



Summaries awarded research proposals

OPERA-First call

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COVRA N.V.

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Introduction

In July 2011, OPERA started with a public invitation for submission of research proposals for tasks selected from the OPERA Research Plan. In this document, the research summaries of the awarded research proposals from the respective organisations and contact persons are listed.

Work package 1

In work package 1, Safety case context, six tasks are defined. In this work package, the principles and boundary conditions for the safety case are determined. In the first call, research proposals for five tasks could be submitted. Three research proposals have been awarded.

Title of Proposal 1: OPERA Waste Characteristics (OPCHAR)

- *Project Leader: Nuclear Research and consultancy Group (Thomas Schröder)*

Task 1.1.1: Definition of radionuclide inventory and matrix composition

Task 1.1.2: Alternative waste scenarios

Research summary

Accurate and complete data on the radionuclide inventory and matrix composition is of great relevance for performance assessment and thus for the overall OPERA program. Therefore, concerning OPERA's Task 1.1.1 the NRG project *OPCHAR* aims to compose a detailed definition of the total expected radioactive waste composition representative for the total radioactive waste composition foreseen to be disposed of in 2130. Based on the Dutch nuclear base scenario, a database will be set-up that integrates existing information, both in terms of the radionuclide inventory as well as of the matrix composition of all waste forms and fractions. These data will be accompanied by an estimation of the associated uncertainty ranges, and by a proper documentation of how these values were derived. While it is expected that the matrix composition of the HLW fraction will be accurately known, special attention is necessary for the characterization of the matrix of the large volumes of Category A - D ILW/LLW waste fractions. The information on the matrix composition forms an essential input for the work projected in Task 5.1.1 (Waste matrix corrosion) and Task 5.1.2 (ILW/LLW degradation) and must enable the assessment of interactions between the waste and the engineered barrier system and the host rock. Here, *OPCHAR* will define meaningful parameters on basis of the accompanying safety relevant processes and extract and compile these out of the existing data in a way that it can be serve as basis for WP5.1.

Changes in the presently adopted nuclear fuel cycle strategy in the Netherlands may impact both the quantities of generated radioactive waste as its composition: for the production of nuclear energy, several technological and logistic options are possible, i.e. reprocessing of waste, the utilisation of MOX-fuels in current reactors, the deployment of gas-cooled high temperature reactors (HTRs) or other 3rd or 4th generation technologies, including fast breeder reactors. Concerning OPERA's Task 1.1.2 *OPCHAR* sets out to quantify the consequences for several possible alternative nuclear fuel cycle scenarios in terms of waste amounts and compositions. A dedicated performance indicator will be elaborated that enables the direct (conservative) estimation of the impact of altered waste amounts on the long-term safety on basis of the calculated results of WP7.3. This allows OPERA to anticipate on the uncertainty on future nuclear energy use.

Title of Proposal 2: End repository Network Geared towards Actor Groups involvement and Effective Decisionmaking (ENGAGED)

- *Consortium Leader: Energy Research Centre of the Netherlands (Hamid Mozzafarian)*
- *Consortium Member 1: Nederlandse organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Adriaan Slob)*
- *Consortium Member 2: Nuclear Research and consultancy Group (Thomas Schröder)*
- *Subcontractor: Duneworks (Ruth Mourik)*
- *In order to minimize administrative burdens, Duneworks has been conceived as sub-contractors for accounting objectives.*

Task 1.2.1 Arena or stakeholder analysis

Task 1.2.2 Legal requirements

Task 1.2.4 Public & stakeholder involvement

Research summary

The management of radioactive waste is a topic with diverging perspectives among societal actors. Therefore there is a need for an analysis of potential (public) stakeholders and strategies to effectively engage these stakeholders in the design and implementation process of the geological disposal of radioactive waste. To address this complex socio-technical topic properly, in the *ENGAGED* project a broad cross-disciplinary team of experts will analyse a large range of aspects, with a focus on the specific needs within the context of the OPERA Safety Case. In the contribution to Task 1.2.1 and 1.2.4, *ENGAGED* will address these needs, using a methodology that takes into account future uncertainties about stakeholders and their engagement due to the very long time frame of the planning and realization of a geological disposal. An arena and stakeholder inventory will be made by identifying relevant decision making processes, and review (current) stakeholders' and their expectations regarding engagement in these processes under different scenarios. Furthermore, to address the influence of potential societal future changes, a scenario development methodology will be applied that enables the project to construct and elaborate imaginable futures and their uncertainties from which different societal contexts for the decision making can be sketched. The output of this analysis will be used to elaborate relevant determinants and propose strategies (guidelines) for stakeholder engagement that are both robust (scenario insensitive) and able to anticipate on different future scenarios. In the contribution of *ENGAGED* to Task 1.2.2, several aspects related to the regulatory context of the OPERA Safety Case will be addressed. Due to the lack of explicit legislation on radioactive waste disposal in the Netherlands, a high-level analysis of potential relevant requirements for the OPERA Safety Case will be performed, and the outcome will be discussed with stakeholders. A set of reference values that can be used to evaluate the outcomes of a performance assessment will be elaborated and substantiated by analysing the underlying arguments. Also here, the outcome will be discussed with different stakeholder to investigate whether if the used set of values and indicator answers public and stakeholders concerns. Altogether, the interdisciplinary *ENGAGED* project will generate better insight in key stakeholders, their vision on the safety disposal of radioactive waste and practical guidance and tools for their engagement that are relatively 'future-proof'.

Title of Proposal 3: Communication In Perspective (CIP)

- *Consortium Leader: Nuclear Research and consultancy Group (Thomas Schröder)*
- *Consortium Member: Sherpa & De Fries (Ellen Jelgersma)*

Task 1.3.1: Communication Safety Case results

Research summary

In the past decades, extensive research has been conducted in the areas of science communication, framing, risk perception and communicating nuclear and/or scientific controversies. The outcomes of these studies provide valuable information on how to communicate the outcomes of a Safety Case study. Based on this knowledge and experience, the project CIP (Communication in Perspective) will set-up a tailor-made communication strategy for the specific needs of the OPERA Safety Case. The project CIP will be conducted by an interdisciplinary team with members of the Dutch research organisation NRG and the Dutch communication consultant Sherpa & De Fries, complementing each other in their specific expertise areas, which guarantees the development of an effective communication strategy.

To avoid reinventing the wheel, CIP will closely scrutinize existing studies on communication of Safety Case results and related topics to provide a proper basis for the OPERA communication strategy to be developed. As the Latin proverb goes: 'A smart man learns from his mistakes; a wise man learns from the mistakes of others'. Other countries and organizations have faced similar challenges when it comes to communication, public resistance, and information gaps about radioactive waste disposal or comparable controversial topics. Obtaining a holistic view on the challenges, successes and pitfalls in public communication of a controversial topic will increase the chances of success of communicating Safety Case results. Examples of positive and negative experiences that CIP will take into account are those around the repositories in Forsmark (Sweden) or Onkalo (Finland), and the (attempted) geological storage of CO₂ in Barendrecht. By interviewing experts in the areas of (science) communication, framing and/or nuclear communications CIP will acquire vision, opinions and advice on specific issues related to the communication of the Safety Case results. These activities will form the basis of the communication strategy CIP will elaborate, addressing aspects like timeframes, strategic use of language, targeting the public, framing, use of new media, risks and chances etc. It will be accompanied by a detailed risk analysis that maps the strengths and weaknesses of the approach. Furthermore, CIP will develop a tailor-made 'Communication Toolbox'. The Toolbox is set-up/ designed in a way that it can serve as a guideline for all communication-related activities and provide a set of practical 'tools', complete with manuals. Finally, the current and ongoing media status of the OPERA programme and the issue of radioactive waste disposal will be monitored to measure the effects of the communication enabling to make adjustments where needed.

Work package 2

In work package 2, Safety Case, three tasks are defined. This work package constitutes the framework of the research within OPERA. In the first call, research proposals for two tasks could be submitted. One research proposal has been awarded.

Title of Proposal 1: Definition of the OPERA Safety Case for Radioactive waste disposal (OSCAR)

- Consortium Leader: Nuclear Research and consultancy Group (Jaap Hart)
- Consortium Member 1:
- Nederlandse organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Ton Wildenburg)
- Consortium Member 2: Envirollogic Inc (Paul Davis)
- Consortium Member 3:
- Gesellschaft für Anlagen und Reaktorsicherheit mbH (Dirk-Alexander Becker)

Task 2.1.1 Structure of the OPERA Safety Case

Task 2.1.2 Safety assessment methodology

Research summary

The proposed research will be carried out in interaction with the 'Safety Case Group', which is the group composed of national and international experts referred to in the Research Plan. The OSCAR project aims at 1) developing the structure of the OPERA Safety Case (OSC) and 2) defining the safety assessment framework.

A Safety Case is a collection of arguments in support of the long-term safety of the repository. It comprises the findings of a safety assessment and a statement of confidence in these findings and it should acknowledge the existence of areas of uncertainty or of any unresolved issues and should provide guidance for work to resolve these issues in future development stages. At the earliest stages, the Safety Case will be based on the existing body of generic science and engineering with more and more site-specific research results entering the Safety Case as the design progresses towards a specific repository design.

The OPERA Safety Case (OSC) will be a report presenting the generic Safety Case for the OPERA outline of a disposal in clay^A. We propose to develop the OSC structure by evaluating the scope, structure, and argumentation of existing international Safety Cases, Safety Reports, and licence applications. We will identify those elements of existing Safety Cases that are best suited for the Dutch program and the OSC. To this end we established a consortium of international partners whose expertise covers the existing and proposed repository Safety Cases. The results of this part of our research will be recorded in two documents, one on the OSC structure and one on a structured method of presenting complex safety arguments, a component of the OSC.

Key to the OSC is a safety assessment. The safety assessment framework defines the approach to quantifying the potential behaviour of a repository system. Some of the consortium partners have been at the cradle of the ISAM scheme, which is represented in the OPERA Research Plan, and which we propose to develop further to be used in OPERA. A component of the ISAM methodology is the identification and assessment of features, events and processes (FEPs) that may affect repository performance. This project will build on the ISAM methodology to develop a catalogue of OPERA-relevant FEPs. All consortium partners will contribute significantly to the OPERA FEP catalogue. The results of this part of our research will be recorded in two documents: the safety assessment methodology and the OPERA FEP catalogue.

^A OPERA-PG-COV008; available at www.covra.nl

Work package 3

In work package 3, Design of repository, two tasks are defined. The technical feasibility of a disposal facility at a depth of 500 meter in Boom Clay is evaluated in this work package. In the first call, a research proposal for one task, namely 3.1.1, could be submitted. One research proposal has been awarded.

Title of Proposal:

Numerical and reliability-based investigation into the principal feasibility of the reference design

- Consortium Leader: Delft University of Technology (Michael Hicks)
- Consortium Member 1:
 - Nederlandse organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Peter Fokker)
 - Consortium Member 2: Nuclear Research and consultancy Group (Jan Fokkens)

Research summary

The proposed research investigates the technical feasibility of a nuclear waste disposal facility at a depth of 500m in Boom Clay; that is, it investigates whether the repository can be constructed and whether it meets the safety requirements. The research will be based on 2D and 3D numerical studies of the reference Dutch design, as well as possible variations on that design; and it will involve analyses of the staged excavation and construction of the repository, as well as pre- and post-closure assessments of repository performance; for example, in terms of (long term) stability, deformations, stress changes, structural integrity and water/gas pathways. A significant feature of the research is that it will take account of the considerable uncertainties in the clay properties and behaviour through a reliability-based design approach.

The research deliverables are as follows:

- An assessment of whether, and under which conditions, the current OPERA disposal concept is feasible;
- An assessment of whether any modification to the design can enhance the safety performance against the occurrence of various failure mechanisms, such as excavation heading instability, unacceptable lining forces, excessive deformations and preferential water/gas pathways, and, if such modifications are deemed appropriate, what form these modifications should take;
- An assessment of the relative importance of parameters (e.g. material properties, material behaviour, design parameters) for the safety case, accounting for parameter uncertainty using a reliability-based design approach;
- The development and validation of a strategy to analyse repository performance with respect to safety, i.e. based on linking 2D and 3D numerical modelling with probability theory, which may be used for conducting more detailed feasibility studies in the future.

Work package 4

In work package 4, Geology and geohydrology, four tasks are defined. Possible evolutions of relevant geological and geohydrological properties in the host formation (Boom Clay) and aquifers surrounding the host formation are described. Also geological, geomechanical and geohydrological boundary conditions for the use of Boom Clay for hosting radioactive waste are described. In the first call, a research proposal for one task, namely 4.1.1, could be submitted. One research proposal has been awarded.

Title of Proposal:

Geological and geohydrological characterisation of the Boom Clay

- *Consortium Leader:*
- *Nederlandse organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Wim Westerhoff)*
- *Consortium Member: Nuclear Research and consultancy Group (Jacques Grupa)*
- *Subcontractor 1:*
- *StudieCentrum voor Kernenergie Centre d'étude de l'énergie nucléaire (Mieke De Craen)*
- *Subcontractor 2: University of Louvain (N. Vandenberghe)*
- *In order to minimize administrative burden, SCK CEN and University of Louvain have been conceived as sub-contractors for accounting objectives.*

Research summary

The geological record of the Boom clay and its overburden determines the current position within the geosphere, the interrelated (variation of) the geological and geohydrological properties, and also the geochemical and geomechanical properties. For the foreseen safety assessment within the OPERA program, it is required to strengthen the current geo(hydro)logical knowledge of the Boom clay by combining data and knowledge from earlier CORA studies with data and knowledge that has been acquired and interpreted since then (a.o. in Belgium).

The aim of this task is to give a generic description of the present geological and geohydrological characteristics and features in the geological environment enclosing the host-rock (Boom Clay) and of the host-rock itself, based on the geological record. The first stage of this task is an inventory of relevant literature references, existing map data, additional well data and recent seismic interpretations. Based on this data capture stage, we will determine the present regional scale geometry (depth and thickness maps) and past geodynamics of the Boom Clay and its hydrostratigraphical overburden. This modelling stage will be followed by both lithological and geohydrological characterisation of the Boom Clay and its overburden, resulting in an assessment of lithological variation, an assessment of geohydrological properties, pressure gradients and the potential of existing overpressures within the Boom Clay and within the hydrostratigraphical units of the overburden.

Discussion and review with Belgium institutes which have intensively studied the Boom Clay in Belgium, and knowledge dissemination, are part of the project proposed.

Work package 5

In work package 5, Geochemistry and geomechanics, eight tasks are defined. All aspects related to the natural evolution of the host rock Boom Clay and potential interactions of this host rock with the materials introduced to it are investigated. In the first call, a research proposal for one task, namely 5.2.1, could be submitted. One research proposal has been awarded.

Title of Proposal: Geochemical properties and long-term evolution of Boom Clay

- Consortium Leader:
- *Nederlandse organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Jasper Griffioen)*
- Consortium Member: *Utrecht University (Thilo Behrends)*
- Subcontractor 1:
- *StudieCentrum voor Kernenergie Centre d'étude de l'énergie nucléaire (Mieke De Craen)*
- Subcontractor 2: *University of Louvain (N. Vandenberghe)*
- *In order to minimize administrative burdens, SCK CEN and University of Louvain have been conceived as sub-contractors for accounting objectives.*

Research summary

Insight into the geochemical properties of the Boom Clay is needed in order to establish: 1. the reactivity towards radioisotopes, 2. the physical properties that depend on sediment-geochemical characteristics and 3. the evolution of the Boom Clay at the geological time scale. The associated aims of the activities proposed are: 1. to establish analytical data on the geochemical properties of the Boom Clay at a national scale, 2. to characterise the reactivity of the Boom Clay, 3. to characterise pore water in the boom Clay and groundwater in adjacent aquifer layers and 4. to set-up a prognosis on the long-term geochemical properties of the Boom Clay under anticipated future geological evolution of the Netherlands.

The approach consists of 1. a series of standard analyses on Dutch archive samples from the Boom Clay, 2. standard and non-standard analyses on newly collected samples, 3. sampling of wells having screens just above or below the Boom Clay and extracting pore water from fresh Boom Clay sediment samples and 4. desk and modelling study on long-term diagenesis of the Boom Clay. To collect new samples, setting a new drillings into the Boom Clay is a strongly preferred activity, otherwise samples will be collected in Belgium from quarries and the underground laboratory in Mol in addition to using a small series of new samples. The results of this project will primarily be national, statistical data about the geochemical properties of the Boom Clay in the Netherlands and the groundwater above and below this geological layer incl. insight into its lateral and vertical variability. Additionally, detailed insight into the redox and sorption properties will be delivered when new drillings will be made. Discussion with Belgium institutes which have intensively studied the Boom Clay, and knowledge dissemination are part of the project proposed.

Work package 6

In work package 6, Migration of radionuclides, nine tasks are defined. Relevant processes with which the migration of radionuclides can be described from the host formation (Boom Clay) to the geosphere (containing aquifers) and reaching the biosphere via the geosphere are investigated in this work package. In the first call, a research proposal for one task, namely 6.1.1, could be submitted. One research proposal has been awarded.

Title of Proposal: Effect of redox conditions on radionuclide sorption and speciation in Boom Clay

- *Consortium Leader: Utrecht University (Thilo Behrends)*
- *Subcontractor 1: StudieCentrum voor Kernenergie Centre d'étude de l'énergie nucléaire (Norbert Maes)*
- *Subcontractor 2: Swiss Federal Institute of Technology Zurich (Michael Sander)*
- *In order to minimize administrative burden, ETH and SCK•CEN have been conceived as sub-contractors for accounting objectives.*

Research summary

The overall goal of the project is to establish how the redox properties of Boom Clay affect the speciation and sorption of radionuclides. First, redox-active constituents of Boom Clay will be identified, the redox state of the Boom Clay matrix will be determined, and its electron donor and acceptor properties will be characterized. Part of the characterization will be achieved using state of the art electrochemical techniques. Second, the relationship between the redox properties of Boom Clay material and the redox speciation of selenium (Se) and uranium (U) will be determined. Third, the consequences of Se and U reduction for the sorption or/and solubility of these elements will be investigated. This will include the characterization of Se and U reduction products in Boom Clay with sophisticated techniques.

Using redox electrodes to determine redox potentials of solutions in contact with natural rocks often leads to very irreproducible and inaccurate measurements due to low current densities and mixed potentials at the redox electrode surface. Alternative techniques are required to overcome the shortcoming of conventional redox measurements^B. The application of advanced electrochemical techniques will allow us to characterize the redox state and the redox properties of Boom Clay with unprecedented fidelity. The research will advance the understanding of the relationship between measured redox characteristics of Boom Clay and the extent and rates of redox transformation of safety-relevant radionuclides in the Boom Clay matrix. Experimental data on the effects of redox transformations of radionuclides on their sorption and/or solubility will be obtained. The obtained mechanistic information on the effect of clay redox state on radionuclide speciation and sorption will provide the basis for adequately implementing redox dependent migration of radionuclides into safety assessments for repositories in Boom Clay.

^B Altmaier, M., Gaona, X., Fellhauer, D. & Buckau, G. Intercomparison of Redox Determination methods on Designed and Near-Natural Aqueous Systems. KIT Scientific Reports 7572 (2010).

Work package 7

In work package 7, Scenario development and Performance Assessment, ten tasks are defined. All methods and instruments that are required for the safety assessments in the Safety Case are defined, developed and documented. For these safety assessments, scenarios need to be identified and represented. In the first call, research proposals for six tasks could be submitted. One research proposal has been awarded.

Title of Proposal: OPERA Performance Assessment Project (OPAP-I)

- Consortium Leader: Nuclear Research and consultancy Group (Jacques Grupa)
- Consortium Member 1:
- Nederlandse organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Ton Wildenborg)
- Consortium Member 2:
- Gesellschaft für Anlagen und Reaktorsicherheit mbH (Dirk-Alexander Becker)
- Consortium Member 3:
- StudieCentrum voor Kernenergie Centre d'étude de l'énergie nucléaire (Jan Marivoet)

- Task 7.1.1 Scenario development
- Task 7.1.2 Scenario representation
- Task 7.2.1 PA model for radionuclide migration in Boom Clay
- Task 7.3.1 Safety and Performance Indicators calculation methodology
- Task 7.3.2 Methods for the uncertainty analysis
- Task 7.3.3 Safety assessment calculations

Research summary

The OPAP-I project will define and build the technical and methodological backbone that enables the safety assessment of the OPERA Safety Case. The OPAP-I project covers all six tasks of WP7 tendered in the 1st Call and forms a consistent package that efficiently addresses the links between all tasks. The project will be executed by an international, interdisciplinary consortium of NRG, TNO, SCK-CEN and GRS, which many years of experience will guarantee the successful application of state-of-the-art methodologies. The project is structured in a way that it enables the integration of the scientific results of all supporting OPERA WPs and translates these results into the technical format necessary to execute PA calculations. The main outcome of the OPAP-I project will be a list of safety and performance indicators and their accompanying probability distributions, calculated for all scenarios. This list enables the OPERA programme to make a statement on the long-term safety of a future disposal of radioactive waste in Boom Clay.

Tasks 7.1.1 and 7.1.2 will provide a list of relevant scenarios regarding normal and altered evolutions, both descriptive (Task 7.1.1) and as model concepts (Task 7.1.2). Task 7.2.1 will provide a computational code for the calculation of radionuclide migration in Boom Clay. OPAP I proposes to make use of the ORCHESTRA modelling framework because: (1) it is capable to represent correctly all current state-of-the-art sorption models; (2) its open, object-oriented structure can be expanded to cover potential model improvements and/or modifications that will be developed during OPERA (WP6.1); (3) ORCHESTRA allows to link complex process-oriented fundamental models with its simplified PA model representation in an efficient way; (4) unlike other modelling codes, it enables OPAP-I to exactly represent the modelling algorithms developed in WP6.1 rather than only approximate them. Task 7.3.1 will provide a list of meaningful safety and performance indicators that enables OPERA to analyse and communicate the extensive output of the PA calculation in Task 7.3.3. In Task 7.3.2, methods for the analysis of uncertainties and variability will be elaborated that enable the incorporation of uncertainty analysis in the PA calculation in Task 7.3.3. Besides the development and description of methods, in this task the

computational code necessary to perform these analyses will be prepared in a way that it can easily be integrated in the modelling framework developed in Task 7.2.4. Task 7.3.3 will prepare, execute and document the PA calculations, the central part of the OPERA safety assessment. The scenarios developed in Task 7.1.1 and 7.1.2 will be assessed. The calculations will include analyses of uncertainties and variability as defined in Task 7.3.2 and will express outcomes as safety and performers indicators, as proposed in Task 7.3.1.

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