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Challenges in Technical Risk Management for High-Power Accelerators

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Abstract. The increasing demands on accelerator-based research facilities to be both reliable and cost-efficient require comprehensive risk management that takes the full scope of the facility into account. Due to the organizational and technical complexity of these facilities, a systematic risk management method is beneficial, if not necessary. However, many other aspects, aside from reliability and cost-efficiency, also call for great attention. This paper discusses the many challenges that are faced when dealing with technical risk management of accelerator facilities, as these efforts are often considered second to e.g. beam parameters and operational schedule. The paper uses the design and construction of the European Spallation Source in Sweden as a basis, but many of the contradictory aspects have been found in other similar facilities around the world. Some of the challenges for technical risk management that are discussed relate to rapid organizational expansion, pressing schedule, knowledge biases, and conflicts of interest.

1. Introduction

The construction of a large-scale research facility, such as a particle accelerator and neutron spallation source, takes on many different phases. Going from concepts and ideas to the final facility often takes decades and involves a large number of people and interest groups [1] [2] [3]. Merging these to finally achieve the end goal is far from straightforward and the approach is typically different from case to case. The ongoing construction of the European Spallation Source (ESS) in Lund, Sweden, has been and is currently undergoing such phase transitions [3].

The first ideas behind ESS dates back to 1999, where the European Neutron Scattering Association (ENSA) convinced the Organization for Economic Cooperation and Development (OECD) that neutron sources were important tools for future research, and that Europe required a new facility that could complement ISIS in the UK. The following decade included discussions and negotiations, and in 2009, Lund was chosen as the place of construction [4]. The year after, ESS was formed as a limited liability company, and in 2015 it received its status as a European Research Infrastructure Consortium (ERIC). The first spallation neutrons are expected to be created in 2020, which is then just over two decades from the initial decision for the facility [3]. ESS is then planned to be operated for 40 years before decommissioning. This shows the long time-scales for such a facility, and highlights the many decisions that need to be made to move the project forward.

The requirements on neutron production, both in terms of quality, or neutron brightness, and operational availability [5], implies a challenging task and all of the internal and external stakeholders need to collaborate and facilitate the design, construction, and operation of ESS. Needless to say, these challenges have been seen in prior accelerator facilities and neutron sources [6], just as they are seen for ESS. One main component in reaching the unprecedented brightness and availability is the management of technical risks. These risks encompass both damage to equipment and loss of neutron production from other aspects. In this paper, some of the challenges associated with performing a rigorous technical risk management are discussed.

2. A Systematic Approach to Risk Management

ESS has developed and is using a systematic approach to technical risk management [7] that involves a machine protection system-of-systems (MP-SoS) as well as a facility-wide reliability, availability, maintainability, and inspectability (RAMI) approach. The MP-SoS and RAMI analysts work closely together to ensure that the end goals of ESS can be fulfilled. This chapter briefly describes the method itself and its place in the ESS organization.

2.1. Method

The risk management method for MP-SoS follows the applicable ISO standards 31000 [8] and 16085 [9]. These standards outline the process of establishing a risk management context followed by identifying, analyzing, evaluating, and treating the risks in a traceable and transparent way. Additionally, the IEC 61508 [10] and 61511 [11] standards for functional safety of electric, electronic, and programmable electronic (E/E/PE) systems are guiding the lifecycle approach as well as the classification of protective functions [12]. This places the ESS risk management in a robust framework that allows for efficient and purposeful analyses and accurate treatment of the technical risks associated with running a complex high power accelerator facility. The method is currently applied at ESS and builds on close collaboration between system owners and risk analysts.

2.2. Organization

The ESS project organization is set up to address each of the three sections of the facility through a dedicated division: the proton accelerator, spallation target, and neutron science systems. Within each division, there is a set of work packages that deal with specific parts identified in the facility breakdown structure (FBS), Figure 1. The MP-SoS and RAMI analyses need to merge into the development of the different work packages at the same time as they tie back to the overall goals of ESS. MP-SoS and RAMI are therefore continuously observing and analyzing the progress of the different work packages, in order to cope with the complexity and system interaction that might lead to damage and losses that would cause ESS to not fulfill the overall goals [13].

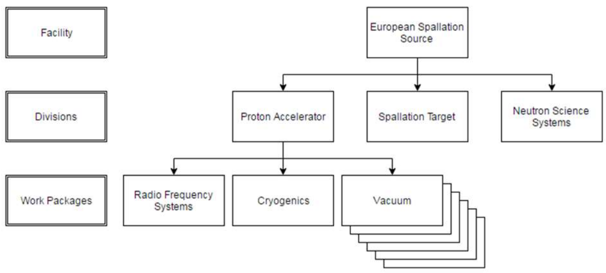

Figure 1: Part of the Facility Break Down Structure

The MP-SoS work is done by three interconnected teams, as seen in Figure 2. The protection analysis team (PAT) is in charge of translating global ESS requirements into manageable requirements and functions to be implemented into the hardware and software of the facility. The integrated protection team (IPT) analyzes interfaces between protection-related systems and the rest of the facility. Finally, the implementation and design team (IDT) makes the implementation of the requirements and serve as system experts in the discussions on possible and relevant designs and functionalities.

The RAMI work takes place through a cross-functional working group that involves stakeholders from all the divisions, where possible issues and suggested improvements can be analysed and verified. The working group meets as per request and has close discussions with external stakeholders. It has successfully derived hands-on requirements for the facility, going from high-level concepts down to applicable RAMI requirements on individual systems [13].

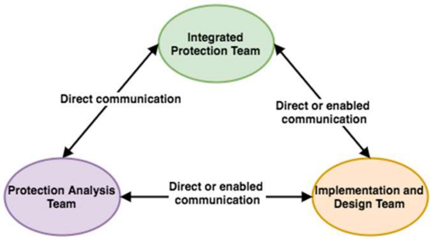

Figure 2: The three teams involved in MP-SoS work at ESS.

3. Technical and Organizational Complexities

The technical risk management in general, and the MP-SoS and RAMI approaches in particular, find certain challenges in the organization that can be attributed to the complexity of a research facility under construction. These challenges need to be highlighted and mitigated in order to avoid accidents during the commissioning and operational stages. In fact, it is claimed that basic culture and commitment to safety or protection is the most important factor in the occurrence of accidents [14].

3.1. Organizational Development

The ESS organization has and is expanding rapidly, hence the culture, communications procedures, and all of the administrative efforts, have to be developed in parallel with the design and construction of the facility. Risk management needs to cope with limited procedures for documentation as well as changing organizational structures internally and externally. This places high demands on flexibility and continuous updates of the information to be analyzed. Traceability then becomes an important aspect already in the early stages, in order to verify that the analyses are matching the latest versions of the hardware.

The rapid expansion can also be viewed from the perspective of scope, where the MP-SoS and RAMI analyses continue to include more systems as the project proceeds, having to inform and set up discussions with new stakeholders. These stakeholders are themselves required to perform concept designs of their systems at the same time as potential interfaces are changing. It is therefore important for the technical risk managers to recognize that the organizational development affects the technical developments, including systems relevant for machine protection and RAMI.

3.2. Schedule

The pressing schedule during the design, construction, and commissioning can lead to predicaments in decision-making. A too rapid decision might miss overlooked opportunities and important factors to account for, at the same time, late, or completely lacking, decisions lead to temporary solutions and workarounds that can be disadvantageous for the robustness and final protection of a system or component. Risk management on all levels needs to account for this and simplify the decisions to be taken by providing appropriate information in a timely manner.

3.3. Prior Knowledge and New Developments

The staff, contractors, and in-kind partners at ESS represent many different labs as prior work places. Each person has their own background and experience, which are to be merged with newly developed technical concepts and specialized equipment that are often not familiar to the stakeholders. Additionally, outcomes of the new organizational setup, including procedures and reporting, are not always in line with the experience from previous labs. At the same time as this work is ongoing, the staff has to ensure that interfaces between systems are in place, despite that this often requires new concepts than has not previously been used.

3.4. Geographical Distribution of Personnel

The process of aligning on-site personnel and in-kind contributors requires much effort in terms of setting up mutual agreements and emphasizing proper documentation and sharing of information since the different labs have different procedures and the countries have varying cultures. Refer to Figure 3. for a graphical overview of in-kind contributors. This affects the risk management process where available and up-to-date reports and documents are necessary to make appropriate analyses and suggestions.

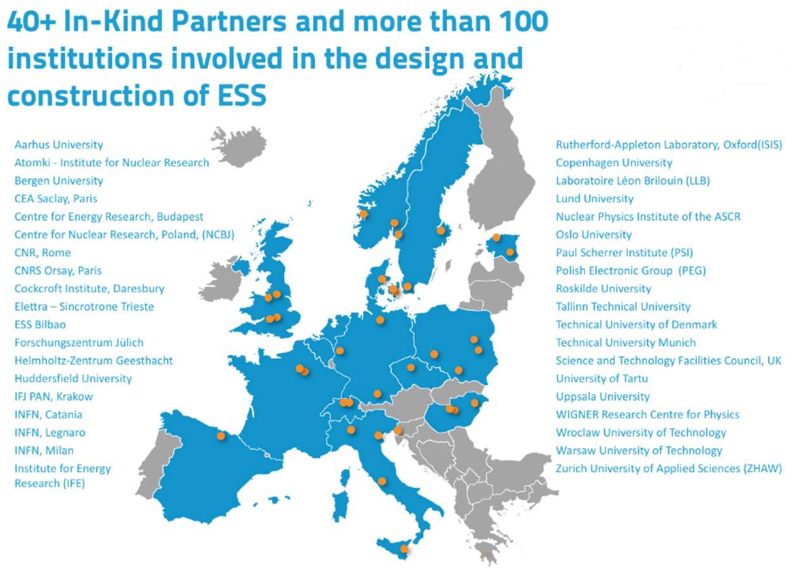

Figure 3: Countries contributing to building ESS

3.5. Conflicting Interests

Related to the previous sections, the different experiences and methods of work across the organization sometimes lead to slowed down decision-making processes, where conflicting ideas or interests might lead to a prolonged process before system design and equipment selections are settled. If not resolved, it is possible that two separate design paths develop in parallel, which is an inefficient use of manpower and complicates the risk analyses. Often, two (or more) ideas can have different benefits and drawbacks and proper risk management is required to make the appropriate trade-offs to achieve the better outcome in the final design.

Another trade-off, or conflict of interest, is that which is involved in the risk management process itself: choosing protection or reliability. In many cases, a design emphasizing protection causes more spurious trips of the proton beam or other equipment, while a reliable design, from the operations point of view, relaxes the protection in favor of a stable operation without interruptions.

Finally, some systems benefit greatly from new developments and designs that have not been previously used. Other systems have a well-defined task that needs to be performed as reliably as possible. This conflict then touches the choice of either allowing for efforts within targeted research to optimize system designs and behavior, or to go for a defined engineering approach where the requirements are implemented with currently available equipment and processes.

4. Conclusions

This paper has highlighted some of the many challenges that appear in a rapidly growing organization that designs and constructs a complex research facility. The associated risk management processes need to be flexible enough to allow for changes and conflicting interests, and the risk managers should be aware of these challenges in order to cope with them in an efficient manner. While it is not beneficial to ignore or hide these challenges, it is not fruitful to accentuate them out of proportion either. These challenges can be difficult to tackle, but are also part of the unique environment that such a project offers.

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