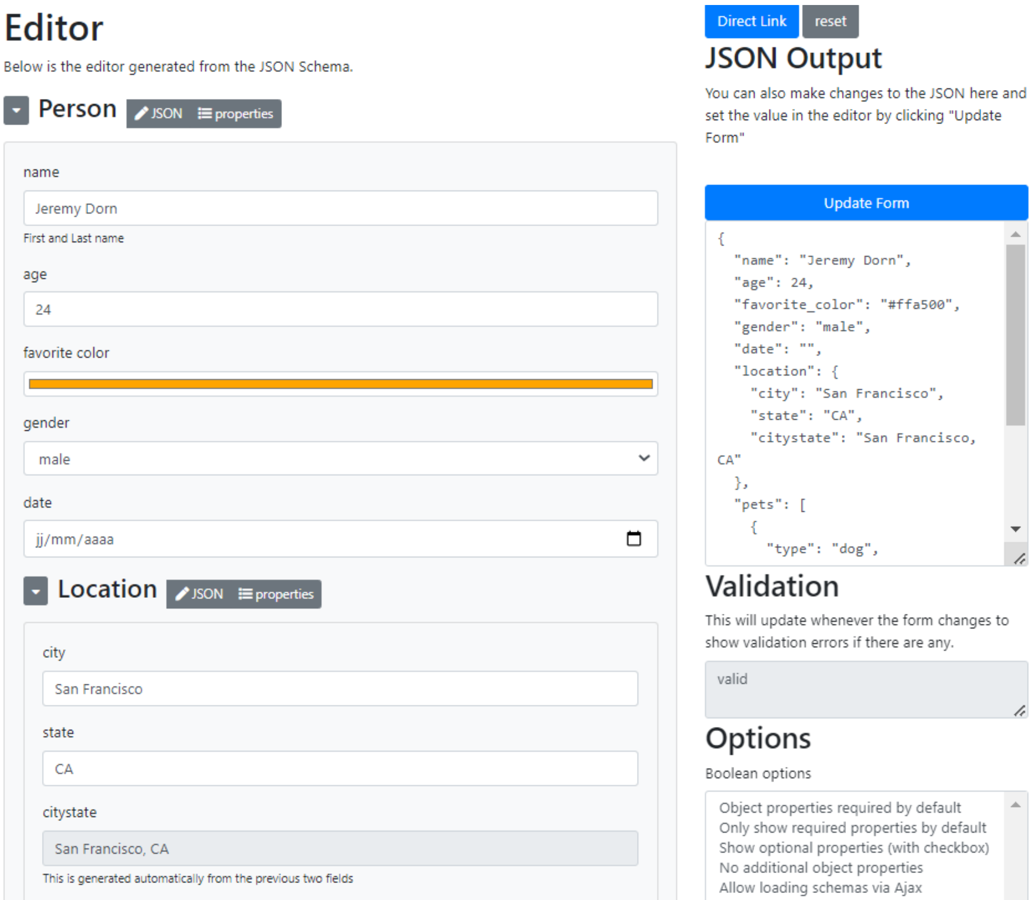

Figure 11: Graphical interface to convert data to JSON file

4.2.2. Output data from PLEIADES platform

One of the advantages of a standardized platform sauch as PLEIADES is to allow the data interoperability. Thanks to the data collection and integration methodology, all the data integrated in the PLEAIDES platform can be available for the connected simulation tools.

Dedicated scenario for test and validate the use of PLEIADES platform have allowed to obtain a large variety of results, sauch as:

- Scenario feasibility: scenarios established were able to integrate the physical and radiological environments, as well as the intervention resources involved.
- Waste estimation: waste produced during the simulated decommissioning scenarios can be estimated and the results obtained investigated.
- Radiation exposure estimation and safety assessment: radiological characterisation data could be imported from the platform into the 3D models within several software tools. Using their modified model and the D&D planning, an estimate of the radiological dose could be established for dedicated scenario. Individual dosimetry may be established on the basis of the worker's profile transposed into exposure fractions in relation to the measurement point,

which in turn depends on the workplaces defined. Thought radiological and physical risk assessment some preventive measures could be proposed, complying with ALARA methodology.

- Cost and duration estimation: all the data from scenario, hosted on the platform databases, can be used to establish an estimate of labour, and tooling costs, including waste management costs.

The deliverable D3.3 presents all the test cases simulations results, performed with PLEIADES platform and digital tools connected.

The aim is to propose through the standardization of the data collection and integration, a standardization of the output data, i.e. simulation results using several digital tools. Indeed, all the results obtained through simulations by using different digital tools, are re-integrated to the platform. In this way some of the platform's tools interact with each other, in particular to share output data from software “A” to be used as input data for software “B”.

5. Conclusion

The state of the art related to the standards applicable to decommissioning projects, combined with the BIM model standards applicable to the nuclear industry, provides a large view of the current existing standards. These standards allow to consider, in a dedicated way for the most part, the various aspects inherent to the decommissioning and dismantling projects studies. These standards are logically organised by category.

As a result, it is necessary to master several reference systems in order to comply with the various standards and best practices in force. In other words, currently there is no ISO standards addressing the full scope of decommissioning activities and the management of related radioactive waste and materials.

Thanks to the structure of the PLEAIDES platform API, standardised database can be created. Certain classes or property units can be discussed to be optimized and completed to cover all the D&D project process. New classes or properties could therefore be added to the API architecture, in order to be able to declare this data on the platform. However, the PLEIADES platform proposes currently a finite list within a given timeframe; the main objective was to demonstrate that such a platform could fulfil the functions envisaged at the start of the project. The exhaustive nature of the data hosted remained an important but not required to perform the first test and validations.

In addition, PLEIADES platform proposes standard related to the data management. From the data collection, selection to integration. The advantages of the use of standard data methodology acquisition and integration is to allow to PLEIADES platform to provide a large type of results and output.

If the API architecture is further tested (by new user stories, for example), then certain classes and calculation methods could evolve to be totally in accordance with the needs of D&D projects. The 20% of properties with a flexible format should also be changed into fixed formats. The API architecture could then be used as the basis for a standard concerning the data and methods for estimating the various key points of D&D projects, such as duration, dose received, quantity of generated waste, overall cost, and to support safety/security analyses.

6. References

- PLEIADES - D1.1: Requirements for the design of the PLEIADES concept
- PLEIADES - D1.2: Specifications for the PLEIADES system prototype and validation tests
- PLEIADES - D1.3: Input BIM data base
- PLEIADES - D1.4: Ontology describing a nuclear decommissioning project
- PLEIADES - D2.1: PLEIADES platform software architecture
- PLEIADES - D3.1: Input Data
- PLEIADES - D3.3: Final report including all test cases simulations results