Model-based Commissioning, a New Methodological Approach for Commissioning of Nuclear Basic Facilities

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■ **ABSTRACT**

This article intents first to formalize commissioning that must be seen as a crucial need and an unavoidable obligation. Second, it aims to introduce a method called COGuiNF (Commissioning Guidelines of Nuclear Facilities) which would allow to prepare in relation with MBSE processes then drive relevant activities for the commissioning of Nuclear Facilities. COGuiNF must define, formalize and feed the inherent relations to be managed between engineering and commissioning. This article focuses on the five components of the COGuiNF method.

INTRODUCTION

The purpose of commissioning is to ensure that the system of interest operates safely and as intended, and that it meets the requirements of all stakeholders from various backgrounds: legal, environmental, social, safety, cost, performance, and more Indeed, Nuclear Facilities (NF) design and realization projects must meet both conceptually and technically, this crucial need, mandatory for their global activity. The goal is then to prepare, optimize, and deliver the necessary deliverables, proofs, and justifications that are requested by the stakeholders depending on their roles and interests: nuclear safety authorities, client, sub-contractor, or also maintainer in charge of operational maintenance of the NF. This article presents the COGuiNF (Commissioning Guidelines of Nuclear Facilities) method. This would allow stakeholders to prepare and then drive relevant activities, resources, and means focusing on NF commissioning objectives. This method must be developed by promoting the importance of the commissioning to be connected and in phase with systems engineering processes (for both NF design and realization). It must rely on and extend Model-based System Engineering (MBSE) principles for many recognized reasons in different industrial fields and be deployed considering company culture and knowledge. Different issues inherent to the commissioning in the nuclear field are presented in the following article. The COGuiNF method is then introduced as an enabler to any commissioning project in this field. Some perspectives will then conclude, aiming to complete and finalize the COGuiNF method.

NUCLEAR FACILITIES COMMISSIONING AIMS AND ISSUES.

Many issues are inherent to the commissioning in the nuclear field. Indeed, because of the complexity of the installations and the lack of a commissioning culture within the industry, commissioning does not benefit from a global vision. Furthermore, there is frequently no formal team assigned to commissioning, resulting in a lack of awareness, training, and operation methods. In addition, the progress of engineering over time has not considered commissioning, therefore MBSE and its principles do not include commissioning as a critical activity. The variability of the roles and duties of the stakeholders involved makes commissioning challenging, particularly because of the various way those stakeholders work. The volume, speed, and variability of data and models created and processed by both commissioning and engineering must be examined, demonstrating how complicated this process can be and how it must be viewed.

Further, costs and delays are crucial indicators for building any industrial complex system and in particular nuclear facilities. It

needs methods to quantify and track the indicators during the commissioning process. In addition, safety and security aspects are specific to this domain and must be drivers in the process. All these indicators lead to the need of more formalized method to pave the way from the design time to the implementation of the solution. Nevertheless, this method has be well connected with enterprise culture about commissioning since it brings some rules to be integrated and followed.

Commissioning does not benefit from a global vision especially because of the complexity of the installations and the lack of commissioning culture within the global nuclear industry. Additionally, there is often no structured team allocated to the commissioning and this leads to a lack of method for awareness, training, and operation. Also, the evolution of engineering through time did not take into account the commissioning fully, therefore MBSE and its concepts does not enough consider the commissioning as a crucial activity.

CONTRIBUTION

Facing these issues, the proposed PhD research work consists in studying and developing a method, called COGuiNF, that must support and guide engineers, architects, and managers of complex systems engineering projects, hereafter NFs. The method must allow the team in charge of the commissioning to:

- First: to prepare and validate requested activities that must consider commissioning dimension, expectations, and needed engagements from all stakeholders involved, implied, or concerned by both engineering and realization activities; to adapt, optimize, and validate resources, means and techniques being considered during these activities. This allows us to define an idealized vision, even optimized, of the activities and operations that are requested during the NF realization phase.
- Second: drive, orient and adapt step by step these activities considering eventual problems and emergent phenomenon that relies during the commissioning of the NF.

So, the main objectives of COGuiNF method are:

- To improve the coordination and therefore the articulation of the various activities of all stakeholders involved both in design and realization phases of a NF by replacing the commissioning as the crucial activity of the project and creating the coordination around it.
- To bridge the gap between systems engineering processes, involving both MBSE practitioners and actors involved in commissioning, each that specialize in their own objectives (requirements engineering, architectural design, or integration, verification, or validation of the NF).
- To head and request these stakeholders to converge and particularly to support them in preparing, managing, and performing activities associated with reach commissioning objectives (in terms of resources, means, and more).
- To check the wholeness and therefore the relevance of these activities (trials, demonstration, report, and more) during a global and holistic way.
- To establish, formalize, and optimize planning of those activities in terms of costs, duration, and performance.
- Last, to arrange and complete the REX of the pointed-out commissioning, to facilitate its reuse by other projects.

Considering the complexity of the commissioning (finality, objectives, missions, number and heterogeneity of actors, skills and fields, duration, and more) and with regard to systemic approach and its advantages, the commissioning is here considered as a system of systems (Luzeaux and Ruault 2010). Indeed, (Konrad et al. 2019) shows how using MBSE to address the management of complex rocesses can be useful.

Therefore, composed of and highlighting various interactions between two abstract sub-systems presented below:

- The commissioning System of Interest (SoI), as classically defined in (ISO, IEC, and IEEE 2015) (ISO/IEC 2016) encapsulates the different activities and tasks that are needed to establish the evidence, provides justifications, and proofs allowing to transfer the responsibility to the future NF operator. It is by evidence closely linked to the NF itself and must interacts(raises awareness, irrigates and guides) with actors that are involved all along the systems engineering processes. It also exchanges flows with the commissioning System Used to Do (SUTD) in terms of management information (planning, milestones, resources availabilities, justifications needed for the regulatory body and the customer, and more).
- The commissioning SUTD helps the elaboration and the construction of the commissioning SOI. It ensures SOI's design, running and management, builds a program to follow ,and ensures the good coordination and exchanges (requirements repository, milestones, models, and more) between the commissioning SOI and other systems engineering processes. For this, it is mandatory to harmonize the vocabulary and to avoid any retroactive actions (requirements repository redaction) that are often encountered during commissioning.

In addition, the commissioning is characterized by two more or less overlaying steps linked to design and realization objectives of the NF:

- **Commissioning Design Time (CDT):** during this step, the commissioning systems (SOI and SUTD) are first defined and then validated. To do so, there is a crucial need to specify the activities and resources requested, the objectives to be achieved, the constraints and requirements to be considered by the NF. The CDT therefore begins at the stage of concept definition

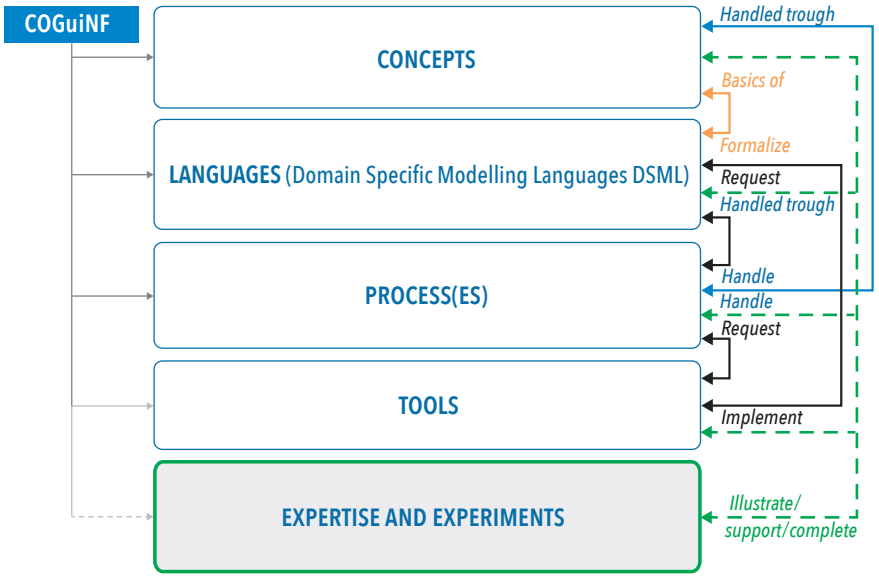

Figure 1. COGuiNF

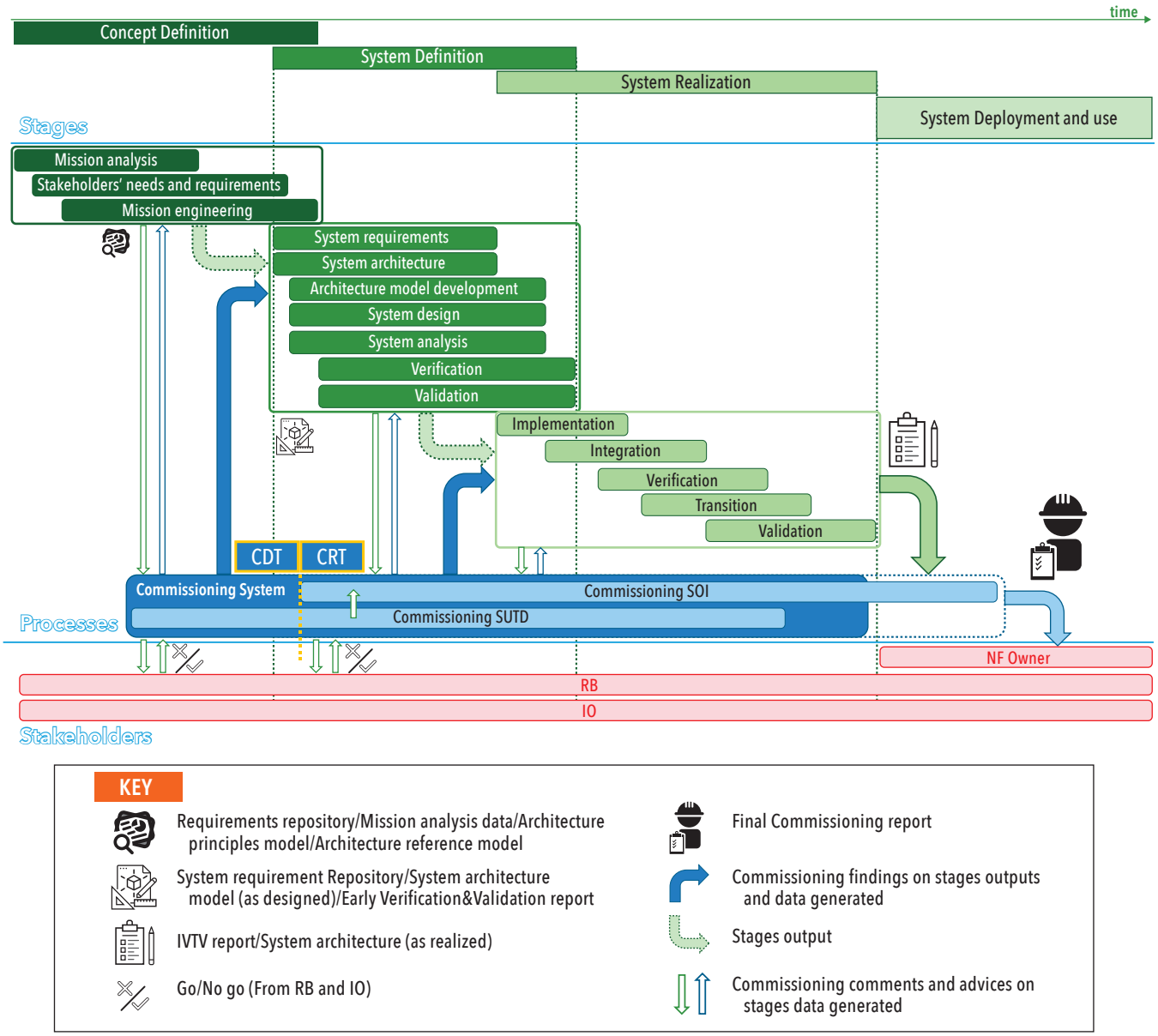

Figure 2. Commissioning Big Picture

of the NF, which allows to trace the data generated and to anticipate the constraints that derive from the construction and deployment of systems.

- **Commissioning Run Time (CRT):** the commissioning SoI performs the trials and other V&V activities that have been defined during the CDT, moreover the SUTD controls their evolution and improvement. Consequently, the SUTD must adapt the commissioning SoI as needed according to the various events or situations encountered during the realization of the targeted NF.

The CoGuiNF method is composed of five elements (Figure 1) that ensure the definition, the design, and the modeling of a commissioning system. It also encompasses the tools recommended and their potential interconnections as well as the commissioning framework and the best way to capitalize on projects by designing the knowledge repository.

Concepts: They express rules and standards of the domain (concepts and properties characterizing each concept), about the connection between these standards (relations and properties requested to characterize each connection when it is essential, but above all, about rules and imperatives linked to each connection) which are valuable to describe, formalize, and process a commissioning. These concepts and relations are vital for occurrence to depict and formalize the distinctive exercises and forms that are to be done all along commissioning. They are from now on formalized by utilizing a metamodeling approach (Bézivin 2005).

Languages: They talk about Domain Specific Modelling Languages (DSML) (Nastov 2016). They permit the modeler to demonstrate commissioning exercises, assets, trials, and more. This requires selecting and formalizing sets of concepts and relations which are asked to speak to a perspective of the commissioning framework. Classically, it is to address the functional, physical, and behavioral perspective as advanced in Framework Sciences field and, for occurrence, by SAGACE approach (Penalva 1997), or more absolutely as advanced in Framework Designing space, for occasion by ARCADIA approach (Roques 2016). Formalizing the DSML implies selecting an existing modeling language that matches with these concepts and relations (BPMN for functional and practical perspective) or characterizing theoretical and

concrete syntaxes, semantic, and modeling and execution rules.

Processes: they depict how the strategy must be utilized for example how the partners must continue when considering commissioning tricky and how it is proposed to characterize and to set up a commissioning framework (outlined to conduct the commissioning) in stage with the building extend. Briefly, it waters and organizes the total set of systems engineering forms the venture demands. These forms are composed of different activities (to model, to check rightness, to assess, to optimize, to run tests, or to supply anticipated deliverable). Partners included in these exercises utilize at that point the proposed concepts and DSML of the strategy in a coherent way.

Tools: all along processes, they reinforce the proposed activities (modeling tools, simulation devices, optimization instruments). They execute the chosen DSML and must oversee all the information conducted and traded with other instruments which are for occasion committed to designing exercises.

Knowledge repository: usually a central component of the strategy that accumulates skill, encounters, design patterns (Pfister et al. 2012), and reference models. This permits clients to reuse different parts from past fruitful encounters at that point to reuse and design for occurrence existing models as of now utilized and approved, decreasing modeling terms, mistakes, or ambiguities. Without a doubt, it is essential to draw motivation from models considered as comparing to proven arrangements. On the opposite, it is additionally critical to require care and to draw motivation from models that compare accurately to arrangements that might not be connected or might not succeed. The objective is at that point to maintain a strategic distance from replicating certain past blunders and pick up time and execution.

Figure 2 presents the expected result of COGuiNF method when applied in various projects, showing the different interactions of the commissioning, the kind of interactions (refer to the caption), with systems engineering processes, Regulatory Body (RB), Inspection Organization (IO) and the NF owner and when they occur.

CONCLUSION AND PERSPECTIVES

This article has illustrated a formalization of commissioning which is a vital and unavoidable commitment. At this stage, the strategy called COGuiNF was presented to prepare and conduct important exercises for the commissioning of Nuclear Facilities. COGuiNF accepted the inalienable relations to be overseen between designing and commissioning goals. We believe that it will encourage, drive, and inundate framework designing System Engineering processes, taking into consideration model-based framework designing (MBSE) standards and practices. In addition, this article presented point by point the five components of the COGuiNF strategy. ■

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