A PLM approach to support nuclear decommissioning process

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Abstract: In a context where decommissioning activities are becoming more and more strategic for the nuclear sector, data information management is of prior interest, especially due to its particular complexity. The main challenge is to ensure the access to the right information at the right time to the right person, in order to provide a consistent basis to the decision support framework. Such information must be well storage, managed and controlled, meaning that the user has to be aware of the level of maturity and uncertainty attached to such information to complete our mastery of nuclear-based energy all along its lifecycle. In order to answer these needs, a PLM approach is proposed and experimented as information backbone for the decommissioning activity and support of the whole process design.

KEYWORDS: *PLM, Nuclear facility, Decommissioning Process, Lifecycle Model*

1 Introduction

At this time, the first generation of Nuclear Power Plants (NPPs) is gradually being taken out of service and decommissioned. Around 300 nuclear facilities will be stopped around the world in the next 20 years and more than 10 decommissioning operations are on-going in France. A decommissioning process is long, complex and requires the determination and the description of the decommissioning scenario of the installation, which means the description of all the operations which are run from the final shutdown of the NPP units.

Amount of data are needed to establish a physical and radiological inventory of the totality of the NPP [1]. The main challenge is to ensure the access to the right information at the right time to the right person, in order to provide a consistent basis to the decision support framework. Such information must be well storage, managed and controlled, meaning that the user has to be aware of the level of maturity and uncertainty attached to such information to complete our mastery of nuclear-based energy all along its lifecycle. In order to efficiently support, manage and control such activities, **information management is so of prior interest**.

Nevertheless, the intrinsic characteristics of Nuclear Facilities Decommissioning (NFD) process make this information management very complex and requires new approaches. In this research work, the authors aim to propose **a PLM (Product Lifecyle Management) approach not only as an information backbone for decommissioning activity but as an approach to support the whole design of the process**.

The paper is structured as follow. Section 2 analyses the literature and the decommissioning practices in order to specify the requirements of the approach. Section 3 develops the proposition made and section 4 gives details on the prototype and experimentation made of this basis. Finally section 5 discusses the results and give some perspectives.

2 A state-of-art

2.1 Specificities of NPP decommissioning process

IAEA (International Atomic Energy Agency) proposes this definition for decommissioning process: “The administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility” [2]. It implies that decommissioning does not restrain to the dismantling activities and covers all operations from the preparation to the final site clean-up (Figure 1). In particular, it begins before the end of nuclear operations.

One can list decommissioning characteristics that will have a strong impact on data and information management:

- long lifetime of facilities (and so some of the information and data may not be digital),

- few standardization between facilities,
- few experiences from dismantling,
- nuclear radiation so strongly driven by regulation,
- few digital information,
- a large number of stakeholders (facility operator, ANDRA, maintenance, etc.) with very specific expertise and dedicated and heterogeneous information systems,
- a very large amount of required data (like requirements (project, regulatory, functional, technical ...), descriptive documents of the installations, data on hardware, operating history, etc.).

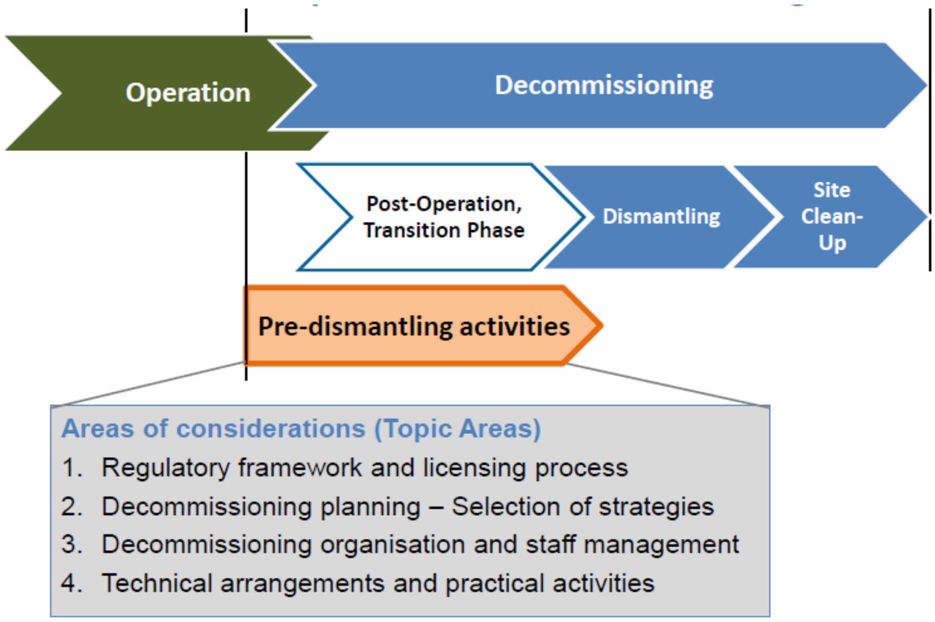


Figure 1. IAEA definition of nuclear facility decommissioning [3]

With the characteristics listed in the previous section, one can imagine the complexity that occurs in information management for NFD process. In this context, data and information are focusing on three essential elements: **the nuclear facility, nuclear wastes and the decommissioning scenario**. The main focus is so on a specific instance of elements that is central to the NFD. Some examples of data and information required by the regulations in the process are: requirements (project, regulatory, functional, technical ...), descriptive documents of the installations, data on hardware, operating history, physical and radioactive inventory, costs, etc.

As a consequence, here is a list of main constraints that create complexity in data and information management for decommissioning activity:

- A large number of data and information **may not be digital**, due to the long life-time of facilities,
- Data and information are **strongly heterogeneous**, due to few standardization between facilities, to the large number of stakeholders with very specific expertise,
- Data and information are **highly spread** over a large number of dedicated and heterogeneous information systems among the stakeholders,
- Data and information are on **very different levels of detail**, with data on very specific parts or information on all the facility, with possibly 1D, 2D or 3D digital mock-up.
- The **quality** of data and information is **untrusty**, with problems of redundancy, inconsistency, uncertainties, inaccessibility and unsuitability for end users that occurs.

Finally, due to the lack of experience and feedback, information management is non-mature at that time and so a strong effort is required to define and share these specifications.

2.2 Information management for NFD process and PLM approach

With all these constraints and specificities, it is not complicated to understand why there is few research works that have tackled this problem of information management in the context of NFD process. Among the literature, one can cite [1], [4] and [5] that have proposed an integrated information systems for NFD process but which implantations are still limited, or [6] that focuses on information management for dismantling planning. If we extend the literature review on two other domains (nuclear facility design and building deconstruction), **two approaches are emerging: PLM** (Product Lifecycle Management) **and BIM** (Building Information Modelling).

PLM can be mostly understood as the information backbone of the organization attached to the all lifecycle of a product. The PLM concept holds to integrate all the information produced throughout all phases of a product's life cycle to everyone in an organization at every managerial and technical level, along with key suppliers and customers [7, 8]. The lifecycle model consists of three phases during which information must be tracked and knowledge capitalized: The Beginning-of-Life (BOL), the Middle-of-Life (MOL) and finally, the End-of-Life (EOL). PLM tools integrate functionalities to enhance collaboration, workflow engine to automate processes, approaches to manage product variants and versions, PLM is supposed to fill the gap between enterprise business processes and product development processes. In other terms, PLM works as glue which adhere all the processes that have something to do with product and connects all functional silos to make them horizontally integrated [9].

BIM is defined as the method of generation execution and monitoring of the "building data" during its life process. Moreover, BIM is also known as a combination of process and technology to improve efficiency and effectiveness of delivering a project from inception to operation and maintenance [10]. In construction projects, BIM has been used by architecture, engineering and construction or facilities management (AEC/FM) to implement collaborative management of construction projects between all stakeholders. The term generally refers both the model(s) representing the physical characteristics of the project and to all the information contained in and attached to the component of theses model [11]. In the recent literature, BIM and PLM are converging and it is difficult to separate them [12].

A large literature exists on the deployment of PLM and/or BIM to support the BOL (Beginning of Life) or MOL (Middle of Life) phases of NPPs [13-15]. One can cite for instance [13] that address the digitized concept of the nuclear industries by deploying PLM and BIM merely focusing on the UK's nuclear sector. In their discussion, they all claim that both PLM and BIM play the remarkable role in the manufacturing and constructing the innovative NPP and industries.

Some authors are enlarging the scope of BIM and/or PLM to tackle the entire NPP lifecycle [16-19]. As an example, authors of [19] examine that one of the critical challenges while keeping the foundation of NPP from set-up to decommission phase is the proper and accurate management of the resources in the short span of time. Besides, most of the societal needs are inter-related to the efficient utilization of the power plants due to various hurdles and expenses to tackle, so PLM is the dire need of the overall nuclear facility environment.

A previous research work [20] has demonstrated that **a mixed PLM-BIM approach can be suitable to support NFD**. The question is so how to adapt and deploy such approach in the NPP decommissioning context.

3 A NF/DLM (Nuclear Facility Decommissioning Lifecycle Management) model

3.1 Core concept of the model

When applying a PLM approach, the first question to ask is: what is the 'P' of PLM, i.e. the product? This question is not so easy to answer in our context, especially when trying to image the lifecycle of such product. As mentioned in the previous section, decommissioning focuses on three main elements: the nuclear facility, nuclear wastes and the decommissioning scenario (Figure 2 and table 1):

- **Nuclear facility** (top line in Figure 2): in one hand, the product is what has been always considered as central in operations, but in the other hand we only focus at its EOL phase since we restrain ourselves to the decommissioning phase.
- **Waste** (bottom line in Figure 2): in one hand, the decommissioning really produces wastes so we are close to classical PLM contexts, but on the other hand, the change is too big in term of mentality and we lose the links with the operations which consider the facility as the product.
- **Decommissioning scenario** (middle line in Figure 2): in one hand, we can easily define its lifecycle from the standardised definition of the process, but in the other hand, it really implies of change of paradigm in the PLM approach.

For all these reasons, we so propose to gather these three elements together, in order to combine all advantages and reduce the constraints of each paradigm. Moreover we decide to have a PPO (Product Process Organisation) point of view on this system in order to enlighten the decommissioning process as the "manufacturing process". With this choice, the lifecycle can be defined like this: the BOL phase is the decommissioning preparation, the MOL (Middle of Life) phase groups all dismantling operations and the EOL phase corresponds to site clean-up and REX.

	BOL phase	MOL phase	EOL phase
Nuclear Facility	Facility design Facility construction	Operations Maintenance	Decommissioning
Waste	Waste design according to the selected waste road	Waste production by type and by geographical area	Waste evacuation by waste road
Decommissioning scenario	Scenario design Scenario validation by authorities	Scenario monitoring	Return of Experience

Table 1: Different "product" lifecycles in NFD

Figure 2: Different "product" lifecycles in NFD
(BOL phase in orange, MOL phase in green and EOL phase in blue)

3.2 Main functionalities

We have determined that none of the research and industrial works listed in the literature review are properly tackling the specificities of NFD and only consider this process as part of EOL phase of NPP lifecycle. In our understanding of these concepts, applying them specifically to this process can improve the overall performance and safety.
In this research works, we extensively synthesize the leading role of our approach on the basis of their significant contribution in the NFD process. After deep analysis and critical examination of the literature [19], a list of functionalities that are required for NFD can be drawn (Figure 3), with PLM specific ones (in green), BIM specific ones (in orange), BIM-PLM common ones (in blue) and NFD specific one (in white) that does not exist at that moment neither in BIM nor PLM.

4 Experimentation

Once the model defined, an experimentation has been organised, with ARAS Innovator PLM system [21]. Globally, we use a 5 step methodology to construct the experimentation.

4.1 Perimeter definition

We decide to focus on the pre-dismantling activities with the objectives to support both the decommissioning scenario elaboration and its definition. As a consequence, we focus on the BOL phase of the considered system.

4.2 Process Modelling

SIPOC (Suppliers, Inputs, Process, Outputs, and Customers) approach has been used to characterise business processes. A special work session has been organised with 12 EDF experts working on 6 different business processes. The results of this session have been shared among the EDF community for validation. Hereafter, we specify the information processes with BPMN language to support these processes (Figure 4).

Figure 3: **BIM-PLM functionalities elicited for NFD: in green PLM-specific functionalities, in red BIM-specific ones, in blue BIM-PLM common ones and in white NFD-specific one [19]**

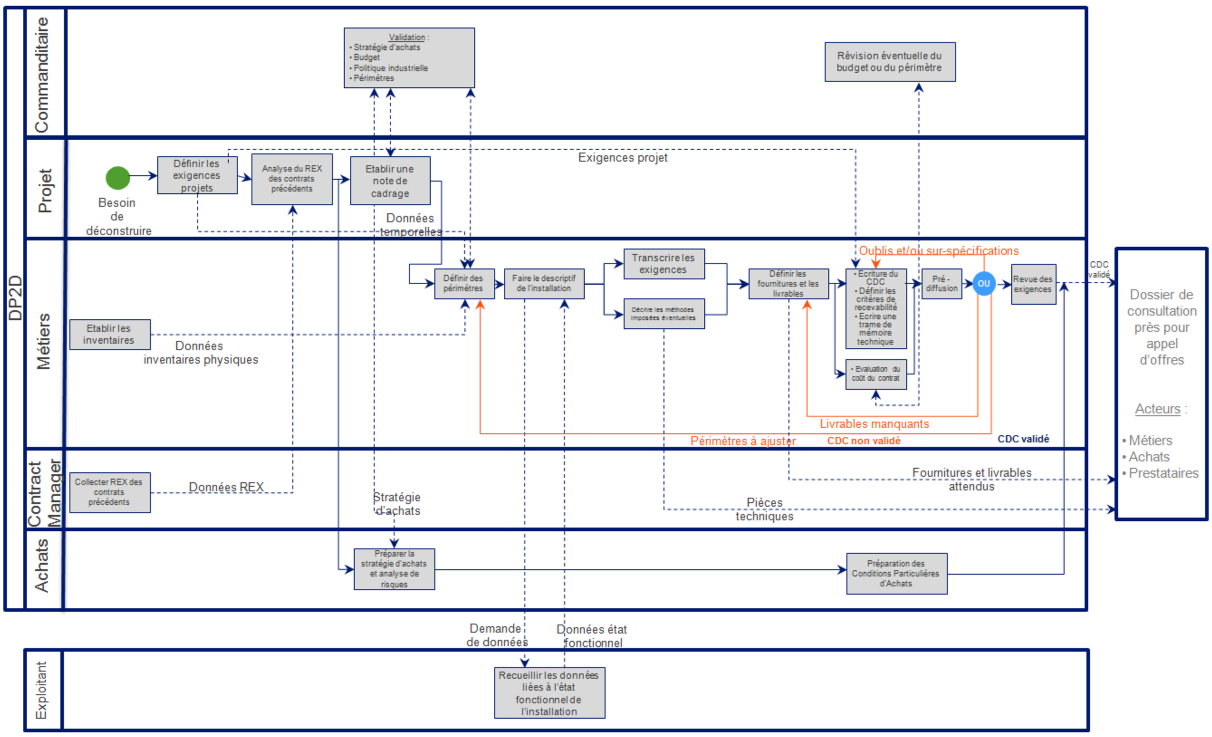


Figure 4: **Information workflow specification with BPMN: Redaction process of a specification note for a dismantling delivery**

4.3 Data model specification

An initial data model has been specified by extraction from the previous stage to fit the exact requirements of decommissioning process (Figure 5). The Part, Documents, CDC and Requirements classes are one proposed in the core model of a PLM, whereas the REP_local, REP_Materiel and REP_SE classes are derived from the Part class to fit the specificities of the NFD process. By following this methodology, we insure the global consistency of the model with PLM approach.

One can take inventory management as an example. The data structuring is geographical, but that does not mean that the functional properties are ignored. Linking a material to elementary system provide

information about its function, but also about its radiological state. The functional position of materials is also recorded and modifiable in the PLM (consigned open, consigned closed, in working order, etc.) which provide necessary information for the elaboration of dismantling scenario.
On the list of functions presented in Figure 3, we select for the first prototype mainly the core BIM-PLM ones, i.e. data vault, project management, collaboration management & product visualisation.

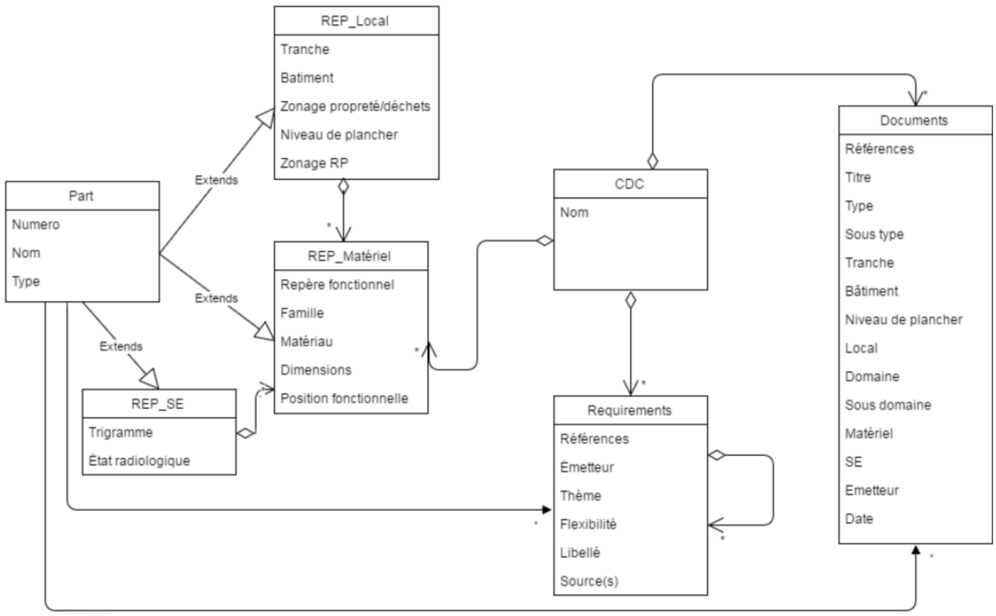


Figure 5: **Initial data model implemented in ARAS**

4.4 Software prototyping

With these inputs, we prototype a software by accordingly configuring the ARAS Innovator PLM. The data and process models have been deployed by adapting the core model proposed by ARAS (Figures 6 and 7).

4.5 Experimentation

An experimentation of this prototype has been realised. The project only focused on one unit of the Fuel building (BK) with simplified dismantling scenarios about representative equipment, collected physical and documentary data, gathered project and technical requirements (Figure 8).
The prototype was tested by a team of seven future users without strong background on PLM and no experience at all on ARAS software tool. The test was organised in a half-day meeting on the basis of the redaction of a specification note for the dismantling of the room of the heat exchangers EAS, including a waste kinematic to extract these big components, which is a representative operation of dismantling. All along the progression of the workflow, various forms of manipulations were proposed to the users. Each participant received a user guide of the prototype, a presentation note of the use context, a TO-DO list and an evaluation grid.
At the end of this session, all participants have been asked for feedbacks, which allowed us to collect commentaries which, with the evaluation grid, help to validate or invalidate the needs and if the responses the PLM provides are satisfying.
Each criterion could be rate (with a points system) to measure the interest of the diverse tested functions. The majority of the functions which received the maximum mark correspond to a job need for which the prototype answers. Those which received a lower mark were mostly system functions shared by all the PLM tools and essential to its proper functioning (lock/unlock function for instance).
The prototype brings an answer to the majority of the needs which have justified its implementation. It is very structuring as well as in terms of data than in regards to working processes. It allows the users to have a better visibility on their workload, a better control of the operation's perimeters and provide a better inventory management. The requirements are well defined, even if the definition is maybe too heavy, and that allows users to view and correct the requirement affected by an upstream modification. This prototype is intuitive, handy and, due to the fact that many people do not want to see their working habits change, it will be able to be used as a demonstrator, to show the benefits of the PLM can bring for dismantling projects.

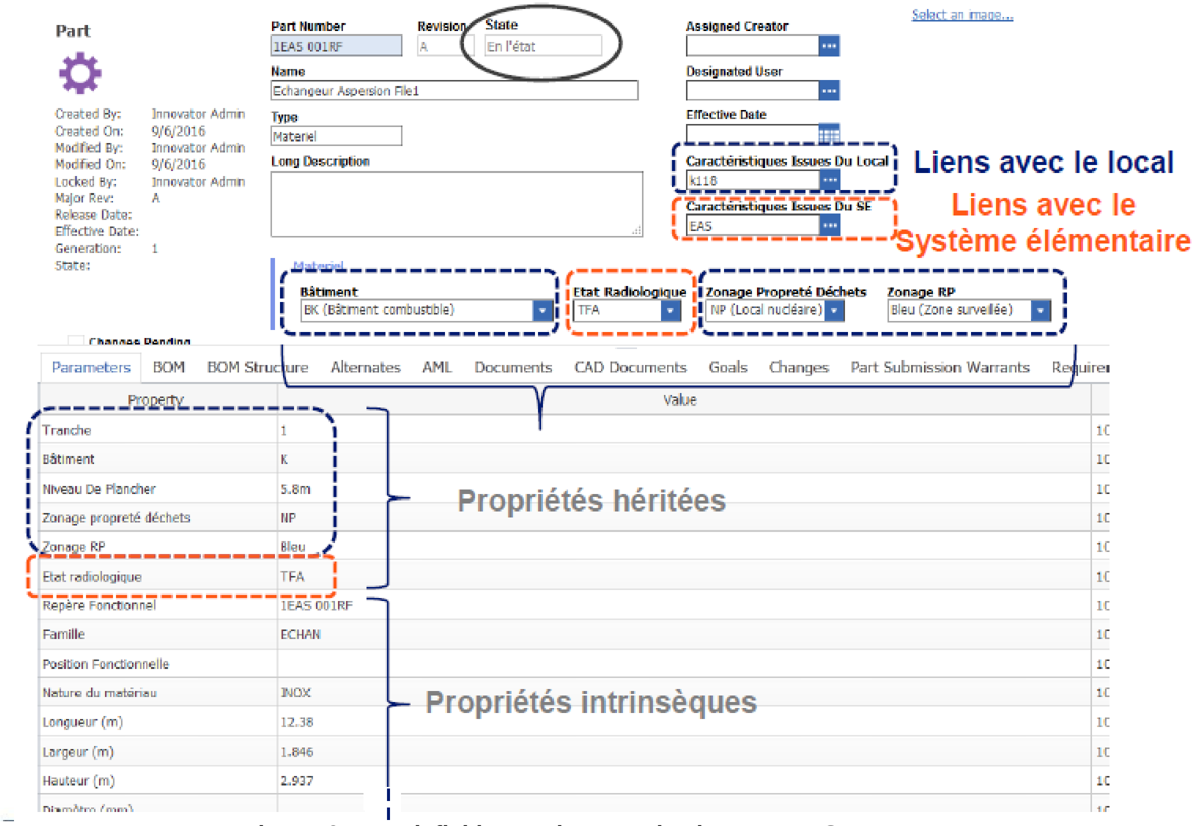


Figure 6: Part definition and customization on ARAS prototype

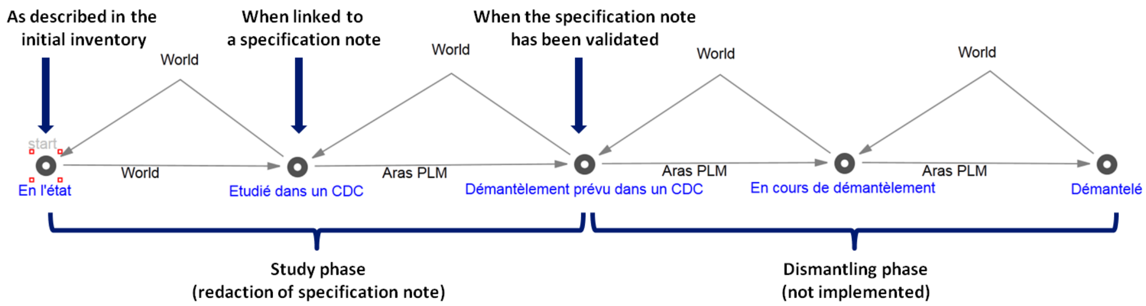
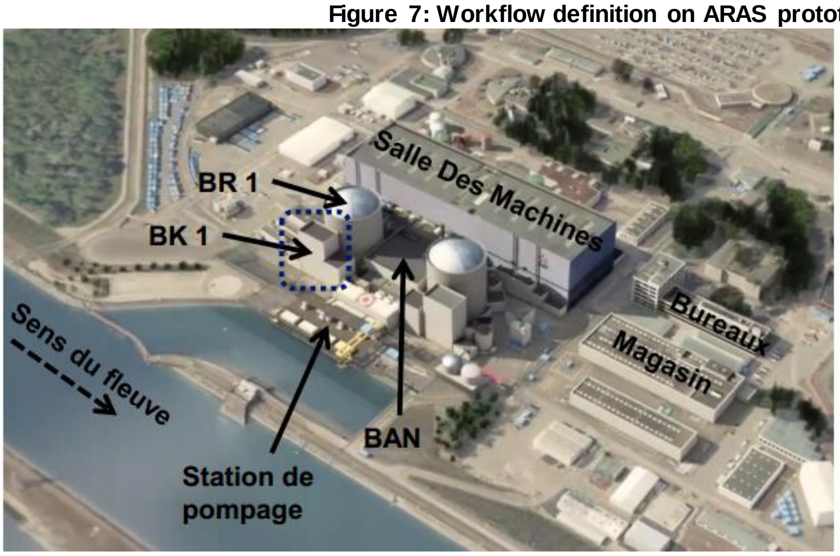


Figure 7: Workflow definition on ARAS prototype



Légende :

BK : Bâtiment combustible
BR : Bâtiment Réacteur
BAN : Bâtiments des Auxiliaires Nucléaires

Figure 8: Heat exchangers EAS example

More than the fact that the prototype answers correctly to the needs, those results highlight different interesting points. The fact that the system functions were less appreciated than others shows the importance of the change management to set up. It also an interesting point, that the prototype could serve as a communication tool.

5 Conclusion

Nuclear facility decommissioning activity is facing an important challenge: an efficient and robust information management is required to handle the intrinsic and extrinsic complexity of this activity and to support the strong increase of activity in the next decades.
Current information systems are not sufficient to tackle this issue and the authors propose to adapt the PLM approach in this context, as an information backbone for decommissioning activity and as an approach to support the whole design of the process.
Based on the NFL/DM model proposed, a software prototype has been developed on the basis of ARAS PLM innovator solution. This prototype has been tested by experts of the domain in order to validate the functionalities.
This experimentation answers the business and information management needs and demonstrates PLM interest in the NPP decommissioning context, like the task coordination between multiple stakeholders, requirements traceability, task perimeter control, data and information backbone, etc. Nevertheless, by nature, a PLM approach is very structuring and so requires a strong change management.

Acknowledgements

The authors would like to thank Jeremie BRY, Lucie DECOURTY and Benjamin DEWIT for their works and experiences on this project.

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