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# REVIEW OF THE INTERNATIONAL INTERCOMPARISON AND HARMONISATION PROJECT ON DEMONSTRATING THE SAFETY OF GEOLOGICAL DISPOSAL (GEOSAF PART III)

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*This paper focuses on the International Intercomparison and Harmonisation Project on Demonstrating the Safety of Geological Disposal (GEOSAF Part III). The current stage of the project aims at providing practical guidance based on the experience of regulatory authorities on the development and upgrading of safety cases in different countries. The main topic in this context is the relationship between regulatory requirements and safety functions, design specification and the actual state of the disposal system during its construction, operation and closure. Considered of key importance in the project is the operational safety of disposal facility and the role of monitoring given the need of managing uncertainties and deviations of the actual repository's state from the design one.*

**Keywords:** *radioactive waste, deep geological disposal facility, safety case and safety assessment.*

## Background of GEOSAF project

The goal of GEOSAF project (The International Project on Demonstration of the Operational and Long-Term Safety of Geological Disposal Facilities for Radioactive Waste) is to compare and summarize the international experience on demonstrating the long-term safety of deep geological facilities for RW. Representatives of operating organizations, regulatory authorities, scientific and technical support organizations are engaged in the project including some meetings held with the engagement of FBU SEC NRS, FSEU NO RAO, Nuclear Safety Institute.

Safety Case is considered as the core element presenting the activities implemented under the project. Relevant concept is discussed in the provisions of a special safety guide developed by IAEA — SSG-23 [1] being a collection of scientific, technical, administrative and managerial arguments demonstrating that all elements of the repository and activities on its development and operation implemented at the site are considered safe.

GEOSAF project was launched in 2008 seeking to harmonize opinions and approaches on the development and further regulatory review of long-term safety case materials developed for RW geological disposal facilities. GEOSAF accounted for the findings of pervious international IAEA projects associated with safety demonstration such as ISAM (Improvement of Safety Assessment Methodologies for Near Surface Disposal Facilities for Radioactive Waste), ASAM (Application of Safety Assessment Methodologies for Near-Surface Radioactive Waste Disposal Facilities), DeSa (Evaluation and Demonstration of Safety during Decommissioning of Nuclear Facilities), SADRWMS (Safety Assessment Driven Radioactive Waste Management Solutions), EMRAS (Environmental Modelling for Radiation Safety) [2]. It was already at the first stage of the project completed in 2011 that particular focus was placed on repository safety at the operational stage [8].

In 2012, the second stage of the project was launched (GEOSAF Part II) aiming to develop common approaches on evaluating and demonstrating that processes associated with construction and operation of geological disposal facility extended in time ensure that the disposal system maintains all its safety functions discussed in the Safety Case following its closure. These activities were based on the findings of GEOSAF Part I, as well as IAEA standards SSR-5 [4], SSG-14 [5] and SSG-23 [1].

Current stage of the project (GEOSAF Part III) is aimed at providing a more in-depth outlook on so-called Safety Envelope, Design Target and As Built State concepts and their development. These concepts present the range of safety barrier and safety function states corresponding to three points of reference — according to the requirements, to the designs, by the time of repository closure. Available Safety Cases developed by different countries, in particular those with rather mature repository designs and being considered as quite successful in their implementation, are viewed as the basis of the project. Also, under GEOSAF III efforts are continued on identifying the gaps in regulations containing provisions on the operational safety of repositories. These efforts should result in a draft document containing possible table of a contents for a guide covering operational safety issues.

## Safety Envelope, Design Target and As Built State

Repository safety after its closure cannot be entirely verified by direct measurements. Since there is no practical possibility to obtain direct evidence demonstrating the fact that given safety functions are maintaned in the long-term, safety at the post-closure stage is demonstrated by indirect methods, usually under the safety case based on relevant safety assessments. The latter ones involve numerical modeling carried out with due account of performed monitoring, research and uncertainty assessments, including various scenarios for disposal system evolution at different time periods. A key element considered crucial in terms of the reliability of such safety assessments consists in the assumption suggesting that the configuration of the disposal system at the time of its closure (following construction and operation) will be exactly the same as provided for in the repository designs and considered at the licensing stage in the Safety Case.

For this reason, a number of essential terms have been proposed under the GEOSAF project each of them discussing the disposal system's state.

The first term is called safety envelope — "safety margins" suggesting a set of criteria the compliance with which enables to state that deep repository can be considered safe. Design Target is the state of safety barriers and safety functions stated in the repository designs by the time of its closure. And, finally, As Built State — actual (measured) state of barriers and behavior of safety functions by the time of repository's closure.

These definitions were introduced under GEOSAF II as it was clearly understood that the requirements imposed on the facility with some uncertainties being in place in any case are viewed as ranges of safety characteristics with a certain "margin of safety". The project was developed in a way ensuring the requirements compliance enabling their transfer into parameter values for particular systems and sub-systems associated with the facility in question, sometimes with some "margin of safety" also being taken into account. At the same time, it also seems quite obvious that with time deviation of a parameters from the design value does not necessarily mean that the facility as a whole ceased to meet the requirements imposed on it, including the safety requirements. If more simple facilities are considered, such as not too complex instruments, Safety Envelope, Design Target and As Built State may represent different ranges of a single measured parameter. If a more complex item is considered, such as geological disposal system, some of the boundary conditions and criteria forming the Safety Envelope may be of a qualitative nature and may not coincide with the set of parameters adopted during design development to meet these criteria. Some of these requirements, for instance, those enabling the possibility of waste retrieval from the repository can not be interpreted in quantitative manner at all. Moreover, during repository operation, acquisition of more data on it and better understanding on its evolution with time, parameter values accounting for the Design Targets may be also reviewed with due account of re-assessments and repository safety evaluations (figure 1 b). Generally, these will evolve along with the Safety Case.

Figure 2 gives some ratios for the states considered in keeping with relevant requirements (Safety Envelope), design provisions (Design Target) and the actual state (As Built State). In reality, the area corresponding to actual states of the safety functions (As Built State) may misalign with the Design Target area or even the Safety Envelope area. In these cases, it is necessary to assess the significance of the deviations from the long-term safety perspective and justify the need for introducing relevant corrective actions.

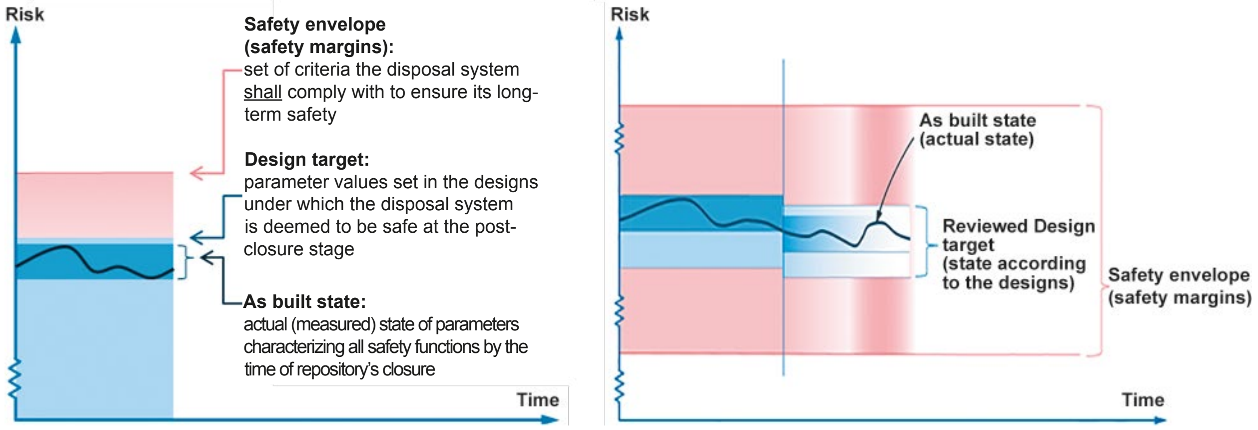


*Figure 1. Visualization of Safety Envelope, Design Target and As Built State concepts (a) and example (b) of Design Target alterations due to Safety Case review*

At the same time, the process of managing the deviations of disposal system's actual state (As Built State) from the design one (Design Target) and the state specified by the requirements (Safety Envelope) should be iterative in its nature (figure 3) [6]. This process should be provided for under the system of repository management (the need for such a system and its functions were discussed in some papers, namely [4]).

Disposal system monitoring is essential for the concept discussed above. Moreover, under present project, monitoring should not cover all features or processes being considered important for repository's safety, but solely the observations aiming to identify to which extent has the state of the disposal system deviated from the one specified in the designs and described in the Safety Case. If monitoring results demonstrate the deviation of the actual state from the design one, the significance of these deviations should be evaluated to demonstrate the long-term safety of the facility in question. If necessary, corrective measures are implemented with relevant information being added to the Safety Case. Furthermore, the management system should also provide for a case when the actual state of the disposal system does not comply with the safety requirements and the long-term safety case and the design solutions are to be reviewed. Thus, to provide the establishment of an effective deep disposal facility management system, the processes and procedures associated with repository operation should be developed and documented first, and then, according to monitoring of the key parameters, compliance with the operational limits and conditions should be ensured. If operational limits or conditions are identified to be not observed, the operator should take corrective actions in order to restore normal operation, taking into account possible consequences of these actions in terms of long-term safety assurance.

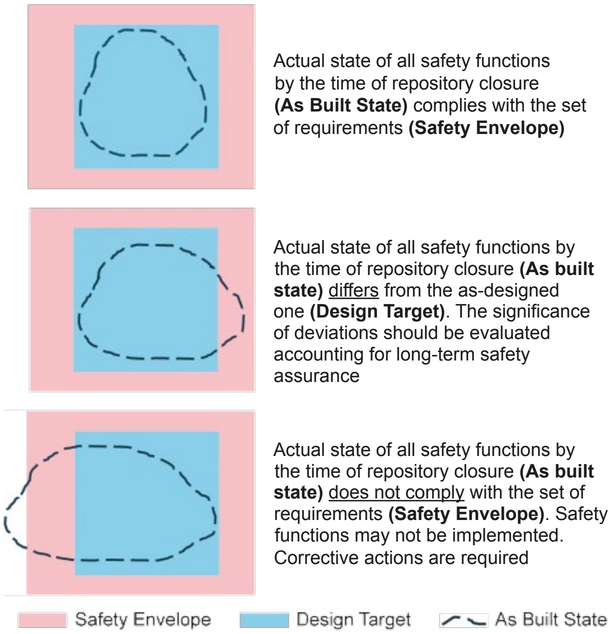


*Figure 2. Cases presenting different relations between three states Safety Envelope, Design Target and As Built State*

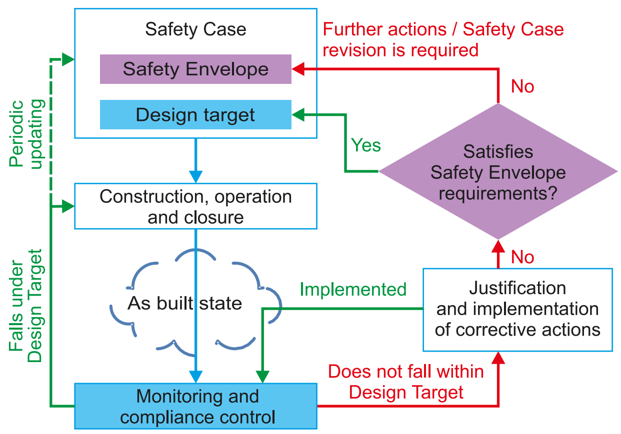


*Figure 3. Decision making flow chart on the key monitoring parameters [6]*

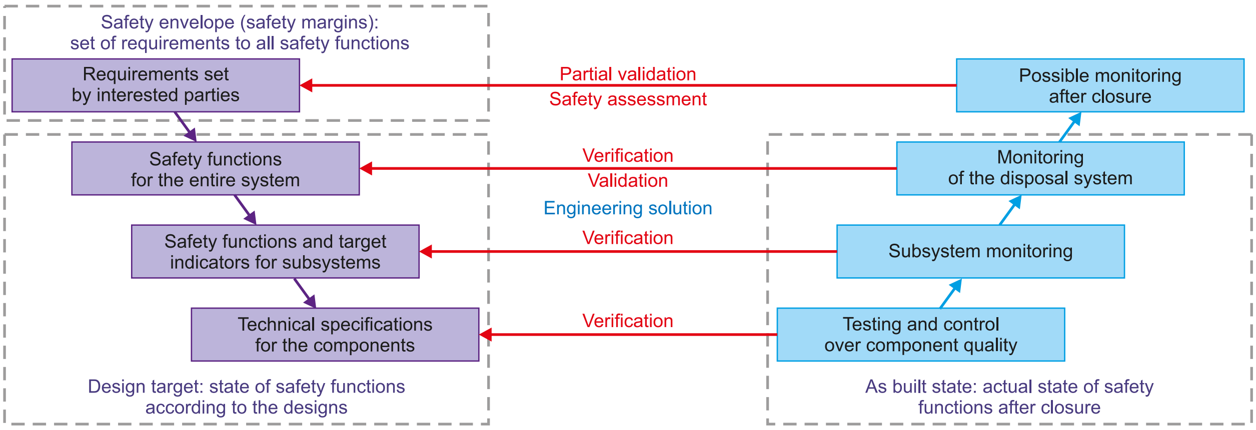


*Figure 4. Entities of GEOSAF project in the structure of requirement management system*

## GEOSAF fields of concern

At present time, GEOSAF III activities are implemented under three working groups. Group 1 is focused on operational safety of deep disposal facilities by evaluating available safety requirements and guidelines, thus, aiming to identify the extent to which a new guideline document is needed and which issues such a unified document should discuss to cover all safety aspects relevant for the operational stage of a deep repository. Current stage involves continued study of challenging topics and development of the document's content and structure.

Working Group 2 deals with the refinement of proposed concepts of Safety Envelope, Design Target, As Built State, their relationship and integration with the main components of the IAEA's Safety Case and Safety Assessment. Many of the questions raised by this Group are still being discussed and need some harmonization and coordination with other currently ongoing IAEA projects, including those associated with monitoring of geological disposal systems, long-term evolution of the environment, building a road map for geological disposal project, summarizing the knowledge gained from experiments in underground research laboratories and etc.

From requirement management perspective, Safety Envelope, Design Target, As Built State may be presented in the form of common V-chart, which however does not provide the answer to the question on how to ensure the compliance of disposal system configuration at the time of its closure with the safety state and what should be the response in case if monitoring results deviate from key parameter values specified in the designs.

Case studies discussing the experience of countries that have been for a long term engaged in the development of long-term safety cases and have reached certain progress in this field, for instance, Sweden and Finland, are applied to evaluate and refine the proposed monitoring approach to ensure the long-term safety in this context.

Working Group 3 focuses on the aspects of managing uncertainties, deviations of actual repository state from the one specified in the designs, implementation of correcting actions and upgrading the Safety Case. Previous stages have enabled to identify a number of specific practical questions arising from these aspects during the development of the Safety Case. At this stage, IAEA safety standards are being studied to find out the answers to these questions and to identify the questions for which no answers are provided in currently available safety standards.

In terms of uncertainty management, these questions are as follows: how to determine which uncertainties should be considered as important for safety and are associated with the greatest risk; how the research program and monitoring should be arranged for to reduce the uncertainties; how to manage uncertainties throughout the entire life cycle and etc. Comparison of practical issues and statements from the guideline documents has demonstrated that IAEA documents basically contain general considerations, a detailed classification of uncertainties and requirements suggesting the consideration of uncertainties at all stages of repository life cycle, but nevertheless provide no specific recommendations on the methods and sufficiency criteria for accounting particular uncertainties. More practical recommendations on uncertainty accounting is expected to be found in the Report drafted under IGSC (Integration Group for the Safety Case) NEA's MeSa initiative that has prepared an overview of modern safety assessment approaches [7].

Key topics considered as part of deviation management are as follows: how to identify the deviations and to distinguish them from uncertainties, how to assess the consequences, what is the level of deviations the regulatory authorities should be notified about, is there enough knowledge, methods and tools to plan and implement corrective actions at all stages of the life cycle, etc.

The key issue associated with upgrading the safety case and periodic assessment of repository's long-term safety still awaiting a uniform answer is to establish links between these updates and Design Target or Safety Envelope modifications. Practical application and sufficiency of SSG-31 [8] and SSG-23 [1] provisions in terms of managing deviations and updating the safety cases are discussed separately as well. Preliminary analysis of relevant documents has shown that similar to the issues of uncertainty accounting, the guideline documents contain only general requirements on the topics of managing deviations and upgrading Safety Case materials with no specific approaches and tools described therein. For this reason, the Working Group continues its efforts on summarizing the experience of the countries engaged in this project. The work of the group is carried out in close cooperation with the Work Group 2.

## Conclusion

Establishment of deep RW disposal facilities is always considered as a unique project due to the particular features of bedrocks, properties of disposed waste, available engineering solutions, cultural and historical background and other factors. Such projects seek to address two key objectives, namely, to ensure confidence in the safety of population and the environment over a long-term perspective following repository closure (safety demonstration) and to demonstrate that all elements of the disposal system and the system as a whole can be implemented (feasibility study).

Terms considered under the GEOSAF projects are seeking to integrate the activities preceding repository closure aiming to ensure its long-term safety so that any deviation in repository configuration from the parameters of barriers and safety functions (Design Target) provided for in the designs and the Safety Case would not result in disposal system's misalignment with the safe state defined by a set of safety criteria (Safety Envelope). Safety Case developed at early stages of geological disposal project based on design configuration should be iteratively updated accounting for the data on the actual state of the disposal system and its evolution with time (As Built State).

Comparison of the actual disposal system's state with its design configuration at any stage of repository's lifecycle should be supplemented by the evaluation of potential impacts produced by identified deviations and possible corrective actions affecting the long-term safety of the facility at the post-closure stage.

GEOSAF participants assume that the suggested approach may be integrated into the Safety Case concept and effectively implemented at the earliest possible stages of the project on DFRW establishment, including monitoring system development.

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