Development of the NUMO Safety Case – Overview

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NUMO has started to develop a generic safety case that builds on both world-wide technical progress and also increased understanding of relevant geological conditions in Japan. Following the NUMO approach of developing tailored designs to siting environments, the safety case has been extended in key areas, including assessing extreme geological events during long-term repository evolution, developing design options for increased flexibility, widening discussion of both operational and post-closure safety, demonstration of retrieval techniques and scenario development based on risk-informed approaches. This paper provides an overview of the resulting NUMO "2015" safety case. More detailed discussion of key elements therein is provided in a series of associated papers at this Conference.

I. INTRODUCTION

I.A. Background

I.A.1. Evolution of geological disposal program in Japan

In 1999, the Second Progress Report on Research and Development for the Geological Disposal of HLW in Japan (hereinafter referred to as "H12 Report")[1] was published by the Japan Nuclear Cycle Development Institute (now the Japan Atomic Energy Agency – JAEA). This demonstrated the feasibility of safe and technically reliable geological disposal based on a generic study. On the basis of the H12 Report, the Act on Final Disposal of Specified Radioactive Waste ("the Final Disposal Act") came into force and the Nuclear Waste Management Organization of Japan (NUMO) was established in 2000. NUMO initiated the siting process by open solicitation of volunteer municipalities in 2002, with development of siting factors for selecting preliminary investigation areas (PIAs) [2] and a Repository Concepts Catalogue[3]. ILW (termed "TRU waste" in Japan) was also included in the inventory to be considered through an amendment of the Act in 2007. NUMO has been developing key technologies required for the safe implementation of the geological disposal project since its establishment and published a comprehensive technical review[4] in 2011.

Unfortunately, there was only one case where a mayor officially applied for the Literature Survey, but the application was withdrawn soon thereafter due to objections from local residents. After this case, in late 2007, an additional process where the Government can propose potential candidate sites was introduced, running in parallel to volunteering in order to advance the site selection. So far, however, no volunteer municipality has appeared and no candidate host rock type can be specified.

I.A.2. Progress after the Great East Japan Earthquake

The Great East Japan Earthquake and the Fukushima-Daiichi nuclear power plant accident in 2011 increased nation-wide concerns about the feasibility and reliability of safe geological disposal in Japan. Multidisciplinary working Groups were established by the Government (Ministry of Economy, Trade and Industry, "METI") to re-evaluate the technical feasibility of geological disposal and re-think the implementation process. The Working Groups concluded that[5,6]…

- Potentially favourable geological environments exist and selecting them is feasible, considering the latest geoscientific knowledge.
- Promoting geological disposal with more explicit consideration of reversibility and retrievability is reasonable.
- Periodic re-evaluation of safety based on the latest knowledge and communicating this to the general public are required.

The Strategic Energy Plan[7] developed by the Cabinet in April 2014 includes a new policy under which the Government will promote site-selection by suggesting locations that are scientifically considered to be more suitable. As a result of this Government commitment, the siting process deadlock is expected to be broken.

Regarding the wastes arising from the decommissioning of the Fukushima-Daiichi nuclear power plant unit 1-4, related activities including R&Ds are ongoing in accordance with the Mid-and-Long-Term Roadmap[8] developed by the Government and the other related organizations. However the such wastes have not

been subjected for geological disposal program prescribed in the Final Disposal Act currently, new management scheme for them will be developed harmonizing with the future progress of the decommissioning works and characterization of the wastes.

I.B. Purpose of Developing the NUMO Safety Case

Public skepticism of the feasibility and safety of geological disposal has been amplified after the natural and nuclear disasters that hit Japan in 2011. In this context, suggesting scientifically suitable locations by the Government introduces a new and highly sensitive stage into the siting process, which will certainly need a more convincing explanation of the safety of geological disposal. Taking such changes in boundary conditions into account, it is important at this time for NUMO to integrate required technologies, including the latest R&D achievements, in order to show the feasibility and safety of geological disposal in Japan. Thus NUMO has started to develop a generic safety case (hereinafter referred to as "NUMO 2015 Safety Case") with reference to the concept of "safety case" as established by OECD/NEA[9] and IAEA[10].

NUMO expects to achieve the following benefits through development of this Safety Case:

- Comprehensive presentation of technical evidence to support the feasibility and safety of geological disposal, which will encourage stakeholder support of implementation
- Providing technical information to answer questions or concerns regarding safety, arising from various stakeholders
- Guidance for planning future R&D
- Providing the basic structure of a Safety Case that would be applicable to any expected selected site
- Technology transfer to the next generation and general human resource development for NUMO and other supporting R&D organizations

This paper will provide only an overview of the NUMO 2015 Safety Case. More detailed discussion of key elements is presented in a series of associated papers[11,12,13] presented at this Conference.

II. BASIC STRATEGY FOR DEVELOPING A SAFETY CASE

II. A. Basic Policies for Developing the NUMO Safety Case

Considering the current status of the Japanese disposal program outlined above, NUMO is developing a Safety Case while taking the following into account:

- State-of-the-art scientific knowledge and technical development
- A range of repository concepts tailored to provide siting environment flexibility
- Realistic modeling on the basis of expected geological characteristics in a Japanese site
- Trial design and safety assessment to demonstrate feasibility and long-term safety of a geological disposal system, although site and host rock type are not yet specified
- Presenting pre-closure safety with consideration of issues arising after the Fukushima nuclear accident
- Demonstrating engineering feasibility of waste emplacement, reversal and retrieval, which were highlighted as an important issue by a METI Working Group
- Developing an effective communication strategy
- Developing a comprehensive management strategy for all stages of the disposal program, to assure reliability of the long-term disposal program.

II. B. Boundary Conditions and Basic Premises

While making the safety case, current constraints on the Japanese geological disposal program have to be considered, including:

1) Any site and geological environment can be proposed, excluding only certain areas defined by the siting factors for initial screening, e.g. within a 15 km radius around a volcanic canter or transected by active faults.
2) The schedule of the disposal program and capacity of the facility as defined by "the Disposal Plan for Final Disposal of Specified Radioactive Waste" in "the Final Disposal Act", which should be revised every five years. The last "Disposal Plan" was published in 2008. The next Plan is currently under review, but the date of its release has not been decided yet.
3) Relevant safety and environmental regulations have not been defined yet. Detail technical requirements for geological disposal and the timeframe of evaluating post-closure safety, e.g. evaluation period, safety standard, design requirements, etc. should be defined in the future.

For developing the NUMO 2015 Safety Case, we thus set the basic premises of the disposal concept considering international norms and the "Disposal Plan" published in 2008.

- A multi-barrier system consisting of engineered barriers and the geological barrier
- Mined geological repository
- Required capacity of the facility:
  - Total HLW: more than 40,000 canisters of vitrified waste
  - Total TRU waste: more than 19,000 m^3

Safety strategies for the current Safety Case have thus been developed considering basic policies, boundary conditions and the premises mentioned above.

II.C. Safety Strategies

II.C.1. Siting Strategy

NUMO will identify a suitable repository site in three stages: literature survey (LS), preliminary investigation (PI) and detailed investigation (DI), as specified in the Disposal Act. A logical, comprehensive and progressive basis for the siting process has been developed, which involves explicit exclusion siting factors that are set on the basis of geological attributes associated with the dynamic tectonic setting in Japan.

In the NUMO 2015 Safety Case, feasibility of selecting a suitable repository site in Japan, where the key safety functions of the host geological environment will persist for a long period of time, is assessed. Fundamental information and basic concepts for staged repository site selection will be presented, including safety functions and factors affecting safety. Advanced methodologies for precluding the potential impacts of natural disruptive events and processes will be shown. Key concepts, technical knowledge bases, and basic methodology for geosynthesis of relevant information into representative 4D models of site evolution also will be documented. The demonstration of feasibility of safe geological disposal will also include an illustrative repository design and safety assessment on the basis of best understanding of potentially suitable geological environments.

II.C.2. Design Strategy

NUMO will design facilities which fulfill the required safety functions on the basis of a Site Descriptive Model (SDM), considering expected future regulations and constraints set by environmental impacts on the site. In the later siting stages, NUMO will:

- Develop designs in a stepwise manner based on the SDM developed at each stage, which will be used to judge feasibility of implementation.
- Develop technologies of construction, operation and closure on the basis of specific repository designs and SDMs, which become more detailed as the project progresses.
- Verify and validate such technologies through demonstration tests to assure that they are mature prior to initiating construction and operation.

In the NUMO 2015 Safety Case, since the host rock has not been identified yet, alternative repository concepts will be presented, which are applicable for the wide range of potential geological conditions encountered in Japan. The designs will fulfill the safety functions required to isolate and contain radioactive nuclides in any selected geological formation. The methodology will be demonstrated by carrying out a full repository design study, tailored to an illustrative SDM in this Safety Case. The engineering feasibility of construction, operation and closure of the repository will be evaluated based on techniques demonstrated in domestic or overseas underground laboratories and related R&D facilities.

II.C.3. Safety Assessment Strategy

NUMO will assess pre- and post- closure safety of the designed repository within the context set by a specific SDM. In the siting stages, this will proceed in an iterative manner and the resulting output will support decisions made at the end of each stage from the perspective on safety. The required safety assessment technology for scenario development, modeling, database development, interpretation, etc. will be maintained at the state-of-the-art.

In the NUMO 2015 Safety Case, for pre-closure safety, feasibility of radiological and non-radiological protection for local residents and workers will be demonstrated, based on the repository design and defined procedures of construction, operation and closure. For post-closure safety, procedures and methodologies to assess long-term safety will be demonstrated for the illustrative geological disposal system and realistic site geological conditions as defined by the illustrative SDM. Since safety standards for Japan have not, as yet, been defined, the results of safety assessment study will be compared to international standards.

II.C.4. Management Strategy

NUMO presented the basic concepts of an overall management strategy in the "2010" technical report[4]. NUMO will expand these concepts, including:

- Risk Management; defining appropriate measures to respond to uncertainties, e.g. potential future technical and/or social developments which might affect the advancing disposal project.
- Management of the R&D Program; developing, implementing and updating in regular intervals R&D plans to deal with issues identified by the developing safety case.
- Requirement Management System (NUMO-RMS)[14]; managing legal and technical requirements and also evidence to support conformity with them, along with associated procedures for change control.
- Quality Management; ensuring a high standard of technical activities and their output, e.g. site surveying, engineering and safety assessment.
- Knowledge Management; managing and transferring a huge knowledge base that continually expands as a result of ongoing R&D
- Strategy on managing human resources
- Strategy on communication with stakeholders

The NUMO 2015 Safety Case will be developed with the following strategy:

- Management of uncertainties; identifying uncertainties and safety related issues to guide future R&D
- Quality Management; ensuring technical reliability of this safety case by appropriate structures, e.g. peer review by outside experts, technical support by related R&D organizations, etc.
- Knowledge Management; the knowledge base acquired through developing the NUMO 2015 Safety Case is linked to the NUMO-RMS to ensure transparency, traceability and ease of reuse / updating.
- Human Resources; commitment to developing skills and accumulating knowledge individually and organizationally, e.g. systematic training, information and human resource exchange with outside experts, etc.
- Communication; the NUMO Safety Case will be provide the technical basis of communication with stakeholders.

III. GEOLOGICAL CHARACTERISATION AND SYNTHESIS

On the basis of the siting strategy, geological characterization and synthesis will be described in the NUMO 2015 Safety Case. Although this Safety Case is still under development, expected key statements would be (see also associated paper[11]):

- Basic concepts required to select a site where the key safety functions (isolation and containment) of the host geological environment will persist for a long period of time are shown.
- A methodology is presented for the staged identification of a suitable repository site, where the key safety functions of the host geological environment can be assured to be adequate and significant impacts of natural disruptive events/processes can be precluded.
- Demonstration that a suitable repository site can be sufficiently described via geosynthesis, showing advanced methodologies for characterizing 4D evolution on the basis of current geoscientific knowledge.
- Illustrative SDMs for subsequent trial repository design and safety assessment are developed. The models are shown to be reasonably representative of the types of potential and realistic host geological environments to be expected, on the basis of field data obtained at the Horonobe and Mizunami Underground Research Laboratories and current best understanding of the geological environment in Japan.

Setting of the 'realistic' geological models compared with the more conservative approach used in the H12 Report is one of the important advances in the NUMO 2015 Safety Case.

IV. DESIGN AND ENGINEERING TECHNOLOGY

Expected key statements for design and engineering technology in the NUMO 2015 Safety Case would be (see also associated paper[12]):

- Alternative repository concepts allow flexibility in tailoring to the wide-range of geological environments expected.
- The design methodology fulfills requirements in terms of the safety functions providing isolation and containment of radioactive waste. The methodology is demonstrated by carrying out a full repository design study, tailored to the illustrative SDM used in the NUMO 2015 Safety Case.
- The robustness of the EBS is evaluated based on state-of–the-art materials science, with consideration of the wide range of geological environments that may need to be considered in the future. The potential for EBS optimization is also assessed.
- The design procedure for tailoring to the typical layout-determining features of host rocks in Japan, such as fractures and faults, is also demonstrated.
- Engineering feasibility and quality assurance of technology for construction, operation and closure of the repository are described on the basis of experience in relevant facilities.
- Overall strategy of environmental protection and monitoring and the methodology required are described.
- State-of-the-art technology for retrieving waste is described and its engineering feasibility is shown.

Assessment of EBS optimization, demonstration of design procedure for tailoring to fractures and faults, engineering feasibility of retrievability are advances, covering topics which were not described in the H12 Report.

V. SAFETY ASSESSMENT

Key statements for pre-closure safety assessment in the NUMO 2015 Safety Case are:

- Based on the repository design and procedures of construction, operation and closure, the radiological and conventional protection of local residents and workers are assured.
- Radiological protection for expected exposure of residents from waste handling in surface facilities assures doses considerably lower than the tentative dose criterion considered.
- For accident situations, such as drops or fires, the thermal and mechanical durability of waste packages or metal overpacks has been confirmed by numerical calculations and full-scale demonstrations. For the examined scenarios, there would be no radiological risk to residents.

- For conventional safety, potential issues and countermeasures for repository construction, operation and closure are assessed on the basis of experience in similar nuclear facilities and tunnel excavations.

Key statements for post-closure safety assessment in the NUMO 2015 Safety Case are (see the associated paper[13]):

- Safety assessment is based on understanding of the geological environment and repository design.
- A risk informed approach is introduced for the safety assessment. The scenarios to be considered in the safety assessment are classified into base scenario, less-likely scenarios, very unlikely scenarios and human intrusion scenarios. Each scenario is developed with consideration of its probability of occurrence during the evaluation period.
- Scenarios for safety assessment will be developed using both FEP-based and safety function-based approaches.
- Since safety standard for Japan have not, as yet, been defined, the results of safety assessment are compared to international standards, e.g. IAEA[15,16], ICRP[17,18], and the safety standard for LLW[19] disposal in Japan.
- By including multiple arguments, such as comparison with overseas dose evaluations, natural analogs, etc., confidence in case for the safety of the geological disposal is established.

Pre-closure safety assessment was not described in the H12 Report. The risk informed approach is an important advance since the H12 Report.

VI. DOCUMENTATION AND COMMUNICATION

VI.A. Documents for Geological Disposal Experts

One of the important roles of developing a safety case is to answer questions and/or concerns on safety issues from a wide range of stakeholders. For promoting communication with various stakeholders, the documentation structure of the NUMO 2015 Safety Case is as illustrated in Fig .1.

VI.A.1. Main Report of NUMO Safety Case

The main Report of NUMO Safety Case will be produced as a technical report that concisely presents the case for the feasibility of safe geological disposal, reflecting the latest knowledge and state-of-the-art technology. The Main Report is planned to be about 200 pages long, with the target audience being experts in the field of disposal technology.

VI.A.2. Supporting Reports of NUMO Safety Case

Supporting Reports will supply the detailed technical description that support the Main Report, e.g. technical basis for parameters used in the safety assessment, detailed results of assessment model calculations, FEP database, etc. Experts/specialists in the appropriate technical field, e.g. geological characterization, facility design and safety assessment, represent the target audience. Contents of Supporting Reports are now under development.

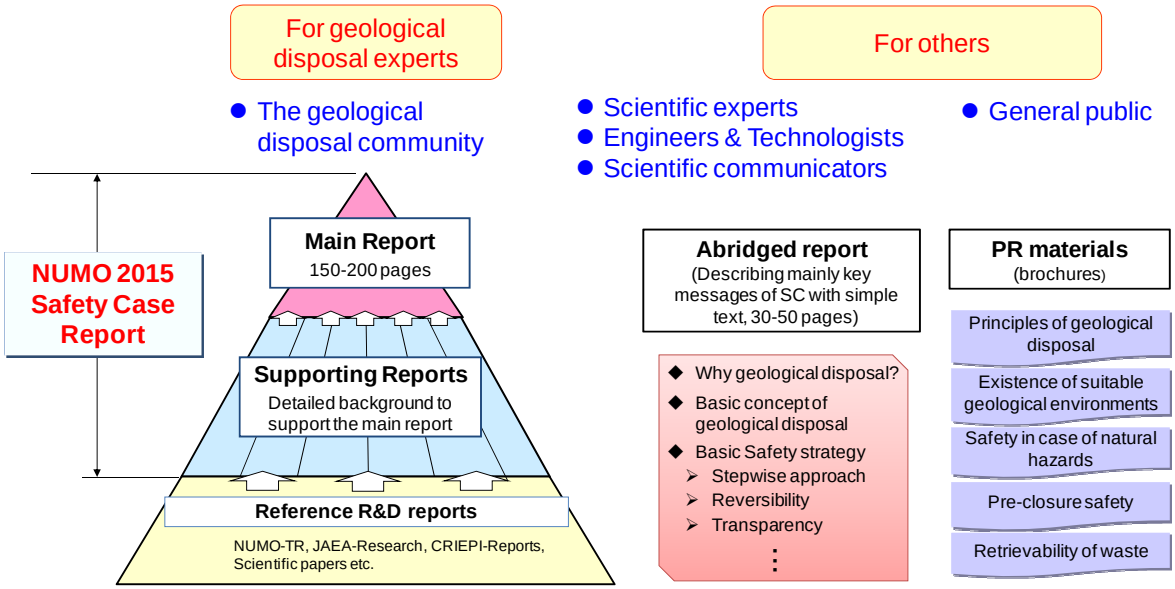

Fig. 1. Structure of the NUMO 2015 Safety Case

To ensure the reliability of the Safety Case, the Main Report and the Supporting Reports will fulfill all expected technical requirements of the geological disposal community.

The reference reports, typically project documentation of supporting research institutes and/or general scientific papers, will be organized in a traceable format and saved as an archive. In addition, in order for all interested parties to be able to access safety case information efficiently and easily, a web-based viewer system linked to NUMO's web-site will be developed. This will provide public access to the Main Report, Supporting Reports and key references.

VI.B. Documents for Others

For interested non-experts in the field of geological disposal, user-friendly descriptive materials will be developed, which present the key arguments supporting the feasibility of safe geological disposal based on the Main Report and Supporting Reports. General public, governmental staff, politicians, general scientists, etc. are all grouped together here. Thus the range of non-experts is quite wide and it is necessary to prepare material that provides a spectrum of communication material tailored to their needs.

VI.B.1.The Abridged Reports

An important audience comprises the members of the METI Working Groups, mentioned in section I, which includes geological disposal experts and also experts of social sciences and general technologists. Discussions and output from such groups are generally opened to the public through a range of communication media. Therefore, it is very important to have these members understand the key issues associated with demonstrating the technical reliability of the geological disposal.

A knowledge base for social scientists, general technologists and/or science communicators, who could act as mediators between geological disposal experts and the general public, will be prepared to build stakeholder trust in the reliability of the geological disposal program. Documentation, with clear and easily understood text, will be prepared to explain the philosophy and safety strategy, which are unique to geological disposal, e.g. reducing uncertainty by adaptive phased implementation, democratic decision making which includes measures to capture the opinions of stakeholders, flexible response to the future developments in science, reversibility and retrievability, etc.

VI.B.2. PR Materials

For the general public, conventional communication materials such as brochures will be prepared, which introduce topics of high general public interest, e.g. presence of a suitable geological environment for geological disposal in Japan despite its location on the junction of four major tectonic plates, in tectonically active circum-Pacific Belt, safety in case of large earthquakes, assured containment of radioactivity during the operational phase, etc. To date, NUMO has held symposia to introduce the concept and project overview of geological disposal and respond to participants' questions at over than 30 large cities in Japan.

Special media and tailored content for such materials will be developed to present and explain the messages of the Main Report.

VI.C. Schedule to Develop the NUMO 2015 Safety Case

Figure.2 shows the outline schedule to develop the NUMO 2015 Safety Case. The first draft of the Main

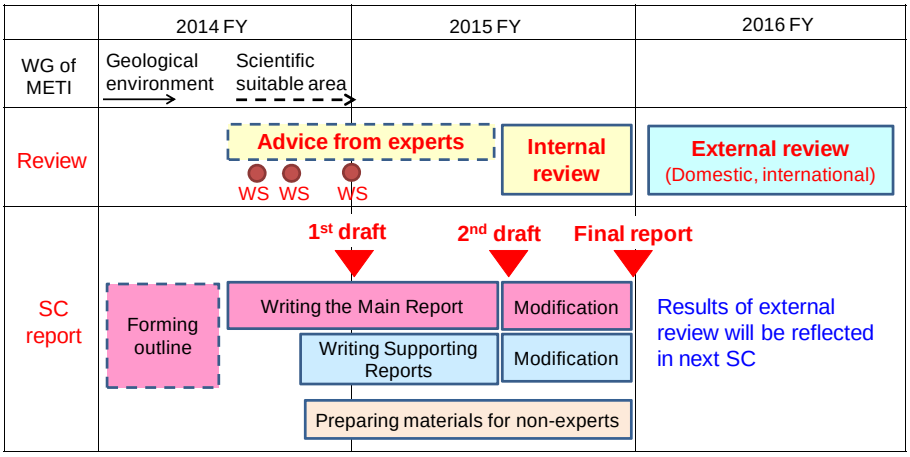

Fig. 2. Outline schedule of the NUMO 2015 Safety Case

Report, describing the framework of safety case and main assessment results will be produced by the end of March 2015. A second draft of the Main Report and drafts of all key Supporting Reports are planned to be completed by October 2015 and reviewed internally by experts in an Advisory Group organized by NUMO. After modification based on such review, the NUMO 2015 Safety Case report will be finalized by the end of March 2016, which is the end of 2015 fiscal year in Japan. The quality of Safety Case report will be enhanced in an iterative manner, utilizing not only the Advisory Group but also general information exchange with specialists in partner organizations and continuous/ad hoc discussions with experts on critical topics.

The NUMO 2015 Safety Case Report is planned to be published and reviewed externally by both domestic and overseas organizations in 2016 to obtain required objective evaluation. The Safety Case will then be revised when sites are specified and the Literature Survey stage is initiated.

VII. CONCLUSIONS

This paper describes the outline of the NUMO 2015 Safety Case, which is presently under development. Basic strategy, expected key statements, advances compared with the H12 Report and structure of documentation are presented. This safety case is the first developed in Japan for HLW since the H12 Report. It is important to recognize that an important feature of NUMO 2015 Safety Case is a focus on 'realistic' geological conditions, representing the existence of fractures and faults within both design and safety assessment, based on the latest understanding of the type of geological environments that might need to be considered in Japan. We expect that the 2015 Safety Case will provide further support on the reliability of the NUMO geological disposal program and form a significant step on the pathway towards repository implementation.

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