A Model-Based Approach to Design, Organize, and Monitor Dismantling and Decommissioning of Nuclear Facilities

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Abstract

Dismantling and Decommissioning (D&D) of nuclear facilities involves complex operations requiring the collaboration of a large number of stakeholders from various activities, and has to deal with numerous significant constraints. The CEA (French Alternative Energies and Atomic Energy Commission), is conducting research to better pilot these operations and reduce their costs and timeframes, and to improve overall performance. To this end, many issues remain to be solved, which lead to studying, then implementing in the form of a method with appropriate tools, the principles from systemics and the engineering of complex projects and systems. This method first consists in formalizing and specifying the entire set of requirements to be taken into consideration. Second, based on these requirements, the method will enable the project team to structure, check, and then to demonstrate the coherence and feasibility of the project from both the technological and organizational points of view. Lastly, the method should permit a constant re-evaluation of the D&D strategy and the management of its products, depending on the possible evolution of the D&D projects. Demonstration software is being developed, aiming to provide the functionalities requested for the design, implementation and maintenance of a future enterprise software, which should provide a complete D&D project Digital Mock-Up being interoperable and connected to the tools and databases of the stakeholders' information systems.

Introduction

Today, more and more nuclear facilities of various types are reaching their Dismantling and Decommissioning (D&D) phase. Managers must pay particular attention to the design and management of the D&D projects. They have to consider the inherent complexity and history of each nuclear facility, especially because it is difficult to generalize elements to all D&D projects despite significant capitalization and valorization of feedback.

Issues

Numerous complexity factors are met in D&D, such as:

- the many activities required to carry out D&D operations;
- the many stakeholders involved, and their various roles and responsibilities;
- the many and various interactions between these elements;
- the significant amount of data, information, and knowledge to handle;
- the strict requirements based on a strong risk culture;
- the project evolutions that require the models to be flexible and adaptable.

At first, each nuclear facility may have been modified or impacted by incidents during its operation phase, which is often very long. These changes should thus be known and taken into account when designing and performing D&D projects, focusing among other constraints on ensuring safety at all times. In addition, designing a D&D project requests to take into consideration the variety of stakeholders and businesses involved: nuclear physics, nuclear chemistry, mechanics, robotics, nuclear instrumentation, computer science, etc. Indeed, they could express various requirements relating to their field of knowledge but dealing with the other fields. This imposes to improve the collaborative work and exchanges. Moreover, to

meet the requirements, a large amount of data from different levels of detail should also be managed all along the D&D project life cycle. To this end, quite a few documents and deliverables of different kinds, involving skills from several businesses, are needed (OECD-NEA 2012) (IAEA 2013). Their creation, provisioning and updating are major stakes for managers. However, the quality and availability of data collected from the different phases of the facility's life cycle (including records, plans, etc.) represent a recurring issue for D&D projects. It is therefore particularly important to define the types of relevant raw data to be collected and traced for D&D projects as early as possible (IAEA 2014).

Towards a new method

Therefore, we have adopted Model Based Systems Engineering (MBSE) approach and principles (ISO, IEC, IEEE 2015) (NASA 2016) (INCOSE 2008). The purpose is to propose and promote a new method for D&D project engineering and monitoring, based on a systemic modeling framework and equipped with tools. This must support on the one hand nuclear facility description and characterization with a sufficient level of detail and considering the various data available, and on the other hand project description at a level of detail enabling first to design and to validate it before its deployment, then to monitor and adapt it in real time when it is in progress (Nastov, et al. 2016).

The modeling framework takes care about the description of stakeholders' perspectives, aiming to be understandable and shareable, by guiding them throughout the classical functional, physical, requirements, behavioral and risks management points of view. This framework is based on systemic approach and is designed in order to integrate the D&D existing vocabulary or to emerge when requested a new common vocabulary. This has to be sufficient and unambiguous to support the collaboration between stakeholders and at the same time to take into account both the technical and organizational aspects of D&D projects.

Current existing standards or methods remain limited when considering various points of view, levels of detail, and modeling languages. Models are realized always using neither the same modeling language (conventionally denoted Domain Specific Modeling language DSML in MBSE context) nor interoperable languages nor even the same media over time. We may mention the case of the maps, which today are evolving on digital media. Models' federation is however requested for validation and monitoring, and more broadly for all activities involving decision-making strategies (Project Management Institute 2017). The goal of the new method is therefore to procure a D&D project "whole model" that is built step by step from the design phase. Especially this results from the federation or composition of current models in each point of view. The framework must integrate and enable the analysis of the interfaces, dependency relations (both from semantic or pragmatic aspect) and related links between all D&D models. This aims the whole project description to gain on relevance and accuracy when managers want to assess the global safety, security and performance of the project, to test and assess alternatives solutions, to trace the impact of some unforeseen events on the behavior of the whole project, and to validate in part or in whole the project.

Progress

Currently, the proposed method is being studied at CEA (Lafon, Chapurlat, et al. 2018) (Lafon, Chapurlat, et al. 2018). For a given D&D project, it first consists in formalizing and specifying all the requirements to be taken into account to bring the project to a successful end. Secondly, based on these requirements, the method should enable to structure, verify, and validate the project while demonstrating its coherence and feasibility both from a technical and an organizational point of view (Pesola 2010). Finally, the method should

permit a continuous reassessment of the dismantling plans and products (e.g. waste), depending on the possible evolution of projects (new stakeholders, unforeseen events, etc.).

The method, especially thanks to MBSE, enables the construction of a formal representation of a D&D system related to each project. Such a D&D system is defined as "a set of elements of various and heterogeneous nature that interact in order to decommission a nuclear facility". It implements a set of basic concepts through some points of view, including the classical points of view previously mentioned.

First, these concepts and relationships are collected, and syntactically and semantically described in a generic metamodel, which is as timeless as possible, and therefore adapted to various nuclear facilities and compatible with the project evolutions.

DSML are defined for each point of view. Project managers will be able to model D&D systems and share their models all along the projects. These DSML must therefore be ergonomic and understandable by experts from various businesses who are not necessarily modeling experts.

The proposed method, to be enforced, has taken into account two important concepts:

- From the modeling side, the formalization of a D&D System as a system of systems including the properties described by (Maier, 1998);
- From the management side and especially during project piloting, the implementation of a process management based on the principle of adaptive workflow as proposed for instance by (Samiri et al, 2017).

These two concepts are used and needed throughout the life cycle of the D&D system.

Finally, we have implemented in the method the concept of modeling patterns, describing elements common to a set of projects (such a dismantling technique that is used in several scenarios, and its different features, or a waste outlet, including technical specifications for a given type of waste that can be found, among others, in several D&D projects). Modeling patterns can be made and shared among the stakeholders of several projects. They allow in particular to facilitate the handling of the metamodel to cope with this heterogeneity of facilities which are decommissioned. They guide, or even compel managers to draw from past experiences. In addition, we can ensure, through especially quite a few features, some flexibility (*e.g.* by an adaptation to evolution) and some dynamism (*e.g.* by an automatic feedback or by the verification and the validation of models) to the organization and the monitoring of a specific D&D project. The use of modeling patterns aims to catalyze the reproducibility and reuse of experienced project elements, to justify their use and thereby to facilitate decision-making steps to achieve and improve in real time the dismantling solution *i.e.* the D&D system as a whole, with a multi-point of view and multidisciplinary approach.

These patterns are made and validated by defined users, often experts in the various businesses involved in the D&D: nuclear measurement and instrumentation, transportation, regulation, etc. They are stored in a database and then can be used by each project manager to feed his specific model, or by other experts to create new patterns.

The patterns can of course evolve over time, consequently it is necessary to guarantee the traceability of the modifications and to manage the impacts on each project having used them.

Prospects

The method is today partially equipped and a demo software has been developed, based on use cases to prove the meeting of conceptual, methodological, technical, economic and human challenges identified at the beginning of the project. Results provide features requested to handle the proposed design and monitoring framework, helpful for the design, implementation and maintenance of a future enterprise software. This last tool should provide

a complete D&D project Digital Mock-Up being interoperable and connected to the tools and databases of the stakeholders' information systems (Chapurlat, Nastov and Lafon 2018). This should be particularly useful for the overall management of D&D projects, and should catalyze collaborative work in D&D projects.

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