Organizing and Structuring the OPERA Research Efforts using Safety Statements

OPERA-PU-NRG2112

Radioactive substances and ionizing radiation are used in medicine, industry, agriculture, research, education and electricity production. This generates radioactive waste. In the Netherlands, this waste is collected, treated and stored by COVRA (Centrale Organisatie Voor Radioactief Afval). After interim storage for a period of at least 100 years radioactive waste is intended for disposal. There is a world-wide scientific and technical consensus that geological disposal represents the safest long-term option for radioactive waste.

Geological disposal is emplacement of radioactive waste in deep underground formations. The goal of geological disposal is long-term isolation of radioactive waste from our living environment in order to avoid exposure of future generations to ionising radiation from the waste. OPERA (OnderzoeksProgramma Eindberging Radioactief Afval) is the Dutch research programme on geological disposal of radioactive waste.

Within OPERA, researchers of different organisations in different areas of expertise will cooperate on the initial, conditional Safety Cases for the host rocks Boom Clay and Zechstein rock salt. As the radioactive waste disposal process in the Netherlands is at an early, conceptual phase and the previous research programme has ended more than a decade ago, in OPERA a first preliminary or initial safety case will be developed to structure the research necessary for the eventual development of a repository in the Netherlands. The safety case is conditional since only the long-term safety of a generic repository will be assessed. OPERA is financed by the Dutch Ministry of Economic Affairs and the public limited liability company Electriciteits-Produktiemaatschappij Zuid-Nederland (EPZ) and coordinated by COVRA. Further details on OPERA and its outcomes can be accessed at www.covra.nl.

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Content

Summary

The present *safety statements* as a tool are being developed by ONDRAF/NIRAS, elucidating how claims regarding the safety of a radioactive waste disposal facility are supported by evidence and arguments. Nowadays, this approach is addressed as *safety and feasibility statements*. It should be recognized that the concept of safety and feasibility statements is still under development.

The present report treats the concept of safety statements as a means to communicate pieces of evidence and claims about the safety aspects of deep geological repositories for the disposal of radioactive waste. The safety statements as developed by ONDRAF/NIRAS have been mapped on the Tasks that are currently being executed within OPERA in order to assess their applicability within the Dutch context.

Samenvatting

Het concept van *safety statements* is ontwikkeld door ONDRAF/NIRAS en kan worden gebruikt om aan te tonen op welke wijze de beoordeling van de veiligheid van een eindberging voor radioactief afval kan worden ondersteund door bewijzen. Tegenwoordig wordt deze benadering aangeduid als *safety and feasibility statements*. Er zij opgemerkt dat het concept van *safety and feasibility statements* nog steeds in ontwikkeling is.

Dit rapport geeft een overzicht van het concept van *safety statements* als middel voor de communicatie van (delen van) bewijsvoeringen en oordelen over veiligheidsaspecten van eindberging in de diepe ondergrond. De *safety statements* zoals ontwikkeld door ONDRAF/NIRAS zijn geprojecteerd op de Taken die momenteel binnen OPERA worden uitgevoerd om zodoende de toepasbaarheid te toetsen aan de Nederlandse context.

1. Introduction

1.1. Background

Conducting a safety assessment and developing a Safety Case for the deep geological disposal of radioactive waste involves coordinating a great variety of interrelated tasks and disciplines. This includes the description of the logistic, legal (e.g. reference values) and societal boundary conditions for the disposal concept under consideration, the definition of the disposal concept and the development of scenarios to substantiate the safety and performance of the system. A crucial outcome of this work is the integration of all evidence and arguments into an overall safety statement that will be communicated to stakeholders and interested people.

A way to organise and document available information obtained from the safety assessment and the Safety Case is by means of "safety statements". Safety statements as a tool are being developed by ONDRAF/NIRAS, and comprises a set of claims regarding what the system does and the properties that is has (ONDRAF/NIRAS, 2013; p.34). The safety statements are arranged in a structured, hierarchical method to divide the top-level safety requirements into increasingly specific statements that can be supported by research tasks. In that sense, safety statements can provide valuable tools for communicating between safety assessors, geoscientists and stakeholders and for assessing the propagation of uncertainties in a bottom-up manner (i.e. from the most specific to the most general statements).

Higher-level statements, such as the statements that define the safety concept, being more general in nature, can already be formulated early on in a disposal program. Other more detailed statements gradually emerge as the program proceeds, as the concept and design become better defined and more firmly established, and geo-scientific evidence and arguments and other elements of the assessment basis are being developed. At the end of OPERA, the safety statements will be used for the definition of topics in a follow-up research program.

1.2. Objectives

The objective of this task is to assess the concept of safety statements as developed by ONDRAF/NIRAS within the context of OPERA and the relation to the Tasks currently being executed within the OPERA program.

1.3. Realization

The present report, carried out as part of the OPERA OSCAR task "Definition of the Safety Case for radioactive waste disposal", treats the concept of safety statements as a means to communicate pieces of claims and arguments about the safety aspects of deep geological repositories for the disposal of radioactive waste.

1.4. Explanation of contents

After a short introduction on the Safety Case for geological disposal in Chapter 2, the present status of the safety statements concept, as developed by ONDRAF/NIRAS, is elucidated in Chapter 3. Chapter 4 evolves this concept in the Dutch context of geological disposal. Concluding remarks and recommendations are formulated in Chapter 5.

2. Safety Case for deep geological disposal

The development of a geological disposal facility for radioactive waste will always cover an extended period of time. At various stages in the lifecycle of such a facility, ranging from siting to final release from regulatory control, decisions are needed to proceed through the lifecycle and move towards the next stage. This process has been indicated in Figure 2-1 (NEA, 2012; p.10). These decisions are supported by safety assessments and evidence from in-situ monitoring and analogues which, in the end, demonstrate that a repository will be safe in the long term.

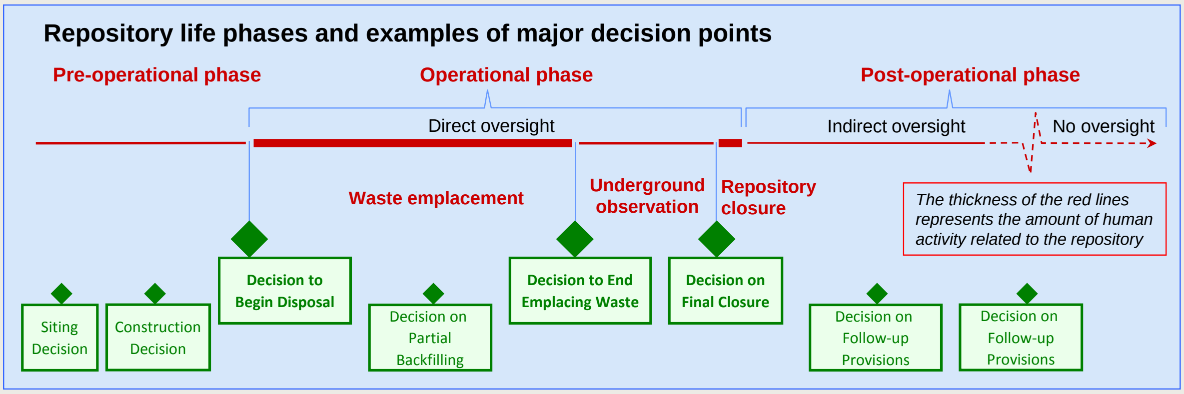

Figure 2-1 Phases of a disposal facility.

The complete set of arguments and underpinning evidence and analyses used to justify the conclusion that a specific repository system will be safe is referred to as a Safety Case (NEA, 2012; p.5). A Safety Case includes, in principle, a presentation of evidence that all relevant regulatory safety criteria, which may either be national or regional, can be met. It usually consists of a series of documents that set out the national or regional context, describe the system design and safety functions, illustrate the performance, present the evidence that supports the arguments and analyses, and that discuss the significance of any uncertainties or open questions in the context of decision making for further repository development.

An additional important function of the Safety Case is to provide a platform for informed discussion whereby interested parties can assess their own levels of confidence in a project, determine any reservations they may have about the project at a given stage of planning and development, and identify the issues that may be a cause for concern or on which further work may be required.

An example of a general scheme that would be applicable to a Safety Case is illustrated in the figure below (IAEA, 2012; p.16).

Taking into account a country's Safety Case context, comprising the boundary conditions (e.g. legal, financial, ..), and safety strategy (a.o. the waste management strategy, definition of safety functions), a disposal concept is being developed, for which a safety assessment has to be conducted. Through the comparison of the outcomes of the safety assessment with regulatory limits, judgments about the safety of the disposal concept can be formulated. This whole system of procedures and activities is under control of an appropriate management system, and is guided by consultation of the regulatory body and stakeholders.

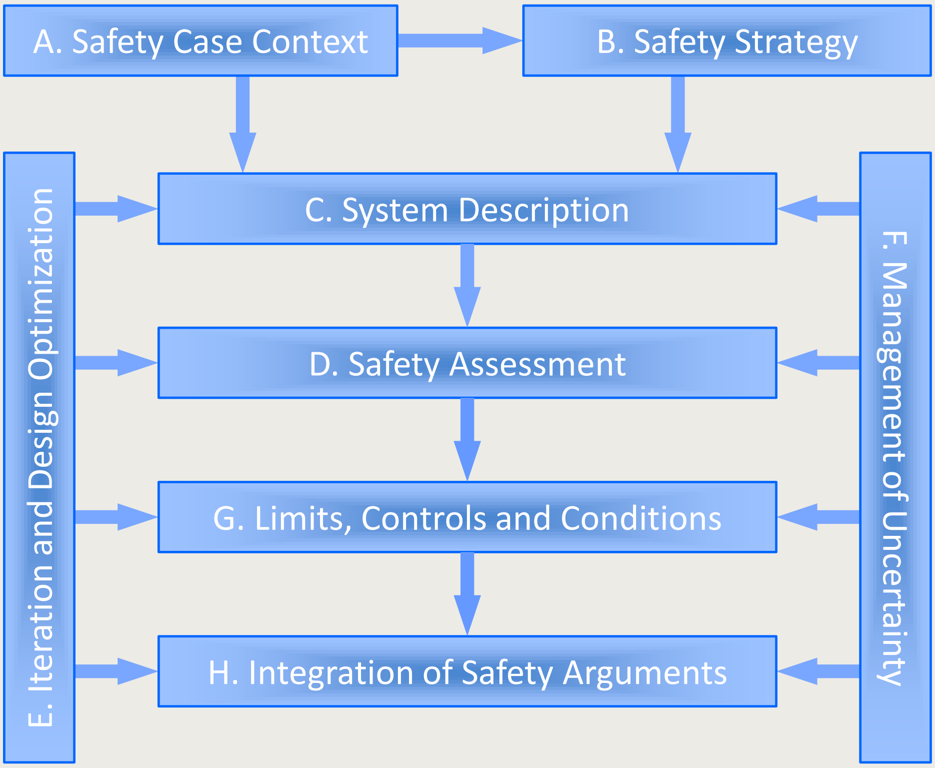

Figure 2-2 Components of a Safety Case

The synthesis of arguments and underlying evidence, and analyses, supported by the quality and reliability of the assessment basis, is comprised in the Safety Case component *Integration of Safety Arguments*, and leads to a Safety Case *statement of confidence* (NEA, 2012; p.7). Such a statement, which may consist of a variety of arguments and judgments, should explicitly state that sufficient confidence exists in the safety of the system to justify a positive decision to proceed to the next stage of planning or implementation or closing of a disposal system.

An approach which aids to demonstrate how claims concerning the repository's safety are supported by evidence is the concept of *Safety Statements*. This tool is being developed by ONDRAF/NIRAS and utilizes a graphical argumentation notation (Smith, 2009a). The present status of safety statements concept, as being developed by ONDRAF/NIRAS, and applied to the Belgian context, is elucidated in the next chapter.

3. Safety Statements in the Belgian context

3.1. *Background*

The concept of *Safety Statements* in relation to the Safety Case of geological disposal is being developed by ONDRAF/NIRAS (Smith, 2009a; Depaus, 2012; ONDRAF/NIRAS, 2013). Safety statements comprise a set of claims and arguments regarding what system/subsystem properties support safety functions of the repository system. In addition, the statements form a hierarchy, with lower-level statements underpinning those at higher levels, and where the lowest level statements are directly supported by phenomenological understanding from the assessment basis. The concept of *Safety Statements*, as outlined in various ONDRAF/NIRAS documents is elucidated in more detail in the present chapter.

The concept of *Safety Statements* is part of the Belgian safety strategy, which has been developed by ONDRAF/NIRAS and which is based on 30 years of experience, knowledge and understanding acquired in the field of geological disposal in poorly indurated clay and on constraints imposed to ONDRAF/NIRAS by third parties.

The safety strategy adopted by ONDRAF/NIRAS includes boundary conditions to be met, requirements that must be satisfied, the adopted safety principles and strategic choices, and the safety concept expounding in broad terms how it is envisaged that safe disposal will be achieved. These aspects have been described and elucidated in the Belgian RD&D Plan (ONDRAF/NIRAS, 2013; Section 2.1) and will not be repeated here.

3.2. *Belgian Safety and Feasibility Statements*

Whereas the safety strategy defines in broad terms how safe disposal is envisaged to be achieved, the management strategy defines how the activities for the implementation (realization) of the safety strategy will be managed to ensure that (1) the boundary conditions, strategic choices and safety principles therein are respected, and (2) a high level of confidence in the results and the quality of the concerned Safety and Feasibility Case (SFC) is achieved.

The high-level management choices are set by ONDRAF/NIRAS, responsible for the Belgian waste disposal program (ONDRAF/NIRAS 2013; p.34). All RD&D and other SFC related activities are driven by the safety functions, which the repository has to fulfill. The safety functions must be translated into a set of more pragmatic requirements to be used for implementation. ONDRAF/NIRAS has chosen to formulate and organize these requirements as a set of claims and arguments – safety and feasibility statements - regarding what the system does and the properties that it has, arranged hierarchically in a tree structure, called the *Safety and Feasibility Statements* tree.

The introduction of the Safety and Feasibility Statements tree has resulted in significant changes in the management in the ONDRAF/NIRAS RD&D program on geological disposal. In particular, reorganization of the RD&D program around the need to substantiate the statements has led to a more efficient and pertinent prioritization of the issues.

The statements in the Safety and Feasibility Statements tree are structured in a top-down manner, starting with the most general (high-level) statements and progressing to increasingly specific (lower-level) statements as depicted in Figure 3-1 (ONDRAF/NIRAS, 2013; p.35). The top-level statements define the main objectives of the safety and feasibility assessment of the Safety and Feasibility Case at hand, i.e. for SFC1: demonstrating that the disposal system can provide long-term safety and that it is feasible to implement. The substantiation of the Safety and Feasibility Statements, with the multiple lines of evidence and their associated uncertainties generated from the

RD&D program, is performed bottom-up. The need to obtain arguments to substantiate the lowest-level statements and to address any open issues guides the RD&D program, ensuring that focus is maintained on the upper claims. At the present stage of the Belgian program, two trees are under development, one focused on long-term safety and the other one on the feasibility and operational safety. These trees will merge at a later stage in the Belgian program. Derivation of the tree statements is part of the management system.

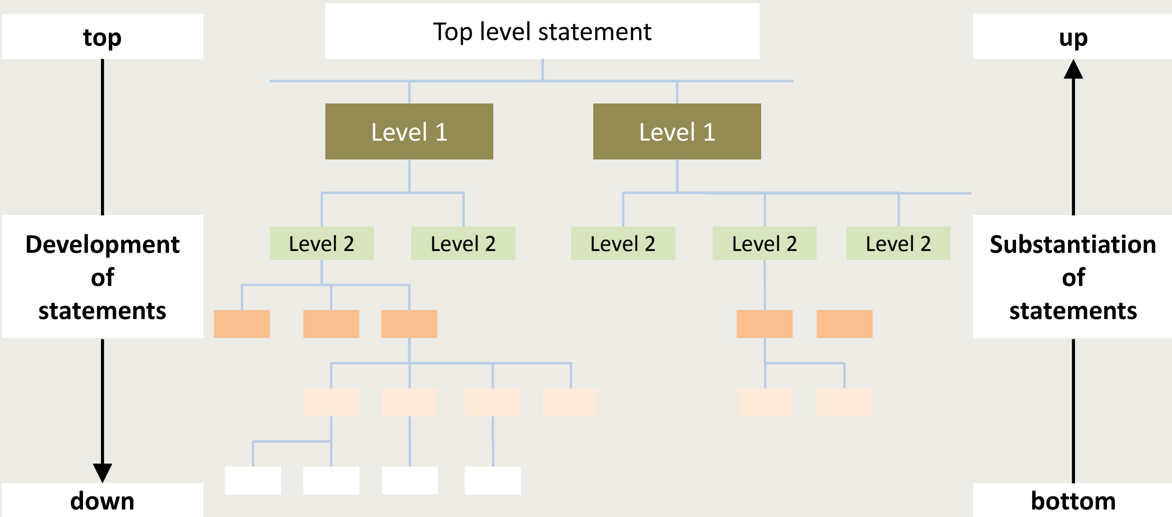

Figure 3-1 The top-down development of the structured set of safety statements and the bottom-up assessment of the level of support for these statements.

All statements will need to be adequately supported to justify a positive decision to proceed with the compilation of the safety and feasibility case aimed at supporting the decision at hand. However, according to the definition of safety and feasibility case, also the significance of the remaining uncertainties and open issues must be discussed and guidance for work to resolve in future program stages must be provided. In addition, the level of support that is required for the successive safety and feasibility cases will increase as the waste disposal program progresses towards a license application.

The Safety Statements tree has evolved with time. Initially (since SAFIR2) Safety Statements were derived top down from safety functions. They were later revised progressively in the light of increasing knowledge from the ongoing RD&D programme addressing wider aspects of system understanding. The Safety Statements thus evolved from being strictly "safety-assessment oriented" to "Safety-Case oriented", able to provide next to the safety, a concise overview of all aspects linked to the implementation of a disposal system. These changes were mainly driven by the iterative interactions between the three “poles of expertise” during the early preparatory phase of SFC1, viz. the “phenomenology pole”, the “feasibility pole”, and the “safety assessment pole” (ONDRAF/NIRAS, 2013; p.40).

3.3. Current status of the Belgian Safety and Feasibility Statement tree

Table 3-1 presents the current version of the high-level Safety Statements (ONDRAF/NIRAS, 2013; p.44). It comprises four branches supporting the assertion that there is confidence in the long-term safety:

- The branch "*the system is known*" comprises the knowledge basis acquired in 30 years of research in Belgium about the waste, the disposal system, its evolution (which can be bounded) and its environment (in which the impact of the system is assessed).
- The branch "*the safety functions that have been defined are relied upon*" aims to show that the proposed disposal system will provide passive safety over the long term. The substantiation of this branch is under way and will be developed for SFC1.
- The branch "*the performance of the disposal system meets the requirements*" includes information about the definition and calculations of the relevant performance and safety indicators and comparison with regulatory requirements, the environment impact of a disposal system and other external requirements. It is under development.
- The branch "*remaining/residual uncertainties*" includes statements explaining that there are no uncertainties that call into question the capacity of the system to fulfil the requirements and that there are good prospects that future RD&D will enable safety-relevant uncertainties to be reduced or even avoided. It will be developed for SFC1.

Table 3-1 Current version of the high-level Safety Statements

Indeed,	The system is known	
	Indeed,	The system components can be characterized
	and,	The evolution can be bounded
and,	The safety functions that have been defined are relied upon	
	Indeed,	Isolation of the system is ensured during the period of concern
	and,	Containment is ensured during at least the thermal phase
	and,	Rate of radionuclide transport is low and some radionuclides are delayed
and,	The performance of the disposal system meets the requirements	
and,	The remaining/residual uncertainties are identified and manageable (by RD&D, conservative assumptions, scenarios, etc.). The irreducible uncertainties do not impact the overall knowledge, understanding and safety of the disposal system.	

Annex A1 of the Belgian RD&D Plan (ONDRAF/NIRAS, 2013) contains additional details concerning the underlying statements for each of the four branches indicated in Table 3-1. That table of Annex A1 has also been used as a basis for the development of safety statements in the Dutch context, as is elucidated in Chapter 4.

In the current version of the Belgian RD&D Plan (ONDRAF/NIRAS, 2013) the statements of the Safety and Feasibility Statement tree have been explained in the appropriate sections. At the end of most of the descriptive sections of the RD&D Plan (i.e. in parts 2, 3 and 4) a 'road map' summarizes issues that need to be addressed to further substantiate the safety statement concerned.

3.4. Conclusions

The concept of safety and feasibility statements plays a fundamental role in the ONDRAF/NIRAS approach to the development of a Safety and Feasibility Case. That concept provides a structured way of organizing the various lines of evidence and arguments that constitute the Safety Case for geological disposal, starting with the highest-level statements and progressing, in a top-down manner, to the underlying basis in scientific understanding and underpinning arguments.

It is recognized that the concept of safety and feasibility statements is still under development. It is likely that the ideas and methodology will be further developed (1) as lessons are learnt from their application in practice, and (2) from discussions with the Belgian safety authorities (FANC).

As in the current version of the Belgian RD&D Plan (ONDRAF/NIRAS, 2013) the Safety and Feasibility Statement tree might be used as a basis for the table of contents for documentation of the Belgian Safety and Feasibility Case.

4. Safety Statements in the Dutch context

4.1. Background

As described in Chapter 3, safety (and feasibility) statements are embedded in the Safety Case, they refer to different aspects and components of the Safety Case. An important aspect of safety statements is that they describe how the various characteristics of the geological and engineered environment underpin the safety functions of a repository. The safety functions on their turn are based on sets of requirements, both applicable to the natural and engineered barriers, to prevent that the radionuclides present in the disposed waste pose an unacceptable hazard to humans or the environment. These requirements are usually based on a country's waste management policy and safety strategy, and they are translated into a safety concept, an adopted or proposed repository design, and a safety assessment methodology. As a consequence, safety statements are not stand-alone features in a Safety Case, but closely connected to the afore-mentioned topics.

In order to set the basis for the development of safety statements in the Dutch context, it is important to take notice of the following aspects:

- The presently adopted safety strategy in the Netherlands, outlined in the recently published Safety Strategy document (Verhoef, 2014);
- The OPERA safety concept, broadly consisting of:
    - Safety functions as are being applied for the OPERA disposal concept for the disposal of HLW in Boom Clay (Smith, 2009b; p. 31) (Neeft, 2013)[a];
    - The multi-barrier system that isolates the radioactive waste from the biosphere until the radioactivity of the waste has decayed to natural levels (Verhoef, 2011a; p.8);
    - The OPERA reference disposal concept, as described in (Verhoef, 2011b).
- The OPERA safety assessment methodology, presented in (Grupa, 2014).

4.2. OPERA safety statements

In developing OPERA safety statements, befitting the present stage of the Dutch waste disposal program, it has to be recognized that the results of the OPERA program to support the safety statements are not yet available. It also has to be acknowledged that the safety statements established by ONDRAF/NIRAS referring to the Belgian safety concept (see e.g. Section 3.3) are based on already available results of earlier R&D performed in Belgium, and that these safety statements are still under development. It therefore makes sense to base the OPERA safety statements on the present Belgian ones.

Since the construction and operation of a geological disposal facility in the Netherlands is only foreseen in the next century, the definition of safety statements in the present phase of the Dutch waste disposal program will be limited to preliminary safety statements. Statements concerning uncertainties can only be elaborated once results of the OPERA program have become available. Statements concerning the feasibility are less relevant for the current situation in the Netherlands. Therefore, the statements of the branches of the Belgian Safety and Feasibility Statement tree might serve as a basis for the OPERA safety statements.

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[a] Note that the presently adopted safety functions in OPERA differ from those described in the OPERA Research Plan (Verhoef, 2011a, p.9,10). In the Netherlands also disposal of non heat-generating radioactive waste is assumed, for which no "Thermal Phase" applies.

Table 4-1 Mapping of OPERA tasks to the four branches of the current version of the Belgian Safety and Feasibility Statement tree.

Indeed,	The system is known				OPERA tasks
	Indeed,	The system components can be characterized			
		Indeed,	The conditioned wastes can be characterized		1.1.1, 1.1.2
		and,	The other parts of the engineered barrier system can be characterized		3.1.1, 3.1.2
		and,	The geological barrier[1] can be characterized		4.2.1, 5.2.1, 5.2.2, 5.2.3, 6.1.1 - 6.1.6
		and,	The environment[2] can be characterized		4.1.1, 6.2.1, 6.2.2, 6.3.1[3]
	and,	The evolution can be bounded			
		Indeed,	Siting and design favour stability		N/A (in a later phase)
			Indeed	Limited number of drivers	4.1.1, 4.1.2
			and,	Robust features	5.2.1, 5.2.2
		and,	For those drivers that cannot be avoided, the changes in properties and conditions can be bounded		
			Indeed	The evolution of the disposal system due to changes in its environment can be bounded	4.1.2, 5.1.1 - 5.1.5
			and,	The evolution of Boom Clay due to repository excavation, operation, and closure can be bounded	5.2.1, 5.2.2, 5.2.3
			and,	The evolution of the EBS with time can be bounded	5.1.1, 5.1.2, 5.1.3, 5.1.4
and,	The safety functions that have been defined are relied upon				
	Indeed,	Isolation of the system is ensured during the period of concern			
		Indeed,	Overburden above the system remains sufficient		4.1.1, 4.1.2
		and,	Human intrusion is unlikely		4.1.1, 4.1.2
	and,	Containment is ensured during at least the thermal phase			
			No loss of integrity		5.1.1 - 5.1.5
	and,	Rate of radionuclide transport is low and some radionuclides are delayed			7.2.1 - 7.2.5, 7.3.3
		Indeed,	The release rates from the waste forms are limited		4.2, 5.1.1, 5.1.4, 5.1.5
			Indeed	Waste forms have a limited degradation rate	5.1.1, 5.1.4, 5.1.5
			and,	The solubility of many radionuclides is limited	6.1.2
		and,	Water flow is limited		4.1.1, 4.1.2, 6.1.3, 6.1.5, 6.2.1
			Indeed	No permanent bypass	5.1.4, 6.1.6
			and,	Limited driving forces	4.1.1, 4.1.2, 6.2.1
			and,	Limited availability of mobile water	4.1.1, 4.1.2, 6.2.1
		and,	Transport is retarded for many radionuclides		4.1.1, 4.1.2, 5.1.4, 5.1.5, 5.2.1, 5.2.2, 6.1.1 - 6.1.4
			Indeed	Host formation displays sorption capacity for many radionuclides	5.1.4, 5.1.5, 6.1.1, 6.1.2, 6.1.4
			and	Dissolved NOM[4] does not excessively reduce the retardation	5.1.5
and,	The performance of the disposal system meets the requirements				
	Indeed,	The radiological impact meets the regulatory requirements			7.3.3
	and,	The environmental impact meets the regulatory requirements			N/A
	and,	The disposal system meets conditions arising from the consultations and included in the technical solution			1.2.1, 1.2.2, 1.2.3, 1.2.4, 1.3.1
and,	The remaining/residual uncertainties are identified and manageable (by RD&D, conservative assumptions, scenarios, etc.). The irreducible uncertainties do not impact the overall knowledge, understanding and safety of the disposal system.				To be identified in all WPs

1 The geological barrier refers to the Boom Clay (ONDRAF/NIRAS, 2013; Section 3.3)
2 The environment refers to the geosphere (ONDRAF/NIRAS, 2013; Section 3.4), possibly(?) including the biosphere
3 Relates to the biosphere
4 NOM: Natural Organic Matter

Note to **Table 4-1**: The statement "The biosphere can be stylized", viz. the header of Section 3.5 of the RD&D Plan, is not mentioned in the current version of Safety and Feasibility Statements (Annex A1 of ONDRAF/NIRAS, 2013).

In Table 4-1 the OPERA tasks are mapped to the statements of the four branches in the current version of the Belgian Safety and Feasibility Statement tree (ONDRAF/NIRAS, 2013; Annex A1). This table clearly shows that all safety statements of the branches - except some statements more fitting to later phases of the waste disposal program – are covered by OPERA tasks.

Since all program phase relevant statements of the branches of the Belgian Safety and Feasibility tree are covered by OPERA tasks, these statements may directly be used in OPERA as well. That does not exclude that between both Safety Cases differences in thoroughness of argumentations and support of the safety statements will occur. However, these must always be attributable to the phase differences between the Dutch and Belgian waste disposal programs.

The statements of the Feasibility branch, related to construction, operation and closure of the repository (ONDRAF/NIRAS, 2013; p.348) can be discarded for the present phase of the Dutch waste disposal program.

Table 4-2 lists the OPERA tasks (Verhoef, 2011a; p.20,21) and relates them to sections in the Belgian RD&D Plan (ONDRAF/NIRAS, 2013). It shows that except for a few specific Dutch tasks regarding retrievability (Task 1.2.3), LILW degradation (5.1.2), and a few interfacing or OPERA-specific tasks, all OPERA tasks can be related to sections in the Belgian RD&D Plan.

Table 4-2 Relation between OPERA Tasks and sections in the Belgian RD&D Plan

OPERA Task		Section in the Belgian RD&D Plan	
1.1.1	Radionuclide inventory and matrix composition	**3.1.1** **3.1.2** **3.1.3** **3.1.5**	Waste classification Technical inventory of the Belgian waste Waste characterization: division in families Uncertainties inherent to the characterization of the conditioned waste
1.1.2	Alternative waste scenarios	**3.1.4**	Potential modifications in the technical inventory of conditioned waste
1.2.1	Stakeholder Analysis	11.2	Waste plan: basic principles of the participative decision-making process
1.2.2	Legal requirements	1	Introduction
1.2.3	Retrievability	9	Other external requirements
1.2.4	Stakeholder involvement	11.2	Waste plan: basic principles of the participative decision-making process
1.3.1	Communicating Safety Case results	11	Societal aspects
2.1.1.B	Safety Case structure	2	Guiding approach for development repository
2.1.1.C	Safety statements	2.3	Management system
2.1.2.A	Safety assessment methodology	2.3.1	Safety assessment methodology
2.1.2.B	Guideline OPERA reporting		
2.1.2.C	FEPs	2.3.1	Safety assessment methodology
2.2.1	Repository design rock salt	10	Ypresian clays as potential host rock
3.1.1	Feasibility reference design	**3.2.1** **3.2.3**	SAFIR2 reference design and its review Current reference design of the engineered barrier system
3.2.1	Design modifications	**3.2.2**	Reconsideration of the SAFIR2 reference concept
4.1.1	Geo(hydro)logical properties	**3.4.1** **3.4.2**	Geological setting Hydrogeological setting
4.1.2	Future evolution geological properties	**4.2.1**	The evolution of the disposal system …

OPERA Task		Section in the Belgian RD&D Plan	
4.2.1	Near field boundary conditions	**3.3**	The geological barrier can be characterized
5.1.1	HLW matrix corrosion	**4.2.2.5** **4.2.3.4**	Gas Evolution of the waste
5.1.2	LILW degradation		N/A in Belgium
5.1.3	Metal corrosion	**4.2.2.5** **4.2.3.3**	Gas Evolution of the overpack
5.1.4	Cementitious degradation	**4.2.3.1**	Evolution of cementitious materials
5.1.5	Microbiological effects	**3.3.12** **4.2.2.6**	Microbes Microbes
5.2.1	Geochemical properties Boom Clay	**3.3.4** **3.3.5** **3.3.8** **3.3.9** **4.2.2**	Mineralogy Density and water content Pore water composition Transport of solutes The perturbations of Boom Clay …
5.2.2	Geochemical interactions Boom Clay	**3.3.9** **4.2.2**	Transport of solutes The perturbations of Boom Clay …
5.2.3	Geochemical/THM evolution Boom Clay	**3.3.10** **3.3.11** **4.2.2.2**	In-situ stress state and hydro-mechanical behavior Thermal properties Thermal output of the category C waste
6.1.1	Fundamental sorption aspects	**3.3.9**	Transport of solutes
6.1.2	Modeling of sorption	**3.3.9**	Transport of solutes
6.1.3	Modeling of diffusion	**3.3.9**	Transport of solutes
6.1.4	Mobility and presence colloids	**3.3.9.3**	Dominant interactions between radionuclides and Boom Clay
6.1.5	Non-diffusive transport	**3.3.7**	Hydraulic conductivity
6.1.6	Gas migration	**4.2.2.5** **6.2**	Gas Is gas an issue for geological disposal in Boom Clay?
6.2.1	Modeling hydraulic transport	**3.4.2**	Hydrogeological setting
6.2.2	Modeling nuclide migration	**3.3.9.4**	Migration
6.3.1	Modeling biosphere process	**3.5**	The biosphere can be stylised
7.1.1	Scenario development	6.1	Reference scenario
7.1.2	Scenario representation	6.1	Reference scenario
7.2.1	Performance Assessment model Boom Clay migration	3.4	The environment can be characterized
7.2.2	Performance Assessment model aquifer migration	3.4.2	Hydrogeological setting
7.2.3	Performance Assessment model biosphere migration	3.5	Stylization of biosphere
7.2.4	Integrated Safety Assessment model		
7.2.5	Model parameterization		
7.3.1	Safety and Performance indicators methodology	2.3.1	Safety assessment methodology
7.3.2	Methodology uncertainty analyses	2.3.1	Safety assessment methodology
7.3.3	Safety assessment calculations		

The correspondence between the Belgian RD&D Plan (ONDRAF/NIRAS, 2013) and the Dutch Research Plan (Verhoef, 2011a; p.20,21) suggests clear added value of collaboration between research teams of both programs.

4.3. Conclusions

The safety of deep geological disposal depends on a variety of aspects which need to be addressed adequately and sufficiently in a Safety Case for the geological disposal of radioactive waste in order to comply with international requirements and national regulations. Also the expectations from different stakeholders, e.g. politicians, the public etc., need to be taken into account. This implies that communicating the above-mentioned topics in a clear, understandable and well-structured manner is crucial. One way to accomplish that is the formulation and assessment of safety statements.

The statements of the four branches of the Belgian Safety and Feasibility tree, related to the long-term safety, may directly be used as Safety Statement tree for OPERA.

It is recommended, at the end of the OPERA program, to re-assess the safety statements formulated in Table 4-1 and take account of the results gained in the program.

Because of the correspondence between research tasks in both the Belgian and Dutch research plans, collaboration between research teams of both programs on corresponding tasks will have clear added value.

5. Concluding remarks

The concept of safety (and feasibility) statements being developed by ONDRAF/NIRAS has been shown to be a useful tool to structure the safety argumentation needed to build a Safety (and Feasibility) Case. The Belgian RD&D Plan for geological waste disposal shows clearly how the Safety and Feasibility Statement tree can be used in this respect.

It has been shown that all OPERA tasks can readily be related to the safety statements of the four branches of the Belgian Safety and Feasibility Statement tree, related to the long-term safety.

Except for the work related to statements of the Feasibility branch of the Belgian Safety and Feasibility Statement tree, clear correspondences exist between the Belgian and Dutch research plans. Hence, collaboration between research teams of both programs on corresponding issues will have clear tasks value.

It is recommended, at the end of the OPERA program, to re-assess the safety statements formulated in Table 4-1 and take into account the results gained in the program.

5.1. Belgian branches and OPERA Safety Statement tree

For the present phase of the Dutch radioactive waste disposal program, the safety statements of the four branches of the current Belgian Safety and Feasibility Statement tree may directly be used as Safety Statement tree in OPERA.

Given collaboration on the further development of the Safety and Feasibility Statement tree, a 1-to-1 adoption of the Belgian safety statement branches will ensure at the same time consistency between both Safety (and Feasibility) Cases.

5.2. Possible further development of the Safety Statement concept

The table of contents of the Belgian RD&D Plan for geological waste disposal can also be compared to the components of a safety case, for example as described by the IAEA (2012; p.17, Figure 2-2):

- Components ‘Safety Case Context’, ‘Safety Strategy’ and ‘Management of Uncertainty’ correspond to Part 1 of the RD&D Plan;
- Component ‘System Description’ corresponds to Part 2 of the RD&D Plan;
- Component ‘Iteration and Design Optimization’ corresponds to Part 3 of the RD&D Plan;
- Components ‘Safety Assessment’, ‘Limits, Controls and Conditions’ and ‘Integration of Safety Arguments’ correspond to Parts 4 and 5 of the RD&D Plan.

Except for the Safety Case context, strategy and management components, all other components of the Safety Case structure correspond to (sub-)branches of the SFS tree. This suggests that statements regarding these issues might grow a fourth (Management) branch to the Safety and Feasibility Statement tree.

Again, collaboration between the Belgian and Dutch waste disposal programs on development of such a new branch to the Safety and Feasibility Statement tree would not only further the consistency between both resulting Safety (and Feasibility) Cases, but would also strengthen the management of both waste disposal programs.

6. References

(Grupa, 2014) Grupa, JB, Report on the safety assessment methodology, OPERA-PU-NRG2121, 2 April 2014.

(Haverkate, 2002) Haverkate BRW, Waste Management Strategy in The Netherlands, Part 2: Strategy Principles and Influencing Issues, contribution to the COMPAS Thematic Network (contract FIKW-CT-2001-20143), NRG 20881/02.50512/P, Petten, 22 November 2002.

(IAEA, 2012) The Safety Case and Safety Assessment for the Disposal of Radioactive Waste, Specific Safety Guide No. SSG-23, STI/PUB/1553, Vienna, September 2012.

(NEA, 2012) Integration Group for the Safety Case (IGSC), The Nature and Purpose of the Post-closure Safety Cases for Geological Repositories, Final draft version, NEA/RWM/IGSC(2012)5/PROV, Paris, 4 October 2012.

(Neeft, 2013) Neeft E, OPERA Update safety functions Research Plan PG-COV004, E-mail, 27 June 2013.

(ONDRAF/NIRAS, 2013) Research, Development and Demonstration (RD&D) Plan for the geological disposal of high-level and/or long-lived radioactive waste – State-of-the-art as of December 2012, NIROND TR 2013-12 E, December 2013.

(Smith, 2009a) Smith P, Dierckx A, Capouet M, van Geet M, Safety statements as a tool to incorporate geoscience in the safety and feasibility case, AMIGO-3, 2009, p.255-263.

(Smith, 2009b) Smith P, Cornélis B, Capouet M, Depaus C, Van Geet M, The Long-Term Safety Strategy for the Geological Disposal of Radioactive Waste, SFC1 level 4 report: second full draft NIROND-TR 2009-12 E, June 2009.

(Verhoef, 2011a) Verhoef E, Schröder TJ, Research Plan, OPERA-PG-COV004, COVRA N.V., June 2011.

(Verhoef, 2011b) Verhoef E, Neeft E, Grupa JB, Poley AD, Outline of a disposal concept in clay, OPERA-PG-COV008, COVRA N.V., July 2011.

(Verhoef, 2014) Verhoef E, Neeft E, Towards a safety strategy - Developing a long-term Dutch research programme into geological disposal of radioactive waste, OPERA-PG-COV014, COVRA N.V., 26 March 2014.

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