3S Approach for advanced SMR designs in Belgium

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**Abstract**

An integrated approach for the implementation of safety, security and safeguards (3S) by design is an important concept, especially for new and advanced reactor designs, and it is essential for an SMR, at an early design stage, in order to optimize its size and performance.

SCK CEN, as a major centre of excellence of heavy liquid metal HLM technology, has the intention to develop and construct a lead cooled fast Technology Demonstrator in support for lead cooled fast SMR’s (SMR-LFR) in collaboration with an international consortium with relevant knowledge in reactor design and specific experience in SMR-LFR and/or technology expertise with HLM systems. The MYRRHA reactor programme with its associated R&D and pre-licensing experience can support the development of SMR working with lead as coolant and therefore accelerate the deployment of lead fast reactors of the SMR type.

In Belgium, the law [1] stipulates that : “The operator of a class I establishment is required to apply the obligations imposed on it by regulations in the areas of “Safety, Security and Safeguards” in a coordinated, consistent, effective and efficient way, in the field, while taking into account the different interfaces.”

This paper will focus on the approach to 3S by design, at an early stage of the reactor design, in order to optimize the implementation of requirements and properly address all the interfaces, including for aspects related to radiation protection of workers, the public and the environment.

An important focus will be put on the management of 3S in design and normal operation, as the first lines of defense against initiating events, hazards and threats.

## INTRODUCTION

An integrated approach for the implementation of safety, security and safeguards (3S) by design is an important concept, especially for new and advanced reactor designs, and it is essential for an SMR, at an early design stage, in order to optimize its size and performance.

The paper will focus on the main reasons for an early integration of the 3S in the design of an advanced SMR and the pre-licensing process as a good practice. This is addressed in the Belgian regulatory context and the legal requirements for the integration of safety, security and safeguards.

## the belgian regulatory context for 3s

In Belgium, while the law of 15th of April 1994 [2] sets the basis for Safety, Security and Safeguards, each of the “S” has its own legal and regulatory texts that impose specific provisions and obligations upon operators. The operator has to implement these provisions and obligations in a coordinated, coherent, efficient and effective manner, taking into account the various interfaces. In this perspective and specifically for the Class I facilities, FANC has issued an internal note entitled “The 3S Approach and the Safety Security interface in Class I facilities” in which it presents the vision of the FANC with regard to the 3S approach and the Safety-Security interface approach. In particular, FANC describes what it is expected from the operators, how the interfaces are handled within the national regulatory body and what role is to be played by the technical support organisation Bel V in this regard.

In terms of safety, a license is required for each activity involving sources of ionising radiation. Class I facilities are the facilities with the highest risk such as nuclear power plants and research reactors, radioisotopes production facilities and waste treatment and storage facilities. Provisions and requirements for Class I facilities are detailed in the royal decree SRNI-2011 [3] which provides generic safety requirements applicable to all of these facilities as well as specific requirements for nuclear power plants and storage facilities for waste and spent fuel. A specific chapter for research reactors based on the WENRA Safety Reference Levels for research reactors, has been formalized in 2023. It should be noted that this specific chapter, which allows for a graded approach when compared to the requirements for NPPs, is expected to be applicable to the SMR-LFR demonstrator project. The SNRI-2011 is further complemented with a technical regulation for the practical implementation of the nuclear safety objectives [4]. The processes applicable for the safety application files are described in the royal decree GRR-2001 [5]

Regarding nuclear security of nuclear material, the four royal decrees of 17th of October 2011 [6] [7] [8] [9] include provisions regarding the categorisation and the definition of nuclear security areas, the physical protection (prescriptive and performance-based approach), the handling of nuclear sensitive documents and trustworthiness. Belgian regulation requires that an operator of a new installation, when applying for a construction and operating license, applies at the same time for approval of the physical protection system. Just like for safety, the security application file must be approved by FANC before the installation is finally put into operation. The operator has to demonstrate through the security application file that the proposed physical protection system is fulfilling security criteria defined by the regulatory body.

Regarding nuclear safeguards, the laws of 20th of July 1978 [10] and 1st of June 2005 [11] set basic provisions regarding accountancy obligations, verification activities and inspections, and reporting obligations. The R302/2005 [12] constitutes also the backbone of the safeguards regime in Belgium in line with the Comprehensive Safeguards Agreement INFCIRC/193 [13] and the Additional Protocol INFCIRC/193/Add.8 [14]. While there is not as such a national licensing process regarding safeguards, it is asked to the operator to inform Euratom and IAEA as soon as possible of the intention to build a new nuclear facility and to provide, as soon as possible, to Euratom the so-called Basic Technical Characteristics (BTC). Moreover, the provisions of the Additional Protocol on providing information should be taken into account in this regard. Early submission of the needed design information is considered as necessary for the conduct of the Safeguards by Design process in which FANC plays an active role.

In terms of safety by design, security by design and safeguards by design, FANC offers the possibility for (future) operators of new nuclear projects to launch pre-licensing projects. This strategy is highly recommended for complex facilities to build up at an early stage sufficient knowledge and expertise and to already identify the main challenges to address before the licensing process is initiated. The pre-licensing process allows for early interaction of the regulatory body with the future operator and contribute to better address 3S by design concerns and opportunities. Such strategy has been chosen for the MYRRHA project and is currently ongoing. In order to support the pre-licensing process, FANC delivered to the attention of the future operator an explanatory note regarding the Design Options and Provisions File (DOPF) which is the main document to be provided by the operator at this stage. This file can be updated progressively based on the exchanges with the regulatory body and the evolution of the analysis and the design. Based on this explanatory note, the future operator is able to identify what are the main concepts and ideas that have to be taken into account from the pre-design stage, what are the early analysis to be conducted and what are the information to be provided to the regulatory body for the conduct of the process. In addition and in parallel to the DOPF, the stakeholders also agreed on specific safety, security and safeguards focus points that should be further addressed and analysed during the pre-licensing stage.

Regarding the pre-licensing and licensing stages for any future advanced SMR design, the regulatory body will have, based on its experience on important nuclear projects in Belgium (e.g. MYRRHA and RECUMO), to define an approach that might need a revision of laws and decrees applicable for safety, security and safeguards. Strategic notes and explanatory notes will be certainly needed in order to tackle the new challenges and opportunities that might arise specific to the chosen technologies. In this perspective, while in Belgium the federal government took the decision on 23th of December 2021 to invest 100 M€ for research on SMR technologies, FANC developed an Action Plan on SMRs taking into account the uncertainties associated with the SMR national policy. The objective of this Action Plan is to get sufficient technical knowledge and a legal and regulatory framework suitable to handle an SMR licence application if any. Five sub-goals (SGO) have been defined to proceed in line with this objective:

* SGO1: To get sufficient understanding and knowledge about potential relevant stakeholders.
* SGO2: To get sufficient understanding of available sources of knowledge and information.
* SGO3: To get sufficient general knowledge to determine what specific knowledge per relevant SMR concept is necessary for its assessment.
* SGO4: To get sufficient knowledge to develop a legal and regulatory framework suitable for a specific SMR concept depending on the needs.
* SGO5: To get in-house and/or external sufficient specific knowledge to be able to fully assess an SMR concept depending on the needs.

Following a phased approach, the following steps are defined:

* Inventory Phase (SGO1 & SGO2) which should result in getting a good overall overview of stakeholders and available sources of knowledge.
* Build-up Phase (SGO3) which should result in getting a good overall overview on SMR concepts and an estimation of their relevance for the particular case of Belgium.
* Build-out Phase (SGO4) which should result in drafting a (or multiple) Strategic Note about general (legal and regulatory) expectations. Possibly the necessary legal and regulatory initiatives could be initiated in parallel.
* Specialisation Phase (SGO5) suitable for a specific SMR concept project.

So far, a lot has been achieved regarding the inventory phase, and the build-up phase has been initiated. It is foreseen as it was the case for the MYRRHA project to address all the 3S at the same pace and to identify and address in the framework of this Action Plan the positive and negative interfaces. Regarding safeguards, it is to be mentioned that the DOPF which should contain provisions and information regarding proliferation resistance and in particular “safeguardability” aspects is to be seen as a complementary document to the BTC.

## the importance of early 3s integration for an advanced SMR

Traditionally, in the early stages of a reactor design the focus has been mainly put on the safety requirements to shape the concept and incorporate the adequate safety defence in depth levels. The security and safeguards requirements were typically addressed at a later stage, which led many times to a design retrofit to accommodate for these requirements. This strategy is now largely recognised as ineffective and can lead to limiting solutions, unnecessary costs and can negatively affect security and safeguards.

In accordance with current regulations and standards the expected approach is the early integration of 3S in the concept design of a reactor, to ensure in an optimal way that workers, the public and the environment are protected in all cases and from all events, hazards and threats. The figure 1 below is a simple illustration of these expectations.



Fig.1 Ilustration of 3S integration for the protection of the public and the environment

For an advanced non-water cooled SMR, finding the optimal design solutions that meets the 3S requirements is essential but also challenging since the majority of requirements, standards and experiences are still focused on water-cooled designs due to historical reasons. This is one more reason why the interpretation and integration of 3S requirements has to start early and, ideally, be discussed with the regulatory body early in the design phase of new advanced technologies.

SCK CEN and the Belgian regulatory body already have experience in interacting, through pre-licensing, on the implementation of 3S in the design of MYRRHA, an unique Lead-bismuth cooled Accelerator Driven System developed by SCK CEN that currently is the subject of pre-licensing. More information about the pre-licensing of MYRRHA can be found in [15].

Some of the challenges and benefits of an early integration of 3S in the design on an SMR-LFR are presented in subsections 3.1 and 3.2 below.

### Challenges for the 3S integration in the concept design of an advanced SMR

* The need to interpret the existing requirements to address the specificities of an advanced SMR-LFR technology, including for the whole Nuclear Energy System as defined by the GEN IV International Forum (front-end up to the back-end);
* The need to keep up with the extensive international work to update the existing standards and develop new SMR standards;
* Consideration should be given to the need, if any, to adapt the legal and regulatory framework in order to tackle the specificities of an advanced SMR technology ;
* The need of R&D to comply with some of the 3S requirements, e.g. instrumentation applicable in opaque coolants for safeguards and consideration of new sabotage scenarios and accidental conditions ;
* The higher level of digitalization of the I&C systems and the possibility to remotely operate the reactors;
* The planning and timing for interaction with the international inspectorates, IAEA and EURATOM, to address the safeguards requirements needed as an input in the design process;
* The need to work with complex interdisciplinary teams and to develop the safety, security and safeguards cultures in the teams while taking into account the positive and negative interfaces between these cultures, promoting the importance of integrating all requirements rather than focusing on individual areas of expertise;
* Managing the iteration and modification process in design that encompasses the 3S needs.
* The need to reach out to new non-traditional stakeholders who are not always aware of the rules and concepts governing the nuclear industry (vendors, designers, technology providers, new operators, customers outside the energy sector).

### Benefits of the 3S integration in the concept design of an advanced SMR

Some of the benefits for the early integration of the 3S in the concept design of a SMR-LFR include:

* The ability to optimize the position, the orientation and the layout of the reactor facility on the nuclear site taking into account simultaneously the 3S requirements/concerns e.g. the safety and security stand-off distances and acquisition/diversion pathways. Safeguards associated reflexions are taken into account at an early stage;
* The ability to establish the optimal material work flows;
* For reactors constructed on existing sites, the ability to position the installation such that fulfilment of the 3S requirements of all other installations on the site are not impacted;
* The ability to identify early any areas that might require R&D to validate technical solutions e.g. for safeguards instruments ability to operating in opaque coolant and consideration of new sabotage scenarios and accidental conditions.
* The ability to select the optimal routing of support systems considering safety requirements as well as security constrains;
* The ability to foresee the adequate space in the design for the necessary security and safeguards equipment in the reactor building and in and around the fuel manipulation areas;
* The ability to define the operational and maintenance periods of the reactor according to the needs for safety and security controls and inspections, and safeguards surveillance activities;
* The ability to design the radiation protections zones in sync with the security zoning to optimize space.
* The possibility to design dedicated areas for safeguards activities considering together the type and frequency of inspections and safety, security and radiation protection requirements.
* The ability to design ways of accessing all areas that might need to be inspected by safeguards.
* The ability to optimize the design of dedicated security areas for the control of access and deliveries.
* The ability to design the electrical power supply system taking into account the UPS needs for security and safeguards equipment;
* The ability to foster the safety, security and safeguards cultures in the project and encourage a holistic approach to the design.

## THE INTERNAL PROJECT ORGANIZATION FOR 3s IMPLEMENTATION

SCK CEN will leverage the experience gained with the implementation of a 3S approach in the MYRRHA project in the development of an SMR-LFR demonstrator for the lead-cooled reactor technology.

In order to ensure appropriate consideration of all the necessary requirements and international obligations, the SMR-LFR project organization foresees the formation of a multidisciplinary team of experts in safety, security, safeguards, quality assurance and environment protection, that will interact horizontally with the technical teams working on design and R&D and provide them with input and results assessment.

This form of organizing the project will support the early identification of interfaces and challenges and the formulation of appropriate solutions for the SMR-LFR design.

As stipulated in the Belgian Law [16] and its supporting CODEX [17], SCK CEN has an Internal Service for Prevention and Protection at Work (IDPBW) that integrates the disciplines mentioned above and will play an important role in the establishment of the interdisciplinary team as well as in implementing the lessons learned from the recent projects developed by SCK CEN. IDPBW assesses the safety of the installations, workstations and working methods and provides advice with a view to continuous improvement in this area of safety, health, security and the environment.

## The BELGIAN pre-licensing process for an advanced SMR

As seen in section 2, Belgium has regulatory requirements related to the integration of 3S and it also has experience with the implementation of 3S in the design of nuclear facilities.

A good practice in Belgium is the possibility for a designer or future operator to engage in a pre-licensing process with the regulatory body.

As mentioned above, SCK CEN, as a major centre of excellence of HLM technology, has the intention to develop and construct a lead cooled fast Technology Demonstrator in support for lead cooled fast SMR’s (SMR-LFR) in collaboration with an international consortium with relevant knowledge in reactor design and specific experience in SMR-LFR and/or technology expertise with HLM systems. The MYRRHA reactor programme with its associated R&D and pre-licensing experience can support the development of SMR working with Lead as coolant and therefore accelerate the deployment of lead fast reactors of the SMR type.. The strategy for the development of the concept design of the demonstrator is to integrate the 3S requirements from the start of the design process. Based on the positive experience with MYRRHA, a pre-licensing process is considered essential for the SMR-LFR to ensure that all the applicable requirements and standards are considered from the start in the concept design. Identified areas for improvement will be implemented in the SMR-LFR project.

The pre-licensing process is designed to allow for an early interaction with the regulatory body. The objectives are to define the requirements and standards to be applied to the design and the key areas of R&D that need to be addressed. The applicant develops then the concept design and an R&D road map covering all areas requiring further investigation. During the pre-licensing process periodic interactions between the operator and the regulator are foreseen, to ensure a common understanding of the results obtained and to discuss the progress made.

As explained above, the regulatory body defines the expected format and content of the pre-licensing deliverables in consultation with the applicant. An important aspect of the process is the ability to organize workshops on technical topics that might require clarifications, as well as to identify technical focus points that need to be addressed early on.

The process ends with a report from the regulatory body indicating the degree to which the concept design meets the 3S requirements and potential areas where further work is needed. . It should be stressed that any opinions provided by the regulatory body during the pre-licensing does not constitute a guarantee for future licensing of the facility.

## Conclusions

* The implementation of 3S in an early stage of an advanced SMR design is a challenging process but it has multiple benefits in reducing the number of design iterations and ensuring optimal solutions.
* In order to be able to adequately implement 3S requirements in the design of an advance SMR, early interactions with the IAEA and EURATOM has to be foreseen.
* The 3S approach allows to identify early on, areas where future R&D is necessary to comply with the national requirements and international obligations.
* The inclusion of a multidisciplinary team, focused on the 3S implementation, in an SMR project organization is important for an appropriate consideration of all necessary requirements and international standards and obligations.
* The pre-licensing process is a good practice that supports the applicants in the interpretation and integration of 3S in the concept design. It offers the opportunity to align views between the applicant and the regulatory body and to promote the safety, security and safeguards cultures in the project.

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## REFERENCES

[1] Royal Decree of 2 June 2021 amending the Royal Decree of 17/10/2011 regarding the physical security of nuclear material and nuclear installations and the Royal Decree of 30/11/2011 containing safety regulations for nuclear installations.

[2] Law of 15 April 1994 on the protection of the population and the environment against the dangers arising from ionizing radiation and on the Federal Agency for Nuclear Control;

[3] Royal decree of 30 November 2011 on safety requirements for nuclear installations (SRNI-2011)

[4] Technical regulations determining the practical implementation of the nuclear safety objective in accordance with Article 3/1 of the KBVVKI;

[5] General Regulations for the protection of workers, the population and the environment against the hazards of ionizing Radiation, laid down by Royal Decree of 20 July 2001;

[6] Royal Decree of 17 October 2011 on the physical security of nuclear material and nuclear installations (« Royal Decree on Physical Security »)

[7] Royal Decree of 17 October 2011 on the categorization and definition of safety zones in nuclear installations and nuclear transport companies (« Royal Decree on Safety Zones »);

[8] Royal Decree of 17 October 2011 on safety certificates for the nuclear sector and regulating access to safety zones, nuclear material or nuclear documents in certain special circumstances (« Royal Decree on Safety Certificates »);

[9] Royal Decree of 17 October 2011 on the categorization and protection of nuclear documents (« KB Documents »)

[10] Law of 20 July 1978 lays down the national modalities of the safeguards inspections on Belgian territory;

[11] Law of 1st June 2005 on the implementation of the Protocol Additional (INFCIRC/193/Add.8) on Belgium territory.

[12] R 302/2005/Euratom - Application of Euratom safeguards Commission Regulation (Euratom) 302/2005 of 8 February 2005 on the application of the Euratom safeguards;

[13] Agreement Between Belgium, Denmark, the Federal Republic of Germany, Ireland, Italy, Luxembourg, the Netherlands, the European Atomic Energy Community and the Agency in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons;

[14] Protocol Additional to the Agreement between the Republic of Austria, the Kingdom of Belgium, the Kingdom of Denmark, the Republic of Finland, the Federal Republic of Germany, the Hellenic Republic, Ireland, the Italian Republic, the Grand Duchy of Luxembourg, the Kingdom of the Netherlands, the Portuguese Republic, the Kingdom of Spain, the Kingdom of Sweden, the European Atomic Energy Community and the International Atomic Energy Agency in implementation of Article III, (1) and (4) of the NPT;

[15] S. Coenen, F. Henry and I. Sanda, “Belgian Approach for Licensing New Innovative Reactors,” IAEA-CN-308 (TIC2022), Vienna, Austria, 2022.

[16] Law of 1996 on the Wellbeing of workers in the performance of their work.

[17] 2017, ten Royal Decrees constituting the Codex on wellbeing at work.