U.S. Nuclear Waste Technical Review Board

Geologic Repositories: Performance Monitoring and Retrievability of Emplaced High-Level Radioactive Waste and Spent Nuclear Fuel

May 2018

A Report to the U.S. Congress and the Secretary of Energy

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Geologic Repositories: Performance Monitoring and Retrievability of Emplaced High-Level Radioactive Waste and Spent Nuclear Fuel

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UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
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May 28, 2018

The Honorable Paul D. Ryan
Speaker
United States House of Representatives
Washington, DC 20515

The Honorable Orrin G. Hatch
President Pro Tempore
United States Senate
Washington, DC 20510

The Honorable Rick Perry
Secretary
U.S. Department of Energy
Washington, DC 20585

Dear Speaker Ryan, Senator Hatch, and Secretary Perry:

Congress created the U.S. Nuclear Waste Technical Review Board in the 1987 Nuclear Waste Policy Amendments Act (NWPAA) (Public Law 100-203) to evaluate the technical and scientific validity of activities undertaken by the Secretary of Energy to implement the Nuclear Waste Policy Act and to advise Congress and the Secretary on technical issues related to nuclear waste management. In accordance with this mandate, on March 27, 2018, the Board met to hear from experts from several international repository programs on (i) operational and performance confirmation monitoring of a geologic repository for high-level radioactive waste (HLW) and spent nuclear fuel (SNF) and (ii) retrievability of emplaced HLW and SNF. In this letter report, the Board presents its observations from that meeting.

Background

Worldwide, there is strong consensus on the value of a stepwise approach to implementing a geologic repository program where the implementer and regulator periodically assess whether the proposed disposal concept and repository design can meet health, safety, and environmental requirements. Two actions are integral to the success of such an approach: first, successful monitoring of the repository, and second, retaining the option to retrieve the emplaced waste, if necessary. In the United States, the Nuclear Regulatory Commission has promulgated requirements related to HLW and SNF retrievability, as well as requirements for "performance confirmation" monitoring to confirm that subsurface conditions are within licensing limits and that natural and engineered barriers are functioning as intended.

At the Board meeting, the Board heard the views of experts from several countries with national repository programs on challenges intrinsic to both monitoring and waste retrieval. The meeting participants were asked to address three overarching questions:

1. What are the requirements for undertaking operational and performance confirmation monitoring and retrievability?
2. What are the potential technical and institutional challenges involved in carrying out those activities?
3. What lessons can be learned from international programs that can be applied to the U.S. geologic repository program?

Board Observations

Based on the presentations and discussions at the meeting, the Board offers the following observations related to the implementation and monitoring of geologic repositories and the retrievability of emplaced HLW and SNF:

- *Retrievability is an important consideration in the initial repository design, adding only a small increment to the cost of repository development but offering substantial cost reduction if retrieval is determined to be necessary.*
- *Monitoring to assess operations and to support decisions related to repository operations or waste retrieval is also an integral part of repository development.*
- *It is essential that the monitoring objectives and limitations are understood, the indicators that will signal the need for a modified path or retrieval are transparent, and the collected data are broadly accessible to enhance public trust and for use in performance confirmation modeling by the implementer and other stakeholders.*
- *Underground research laboratories and repository pilot facilities improve the technical basis and confidence in the future success of monitoring technologies and potential retrieval, and can serve as demonstration sites to build public acceptance.*
- *Long-term research, development, and demonstration of monitoring and sensor technologies are needed to address current technology limitations.*
- *A stepwise approach to repository program implementation and decision making is important because it provides opportunities to reassess decisions and modify future plans.*
- *Measures are needed to facilitate knowledge transfer to future generations so that expertise is available to access and interpret monitoring data.*

The Board hopes that Congress and the Secretary will find the information in this report useful.

Sincerely,

/s/

Jean M. Bahr
Chair

U.S. Nuclear Waste Technical Review Board

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Introduction

The U.S. Nuclear Waste Technical Review Board (Board)[1] held its 2018 Spring Meeting in Washington, D.C., on March 27, 2018, to review information from several international repository programs related to (i) operational and performance confirmation monitoring of a geologic repository for high-level radioactive waste (HLW) and spent nuclear fuel (SNF) and (ii) retrievability of emplaced HLW and SNF. This report presents a summary of the meeting and the Board's observations related to repository monitoring and retrievability of emplaced HLW and SNF.

Background

Worldwide, a strong consensus has emerged about the value of a stepwise or phased approach to implementing a geologic repository program for the disposal of HLW and SNF (NEA 2001, 2004, 2011, 2012). Under such an approach, the implementer as well as the regulator periodically assess whether the proposed disposal concept and associated repository design can meet health, safety, and environmental standards and rules. Around the world, many national repository programs consider such a process important because it preserves the ability of future generations to modify decisions that were taken during the implementation of the repository program. Some of the decisions that may be taken during the implementation of a repository program are shown in Figure 1. In deciding whether to proceed with the initial path or to take a modified path, decision makers can take into account information that was obtained during the implementation process.

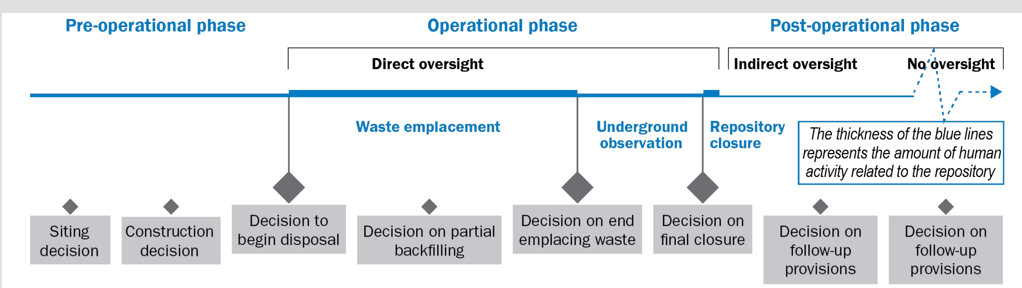

Figure 1. Phases in the implementation of a geologic repository program and examples of decisions associated with implementation (NEA 2012)

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1 The U.S. Nuclear Waste Technical Review Board was created by Congress in the 1987 Nuclear Waste Policy Amendments Act (Public Law 100-203) and charged with evaluating the technical and scientific validity of activities undertaken by the Secretary of Energy to manage and dispose of HLW and SNF. The Board reports its findings and recommendations to Congress and the Secretary of Energy.

Two actions are integral to the success of a stepwise implementation of a repository program. One is successful monitoring of the repository (either during pre-closure or both pre-and post-closure), including its engineered components and natural barriers. The International Atomic Energy Agency (IAEA) defined monitoring as the "continuous or periodic observations and measurements of engineering, environmental or radiological parameters, to help evaluate the behavior of components of the repository system, or the impacts of the repository and its operation on the environment" (IAEA 2001). This monitoring is the primary method used to gather the data required to assess repository performance during and after operations and to make decisions related to continuing repository development and operations as planned or modifying them. The other critical action is retaining the option to retrieve the emplaced waste in the event retrieval is determined to be necessary. Maintaining the retrievability option is dependent on, among other things, the geology of the host formation and the engineered barrier concepts being used. As illustrated in Figure 2, retrievability becomes more difficult and more costly as repository development progresses and disposal cells are backfilled and/or sealed.

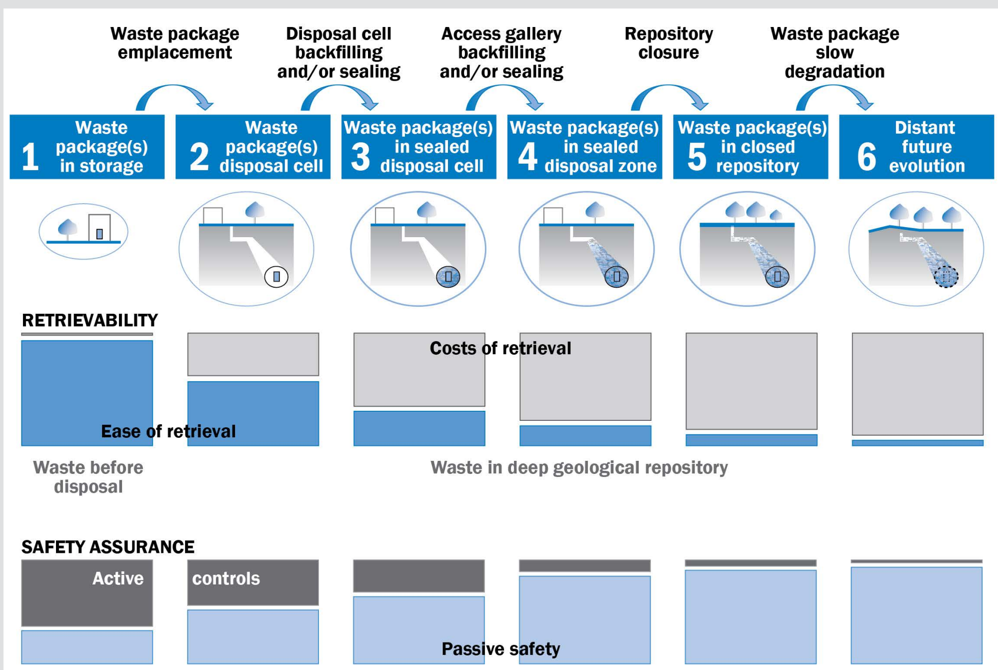

Figure 2. Life cycle stages of radioactive waste, illustrating the changing degree of retrievability, costs of retrieval, and reliance on passive vs. active controls for safety in a deep geologic repository (NEA 2012)

In 2007, the Nuclear Energy Agency (NEA) initiated a survey of repository programs in different countries with respect to retrievability of wastes and reversibility of decisions.[2] The study showed that retrievability and/or reversibility are important aspects of policy or legislation in many countries, but national policies and legislations differ because social, legal, and technical environments vary from country to country and these environments change as time passes (NEA 2011, 2012). Some factors and aspects of HLW and SNF disposal were found to be common to many international programs. First, there is general agreement that waste should be emplaced in a final repository only when there are policy and regulatory decisions ensuring that the "waste" is actually waste and not a potential resource. By definition, "disposal" implies no intention to retrieve, i.e., waste retrieval is a contingency option. Second, a repository must be licensed as safe without requiring or relying on the waste being retrievable after closure. For this reason, passive safety must be demonstrated convincingly. The NEA found that some national programs require that a geologic repository concept include provisions for retrievability before closure for operational safety reasons, but did not find any national program that requires maintaining the option to retrieve the waste after repository closure (NEA 2011, 2012).

In the United States, the Nuclear Waste Policy Act of 1982 requires that "any repository…shall be designed and constructed to permit the retrieval of any spent nuclear fuel placed in such repository, during an appropriate period of operation of the facility, for any reason pertaining to the public health and safety, or the environment, or for the purpose of permitting the recovery of the economically valuable contents of such spent fuel." The Nuclear Regulatory Commission (NRC) has promulgated requirements pertaining to HLW and SNF retrievability. It also has promulgated requirements for pre-closure monitoring to confirm that subsurface conditions are within the limits assumed in the licensing review and that natural and engineered barriers are functioning as intended and anticipated. Monitoring is part of the "performance confirmation" program required by the NRC. The NRC

[2] The NEA states that "reversibility describes the ability in principle to reverse or reconsider decisions taken during the progressive implementation of a disposal system" (NEA 2011). According to the NEA, in the early stages of a waste disposal program, reversal of a decision regarding site selection or the adoption of a particular design option may be considered (NEA 2004). At later stages during construction and operation, or following waste emplacement, reversal may involve modifying one or more components of the facility or even retrieval of waste packages for some period of time.

monitoring and retrievability requirements are given in Title 10 of the Code of Federal Regulations (10 CFR), Parts 60 and 63.[3]

As examples of information that was submitted to the NRC to satisfy the requirements of 10 CFR Part 63, the Department of Energy (DOE) license application for the Yucca Mountain repository described the DOE plans for waste retrieval and the DOE performance confirmation program during the pre-closure period (DOE 2008). DOE identified 20 performance confirmation activities, including seepage monitoring and waste package monitoring. Seepage monitoring would evaluate the spatial and temporal distribution of seepage flux into the repository under ambient and thermally perturbed conditions. It also would analyze the chemistry of any collected waters. Waste package monitoring would include remote monitoring of external corrosion of waste packages.

Board Meeting Objectives and Agenda

The Board meeting was organized to solicit the views of experts from several countries with national repository programs and was focused on the challenges intrinsic to both monitoring and waste retrieval. The meeting participants were asked to address three overarching questions:

1. What are the requirements for undertaking operational and performance confirmation monitoring and retrievability?
2. What are the potential technical and institutional challenges involved in carrying out those activities?
3. What lessons can be learned from international programs that can be applied to a U.S. geologic repository program?

The Board invited seven speakers to address those questions. Five speakers from European countries provided a broad perspective on national policies and approaches to repository monitoring and retrievability of emplaced waste. The first to give a presentation was Dr. Claudio Pescatore, formerly with the NEA and currently an independent consultant affiliated with Linnaeus University in Sweden. Dr. Pescatore discussed work the NEA has done over the past twenty years on retrievability of wastes and reversibility of decisions. Dr. Patrick Landais of Andra, the French national radioactive waste management agency, followed with a presentation on the governance and technical approach to retrievability and reversibility in France. Then, Dr. Piet

[3] 10 CFR Part 60—Disposal of High-Level Radioactive Wastes in Geologic Repositories; 10 CFR Part 63—Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada.

Zuidema, formerly with the National Cooperative for the Disposal of Radioactive Waste (Nagra), the implementer of the radioactive waste geologic disposal program in Switzerland, described the role of monitoring in the Swiss geologic disposal program. Dr. Maarten van Geet of ONDRAF/NIRAS, the Belgian Agency for Radioactive Waste and Enriched Fissile Materials, followed with a presentation on research, development, and design work being conducted for monitoring and retrieving waste in a geologic disposal facility in Belgium. Dr. Horst Geckeis (Karlsruhe Institute of Technology, Germany) then made a presentation on the experience of and the challenges involved in retrieving waste from the Asse salt mine in Germany, which was used for disposal of low- and intermediate-level radioactive waste.

Two technical specialists gave presentations on the state-of-the-art in sensors and technologies for monitoring. Professor Dani Or (Swiss Federal Institute of Technology Zurich, Switzerland) summarized the state-of-the-art of sensors and technologies for monitoring subsurface water seepage in a geologic repository. Dr. Raul Rebak (G.E. Global Research) gave a presentation on the state-of-the-art of sensors and technologies for monitoring waste package corrosion in a geologic repository.

A panel session followed the presentations and the meeting participants discussed various aspects of repository monitoring and waste retrievability. There were no presentations by representatives from the DOE, but several DOE staff members and members of the public attended the meeting.

The meeting agenda and list of speakers are included in Appendix A. The presentations, the transcript of the proceedings, and an archived webcast of the meeting are available on the Board's Past and Public Meetings webpage (http://www.nwtrb.gov/meetings/past-meetings).

Board Observations

Based on the presentations given at the meeting, the Board offers the following observations related to the implementation and monitoring of geologic repositories and the retrievability of emplaced HLW and SNF:

- Retrievability is an important consideration in the initial repository design, adding only a small increment to the cost of repository development but offering substantial cost reduction if retrieval is determined to be necessary.
- Monitoring to assess operations and to support decisions related to repository operations or waste retrieval is also an integral part of repository development.
- It is essential that the monitoring objectives and limitations are understood, the indicators that will signal the need for a modified path or retrieval are transparent, and the collected data are broadly accessible to enhance public trust and for use in performance confirmation modeling by the implementer and other stakeholders.
- Underground research laboratories and repository pilot facilities improve the technical basis and confidence in the future success of monitoring technologies and potential retrieval, and can serve as demonstration sites to build public acceptance.
- Long-term research, development, and demonstration of monitoring and sensor technologies are needed to address current technology limitations.
- A stepwise approach to repository program implementation and decision making is important because it provides opportunities to reassess decisions and modify future plans.
- Measures are needed to facilitate knowledge transfer to future generations so that expertise is available to access and interpret monitoring data.

These observations are discussed below.

Retrievability is an important consideration in the initial repository design, adding only a small increment to the cost of repository development but offering substantial cost reduction if retrieval is determined to be necessary.

As noted in the introduction to this report, there is broad international recognition of the value of establishing contingency options to retrieve waste from a repository, particularly before repository closure to ensure operational safety. At the meeting, Dr. Pescatore noted that the degree of acceptance of an option for waste retrieval after repository closure varies among countries, but regardless of the degree of acceptance, no country is prepared to say it will "walk away" from a site should problems arise with the repository after closure.

There was general agreement among the speakers at the meeting that it is important to incorporate features into the initial repository design that will facilitate waste retrieval if that is deemed necessary. An example of the consequences of failure to do this comes from the Asse II salt mine in Germany. Asse II was used to dispose of low- and intermediate-level radioactive waste between 1967 and 1978. As Dr. Geckeis discussed during his presentation, waste retrieval currently is under consideration because brine is flowing into parts of the mine and some radioactive contamination (tritium, cesium-137) of the brine has been reported. According to Dr. Geckeis, retrieving the waste is challenging because of uncertainty associated with the current conditions of the waste and the emplacement chambers. It is also not clear how the waste might be retrieved, as no thought had been given to possible retrieval at the time that waste was being emplaced in the mine. According to Dr. Geckeis, this absence of a clear path forward has engendered mistrust by the local population in the mitigation measures that have been proposed for the site.

It is recognized that waste retrieval becomes more difficult and more costly as implementation of the repository program progresses (see Figure 2; NEA 2011, 2012). But according to the speakers at the meeting, there are measures that can be taken to enhance, or at least not impede, retrievability. These measures can be technical or non-technical. Technical measures include (i) providing ready access to the waste packages (e.g., by using concrete or steel liners to enhance the stability of underground openings, delaying backfilling of emplacement drifts, and delaying the final sealing of access shafts to the underground facility) and (ii) providing improved capability to reach and handle the waste packages (e.g., by using easier-to-remove buffer materials, longer-lasting containers, or more durable waste forms). Non-technical measures include institutional provisions to preserve repository program implementation records and memory. According to the speakers at the meeting, the cost of retrieving waste would add possibly less than 10 percent to the cost of repository development if retrievability is included as an essential feature in the overall repository concept and in the repository design. Re-design or modifications to facilitate retrieval that is added later in the repository program would have a larger impact on the costs and schedules.

The Board recognizes that there can be trade-offs between design features that facilitate retrievability (and monitoring) and those that might enhance long-term containment of wastes or that promote safety and efficiency of operations prior to repository closure. A prime example is the decision of when (or whether) to backfill emplacement drifts. The Board was encouraged to hear from several of the presenters that some countries have come up with options to address these trade-offs, for example by using backfill materials that can be easily removed after waste emplacement in the event that wastes must be retrieved.

While some countries, such as France, have active programs to develop and test retrieval technologies, others have not yet begun such work. However, several speakers at the meeting expressed confidence that if it is decided to retrieve the waste from a repository after closure, technology for retrieval would be available or could be developed.

Monitoring to assess operations and to support decisions related to repository operations or waste retrieval is also an integral part of repository development.

Information provided at the meeting also shows that monitoring activities to generate the data required for a decision to modify operations or retrieve waste should not be simple add-ons to a repository program. The speakers at the meeting recommended that these activities should be integral to repository development and must be taken into account in the early design stages of the repository program. Not only can monitoring inform decisions, but it can also give the public confidence that authorities have a long-term commitment to the safety of the host community and that, if a problem should arise with the repository, strategies have been developed to respond. As monitoring data are used to update performance assessment models, they also could enhance public confidence in cases where the data serve to reduce uncertainties and lead to a more robust forecast of long-term repository performance. Finally, monitoring data also could enhance public confidence in operational safety, which may well be of greatest concern to the community near a repository site.

Taking account of monitoring early in the repository program enables planning for and conducting the research, development, and demonstration activities of sensors and technologies required for monitoring. However, throughout the development of a repository as well as through operations, the monitoring program needs flexibility to address spatial and temporal variability in properties and processes and the ability to replace or retrieve sensors (in some cases using robotic or other remote handling capabilities) or to incorporate new sensor technologies as they evolve and improve.

Several speakers discussed anticipated time-frames for post-closure monitoring. In most cases, these extend, at most, a few hundred years after closure. Monitoring is likely more difficult after closure and the options for using monitoring data in retrieval decisions may be more limited. Some speakers suggested, however, that even if data collected during post-closure are not very useful to retrieval decisions, they can be helpful in promoting public "memory" of the repository and, thus, in sustaining institutional controls.

It is essential that the monitoring objectives and limitations are understood, the indicators that will signal the need for a modified path or retrieval are transparent, and the collected data are broadly accessible to enhance public trust and for use in performance confirmation modeling by the implementer and other stakeholders.

The speakers at the meeting acknowledged there are limitations to what can be monitored. For example, Dr. Zuidema commented that direct monitoring of some aspects of overall repository performance is likely not possible over all timescales. For example, some thermal, hydrologic, mechanical, and/or chemical processes that could negatively impact repository performance (e.g., waste package corrosion and breaching, hydrologic resaturation of emplacement drifts, waste form degradation) may occur only after hundreds to thousands of years. This is much longer than the repository performance confirmation period (100 years during pre-closure for the U.S. program). Thus, in the Board's view, the implementer needs to be open and honest about the objectives, strengths, and limitations of monitoring so the public understands what monitoring can and cannot accomplish. Transparency and making the monitoring and other data available to the public may enhance trust and build credibility. The implementer also has to be open to stakeholder recommendations on what parameters to monitor, such as those that were measured in the Nye County, Nevada, Early Warning Drilling Program (EWDP), and has to be clear on how the measured results will be used. The EWDP was funded by the DOE Yucca Mountain Program to provide geologic and hydrologic information independent of DOE measurements.

The Board believes that the implementer, in developing a monitoring program, needs to clearly define the "thresholds" for action, i.e., the monitoring results or other indicators that will signal the need to start considering and possibly implementing plans for a modified path forward or retrieval based on repository modeling results obtained as part of performance confirmation. This avoids the potential appearance that the rules are being changed to avoid a modified path rather than according to a pre-determined plan. The implementer has to develop scenarios and assess what actions should be taken before a scenario becomes a reality. For example, the implementer should determine in advance what action would be required if a quality assurance problem is found with an emplaced waste package (e.g., should this lead to additional monitoring or to removing the waste package from the emplacement drift?). These scenarios can help the implementer determine what should be monitored and develop its retrieval plans.

Underground research laboratories and repository pilot facilities improve the technical basis and confidence in the future success of monitoring technologies and potential retrieval, and can serve as demonstration sites to build public acceptance.

The Board considers that useful "tools" to provide information needed to make decisions on monitoring and retrievability include (i) underground research laboratories, which may be generic or near a site of a proposed repository, and (ii) pilot facilities, which may be areas within a repository that are monitored intensively as an alternative to attempting to monitor the entire repository. Underground research laboratories and pilot facilities allow the testing and demonstration of waste emplacement, waste retrieval, and monitoring technologies in prototypical environments. These test activities can greatly improve the technical basis and confidence in the future success of the technologies, demonstrate operational safety, and help to find "unexpected" events. Such facilities also can serve as demonstration sites to build public acceptance of the repository. Different countries have chosen to use different combinations of these facilities in their repository programs, but all include some facilities for underground measurements at scales that are relevant to repository performance.

Long-term research, development, and demonstration of monitoring and sensor technologies are needed to address current technology limitations.

The meeting presentations on monitoring and sensor technologies indicate techniques already are available for measuring most of the key parameters of interest in repository performance confirmation. Dr. Landais, in his presentation, described the use of 11,000 sensors in in-situ experiments at an underground research laboratory in Bure, France. In these experiments, the parameters that are measured include temperature, pore pressure, water content, relative humidity, deformation, conductivity, pH and Eh. But the meeting presentations also indicate much work is still needed to improve these technologies for use in a geologic repository for SNF and HLW. Most existing sensors have relatively short lives, make point rather than spatially distributed measurements, are designed for near-surface applications, lack the ability to self-calibrate, show long-term instrumental drift, require power for long-term operation, and need to be radiation- and heat-hardened. Work to improve currently available technologies will take a sustained research, development, and demonstration program over many years.

In the case of vadose zone[4] monitoring, technology needs to be developed to measure moisture content and matric potential, two properties used to estimate seepage flux, continuously over long distances and at greater depths and harsher (high temperature, high radiation) environments than at the relatively shallow depths for which current sensors have been developed. For example, Dr. Or indicated opportunities exist for sensing based on fiber optics to allow collecting better spatially resolved data. Spatial resolution is important in order to detect a seepage event that may occur through a preferential pathway in fractured rock systems.

Dr. Rebak indicated there has been rapid development of sensor technology that may be applicable to waste package corrosion monitoring based on advances in material science and nanotechnology. However, the long-term stability of these sensors needs to be studied. For waste package monitoring, Dr. Rebak recommended using coupons made of different materials with a wide range of corrosion susceptibility. These coupons can be placed at different locations of an emplacement drift where the environmental conditions are expected to be different. Early corrosion of the most susceptible materials provides a robust indication of environmental conditions that could lead to corrosion of less susceptible materials over longer periods.

A stepwise approach to repository program implementation and decision making is important because it provides opportunities to reassess decisions and modify future plans.

All countries with a geologic repository program, including the United States, have a stepwise or phased approach to repository program implementation. Each country develops its own requirements based on its respective social, political, legal, and technical environments. The NEA (2011) report states there is no "one-size-fits-all" approach to retrievability and/or reversibility that can be applied to all situations.

The experience of European countries in implementing repository programs, summarized by several of the meeting speakers, demonstrates that in a discrete, stepwise approach, the regularity of decision making (e.g., periodically updating the safety documentation or the research, development,

[4] The vadose zone extends from the earth's surface to the regional groundwater table. It may be very shallow (less than 1 m) or very deep (extending hundreds of meters or more), depending on the depth to the water table. The vadose zone has lower water content relative to the saturated zone below the water table and, therefore, is commonly referred to as the unsaturated zone.

and demonstration program) facilitates systematic re-assessment of the program over time and allows potential changes on a regular basis. Smaller steps mean more frequent engagement between the implementer, the regulator, and the stakeholders. Stepwise and flexible decisions, as well as incorporation of improved technologies during development and operation of a repository, may be easier to achieve when they are explicitly incorporated into the licensing/approval process.

The U.S. program has discrete steps in its repository program implementation process, including decision making for construction authorization, receipt and possession of HLW and SNF, and closure of the repository. Between these steps, DOE can make changes in design, procedures, tests, and experiments (e.g., based on the results of performance monitoring activities). These changes may need to address specific NRC requirements (e.g., some changes require prior NRC approval and there is a periodic reporting requirement to describe the changes, tests, and experiments and a summary of the evaluation for each).

Measures are needed to facilitate knowledge transfer to future generations so that expertise is available to access and interpret monitoring data.

Given the long time horizon of repository operations and pre-closure monitoring, the Board believes that particular effort is needed to develop institutional and other mechanisms to ensure the transfer of relevant knowledge, the capability to apply that knowledge, and the sustainability of stewardship into the future. There is a need to ensure adequate scientific and engineering talent, for example, by engaging the younger generation in nuclear waste management issues, training them in the nuclear field, and enhancing nuclear-related research. Emphasis should be placed on expertise to develop, maintain, and interpret sensor data and to maintain data cyberinfrastructure.

Conclusion

Reflecting on all the Board heard at the meeting, it is clear that repository programs in other countries offer lessons related to the implementation and monitoring of geologic repositories and the retrievability of emplaced HLW and SNF. The Board has recorded its observations from the meeting in this report, with the objective of informing DOE's activities when it moves forward with a program for geologic disposal of U.S. HLW and SNF.

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Appendix A

Agenda and List of Speakers

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AGENDA
Spring Board Meeting
Tuesday, March 27, 2018

Embassy Suites D.C. Convention Center
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8:00 a.m.	**Call to Order and Introductory Statement** *Jean Bahr*, Board Chair
8:15 a.m.	**When the Rocket is Up: Twenty Years of Retrievability/Reversibility Work at the International Level** *Claudio Pescatore*, formerly Nuclear Energy Agency i. What projects has the NEA undertaken related to monitoring and retrievability/reversibility? ii. What prompts some countries and not others to establish requirements for retrievability or reversibility? Is there a trend? iii. Can a repository be designed to facilitate retrievability/reversibility without compromising its ability to isolate and contain waste? iv. What are the challenges for implementing monitoring and retrievability/reversibility? v. Are commitments to monitor and to retrieve/reverse anything more than symbolic?
8:45 a.m.	*Questions, discussion*
9:05 a.m.	**Reversibility and Retrievability: Governance and Technical Approach** *Patrick Landais*, Andra, France i. How is monitoring related to Andra's safety case? ii. How was the requirement for reversibility established in France? How does it differ from retrievability? iii. What will be monitored during the preclosure period? Postclosure period? Has the instrumentation been developed to carry out the monitoring? iv. What benchmarks, if any, have been identified that would trigger either a decision to retrieve the waste or to reverse course? v. How would that decision be made? What are the institutional and technical challenges of implementing such a decision?
9:35 a.m.	*Questions, discussion*

9:55 a.m.	Break
10:10 a.m.	**The Role of Monitoring in the Swiss Disposal Program** *Piet Zuidema*, formerly Nagra, Switzerland i. How is monitoring related to Nagra's safety case? ii. What motivated Nagra to adopt a repository design that features a separate area for monitoring? iii. What features, events, or processes will be monitored during the preclosure period? Postclosure period? Has the instrumentation been developed to carry out the monitoring? iv. What are the requirements in Switzerland for retrievability? v. What benchmarks, if any, have already been identified that would trigger a decision to retrieve the waste? vi. How would that decision be made? What are the institutional and technical challenges of implementing such a decision?
10:40 a.m.	*Questions, discussion*
11:00 a.m.	**Preliminary R&D and Design Work for Monitoring and Retrieving Waste in a Geologic Disposal Facility in Belgium** *Maarten van Geet*, ONDRAF/NIRAS, Belgium i. What policies have been adopted for disposing of high-activity waste in Belgium? ii. How is monitoring related to the safety case for disposal of waste in Boom clay? iii. What features, events, or processes will be monitored during the preclosure period? Postclosure period? Has the instrumentation been developed to carry out the monitoring? iv. What retrievability requirements are being considered in Belgium? What institutional and technical challenges are anticipated in implementing retrievability?
11:30 a.m.	*Questions, discussion*
11:50 a.m.	**Public Comments**
12:00 p.m.	Lunch Break (1 hour)
1:00 p.m.	**Retrieving Waste from the Asse Salt Mine: Facts and Challenges** *Horst Geckeis*, Karlsruhe Institute of Technology, Germany i. What are the main provisions of the repository-siting legislation recently approved in Germany? ii. What events led to the passage of the *Lex Asse*? iii. What technical analyses were carried out for alternatives options to manage the waste disposed in the Asse II mine? iv. What policy considerations determined which option would be adopted? v. What are the challenges for implementing the retrievability option?
1:30 p.m.	*Questions, discussion*

1:50 p.m.	**Sensors and Technologies for Monitoring Subsurface Seepage in a Geologic Repository** *Dani Or*, Swiss Federal Institute of Technology Zurich (ETHZ), Switzerland i. What are the key parameters to monitor to confirm the performance of a geologic repository for high-level radioactive waste and spent nuclear fuel with respect to subsurface seepage? ii. What is the state of the art in sensors and technologies that can be used to monitor those key parameters? iii. What are the technical challenges in applying those sensors and technologies to monitor repository performance? iv. What are the main areas for improvement in currently available sensors and technologies?
2:20 p.m.	*Questions, discussion*
2:40 p.m.	**Sensors and Technologies for Monitoring Waste Package Corrosion in a Geologic Repository** *Raul Rebak*, G.E. Global Research i. What are the key parameters to monitor to confirm waste package performance in a geologic repository for high-level radioactive waste and spent nuclear fuel? ii. What is the state of the art in sensors and technologies that can be used to monitor those key parameters? iii. What are the technical challenges in applying those sensors and technologies to monitor waste package performance? iv. What are the main areas for improvement in currently available sensors and technologies?
3:10 p.m.	*Questions, discussion*
3:30 p.m.	Break
3:45 p.m.	**Panel Discussion** *C. Pescatore, P. Landais, P. Zuidema, M. van Geet, H. Geckeis, D. Or, R. Rebak*
4:45 p.m.	**Public Comments**
5:00 p.m.	**Adjourn Public Meeting**

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United States

Nuclear Waste Technical Review Board

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