U. S. Nuclear Waste Technical Review Board

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

Board Activities for the Period January 1, 2008 – December 31, 2012

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UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

December 2014

The Honorable John Boehner
Speaker
United States House of Representatives
Washington, DC 20515

The Honorable Patrick J. Leahy
President Pro Tempore
United States Senate
Washington, DC 20510

The Honorable Ernest Moniz
Secretary
U.S. Department of Energy
Washington, DC 20585

Dear Speaker Boehner, Senator Leahy, and Secretary Moniz:

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. In accordance with provisions of the NWPAA directing the Board to report its findings and recommendations to Congress and the Secretary of Energy, the Board submits this *Report to the U.S. Congress and the Secretary of Energy*. The Report summarizes Board activities, conclusions, and recommendations for the period January 1, 2008, through December 31, 2012.

The period covered by the Report was consequential for the U.S. program for managing and disposing of spent nuclear fuel and high-level radioactive waste and for the Board. The Board wishes to recognize the contributions of Dr. B. John Garrick, who was Board Chairman during the five years covered by the report, and whose leadership was an important factor in the Board's accomplishments during the period.

We hope that Congress and the Secretary will find the information in this archival summary report useful. The Board looks forward to continuing its ongoing technical and scientific review of DOE activities related to nuclear waste management and disposal.

Sincerely,

Rodney C. Ewing
Chairman

U.S. Nuclear Waste Technical Review Board

U.S. Nuclear Waste Technical Review Board Staff

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Executive Summary

The U.S. Nuclear Waste Technical Review Board was established by Congress in the 1987 Nuclear Waste Policy Amendments Act (NWPAA) to undertake an independent and ongoing evaluation of the technical and scientific validity of U.S. Department of Energy (DOE) activities related to implementing the Nuclear Waste Policy Act (NWPA) of 1982. The Board's 11 members serve part time and are appointed by the President from a list of nominees submitted by the National Academy of Sciences. The Board reports its findings, conclusions, and recommendations to the U.S. Congress and the Secretary of Energy. This report summarizes the Board's activities for the period January 1, 2008, through December 31, 2012. All Board documents referred to in the report are available on the Board's website at www.nwtrb.gov. Board congressional testimony and correspondence for the period and other information on the Board can also be found in the appendices to this report.

The five years covered by the report were consequential for the U.S. program for managing and disposing of spent nuclear fuel (SNF) and high-level radioactive waste (HLW). During that time, the direction of DOE's management and disposal activities changed significantly.

Background

In June 2008, DOE submitted a license application to the Nuclear Regulatory Commission (NRC) for authorization to construct a deep geologic repository at Yucca Mountain in Nevada, and NRC staff commenced a review of the license application.

Early in 2010, funding for the Yucca Mountain licensing effort and for DOE's Office of Civilian Radioactive Waste Management—the entity responsible for implementing DOE's obligations under the NWPA—was eliminated from DOE's budget and responsibilities for most of DOE's activities related to managing and disposing of commercial SNF were assigned to DOE's Office of Nuclear Energy. Also in early 2010, DOE filed a motion with NRC to withdraw the Yucca Mountain license application. Subsequently, several parties that had petitioned to intervene in the licensing hearing process, including the states of Washington and South Carolina and the County of Aiken in South Carolina, filed suit in the U.S. Court of Appeals for the District of Columbia Circuit to compel DOE and NRC to restart the licensing process. NRC's Construction Authorization Board denied DOE's motion to withdraw the license application in June 2010; however, the NRC Chairman at the time stopped all work on the license application by NRC staff in October 2010.

In January 2010, at the direction of the President, the Secretary of Energy created the Blue Ribbon Commission on America's Nuclear Future (BRC) to look at alternatives for managing "the back end of the nuclear fuel cycle." During 2010 and 2011, the BRC held numerous hearings and Board members and staff provided technical and scientific information to the

BRC on several occasions. The Board also commented on draft reports issued by the BRC's subcommittees and on the draft BRC report. In January 2012, the BRC issued its final *Report to the Secretary*. Among the BRC recommendations was the establishment of a consent-based process for siting a repository for permanent disposal of SNF and HLW and a consolidated facility for interim storage of the waste. The BRC also recommended the creation of a new implementing organization for the disposal of SNF and HLW. The Board provided comments to Secretary Chu on the final BRC report.

Board Response to Evolving SNF and HLW Program

As the focus of DOE's NWPA implementation activities transitioned from licensing a Yucca Mountain repository to identifying a new path forward for nuclear waste management, the Board continued to review the technical and scientific validity of DOE activities. The Board sent a letter to the Secretary of Energy in August 2009, in which the Board described its priorities during this period: (1) continue reviewing DOE's ongoing nuclear waste management activities; (2) provide technical findings and information to Congress, the Secretary of Energy, and the BRC that could be used in evaluating alternatives for managing nuclear waste; and (3) create information products that could be used to inform, from a technical perspective, the discussion of waste management alternatives.

The Board sent a letter report to Congress and the Secretary of Energy in October 2009, in which the Board articulated the direction and focus of its ongoing review of DOE activities, given changes that were anticipated in the DOE program. In particular, the Board clarified that its statutorily mandated technical evaluation of DOE activities related to implementing the NWPA would continue regardless of where in DOE the activities were undertaken.

Board Activities during the Period

Board Reports—One of the primary means by which the Board communicates its findings, conclusions, and recommendations on the technical and scientific validity of DOE activities and related issues is to submit written reports to the U.S. Congress and the Secretary of Energy. During the period covered by this report, the Board published seven such reports, including the letter report discussed in the previous paragraph and the following:

- *U.S. Nuclear Waste Technical Review Board Report to the U.S. Congress and the Secretary of Energy March 1, 2006 - December 31, 2007 (September 2008)*
- *Survey of National Programs for Managing High-Level Radioactive Waste and Spent Nuclear Fuel (October 2009)*
- *Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel—Executive Summary (December 2010)*
- *Experience Gained from Programs to Manage High-Level Radioactive Waste and Spent Nuclear Fuel in the United States and Other Countries (April 2011)*
- *Technical Advancements and Issues Associated with the Permanent Disposal of High-Activity Wastes: Lessons Learned from Yucca Mountain and Other Programs (June 2011)*

- *Nuclear Waste Assessment System for Technical Evaluation (NUWASTE): Status and Initial Results (June 2011)*

Board Testimony—An important aspect of the Board's peer-review responsibilities involves advising decision-makers in Congress and the Administration on technical and scientific issues associated with SNF and HLW management and disposal. In addition to issuing reports, the Board fulfills this responsibility by providing testimony on nuclear waste issues at the request of congressional committees. During the period covered by this report, the Board provided testimony on two occasions to congressional committees.

Board Meetings and DOE Correspondence—During the reporting period, the Board held 15 public meetings, at which DOE and its contractors presented their technical and scientific work related to implementing the NWPA. In accordance with established practice and to ensure the timeliness of Board comments, after every public Board meeting, the Board sends follow-up correspondence to DOE, which includes observations and recommendations on DOE's work presented at the meetings. Together with Board reports and congressional testimony, the letters represent a substantial body of technical and scientific information and a record of key issues related to the U.S. program for managing and disposing of SNF and HLW. The last section of this report presents a discussion of significant technical and scientific issues that emerged from the Board's review of DOE's work during the period January 1, 2008, through December 31, 2012.

Interactions with the Interested Public—A fixture of all Board meetings is the public comment session, where members of the interested public are invited to comment and ask questions regarding the information presented at the meetings. In addition to providing the Board with the most recent and relevant information on DOE's nuclear waste activities, the Board's meetings provide a unique forum for the interested public to interact directly with the Board and its staff; DOE managers, scientists, engineers, and consultants; and other program participants. Public comments offered at the meetings are included in meeting transcripts, and written comments and other materials submitted by public commenters are included in the meeting records on the Board's website: www.nwtrb.gov.

Interactions with Other SNF and HLW Programs—Since its inception, the Board has interacted in various ways with SNF and HLW management and disposal programs in other countries. The objective of these interactions has been to gain knowledge and perspective from the relevant experiences of these programs to enhance the Board's technical and scientific evaluation of DOE activities. During the period covered by this report, small delegations of Board members and staff visited SNF management programs in several countries. The Board also involved representatives of programs in other countries as presenters at several of the Board's public meetings.

Contents

Contents Continued

The Board and Its Mission

The U.S. Nuclear Waste Technical Review Board (NWTRB) was established by Congress in the 1987 Nuclear Waste Policy Amendments Act (NWPAA) to undertake an independent and ongoing evaluation of the technical and scientific validity of U.S. Department of Energy (DOE) activities related to implementing the Nuclear Waste Policy Act (NWPA) of 1982. The 1987 Act also designated Yucca Mountain in Nevada as the sole site to be characterized by DOE for its suitability as the location of a deep geologic repository for the disposal of spent nuclear fuel (SNF) and high-level radioactive waste (HLW). The Board is charged with reporting its findings, conclusions, and recommendations to Congress and the Secretary of Energy. This report summarizes the Board's activities for the period January 1, 2008, through December 31, 2012. All Board documents referred to in the report are available on the Board's website at www.nwtrb.gov. Board congressional testimony and correspondence for the period and other information on the Board can also be found in the appendices to this report.

The Board's 11 members serve part time and are appointed by the President from a list of nominees submitted by the National Academy of Sciences. Board members are nominated solely based on established records of expertise and eminence in technical and scientific disciplines relevant to work performed by DOE in implementing the NWPA. During the period covered by this report, the following former members served on the Board: B. John Garrick, Ph.D., Chairman; Mark D. Abkowitz, Ph.D.; Thure E. Cerling, Ph.D.; George M. Hornberger, Ph.D.; Ronald M. Latanision, Ph.D.; William M. Murphy, Ph.D.; William Howard Arnold, Ph.D., P.E.; David J. Duquette, Ph.D.; Andrew C. Kadak, Ph.D.; Ali Mosleh, Ph.D.; and Henry Petroski, Ph.D., P.E.[1]

All of the current Board members were appointed to the Board by President Barack Obama. Three of the current Board members—Sue B. Clark, Ph.D.; Rodney C. Ewing, Ph.D.; and Linda K. Nozick, Ph.D.—were appointed in July 2011, and eight more members—Jean M. Bahr, Ph.D.; Steven M. Becker, Ph.D.; Susan L. Brantley, Ph.D.; Efi Foufoula-Georgiou, Ph.D.; Gerald S. Frankel, Sc.D.; Kenneth Lee Peddicord, Ph.D., P.E.; Paul J. Turinsky, Ph.D.; and Mary Lou Zoback, Ph.D.—were appointed in September 2012. Also in September 2012, Dr. Rodney C. Ewing was designated by the President to serve as Board Chairman. Biographies of the current Board members are included in Appendix A.

Developments Related to Nuclear Waste Management

The five years covered by this report were consequential for nuclear waste management and disposal efforts in the U.S. In June 2008, following some 20 years of technical, scientific, and operational analyses and investigations, DOE submitted a license application to the U.S. Nuclear Regulatory Commission (NRC) for authorization to construct a Yucca Mountain repository, and NRC staff commenced a review of the license application. Then, as discussed below, in 2010, the Administration of President Barack Obama undertook several major actions that signaled a significant change in approach to SNF and HLW management and disposal.

[1] Full biographies of members of the Board who served during the period covered by this report can be found in the Board's Report to the U.S. Congress and the Secretary of Energy, issued in September 2008. The report is available on the Board's website at www.nwtrb.gov.

In February 2010, the Administration submitted a budget to Congress that included zero funding in fiscal year 2011 for DOE's Office of Civilian Radioactive Waste Management (OCRWM). OCRWM was the entity that had until that time been responsible for implementing DOE's responsibilities—established in the NWPA—for managing and disposing of SNF and disposing of HLW. At this point, OCRWM's responsibilities under the NWPA transitioned primarily to DOE's Office of Nuclear Energy, while the DOE Office of Environmental Management retained responsibility for environmental cleanup of DOE sites and acquired responsibility for managing the shutdown of the Yucca Mountain site in Nevada. DOE's Office of Legacy Management was given responsibility for preserving data and documents associated with the Yucca Mountain repository program.

DOE petitioned NRC in early 2010 for permission to withdraw the license application for Yucca Mountain. At about the same time, some of the parties that had petitioned to intervene in the licensing hearing process, including the states of Washington and South Carolina and the County of Aiken in South Carolina, filed suit in the U.S. Court of Appeals for the District of Columbia Circuit to prevent DOE's withdrawal of the license application. In June 2010, NRC's Construction Authorization Board denied DOE's request, but in October 2010, NRC Chairman Gregory Jaczko directed NRC staff to cease its technical review of the Yucca Mountain license application.

In January 2010, at the direction of the President, Energy Secretary Steven Chu established the Blue Ribbon Commission on America's Nuclear Future (BRC) to evaluate options for managing the back end of the nuclear fuel cycle. Throughout 2010 and 2011, the BRC continued its deliberations and held numerous hearings, at which stakeholders and members of the public were given the opportunity to present their points of view on managing nuclear wastes. The BRC issued its final report and recommendations in January 2012. The BRC recommendations included the establishment of a consent-based process for siting a repository for permanent disposal of SNF and HLW and a consolidated facility for interim storage of the waste. The BRC also recommended the creation of a new implementing organization for the disposal of SNF and HLW.

Board Response to Evolving SNF and HLW Program

As DOE's activities related to implementing the NWPA transitioned from licensing the Yucca Mountain repository to identifying a new path forward for nuclear waste management, the Board continued its statutorily mandated technical and scientific review of DOE activities. The Board also expanded its efforts to develop technical and scientific information and insights from the experiences of nuclear waste disposal programs in the U.S. and other countries that could be used to advise decision-makers in Congress and the Administration.

In June 2009, the Board wrote to Congress and Secretary Chu (Garrick 2009b), expressing Board support for the Secretary's decision (at the time) to continue the licensing process for a Yucca Mountain repository. The Board noted that this decision "allows a full adjudication of the technical issues and allows all the parties to the process, including the state of Nevada, to identify and support their contentions so that the maximum scientific and engineering benefit can be derived from the effort."

In an August 2009 letter to Secretary Chu (Garrick 2009c), the Board identified three objectives that would guide its ongoing review of DOE activities:

> 1. To the extent that DOE engaged in technical work related to the management and disposal of SNF and HLW, the Board would continue to monitor and evaluate that work and report on the technical validity of the work to Congress and the Secretary.
>
> 2. The Board would continue developing and compiling objective technical information to inform Congress, the Secretary of Energy, and a blue ribbon commission, should one be established. In developing such information, the Board would look broadly at an integrated waste management system and potential waste management alternatives and provide its objective view of technical questions and issues needing to be addressed.
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> 3. The Board would draw on its extensive experience, including knowledge gained from observing efforts in other countries, to develop and provide technical and scientific information and "lessons learned" about the U.S. nuclear waste management program, including the operational and safety risks of alternatives for managing high-level radioactive waste.

The Board sent a letter report to Congress and the Secretary of Energy in October 2009 (Garrick 2009d), in which the Board articulated the direction and focus of its ongoing review of DOE activities, given changes that were anticipated in the DOE program. In particular, the Board clarified that its statutorily mandated technical review of DOE activities related to implementing the NWPA would continue regardless of where in DOE the activities were undertaken. The Board also identified relevant technical and scientific topics on which information would be developed that would help inform decision-makers in the Administration and Congress.

In September 2010, the Board issued its Strategic Plan for fiscal years 2011 to 2016. The updated Plan clarified the Board's continuing peer-review mandate, its strategic goals and objectives, and its vision for making an ongoing contribution to the technical and scientific validity of activities and decisions related to nuclear waste management and disposal.[2] The Board's primary objectives for the period were focused on its review of DOE activities and on providing technical and scientific information to decision-makers in Congress, DOE, and the Administration. The Board also placed a very high priority on interacting with and providing access for the public to its technical and scientific reviews and information. The Board's Strategic Plan for fiscal years 2011 to 2016 can be found in Appendix B.

Board Activities: January 1, 2008 - December 31, 2012

Board Reports

One of the primary means used by the Board for communicating its official findings, conclusions, and recommendations is to send written reports to the U.S. Congress and the Secretary of Energy. During the period covered by this report, the Board published seven such reports, including the letter report discussed in the previous section and the six

[2] The Board's annual performance goals and evaluations are included in its annual budget submittals, which are available on the Board's website: www.nwtrb.gov.

reports summarized below. A chronological listing of Board publications is included in Appendix C.

In September 2008, the Board issued a *Report to the U.S. Congress and the Secretary of Energy* summarizing the Board's activities from March 1, 2006, through December 31, 2007. During the period covered by that report, the Board focused its evaluation of DOE activities on five critical technical issues dealing with the system for managing SNF and HLW and six critical technical issues dealing with the post-closure performance of the proposed Yucca Mountain repository. The Board also explored in depth the crosscutting issue of thermal management.

In October 2009, the Board published a report titled *Survey of National Programs for Managing High-Level Radioactive Waste and Spent Nuclear Fuel*. The report describes 30 technical and institutional attributes of nuclear waste programs in 13 countries. The purpose of the report was to provide up-to-date information to Congress, the Secretary of Energy, and other interested parties on the status of the various national programs for managing SNF and HLW. The report does not make judgments; rather, it provides factual information for Congress and the Secretary that can be used for evaluating waste management options.

The Board's report *Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel—Executive Summary* was released in December 2010. The document summarizes and draws conclusions from a review of the literature undertaken by Board staff related to the challenges—including materials degradation—associated with very long-term dry storage of SNF at commercial nuclear power plants and the problems that might be encountered when the SNF is subsequently transported to a repository or consolidated storage facility.

The report *Experience Gained from Programs to Manage High-Level Radioactive Waste and Spent Nuclear Fuel in the United States and Other Countries* was issued by the Board in April 2011. This report built on information in the 2009 Survey Report and explored the efforts of 13 nations to find a permanent solution for isolating SNF and HLW generated within their borders. Unlike the earlier document, however, this report not only described the programs, it made observations drawn from the experiences of the 13 programs.

In June 2011, the Board released the report *Technical Advancements and Issues Associated with the Permanent Disposal of High-Activity Wastes: Lessons Learned from Yucca Mountain and Other Programs*. The purpose of this report was to gather and record knowledge, while it was still available, from experiences of the Yucca Mountain program and other management programs for SNF and HLW. In the report, the Board examined, from a technical and scientific perspective, the history of the Yucca Mountain program and other nuclear waste programs around the world, and discussed technical and scientific information and insights that could be useful for future SNF and HLW management and disposal efforts in the U.S.

In 2010, the Board began developing an analytical tool called the Nuclear Waste Assessment System for Technical Evaluation (NUWASTE) for analyzing options for managing the back end of the nuclear fuel cycle. Of particular interest to the Board were the types and quantities of the radioactive waste streams that would be generated by the different options. In June 2011, the Board issued the report *Nuclear Waste Assessment*

System for Technical Evaluation (NUWASTE): Status and Initial Results. In addition, the Board held a workshop on Evaluation of Waste Streams Associated with Light Water Reactor Fuel Cycle Options to provide a forum for developers and users of computer models and analytical tools to benchmark their results.

Board Testimony before Congress

A very important part of the Board's mandate involves advising and reporting to the U.S. Congress regarding the many technical and scientific issues associated with nuclear waste management. As discussed above, the Board sends written reports on a regular basis to Congress and the Secretary of Energy. The Board also provides information, conclusions, and recommendations in testimony presented to Congress at the request of congressional committees. During the period covered by this report, the Board provided testimony on two occasions to congressional committees, first to a Committee of the House of Representatives and then to a Senate Committee. The full text of the testimonies can be found in Appendix D.

House Committee on Energy and Commerce—On July 15, 2008, Board Chairman B. John Garrick testified before the U.S. House of Representatives Committee on Energy and Commerce, Subcommittee on Energy and Air Quality (Garrick 2008c). Dr. Garrick observed in his testimony that DOE's submittal to NRC of a Yucca Mountain license application in June 2008 was a major program milestone. He noted that because the Board performs independent peer review of DOE activities, the Board would not be a party to the Yucca Mountain licensing proceeding. The Board would contribute to the licensing process by making the results of its ongoing technical and scientific evaluation of DOE activities publicly available on the Board's website. That information could be used by anyone, including parties to the licensing proceeding. Dr. Garrick told the Committee that some technical issues that could affect calculations of repository performance had been identified by the Board before the submission of the license application. These issues included potential deliquescence-induced localized corrosion of the repository waste packages during the thermal pulse, general corrosion of waste packages, water recharge resulting from climate change, and seismicity and volcanism associated with the Yucca Mountain site.

Senate Committee on Environment and Public Works—On June 7, 2012, Daniel S. Metlay, a member of the Board's senior professional staff, was invited to testify on the history of U.S. disposal efforts and on disposal programs in other countries before the U.S. Senate Subcommittee on Clean Air and Nuclear Safety, Committee on Environment and Public Works (Metlay 2012). Among the key points in his testimony were the following:

- Site-selection strategies for deep-mined geologic repositories in the U.S. and other countries involve two "filters," one consisting of technical requirements and the other of nontechnical considerations.
- A deep-mined geologic repository is the preferred disposal option of all countries with SNF and HLW management programs.
- What characterizes national repository programs most is their variety.
- The experience of the U.S. Nuclear Waste Negotiator may be especially relevant because it is an example of a consent-based siting effort undertaken in the U.S.

- Public trust in the institutions involved in a consent-based site-selection process is an essential element for success.

Board Interactions with the BRC

Board Presentations to the BRC—On several occasions in 2010 and 2011, Board members and Board staff presented technical and scientific information on SNF and HLW management and disposal to the BRC. Board presentations to the BRC are included in Appendix E.

In July 2010, Daniel S. Metlay testified before the BRC on the experiences of programs in other countries with SNF and HLW management and disposal programs (Metlay 2010). Dr. Metlay observed that an international consensus exists that deep geologic disposal "provides a unique level and duration of protection" of public health and safety and that it is technically feasible. He pointed out that most repository siting programs rely on two "filters," a technical filter and a nontechnical filter. The filters can be employed in any order, but both must ultimately be applied. He discussed the ways in which the U.S. governmental system is different from systems in other countries where consent-based approaches have been used and noted that there are no simple solutions to complex problems.

In October 2010, Board member Mark Abkowitz appeared before the BRC (Abkowitz 2010). Dr. Abkowitz presented a description of the Board's NUWASTE systems analysis tool and some observations that had emerged as part of the NUWASTE analysis:

- Under all likely scenarios, a geologic repository will be needed for disposal of both SNF and HLW.
- Significant delays in opening a repository will substantially increase the quantity of commercial SNF in dry storage in at least 33 states.
- The NUWASTE analyses completed to date have not identified any major advantages from reprocessing in terms of either reduction in repository volume required for disposal of SNF and HLW or in uranium demand.

In November 2010, Board Chairman B. John Garrick testified before the BRC (Garrick 2010c) regarding a number of technical and scientific lessons that had been learned from the experiences of nuclear waste disposal programs in the U.S. and other countries, including the following:

- Expect surprises in the underground. At Yucca Mountain, two surprises were the discovery of "bomb pulse" chlorine-36 at the repository level and the existence of lithophysae in the waste emplacement area, which complicated geotechnical and heat-transfer modeling.
- Most disposal concepts rely on both natural and engineered barriers; an engineered system can enhance the robustness and reliability of the repository system.
- Analyzing the characteristics of the waste forms to be disposed of is important.
- A prototyping program is essential to understanding the potential performance of the components of a first-of-a kind repository system.
- Unless large dry-storage canisters can be directly disposed of, repackaging and extensive handling of the SNF they contain may be necessary.

- Disposing of SNF and HLW in many different geologic media, including tuff, granite, clay/shale, and salt, is technically feasible.

Board Comments on BRC Reports—The Board provided comments on draft reports submitted by the BRC Subcommittee on Disposal and the BRC Subcommittee on Transportation and Storage in June 2011 (Garrick 2011a and Garrick 2011b) and on the draft report of the BRC Subcommittee on Reactor and Fuel Cycle Technology in July 2011 (Garrick 2011c). The Board also commented on the draft report of the full BRC in October 2011 (Garrick 2011f) and on the final BRC report in April 2012 (Garrick 2012c). Highlights from the Board letters are provided below; the full text of the letters can be found in Appendix E.

BRC Subcommittee on Disposal

- *Need for Deep-Mined Geologic Disposal*—The Board agreed with the Subcommittee conclusion (BRC 2011b) that "one or more permanent disposal facilities for high-level nuclear waste will be needed in the United States under all reasonably foreseeable scenarios" and that "[d]eep geologic disposal has emerged as the most promising and technically acceptable option."
- *Organizational Form for the Implementer*—The Board took no position on the BRC Subcommittee recommendation that a FEDCORP-like organization be created to direct future nuclear waste management efforts. The Board said that international experience indicates that a single-purpose organization seems to work best, regardless of its other attributes (government, nongovernment, or hybrid).
- *Structure of Siting and Development Process*—The Subcommittee recommended that a "phased, adaptive approach" for siting and constructing a repository be adopted. In its letter commenting on the draft report, the Board noted that the Subcommittee's discussion does not fully reflect the strengths and the weaknesses of that approach. The Board goes on to say that, "At the theoretical level, it is hard to find fault with a decision-making strategy that seems to promise so much [in terms of potential benefits]. As a more practical matter, however, it is unclear whether it can be any more successful than earlier efforts in overcoming local and state opposition to specific siting decisions, whether it can be implemented, and whether it should be implemented."

BRC Subcommittee on Transportation and Storage

- *Subcommittee Recommendation: One or More Consolidated Interim Storage Facilities Should Be Implemented Expeditiously (BRC 2011a)*—The Board urged consideration of the system-wide implications of developing consolidated interim storage for SNF and/or HLW, as recommended by the Subcommittee.
- *Subcommittee Recommendation: Active Research Should Continue on Extended Storage Phenomena*—The Board strongly endorsed the Subcommittee's finding that an active and sustained research program is necessary to have high confidence in the safe extended storage and subsequent transportation of high-burnup fuel.
- *Subcommittee Recommendation: SNF in Storage at Decommissioned Reactor Sites Should Be First in Line for Transfer to a Consolidated Storage Facility*—The Board agreed in principle with the basis for the BRC recommendation but noted that

implementing such a preference would require either dry-transfer capability or the availability of an operational SNF pool at the interim facility.

- *Subcommittee Recommendation: Planning and Coordination for Transporting SNF and HLW Should Commence at the Start of a Consolidated Storage Program*—The Board concurred with the Subcommittee recommendation and noted that there are inconsistencies in NRC's regulations for transportation and storage that need to be addressed. Also, the Board noted that while the safety record for transporting SNF is excellent, the scale of the transportation campaign needed to transfer SNF and HLW to one or more consolidated storage facilities would dwarf previous efforts.

BRC Subcommittee on Reactor and Fuel-Cycle Technology

- *Subcommittee: There is a need to provide "near-term improvements in the safety and performance of existing light-water reactor technology as currently deployed in the United States" and the need for "longer-term efforts to advance potential 'game-changing' nuclear technologies and systems that could achieve very large benefits across multiple evaluation criteria compared to current technologies and systems"* (BRC 2011c). The Board commented in its letter to the Subcommittee that it believed that consideration of improvements in existing technologies and development of new nuclear technologies should include the waste-stream consequences of the adoption of the changes as part of the decision-making process, and that "any evaluation of the benefits of such changes should take into account the impact on the waste management requirements that will result from the adoption of the changes."

- *Subcommittee: "No currently available or reasonably foreseeable reactor and fuel cycle technologies—including current or potential reprocess and recycle technologies—have the potential to fundamentally alter the waste management challenge this nation confronts over at least the next several decades, if not longer."* The Board essentially concurred with this BRC finding and reiterated the importance of moving on to a disposal solution, which ultimately will be required regardless of waste form(s). The Board went on to say that, in its view, a disposal facility should not be delayed by research and development (R&D) on fuel-cycle alternatives.

BRC Draft Report to the Secretary of Energy

On October 31, 2011, the Board sent a letter to BRC Co-Chairs Lee Hamilton and Brent Scowcroft commenting on the BRC's Draft Report to the Secretary of Energy, dated July 29, 2011 (BRC 2011d). Following are some observations from the Board's letter:

- *Deep Geologic Disposal:* "The Board strongly concurs with the Commission's findings that deep geologic disposal is the most promising and accepted method currently available for safely isolating spent nuclear fuel (SNF) and high-level radioactive waste (HLW) for very long periods and that a permanent repository will be needed for any fuel cycle option that might be implemented in the reasonably foreseeable future."

- *Developing Generic Siting Criteria:* "The Board concurs with the Commission that development of generic repository siting criteria should

proceed without delay. The Board notes that from a technical perspective, generic studies do not replace the need to focus on specific geologies and potentially available sites in the United States that may meet the criteria."

- *Deep Borehole Disposal:* "While deep boreholes are suggested in the Commission's Draft Report as a substitute for mined geologic disposal, the Board recommends additional RD&D on deep borehole disposal to help resolve uncertainties about this approach and to allow for a more conclusive evaluation of its feasibility."
- *Radiation Source Term:* "The Board believes that determining the radiation source term realistically, particularly with respect to the processes involved in mobilizing the waste, is critical to obtaining a fundamental understanding of the disposition of dose-contributing radionuclides. Such analyses can potentially help support a repository compliance case and can provide a much more credible understanding of how natural and engineered barriers would work together in a repository to contain and delay the release of radionuclides from the waste into the accessible environment."
- *Extended Storage of SNF:* "The Board concurs strongly with the Commission that research is needed on fuel degradation mechanisms and other factors that may affect the ability to store SNF for long periods. As discussed in the Board's report on Extended Dry Storage and Transportation of Used Fuel, issued in late 2010 [NWTRB 2010a], the Board recommends that the ability to handle and transport such waste after extended storage also should be studied."
- *Management of DOE SNF and HLW:* "The discussion of the wastes stored at these facilities in the Commission's Draft Report correctly reflects the importance of considering how defense wastes should be managed and disposed of when evaluating options for permanent disposal of high-activity waste. The Board believes that a full discussion of the issues related to the need to permanently dispose of these wastes should be included in the Commission's final report."
- *Systems Approach to Study of Alternative Fuel-Cycle Technologies:* "The Board has consistently urged DOE to adopt a 'systems' approach to radioactive waste management and strongly supports the Commission's finding that studies of alternative fuel-cycle technologies should account for linkages among all elements of the fuel cycle, including reactor technologies, fuel processing, transportation, storage, and disposal of SNF and HLW."
- *Technical Basis for Taking Burnup Credit:* "The Board advocates developing a technical basis for taking full credit for the loss of fuel reactivity as a result of burnup. The Board believes such work should have high priority because taking burnup credit potentially offers significant economies in developing a transportation system and cost savings at other stages of a spent fuel management program."
- *International Experience:* "The Board has found its interactions with programs in other countries to be extremely valuable and joins the Commission

in urging that U.S. program managers take full advantage of the experiences gained."

- *Preservation of Yucca Mountain Data and Documents:* "The Board believes that it is imperative that information and data generated previously by the Office of Civilian Radioactive Waste Management be preserved in a reasonably accessible (electronic) form and recommends that the final Commission report address this important issue."

BRC Final Report to the Secretary of Energy

Following are comments from the Board's April 18, 2012, letter to Secretary Chu (Garrick 2012c) on the final BRC Report (BRC 2012).

- "Lessons learned from U.S. and international experience should be taken into account in developing guidelines, for siting, for the solicitation of volunteer sites, and for integrating the overall process. In particular, lessons learned from the failure of the Nuclear Waste Negotiator approach should inform any consent-based volunteer-siting process."
- "Because spent fuel and high-level wastes are quite different in volume and activity, we think that a technical study to determine whether to separate commercial spent fuel from defense and DOE waste should be expeditiously completed in order to help establish a clear vision and mission for the organization charged with implementing the waste storage and disposal program."
- "The bore-hole concept has simply not yet been vetted technically to the extent that deep-mined geological disposal has. Furthermore, the need to disassemble fuel assemblies to implement bore-hole disposal would result in unnecessary worker exposure, and a decision to use bore holes might preempt retrievability options at a later time."
- "From a technical point of view, the Board generally supports the development of underground research laboratories as a preliminary step in designing and constructing a full-scale geologic repository."
- "With the curtailment of the Yucca Mountain Project, the appeal for this interim step [consolidated storage] increases since it is not clear when a disposal site might be available."
- "In order to handle the massive shipments of spent fuel that will be involved and to implement the needed infrastructure in terms of rail cars and handling systems, work [on transportation] needs to be started now."
- "…we support the need to review the outdated waste classification system and make it based on the form and activity of the waste rather than its source."

Board Interactions with the Interested Public and with Radioactive Waste Management Programs in Other Countries

Interacting with the Public—An important fixture of each Board public meeting is the public comment session, where members of the interested public are invited by the Board to

comment and ask questions regarding the information presented at the meetings. Over the past 25 years, Board meetings have provided a unique forum for the public to interact directly with the Board and its staff; DOE program managers, scientists, engineers, and consultants; and other program participants. The public comments offered at the meetings are included in meeting transcripts, and written materials submitted by public commenters at Board meetings are included in the meeting records on the Board's website.

Interacting with SNF and HLW Programs in Other Countries—Since its inception, the Board has interacted in various ways with SNF and HLW management and disposal programs in other countries. The objective of these interactions has been to gain knowledge, perspective, and insights from the experiences of these programs that can enhance the Board's review of DOE activities. During the five years covered by this report, small delegations of Board members and staff visited SNF management programs in several countries, including Finland, France, Sweden, and the United Kingdom. The Board also hosted representatives of some programs when they visited the U.S. and included them in Board meetings, when appropriate.

During the five years covered by the report, Board Chairman B. John Garrick participated in several meetings of the Advisory Bodies to Government (ABG), which was established by the Organization for Economic Cooperation and Development's Nuclear Energy Agency. The ABG provides a forum that allows the chairs and assigned staff of organizations similar to the Board to exchange views informally. Currently, Chairs from the organizations in six countries (France, Germany, Sweden, Switzerland, the United Kingdom, and the United States) participate in the meetings, which are held approximately every 18 months.

Lessons Learned—Partly at the suggestion of a representative of an affected unit of local government during a public comment session at one of the Board's meetings, the Board held meetings in October 2010 and in February 2011, at which panels discussed potential "lessons learned" from the Yucca Mountain project and from the experiences of nuclear waste disposal programs in other countries (NWTRB 2010b and NWTRB 2011). The panels included former Yucca Mountain program managers, representatives of local governments and stakeholder groups, and representatives of international waste management and disposal programs. All materials and records related to these meetings are available on the Board's website.

Board Review of DOE Activities Related to Implementing the NWPA - Significant Issues

During the period covered by this report, the Board held 15 public meetings, at which DOE and its contractors presented their technical and scientific work related to implementing the NWPA. A chronological listing of the meetings can be found in Appendix F.

As discussed earlier, until 2010, DOE's SNF and HLW R&D focused primarily on activities and investigations related to supporting a Yucca Mountain license application. After 2010, much of the R&D undertaken by DOE transitioned to generic studies, including investigations of different geologic media. The Board's technical and scientific review of DOE's work continued through this transition.

In accordance with established practice and to ensure the timeliness of Board comments, after every public meeting the Board sends follow-up correspondence to DOE, which

includes comments and recommendations on DOE activities discussed at the meetings. Board correspondence with DOE from January 1, 2008, through December 31, 2012, is included in Appendix G. Significant Board comments from some of these follow-up letters have been organized according to technical and scientific topic and are summarized in the following sections.

Yucca Mountain

Total System Performance Assessment (TSPA)—The Board made the following comments on TSPA assumptions, methods, and results in a letter to DOE in September 2008 (Garrick 2008d):

- DOE analyses show that the engineered barrier system contributes very significantly to overall repository performance.
- DOE sometimes uses what it considers conservative assumptions about the features or processes being modeled while taking an opposite approach in other instances.
- Assumptions and methods in TSPA-LA are not consistently well supported.

In the same letter, the Board made the following recommendations for enhancing confidence in the assumptions, methods, and results supporting TSPA-LA:

1. The technical basis for screening out deliquescence-induced localized corrosion should be improved.
2. Prototypes of novel engineered systems should be developed.
3. Fundamental understanding of the geologic environment should be enhanced.

DOE responded to the Board's recommendations in a letter to the Board in September 2008 (Sproat 2008b), stating that the Yucca Mountain license application had been docketed with NRC, and from that point, DOE "does not intend to formally respond to issues regarding the [license application] raised by the NWTRB or others outside the context of the licensing proceeding." Chairman Garrick responded to DOE (Garrick 2008e) by clarifying the Board's statutory mandate, which requires the Board to continue its technical and scientific evaluation of DOE activities until no later than one year after the date on which DOE begins disposing of SNF and HLW in a repository. Dr. Garrick went on to state that "the Board's responsibilities under the law require it to continue its evaluation of the technical and scientific validity of the full range of activities undertaken by the Secretary of Energy to implement the Nuclear Waste Policy Act and its amendments."

Drip Shield Performance—The drip shields, which would be placed over and around waste packages to divert water and deflect rock fall, are an important part of the engineered barrier system for a Yucca Mountain repository. In an August 2009 letter to Secretary Chu (Garrick 2009c), the Board noted that DOE had not developed prototypes for equipment that would emplace, monitor, inspect, adjust, or, if necessary, retrieve the drip shields. The Board recommended developing prototypes for the drip shields and for the equipment that would be used to install and maintain them. The Board also told DOE that the cumulative effects of modeling assumptions in the license application "may result in a lack of realism about how barriers and waste would behave in a repository." The Board urged DOE to develop more realistic models.

Thermal-Loading Strategy—The thermal-loading strategy for the Yucca Mountain repository also has important implications for repository capacity and performance. In reviewing DOE's repository design, the Board observed in a letter to DOE in April 2008 (Garrick 2008b) that a better justification was needed for the thermal limits established by the program. The Board recommended that DOE investigate the feasibility and technical advantages of determining thermal limits at repository closure and varying the duration of ventilation accordingly.

Emplacement Drift Stability—The Board pointed out in its April 2009 letter to DOE (Garrick 2009a) that the lithophysal tuff, in which 85 percent of the repository emplacement drifts would be located, contains cavities that are highly heterogeneous in size and spatial distribution. The other 15 percent of the repository rock appeared to be stronger, more uniform, and better characterized. Testing being done by DOE at the time was in non-representative intact lithophysal rock, not in rock with abundant fracturing, typical of the rock in the emplacement zone. The Board recommended conducting full-scale or near-full-scale thermomechanical testing of fractured lithophysal tuff to help validate models and estimates. In a June 2009 response to the Board, DOE disagreed with the value of full-scale testing, stating that "existing data and models provide conservative estimates of the drift response."

Deliquescence-Induced Localized Corrosion of Repository Waste Packages—In a letter to DOE sent in 2007 (Garrick 2007), the Board had raised concerns about the potential for deliquescence-induced localized corrosion of the repository waste packages after they were emplaced in the repository. DOE presented its latest work on this issue at a Board meeting held January 16, 2008 (Russell 2008). In a follow-up letter to DOE (Garrick 2008b), the Board said that it continued to have questions about the technical basis for DOE's decision to exclude deliquescence-induced localized corrosion from the TSPA and recommended, among other things, that DOE improve its understanding of the evolution of the waste package environment.

Waste Package Closure—In an April 2009 letter to DOE (Garrick 2009a), the Board noted that development of a complex prototype system for closure of a loaded waste package was being studied at the Idaho National Laboratory. The Board asked for more information on the potential advantages of evacuating and filling the inner waste packages with an inert gas and pointed out that tolerances between the lid and the waste package seemed very tight. DOE acknowledged in a June 2009 response to the Board (Kouts 2009b) that this was an important technical issue.

Dual-Purpose Canisters (DPCs) —The Board commented in a letter to DOE (Garrick 2009a) that, based on information provided by the Electric Power Research Institute in a presentation at the Board's January 2009 meeting (Machiels 2009), it appeared that the potential for criticality of some or many of the already loaded dual-purpose canisters (DPCs) may be low enough to permit direct disposal in a repository. The presentation also indicated that criticality potential could be reduced and shielding could be improved by placing more reactive fuel assemblies in the periphery of the DPC. However, such loading could increase temperatures at the DPC centerline. The Board recommended that, when funding would permit, DOE should investigate direct disposal of DPCs because transferring SNF into transportation, aging, and disposal (TAD) canisters would require cutting open the DPCs and repackaging the waste.

In an August 2009 letter to Secretary Chu (Garrick 2009c), the Board called attention to the fact that while DOE had contracted with cask manufactures to develop designs for TAD canisters, nuclear utilities were using dry-storage canisters that held significantly more SNF and produced a higher heat load than intended for TAD canisters, and the trend was for the capacity of the dry-storage canisters to increase in the future. The Board recommended consideration of direct disposal of loaded dry-storage dual-purpose canisters, noting that direct disposal would require full burnup credit and an increase in the diameter of TAD canisters.

Surface-Facility Design—In commenting on DOE's work related to Yucca Mountain surface-facility designs (Garrick 2008f), the Board observed that DOE had not provided clear explanations of the following:

- Why surface facilities were designed with four-foot-thick walls
- The percentage of completeness, at the time, of the facility designs
- How the SNF-pool cooling and cleanup systems would operate

Moreover, many of the design elements appeared to be non-standard, suggesting that in designing the system, DOE had not benefited from the experience of the nuclear industry. The Board recommended reevaluating the seismic aspects of the design basis for consistency with commercial nuclear facilities and addressing what appeared to be excessively robust design of facilities that would not need to be operational over periods of hundreds of thousands of years.

In a February 2009 response to the Board (Kouts 2009a), DOE pointed out that nuclear facility structures must meet two requirements: (1) code requirements for seismic forces resulting from design-basis ground motion, and (2) design margins adequate to meet performance requirements of 10 CFR Part 63, *Disposal of High-level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada*, for ground motions beyond design basis.

Surface Facility Throughput—In a letter to DOE (Garrick 2008b), the Board noted that in analyzing the throughput of repository surface facilities, DOE assumed that loaded transportation casks and empty waste packages would be available on-demand and that empty transportation casks and loaded waste packages could be moved efficiently through the system. However, the Board said that the availability of these containers likely will fluctuate for various reasons. The Board suggested that more realistic modeling assumptions and a more integrated analysis might show that additional transportation equipment and surface facilities, including aging pads, would be required to achieve the desired throughput. The Board added that confidence in the performance of surface facilities could be enhanced by analyzing the performance of surface facilities under conditions of minimum capacity and maximum rate of receipt to test operations under stress. DOE responded in a letter to the Board (Sproat 2008a) that DOE had included operational and design contingencies to account for uncertainties in the mix of TAD-canistered to non-TAD canistered SNF. DOE went on to say that options similar to those raised by the Board had been assessed, and the conclusion was that the proposed facilities are expected to meet DOE's operational requirements.

The Board's views were reiterated in a November 2008 letter to DOE (Garrick 2008f), in which the Board suggested that additional conditions should be evaluated, such as

- Delays in the construction of the rail line from Caliente to Yucca Mountain
- Delays in the deployment of TAD canisters beyond 2013
- The possibility that less than 90 percent of SNF would arrive in TAD canisters
- Seasonal variations in the receipt rate of SNF
- Delays in the receipt of DOE waste, or not receiving DOE waste in the order needed
- Less than 75 percent of the surface facilities being available
- Occurrence of upset conditions in any part of the system
- Utility sites lacking usable rail access
- Need to accommodate SNF in storage
- Potential disposal of SNF in dual-purpose casks

DOE responded in a February 2009 letter (Kouts 2009a) that prototyping had or would be done on waste packages and associated equipment, the waste package closure system, and the dual-purpose cask-cutting machine.

Construction of a Rail Spur to Yucca Mountain—In an April 2008 letter to the Board (Sproat 2008a), DOE said that the most practicable solution for SNF transportation in Nevada was expeditious development of a new rail line. In an April 2008 letter to DOE (Garrick 2008b), the Board reiterated a previous recommendation that DOE should initiate contingency planning to identify alternatives to rail transport that could be implemented if significant delays were encountered during construction of the rail spur.

DOE Preservation of Yucca Mountain Data and Documents—After funding for Yucca Mountain was eliminated and DOE notified NRC of its intention to withdraw the Yucca Mountain license application, responsibility for archiving and preserving Yucca Mountain scientific and engineering information passed to DOE's Office of Legacy Management. The Board's review of the resulting DOE activities started in 2010 as part of the Board's ongoing evaluation of DOE activities and continued at the direction of the House Appropriations Committee (U.S. House 2011). DOE updated the Board on its legacy management activities at a Board meeting held in September 2011 (Parks 2011). The Board's review of these DOE activities included visits to DOE facilities in Las Vegas, Nevada, and a "spot check" retrieval exercise at the DOE Legacy Management facility in Morgantown, West Virginia, in August 2012.[3]

Generic Investigations and Analyses

Deep Geologic Disposal—In a March 2012 letter to DOE following its January 9, 2012, public meeting (Garrick 2012b), the Board reiterated its concurrence with the finding that deep geologic disposal continues to be the most promising and accepted method currently available for safely isolating SNF and HLW. Given this, the Board recommended that DOE initiate the following actions without delay:

- Development of generic site-selection criteria

[3] The Board's report on DOE's work in this area was released in August 2013. The report will be discussed in a subsequent summary report of Board activities.

- Development of a realistic understanding of the source term
- Because of the prospect of extended storage of SNF, development of a better understanding of fuel-degradation mechanisms, especially for high-burnup fuel

Generic Research on Disposal Options—At a Board meeting held in September 2011, DOE presented its plans, based on systems engineering techniques, for studying disposition options, including deep-mined geologic repositories in salt, granite, and clay/shale formations and deep borehole disposal (Swift 2011). In a follow-up letter sent in December 2011 (Garrick 2011h), the Board acknowledged DOE's efforts and urged DOE to strengthen its interactions with SNF and HLW management programs in other countries to take advantage of the wealth of relevant information that had been amassed and to avoid duplicating the research of other programs.

Salt Disposal Investigations with a Field-Scale Heater Test at the Waste Isolation Pilot Plant—In a January 2012 letter (Garrick 2012a), the Board told DOE that it supported generic R&D tasks in the context of geologic repository program development, as long as they are (1) based on realistic concepts of host rock geology; (2) focused on identifying and evaluating significant features, events, and processes and their constitutive relationships; and (3) shown to reduce uncertainties and adverse risk related to generic technical and scientific objectives. In terms of the Salt Disposal Investigations proposal that had been prepared by DOE and issued in June 2011, the Board noted that the proposal did not specify the basis for the proposed work. Instead, the proposal identified gaps in experimental work and modeling and proposed R&D activities that did not appear to be ranked by their importance in meeting generic repository objectives. The Board said that not presenting an explicit evaluation of generic salt information needs in the context of a relevant uncertainty and risk assessment was a significant shortcoming of the proposal. Following are some additional points from the letter:

- It was difficult to assess the importance of work in salt compared with work in other geologic media without knowing the basis for the selection of salt. The Board could not make a proper evaluation of the salt proposal without knowing what alternatives were under consideration.
- It was unclear whether the proposed tests at the Waste Isolation Pilot Plant (WIPP) were intended to investigate the suitability of generic salt as a repository medium or the potential of bedded salt for such a purpose. In either case, the proposal should also provide the technical basis for performing the proposed testing at WIPP.

Fuel Disposition Program—The Board wrote to DOE in October 2010, following up on the Board's June 2010 meeting (Garrick 2010a). The Board said in the letter that as DOE developed its Used Fuel Disposition Program, it should consider an approach similar to one established in 2003 by DOE to develop scientific and technical information. The Science and Technology program assembled several teams of highly qualified engineers and scientists who, until the program was terminated, produced significant results. The Board said that a similar effort was needed for the Fuel Disposition Program because the scope of scientific and technical options had grown. The Board noted that the success of such an effort depended on continuity in leadership and funding.

Canister and Waste Package Temperatures—Waste package temperatures were discussed at a meeting of the Board held in October 2012, in Idaho Falls, Idaho. At that meeting, there was discussion of an "open" repository design that would allow for ventilation of the repository drifts containing the waste packages in order to remove some heat before repository closure. The presentations at the meeting indicated that there might be more flexibility than previously assumed in waste-package sizes (Adkins 2012 and Hardin 2012b). The Board recommended in a December 2012 letter to DOE (Ewing 2012b) that this work should continue.

Deep Borehole Disposal—At the Board's February 2011 meeting, DOE provided information supporting the case that many geologic media in the United States would be suitable for geologic disposal (Hardin 2011). Also discussed was potential testing of deep borehole disposal as an option for some waste, including field investigations, a test drilling program, and emplacing surrogate SNF and HLW in a borehole (Brady 2011, Hardin 2011, and Orrell 2011). In a letter to DOE following the meeting (Garrick 2011e), the Board said that if such a testing program were to go forward, it should be coupled with a program for developing the appropriate facility designs and evaluating the necessary operational requirements for a deep borehole disposal program. The Board asked for more information on DOE's deep borehole disposal activities and other geology-specific disposal programs that were under consideration. The Board was particularly interested in work directed at optimizing the characteristics of the waste forms intended for disposal in specific geologic media. In a December 2011 follow-up letter to DOE on information presented at a September 2011 Board meeting (Garrick 2011h), the Board said that in establishing research priorities, "when compared with mined deep geologic disposal, the development of deep borehole disposition as a potential waste management option should be given a lower priority."

In a March 2012 letter to DOE (Garrick 2012b), the Board noted that it had on several occasions recommended that consideration be given to different methods of geologic disposal for different high-activity waste, such as minor actinides or vitrified fission products, which have no apparent value for reuse. However, the Board acknowledged that there might be significant complications associated with using deep borehole disposal for other wastes. For example, current technology would require SNF to be repackaged into small-diameter containers that would fit the borehole. The Board said that the increased handling of SNF would be, at best, "highly undesirable." The Board made the following comment: "In the Board's view, research related to deep borehole disposal should not delay higher priority research on a mined geologic repository. However, if that condition can be met, the Board believes that DOE should continue its research on deep borehole disposal. This information would provide a realistic basis for comparison with other geologic disposal options."

Suitability of Yucca Mountain Canisters for Other Geologies—In a letter to DOE in October 2010 (Garrick 2010b), the Board recommended that studies be undertaken to determine whether the packaging developed for a Yucca Mountain repository would be suitable for other geologies. The Board suggested that DOE look at work already underway or completed in the U.S. and in other countries.

Repackaging of SNF—This subject was discussed in a presentation at a meeting of the Board on January 9, 2012 (Hardin 2012a and Williams 2012). In its March 2012 letter to DOE following the meeting (Garrick 2012b), the Board noted that the presentations con-

veyed an essential message: "Decisions about waste packaging and storage that have been or are being taken may have a profound effect on repository design." The Board recommended that DOE consider the existing and expected inventory of SNF in storage as a waste form that needs to be disposed of in a geologic repository.

SNF and HLW Storage and Transportation

Modeling the Transportation System—Questions raised by stakeholders and the interested public at the Board's October 2012 meeting in Idaho Falls, Idaho, made clear that transportation of SNF and HLW remained a major concern. In the Board's December 2012 letter to DOE following the meeting (Ewing 2012b), the Board said that the transportation modeling results presented by DOE at the meeting did not reflect possible upset conditions or the possibility of transportation to multiple sites. The Board urged DOE to attach a high priority to ensuring that cask licenses and yet-to-be-fabricated casks would be available to support DOE's transportation requirements and schedule.

Very Long-Term Dry Storage of SNF—The Board held a meeting in June 2009, at which it invited a panel of experts to discuss research and data needs for extended (120 years or more) dry storage of SNF (NWTRB 2009a). In a letter to DOE Secretary Steven Chu following the meeting (Garrick 2009c), the Board noted that extended dry storage of SNF and HLW was likely, and there appeared to be no technical factors that would prevent designing and safely operating dry-storage systems for decades, providing that there is regular monitoring. However, it was not clear at that time whether a technical basis existed for operating dry-storage systems for very long periods. On the basis of discussions among panelists at the meeting, the condition of the SNF in dry-storage canisters appeared to be the most important factor to be considered in analyzing the effects of extended storage because the SNF must be shipped, possibly repackaged, and eventually disposed of (or reprocessed) after a long period in dry storage. Addressing this issue is complicated by the situation in the U.S. where experience is limited to the examination of a few fuel assemblies with burnups that are significantly lower than current practice.

In an October 2010 letter to DOE (Garrick 2010a), the Board recommended studies to identify necessary actions for preventing problems during transportation, repackaging, or disposal of DOE SNF following extended storage.

In December 2011, the Board commented in a letter to DOE (Garrick 2011g) on DOE's draft *Gap Analysis to Support Extended Storage of Used Nuclear Fuel* issued June 30, 2011. In particular, the Board was interested in learning more about why the delayed hydride cracking degradation mechanism was designated in the Gap Analysis as a medium and not a high research priority. Among other things, the Board underscored the need to carry out additional cask-demonstration and fuel-inspection projects and recommended characterizing SNF before dry storage to establish a baseline, against which to monitor changes in fuel condition during storage. The Board recommended opening representative casks periodically to identify changes from the baseline conditions and encouraged DOE to take advantage of similar work being done in other countries. The Board also supported research by DOE to quantify the amount of residual water that remains in casks after drying and to develop new monitoring instrumentation.

In a letter following its September 2011 meeting (Garrick 2011h), the Board raised additional issues that it believed needed to be addressed related to DOE's studies on extended storage and subsequent transportation of SNF and HLW, including:

- The potential that operations might be undertaken today that would limit future options in managing SNF and HLW.
- The dose and cost implications of needing to repackage SNF.
- The implications of requiring early removal of SNF from reactor storage pools in response to concerns caused by the events at Fukushima Daiichi in March 2011.

Nuclear Fuel Cycle

Implications of Fuel-Cycle Technology for Waste Management—At a Board meeting held in February 2011, DOE presented its plans for R&D on fuel-cycle technology that would be undertaken by DOE's Office of Nuclear Energy (Boyle 2011 and Regalbuto 2011). In a follow-up letter (Garrick 2011e), the Board noted its particular interest in the implications of these studies for SNF management and disposal, including the effects on the quantities and volumes of waste that would be generated. The Board was especially interested in DOE's work on the "once-through" fuel cycle and limited recycling because other options "do not appear to have the potential to be deployed in the next few decades."

At a meeting held in Arlington, Virginia, in January 2012, the technical and institutional complexities of integrating activities throughout the nuclear fuel cycle were presented by DOE (Regalbuto 2012 and Wigeland 2012). In a March 2012 letter to DOE following up on that meeting (Garrick 2012b), the Board strongly encouraged DOE to work with nuclear utilities in developing approaches for managing the storage and disposal of SNF and HLW to ensure that "pieces" of the strategy work together. The Board noted concerns with a comprehensive fuel-cycle evaluation project that was in the early stages:

- There seems to be a risk that comprehensiveness will be purchased at the price of relevance.
- Simplifying the analysis would have the added benefit of increasing the timeliness of the results of the analysis.
- Methodological challenges to carrying out this type of evaluation are significant.
- Only a very abbreviated description of the study was available publicly.
- The conclusions of the study should not go beyond what can be reasonably and conservatively inferred.

Disposal and Management of DOE SNF and HLW

Implications of Delay in Repository Development—Following its June 2010 meeting, the Board wrote to DOE (Garrick 2010b) recommending that as-built lifetimes (as opposed to design lifetimes) of SNF dry-storage systems at the Idaho National Laboratory should be assessed with the understanding that a date for constructing a repository or storage facility had not been established and that that uncertainty could continue well into the future.

The Board noted in a July 2011 letter following an April 2011 meeting at the West Valley Demonstration Project (WVDP) (Garrick 2011d) that a key assumption in disposing of the vitrified waste at WVDP was that a Yucca Mountain repository would be available to take the waste at a time within the facility planning horizon. A repository other than Yucca Mountain might have trouble accepting the five- and seven-canister multiple purpose casks, which were planned for use at West Valley. The Board recommended that the

WVDP maintain flexibility in its relocation project to adapt to future changes in repository design and schedule.

Integration and Sharing of Program Data—The Board has always placed a high priority on integration of information among entities that are part of the waste management system. After the Board's visit to WVDP in April 2011, in a letter to DOE (Garrick 2011d) the Board invited a representative from the WDVP to participate in a later Board meeting, at which procedures in place at DOE's Office of Environmental Management for preserving and sharing information would be discussed. The Board emphasized the importance of sharing decommissioning information among facilities across the DOE complex. The Board recommended that the DOE Office of Nuclear Energy and the DOE Office of Environmental Management share such information.

Calcined Wastes—The Board noted in a letter following up on its June 2010 meeting in Idaho (Garrick 2010b) that the design lifetime of 500 years for storing solid granular calcined waste in shielded bins made of ferrous alloys and concrete was unprecedented. The Board recommended examining in detail the technical basis for the lifetime estimate associated with the design. DOE chose hot isostatic pressing as a treatment method for the calcine before it was transported off site. A key technical assumption affecting this decision was that treated calcine would be loaded into canisters that were 2 feet in diameter by 10 or 15 feet long. These canisters would be loaded into TAD canisters. This assumption could increase the number of containers requiring storage, transportation, and disposal. It was not clear from DOE presentations whether the operational risks of alternative treatment options were compared or if probabilistic risk assessments were performed on the safety of alternatives after disposal in a repository. The Board recommended another cost comparison to take into account technical assumptions and operational risks of various treatment options.

Sodium-Bearing Waste—The Board suggested in its October 2010 letter to DOE (Garrick 2010b) that a risk assessment could help determine whether sodium-bearing waste (SBW) is a high-level radioactive waste. In the same letter, the Board concurred with DOE that changing SBW from a liquid to a solid waste was necessary. In another letter on this subject sent to DOE in December 2012 (Ewing 2012a), the Board stated that, at that time, it had no technical reason to question DOE's decision to manage SBW as transuranic-contaminated (TRU) waste. Because TRU waste falls outside the Board's statutory purview, the Board indicated it would not comment on the execution of DOE's plan to process SBW. The Board recommended that DOE formalize the classification of the material before processing it and noted that if the designation should change in the future, it might be necessary to dispose of SBW as HLW. The Board asked to be kept informed of that eventuality.

Management and Disposal of Melter from WVDP—In a July 2011 letter to DOE following its April 2011 meeting (Garrick 2011d), the Board noted that DOE had issued a draft determination in March 2011 that the melter from the vitrification plant at WVDP could be managed and disposed of as low-level waste. The Board observed that this determination could set a precedent for the disposal of melters at Hanford and the Savannah River Site and recommended that DOE take this into account in finalizing the determination.

Future Plans

Since the end date of this report, the Board has actively continued its evaluation of DOE activities and of issues related to SNF and HLW management and disposal, including the preservation of Yucca Mountain data and documents, factors affecting deep borehole disposal, the implications of the continued dry storage of commercial SNF in large canisters at U.S. nuclear utility sites, and the management of DOE SNF that will require disposal. The Board will provide its findings, conclusions, and recommendations on these and other issues in upcoming reports to the U.S. Congress and the Secretary of Energy.

Abbreviations and Acronyms

ABG	Advisory Bodies to Government
Board	U.S. Nuclear Waste Technical Review Board
DOE	U.S. Department of Energy
DPC	dual-purpose canister
FEDCORP	Federal Corporation
HLW	high-level radioactive waste
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
NWPAA	Nuclear Waste Policy Amendments Act
NWTRB	U.S. Nuclear Waste Technical Review Board
OCRWM	DOE Office of Civilian Radioactive Waste Management
SBW	sodium-bearing waste
SDI	Salt Disposal Investigations
SNF	spent nuclear fuel
TAD	transportation, aging, and disposal canister
TSPA	Total System Performance Assessment
TSPA-LA	Total System Performance Assessment – License Application
TRU	transuranic waste
WIPP	Waste Isolation Pilot Plant
WVDP	West Valley Demonstration Project

Glossary of Terms

back end of the nuclear fuel cycle All activities related to processing, storage, and/or final disposal of spent nuclear fuel and high-level radioactive wastes.

bomb-pulse chlorine-36 See **chlorine-36**.

Blue Ribbon Commission on America's Nuclear Future (BRC) A temporary commission formed by former Secretary of Energy Steven Chu to (1) review policies for managing the back end of the nuclear fuel cycle and (2) recommend a new strategy.

branch line A secondary railway line, which branches off a more important through route, usually a main line. A very short branch line may be called a spur line.

burnup A measure of reactor fuel consumption expressed as the percentage of fuel atoms that have undergone fission, or the amount of energy produced per unit weight of fuel.

calcination A process of drying and heating substances in air to sufficiently high temperatures so that oxides of the constituents are produced. A technique usually employed for processing of residues from evaporation of liquid wastes.

calcine A general term for the granular, dehydrated ceramic powder created when high-level radioactive waste and certain chemical additives are heated to a high temperature in air.

chlorine-36 (36Cl) A long-lived radioactive isotope of chlorine produced by irradiation of natural chlorine, argon, or other materials by cosmic rays or neutrons. Atmospheric testing of nuclear weapons in the 1950s temporarily increased concentrations of chlorine-36 in the area of the tests. The resulting "bomb-pulse" levels of chlorine-36 can sometimes serve as a tracer to determine how rapidly precipitation from the 1950s has moved through soil and rocks, such as those present at Yucca Mountain.

clay Sediment composed of rock or mineral fragments smaller than 4 microns. Also, the geological strata formed from such sediments. Clays typically have relatively low permeability and relatively high capacity for sorption of positively charged chemical species.

conservative estimates Projections of repository performance using parameters and models that systematically underestimate the system's ability to isolate and contain waste.

Construction Authorization Board (CAB) A Board established by the Nuclear Regulatory Commission to preside over petitions to intervene and requests to participate in the Yucca Mountain licensing proceeding.

corrosion Progressive surface dissolution of a material, generally metal. In radioactive waste management, it is also used for glasses and ceramic waste forms. Corrosion can be uniform over the surface of the material or non-uniform through enhanced corrosion in stressed areas at physical discontinuities. Selective localized formation of rounded cavities on the surface is called pitting corrosion.

criticality A reactor achieves criticality (and is said to be critical) when each fission event releases a sufficient number of neutrons to sustain an ongoing series of reactions. In nuclear waste management, criticality refers to the probability and circumstances under which a quantity of waste could achieve criticality.

decommissioning Administrative and technical actions taken to remove nuclear fuel and radioactive material from a facility and to allow the removal of some or all of the regulatory controls. This does not apply to a repository or to certain nuclear facilities used for mining and milling of radioactive materials, for which the term "closure" is used.

deliquescence The absorption of atmospheric water vapor by a solid salt to the point where the salt dissolves into a saturated solution.

drift An underground opening or tunnel that is used for access/egress, to facilitate repository construction, ventilation, and transportation and emplacement of nuclear waste.

drip shield Barriers placed over and around waste packages to divert water from the packages and deflect falling rocks from impacting the waste package.

dry-cask storage system Any system that uses a cask or canister as a component in which to store spent nuclear fuel without using water to remove decay heat. A dry-cask storage system provides confinement, radiological shielding, physical protection, and inherently passive cooling of the spent nuclear fuel.

dual-purpose canister (DPC) A transportable storage cask, which has been licensed for the storage and transportation of spent nuclear fuel by the Nuclear Regulatory Commission.

engineered barrier system The designed, or engineered, components of a repository, including waste packages and other engineered barriers.

features, events, and processes (FEPs) Used in the field of radioactive waste management to define relevant scenarios for safety assessment studies.

FEDCORP A self-sustaining, quasi government entity that would manage the federal government's responsibilities for managing and disposing of spent nuclear fuel and high-level radioactive waste.

field-scale heater test Large-scale tests that use electric heaters to simulate nuclear waste canisters.

fuel cycle All operations associated with the production and use of nuclear fuel, including mining and milling, processing and enrichment of uranium or thorium, manufacture of nuclear fuel, operation of fuel in nuclear reactors, reprocessing of nuclear fuel, related research and development activities, and all activities related to radioactive waste management, including disposal.

geologic repository A facility for disposing of radioactive waste located underground (usually several hundred meters or more below the surface) in a geologic formation intended to provide long-term isolation of radionuclides from the biosphere.

geotechnical engineering The branch of civil engineering concerned with the engineering behavior of earth materials.

granite Broadly applied, any holocrystalline quartz-bearing plutonic rock. The main components of granite are feldspar, quartz, and as a minor essential mineral, mica.

Hanford A 586-square-mile site located in southeastern Washington state. Beginning in 1943, the site was used to produce plutonium for the Manhattan Project and later for other weapons. The last reactor at the site ceased production in 1987, but solid and liquid wastes from weapons-production processes remain at the site. In 1989, the U. S. Department of Energy, the U.S. Environmental Protection Agency, and Washington State Department of Ecology entered into a legally binding accord, the Tri-Party Agreement (TPA), with the objective of cleaning up the Hanford site.

heterogeneous A quantity of material that is non-uniform and may consist of dissimilar or diverse ingredients or constituents.

high-burnup fuel Reactor fuel with burnups exceeding 45 GWd/MT.

high-level radioactive waste (HLW) Highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly from reprocessing and any solid material derived from such liquid waste that contains fission products in concentrations above levels specified in regulations. Any other highly radioactive material that the Nuclear Regulatory Commission, consistent with existing law, determines requires permanent isolation by disposal in a geologic repository.

hot isostatic pressing (HIP) A process that is generally used to reduce the porosity and increase the density of metal and ceramic materials during manufacturing, including the consolidation of metal powders and ceramic composites. HIPping has been selected as the means to stabilize and reduce the volume of high-level waste calcine, where calcined waste is retrieved, mixed with suitable additives, canistered, then heated and pressed in the container to form a ceramic-like material. The resulting waste form is expected to be equivalent to vitrified waste and potentially acceptable as a waste form for disposal in a geologic repository.

Idaho National Laboratory (INL) A science-based, applied engineering national laboratory located on an 890-square-mile complex in Southeastern Idaho that supports the U.S. Department of Energy's missions in nuclear and energy research, science, and national defense.

license An authorization issued by a regulatory body granting permission to perform specified activities related to a facility or an activity. The holder of a current license is termed a "licensee."

license application A document submitted to the Nuclear Regulatory Commission containing general information and a safety analysis for certain nuclear facilities such as a nuclear power plant, a geologic repository, or a spent-fuel storage facility. A license application must be approved before the facility is constructed and before it can be operated.

light water reactor A common type of thermal-neutron reactor that uses normal water, as opposed to heavy water, as both coolant and neutron moderator; a solid form of fissile elements is used as fuel.

lithophysae Cavities in silicic volcanic rock that are formed soon after the volcanic rocks are deposited because of the presence of vapors under very high pressure.

National Academy of Sciences (NAS) A private, non-profit society of distinguished scholars. Established by an Act of Congress in 1863, and charged with providing independent, objective advice to the nation on matters related to science and technology. Scientists are elected by their peers to membership in the NAS.

natural barriers Attributes of the earth that tend to isolate radionuclides from the human-accessible environment.

Nuclear Regulatory Commission (NRC) A federal agency headed by a five-member Commission, that formulates policies and regulations governing nuclear facilty and materials safety, issues orders to licensees, and adjudicates legal matters brought before it.

Nuclear Waste Assessment System for Technical Evaluation (NUWASTE) A computer-based, systems analysis tool developed by the U.S. NWTRB to evaluate the types and quantities of radioactive waste streams that would be generated by various fuel-cycle options considered by the U.S. Department of Energy.

Nuclear Waste Policy Act (NWPA) The federal statute enacted in 1982 that established the Office of Civilian Radioactive Waste Management and defined its mission to develop a federal system for the management and geologic disposal of commercial spent nuclear fuel and other high-level radioactive wastes, as appropriate. The Act also specified other federal responsibilities for nuclear waste management, established the Nuclear Waste Fund to cover the costs of geologic disposal, and defined interactions between federal agencies and the states, local governments, and Native American Tribes.

Nuclear Waste Policy Amendments Act (NWPAA) The federal statute enacted in 1987 that amended the Nuclear Waste Policy Act by limiting repository site-characterization activities to Yucca Mountain, Nevada; establishing the Office of the Nuclear Waste Negotiator to seek a state or Native American Tribe willing to host a repository or monitored retrievable storage facility; creating the Nuclear Waste Technical Review Board; and increasing state and local government participation in the waste program.

Office of Civilian Radioactive Waste Management (OCRWM) An office in the U.S. Department of Energy established in the Nuclear Waste Policy Act to carry out the responsibilities of the Secretary of Energy under the Act.

Office of Environmental Management (DOE-EM) An Office in the U.S. Department of Energy with the mission of completing the safe cleanup of the environmental legacy of five decades of nuclear weapons development and government-sponsored nuclear energy research.

Office of Nuclear Energy (DOE-NE) An Office in the U.S. Department of Energy with the primary mission of advancing nuclear power as a resource capable of meeting the Nation's energy, environmental, and national security needs by resolving technical, cost, safety, proliferation resistance, and security barriers through research, development, and demonstration, as appropriate. When funding for the Office of Civilian Radioactive Waste Management was terminated in 2010, the Office of Nuclear Energy was assigned many of the responsibilities previously held by OCRWM for implementing the Nuclear Waste Policy Act.

Office of the Nuclear Waste Negotiator A federal agency created in the 1987 amendments to the Nuclear Waste Policy Act. The Negotiator was given authority by Congress to search the country for willing hosts for facilities to store or dispose of spent nuclear fuel and high-level radioactive waste. Funding for the agency was eliminated by Congress in 1995.

performance assessment An assessment of the performance of a system or subsystem and its implications for protection and safety at a planned or authorized facility. Differs from safety assessment in that it can be applied to parts of a facility, and it does not necessarily require assessment of radiological impacts.

Probabilistic Risk Analysis A simulation of the behavior of a system defined by parameters, events, and features whose values are represented by a statistical distribution. The analysis gives a corresponding distribution of results.

radiation source term The radiation "source term" sets the boundary condition for assessing the containment capability of the undisturbed geology in a repository system. Knowing the source term accurately is beneficial for properly assessing the performance of a repository and the potential radiation dose to the public.

radioactivity The spontaneous transformation of one radioisotope into one or more different isotopes (known as "decay products" or "daughter products"), accompanied by a decrease in radioactivity (compared to the parent material). This transformation takes place over a period of time (defined by the "half-life"), as a result of electron capture; fission; or the emission of alpha particles, beta particles, or photons (gamma radiation or x-rays) from the nucleus of an unstable atom. Each isotope in the sequence (known as a "decay chain") decays to the next until it forms a stable end product.

rail spur See **branch line**.

regulator An entity or a system of entities designated by the government of a nation as having legal authority for conducting the regulatory process, including issuing authorizations, and thereby for regulating the siting, design, construction, commissioning, operation, closure, decommissioning, and, if required, subsequent institutional control of nuclear facilities or specific aspects of nuclear facilities.

research and development (R&D) Activities whose primary function is to discover and create new knowledge about scientific and technical topics.

safety assessment An assessment of the performance of an overall system and its impact, where the performance measure is radiological impact or some other measure of impact on safety.

safety case An integrated collection of arguments and evidence for demonstrating the safety of a facility. The safety case will typically include a safety assessment, but could also include independent lines of evidence and reasoning on the robustness and reliability of the safety assessment and the assumptions.

salt formation A geologic formation resulting from the evaporation of sea water. Salt formations occur as bedded or domal (salt dome) deposits. In a bedded formation, the salt formation is similar in shape to when it was deposited. A salt dome results from uplift within a bedded salt formation.

Savannah River Site (SRS) A 310-square-mile nuclear reservation located in the state of South Carolina, built during the 1950s to produce and process nuclear materials for deployment in nuclear weapons. The major focus of the site is cleanup of the nuclear activities previously undertaken there.

seismic Pertaining to an earthquake or earth vibration.

shale A consolidated clay rock that possesses closely spaced, well-defined layers.

s**odium-bearing waste (SBW)** A mixed hazardous, radioactive waste generated as a by-product of spent nuclear fuel reprocessing at the Idaho Nuclear Technology and Engineering Center on the Idaho National Laboratory site. The waste is composed primarily of decontamination solutions used over the years in support of operations, but includes small fractions of first-, second-, and third-cycle extraction wastes from fuel reprocessing. The acidic wastes are relatively high in sodium and potassium from the decontamination solutions, thus the name "sodium-bearing waste." Sodium-bearing waste is high in transuranics, but has significantly less fission product activity than calcine derived from first-cycle raffinate (waste solution).

spent nuclear fuel (SNF) Nuclear fuel removed from a reactor following irradiation that is not intended for further use in its present form because of depletion of fissile material, buildup of poison, or radiation or other damage.

thermal management strategy A plan for maintaining the temperatures of the waste form, the cooling system, the facility, and the natural and engineered barrier systems within design limits.

thermal pulse The period of approximately one thousand years immediately following repository closure during which temperatures on the waste package surface can rise to more than 150°C, according to the Department of Energy's repository design for Yucca Mountain.

thermomechanical analysis A technique used in thermal analysis, a branch of materials science, which studies the properties of materials as they change with temperature.

Total System Performance Assessment (TSPA) Term used by the U.S. Department of Energy to describe the particular performance assessments conducted to determine whether a Yucca Mountain repository would comply with the relevant regulatory requirements for waste isolation and containment and protection of human health.

transuranic (TRU) waste Waste defined in Title 40, Part 191 of the Code of Federal Regulations (Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes) as waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes, with half-lives greater than 20 years, per gram of waste, except for: (1) high-level radioactive wastes; (2) wastes that the Department [of Energy] has determined, with the concurrence of the [EPA] Administrator, do not need the degree of isolation required by this part; or (3) wastes that the [Nuclear Regulatory] Commission has approved for disposal on a case-by-case basis in accordance with Title 10, Part 61 of the Code of Federal Regulations. Transuranic elements are artificially created in a reactor by irradiating uranium. These elements include neptunium, plutonium, americium, and curium. TRU waste results from reprocessing spent nuclear fuel to remove pluto-

nium-239 or other transuranic elements, and from fabricating nuclear weapons and plutonium-bearing reactor fuel. The waste may consist of plutonium-contaminated debris (such as worker clothing, tools, and equipment), sludge or liquid from reprocessing, or cuttings and scraps from machining plutonium.

tuff A rock composed of compacted volcanic ash.

underground research laboratory A facility where in situ testing can take place to stimulate repository operations and research aspects of potential repository performance.

vitrification The process of incorporating materials into a glass or glass-like form. Vitrification is commonly applied to the solidification of liquid high-level radioactive waste from the reprocessing of spent nuclear fuel.

volcanism The phenomenon of eruption of molten rock (magma) onto the surface of the Earth or a solid-surface planet or moon, where lava, pyroclastics, and volcanic gases erupt through a break in the surface called a vent. It includes all phenomena resulting from and causing magma within the crust or mantle of the body to rise through the crust and form volcanic rocks on the surface.

waste emplacement area Tunnels in which radioactive waste will be placed in a repository.

Waste Isolation Pilot Plant (WIPP) The U.S. Department of Energy's (DOE) Waste Isolation Pilot Plant (WIPP) is a deep geologic repository for permanent disposal of transuranic waste from the Nation's nuclear defense program. The waste consists of clothing, tools, rags, residues, debris, soil, and other items contaminated with small amounts of plutonium and other man-made radioactive elements.

waste package The waste material and any containers, shielding, packing, and other absorbent materials immediately surrounding an individual waste container.

West Valley Demonstration Project (WVDP) The site of the first and (to date) only commercial reprocessing plant in the United States. The plant began operations in 1966 and shut down in 1972. The West Valley Demonstration Project Act of 1980 charged the U.S. Department of Energy with solidifying the high-level radioactive waste still at the site, disposing of the solidified waste, and decommissioning the facilities used in the process. However, the land and facilities are the property of the New York State Energy Research and Development Authority, not the Department of Energy. After DOE's responsibilities under the Act are completed, the Act requires that the site be returned to the state of New York.

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Appendices

A. Board Members

B. Board Strategic Plan

C. Board Publications

D. Board Testimony

E. Board Presentations and Letters to the BRC

F. Meetings of the Board

G. Board Correspondence with DOE

APPENDIX A

U.S. NUCLEAR WASTE TECHNICAL REVIEW BOARD MEMBERS

Rodney C. Ewing, Ph.D.

Chairman

Dr. Rodney C. Ewing was appointed to the U.S. Nuclear Waste Technical Review Board by President Barack Obama on July 28, 2011, and designated by the President to serve as Chairman of the Board on September 25, 2012. Dr. Ewing was reappointed as Chairman and member of the Board by the President on July 1, 2014.

Dr. Ewing is the Frank Stanton Professor in Nuclear Security in the Center for International Security and Cooperation and a Professor of Geological and Environmental Sciences in the School of Earth Sciences at Stanford University. He is also the Edward H. Kraus Distinguished University Professor Emeritus at the University of Michigan and Regents' Professor Emeritus at the University of New Mexico.

Dr. Ewing is a fellow of the Geological Society of America, the Mineralogical Society of America, the American Geophysical Union, the Geochemical Society, the American Ceramic Society, the American Association for the Advancement of Science, and the Materials Research Society. He has been a guest scientist at numerous institutions, including the Centre D'Études Nucléaires de Fontenay-Aux-Roses, Commissariat A L'Énergie Atomique et aux Énergies Alternatives, Paris, France; Hahn-Meitner Institut in Berlin, Germany; and the University of Tokyo in Japan.

Among Dr. Ewing's numerous awards and honors are Royal Society of Canada, Foreign Fellow; Honorary Doctor of Université Pierre et Marie Curie; Dana Medal of the Mineralogical Society of America; Lomonosov Great Gold Medal of the Russian Academy of Sciences; and Association of Earth Science Editors Award for Outstanding Editorial or Publishing Contributions.

Dr. Ewing has written extensively on issues related to nuclear waste management and is co-editor of *Radioactive Waste Forms for the Future* (1988) and *Uncertainty Underground - Yucca Mountain and the Nation's High-Level Nuclear Waste* (2006). He has published over 600 scientific papers in journals and proceedings volumes.

Dr. Ewing received a Ph.D. from Stanford University in 1974 and an M.S. from Stanford in 1972. He received a B.S. in geology from Texas Christian University.

Dr. Ewing lives in Menlo Park, California.

Jean Bahr, Ph.D.

Dr. Jean M. Bahr was appointed to the U.S. Nuclear Waste Technical Review Board by President Barack Obama on September 25, 2012.

Dr. Bahr is a professor in the Department of Geoscience at the University of Wisconsin-Madison, where she has been on the faculty since 1987. She also is a member of the UW-Madison Geological Engineering Program Faculty and is a faculty affiliate of the Nelson Institute for Environmental Studies. She served as chair of Geoscience (formerly Geology and Geophysics) from 2005 to 2008 and of the Nelson Institute's Water Resources Management Graduate Program from 1995 to 1999. Dr. Bahr's research explores physical, geochemical, and biogeochemical controls on the movement of water and associated solutes in subsurface geologic systems.

Dr. Bahr has served on many advisory committees through the National Research Council of the National Academies and was a member of the Board on Radioactive Waste Management from 1992 to 1997. She chaired the Committee on Restoration of the Greater Everglades Ecosystem, and from 2004 to 2006 she was a member of the Committee on Research Priorities in Earth Science and Public Health. In addition to her service for the National Academies, Dr. Bahr has been a member of proposal review panels for the National Science Foundation, the U.S. Environmental Protection Agency, the U.S. Department of Energy, and the international Ocean Drilling Program. She served terms on the editorial boards of the journals *Water Resources Research, Ground Water*, and *Hydrogeology*.

Dr. Bahr was elected to Sigma Xi in 1984, named a fellow of the Geological Society of America (GSA) in 1996, and received the GSA Hydrogeology Division's Distinguished Service Award in 2006. She was the 2003 GSA Birdsall-Dreiss Distinguished Lecturer and was elected President of GSA for 2009-2010. She was named a lifetime National Associate of the National Academies in 2002 and is the 2012 recipient of the Association for Women Geoscientists' Outstanding Educator Award.

Dr. Bahr received a B.A. in geology and geophysics from Yale University in 1976, and an M.S. and a Ph.D. in 1985 and 1987, respectively, in applied earth sciences (hydrogeology) from Stanford University.

Dr. Bahr resides in Madison, Wisconsin.

Steven M. Becker, Ph.D.

Dr. Steven M. Becker was appointed to the U.S. Nuclear Waste Technical Review Board by President Barack Obama on September 25, 2012.

Dr. Becker is professor of community and environmental health in the College of Health Sciences at Old Dominion University in Norfolk, Virginia. He is a leading expert in emergency planning, public health preparedness, and crisis and emergency risk communication for chemical, biological, radiological, and nuclear issues. Dr. Becker also has extensive on-the-ground experience at the sites of major events and emergencies around the world. In 2011, he was a member of a three-person assistance team invited to Japan in response to the earthquake-tsunami and accident at the Fukushima Daiichi nuclear plant.

Before becoming a professor at Old Dominion University, Dr. Becker was a professor of environmental health sciences at the University of Alabama at Birmingham School of Public Health. For the last 11 years, he also has been an invited faculty member for the Harvard School of Public Health training course on radiological emergency planning.

In 2005, Dr. Becker was elected by his scientific peers to serve on the National Council on Radiation Protection and Measurements. His work on emergency preparedness and risk communication has been recognized with awards from such scientific organizations as the Health Physics Society and the Oak Ridge Associated Universities.

Dr. Becker holds a B.A. from George Washington University, an M.A. from Columbia University, and a Ph.D. from Bryn Mawr College. He also was a Kreitman Scholar and postdoctoral fellow at Ben-Gurion University of the Negev in Israel and a Visiting Fellow at the Japan Emergency Medicine Foundation and National Hospital Tokyo Disaster Medical Center.

Susan L. Brantley, Ph.D.

Dr. Susan L. Brantley was appointed to the U.S. Nuclear Waste Technical Review Board on September 25, 2012, by President Barack Obama.

Dr. Brantley is Distinguished Professor of Geosciences in the College of Earth and Mineral Sciences at Pennsylvania State University, where she also is Director of the Earth and Environmental Systems Institute. She has been a member of the faculty at the University since 1986. As a geochemist, Dr. Brantley has concentrated on the chemistry of natural waters, both at the surface of the earth and deeper in the crust. Much of her research focuses on understanding what controls the chemistry of natural water and how water interacts with the rocks through which it flows. Dr. Brantley and her research group investigate chemical, biological, and physical processes associated with the circulation of aqueous fluids in shallow hydrogeologic settings through field and laboratory work and theoretical modeling of observations. Of particular interest are questions concerning the measurement and prediction of the rates of natural processes, including chemical weathering with and without microorganisms. Her recent work has focused on the effect of microbial life on mineral reactivity and measuring and modeling how rock turns into regolith. Dr. Brantley has published more than 160 refereed journal articles and 15 book chapters.

Professor Brantley is a fellow of the American Geophysical Union, a fellow of the GSA, a fellow of the Geochemical Society, a fellow of the European Association of Geochemistry, and a fellow of the International Association for GeoChemistry. She was president of the Geochemical Society from 2006 to 2008. She has served on several National Research Council committees, and she has been a member of the U.S. Department of Energy Council on Earth Sciences since 2009.

In 2011, Professor Brantley received the Arthur L. Day Medal from GSA, as well as an honorary doctorate from the Paul Sabatier University (Toulouse III) in France. In 2012, she received the Presidential Award from the Soil Science Society of America, and she also was elected to membership in the U.S. National Academy of Sciences.

Dr. Brantley received an A.B. in chemistry in 1980 and an M.A. and a Ph.D. in geological and geophysical sciences in 1983 and 1987, respectively, from Princeton University.

Dr. Brantley lives in State College, Pennsylvania.

Sue B. Clark, Ph.D.[1]

Dr. Sue B. Clark was appointed to the U.S. Nuclear Waste Technical Review Board by President Barack Obama on July 28, 2011. Dr. Clark was reappointed to the Board by the President on July 1, 2014.

Dr. Clark is Regents Professor of Chemistry at Washington State University in Pullman, Washington, where she has taught and conducted research in actinide environmental chemistry and radioanalytical chemistry since 1996. From 1992 to 1996, she was a research ecologist at the University of Georgia's Savannah River Ecology Laboratory. From 1991 to 1996, she was an adjunct assistant professor in the Environmental Systems Engineering Department at Clemson University, and from 1989 to 1992, she was a senior scientist in the Interim Waste Technology Division at the Westinghouse Savannah River Laboratory.

Dr. Clark has served on numerous national advisory committees. From 2009 to 2011, she was a member of the Board of Directors of the U.S. Council for Chemical Research. From 2005 to 2009, she served on the Nuclear and Radiation Studies Board of the National Research Council. From 2004 to 2005, she served on the Board on Radioactive Waste Management of the National Research Council and various study committees for that Board. From 2003 to 2011, she was a member of the Basic Energy Sciences Advisory Committee of the Office of Science, U.S. Department of Energy.

Dr. Clark's awards and achievements include being a fellow of the American Chemical Society, selected in 2010. In 2008, she was Fink Distinguished Lecturer, Georgia Institute of Technology, Department of Chemistry. From 2002 to 2008, she was Westinghouse Distinguished Professor of Materials Science and Engineering at Washington State University.

Professor Clark has published over 100 peer-reviewed papers in environmental chemistry of plutonium and other actinides, chemistry of high-level radioactive waste systems, and actinide radioanalytical chemistry. She is currently serving as an Editor for the journal *Radiochimica Acta*. Dr. Clark earned a Ph.D. and an M.S. in inorganic/radiochemistry from The Florida State University. She earned a B.S. in chemistry from Lander College in Greenwood, South Carolina.

Dr. Clark lives in Pullman, Washington.

[1] Dr. Clark resigned from the Board effective October 31, 2014.

Efi Foufoula-Georgiou, Ph.D.

Dr. Efi Foufoula-Georgiou was appointed to the U.S. Nuclear Waste Technical Review Board by President Barack Obama on September 25, 2012.

Dr. Foufoula-Georgiou is a University of Minnesota McKnight Distinguished Professor in the Department of Civil Engineering and the Joseph T. and Rose S. Ling Chair in Environmental Engineering. She is Director of the National Science Foundation (NSF) Science and Technology Center "National Center for Earth-Surface Dynamics," and has served as Director of St. Anthony Falls Laboratory at the University of Minnesota. Her area of research is hydrology and geomorphology, with special interest in scaling theories, multiscale dynamics, and space-time modeling of precipitation and landforms.

Dr. Foufoula-Georgiou has served on many national and international advisory boards, including the Water Science and Technology Board of the National Academies, the Advisory Council of the Geosciences Directorate of NSF, and the Earth Sciences Subcommittee of the Science Advisory Council of NASA. She has also been a member of several National Research Council committees, the most recent one producing the report "Challenges and Opportunities in the Hydrologic Sciences." She has served as chair of the Board of Directors of the Consortium of Universities for the Advancement of Hydrologic Sciences and as an elected Trustee of the University Corporation for Atmospheric Research. Dr. Foufoula-Georgiou has published over 130 journal refereed papers and has been the recipient of the John Dalton Medal of the European Geophysical Society and the American Geophysical Union's (AGU) Hydrologic Sciences Award. She is a fellow of AGU and the American Meteorological Society and is an elected member of the European Academy of Sciences. In 2012, she was elected president of the Hydrology Section of AGU.

Dr. Foufoula-Georgiou received a diploma in civil engineering (1979) from the National Technical University of Athens, Greece, and an M.S. and a Ph.D. (1985) in environmental engineering from the University of Florida.

Dr. Foufoula-Georgiou resides in Saint Paul, Minnesota.

Gerald S. Frankel, Sc.D.

Dr. Gerald S. Frankel was appointed to the U.S. Nuclear Waste Technical Review Board by President Barack Obama on September 25, 2012.

Dr. Frankel is the DNV Chair, Professor of Materials Science and Engineering, and Director of the Fontana Corrosion Center at The Ohio State University (OSU). Before joining OSU, he was a postdoctoral researcher at the Swiss Federal Technical Institute in Zurich and a research staff member at the IBM Watson Research Center in Yorktown Heights, New York. His primary research interests are in the passivation and localized corrosion of metals and alloys, corrosion inhibition, and protective coatings.

Dr. Frankel is a member of the editorial board of *The Journal of the Electrochemical Society*; *Corrosion; Materials and Corrosion;* and *Corrosion Reviews*. He also is past chairman of the Corrosion Division of The Electrochemical Society and past chairman of the Research Committee of NACE. Dr. Frankel is a fellow of NACE International, The Electrochemical Society, and ASM International. He received the UR Evans Award from the Institute of Corrosion in 2011, the OSU Distinguished Scholar Award in 2010, the 2010 ECS Corrosion Division H.H. Uhlig Award, the Alexander von Humboldt Foundation Research Award for Senior US Scientists in 2004, the 2007 TP Hoar Prize from the UK Institute of Corrosion, the 2000 Uhlig Award from NACE, and the Harrison Faculty Award from the OSU College of Engineering in 2000. He was on sabbatical at the Max Planck Institute for Iron Research in Dusseldorf in 2005, a visiting professor at the University of Paris in 2008, and a visiting professor at Monash University in Melbourne in 2012. In 2009, he was named adjunct professor, Pohang Institute of Science and Technology, Graduate Institute of Ferrous Technology, Pohang, Korea.

Dr. Frankel earned a Sc.B. degree in materials science and engineering from Brown University in 1978 and a Sc.D. degree in materials science and engineering from The Massachusetts Institute of Technology in 1985.

Dr. Frankel resides in Bexley, Ohio.

Linda K. Nozick, Ph.D.

Dr. Linda Nozick was appointed to the U.S. Nuclear Waste Technical Review Board by President Barack Obama on July 28, 2011. Dr. Nozick was reappointed to the Board by the President on July 1, 2014.

Dr. Nozick is a professor of civil and environmental engineering at Cornell University. She also is Director of the College Program in Systems Engineering, a program that she co-founded. She has been on the Cornell faculty since 1992 and has been a Full Professor since 2003. From 1998 to 1999, Dr. Nozick was Visiting Associate Professor in the Operations Research Department at the U.S. Naval Postgraduate School in Monterey, California. In 1998, she was Visiting Professor in the Operations Research Department at General Motors Research & Development in Warren, Michigan. She has played a leading role in developing optimization models for planning and policy to support the National Security Enterprise and Homeland Security.

Dr. Nozick has served on two National Academy committees to advise the U.S. Department of Energy on renewal of their infrastructure. She has authored more than 60 peer-reviewed publications, many focused on transportation, moving hazardous materials, and modeling critical infrastructure systems. She has been an associate editor for Naval Research Logistics and a member of the editorial board of Transportation Research Part A.

She has received numerous awards, including a CAREER award from the National Science Foundation and a Presidential Early Career Award for Scientists and Engineers from President Bill Clinton for "the development of innovative solutions to problems associated with the transportation of hazardous waste." Dr. Nozick also received several recognition awards from Sandia National Laboratories and the National Nuclear Security Administration for the development of modeling tools for nuclear stockpile analysis, transportation of hazardous/sensitive materials, enterprise planning, and budget analysis.

Dr. Nozick received a Ph.D. and an M.S.E. in systems engineering from The University of Pennsylvania and a B.S. in systems analysis and engineering from The George Washington University.

Dr. Nozick lives in Ithaca, New York.

Kenneth Lee Peddicord, Ph.D., P.E.

Dr. Kenneth L. Peddicord was appointed to the U.S. Nuclear Waste Technical Review Board by President Barack Obama on September 25, 2012. Dr. Peddicord was reappointed to the Board by the President on July 1, 2014.

Dr. Peddicord is Director of the Nuclear Power Institute (NPI) and a professor of nuclear engineering at Texas A&M University, where he has been a member of the faculty since 1983. From 1972 to 1975, he was employed as a research nuclear engineer at the Eidgenössisches Institut für Reaktorforschung (the Swiss Federal Institute for Reactor Research), now the Paul Scherrer Institut, in Würenlingen, Switzerland. From 1975 to 1981, he was an assistant professor and an associate professor of nuclear engineering at Oregon State University. From 1981 to 1982, he was a Visiting Scientist at the EURATOM Joint Research Centre in Ispra, Italy.

At Texas A&M University, Dr. Peddicord has served as Head of the Department of Nuclear Engineering, Associate Dean and Interim Dean of the College of Engineering, Associate Vice Chancellor and Vice Chancellor of The Texas A&M University System for Research and Federal Relations. Since 2007, he has been the Director of NPI, a joint institute of the Texas Engineering Experiment Station and Texas A&M University. NPI is a partnership involving universities, community colleges, industry, high schools and junior highs, teachers, students, elected and civic leaders, and government agencies. The focus is to inform, attract, and prepare students for the nuclear industry.

Dr. Peddicord has published more than 200 articles, papers, and reports. His technical interests include nuclear engineering education, human resources and nuclear workforce development, and advanced nuclear fuels. He is a licensed Professional Engineer in the State of Texas.

Dr. Peddicord received a B.S. degree in mechanical engineering from the University of Notre Dame in 1965 and an M.S. in 1967 and a Ph.D. in 1972 in nuclear engineering from the University of Illinois at Urbana-Champaign.

Dr. Peddicord resides in College Station, Texas.

Paul J. Turinsky, Ph.D.

Dr. Paul J. Turinsky was appointed to the U.S. Nuclear Waste Technical Review Board by President Barack Obama on September 25, 2012. Dr. Turinsky was reappointed to the Board by the President on July 1, 2014.

Dr. Turinsky is a professor of nuclear engineering at North Carolina State University in Raleigh, North Carolina. He also is the Chief Scientist for the Department of Energy's (DOE) Innovation Hub for Modeling and Simulation of Nuclear Reactors.

Dr. Turinsky's areas of expertise are computational reactor physics in support of mathematical optimization of fuel management and nuclear fuel-cycle multiobjective decisions; uncertainty quantification and data assimilation in support of optimum experimental design applied to nuclear power plant safety and fuel-cycle assessments; and adaptive model refinement applied to nuclear power plant transient simulation.

Dr. Turinsky's writings and publications include contributions to three books and numerous peer-reviewed technical publications. He is the recipient of the American Society for Engineering Education Glenn Murphy Award, Edison Electric Institute Power Engineering Educator Award, the US DOE E.O. Lawrence Award in Atomic Energy, and American Nuclear Society (ANS) Eugene P. Wigner Reactor Physics Award and Arthur Holly Compton Award.

Dr. Turinsky has been on the faculty of Rensselaer Polytechnic Institute and has held engineering and management positions at Westinghouse Electric Corporation. He also has served on the Commissariat à l'énergie Atomique Scientific Committee of the Nuclear Energy Division, Duke Power Company Nuclear Safety Review Board, DOE Fuel Cycle R&D External Review Committee, and Board of Managers of Battelle Energy Alliance.

Dr. Turinsky is a fellow of the ANS and a member of the Society for Industrial and Applied Mathematics, the American Society for Engineering Education, and the American Association for the Advancement of Science.

Dr. Turinsky received a B.S. (1966) in chemical engineering from the University of Rhode Island, an M.S.E. (1967) and a Ph.D. (1970) in nuclear engineering from the University of Michigan, and an M.B.A. (1979) from the University of Pittsburgh.

Dr. Turinsky resides in Raleigh, North Carolina.

Mary Lou Zoback, Ph.D.

Dr. Mary Lou Zoback was appointed to the U.S. Nuclear Waste Technical Review Board by President Barack Obama on September 25, 2012.

Dr. Zoback is a seismologist and a consulting professor in the Geophysics Department at Stanford University. From 2006 to 2011, she was Vice President for Earthquake Risk Applications with Risk Management Solutions, a private catastrophe-modeling firm serving the insurance industry. In that role, she utilized the company's commercial risk models to explore the societal role of earthquake insurance and to quantify the costs and benefits of risk reduction. She previously was a senior research scientist at the U.S. Geological Survey in Menlo Park, California, where she served, among other positions, as Chief Scientist of the Western Earthquake Hazards team. Her research interests include the relationship between active faulting, deformation and state of stress in the earth's crust, quantifying earthquake likelihood, and characterizing natural-hazard risk.

Dr. Zoback has served on numerous national committees and panels on topics ranging from increasing the nation's resilience to disasters, defining the next generation of Earth observations from space, storage of high-level radioactive waste, facilitating interdisciplinary research, and science education. From 1997 to 2000, she was a member of the National Research Council's Board on Radioactive Waste Management.

In 2007, she received from the Geological Society of America (GSA) both the Day Medal "for outstanding distinction in contributing to geologic knowledge through the application of physics and chemistry to the solution of geologic problems" and their Public Service Award. In 2002, she was awarded the Department of Interior Meritorious Service Award, and in 1987, she received the James B. Macelwane Award of the American Geophysical Union (AGU) for "significant contributions to the geophysical sciences by a young scientist of outstanding ability."

In 1995, Dr. Zoback was elected a member of the U.S. National Academy of Sciences (NAS). She is a member of the AGU and the Seismological Society of America and is a past president of GSA. Dr. Zoback also is past chair of the Advisory Committee for San Francisco's Community Action Plan for Seismic Safety (CAPSS) program. She is a member of the NAS Disaster Roundtable and the Advisory Committee for the National Earthquake Hazard Reduction Program.

Dr. Zoback received a Ph.D. in 1978, an M.S. in 1975, and a B.S. in 1974, all in geophysics and all from Stanford University.

Dr. Zoback resides in Stanford, California.

FORMER MEMBERS
OF THE
U.S. NUCLEAR WASTE TECHNICAL REVIEW BOARD
Who Served During the Period Covered by This Report [2]

B. John Garrick, Ph.D., P.E., Chairman

Mark D. Abkowitz, Ph.D.

William Howard Arnold, Ph.D., P.E.

Thure E. Cerling, Ph.D.

David J. Duquette, Ph.D.

George M. Hornberger, Ph.D.

Andrew C. Kadak, Ph.D.

Ronald M. Latanision, Ph.D.

Ali Mosleh, Ph.D.

William M. Murphy, Ph.D.

Henry Petroski, Ph.D, P.E.

[2] Full biographies of former Board members who served during the period covered by this report can be found in the Board's Report to the U.S. Congress and the Secretary of Energy, issued in September 2008. The report is available on the Board's website at www.nwtrb.gov

APPENDIX B

U.S. NUCLEAR WASTE TECHNICAL REVIEW BOARD STRATEGIC PLAN – FISCAL YEARS 2011-2016[1]

[1] The Board's Strategic Plan was revised in March 2014. It is available on the Board's website: www.nwtrb.gov

U.S. NUCLEAR WASTE TECHNICAL REVIEW BOARD
STRATEGIC PLAN

FISCAL YEARS 2011-2016

REVISED SEPTEMBER 13, 2010

U.S. Nuclear Waste Technical Review Board Strategic Plan

FY 2011-2016

Mission

The U.S. Nuclear Waste Technical Review Board was established in the 1987 amendments to the Nuclear Waste Policy Act (NWPA) to "...evaluate the technical and scientific validity of activities [for managing and disposing of spent nuclear fuel and high-level radioactive waste] undertaken by the Secretary [of Energy], including

(1) site characterization activities; and

(2) activities relating to the packaging or transportation of high-level radioactive waste or spent nuclear fuel."

As set forth in the legislative history, the purpose of the Board is to provide independent expert advice to Congress and the Secretary on technical issues and to review the technical validity of the U.S. Department of Energy's (DOE) implementation of the NWPA (P.L. 97-145, as amended). In accordance with this mandate, the Board conducts an objective, ongoing, and integrated technical peer review of DOE activities related to the management, transportation, packaging, storage, and disposal of commercial spent nuclear fuel and of DOE-owned spent nuclear fuel and high-level radioactive waste. The Board reports its findings, conclusions, and recommendations to Congress and the Secretary at least twice yearly.

Vision

By performing ongoing and independent technical and scientific peer review of the highest quality, the Board makes a unique and essential contribution to increasing confidence in the technical validity of DOE activities related to the management and disposition of spent nuclear fuel and high-level radioactive waste. The Board provides technical and scientific information to decision-makers in Congress, the Administration, DOE, and the public on the full range of technical issues related to the management and disposition of such waste.

Values

The Board conducts its technical and scientific peer review according to the following values:

- Board members have no real or perceived conflicts of interest related to the Board's mission.
- Board findings and recommendations are based on objective and unbiased evaluations of the technical and scientific validity of the Secretary's activities.
- The Board's deliberations are transparent and conducted in such a way that its integrity and objectivity are above reproach.

- The Board's findings, conclusions, and recommendations are technically and scientifically sound and are based on the best available technical analysis and information.

- The Board's findings, conclusions, and recommendations are communicated clearly and in time for them to be most useful to Congress, the Secretary, and the public.

- The Board encourages public comment and discussion of DOE activities and Board findings, conclusions, and recommendations.

Members

The Board is composed of 11 members who are appointed by the President from a list of nominees submitted by the National Academy of Sciences (NAS). Nominees to the Board must be eminent in a field of science or engineering and are selected solely on the basis of established records of distinguished service. The Board is nonpartisan and apolitical. By law, no nominee to the Board may be an employee of DOE, a National Laboratory under contract to DOE, or an entity performing high-level radioactive waste or spent nuclear fuel activities under contract to DOE.

Powers

The law grants significant investigatory powers to the Board. The Board may hold such hearings, sit and act at such times and places, take such testimony, and receive such evidence as it considers appropriate. At the request of the Board and subject to existing law, DOE is required to provide all records, files, papers, data, and information necessary for the Board to conduct its technical review, including drafts of work products and documentation of work in progress. According to the legislative history, Congress provided such access with the expectation that the Board will review and comment on DOE decisions, plans, and actions as they occur, not after the fact.

Continuing Role

For 20 years, DOE focused on developing a deep geologic repository for the permanent disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain in Nevada. In January 2010, Secretary of Energy Steven Chu appointed a Blue Ribbon Commission on America's Nuclear Future (BRC) that was established to consider alternatives for managing the back end of the nuclear fuel cycle. At approximately the same time, DOE petitioned the Nuclear Regulatory Commission (NRC) for permission to withdraw the license application (LA) for constructing a repository for disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain.

Even as new options for managing nuclear waste are evaluated, DOE continues to have responsibility under the NWPA for the management and disposition of DOE-owned spent nuclear fuel and high-level radioactive waste and for the disposition of spent nuclear fuel from commercial reactors. Similarly, the Board's statutory responsibility for conducting ongoing technical peer review of DOE's nuclear waste management and disposition activities and for advising Congress and the Secretary on the technical and scientific validity of those activities remains unchanged.

Strategic Goals

Given the Board's ongoing peer review role, the Board's overarching strategic goals are the following:

- The Board will perform ongoing and objective technical and scientific peer review of DOE activities related to the management, packaging, transportation, storage, and disposition of spent nuclear fuel and high-level radioactive waste.
- The Board will make findings and recommendations that are based on its ongoing peer review related to the technical and scientific validity of DOE activities.
- The Board will report its findings and recommendations to Congress and the Secretary and will provide technical and scientific information to policy-makers to help inform decision-making and increase confidence in the validity of the technical and scientific process.

Performance Goals for FY 2011-2016

To accomplish its strategic goals, the Board has established three performance goals for fiscal years (FY) 2011-2016. The performance goals refocus the work of the Board to reflect plans, discussed in DOE's FY 2011 budget justification document, for transitioning activities related to DOE obligations under the NWPA from the Office of Civilian Radioactive Waste Management (DOE-RW) to the Office of Nuclear Energy (DOE-NE). The performance goals also reflect the Board's continuing evaluation of activities undertaken by the Office of Environmental Management (DOE-EM) related to DOE-owned spent nuclear fuel and high-level radioactive wastes that require treatment, storage, and eventual disposal. The Board has the necessary authority, under current law, to achieve its performance goals.

During FY 2011-2016, the Board will do the following:

- Compile objective technical information required to perform its technical review of DOE nuclear waste management activities and to advise Congress and the Secretary on the technical implications of alternatives for nuclear waste management.
- Continually update and report on Board experience with the U.S. nuclear waste program and programs in other countries.
- Review and report on the technical and scientific validity of DOE activities related to implementation of the NWPA, including the activities transitioning from the DOE-RW to DOE-NE and DOE-EM.

Achieving the Performance Goals

Priority Goals. For each performance goal, shorter-term "priority goals" have been established and are expected to be completed by the end of FY 2012. The priority goals are discussed in more detail in the Board's performance budget for FY 2012. The Board will evaluate its performance in achieving the priority goals in its performance budget and will update them as appropriate.

Board Panels. The Board maintains the option of organizing panels and working groups that correspond with its performance and priority goals to help facilitate and focus its technical review.

Information Gathering. Much of the Board's peer review and information gathering takes place at open public meetings where technical information is presented according to an agenda prepared by the Board. At the meetings, Board members and staff question presenters, and time is provided for comments from interested members of the public. The Board typically holds two or three public meetings each year. Board panels and smaller groups of Board members and staff meet, as needed, to investigate specific technical topics. The Board's public meetings are announced in the *Federal Register* four to six weeks before the meetings are held.

The Board also gathers information from site visits, visits to National Laboratories and facilities, and meetings with individuals working on specific projects and programs. Board members and staff attend national and international symposia and conferences related to the science and technology of nuclear waste management and disposition. From time to time, Board members and staff visit other countries to meet with organizations involved in the management of spent nuclear fuel and high-level radioactive waste to review best practices, perform benchmarking, and assess potential analogs.

Technical Analysis. Technical information is analyzed by Board members with assistance from a full-time senior professional staff. When necessary, the Board is authorized to hire expert consultants to perform in-depth reviews of specific technical and scientific topics. On the basis of the analyses, the Board reports its findings and recommendations to Congress and the Secretary of Energy. Board reports, testimony, correspondence and meeting agendas, transcripts, presentations, and public comments are posted on the Board's Web site at www.nwtrb.gov.

Crosscutting Functions

Many agencies, organizations, and entities are involved in some aspect of managing spent nuclear fuel and high-level radioactive waste, including, but not limited to, Congress, DOE, the BRC, the NRC, the Environmental Protection Agency (EPA), the Department of Transportation, the NAS, the Government Accountability Office, the State of Nevada and affected units of local governments in Nevada and California, the National Association of Utility Commissioners, the National Governors' Association and regional governors' groups, the National Conference of State Legislatures, the Nuclear Energy Institute, the Electric Power Research Institute, and environmental organizations, such as the Natural Resources Defense Council.

The Board's technical evaluation is at once different from and complementary to the activities of most of these groups in that the Board is (1) unconstrained by any stake, beyond technical and scientific credibility, in the outcome of the activities it reviews, (2) limited by its statutory mandate to reviewing the technical and scientific validity of DOE activities (not the policy implications or regulatory compliance), and (3) a permanent independent federal agency whose members are appointed by the President.

Key External Factors

As discussed below, some factors that are outside the Board's control can alter nuclear waste policy and could require the Board to revise its strategic goals to enable it to fulfill its mandated responsibilities.

- *The Board has no authority to implement its recommendations.* The Board is, by statute, a technical and scientific peer-review body that makes findings and recommendations. According to the legislative history, Congress expected that DOE would accept Board recommendations or indicate why the recommendations could not or should not be implemented. However, the statute does not obligate DOE to comply with Board recommendations. If DOE does not accept a Board recommendation, the Board can advise Congress, reiterate its recommendation to DOE, or both.
- *Funding levels may not be consistent or adequate.* Funding constraints can affect the Board's ability to conduct its comprehensive review of DOE activities and provide technical and scientific findings and recommendations to Congress and the Secretary. Funding levels and allocation decisions also affect the kinds and extent of activities undertaken by DOE that are subject to the Board's ongoing technical and scientific review.
- *Administrative, judicial, or legislative actions may alter nuclear waste policy.* As discussed in an earlier section, in the last year, DOE has petitioned NRC to withdraw the LA for constructing a repository at Yucca Mountain in Nevada, and a decision by NRC is expected soon. Court challenges to DOE's decision to withdraw the LA already have been filed, and more can be expected once NRC makes a final decision on DOE's petition. Many DOE activities related to its obligations under the NWPA are transitioning from DOE-RW to DOE-NE, while others remain with DOE-EM. The BRC was established to consider alternatives for managing the back-end of the nuclear fuel cycle, and, if implemented, the BRC recommendations may be expected to change further national policy on nuclear waste management.

The Board's ongoing technical peer review is especially important in enhancing confidence in the technical and scientific process during periods of uncertainty. The Board will continue to evaluate the status of these external factors, identify any new factors, and, if warranted, modify the "external factors" section of the strategic plan as part of the annual program evaluation described below.

Evaluating Board Performance

To measure its performance in a given year, for each priority goal, the Board considers the following criteria:

1. Did the Board undertake the activities needed to complete the priority goal effectively and efficiently?
2. Did the Board complete its review of DOE's work on schedule and at reasonable cost?
3. Were the findings and recommendations associated with the priority goal communicated in a timely, understandable, and appropriate way to Congress, the Secretary of Energy, and the public?

Progress in meeting the priority goals will be evaluated quarterly, and adjustments will be made, as necessary. At the end of the fiscal year, the Board's success in meeting each of the performance criteria will be measured on a numerical scale of 1 to 5, with 1 being minimally successful and 5 being fully successful. Each priority goal will be given an overall performance measure based on the sum for the three criteria. The Board will use the evaluation of its performance as input in developing its annual performance goals and performance budget for subsequent years. The results of the Board's annual performance evaluations are included in its summary reports.

Transparency

In developing its Strategic Plan for FY 2011-2016, the Board consulted with the Office of Management and Budget and will solicit comment from Congress, the Department of Energy, and members of the public. Copies of the strategic plan will be provided to NRC, NAS, and other interested parties and will be posted on the Board's Web site for a 90-day comment period. After incorporating comments, the final plan will be posted on the Board's Web site.

APPENDIX C

NUCLEAR WASTE TECHNICAL REVIEW BOARD PUBLICATIONS

Nuclear Waste Assessment System for Technical Evaluation (NUWASTE): Status and Initial Results.
June 2011.

The report describes work being performed by the Board to evaluate the effects on the management of spent nuclear fuel and high-level radioactive waste of various fuel-cycle options being considered by the U.S. Department of Energy (DOE). Of particular interest to the Board are the types and quantities of the radioactive waste streams that would be generated. The Board has developed a computer-based systems analysis tool (NUWASTE) to support its technical evaluation of DOE activities in this area. Included in the report are initial findings from NUWASTE analyses.

Technical Advancements and Issues Associated with the Permanent Disposal of High-Activity Wastes: Lessons Learned from Yucca Mountain and Other Programs.
June 2011.

The purpose of this report is to extract knowledge while it is still available from experiences to date of the Yucca Mountain deep geologic repository program and other management programs for high-activity waste. In this report, the Board examines from a technical perspective the history of the Yucca Mountain program and some other nuclear waste programs and discusses technical information and insights that may be useful for future U.S. high-activity waste management and disposal efforts.

Experience Gained from Programs to Manage High-Level Radioactive Waste and Spent Nuclear Fuel in the United States and Other Countries.
April 2011.

This report explores the efforts of 13 nations to find a permanent solution for isolating high-level radioactive waste and spent nuclear fuel generated within their borders. It builds on information in the Board's 2009 *Survey of National Programs for Managing High-Level Radioactive Waste and Spent Nuclear Fuel*. Unlike the earlier document, however, this report describes the programs and their histories and discusses inferences that can be drawn from their experiences.

Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel - Executive Summary.
December 2010.

This report was prepared to inform DOE and Congress about the current state of the technical basis for extended dry storage of used nuclear fuel and its transportation following storage.

Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel.
December 2010.

This report reviews available public literature on storage and handling of used nuclear fuel related to the safety of extended-term dry storage and subsequent transportation of U.S. commercial used nuclear fuel after long storage periods.

Survey of National Programs for Managing High-Level Radioactive Waste and Spent Nuclear Fuel.
October 2009.

The report describes 30 technical and institutional attributes of nuclear waste programs in 13 countries. It does not make judgments; rather the report provides factual information for Congress and the Secretary that can be used for evaluating waste management options.

Letter Report to Congress and the Secretary of Energy.
October 27, 2009.

This letter report updates Congress and the Secretary of Energy on the U.S. Nuclear Waste Technical Review Board's mission, continuing role, and refocused goals as the U.S. approach to managing spent nuclear fuel and high-level radioactive waste (HLW) is evolving.

Report to Congress and the Secretary of Energy.
September 2008.

Between March 1, 2006, and December 31, 2007, the period covered by this report, the Board focused its evaluation on five critical technical issues dealing with preclosure operations of the waste management system and on six critical technical issues dealing with post-closure performance of the proposed Yucca Mountain repository. The Board also explored in depth the crosscutting issue of thermal management. The Board's views on these issues are summarized below and are explained in greater detail in the body of this report.

Technical Evaluation of U.S. Department of Energy Yucca Mountain Infiltration Estimates: A Report to Congress and the Secretary of Energy.
December 2007.

In this report, the U.S. Nuclear Waste Technical Review Board presents its evaluation of revised DOE estimates of water infiltration at Yucca Mountain. The infiltration estimates were revised because violations of quality assurance procedures were alleged to have been committed by U.S. Geological Survey employees involved in gathering and analyzing infiltration data at Yucca Mountain in the 1990s.

Report to Congress and the Secretary of Energy.
January 2007.

This report contains summaries of Board findings and recommendations contained in the following: letters to the Director of the Office of Civilian Radioactive Waste Management (OCRWM) following Board meetings held in February, May, and September 2006, a letter and enclosures sent to the Director of OCRWM following a Board workshop on deliquescence-induced localized corrosion in September 2006, and testimony presented in May 2006 by the Board's Chairman before the Senate Energy and Natural Resources Committee.

Report to Congress and the Secretary of Energy.
June 2006.

In this report, the Board summarizes its major activities from January 1, 2005, through February 28, 2006. During that period, the Board focused its attention on the Project's efforts to develop post-closure performance estimates for the repository it proposes to construct at Yucca Mountain in Nevada. Correspondence and related materials are included in the appendices to the report along with the Board's strategic plan for fiscal years 2004-2009, its performance plans for fiscal years 2005-2006, and its performance evaluation for 2005.

Letter Report to Congress and the Secretary of Energy.
December 2005.

In this letter report to Congress and the Secretary of Energy, the Board presents its views on the status of some important issues related to the technical basis for DOE activities related to the waste management system, the engineered system, the natural system, the repository system, and the assessment of the performance of the systems. The Board also outlines issues that it expects may continue to be of interest in the future.

Report to Congress and the Secretary of Energy.
May 2005.

In this report, the Board summarizes its major activities from January 1, 2004, through December 31, 2004. During that period, the Board focused on the Department of Energy's efforts to develop a system for accepting, transporting, and handling high-level radioactive waste and spent nuclear fuel before disposal in the repository proposed for Yucca Mountain. Correspondence and related materials are included in the appendices to the report along with the Board's strategic plan for fiscal years 2004-2009, its performance plans for 2005, and its performance evaluation for 2004.

Letter Report to Congress and the Secretary of Energy.
December 2004.

This letter and enclosure comprise the Board's second report to Congress and the Secretary of Energy for calendar year 2004. The letter briefly summarizes areas where the Board believes the DOE has made progress, areas requiring attention, and the Board's priorities for the coming year. The enclosure contains a more detailed discussion of these topics.

Report to Congress and the Secretary of Energy.
May 2004.

In this report, the Board summarizes its major activities from January 1, 2003, through December 31, 2003. During that period, the Board continued its evaluation and held meetings on a range of technical and scientific issues, including seismicity, DOE plans for transporting spent nuclear fuel and high-level radioactive waste, the design and operation of facilities at the proposed repository site, performance-confirmation activities, and the potential for localized corrosion. Correspondence and related materials are included in the appendices to the report along with the Board's strategic plan for fiscal years 2004-2009, its performance plans for 2004 and 2005, and its performance evaluation for 2003.

Report to Congress and the Secretary of Energy.
December 19, 2003.

This letter and attachments constitutes the Board's second report to Congress and the Secretary of Energy for calendar year 2003. This letter report is composed of letters on localized corrosion sent to the director of the Office of Civilian Radioactive Waste Management (OCRWM) on October 21, 2003, and November 25, 2003.

Board Technical Report on Localized Corrosion.
November 25, 2003.

Technical report supporting Board conclusions in October 21, 2003, letter to the DOE related to the potential for localized corrosion of waste packages during the thermal pulse.

Report to the Secretary of Energy and the Congress.
April 2003.

This report summarizes the Board's major activities between January 1, 2002, and December 31, 2002. During this period, the Board focused on evaluating the technical basis of the DOE's work related to analyzing a planned repository site at Yucca Mountain in Nevada. Included in an appendix to the report are letters to the DOE related to technical issues identified by the Board as part of its ongoing review in 2002. Also included in the appendices are the Board's strategic plan for fiscal years 2003-2008, its performance plans for FY 2003 and FY 2004, and its performance evaluation for FY 2002.

Report to the Secretary of Energy and the Congress.
April 2002.

This report summarizes the Board's major activities between February 1, 2001, and January 31, 2002. During this period, the Board focused on evaluating the technical basis of the DOE's work related to a site recommendation, including the DOE's characterization of the Yucca Mountain site, the DOE's design of the repository and waste package, and the DOE's estimates of how a repository system developed at the site might perform. The report includes a description of activities undertaken by the Board in developing its assessment of the technical basis for the DOE's current performance estimates.

Letter report to Congress and the Secretary of Energy.
January 24, 2002.

Letter report summarizing the Board's evaluation of the DOE's technical and scientific investigation of the Yucca Mountain site.

Proceedings from an International Workshop on Long-Term Extrapolation of Passive Behavior, July 19-20, 2001, Arlington, Virginia.
December 2001.

The Board conducted a workshop on issues related to predicting corrosion behavior for periods of unprecedented duration. The workshop was held on July 19 and 20, 2001, in Arlington, Virginia. The workshop consisted of a panel of 3 Board members and 14 internationally recognized corrosion scientists, 8 of whom were from outside the United States. Following the workshop, most panelists submitted brief papers giving their views on issues related to predicting very long term corrosion. This publication is a compilation of those submissions.

Report to the Secretary of Energy and the Congress.
April 2001.

In this report, the Board summarizes its major activities in calendar year 2000. During 2000, the Board identified four priority areas for evaluating the potential repository at Yucca Mountain. The areas are the following:
• meaningful quantification of conservatisms and uncertainties in the DOE's performance assessments
• progress in understanding the underlying fundamental processes involved in predicting the rate of waste package corrosion
• an evaluation and a comparison of the base-case repository design with a low-temperature design
• development of multiple lines of evidence to support the safety case of the proposed repository, the lines of evidence being derived independently of performance assessment and thus not being subject to the limitations of performance assessment.
The report summarizes the Board's views on each priority area. A more detailed discussion of the priorities can be found in letters to the DOE included among the appendices to the report.

Report by letter to the Secretary of Energy and the Congress.
December 2000.

This report, in the form of a letter, presents a brief update of the Board's views on the status of the DOE program.

Report to the U.S. Congress and the Secretary of Energy.
April 2000.

In this report, the Board summarizes its major activities in calendar year 1999. Among the activities discussed in the report is the Board's 1999 review of the DOE's viability assessment (VA) of the Yucca Mountain site. The Board's evaluation of the VA concludes that Yucca Mountain continues to warrant study as the candidate site for a permanent geologic repository and that work should proceed to support a decision on whether to recommend the site for repository development. The Board suggests that the 2001 date for a decision is very ambitious, and focused study should continue on natural and engineered barriers. The Board states that a credible technical basis does not currently exist for the above-boiling repository design included in the VA. The Board recommends evaluation of alternative repository designs, including lower-temperature designs, as a potential way to help reduce the significance of uncertainties related to predictions of repository performance.

Report to the U.S. Congress and the Secretary of Energy.
April 1999.

In this report, the Board summarizes its major activities during calendar year 1998. The report discusses the research needs identified in the DOE's recently issued Viability Assessment of the Yucca Mountain site, including plans to gather information on the amount of water that will eventually seep into repository drifts, whether formations under the repository will retard the migration of radionuclides, the flow-and-transport properties of the groundwater that lies approximately 200 meters beneath the repository horizon, and longterm corrosion rates of materials that may be used for the waste packages. The report describes other activities undertaken by the Board in 1998, including a review of the hypothesis that there were hydrothermal upwellings at Yucca Mountain, a workshop held to increase understanding of the range of expert opinion on waste package materials, and a review of the DOE's draft environmental impact statement for the Yucca Mountain site.

Report to the U.S. Congress and the Secretary of Energy: Moving Beyond the Viability Assessment.
April 1999.

In its report, the Board offers its views on the DOE's December 1998 Viability-Assessment of the Yucca Mountain site in Nevada. The Yucca Mountain site is being characterized to determine its suitability as the location of a permanent repository for disposing of spent nuclear fuel and high-level radioactive waste. The Board discusses the need to address key uncertainties that remain about the site, including the performance of the engineered and natural barriers. The Board addresses the DOE's plans for reducing those uncertainties and suggests that consideration

be given to alternative repository designs, including ventilated low-temperature designs that have the potential to reduce uncertainties and simplify the analytical bases for determining site suitably and for licensing. The Board also comments on the DOE's total system performance assessment, the analytical tool that pulls together information on the performance of the repository system.

Report to the U.S. Congress and the Secretary of Energy.
November 1998.

In its report, the Board offers its views on the direction of future scientific and technical research under way and planned by the DOE as part of its program for characterizing a site at Yucca Mountain, Nevada, as a potential repository for spent fuel and high-level radioactive waste. The Board discusses some of the remaining key scientific and technical uncertainties related to performance of a potential repository. The Board's report addresses some of these uncertainties by examining information about the proposed repository system presented to it in meetings and other technical exchanges. The Board considers and comments on some of the important connections between the site's natural properties and the current designs for the waste package and other engineered features of the repository.

Board Completes Review of Material on Hydrothermal Activity.
July 24, 1998.

This series of documents concerns the Board's review of material related to Mr. Jerry Szymanski's hypothesis of ongoing, intermittent hydrothermal activity at Yucca Mountain and large earthquake-induced changes in the water table there. The series includes a cover letter, the Board's review, and the reports of the four consultants the Board contracted with to assist in the review.

1997 Findings and Recommendations.
April 1998.

This report details the Board's activities in 1997 and covers, among other things, the DOE's viability assessment, due later this year; underground exploration of the candidate repository site at Yucca Mountain, Nevada; thermal testing underway at the site; what happens when radioactive waste reaches the water table beneath Yucca Mountain; transportation of spent fuel; and the use of expert judgment. The Board makes four recommendations in the report concerning (1) the need for the DOE to begin now to develop alternative design concepts for a repository, (2) the need for the DOE to include estimates of the likely variation in doses for alternative candidate critical groups in its interim performance measure for Yucca Mountain, (3) the need for the DOE to evaluate whether site-specific biosphere data is needed for license application, and (4) the need for the DOE to make full and effective use of formally elicited expert judgment.

Report by Letter to the Secretary of Energy and the Congress.
December 23, 1997.

This report, in the form of a letter, addresses several key issues, including the DOE's viability assessment of the Yucca Mountain site, design of the potential repository and waste package, the total system performance assessment, and the enhanced characterization of the repository block (east-west crossing).

Report to the U.S. Congress and the Secretary of Energy: 1996 Findings and Recommendations.
March 1997.

This report summarizes Board activities during 1996. Chapter 1 provides an overview of the Department of Energy's high-level nuclear waste management program from the Board's perspective, including the viability assessment, program status, and progress in exploration and testing. The chapter ends with conclusions and recommendations. Chapter 2 examines the three technical issues—hydrology, radionuclide transport, and performance assessment—and provides conclusions and recommendations. Chapter 3 deals with design, including the concept for underground operations, repository layout and design alternatives, construction planning, thermal loading, and engineered barriers. The Board also makes conclusions and recommendations. Chapter 4 provides an overview of recent Board activities, including the international exchange of information, the Board's visit to the River Mountains tunnel, and a presentation to the Nuclear Regulatory Commission.
Appendices include information on Board members, the organization of the Board's panels, meetings held in 1996 and scheduled for 1997, the DOE's responses to previous Board recommendations, a list of Board publications, references for the report, and a glossary of technical terms.

Nuclear Waste Management in the United States - The Board's Perspective.
June 1996.

This publication was developed from remarks made by Dr. John Cantlon, Chairman of the Nuclear Waste Technical Review Board, at Topseal '96, an international conference on nuclear waste management and disposal. The meeting was sponsored by the Swedish Nuclear Fuel and Waste Management Company (SKB) and the European Nuclear Society. The publication highlights the Board's views on the status of the U.S. program for management and disposal of commercial spent nuclear fuel and provides a brief overview of the program's organization. It summarizes the DOE's efforts to characterize the Yucca Mountain site and to develop a waste isolation strategy for the site. The publication also outlines legislative and regulatory changes under consideration at that time and the Board's views on the technical implications of those possible changes.

Report to the U.S. Congress and the Secretary of Energy: 1995 Findings and Recommendations.
April 1996.

This report summarizes Board activities during 1995. Chapter 1 provides an overview of the DOE's high-level radioactive waste management program, including highlights, current status, legislative issues, milestones, and recommendations. Chapter 2 reports on Board Panel activities and Chapter 3 provides information on new Board members, meetings attended, interactions with Congress and congressional staff, Board presentations to other organizations, interactions with foreign programs, and a review of the Board's report on interim storage of spent nuclear fuel. Appendices include Board testimony and statements before Congress, Board correspondence of note, and the Department of Energy's responses to recommendations in previous Board reports.

Disposal and Storage of Spent Nuclear Fuel - Finding the Right Balance.
March 1996.

This special report caps more than two years of study and analysis by the Board into the issues surrounding the need for interim storage of commercial spent nuclear fuel and the advisability and timing of the development of a federal centralized storage facility. The Board concludes in the report that the DOE's efforts should remain focused on permanent geologic disposal and the site investigations at Yucca Mountain, Nevada; that planning for a federal centralized spent fuel storage facility and the required transportation infrastructure be begun now, but actual construction delayed until after a site-suitability decision is made about the Yucca Mountain site; that storage should be developed incrementally; that limited, emergency backup storage capacity be authorized at an existing nuclear facility; and that, if the Yucca Mountain site proves unacceptable for repository development, other potential sites for both centralized storage and disposal be considered.

Report by Letter to the Secretary of Energy and the Congress.
December 13, 1995.

This report, in the form of a letter, addresses the DOE's progress in underground exploration with the tunnel boring machine, advances in the development of a waste isolation strategy, new work on engineered barriers, and progress being made in performance assessment.

Report to the U.S. Congress and the Secretary of Energy: 1994 Findings and Recommendations.
March 1995.

This report summarizes Board activities during 1994. It covers aspects of the DOE's Program Approach, their emerging waste isolation strategy, and their transportation program. It also explores the Board's views on minimum exploratory requirements and thermal-loading issues. The report focuses a chapter on the lessons that have been learned in site assessment from projects around the world. Another chapter deals with volcanism and resolution of difficult

issues. The Board also details its observations from its visit to Japan and the Japanese nuclear waste disposal program. Findings and recommendations in the report centered around structural geology and geoengineering, hydrogeology and geochemistry, the engineered barrier system, and risk and performance analysis.

Report to The U.S. Congress and the Secretary of Energy: January to December 1993.
May 1994.

This report summarizes Board activities primarily during 1993. It reviews the nuclear waste disposal programs of Belgium, France, and the United Kingdom; elaborates on the Board's understanding of the radiation protection standards being reviewed by the National Academy of Sciences; and, using "future climates" as an example, examines the DOE's approach to "resolving difficult issues." Recommendations center on the use of a systems approach in all of OCRWM's programs, prioritization of site-suitability activities, appropriate use of total system performance assessment and expert judgment, and the dynamics of the Yucca Mountain ecosystem.

Letter Report to Congress and the Secretary of Energy.
February 1994.

This report is issued in letter format due to impending legislative hearings on the DOE's fiscal year 1995 budget and new funding mechanisms sought by the Secretary of Energy. The 8-page report (ninth in the NWTRB series) restates a recommendation made in the Board's Special Report, that an independent review of the OCRWM's management and organizational structure be initiated as soon as possible. Also, it adds two additional recommendations: ensure sufficient and reliable funding for site characterization and performance assessment, whether the program budget remains level or is increased, and build on the Secretary of Energy's new public involvement initiative by expanding current efforts to integrate the views of the various stakeholders during the decision-making process—not afterward.

Underground Exploration and Testing at Yucca Mountain: A Report to Congress and the Secretary of Energy.
October 1993.

This report (eighth in the NWTRB series) focuses on the exploratory studies facility at Yucca Mountain, Nevada: the conceptual design, planned exploration and testing, and excavation plans and schedules. In addition to a number of detailed recommendations, the Board makes three general recommendations. First, the DOE should develop a comprehensive strategy that integrates exploration and testing priorities with the design and excavation approach for the exploratory facility. Second, underground thermal testing should be resumed as soon as possible. Third, the DOE should establish a geoengineering board with expertise in the engineering, construction, and management of large underground projects.

Special Report to Congress and the Secretary of Energy.
March 1993.

The Board's seventh report provides a nontechnical approach for those not familiar with the details of the DOE's high-level nuclear waste management program. It highlights three important policy issues: the program is driven by unrealistic deadlines, there is no integrated waste management plan, and program management needs improvement. The Board makes three specific recommendations: amend the current schedule to include realistic intermediate milestones; develop a comprehensive, well-integrated plan for the overall management of all spent nuclear fuel and high-level defense waste from generation to disposal; and implement an independent evaluation of the Office of Civilian Radioactive Waste Management's (OCRWM) organization and management. These recommendations should be implemented without slowing the progress of site characterization activities at Yucca Mountain.

Sixth Report to the U.S. Congress and the U.S. Secretary of Energy.
December 1992.

The sixth report begins by summarizing recent Board activities, congressional testimony, changes in Board makeup, and the Little Skull Mountain earthquake. Chapter 2 details panel activities and offers seven technical recommendations on the dangers of a schedule-driven program; the need for top-level systems studies; the impact of defense high-level waste; the use of high capacity, self-shielded waste package designs; and the need for prioritization among the numerous studies included in the site-characterization plans. In Chapter 3, the Board offers candid insights to the high-level waste management program in five countries, specifically those areas that might be applicable to the U.S. program, including program size and cost, utility responsibilities, repository construction schedules, and alternative approaches to licensing. Appendix F provides background on the Finnish and Swiss programs.

Fifth Report to the U.S. Congress and the U.S. Secretary of Energy.
June 1992.

The Board's fifth report focuses on the cross-cutting issue of thermal loading. It explores thermal-loading strategies (U.S. and others) and the technical issues and uncertainties related to thermal loading. It also details the Board's position on the implications of thermal loading for the U.S. radioactive waste management system.

Also included are updates on Board and panel activities during the reporting period. The report offers fifteen recommendations to the DOE on the following subjects: ESF and repository design enhancements, repository sealing, seismic vulnerabilities (vibratory ground motion and fault displacement), the DOE approach to the engineered barrier system, and transportation and systems program status.

Fourth Report to the U.S. Congress and the U.S. Secretary of Energy.
December 1991.

The fourth report provides update on the Board's activities and explores in depth the following areas: exploratory studies facility (ESF) construction; test prioritization; rock mechanics; tectonic features and processes; volcanism; hydrogeology and geochemistry in the unsaturated zone; the engineered barrier system; regulations promulgated by the Environmental Protection Agency, the Nuclear Regulatory Commission (NRC), and the DOE; the DOE performance assessment program; and quality assurance in the Yucca Mountain project. Ten recommendations are made across these diverse subject areas. Chapter 3 offers insights from the Board's visit with officials from the Canadian nuclear power and spent fuel disposal programs. Background on the Canadian program is in Appendix D.

Third Report to the U.S. Congress and the U.S. Secretary of Energy.
May 1991.

The third report briefly describes recent Board activities and congressional testimony. Substantive chapters cover exploratory shaft facility alternatives, repository design, risk-benefit analysis, waste package plans and funding, spent fuel corrosion performance, transportation and systems, environmental program concerns, more on the DOE task force studies on risk and performance assessment, federal quality assurance requirements for the repository program, and the measurement, modeling, and application of radionuclide sorption data. Fifteen specific recommendations are made to the DOE. Background information on the German and Swedish nuclear waste disposal programs is included in Appendix D.

Second Report to the U.S. Congress and the U.S. Secretary of Energy.
November 1990.

The Board's second report begins with the background and framework for repository development and then opens areas of inquiry, making 20 specific recommendations concerning tectonic features and processes, geoengineering considerations, the engineered barrier system, transportation and systems, environmental and public health issues, and risk and performance analysis. The report also offers concluding perspectives on DOE progress, the state of Nevada's role, the project's regulatory framework, the nuclear waste negotiator, other oversight agencies, and the Board's future plans.

First Report to the U.S. Congress and the U.S. Secretary of Energy.
March 1990.

The first report sets the stage for the Board's evaluation of the Department of Energy's (DOE) program to manage the disposal of the nation's spent fuel and high-level waste. The report outlines briefly the legislative history of the nation's spent fuel and high-level waste management program including its legal and regulatory requirements. The Board's evolution is described, along with its protocol, panel breakdown, and reporting requirements. The report identifies major issues based on the Board's panel breakdown, and highlights five cross-cutting issues.

APPENDIX D
U.S. NUCLEAR WASTE TECHNICAL REVIEW BOARD TESTIMONY

- **Statement of Dr. B. John Garrick, Chairman, U.S. Nuclear Waste Technical Review Board**
  July 15, 2008
  Presented to the Subcommittee on Energy and Air Quality Committee on Energy and Commerce; United States House of Representatives

- **Summary of Statement of Dr. B. John Garrick, Chairman, U.S. Nuclear Waste Technical Review Board**
  July 15-16, 2008
  Presented to the Subcommittee on Energy and Air Quality

- **Summary and Statement of Dr. Daniel S. Metlay, Senior Professional Staff; U.S. Nuclear Waste Technical Review Board**
  June 7, 2012
  Presented to the Subcommittee on Clean Air and Nuclear Safety Committee on Environment and Public Works; United States Senate

Statement of Dr. B. John Garrick, Chairman
U.S. Nuclear Waste Technical Review Board
Before the
Subcommittee on Energy and Air Quality
Committee on Energy and Commerce
United States House of Representatives
July 15, 2008

Mr. Chairman and members of the Subcommittee, good morning. My name is John Garrick. I am Chairman of the U.S. Nuclear Waste Technical Review Board. The 11 part-time members of the Board are appointed by the President and most of us have other occupations. In my case, I am a consultant specializing in the application of the risk sciences to complex technological systems in the space, defense, chemical, marine, and nuclear fields. I am pleased to represent the Board at this hearing on "progress toward opening a storage facility for high-level civilian nuclear waste at Yucca Mountain in Nye County, Nevada."

As has been discussed, Mr. Chairman, after many years of characterizing Yucca Mountain for its suitability as the proposed site for a deep geologic repository for the permanent disposal of spent nuclear fuel and high-level radioactive waste, the Department of Energy (DOE) recently submitted a license application to the Nuclear Regulatory Commission (NRC). This action represents the achievement of a major program milestone. The questions asked by the Subcommittee in its invitation letter about what happens next are very timely. The questions are paraphrased in my written statement, and I will do my best to present the Board's answers to the questions as directly and succinctly as possible.

What is the timing of decisions on the license application?

NRC will address the adequacy of DOE's license application in relation to NRC regulations and will determine whether the proposed repository complies with whatever repository radiation standard is ultimately promulgated by the Environmental Protection Agency. The NRC is therefore in a better position to respond to questions about the timeline for decisions on a license application.

What is the Board's role going forward?

The Board's congressional mandate, set forth in the 1987 amendments to the Nuclear Waste Policy Act (NWPA), is to perform an unbiased ongoing peer review of the technical and scientific validity of DOE activities related to implementing the NWPA. Because the Board is completely independent, it does not have a direct stake in the development of a Yucca Mountain repository and will not be a party to the licensing proceeding. That is as it should be.

In carrying out its technical peer review, the Board takes an integrated view of the many diverse components of the DOE program and focuses on fundamental understanding as opposed to regulatory compliance. Using the extensive scientific and engineering expertise of its members, the Board evaluates the technical basis of DOE's approach to the entire waste management system, from waste acceptance (i.e., handling of waste at generation sites) through transportation and isolation of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The Board provides an integrated technical assessment of whether the waste management system will work, based on answers to the following questions:

- Will DOE (or any managing entity) be able to effectively implement the design and fabrication of waste packages; accept spent nuclear fuel at reactor sites or high-level

radioactive waste at federal facilities; transport the waste to the repository; perform necessary surface operations at the repository site, including storage; and emplace waste packages and other engineered barriers underground?

- How strong is the technical basis supporting DOE's assessment that the repository system, including the natural and engineered barriers, will perform as planned?

The Board attempts to make its body of technical work available to the public. For example, most of the Board's public meetings are held in Nevada. The Board reports its findings and recommendations regularly to Congress and the Secretary of Energy. Finally, Board documents, including letters, reports, congressional testimony, and meeting transcripts, are posted on the Board's Web site at www.nwtrb.gov. Anyone can use this information, including parties involved in NRC's licensing proceedings.

Going forward, based on its ongoing technical review the Board will continue to make recommendations to DOE on designing and implementing a safe and effective waste management system, including a permanent repository. We hope that Congress will find the Board's technical findings and recommendations useful as context for policy decisions about radioactive waste management.

What are the outstanding technical issues that could potentially cause delay or increase the costs associated with developing a repository?

Mr. Chairman, as part of its ongoing evaluation, the Board has identified several priority technical issues that if addressed could increase operational effectiveness or feasibility, enhance the technical basis for repository performance estimates, or improve fundamental understanding. Before I present examples of the technical issues, Mr. Chairman, I want to make clear that the Board's identification of these issues should not be construed as comment on the sufficiency of DOE's license application; NRC will make that determination. Furthermore, the Board's

systematic review of DOE activities did not uncover any issue that it believes would have prevented DOE from submitting its license application for regulatory review.

I will begin by commenting on issues related to the first component of the waste management system: preclosure operations.

Preclosure Operational Issues

Several operational and design issues identified by the Board could significantly affect funding requirements and schedules.

First, DOE has designed its waste management system around a canister system that can be used for transportation, aging, and disposal (TAD) of spent nuclear fuel. The Board believes that the TAD concept may have merit. However, a smaller TAD that could be transported by truck does not currently exist. DOE representatives confirmed at a Board meeting held in January that developing a waste management system using TADs makes the Nevada rail line necessary. DOE also has acknowledged in correspondence to the Board that constructing a Nevada rail line may present significant institutional challenges. The Board therefore has recommended that DOE initiate contingency planning to identify alternatives that can be implemented if significant delays are encountered during construction of the rail line to Yucca Mountain.

Second, DOE has established requirements for a TAD-based repository design assuming that 90 percent of commercial spent nuclear fuel will arrive at the repository in TAD canisters. However, utilities may need incentives to use TADs, and some nuclear power plants appear to lack the necessary infrastructure for handling the large TAD canisters. If TAD utilization falls below the planned 90 percent, the lower utilization rate could adversely affect surface facility throughput. It also may require constructing additional waste handling facilities or increasing the amount of spent nuclear fuel that must be placed in storage at the repository site, thus reducing the rate of waste emplacement into the repository. The Board recommends that DOE consider

operational and design contingencies that could be implemented if TAD utilization rates are significantly lower than the 90 percent utilization currently assumed, including an analysis of the effects of direct disposal of dual-purpose canisters.

Third, repository performance estimates included in DOE's total system performance assessment (TSPA) depend on functioning drip shields to prevent water and rocks from falling on waste packages. However, DOE assumptions about drift degradation and repository tunnel tolerances may make installation of the drip shields, as currently designed, problematic.

Issues Affecting Repository Performance Estimates

Examples of technical issues that could affect calculated repository performance estimates are the potential for the occurrence of deliquescence-induced localized corrosion of the waste packages during the thermal pulse, questions about the rates of general corrosion of waste packages, and the magnitude and variability of water recharge that occurs as a result of climate change. The Board also will continue to follow DOE's ongoing scientific investigations of seismicity and volcanism at Yucca Mountain. It is very likely that many of these issues will be addressed during licensing. In any case, the Board believes that addressing these issues is feasible and could reduce uncertainty and strengthen the technical basis for DOE's repository performance estimates.

Mr. Chairman, we can report that DOE has made very significant progress over the last several years in enhancing the technical basis for the assumptions and analyses supporting its repository performance estimates in the TSPA used in the license application. As can be expected, however, for time periods of up to one million years, some uncertainty related to estimates of repository performance are inevitable.

Deciding on the best way to address such uncertainties can be challenging. DOE has addressed uncertainties by making conservative assumptions and using probabilistic representations of performance indicators. In its letters and reports, the Board has suggested design changes, contingency planning, and additional research as ways of addressing uncertainties. Different approaches require different time and resource commitments. The Board will continue to evaluate the possible use of all of these methods to achieve defensible technical assessments.

Does the Board have any recommendations related to nuclear legislation or policy?

Mr. Chairman, the Board historically has not recommended changes in legislation or policy because it views its role as providing needed technical context and information for decision-makers. The Board is very comfortable with its statutory mandate and takes its mission very seriously. The Board looks forward to continuing its independent technical peer review, as described earlier in my statement.

On behalf of the Board members, I thank the Subcommittee for inviting us to participate in this hearing. We hope that the information we have furnished today will be useful.

I will be pleased to respond to your questions.

Summary of Statement of Dr. B. John Garrick, Chairman
U.S. Nuclear Waste Technical Review Board Before
the Subcommittee on Energy and Air Quality July
15-16, 2008

- The Board's role was established in the Nuclear Waste Policy Amendments Act of 1987. The Board is expected to perform ongoing peer review of the technical and scientific validity of DOE activities related to implementing the Nuclear Waste Policy Act. The Board reports its findings and recommendations at least twice a year to Congress and the Secretary of Energy.
- The Department of Energy's (DOE) submittal of a Yucca Mountain license application to the Nuclear Regulatory Commission (NRC) represents the achievement of a major program milestone.
- Because the Board is completely independent, it does not have a direct stake in the development of a Yucca Mountain repository and will not be a party to the licensing proceeding. That is as it should be.
- Focusing on fundamental understanding as opposed to regulatory compliance, the Board evaluates the technical basis of DOE's approach to the entire waste management system, from waste acceptance through transportation and isolation of spent nuclear fuel and high-level radioactive waste as proposed at Yucca Mountain.
- The Board makes its technical evaluation available by posting Board documents, including letters, reports, congressional testimony, and meeting transcripts, on its Web site at www.nwtrb.gov. Anyone can use this information, including parties involved in NRC's licensing proceedings.
- The Board has identified several technical issues that if addressed could increase operational effectiveness or feasibility, enhance the technical basis for repository performance estimates, or improve fundamental understanding. The Board did not uncover any issue that it believes would have prevented DOE from submitting its license application for regulatory review.
- Operational issues identified by the Board include developing contingencies in case of (1) delay in the development of a Nevada rail spur, (2) lower rate of TAD utilization, and (3) potential problems related to drip shield installation.
- Technical issues that might affect calculated repository performance estimates are deliquescence-induced localized corrosion of the waste packages during the thermal pulse, general corrosion of waste packages, and water recharge that results from climate change. DOE also is investigating seismicity and volcanism at Yucca Mountain.
- DOE has made very significant progress over the last several years, but given the million-year timeframe, some uncertainty in repository performance estimates is inevitable. Uncertainty can be addressed in several ways, and different approaches require different time and resource commitments.
- The Board is very comfortable with its statutory mandate and looks forward to continuing its independent technical peer review.

Summary

Statement of Dr. Daniel S. Metlay,
Senior Professional Staff
U.S. Nuclear Waste Technical Review Board
Before the
Subcommittee on Clean Air and Nuclear Safety
Committee on Environment and Public Works
United States Senate
June 7, 2012

- *The U.S. Nuclear Waste Technical Review Board* was created in the 1987 amendments to the Nuclear Waste Policy Act to provide an ongoing and independent technical and scientific evaluation of activities undertaken by the Secretary of Energy related to implementing the Nuclear Waste Policy Act.
- *Site-selection strategies* for a deep-mined geologic repository involve two "filters," one consisting of technical requirements and the other consisting of nontechnical considerations. The two filters can be applied in any order, although the suite of sites eventually selected may be different.
- *The Nuclear Waste Policy Act, passed in 1982*, provided for two repositories, one that presumably would be in the western U.S. and another presumably one in the east. Three western sites were to be characterized simultaneously to assess their suitability as the location of the first repository. After the second repository program was suspended in 1986, Congress amended the Nuclear Waste Policy Act in 1987. Among other things, the amendments act identified one of the western sites, Yucca Mountain in Nevada, as the sole site to be characterized for the first repository. The Department of Energy (DOE) recommended the Yucca Mountain site to President George W. Bush in 2002, and Congress overturned a veto by the State of Nevada of the site recommendations later that year. In 2008, DOE submitted a license application for the Yucca Mountain repository to the U.S. Nuclear Regulatory Commission. DOE requested withdrawal of the license application in 2010. A final decision on whether the licensing process will proceed is pending in the courts.
- *A deep-mined geologic repository is the preferred option of all countries* for disposing of high-activity radioactive waste. In the last 40 years, the U.S. and other nations have initiated roughly two-dozen efforts to identify potential repository sites. Only three of those efforts have led to the selection of a site and are still on track. In no case has a construction license for a high-activity waste repository been issued by the responsible regulatory authority.
- *The experiences in selected countries can be summarized briefly*:
  - In France, two communities volunteered to be considered for an underground research laboratory (URL), but the granite underlying one of them proved to be technically unsuitable. Today a URL has been constructed in clay near the village of Bure. A site adjacent to the laboratory has been chosen for a repository for high-activity waste.
  - Sweden's consent-based siting process resulted in a competition between two municipalities, Osthammar and Oskarshamn, to host a repository for high-activity waste. Osthammar ultimately was selected.

- The United Kingdom initiated a new approach to repository siting, inviting communities to express interest in hosting such a facility. Several borough and county councils near the Sellafield reprocessing site in West Cumbria are considering whether to participate. A decision is expected in the fall.
- In Canada, after a deliberate effort by the siting implementer to understand the views of Canadians, including Canada's aboriginal people, more than a dozen communities have expressed interest in learning more about the implications of hosting a repository.
- Japan called for volunteers to host a repository more than a decade ago. The one mayor that accepted the offer was recalled, and no other communities have come forward since. The damage to the facilities at the Fukushima-Daiichi site caused by last year's tsunami may have reduced the prospects for finding a volunteer host still further.
- In Switzerland, after identifying regions of Opalinus clay as potentially suitable for repository siting, discussions are underway with communities to determine their willingness to host a disposal facility. The Swiss government will ultimately make the siting decision, but the decision could be overturned by national referendum.
- The German State of Lower Saxony invited the German Federal Government to develop a repository at a salt site near the community of Gorleben decades ago, but the expression of interest created considerable controversy nationally. After 35 years, the site is still under consideration, but selection of the site remains problematic.

- *What characterizes national repository programs most is their variety*. In some cases, efforts to identify candidate sites have focused from the beginning on specific host-rock formations. In other cases, countries have used generic qualifying and disqualifying conditions. Some countries evaluate sites one by one, while others adopt a "parallel" approach, characterizing and comparing at least two sites simultaneously.
- *Communities already hosting nuclear facilities* may be especially receptive to consideration as a candidate repository site. The prospect of receiving a generous benefits package is instrumental in gaining community acceptance, in some cases.
- *Lessons that can be taken from the U.S. and other countries*: (1) Potential host communities must at least acquiesce to site investigations. (2) Implementers must engage potential host communities by establishing a strong, long-term local presence. (3) Potential host communities must have a realistic, practical way to withdraw from the siting process.
- *The experience of the U.S. Nuclear Waste Negotiator may be especially relevant* because it reflects a consent-based siting effort undertaken in the U.S. The Negotiator was given authority to search for a voluntary host for a storage facility or a permanent repository site and could negotiate a benefits package with any acceptable incentives. Approval by act of law would have been required to complete the process. At least one Native American Tribe sought to negotiate an agreement, but funding was eventually eliminated for the Negotiator's Office by Congress.
- *Public trust in the institutions involved in a consent-based site-selection process* is an essential element underlying the potential for success of all the efforts discussed in this testimony. It is vitally important that entities and localities that might consider hosting a storage or disposal facility for high-activity waste have confidence in the credibility of the process and the trustworthiness of the implementer of the program.

Statement of Dr. Daniel S. Metlay
Senior Professional Staff
U.S. Nuclear Waste Technical Review Board

Before the

Subcommittee on Clean Air and Nuclear Safety
Committee on Environment and Public Works
United States Senate
June 7, 2012

Mr. Chairman and members of the Subcommittee, good morning. My name is Daniel Metlay. I am a senior professional staff member at the U.S. Nuclear Waste Technical Review Board. The Board was created in the 1987 amendments to the Nuclear Waste Policy Act to provide an ongoing and independent technical and scientific evaluation of activities undertaken by the Secretary of Energy related to implementing the Nuclear Waste Policy Act. The Board's 11 members are technical and scientific experts who are nominated by the National Academy of Sciences and appointed by the President. A small professional staff supports the work of the part-time Board members. I am a member of that staff. I hold a Ph.D. in public policy, and I have a scientific undergraduate degree. Over several decades, I have held various positions in academia and in government related to nuclear waste management and disposal. A short biography is attached to this statement. My responsibilities on the Board staff include nuclear waste transportation, institutional issues, and, most particularly, the ongoing work in other countries for managing their high-level radioactive waste and spent nuclear fuel.

Today, I have been asked by the Subcommittee to provide a historical perspective on efforts in this country and in other countries for establishing a consent-based process for siting nuclear waste storage and disposal facilities. Developing such a consent-based approach to siting was a major recommendation of the Blue Ribbon Commission on America's Nuclear Future (BRC).

Before I begin, I want to make clear that I can only convey Board comments that are part of publicly available Board documents; I cannot speculate about Board opinions, findings, or recommendations. What I will try to do is provide relevant general information that is based on my own experience and expertise and on information that is included in two Board publications: *Survey of National Programs for Managing High-Level Radioactive Waste and Spent Nuclear Fuel*, issued in October 2009; and *Experience Gained From Programs to Manage High-Level Radioactive Waste and Spent Nuclear Fuel in the United States and Other Countries*, issued in April 2011. I also have attached to this statement a letter that the Board wrote to the Secretary of Energy on the BRC recommendations. These and all other Board documents, including Board presentations and correspondence to the BRC, are available on the Board's Web site at www.nwtrb.gov. I hope that the Committee will find these perspectives useful as context for considering BRC recommendations on establishing a consent-based process for siting a nuclear waste storage or disposal facility in the United States.

I will begin today by talking generally about the requirements for developing a siting process. I then will provide a brief history of efforts in this country to site and develop storage and disposal facilities for high-level radioactive waste and spent nuclear fuel. I next will discuss factors affecting consent-driven site-selection activities in other countries. I will end with some tentative conclusions that might be drawn from these efforts and with a short discussion of some factors that may limit the lessons that can be applied to this country from international experience.

Designing a Siting Process

Site-selection strategies for a deep-mined geologic repository necessarily involve passing candidates through what is, in effect, two different "filters." On the one hand, detailed and

quantitative technical requirements have to be met. They include such issues as suitability criteria related to geologic stability, hydrologic conditions, geochemical conditions, disruptive processes, coupled processes, and operational practicality. On the other hand, sites could be disqualified because of nontechnical considerations, such as the "lack of social acceptance, high population density, or difficulty of access." These two filters, the "technical" and the "non-technical," can be applied in any order, although the suite of sites eventually selected might be different.

In constructing the filters, formal processes need to be crafted that can be used to establish technical criteria, prescribe how the criteria will be updated, specify how a "safety case" will be constructed, lay out compliance methodologies, and provide resources for public involvement and support of local and state oversight activities. Describing every aspect of these filters and how they have been applied would require a very long discussion. I will limit my testimony to the experiences in the United States and internationally that are relevant to the BRC's recommendation for a consent-based site-selection process.

History of the U.S. Program

Members of the Subcommittee are familiar with how the waste management program in the United States has evolved to its present state. I will mention just a few salient episodes.

Early efforts to develop a permanent repository for high-activity radioactive waste focused on finding a site in salt, a host-rock recommended in a 1957 National Academy of Sciences report. In 1970, on the basis of some preliminary investigations undertaken by Oak Ridge National Laboratory, the Atomic Energy Commission (AEC) announced plans for siting a repository for high-activity waste at an abandoned salt mine near Lyons, Kansas. The AEC's announcement took state and local officials by surprise. The State Geologist, strongly supported

by the Kansas congressional delegation, opposed this siting effort. In the end, unresolved technical issues forced the AEC to abandon its plans in 1974. Subsequently, two other salt formations were considered as potential locations for a repository. Community leaders in Carlsbad, New Mexico, launched an initiative to persuade the AEC to look at potential repository sites in the Permian Basin; at the same time, the federal government sought permission from governors to investigate possible locations for a repository in the Salina Basin around the Great Lakes. The latter efforts provided futile, but, as the Subcommittee knows well, a sustained campaign by congressional, legislative, and community leaders around Carlsbad resulted in the construction of the Waste Isolation Pilot Plant (WIPP) repository, which began receiving transuranic-contaminated waste in 1999.

Problems encountered in trying to site a repository for high-activity radioactive waste led policy-makers in the late 1970s and early 1980s to try developing principles that would form the basis of a national policy for managing and disposing of spent nuclear fuel and high-level radioactive waste. President Jimmy Carter created the Interagency Review Group on Nuclear Waste Management (IRG) in 1978. Represented on the IRG were more than 20 federal agencies that had a "stake" in the long-term management of high-activity waste. Of particular importance was the IRG's recommendation that a policy of "consultation and concurrence" be adopted. Such a policy would walk a fine line between, on the one hand, outright federal preemption of any state role in siting a repository, and, on the other, an absolute state veto, exercised at one specific moment in time. Instead, the IRG argued for an adaptive process with full involvement by affected states. "Under this approach, a state effectively has the continuing ability to participate in activities at all points throughout the course of [site investigations] and, if it deems appropriate, to prevent the continuance of Federal activities."

Although other elements of the IRG recommendations found their way into the Nuclear Waste Policy Act (NWPA), which passed in 1982 after almost 4 years of debate, Congress transformed the notion of "consultation and concurrence" into "consultation and cooperation." The NWPA also provided that the President's decision to develop a repository could be vetoed by the governor of the *situs* state. That veto, however, could be overridden by a majority vote in both Houses of Congress.

To increase geographic equity, the Act also authorized the development of two repositories, presumably one in the eastern United States and one in the west, which would be selected after a technically based evaluation process. Three western sites eventually were chosen that would be characterized simultaneously for their suitability as the location of the first repository. As opposition grew in the eastern United States to a second repository, Secretary of Energy John Harrington suspended the second repository program in 1986.

In 1987, Congress tried to address the resistance that had developed over time to some of the policies and practices established in the NWPA. Congress amended the NWPA in December of that year and identified Yucca Mountain in Nevada as the sole site to be characterized for a first repository. The Office of the Nuclear Waste Negotiator also was created in the Amendments Act. The Negotiator was authorized by the legislation to "find a State or Indian tribe willing to host a repository or monitored retrievable storage facility at a technically qualified site on reasonable terms and…to negotiate with any State or Indian tribe which expresses an interest in hosting a repository or monitored retrievable storage facility." After several years of effort, the first Negotiator, David Leroy, and then his successor, Richard Stallings, were unable to reach an agreement with a willing host, although one Native American

tribe, the Mescaleros of New Mexico, expressed some interest. Congress defunded the Office of the Nuclear Waste Negotiator in 1995.

For more than 20 years after passage of the Amendments Act, the Yucca Mountain site was technically evaluated by the U.S. Department of Energy (DOE), even as the State of Nevada voiced its strong and unwavering opposition to locating a repository at the site. In early 2002, DOE recommended to President George W. Bush that the site be developed as a repository. Congress overturned a veto of the President's suitability decision by the state of Nevada later in 2002. In 2008, DOE submitted a license application for a Yucca Mountain repository to the U.S. Nuclear Regulatory Commission. DOE requested that the license be withdrawn in 2010. A final decision on whether the licensing process will proceed is pending in the courts.

Now I will move on to a discussion of factors that have shaped the site-selection approaches of other countries.

International Experience in Site Selection

Almost universally, policy-makers have determined that disposal of high-activity waste in a deep-mined geologic repository is the preferred option for protecting human health and the environment for many millennia. In the last 40 years, the United States and other nations have initiated roughly two-dozen efforts to identify or create processes for identifying potential repository sites. Only three of those efforts have identified a potentially suitable site *and* are still on track. In no case has a license been issued by the cognizant regulatory authority to construct a deep-mined geologic repository for high-activity radioactive waste. The experience in selected countries can be summarized briefly.

France

When the call went out for volunteer communities to host underground research laboratories both in clay and in granite, potential host localities knew from the start that if the laboratory site or a site nearby were found to be technically sound, then a full-scale repository might be constructed there. Two communities stepped forward. However, the granite formation underlying one of them proved technically unsuitable for repository development. After several years of informal consultations and negotiations by the French Government, no other community was willing to volunteer to host an underground laboratory in granite. Today, the village of Bure, the community that agreed to host an underground laboratory in clay, strongly supports activities conducted by the implementer, the National Radioactive Waste Management Agency (ANDRA), related to constructing a repository. Noteworthy, however, is that when ANDRA called for volunteers to host a separate repository for long-lived, intermediate-level waste, several communities in the same province as Bure declined.

Sweden

Perhaps the most encouraging example of the efficacy of a consent-based siting process is the approach used in Sweden. In the 1970s, the implementer there, Swedish Nuclear Fuel and Waste Management Company (SKB), developed a disposal concept, which evolved incrementally into the current concept, KBS-3. The disposal concept received strong technical support from the international scientific community. It could be employed throughout most of Sweden, which lies largely on the granitic Baltic Shield. In the late 1980s, SKB unilaterally sought to characterize sites in several areas. That effort was met by strong opposition and blockaded entry roads. Reassessing the situation, SKB approached four northern municipalities, asking for their consent to initiate site investigations. Two municipalities declined early on;

referenda were held in two others, and, by varying margins, those municipalities also declined to participate further. Without hesitation, SKB stopped its work in all four places.

Subsequently, SKB invited approximately a dozen communities to join in a process to explore whether they would be interested in hosting a repository for high-activity waste. At the end of a very extensive engagement process, two municipalities, Osthammar and Oskarshamn, signaled that they were prepared to host such a facility. SKB ultimately selected Osthammar.

United Kingdom

In 2006, the government of the United Kingdom approved a new approach—Managing Radioactive Waste Safely—for developing a repository. Key to that new approach was an invitation for willing and informed communities to express an interest in hosting such a facility. The response from communities in the United Kingdom, however, has been quite subdued to date. Several borough and county councils near the Sellafield reprocessing plant in West Cumbria have begun investigating whether they should participate in the new initiative. Studies by the British Geological Survey suggested that at least some of the "rock" in the area might be suitable for constructing a repository. A decision by the West Cumbria partnership on whether to participate is expected in the fall. Ironically, the same councils that denied local planning permission for constructing an underground research laboratory 20 years ago are the ones now considering participation in the repository program. One important factor that may have caused this shift in attitude has been the concerted efforts by the U.K. implementer, the Nuclear Decommissioning Authority, to establish trustworthy relations with the localities.

Canada

Perhaps the most promising national initiative that relies on a consent-based siting process has unfolded in Canada. Adopting a very deliberate and careful approach to understanding the views of Canadians, especially those belonging to that country's aboriginal people, the implementer, the Nuclear Waste Management Organization (NWMO), put forward a plan for adaptive management of Canada's high-activity waste. NWMO is working with more than a dozen communities that have expressed interest in learning more about the implications of hosting a deep-mined repository.

Japan

In sharp contrast to the Canadian experience, more than a decade ago, Japan's implementer, Nuclear Waste Management Organization (NUMO), called for volunteers to participate in a stepwise siting process. Although the mayor of one southern Japanese town accepted NUMO's offer, opposition quickly developed at both the local and prefectural levels. The mayor was recalled; no other community has come forward since. After the damage caused to the Fukushima-Daiichi reactors and spent-fuel storage pools by last year's earthquake and tsunami, the prospects for volunteers now appear to be even slimmer.

Switzerland

In Switzerland, the steps of the typical siting process have been reversed. Under the country's Sectoral Plan, the implementer, National Cooperative for the Disposal of Radioactive Waste, first identified potential regions where Opalinus clay might be suitable for locating a repository. Altogether, five regions were identified in the first phase of the plan. Now, in the plan's second phase, discussions are under way with communities in the regions to determine if

any of them are prepared to host a facility for disposing of high-activity waste. Ultimately, the Swiss Federal Government will decide where a repository will be sited, but that decision could be overturned by a national referendum.

Germany

In many respects, the siting efforts in Germany parallel those in the United States. When, in the 1970s, the State of Lower Saxony invited the German Federal Government to develop a repository in salt near the community of Gorleben, that expression of interest aroused considerable controversy nationally. Although the site is still under consideration 35 years later, its selection remains problematic.

What Can We Learn from U.S. and International Experiences?

In discussions of the international efforts for implementing a consent-based approach, it is important to remember, as noted above, that there are several aspects to the process that can have significant consequences for the outcome. First are technical factors, including choices about what reactor technology to adopt and about what nuclear fuel cycle to pursue. Others are social and political in nature, including how concerns about intergenerational equity should be addressed and what pace should be followed in implementing a long-term management option. Importantly, the interdependencies, both subtle and overt, among the technical, social, and political forces are inescapable.

Because of those interdependencies, what characterizes national programs most notably is their variety. In some cases, efforts to identify candidate sites have focused from the beginning on specific host-rock formations. The choice of those formations has been dictated by constraints imposed by a country's geology or land-use patterns, by a view that particular host-

rock formations possess distinctive advantages in terms of isolating and containing high-activity radioactive waste, or by a combination of these rationales. In other cases, efforts to identify candidate sites cast the net more broadly by enumerating generic qualifying and disqualifying conditions. Qualifying conditions must be satisfied for a candidate site to be considered acceptable; disqualifying conditions eliminate a candidate site from further consideration.

An additional source of variation among national programs can be traced to policies that govern the sequence for accepting or rejecting a candidate site. A country can adopt a "serial" policy whereby sites would be evaluated formally one by one until a suitable site is found. Alternatively, a "parallel" approach can be adopted in which at least two candidate sites would be characterized simultaneously and compared.

Just as the construction of the technical filter introduces considerable variation in strategies for selecting candidate sites for a deep geologic repository, so does the construction of the nontechnical filter. Arguably this filter's most important property relates to the power that a state or community can exercise. Since the early 1990s, nations outside the United States increasingly have constructed their nontechnical filters in ways that empower local jurisdictions. Especially when issues of federalism come to the fore, how power is distributed between the central government and state governments can be very consequential, as the cases of Japan, Germany, and the United States illustrate. So does the situation in Switzerland. There, a change in the law governing the management of high-activity waste eliminated the possibility of a cantonal referendum after one canton (roughly equivalent to a U.S. state) disapproved of the siting of an intermediate-level waste repository.

Experiences in the United States and other nations also suggest that communities already hosting nuclear facilities or communities where benefits might make a significant economic or

social difference may be especially receptive to being considered a candidate repository site. For example, in Sweden and Finland, candidate sites were identified in communities with nuclear reactors, and in the United Kingdom, borough and county councils in West Cumbria near the Sellafield nuclear facilities have expressed interest in becoming considered a repository site. For many, but not all, municipalities and states, the prospect of receiving generous benefit packages is instrumental in gaining community acceptance for a repository.

Lessons from all of these siting experiences have not been lost on the directors of national waste-management programs. Siting efforts now under way in Canada and the United Kingdom reflect these lessons, and the recommendations by the BRC in the United States are in line with this "new" understanding:

- *Potential host communities must at least acquiesce to site investigations*. Carlsbad, New Mexico, the town closest to WIPP, assertively lobbied for the facility. The Meuse and Haute Marne districts surrounding Bure in France welcomed the construction of a URL, knowing that if the argillite clay there was suitable, a full-scale repository might be constructed nearby. In Finland and in Sweden, the town of Eurajoki and the municipality of Osthammar, respectively, responded positively to invitations from the two national implementers, Posiva and SKB, respectively.

- *Implementers must work intensively to engage potential host communities by establishing a strong, long-term local presence*. DOE required that officials involved with the WIPP project and researchers from National Laboratories live in Carlsbad, New Mexico, even requiring those not already living there to relocate. In France, a Local Information and Oversight Committee has been established so that representatives of communities in the Meuse and Haute-Marne districts near Bure can continuously interact with ANDRA. In

Sweden and Finland, the potential repository host communities had already become familiar with the implementers because they (or their consortium members) had operated nuclear reactors at those sites for a long time. In each case, however, interactions were intensified when the municipalities began to be considered potential locations for deep-mined geologic repositories.

- *Potential host communities must have a realistic, practical way to withdraw from the siting process*. The state of New Mexico was a full partner in negotiating the terms of the Land Withdrawal Act that permitted WIPP to operate. In France, the districts near Bure willingly accepted the prospects of hosting a deep-mined geologic repository when they volunteered to host the research laboratory. Yet, despite considerable effort by the French Government, no community located above a granite formation was willing to step forward, and none were forced to. In Finland, Eurajoki's consent was required before Parliament could pass the "decision-in-principle" to site the proposed geologic repository. In Sweden, Osthammar must agree to the granting of a license by the government. If the municipality decides for some unexpected reason to exercise its veto power, the veto could, in theory, be overridden by the government. As a pragmatic matter, however, national culture and historical precedents would make such an override highly unlikely.

In the United States, the experience of the Nuclear Waste Negotiator may be especially relevant because that effort was truly consent-based. The Negotiator was given authority to search for a voluntary host for a storage facility or a permanent repository site and could negotiate a package with any acceptable incentives. Approval by act of law would be required to complete the process. Some local communities expressed interest, but the states in which they were located prevented them from pursuing an agreement with the negotiator. Some Native

American Tribes sought agreements, but funding was eventually eliminated for the Office of the Negotiator by Congress. It is not clear what factors would lead to a different outcome if that effort were reinitiated today.

Finally, public trust in the institutions involved in a consent-based site-selection process is an essential element underlying the potential for success of all the efforts I have discussed today. Vitally important is that entities and localities that might consider hosting a storage or disposal facility for high-activity waste have confidence in the credibility of the process and the trustworthiness of the implementer of the program.

Summary

In closing, I would observe that few public policy issues rival the management of high-activity radioactive waste in terms of the demands placed on scientific research and engineering practice and the controversy that is engendered. After decades of dedicated work in more than a dozen nations, evidence is beginning to increase confidence that "solutions" can be found to this pressing environmental problem. More important, lessons are being learned about how to design social processes that lead to technically and politically defensible outcomes. Given this progress, and because the stakes are so high, it would be unfortunate if temporization displaced action.

Appendix E
U.S. Nuclear Waste Technical Review Board
Comments, Presentations, and Letters — Blue Ribbon Commission on America's Nuclear Future

- Presentation to Blue Ribbon Commission on America's Nuclear Future Disposal Subcommittee by Daniel Metlay; *International Experience Developing Deep Geologic Repositories*
  July 7, 2010

- Presentation to BRC Reactor & Fuel Cycle Technology Subcommittee by Mark Abkowitz; *Nuclear Waste Assessment System for Technical Evaluation (NUWASTE): Status and Initial Results*
  October 12, 2010

- Statement of Dr. B. John Garrick, Chairman, U.S. Nuclear Waste Technical Review Board on Experiences Gained On the Management and Disposition of High-Activity Waste - Presented to the Blue Ribbon Commission on America's Nuclear Future
  November 16, 2010

- Board comments on the Subcommittee on Disposal's draft report
  June 30, 2011

- Board comments on recommendations in the Transportation and Storage Subcommittee's draft report
  June 30, 2011

- Board comments on the Reactor and Fuel Cycle Technology Subcommittee draft report
  July 14, 2011

- Board comments on the Commission's *Draft Report to the Secretary of Energy*
  October 31, 2011

- Board comments on the final report of the Blue Ribbon Commission on America's Nuclear Future
  April 18, 2012

International Experience Developing Deep Geologic Repositories

Presented to:

Blue Ribbon Commission on America's Nuclear Future
Disposal Subcommittee

Presented by:

Dr. Daniel Metlay
Nuclear Waste Technical Review Board

July 7, 2010 Washington, D.C.

About the Board

- The Board is an independent Federal agency.
  - It was established in 1987 by the Nuclear Waste Policy Amendments Act.
  - Its mandate is to "…evaluate scientific and technical validity …" of activities undertaken by the Secretary of Energy to implement the Nuclear Waste Policy Act.
- The Board is composed of eleven members, selected strictly on the basis of their expertise.
  - They are nominated by the National Academy of Sciences.
  - They are appointed by the President.
  - They serve part-time.
- The Board reports to Congress and the Secretary of Energy on its findings, conclusions, and recommendations at least twice a year.

Background

- This presentation is largely based on the Board's October 2009 report: *Survey of National Programs for Managing High-Level Radioactive Waste and Spent Nuclear Fuel.*
  - Compendium of information on 30 institutional and technical program attributes in 13 countries
  - Does not make judgments or draw conclusions
- The Board expects in the coming months to follow up the "Survey of National Programs" report with an "Experience Gained" report. This report will have a historical dimension and will provide context—both technical and process—to the information contained in the "Survey" report.

Is a Disposal Facility Needed? (1)

- NEA Collective Statement: A deep geologic repository "provides a unique level and duration of protection" of public health and safety. It is "technically feasible."
- The only issue appears to be timing.
  - **Early operation:** United States (YM and WIPP), Sweden, France, and Finland
  - **Operation anticipated by mid-century:** Belgium, China, and Switzerland
  - **No official decision made on when operations might begin:** Canada, Germany, Japan, Korea, United Kingdom (except Scotland), and the United States
  - **No official decision to develop a deep geologic repository:** Scotland and Spain

Is a Disposal Facility Needed? (2)

Deep geologic repositories can be designed to isolate and contain a wide variety of waste forms.

- **High-level radioactive waste:** United States, Belgium, China, France, Germany, Japan, Switzerland, and United Kingdom (except Scotland)
- **Commercial spent nuclear fuel:** United States, Canada, Finland, Germany, Korea, Sweden, and United Kingdom (except Scotland)
- **Defense-related spent nuclear fuel:** United States, France, and United Kingdom (except Scotland)
- **Long-lived intermediate level waste:** France and United Kingdom (except Scotland)
- **Heat-generating intermediate level waste:** Germany
- **Transuranic-contaminated waste:** United States

Is a Disposal Facility Needed? (3)

Countries have made the decision to develop a deep geologic repository in a variety of ways.

- **Adopt disposal without a formal comparative analysis:** United States (early), Belgium, Canada (early), China, Finland, France (early), Germany, Japan, Korea, Sweden, Switzerland, and United Kingdom (early)
- **Adopt disposal after a formal comparative analysis:** United States (GEIS), Canada (NWMO), France (ANDRA), and United Kingdom (except Scotland) (MRWS)

Alternative Approaches? (1)

- Fundamental Prerequisites
  - Technical competence
  - Technical confidence and robustness (defense-in-depth, retrievability/reversibility, monitoring, and the use of natural analogues)
  - Socially acceptable process
  - Open, transparent, respectful, fair, and trustworthy behavior
- Focus will be on the site-selection process because it is here that the rubber first hits the road.
  - Technical filter
  - Nontechnical filter

Alternative Approaches? (2)

Technical filter

- **Focus on specific host-rocks**
  - Salt: United States and Germany
  - Granite: United States, France, Canada, China, Finland, Japan, Korea, Sweden, and Switzerland
  - Basalt: United States
  - Sedimentary rocks including clay: United States, Belgium, Canada, France, Japan, and Switzerland
- **Qualifying and disqualifying conditions**
  - General (host-rock neutral): Canada, Germany (AkEnd), Japan, Switzerland, and United Kingdom (except Scotland)
  - General (host-rock specific): China (granite), Finland (granite), France (granite), and Switzerland (clay)
  - Detailed (host-rock neutral): United States (10 CFR 960)

Alternative Approaches? (3)

Nontechnical filter (State/regional and local involvement)

- **Volunteer community with right of withdrawal deep into the repository development process:** Canada, Japan, Sweden, and United Kingdom (except Scotland)
- **State or local veto either at the beginning or the end of the site-selection process:** Finland and United States
- **Volunteer for URL with the understanding that a repository might be sited in community:** France
- **Informal regional participation, formal consultation, and possible national referendum:** Switzerland
- **No decision made:** Belgium, China, Germany, and Korea.

Alternative Approaches? (4)

- Selecting sites for development of a deep geologic repository that pass through both filters
  - **Serial approach:** United States (YM and WIPP) and France (clay).
  - **Parallel approach:** United States (NWPA), Finland, France (granite), Sweden, and Switzerland
  - **Depends on the number of volunteers:** Canada, Japan, and United Kingdom (except Scotland)
  - **No decision made:** Belgium, China, Germany, and Korea
- Formal designation of a site for a deep geologic repository typically is done by the legislature.
- What if no site can pass through both filters?

Development Process?

- Institutional form of the implementer
  - **Government agency:** United States (YM and WIPP), Belgium, Germany, Korea, and United Kingdom
  - **Government-owned corporation:** China and France
  - **Utility-owned corporation:** Canada, Finland, Japan, Sweden
  - **Public-private partnership:** Switzerland
- Step-wise development
  - What isn't?
  - Critical variables
    - How large are the steps?
    - What are the rules for moving from one step to the next?
  - Based on an incremental or "trial-and-error" theory of decision-making

Two Personal Observations

- There are no simple solutions to complex problems.
  - Alter institutional form
    - Empirical evidence is not compelling
    - AMFM report
  - Find a volunteer community/allow an absolute veto
    - Swedish "model"
    - Consultation and concurrence
- What should be the connection between "new build" and long-term management of HLW and SNF?
  - Public will never believe we have a permanent solution until there is evidence of one.
  - At least outside of the United States, the imperative to develop waste management solutions is independent of the future of nuclear power.

Nuclear Waste Assessment System for Technical Evaluation (NUWASTE): Status and Initial Results

Presented to:
BRC Reactor & Fuel Cycle Technology Subcommittee

Presented By:
Mark Abkowitz

October 12, 2010

The Board's Role

- Conduct an independent and ongoing evaluation of the technical activities undertaken by the Secretary of Energy in managing:
  - High-level radioactive waste (HLW)
  - Commercial, research, and defense-related spent nuclear fuel (SNF)
- Report its findings to Congress and the Secretary of Energy at least twice per year.
- The Board's statutory responsibility is unchanged by the status of the Yucca Mountain repository program, though the DOE activities the Board reviews in future will necessarily be different.

About the Board

- The 11-person Board was created in the 1987 amendments to the Nuclear Waste Policy Act.
- Members are nominated by the National Academy of Sciences and appointed by the President to four-year terms.
- The Board is an independent agency in the Executive Branch, ***not*** part of the Department of Energy (DOE).
- The Board typically holds 2 or 3 public meetings each year, plus smaller topical meetings and fact-finding trips.

Board Priority Tasks

- Analyze the impact of new SNF and HLW management options being considered by DOE (NUWASTE).
- Consider options for dealing with “stranded” SNF and HLW.
- Identify technical issues involving very long term storage.
- Characterize waste management programs and derive lessons learned based on SNF and HLW experiences in the U.S. and abroad.
- Perform technical review of other activities conducted by DOE-NE and DOE-EM under the NWPA.

NUWASTE Objectives

- Understand the impacts of potential fuel cycle initiatives on the generation and management of SNF and HLW.
- Create ability to vary system parameters to represent different scenarios that DOE may consider.
- Explore opportunities to balance potentially conflicting waste management criteria:
  - Surface dry storage volume
  - Number of waste packages generated
  - Mass of natural uranium used
  - Introduction of new waste streams
  - Proliferation risk
  - Relative dose to the public
  - Relative cost (construction, operating, decommissioning)

NUWASTE Features

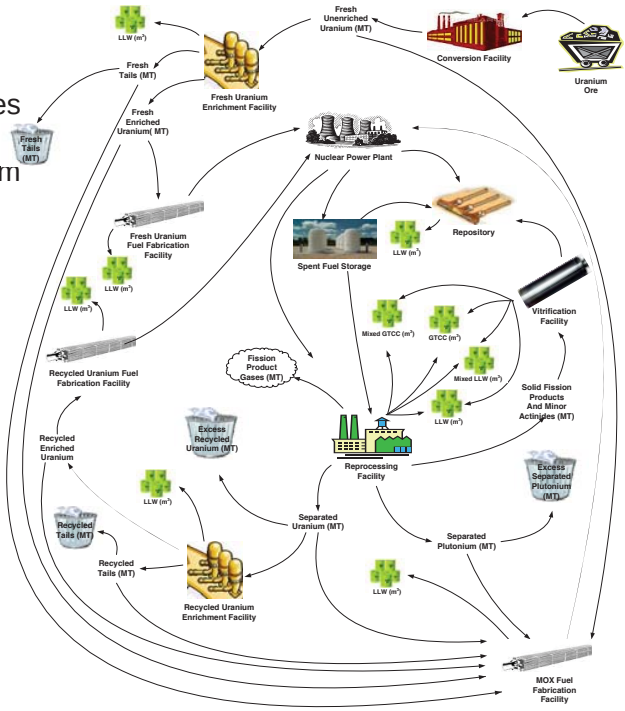
- Projects types, volumes and locations of SNF, HLW and other wastes
- Includes entire U.S. program – not focused on theoretical waste streams or specific fuel cycle facilities
- Currently includes LWR program using existing technologies
- Evaluates the impact of alternative SNF management options:
  - Dry surface storage
  - Reprocessing/recycling
  - Direct repository disposal
- Considers nuclear electricity generating capacity alternatives:
  - Present nuclear power plants only
  - Present plus planned nuclear power plants
  - New nuclear power plants as needed to maintain present generating capacity
- Allows selection of a variety of fuel fabrication options:
  - New uranium fuel
  - Recycled uranium fuel
  - MOX fuel

Other Factors Considered

- Facility availability
  - Start date
  - Operating period
  - Capacity
- PWR/BWR burn-up (GWd/MT)
- Fuel age ranges, and order of selection, for disposal and reprocessing
- Applying importance weights to various criteria
- Length of evaluation period

NUWASTE Process Operations & Material Flow

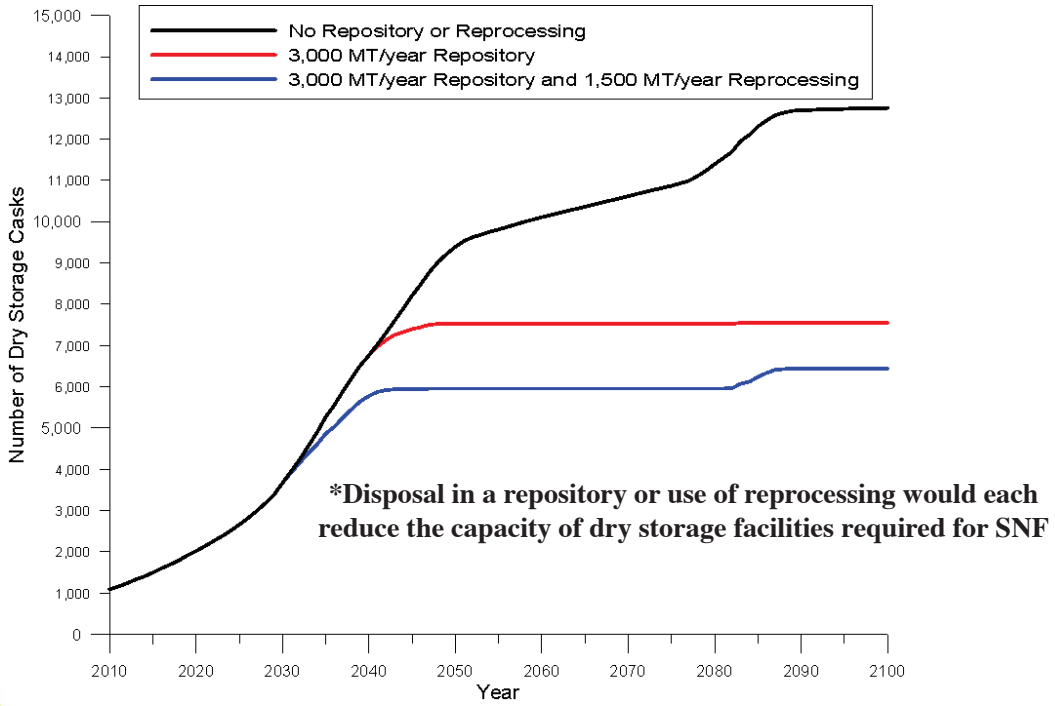
- Waste streams generated
  - Fission products and minor actinides
  - Fuel assembly components
  - Tails from new and recycled uranium
  - Low-level waste
  - Greater than Class C waste
  - Transuranic waste
- Facilities required
  - Recycled uranium enrichment
  - Recycled fuel fabrication
  - Spent fuel storage
  - Reprocessing
  - Vitrification
  - Repository for CSNF and HLW
  - Repositories for other wastes
- Transportation logistics



Scenarios Presented Today

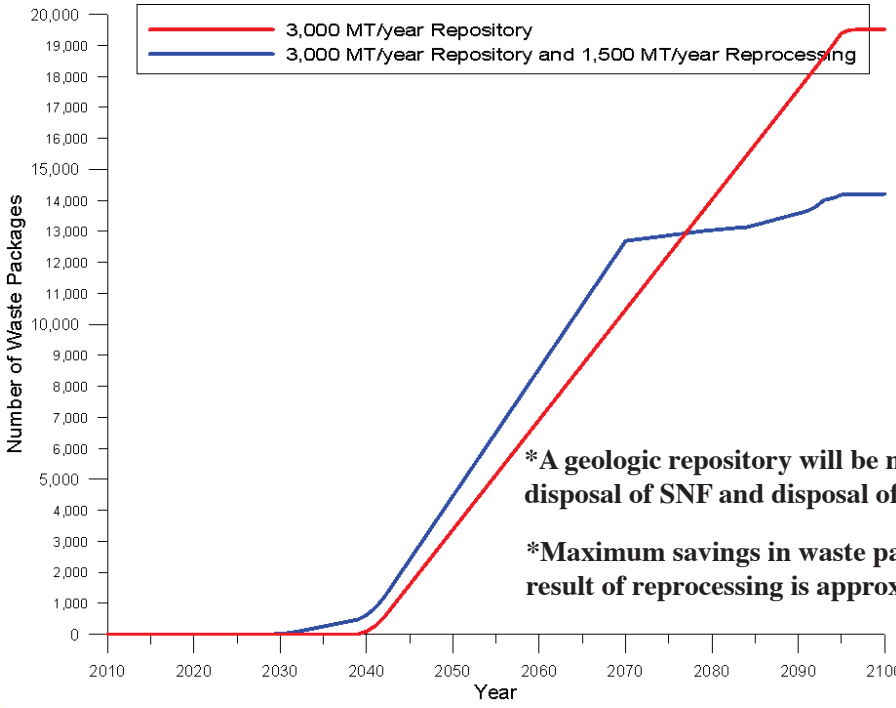
- Waste Stream
  - Existing plus 28 plants that have submitted license applications to the NRC
  - All plants operate for 60 years
  - 40 GWd/ton for assemblies discharged prior to 2010 and 60 GWd/ton burnup for assemblies discharged in 2010 and beyond
- Scenarios
  - Scenario 1: Long-Term Storage Only
    - No repository
    - No reprocessing facility
  - Scenario 2: Direct Disposal of SNF
    - Repository starts in 2040 with a capacity of 3,000 MT/year
    - No reprocessing facility
  - Scenario 3: Recycle of Uranium and Plutonium (Once)
    - Repository starts in 2040 with a capacity of 3,000 MT/year
    - Reprocessing starts in 2030 with a capacity of 1,500 MT/year
    - All separated uranium and plutonium recycled within one year

Number of Dry Storage Casks Required



***Disposal in a repository or use of reprocessing would each reduce the capacity of dry storage facilities required for SNF**

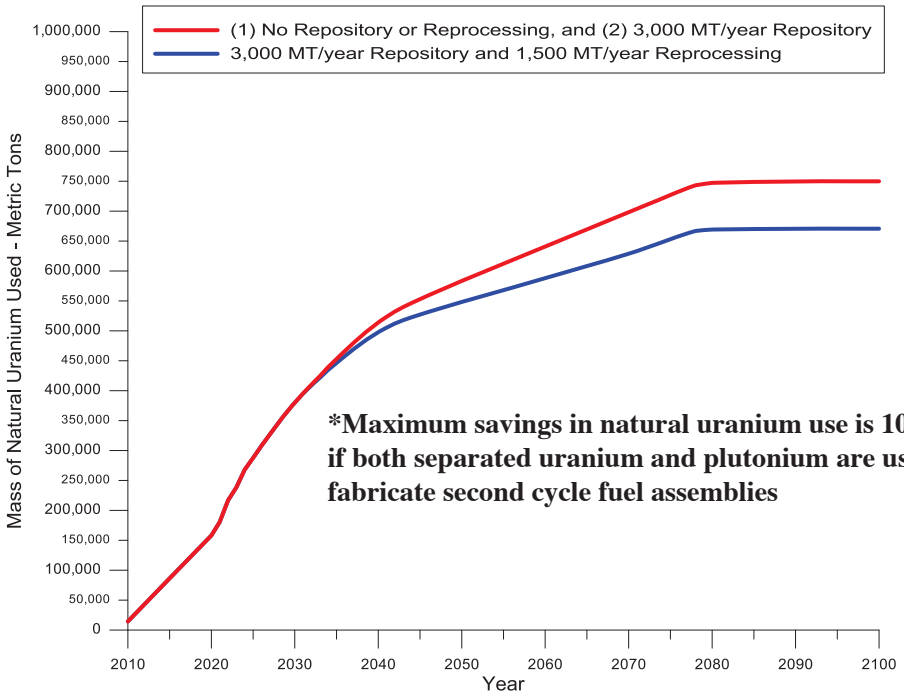
Number of Waste Packages Required



***A geologic repository will be needed for direct disposal of SNF and disposal of vitrified HLW**

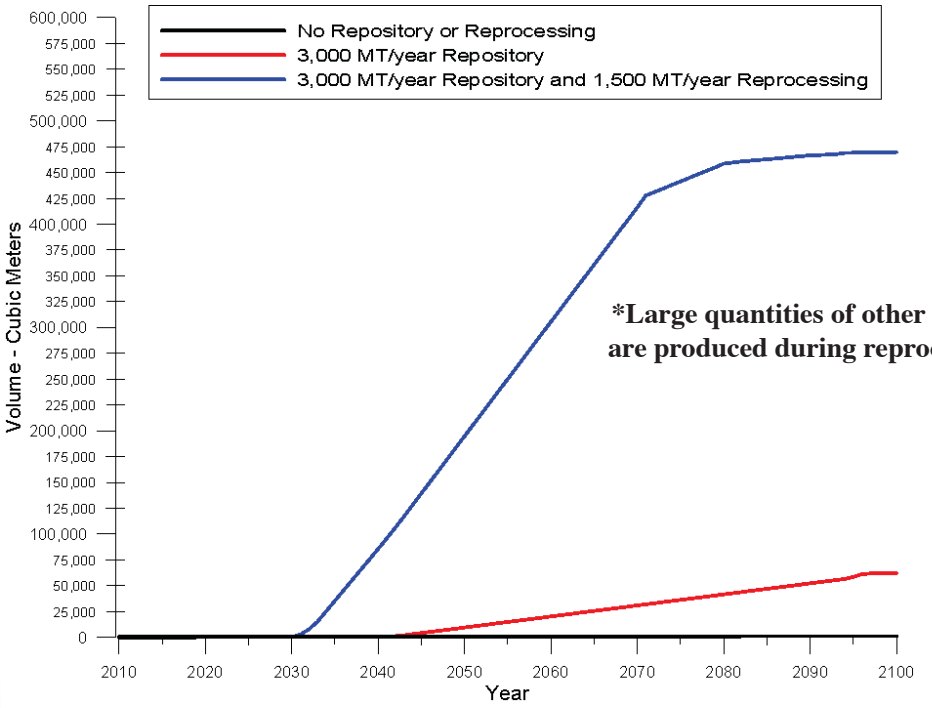
***Maximum savings in waste packages as a result of reprocessing is approx 25%**

Natural Uranium Usage



***Maximum savings in natural uranium use is 10-15% if both separated uranium and plutonium are used to fabricate second cycle fuel assemblies**

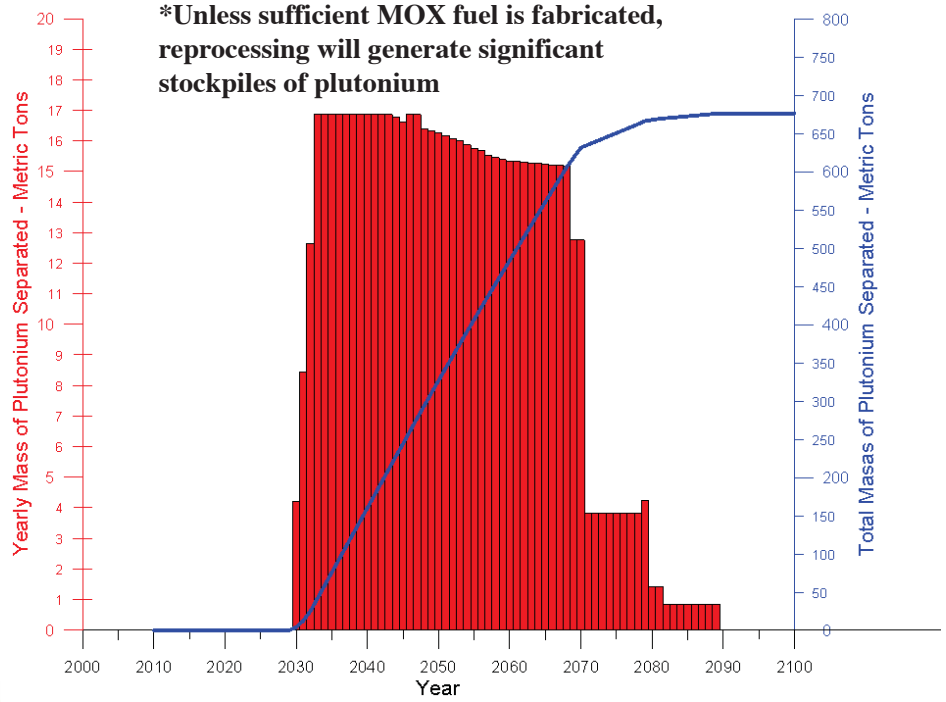
Quantity of LLW and GTCC Waste Generated



*Large quantities of other wastes are produced during reprocessing

Quantity of Plutonium Separated

*Unless sufficient MOX fuel is fabricated, reprocessing will generate significant stockpiles of plutonium



Overarching Observations

- NUWASTE can help understand the impacts of potential fuel cycle initiatives on the generation and management of SNF and HLW.
- A variety of waste management criteria warrant consideration.
- Under all likely scenarios, a geologic repository will be needed for disposal of both SNF and vitrified HLW.
- Significant delays in opening a repository will substantially increase the quantity of SNF in dry storage, potentially in at least 33 states.
- The analyses completed to date have not identified any major advantages from reprocessing, in terms of either reduction in repository volume required for disposal of SNF and HLW or in uranium demand.

NUWASTE – Ongoing Activities

- Communicate results to Congress, DOE, BRC and other interested parties.
- Include additional functionality
  - relative facility construction, operating and decommissioning costs
  - relative dose to the public
- Identify and evaluate additional scenarios.
- Extend NUWASTE capabilities
  - away from reactor central storage facility/facilities
  - processing of DOE SNF, disposal of all DOE HLW
  - transportation equipment/facility characteristics and logistics
  - small modular reactors
  - advanced (Gen III and IV) reactor designs, fast reactors

Experience Gained On the Management and Disposition of High-Activity Waste

Presentation to the Blue Ribbon Commission on America's Nuclear Future

U.S. Nuclear Waste Technical Review Board
B. John Garrick, Chairman November 16, 2010

Thank you for inviting me here today to discuss lessons learned from U.S. and international waste disposal efforts. I am John Garrick, Chairman of the U.S. Nuclear Waste Technical Review Board. Four members of the Board are in the audience to provide assistance in answering your questions.

About the Board

I know that two of your subcommittees have heard from other Board members and staff, so I will only very briefly describe the Board and its role. The Board is an independent federal agency composed of 11 technical and scientific experts. It is nonpartisan and apolitical. Members are appointed by the President to 4 year terms from a list of nominees submitted by the National Academy of Sciences. By the way, I should mention that former Congressman and current Commissioner Phil Sharp played a pivotal role in crafting an amendment that created the Board in the 1987 amendments to the Nuclear Waste Policy Act. I know that Senator Domenici also played an important role in the passage of that legislation. The Board is charged with conducting unbiased ongoing technical peer review of activities undertaken by the Secretary of Energy related to the implementation of the Nuclear Waste Policy Act. In particular, we assess the technical and scientific validity of DOE activities to manage and dispose of spent fuel and high-level radioactive waste, which I lump together under the rubric of "high-activity waste." The law requires us to report our findings, conclusions, and recommendations at least twice a year to Congress and the Secretary.

I should establish at the outset that the Board's statutory mandate continues even as alternatives to a Yucca Mountain repository are considered. The Board's current review work and priority tasks reflect the transition of DOE's nuclear waste-management activities to include potential fuel cycle alternatives to direct disposal of spent fuel.

What are our current priorities?

I will list very briefly some of the Board's current priority tasks:

- Since June 2009, the Board has reviewed the technical issues of *very long-term storage* of commercial spent fuel. The Board is developing a White Paper on this subject that we will use as the basis for reviewing DOE's research related to extended storage of both commercial and government-owned high activity waste.
- Another effort supporting our ongoing review is a material-balance analytical tool called NUWASTE, which was introduced to the Blue Ribbon Commission's Reactor and Fuel Cycle Technologies Subcommittee last month by my Board colleague Mark Abkowitz. The results provide

important insights on the potential benefits of different back-end processes and activities such as recycling of uranium and plutonium and long-term storage of spent fuel.

- To determine the technical effects of how a delay in repository availability affects the plans of federal facilities that store government-owned high-activity waste, the Board has visited most of the facilities where these wastes are stored. We plan to issue a report on our findings and conclusions during 2011.
- We are in the process of revising the report we published a year ago that presents information on the programs being developed in other countries for managing high-activity waste. Board staff member, Daniel Metlay, presented the original report at the Blue Ribbon Commission's Disposal Subcommittee meeting in July this year. The revised report will be extended to include a qualitative and historical assessment of how the countries we surveyed are going about developing their geologic repository programs, and it will draw some conclusions on how external factors have impacted the repository programs in those countries.
- Last, but far from the least, is the Board's preparation of a report of technical lessons learned from the U.S. and repository programs worldwide. This report will be made available to the Blue Ribbon Commission when it has been finalized. Much of the balance of my talk will focus on the highlights from this report.

Deep Geologic Disposal

First however, the Board feels compelled to express its support of the opinion voiced by many others that regardless of the nuclear fuel-cycle option adopted, a repository for permanent disposal of high-activity wastes will be necessary. In addition, I personally believe that having a plan in place for permanent disposition of the waste, on which there is agreement and a path forward, is essential to gaining public confidence in the nation's ability to manage nuclear waste.

Right now, I think we have a temporary fix for a problem that very much requires a permanent solution. Government-owned high-activity waste is being stored at several federal facilities, and commercial spent nuclear fuel is being stored at more than 100 nuclear power plants nationwide at over 70 different sites. The current inventory of high-activity waste in storage is greater than 60,000 metric tons of heavy metal and is being added to at the rate of about 2,000 metric tons per year.

So, what is *the solution?* That is, of course, part of what the Blue Ribbon Commission has been asked to consider. But, deep geologic disposal must be at least part of the answer.

The objective of deep geologic disposal is to isolate high-activity radioactive waste from humans and the accessible environment for durations that are unprecedented in our history. This is, of course, easier said than done. Some of the more important technical challenges to waste isolation are that high-activity waste is made up of diverse radioactive species with widely differing inventories; different types of radiation; different rates of decay; and different physical, chemical, and thermal properties. The waste generates heat in the geological environment, which results in high temperatures for a relatively long period of time — on the order of a thousand years. The high temperatures significantly affect geochemical processes associated with mobilizing the radionuclides as well as the rates and mechanisms of degradation of the engineered barriers. Additional complexity is introduced by hydrogeological and "coupled processes," that is, the interactions of nuclear, thermal, chemical, and mechanical processes.

The result is a dynamic system and considerable complexity in predicting the long-term performance of a repository.

Experience Gained from Efforts in the U.S. and Other Countries to Develop a Geologic Repository

Every time I think or talk about learning from experience, I'm reminded of what President Truman once said, "There is nothing new in the world except the history you do not know." And the late great nuclear pioneer Walter Zinn several decades ago often pointed out that many scientists and engineers complain that there is too little data, when in fact the problem is that we seldom take advantage of the data that is available. In the spirit of President Truman and Dr. Zinn, we have attempted to capture some nuggets from what has been learned during the last several decades from disposal efforts in the U.S. and other countries that might be useful in the future. Because we know the U.S. program from our own involvement, the Yucca Mountain Project provides the primary source of information for our retrospective. Obviously we have learned much more about geologic disposal than I can cover in a few short moments, but let me highlight a few examples.

Preliminary Findings

- First and foremost, the cumulative experience of the Yucca Mountain program, the Finnish, French, Swedish, Swiss, and the Waste Isolation Pilot Plant program provides a high level of confidence that deep geologic repositories are indeed feasible. And it should be noted that the planned repositories for these programs and the operating Waste Isolation Pilot Plant are located in different geological environments including tuff, granite, clay, clay and granite, and salt.
- We learned to expect surprises when you get underground during the site-characterization phase, so the sooner you go underground the better. Two examples of surprises at Yucca Mountain were (1) the possible discovery of bomb-pulse chlorine-36 at the repository level, which if eventually confirmed, means that a small amount of surface precipitation could reach the repository level in 50 years or less; and (2) the discovery of a repository environment riddled with pockets (the technical term is lithophysae) ranging in size from the diameter of your thumb to the diameter of a basketball and larger, which considerably complicated geotechnical and heat transfer modeling. Another example of a surprise is that in the early days of the Waste Isolation Pilot Plant characterization, experiments with heat-generating surrogates demonstrated that the creep rate of the salt at higher temperatures was far greater than had been determined in the laboratory.
- We learned that including a robust engineered barrier system can have significant advantages over a program that relies primarily on what is referred to as the "natural system." Because the materials and manufacturing methods used for the engineered barriers can be specified and controlled, confidence in their predictability may be greater than that of the natural system. Of course this assumes that the environment in which the engineered barriers would operate is understood. The result can be much greater confidence in the form, quantity, and rate (the source term) of radioactive material from the disposed waste entering the natural system.
- We have learned a great deal about the importance of analyzing the contribution to overall risk of different waste forms. A much improved knowledge base now exists to guide future efforts in specifying the most appropriate waste forms for permanent disposal.

- A disposal facility involves many first of a kind systems and components for which there is minimum experience. A carefully planned and systematic program of prototyping such systems and components in their expected environments is essential to understanding and modeling their potential performance.
- We learned how important it is to have a waste package design that allows for direct disposal of a variety of canisters, including loaded dual-purpose canisters, to minimize the handling of high-activity waste. Waste handling is considered a significant contributor to the risk of any high activity waste management system.
- Major advancements were made in the Yucca Mountain Project on how to use the risk sciences to quantify postclosure performance over extremely long time periods. An important spinoff of this work is the use of phased and interactive probabilistic performance assessments to identify what is important to focus on in the characterization program.
- We learned how important it is to implement a rigorous and integrated total systems approach to characterizing a repository site, developing a repository, and designing and operating a waste management system that involves such diverse activities as transportation, storage, packaging, handling, and disposal. It is important to know how decisions made in each functional area of the waste management system affect other parts of the system. In particular, the impact of decisions and design requirements having to do with postclosure have to be traceable to their impact on preclosure activities including waste handling and transporting, and the actual design and construction of the surface facilities for the project to be efficient in its operation.
- We learned that it is essential to have a close relationship between the science program and the engineering activities in such projects to control costs, schedules, and other performance goals. Experience indicates the importance of making the transition from a science program to an engineering project at the right time.
- And finally, experience tells us that a license application in the U.S. can be developed that meets the requirements of the Nuclear Regulatory Commission for accepting a license application to review—a major achievement.

Experience in Other Countries

Experience in other countries could become increasingly significant depending on when the United States resumes efforts to site and develop a deep geologic repository.

Some findings from the experiences of programs worldwide are:

- Repository systems can be developed in a variety of geological environments.
- Most proposed disposal concepts rely on both natural and engineered barriers, although the degree of reliance on one or the other varies considerably.
- Research carried out at-depth in underground research laboratories has been extremely valuable.

Moving Forward

These are some of the lessons that the Board learned from its review of different high activity waste repository programs, although I have only had time to present them here at the highest level. As I

mentioned, I believe that keeping a focus on a permanent solution is critical regardless of what interim alternatives to managing high-activity nuclear waste are recommended. The basis for this view is:

- A permanent solution is critical to building public confidence that there is indeed a way of isolating high-activity waste;
- History teaches us that institutional stability is not guaranteed forever. The longer the delay in resuming a repository program the higher the probability that it could be disrupted during the operational phase by institutional changes;
- An international scientific consensus exists that a permanent geologic repository is the preferred disposal option and that it is technically feasible.

It appears that the following are necessary to move forward:

1. An assessment of repository-development experiences to date should be used as a baseline for future geologic disposal programs; site-selection and site-characterization activities in the U.S. would benefit from such an assessment.
2. Characterization of waste forms together with existing inventories of high-activity waste should be revisited, and the issue of the optimal method of disposal for each waste form should be addressed. In other words, the one-size-fits-all approach used at Yucca Mountain may or may not be the best approach.
3. Once a site has been selected, characterized, and found suitable, an engineering-oriented project plan for the design, construction, licensing, and operation of a geologic disposal facility for high-activity waste should be developed. At the same time, a scientific research program that is tailored to the requirements of the engineering plan and the repository site selected should continue in parallel, both for better technical understanding and to identify potential improvements to the engineering plan.

I hope that this brief representation of some findings from the Board's work undertaken as part of its review of DOE activities has been useful. We look forward to providing other technical information that you feel would be helpful to your deliberations, and, of course, all the Board's reports, correspondence, congressional testimony, and meeting materials are available on our website.

Thank you for your time. I will be pleased to respond to questions.

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

June 30, 2011

The Honorable Chuck Hagel
The Honorable Jonathan Lash
Co-Chairs
Disposal Subcommittee
Blue Ribbon Commission on the America's Nuclear Future
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Commissioner Hagel and Commissioner Lash:

On behalf of the Nuclear Waste Technical Review Board, I would like to submit general comments on the Subcommittee on Disposal's draft report, dated June 1, 2011.

As you know, the Board has followed closely the Commission's activities since its inception. Board members and staff have testified on several occasions, either before subcommittees or the full Commission. The Disposal Subcommittee's draft report provides a strong foundation for debating key institutional issues that need to be addressed as the Nation moves forward with its efforts to provide a long-term solution to the problem of managing high-level radioactive waste and spent nuclear fuel.

Given its *technical* mandate, the Board will not offer a detailed critique of the Subcommittee's three key recommendations dealing with institutional design (organizational form, funding, and siting strategy), other than to note that Board members with extensive program management experience concur with the draft report's conclusion that substantial changes are necessary in these areas. Nor, consistent with its past practice, will the Board comment on the Subcommittee's recommendations dealing with the Environmental Protection Agency and the Nuclear Regulatory Commission.

The Board has, however, recently published two substantial reports—*Technical Advancements and Issues Associated with the Permanent Disposal of High-Activity Wastes* (TAI) and *Experience Gained from Programs to Manage High-Level Radioactive Waste and Spent Nuclear Fuel in the United States and Other Countries* (EG)—that speak to matters raised by the Subcommittee.[1] As the following paragraphs suggest, the Subcommittee has reached conclusions that are tightly aligned with many of the views contained in those Board reports.

[1]Both of these reports are available on the Board's website: www.nwtrb.gov.

On the need for a deep-mined geologic repository

In Chapter Four of the draft report, the Subcommittee maintains that "one or more permanent disposal facilities for high-level nuclear waste will be needed in the United States under all reasonably foreseeable scenarios" and that "[d]eep geologic disposal has emerged as the most promising and technically acceptable option" [pg. 27]. The Board agrees. As it states in its TAI report:

> The Board believes that keeping a focus on a permanent solution is critical regardless of what interim measures for managing high-activity waste are charted. Among the reasons are (1) a permanent solution is critical to building public confidence that there is a way of isolating nuclear waste radioactivity from the biosphere to acceptable levels; (2) given the long duration of the hazard of high-activity waste, undue delay in implementing a permanent solution could make tenuous a concept of waste management dependent on institutional stability; (3) experience to date has indicated that deploying a permanent solution to isolating high-activity waste could take decades; and (4) there is an international consensus that a permanent solution to high-activity waste isolation is feasible via geologic disposal. [pg. 69]

On the question of organizational form for the implementer

In Chapter Five of the draft report, the Subcommittee considers alternative organizational forms that a new manager of a nuclear waste program might take on. The Subcommittee recommends that a FEDCORP-like organization be created to direct future efforts. The Board takes no position on this particular recommendation, but it is cognizant of language in the draft report that seems to qualify the Subcommittee's position. To begin with, the Subcommittee realizes that the choice of organizational form depends on how potentially conflicting values, such as independence and accountability [pg. 31], are traded off. Further, the Subcommittee understands that "[t]he general conclusion has been that a number of different organizational forms are viable and could work to provide the focus and effectiveness needed to successfully implement program objectives" and "[m]ore importantly than what form it takes is that a new waste management organization display certain behaviors and attributes (i.e., competence, transparency, flexibility, responsiveness, accountability, etc.)" [pgs. 41, 42].

Both of these conclusions very closely reflect views that the Board expresses in its TAI and EG reports. The impact of organizational arrangements on technical work, for instance, is addressed in the TAI report.

> [There is a] need for continuity of management, personnel, and funding. Contractors came and went, and managers cycled in and out, while the amount of money available in the next fiscal year was always in doubt and not under the control of the management of the program. Any engineering program would benefit greatly from having a dedicated organization that would maintain continuity of its personnel, especially of its management and principal engineers and scientists. [pg. 40]

More generally, the EG report considers how different countries have organized their waste-management programs.

> The choice of organizational form for the implementer depends in each country on how value-based conflicts are resolved. There does not seem to be "one best way" that can be universally applied. [pg. 22]
>
> Rather than organizational form *per se*, what appears to be important are organizational behaviors, such as leadership continuity, funding stability, and the capacity to inspire public trust and confidence over long periods of time. [pg. 60]

The Board believes that the experience of the 13 national waste-management programs it examined in its EG report does not unequivocally support the Subcommittee's claim that FEDCORP-like organizational form is the most appropriate for the United States. At most, the international experience suggests that an organization devoted exclusively to managing high-level radioactive waste and spent nuclear fuel, whether government, private, or hybrid, seems to work better than an organization that has multiple missions, some of which may be at cross-purposes with its waste-management responsibilities.

On structuring a new siting and development process

In Chapters Three and Seven of the draft report, the Subcommittee devotes considerable attention to diagnosing the root causes of the problems encountered in the United States in siting and developing both consolidated interim storage facilities and deep-mined geologic repositories. The Board believes that the Subcommittee's historical analysis is largely correct and informed. Out of the Subcommittee's evaluation comes the recommendation that a "phased, adaptive approach" be adopted. Support for this recommendation comes from a report by the National Research Council (NRC), *One Step at a Time,* as well as from international experience especially in Canada.[2]

In its EG report, the Board takes note of the fact that the approach the Subcommittee recommends is derived from research on decision-making dating back to the 1950s. Subsequently, researchers have assessed both the strengths and weaknesses of such an approach. The Subcommittee's discussion does not fully reflect the balance of those assessments, which are well-described in both the NRC report cited above and key documents issued by the Canadian program. For example, the Subcommittee does not examine the difficulties the Japanese have encountered, even pre-Fukushima, in implementing a phased, adaptive siting strategy.

As the Board observes,

> At the theoretical level, it is hard to find fault with a decision-making strategy that seems to promise so much [in terms of potential benefits]. As a more practical matter, however, it is unclear whether it can be any more successful than earlier efforts in overcoming local and state opposition to specific siting decisions, whether it can be implemented, and whether it *should* be implemented. [pg. 6]

[2]The Subcommittee's draft report asserts that the phased adaptive approach also has been used in Finland and Sweden. A review of the historical record in both these countries suggests that neither one originally cast its siting process in those terms. Although it is possible to interpret what both countries did as being consistent with a phased, adaptive approach, such an interpretation probably reflects the malleability of the concept most of all.

The Board thanks the Commission for the opportunity to comment on the draft report prepared by the Disposal Subcommittee. The Board looks forward to interacting with the Commission as it moves forward in preparing its final report.

Sincerely,

{Signed by}

B. John Garrick
Chairman

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

June 30, 2011

The Honorable Phil Sharp
The Honorable Richard Meserve
Co-Chairs
Transportation and Storage Subcommittee
Blue Ribbon Commission on the Nation's Nuclear Future
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Commissioner Sharp and Commissioner Meserve:

On behalf of the U.S. Nuclear Waste Technical Review Board, I am submitting these Board comments on recommendations in the Transportation and Storage Subcommittee's draft report, dated May 31, 2011. The Subcommittee in its draft report identifies many important issues and makes recommendations that will contribute positively to a discussion among policy-makers on an effective approach for managing high-level radioactive waste (HLW) and spent nuclear fuel (SNF). As the Board has often stated, we believe that it is important to move forward expeditiously in establishing policies and taking actions that demonstrate the will and the capacity for addressing these critical national issues.

As you know, the Board has followed closely the deliberations of the Blue Ribbon Commission on America's Nuclear Future (Commission) since the Commission was established in January 2010. Board members and staff have testified on several occasions, either before the full Commission or its subcommittees. In its presentations and written documents, the Board has provided its technical perspective, consistent with its mandate to review the technical and scientific validity of activities undertaken by the Secretary of Energy related to implementing the Nuclear Waste Policy Act and to report Board findings and recommendations to Congress and the Secretary.

Based on the Board's experience in reviewing DOE SNF and HLW management activities and its strong interest in an integrated systems approach to U.S. high-level radioactive waste management (an interest shared by the Commission's Transportation and Storage Subcommittee), the Board conveys the following comments on Subcommittee recommendations numbers 1 through 3, and recommendation number 6.

Subcommittee Recommendation #1: *The United States should proceed expeditiously to establish one or more consolidated interim storage facilities as part of an integrated, comprehensive plan for managing the back end of the nuclear fuel cycle. An effective integrated plan must also provide for the siting and development of one or more permanent disposal facilities.*

Board Comments: The Board believes that the system-wide implications of developing consolidated interim storage should be considered as part of a detailed evaluation that includes the advantages and disadvantages of such an approach. For example, the Board notes in its report, *Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel*,[1] that the length of time SNF is stored at commercial nuclear power plant sites will affect the degree to which fuel or dry storage system components may degrade. Such degradation affects compliance with the regulatory requirements for storage, retrieval, and transport of SNF. Information from the detailed analysis, suggested above, also will inform decisions about what technical capabilities may be required at SNF storage-site locations. The Board agrees that taking full account of the complex nature and integrated dependencies of the entire waste disposal system is vitally important in making any decisions about options for managing SNF and HLW. Thus, siting an interim storage facility without an integrated waste management plan is not recommended.

Subcommittee Recommendation #2*: Recognizing the substantial lead-times that may be required in opening one or more consolidated storage facilities, dispersed interim storage of substantial quantities of spent fuel at existing reactor sites can be expected to continue for some time. The Subcommittee has concluded that there do not appear to be unmanageable safety or security risks associated with current methods of storage (dry or wet) at existing sites. However, to ensure that all near-term forms of storage meet high standards of safety and security for the multi-decade-long time periods that they are likely to be in use, active research should continue on issues such as degradation phenomena, vulnerability to sabotage and terrorism, full-scale cask testing, and other matters.*

Board Comments: The Board agrees that technical information and experience to date indicates that low-burnup SNF can be stored safely in the short-term and then transported for additional storage, processing, or disposal. However, as noted in its report on *Extended Dry Storage*, referenced above, the Board believes that there are outstanding issues for which more information is needed before it can be concluded that SNF can be safely placed in dry storage over an extended period of time. For this reason, the Board strongly endorses the Subcommittee's recommendation that an active and sustained research program is required to obtain the additional information necessary to have similar high-confidence in the safe extended storage and subsequent transportation of SNF, particularly for high burn-up SNF, and HLW. Recommendations for future research described in the Board's report concur with the summary of research needs that are discussed in in Chapters 3, 4, and 7 of the draft Subcommittee report. Additionally, after extended storage at an interim site, and particularly after transportation, the condition of the spent fuel would need to be established to confirm the integrity of the cladding.

Subcommittee Recommendation #3: *Spent fuel currently being stored at decommissioned reactor sites should be "first in line" for transfer to a consolidated interim storage facility as soon as such a facility is available.*

Board Comments: The Board believes that, should one or more consolidated interim storage facilities be constructed, an incremental, staged approach for transferring SNF and HLW to an interim facility is appropriate. It makes sense for the reasons outlined in your report to consider

[1] This report is available on the Board's website: www.nwtrb.gov.

decommissioned sites as "first in line." However, should it be necessary to transfer SNF or HLW from storage containers to transportation casks after extended storage, this will require either dry-transfer capability or the availability of an operational spent fuel pool at the interim facility.

Subcommittee Recommendation #6: *The current system of standards and regulations governing the transport of spent fuel and other nuclear materials appears to be functioning well, and the safety record for past shipments of these types of materials is excellent. However, planning and coordination for the transport of spent fuel and high-level waste is complex and should commence at the very start of a project to develop consolidated storage capacity.*

Board Comments: The Board strongly concurs with the Subcommittee that transportation planning should be considered as early as possible in the development of any waste management system in line with the Board's comment on Subcommittee Recommendation 1. As the Board has noted in its "Extended Storage Report", there are inconsistencies in NRC's storage and transportation regulations that need to be addressed. Based on prior experience with the U.S. repository program, the Board notes the existence of transportation logistics challenges that can affect safety and operational efficiency with respect to loading/unloading, access/egress, and line-haul operations. The Board also notes that, although the safety record for past shipments of these types of materials may be excellent, the scale of the transportation campaign involved in transferring SNF and HLW to one or more interim storage facilities could dwarf those of previous shipments.

Finally, the Board notes that during the next year, a significant amount of new technical information may be available from the Extended Storage Collaboration Program (ESCP), with which the Board interacts, which is focusing on research and information needs related to extended dry storage. The ESCP effort and other analysis and planning work being carried out by the Department of Energy, the Nuclear Regulatory Commission, and the nuclear industry, may provide useful technical information on aspects of the system for managing and disposing of SNF and HLW. The Board suggests that to the extent new technical findings become available in the next few months, the Commission consider such information, if possible, in drafting its final report.

The Board appreciates the interest and courtesy the Commission has extended to the Board during the Commission's deliberations. We hope that the Commission will continue to call on the Board when it requires technical information related to the management or disposal of SNF and HLW.

Sincerely,

{Signed by}

B. John Garrick
Chairman

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

July 14, 2011

The Honorable Pete Domenici
The Honorable Per F. Peterson
Co-Chairs
Reactor and Fuel Cycle Technology Subcommittee
Blue Ribbon Commission on the Nation's Nuclear Future
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Commissioner Domenici and Commissioner Peterson:

On behalf of the U.S. Nuclear Waste Technical Review Board, I submit these Board comments on the Reactor and Fuel Cycle Technology Subcommittee draft report, dated June 2011.

As you know, the Board has followed closely the Commission's activities since the Commission was established. Board members and staff have testified on several occasions, either before Commission subcommittees or the full Commission. Given the Board's technical mandate, it would not be appropriate for the Board to make comments on non-technical aspects of the Subcommittee's recommendations. However, the Board is pleased to provide the following technical comments.

The Board notes the Subcommittee's discussions on the need to provide *"near-term improvements in the safety and performance of existing light-water reactor technology as currently deployed in the United States"* and the need for *"longer-term efforts to advance potential 'game-changing' nuclear technologies and systems that could achieve very large benefits across multiple evaluation criteria compared to current technologies and systems."* The Board believes that consideration of improvements in existing technologies and development of new nuclear technologies should include the waste-stream consequences of the adoption of the changes as part of the decision-making process. For example, changes in fuel burnup levels achieved in reactors, together with changes in other performance parameters and the introduction of "game-changing" technologies, such as advanced reprocessing flowsheets, may have a significant impact on both waste streams requiring disposal and the final waste forms best suited to their disposal. The Board thus recommends that any evaluation of the benefits of such changes also take into account the impact on the waste management requirements that will result from the adoption of the changes.

Evaluation of various potential fuel cycles is extremely difficult due to the highly technical aspects of these fuel cycles and the lack of mature development of the technologies. The Board agrees with your conclusion that *"No currently available or reasonably foreseeable reactor and fuel cycle technologies—including current or potential reprocess and recycle*

technologies—have the potential to fundamentally alter the waste management challenge this nation confronts over at least the next several decades, if not longer." This conclusion should be integrated into the nation's near-term planning for what needs to be done to deal with the continuing build up of nuclear waste from commercial nuclear plants and the existing stockpile of defense and DOE wastes stored across the country. While RD&D is important, it also is important to move on a disposal solution which will ultimately be required regardless of waste form(s). Efforts at siting such a facility should not be delayed by RD&D on fuel-cycle alternatives.

The Board thanks the Commission for the opportunity to comment on the draft report prepared by the Reactor and Fuel Cycle Technology Subcommittee. The Board looks forward to interacting with the Commission as it moves forward in preparing its final report.

Sincerely,

{Signed by}

B. John Garrick
Chairman

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

October 31, 2011

The Honorable Lee H. Hamilton
The Honorable Brent Scowcroft
Co-Chairs
Blue Ribbon Commission on America's Nuclear Future
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Representative Hamilton and General Scowcroft:

On behalf of the U.S. Nuclear Waste Technical Review Board, I am submitting comments to the Blue Ribbon Commission on America's Nuclear Future on the Commission's *Draft Report to the Secretary of Energy*, dated July 29, 2011.

As you know, the Board has followed closely the work of the Commission since the Commission was established in January 2010, and Board members and staff have testified on several occasions before the Commission and its subcommittees. In addition, we provided comments on June 30, 2011, on the draft reports issued by the Commission's Subcommittee on Disposal and Subcommittee on Transportation and Storage, and on July 14, 2011, on the draft report of the Commission's Subcommittee on Reactor and Fuel Cycle Technology. Those comments are available on the Board's website, www.nwtrb.gov, as well as on the BRC website. The comments in this letter are in addition to our comments on the subcommittee drafts.

The Board believes that the Commission's *Draft Report* reflects the substantial time and effort the Commission has invested in gathering information and in sorting through a diversity of views on policies that are needed to effectively manage the country's high-activity nuclear waste. The Board strongly concurs with the Commission's findings that deep geologic disposal is the most promising and accepted method currently available for safely isolating spent nuclear fuel (SNF) and high-level radioactive waste (HLW) for very long periods and that a permanent repository will be needed for any fuel cycle option that might be implemented in the reasonably foreseeable future. We also believe that as decisions are made on how to accomplish deep geologic disposal, it is very important that ongoing technical work should continue.

The Board's statutory mission is to evaluate the technical and scientific validity of Department of Energy (DOE) activities related to managing and disposing of SNF and HLW and to report Board findings, conclusions, and recommendations to Congress and the Secretary of

Energy. In the following paragraphs, the Board comments on technical topics discussed in the Commission's *Draft Report*.

Developing Generic Siting Criteria – The Board concurs with the Commission that development of generic repository siting criteria should proceed without delay. The Office of Used Nuclear Fuel Disposition Research and Development, which reports to the Deputy Assistant Secretary for Fuel Cycle Technologies within DOE's Office of Nuclear Energy, is commencing research on generic siting criteria. As a starting point for this work, it is very important that DOE take into account its past efforts related to developing siting criteria along with similar work that has been undertaken by nuclear waste repository programs in other countries. The Board notes that from a technical perspective, generic studies do not replace the need to focus on specific geologies and potentially available sites in the United States that may meet the criteria. The Board suggests that the Commission consider encouraging DOE's ongoing generic siting work in the Commission's final report.

Generic Research on Geologic Media – The Board concurs with the Commission's finding that experience in the United States and other countries has shown that from a technical perspective suitable sites for deep geologic repositories for the disposal of SNF and HLW can be identified and developed. This experience can be applied to geologies in the United States to identify potentially viable locations for detailed site characterization. DOE currently is planning research that will provide generic information on geologic media.

Methods of Deep Geologic Disposal, including Deep Borehole Disposal – The Commission's *Draft Report* discusses disposal in mined geologic repositories and in deep boreholes. In the Board's report on *Technical Advancements and Issues Associated with the Permanent Disposal of High-Activity Wastes: Lessons Learned from Yucca Mountain* issued earlier this year, the Board recommends that consideration be given to using different methods of geologic disposal for different kinds of wastes depending on their potential for reuse. While deep boreholes are suggested in the Commission's *Draft Report* as a substitute for mined geologic disposal, the Board recommends additional R&D on deep borehole disposal to help resolve uncertainties about this approach and to allow for a more conclusive evaluation of its feasibility. Deep boreholes may play a role in disposal of small quantities of long-lived separated actinide wastes, but further study is needed on the effects of implementing this approach on the overall nuclear waste management system.

Radiation Source Term – The Commission's *Draft Report* discusses approaches to determining compliance with repository requirements. The Board believes that determining the radiation source term *realistically,* particularly with respect to the processes involved in mobilizing the waste, is critical to obtaining a fundamental understanding of the disposition of dose-contributing radionuclides. Such analyses can potentially help support a repository compliance case and can provide a much more credible understanding of how natural and engineered barriers would work together in a repository to contain and delay the release of radionuclides from the waste into the accessible environment.

Fuel-Degradation Mechanisms Related to Extended Dry Storage of SNF – The Board concurs strongly with the Commission that research is needed on fuel degradation mechanisms

and other factors that may affect the ability to store SNF for long periods. As discussed in the Board's report on *Extended Dry Storage and Transportation of Used Fuel,* issued in late 2010, the Board recommends that the ability to handle and transport such waste after extended storage also should be studied. DOE recently issued a draft "Gap Analysis" report on its research plans in this area and is collaborating closely with industry and with other government agencies, including the Nuclear Regulatory Commission and the Board, to develop its research program. The Board expects that this collaboration will result in a better understanding of the implications of extended dry storage.

Management of Federally Owned SNF and HLW – As noted in the Commission's *Draft Report*, DOE manages its own radioactive wastes from defense and research activities. Most of this waste is stored at three federal facilities: Hanford in Washington, Idaho National Laboratory (INL) in Idaho, and the Savannah River Site in South Carolina. DOE's Office of Environmental Management also participates with the state of New York in managing radioactive wastes from the country's only commercial reprocessing facility, which was located in West Valley, New York, and ceased operation in 1972. In addition, a joint DOE-Navy program manages spent naval reactor fuel at INL. The discussion of the wastes stored at these facilities in the Commission's *Draft Report* correctly reflects the importance of considering how these wastes should be managed and disposed of when evaluating options for permanent disposal of high-activity waste. The Board believes that a full discussion of the issues related to the need to permanently dispose of these wastes should be included in the Commission's final report.

The Board has visited the SNF and HLW management facilities at all four of these locations over the past two years and is preparing a report characterizing the amounts and types of wastes stored at each of them along with technical issues related to the management of the waste. The report will provide technical information for decision-makers as they discuss the Commission's recommendations on managing these wastes.

Effects of Various Fuel Cycle Technologies on SNF and HLW Management – The Board has consistently urged DOE to adopt a "systems" approach to radioactive waste management and strongly supports the Commission's finding that studies of alternative fuel-cycle technologies should account for linkages among all elements of the fuel cycle, including reactor technologies, fuel processing, transportation, storage, and disposal of SNF and HLW.

Transport of High Burnup Fuel –The Commission's *Draft Report* refers to the potential need to update regulations to allow for efficient transport of high burnup SNF. As mentioned above, the Board believes that research into technical factors associated with transporting such fuels also should be undertaken. As part of this exercise, the Board also advocates developing a technical basis for taking full credit for the loss of fuel reactivity as a result of burnup. The Board believes such work should have high priority because taking burnup credit potentially offers significant economies in developing a transportation system and cost savings at other stages of a spent fuel management program. The Board suggests that discussion of these issues be included in the Commission's final report.

International Cooperation – Over the last 20 years, the Board has engaged extensively with its counterparts in other countries that have nuclear waste programs and with the senior technical

personnel and managers of those programs to gain technical insights and perspectives that are useful in reviewing DOE activities. Information and analysis resulting from those interactions are included in two Board reports, *Survey of National Programs for Managing High-Level Radioactive Waste and Spent Nuclear Fuel* (October 2009) and *Experience Gained From Programs to Manage High-Level Radioactive Waste and Spent Nuclear Fuel in the United States and Other Countries* (April 2011). The Board has found its interactions with programs in other countries to be extremely valuable and joins the Commission in urging that U.S. program managers take full advantage of the experiences gained.

Retaining Technical Capability and Preservation of Technical Experience – The Board believes that it is imperative that information and data generated previously by the Office of Civilian Radioactive Waste Management be preserved in a reasonably accessible (electronic) form and recommends that the final Commission report address this important issue. Much of this information has generic attributes relevant to any geologic media. If the information and data are not retained, attempting to recover them after decisions are made on future waste management policies will be time-consuming and expensive. DOE's Office of Legacy Management has developed a plan for transferring and preserving this information. The Board is reviewing DOE's legacy management activities as part of its ongoing technical evaluation.

Many of these issues were discussed at a public meeting held by the Board in Salt Lake City, Utah, on September 13 and 14, which included a panel on the Commission's *Draft Report*. We were very pleased that John Kotek, the Commission's Executive Director, was able to participate in that panel. We would like to thank him for providing an excellent and very useful overview of the Commission's *Draft Report*. The panel also included Mr. Ward Sproat, former director of DOE's Office of Civilian Radioactive Waste Management, who presented his views on the *Draft Report*. The presentation by Mr. Sproat and the transcript from the meeting are available on the Board's website.

We appreciate this opportunity to provide comments on the Commission's *Draft Report*. We look forward to continuing our interactions and would be pleased to provide any additional technical information you might find useful as you prepare your final report.

Sincerely,

{Signed by}

B. John Garrick
Chairman

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

April 18, 2012

The Honorable Steven Chu
Secretary of Energy
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, DC 20585

Dear Secretary Chu:

The Nuclear Waste Technical Review Board (the Board) has read with considerable interest the final report of the Blue Ribbon Commission on America's Nuclear Future (the Commission). The report addresses a number of major issues that are important for our nation to succeed in answering the question of what we are going to do with our nuclear waste. The Commission conducted a comprehensive review of the problem and produced a frank and informative report on the many dimensions of a workable solution. The Board endorses the Commission's commitment to independent technical review, and believes that public trust in the storage and repository siting process can be enhanced by demonstrating that policy decisions have a firm and independently reviewed technical basis.

We understand that you have now appointed a Working Group to advise you on how DOE should respond to the recommendations in the report. Policies regarding nuclear waste must inherently involve questions of a technical nature. For the consideration of the DOE Working Group, we offer comments here on some of the more salient technical issues that we believe can affect the implementation of policies and the realization of plans to manage the nation's nuclear waste.

A New Consent-Based Approach to Siting Nuclear Waste Management Facilities

The Board has for some time had a keen interest in the domestic and international experience with consent-based siting approaches for nuclear waste storage and disposal facilities. We have also lamented, in the Commission's words, "the erosion of trust in the federal government's nuclear waste management program," which has certainly complicated finding technical solutions to the nuclear waste problem in our country. One aspect of establishing trust is to ensure a thorough consideration of technical issues that can guide the site-selection process. The establishment of site-independent safety criteria must be based on informed technical considerations, including technical lessons learned from both successful and failed projects in the U.S. and abroad.

Lessons learned from U.S. and international experience should be taken into account in developing guidelines, for siting, for the solicitation of volunteer sites, and for integrating the overall process. In particular, lessons learned from the failure of the nuclear waste negotiator approach should inform any consent-based volunteer-siting process.

A New Organization to Implement the Waste Management Program

The Board encourages the pursuit of the idea of "a new, single-purpose organization to provide stability, focus, and credibility." The Board has been concerned for some time with the lack of stability and, hence, of technical focus that results from management changes that accompany inevitable changes in the federal administration. This seemingly non-technical aspect of the program can in fact have severe implications for the technical direction and emphasis of a developing waste management program, which we see as being fundamentally one of science and engineering. We agree that the issues that the Commission defines regarding organizational structure require attention. We would add that rigorous peer review of technical aspects of the project must be part of the structure as is clear from the broad international experience to date.

The Commission declined to comment on the issue of comingling of waste from defense programs with the spent nuclear fuel from commercial power reactors at a single repository site. Nevertheless, we think that this is a technical issue that deserves consideration as a new organizational structure is considered. Because spent-fuel and high-level wastes are quite different in volume and activity, we think that a technical study to determine whether to separate commercial spent-fuel from defense and DOE wastes should be expeditiously completed in order to help establish a clear vision and mission for the organization charged with implementing the waste storage and disposal program.

Prompt Efforts to Develop a New Geologic Disposal Facility

The Board agrees with the Commission's position that disposal must be pursued with the same vigor as interim storage, because both need to be done in order to provide confidence that there is a solid integrated technical solution to the problem of the disposition of nuclear waste. One item that should be addressed expeditiously is the establishment of clear guidelines for identifying, and also potentially disqualifying, possible locations for one or more repositories. This work can draw on information from a variety of sources including geological information, census data, transportation networks, and so forth. In addition, the experience gained in other national programs should be carefully considered.

However, we are not particularly convinced that a demonstration of bore-hole disposal should be given the same priority as identifying, characterizing, designing, and developing a mined disposal site (to the point of a licensed demonstration project). The bore-hole concept has simply not yet been vetted technically to the extent that deep-mined geological disposal has. Furthermore, the need to disassemble fuel assemblies to implement bore-hole disposal would result in unnecessary worker exposure, and a decision to use bore holes might preempt retrievability options at a later time.

Another issue that the Commission recognized was the need to establish a new standard for repositories, because 10 CFR 63 is specific to Yucca Mountain. Specific choices related to the time period(s) chosen for demonstrating compliance with a standard are policy decisions, but we think scientific insights can be instructive and should be included in consideration of new standards and regulations.[1] Although one can greatly benefit from the use of probabilistic risk assessment methodologies in developing strategies for the safe disposal of highly radioactive waste, the length of the compliance period may well modify how these methods are applied. As an example, surface facilities

[1] For example, the Advisory Committee on Nuclear Waste issued a letter on the time of compliance (TOC) following a workshop that involved multiple parties (Letter of November 14 1996 to Chairman Shirley Jackson), in which it was stated that, "The dilemma in developing a TOC is that the time span must be sufficiently long to permit evaluation of potential processes and events leading to the loss of integrity of the repository and transport of radionuclides to the critical population. Yet the period must be short enough that inherent uncertainties in processes and events and in the biosphere and critical population group, which will increase with time, will not invalidate the results of the evaluation."

that operate for 100 years can use methods of analysis presently applied to conventional reactor-type standards, while a geologic repository, for which compliance periods stretch to hundreds of thousands of years, may require additional considerations.

Support for Underground Test Facilities

From a technical point of view, the Board generally supports the development of underground research laboratories as a preliminary step in designing and constructing a full-scale geologic repository. International experience has demonstrated the scientific and public acceptance benefits of the concept of geologic disposal. The ideal scenario from the point of view of economics and timing is a laboratory at a site that has been selected on the basis of a comprehensive siting process, the suitability of which is confirmed with strong scientific evidence from a variety of sources, including the underground research laboratory. To be sure there are circumstances where it may be expedient to use a surrogate site for an underground research laboratory that is an analog to the actual site or sites selected. There is the possibility that social or other reasons may exist for not locating an underground laboratory at a potential repository site. There is also the possibility that by the time a site is selected in the U.S. sufficient underground research exists in different geological media that a convincing scientific and technical basis can be developed to support a site without the need for a site-specific laboratory. The key point is that the siting process, whether it is for a repository, a laboratory, a pilot repository with a laboratory, or the combination of a laboratory and a full-scale repository, must make the intentions explicitly clear and acceptable to all stakeholders prior to project initiation.

Prompt Efforts to Develop One or More Consolidated Interim Storage Sites

Spent fuel is presently being stored at reactor sites. The BRC recommended, for several reasons, that this spent fuel be moved to one or more centralized interim storage sites. With the curtailment of the Yucca Mountain Project, the appeal for this interim step increases since it is not clear when a disposal site might be available. This is particularly true for decommissioned sites where the only remaining vestige of nuclear power operation is the spent fuel casks on secure pads. In the spirit of a pilot-scale approach, the Board recommends that an interim site be used for the early demonstration of the safe shipment of spent fuel to a centralized interim storage site. This would provide early technical input regarding the implementation of a much larger transportation program described below. Logical site choices with the consent of the states and local population would include national laboratories, DOE facilities, and former military sites where security and infrastructure would already be present. The interim nature of this storage would be evidenced by moving this spent fuel to the centralized storage facility when it becomes operational in the future.

Early Preparation for the Eventual Large-Scale Transport of Spent Nuclear Fuel and High-Level Waste to Consolidated Storage and Disposal Facilities

Regarding transportation, which is a near-term need for centralized interim storage and a mid-term need for repository disposal, the Board does not believe that the Commission report goes far enough. In order to handle the massive shipments of spent fuel that will be involved and to implement the needed infrastructure in terms of rail cars and handling systems, work needs to be started now. The technical challenges of upgrading existing rail lines have been evident in just the maintenance of the infamous Northeast Corridor to carry high-speed rail traffic. Different but analogous technical challenges can be expected to accompany the adaptation of existing rights-of-way to accommodate nuclear waste shipments, even if they will not travel at commuter speeds. The construction of new rail lines where none at all currently exist might present even greater technical challenges. The early selection of a centralized interim storage site could be the starting point for developing strategies and methods for the transport of highly radioactive waste to a geologic repository. The Private Fuel Storage Project has done much of this work already and that should be used as a basis. A solid technical understanding of the capacities and

limitations of the existing rail network and the possibilities for expanding it may have profound effects on where candidate sites can reasonably be located.

We support the recommendation that DOE should make public its suite of preferred routes for shipment of nuclear waste, because independent of site location this can reveal technical challenges involved (such as possible pinch points) and encourage open discussion of innovative technical solutions. We also support strongly the development of a technical basis for burn-up credit, i.e., the taking into account the reduction in reactivity that results from nuclear fuel having been used in a reactor, because this will greatly simplify all aspects of storage, transportation, and disposal. Finally, while the Commission has addressed transportation in its report, it does not address the difficult process of dealing with multiple state agencies for the transportation of spent fuel across states. The merits of having initial and daily inspections designed to insure the safety of the shipments augmented by detailed inspections at each state border deserve discussion that includes technical issues that may help shape risk-informed regulations.

Updating the Waste Classification System

Lastly, we support the need to review the outdated waste classification system and make it based on the form and activity of the waste rather than its source. Currently there is some waste generated at DOE sites that is orphaned in that there is no regulatory path for disposal. Rationalization of the waste classification system is needed to resolve this problem.

In summary, the Board believes that there are many technical issues that should be part of the discussions of the Working Group. Our aim in this letter is to convey what the Board considers to be some of the most important issues. Thank you for considering our thoughts on these important matters.

Sincerely,

{Signed by}

B. John Garrick
Chairman

cc:
Subcommittee on Energy and Water Development, Committee on Appropriations, U.S. Senate
Committee on Energy and Natural Resources, U.S. Senate
Subcommittee on Clean Air and Nuclear Safety, Committee on Environment and Public Works, U.S. Senate
Subcommittee on Energy and Water Development, Committee on Appropriations, U.S. House of Representatives
Subcommittee on Environment and the Economy, Committee on Energy and Commerce, U.S. House of Representatives
Committee on Science, Space, and Technology, U.S. House of Representatives

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Sincerely,

{Signed by}

B. John Garrick
Chairman

cc:
Subcommittee on Energy and Water Development, Committee on Appropriations, U.S. Senate
Committee on Energy and Natural Resources, U.S. Senate
Subcommittee on Clean Air and Nuclear Safety, Committee on Environment and Public Works, U.S. Senate
Subcommittee on Energy and Water Development, Committee on Appropriations, U.S. House of Representatives
Subcommittee on Environment and the Economy, Committee on Energy and Commerce, U.S. House of Representatives
Committee on Science, Space, and Technology, U.S. House of Representatives

APPENDIX F
MEETINGS OF THE U.S. NUCLEAR WASTE TECHNICAL REVIEW BOARD

JANUARY 1, 2008, THROUGH DECEMBER 31, 2012

Nuclear Waste Technical Review Board Meetings
2008 – 2012

January 16, 2008	**Winter Board Meeting** Las Vegas, NV Topics: Transportation of the Wastes Potential Tunnel Environments after Repository Closure Waste-Package Corrosion Issues
May 29, 2008	**Spring Board Meeting** Las Vegas, NV Topics: Total System Performance Assessment
September 24, 2008	**Fall Board Meeting** Las Vegas, NV Topics: Waste Management System Operations
January 28, 2009	**Winter Board Meeting** Las Vegas, NV Topics: Repository Tunnel Stability Issues Related to "Burnup" Credit
June 11, 2009	**Summer Board Meeting** Las Vegas, NV Topics: Nuclear Waste Inventories Waste Management Options Long-Term Storage
September 23, 2009	**Fall Board Meeting** National Harbor, MD Topics: Implications of Fuel-Cycle Technologies for Nuclear Waste Management and Disposal
June 29, 2010	**Full Board Meeting** Idaho Falls, ID Topics: DOE Plans for Managing Spent Nuclear Fuel and High-Level Waste
October 26, 2010	**Fall Board Meeting** Dulles, VA Topics: Technical Experience Gained During Development of the Yucca Mountain Repository Program

February 16, 2011	**Winter Board Meeting** Las Vegas, NV Topics: Discussions of Technical Issues Related to High-Level Nuclear Waste Management Efforts
April 27, 2011	**Spring Board Meeting** Amherst, NY Topics: West Valley Demonstration Project
June 6-7, 2011	**Workshop on Evaluation of Waste Streams Associated with LWR Fuel Cycle Options** Arlington, VA Topics: Evaluating Waste Streams
September 13-14, 2011	**Fall Board Meeting** Salt Lake City, UT Topics: DOE Plans for Research and Development related to Used-Fuel Disposition
January 9, 2012	**Winter Board Meeting** Arlington, VA Topics: DOE Integration Issues
March 7, 2012	**Spring Board Meeting** Albuquerque, NM Topics: Geologic Disposal of Nuclear Waste
October 17, 2012	**Fall Board Meeting** Idaho Falls, ID Topics: Transportation of High Activity Nuclear Waste

APPENDIX G

U.S. NUCLEAR WASTE TECHNICAL REVIEW BOARD

CORRESPONDENCE TO AND FROM THE U.S. DEPARTMENT OF ENERGY JANUARY 1, 2008 – DECEMBER 31, 2012

Nuclear Waste Technical Review Board
Correspondence with the Department of Energy

- Letter from B. John Garrick to Edward F. Sprout, III, Director, OCRWM; January 16, 2008

  Subject: DOE's participation at the September 2007 Board Meeting

- Letter from Edward F. Sproat, III, Director, OCRWM to B. John Garrick April 11, 2008

  Subject: DOE's response to the Board's comments in the January 16, 2008, letter

- Letter from B. John Garrick to Edward F. Sprout, III, Director, OCRWM; April 22, 2008

  Subject: DOE's participation at the January 2008 Board Meeting

- Letter from B. John Garrick to Edward F. Sprout, III, Director, OCRWM; September 4, 2008

  Subject: DOE's participation at the May 2008 Board Meeting

- Letter from Edward F. Sproat, III, Director, OCRWM to B. John Garrick September 18, 2008

  Subject: DOE's response to Board comments in the September 18, 2008, letter

- Letter from B. John Garrick to Edward F. Sprout, III, Director, OCRWM; October 1, 2008

  Subject: Board's response to the DOE's September 18, 2008, letter

- Letter from B. John Garrick to Edward F. Sprout, III, Director, OCRWM;
  November 5, 2008

  Subject: DOE's participation at the September 2008 Board Meeting

- Letter from Christopher Kouts, Acting Director, OCRWM to B. John Garrick
  February 17, 2009

  Subject: DOE's responses to the Board comments in the November 5, 2008, letter

- Letter from B. John Garrick to Christopher A. Kouts, Acting Director, OCRWM;
  April 6, 2009

  Subject: DOE's participation at the January 2009 Board Meeting

- Letter from Christopher A. Kouts, Acting Director, OCRWM to B. John Garrick
  June 1, 2009

  Subject: DOE's responses to the Boards comments in the April 6, 2009, letter

- Letter from B. John Garrick to The Honorable Steven Chu, Secretary, U.S. Department of Energy
  August 13, 2009

  Subject: Board comments from the June 11, 2009, meeting

- Letter from B. John Garrick to The Honorable Warren F. Miller, Jr, Assistant Secretary, U.S. Department of Energy
  October 16, 2010

  Subject: Board comments from the June 29, 2010, meeting

- Letter from B. John Garrick to The Honorable Inés R. Triay, Assistant Secretary, U.S. Department of Energy
  October 21, 2010

  Subject: Board comments from the June 29, 2010, meeting

- Letter from B. John Garrick to David G. Huizenga, Acting Assistant Secretary, U.S. Department of Energy
  July 26, 2011

  Subject: Relevant issue from the Board's second public meeting

- Letter from B. John Garrick to The Honorable Peter B. Lyons, Assistant Secretary for Nuclear Energy, U.S. Department of Energy
  July 26, 2011

  Subject: Important Issues from Board meetings for the first half of 2011

- Letter from B. John Garrick to Monica Regalbuto, Deputy Assistant Secretary, U.S. Department of Energy
  December 8, 2011

  Subject: Comments on draft report, *Gap Analysis to Support Extended Storage of Used Nuclear Fuel*

- Letter from B. John Garrick to The Honorable Peter Lyons, Assistant Secretary for Nuclear Energy, U.S. Department of Energy
  December 30, 2011

  Subject: Board comments on the September 13-14, 2011, meeting

- Letter from B. John Garrick to Monica Regalbuto, Deputy Assistant Secretary, U.S. Department of Energy
  January 6, 2012

  Subject: Board comments on report, *A Management Proposal for Salt Disposal Investigations with a Field Scale Heater Test at WIPP*

- Letter from B. John Garrick to The Honorable Peter Lyons, Assistant Secretary for Nuclear Energy, U.S. Department of Energy
  March 28, 2012

  Subject: Board's comments on January 9, 2012, meeting

- Letter from Rodney C. Ewing to Dr. Peter Lyons, Assistant Secretary for Nuclear Energy U.S. Department of Energy
  December 11, 2012

  Subject: Board comments from October 16-17, 2012, meeting

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

January 16, 2008

Mr. Edward F. Sproat III
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Mr. Sproat:

Thank you very much for participating in the U.S. Nuclear Waste Technical Review Board's meeting in Las Vegas, Nevada, on September 19, 2007. The Board appreciated your overview of the Yucca Mountain Program and realizes that the Project is making an effort to complete numerous major milestones in the next few months. The meeting gave the Board an opportunity to look at program activities broadly and to ask whether the systems that are being proposed will work safely and efficiently, given current plans. The following paragraphs contain Board comments on information presented by DOE at the meeting and on the Board's assessment of how the designs for surface facilities and a transportation, aging, and disposal (TAD) canister-based repository might evolve in the future.

TAD Canister Concept

The Board considers TAD a promising concept that could result in a safer, simpler, and more efficient means of directly disposing of spent nuclear fuel. However, the success of TAD will depend on its being effectively integrated by DOE into the overall waste management system.

DOE has established requirements for a TAD-based repository design on the basis of the assumption that 90 percent of commercial spent nuclear fuel (CSNF) will arrive at the repository in TAD canisters. The Board understands that to help achieve that objective, DOE is negotiating with nuclear utilities on incentives that would make using TAD canisters more economically attractive. However, some nuclear power plants appear to lack the necessary infrastructure for using TAD canisters. This and other possible constraints (e.g., delays in TAD availability) make unclear whether a TAD utilization rate as high as 90 percent can be achieved. Because of this, the Board recommends that DOE carry out comprehensive analyses to understand better the implications of not achieving the 90 percent TAD utilization rate. Furthermore, the Board continues to encourage DOE to study actively all possible options for dealing with spent nuclear fuel in dual purpose canisters (DPC's) — including direct disposal.

Surface-Facility Throughput

The information presented by DOE on throughput rates for the surface facilities appears to be overly optimistic — that is, actual processing rates achieved by the surface facility complex as a whole may be lower than assumed. In some cases, operational activities do not appear to have been fully accounted for (e.g., upset conditions), which may further increase operational

times. In addition, if TAD utilization is reduced, the lower utilization rate could adversely affect surface facility throughput and could require construction of additional waste handling facilities. The Board recommends that DOE consider operational and design contingencies that could be implemented if TAD utilization rates turn out to be significantly lower than the 90 percent TAD utilization currently assumed.

The Board believes that DOE should consider adding supplemental operational features to current facility layouts as a means of addressing operational risk and mitigating constraints on facility throughput. Examples of measures that could improve throughput are increasing the capacity of the Wet Handling Facility (WHF) pool to allow parallel removal and transfer of fuel contained in DPC's, adding a welding station to the WHF to increase the capacity of the waste package welding stations, and increasing the number of welding stations in the Canister Receipt and Closure Facility (CRCF).

To assess operational risk and the viability of the waste management system, the Board recommends that DOE develop a series of realistic and detailed throughput analyses that go beyond a deterministic, steady-state approach. Such analyses should consider potential off-normal operational scenarios and should specifically address the throughput achieved by individual surface facilities, the integrated surface facility complex, and the waste management system as a whole.

Transportation System

Given the current configuration of the waste management system, the Nevada rail line is a critical factor that potentially will affect the viability of the entire waste management system. At this time, DOE does not consider alternative transportation modes to rail, such as a truck-based TAD transport system, realistic options because of their adverse effect on the throughput capacity and efficiency of the waste management system. The Board notes that technical, economic, political, and legal circumstances could create significant programmatic risks for the transportation system that DOE proposes to implement.

Preclosure Safety Analysis (PCSA)

At this time, the level of detail provided by DOE does not facilitate an in-depth assessment of the preclosure safety of surface facility design and concept of operations. The Board is concerned that the approach outlined for the development of the PCSA is a combination of deterministic and risk-informed, probabilistic methodologies. How DOE intends to address the uncertainties associated with the aggregation of risk is not clear to the Board. The Board would like DOE to explain in greater detail how the PCSA will address the remaining design uncertainties.

Thank you again for participating in the Board's September meeting. We look forward to your comments on the issues raised in this letter.

Sincerely,

{Signed by}

B. John Garrick

Chairman

bjg085vf

Department of Energy
Washington, DC 20585

QA: N/A

April 11, 2008

B. John Garrick, Ph.D.
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

Dear Dr. Garrick:

The purpose of this letter is to respond to your letter dated January 16, 2008. I appreciate the Nuclear Waste Technical Review Board's (Board) comments related to design of surface facilities and the implementation of a transportation, aging, and disposal (TAD) canister-based concept at the Yucca Mountain repository.

As part of the process leading to the submission of the license application (LA), the U.S. Department of Energy (DOE) has undertaken a number of assessments to ensure that the LA reflects a sound operational and scientific basis for the design, construction, and operation of the repository. These assessments have included the type of contingency analyses that the Board advocates. As addressed below, we believe that the proposals for the design, construction, and operation of the repository that will be embodied in the LA are sound, and that the Board's recommendations do not present any significant new information or circumstances that would lead DOE to depart from its planning basis.

TAD Canister Concept

Board Comments

The Board considers TAD a promising concept that could result in a safer, simpler, and more efficient means of directly disposing of spent nuclear fuel. The Board notes, however, that the success of the TAD concept will depend on its being effectively integrated by DOE into the overall waste management system.

DOE Response

In establishing the design basis for the TAD-based repository design, DOE has considered the situation that could arise if the split between Commercial Spent Nuclear Fuel (CSNF) received in TADs, and CSNF received either in dual purpose canisters or uncanistered in transportation casks, is appreciably different than the design basis. DOE has established initial design requirements that are based on the 90 percent - 10 percent split between TAD and non-TAD CSNF and has developed a suite of facilities that can handle that projected waste stream. These facilities include a certain level of flexibility to handle a different percentage split between

TAD and non-TAD CSNF. The preclosure safety analysis (PCSA) will evaluate potential event sequences and consequences associated with operations of the facilities "at the maximum capacity and rate of receipt" as required by the regulation at 10 CFR 63.21(c)(5). DOE is confident that it has adequately evaluated the TAD interfaces in the waste management system, and the concept is now fully integrated into that system.

Surface-Facility Throughput

Board Comments

The information presented by DOE on throughput rates for the surface facilities appears to be overly optimistic - that is, actual processing rates achieved by the surface facility complex as a whole may be lower than assumed. In some cases, operational activities do not appear to have been fully accounted for (e.g., upset conditions), which may further increase operational times. In addition, if TAD utilization is reduced, the lower utilization rate could adversely affect surface facility throughput and could require construction of additional waste handling facilities. The Board recommends that DOE consider operational and design contingencies that could be implemented if TAD utilization rates turn out to be significantly lower than the 90 percent TAD utilization currently assumed.

DOE Response

As discussed above, DOE has included a certain amount of operational and design contingencies to account for uncertainties in the mix of TAD canistered to non-TAD canistered CSNF. The Board raises the issue of evaluating certain design changes as a means of addressing operational risk and mitigating constraints on facility throughput. As part of the selection of the proposed surface facility capabilities and construction phasing, DOE assessed options similar to those raised by the Board and concluded that the proposed facilities are expected to meet DOE's operational requirements. Because of the modular design of the surface facilities, it will be relatively easy to add additional processing capability after the repository is operational, if it is determined to be of operational benefit at that time.

Transportation System

Board Comment

The Board notes there are technical, economic, political, and legal circumstances that could create "significant programmatic risks" for the rail transportation system that DOE proposes to implement.

DOE Response

DOE recognizes the existence of economic, political and legal challenges associated with the proposed Yucca Mountain Repository system, including the Nevada Rail Line. However, there are no significant technical challenges associated with developing the Nevada Rail Line since it is a conventional civil engineering project requiring no tunneling and construction of only one

major, standard design bridge. In a 2002 Record of Decision (69 *Fed. Reg.* 18557), DOE selected the mostly rail scenario (which includes some truck or barge shipments to railheads from reactor sites that do not have existing rail access) as the means of transporting radioactive materials to the repository. Prior to announcing that decision, DOE prepared a comprehensive, comparative analysis of alternative means of transporting such materials to the repository, including transportation modes that could be used if the rail line were not operational by the time materials would need to be transported. *See Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada,* DOE/EIS-0250F (2002). Heavy-haul shipments in rural Nevada over distances exceeding 200 miles would require significant investment in alternative infrastructure and would divert resources from completion of the rail line. Our conclusion remains that the most practicable solution for SNF transportation in Nevada that integrates with repository operations is expeditious development of a new rail line.

PCSA

Board Comment

The Board is concerned that the approach outlined for the development of the PCSA is a combination of deterministic and risk-informed, probabilistic methodologies. How DOE intends to address the uncertainties associated with the aggregation of risk is not clear to the Board. The Board would like DOE to explain in greater detail how the PCSA will address the remaining design uncertainties.

DOE Response

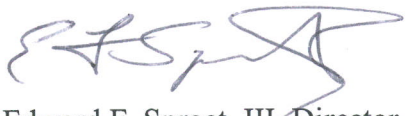
DOE has finalized the PCSA for the preclosure operational phase. This analysis, and the engineering design work upon which it is based, will largely address the Board's concerns, and it will be provided to the Board for its review. This analysis was performed to support DOE's LA; and, therefore, the analysis is necessarily focused on demonstrating compliance with 10 CFR Part 63. Part 63 does not require DOE to perform a probabilistic risk assessment similar to those completed for commercial nuclear power plants. In particular, Part 63 evaluates compliance with dose consequences based upon the frequency of potential event sequences, rather than explicitly evaluating the total aggregation of risk.

As discussed at the September 19, 2007 meeting, the PCSA analysis incorporates both epistemic and aleatory uncertainties associated with the reliability of information used in the PCSA. Determination of structures, systems, and components (SSCs) important to safety (ITS)

will be based upon the identification of SSCs that prevent or mitigate potential consequences resulting from event sequences, as provided by Part 63. DOE does not intend to classify an SSC as ITS based upon deterministic methods.

If you have any questions concerning this letter, please contact Abraham Van Luik at 702-794-1408.

Sincerely,



Edward F. Sproat, III, Director
Office of Civilian Radioactive
Waste Management

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

April 22, 2008

Mr. Edward F. Sproat III
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Mr. Sproat:

Thank you very much for participating in the U.S. Nuclear Waste Technical Review Board's meeting in Las Vegas, Nevada, on January 16, 2008. The Board appreciates your comments about issues related to the schedule for submitting a Yucca Mountain license application (LA) to the Nuclear Regulatory Commission (NRC). We understand from remarks you made on March 13, 2008, at an NRC conference that the Department of Energy (DOE) plans to submit a high-quality LA by late June of this year. The Board looks forward to updates on this and other program milestones. The Board also thanks the other DOE and DOE-contractor personnel who participated in the meeting. We believe that the technical content of the meeting was good and that the discussions were open and productive. The Board's comments on the discussions follow.

Deliquescence-Induced Localized Corrosion

At the meeting, DOE representatives described corrosion research that is planned for the next several years. The plans do not appear to address issues that the Board has raised regarding deliquescence-induced localized corrosion. The Board continues to have questions about the technical basis for DOE's decision to exclude deliquescence-induced localized corrosion of waste packages from the total system performance assessment, as discussed in the Board's January 2007 and July 2007 letters to DOE.

Among other things, the Board noted in its January 2007 letter that DOE could strengthen the technical basis for screening out deliquescence-induced localized corrosion by (1) determining nitrate-to-chloride ratios inhibitive of localized corrosion over the *entire* range of temperatures at which brines could form on waste package surfaces due to deliquescence, and (2) showing that nitrate ions sufficient to maintain inhibitive nitrate-to-chloride ratios would preferentially migrate into crevices. DOE's November 20, 2007, letter to the Board discussed issues raised in the Board's January 2007 letter, but resolving most of the issues will require additional laboratory work. It appears that the national laboratories supporting DOE's work have the equipment and staff capabilities to perform the tests needed to resolve these two issues.

In its July 2007 letter, the Board stated that DOE should analyze the full range of factors that would affect nitrate-to-chloride ratios (e.g., organics in dust, acid-gas devolatilization, radiolysis). DOE's November 20, 2007, letter did not respond to that Board recommendation. How the waste package environment will evolve because of factors such as the passage of time, thermal conditions, radiolysis, or chemical reactions (e.g., reactions between nitrate salts and organic materials in the

dust that is deposited on waste packages) is important. The Board believes that a basic understanding of the evolution of the waste package environment due to *all* factors is needed.

Providing the evidence and analysis asked for in the Board letters is important because DOE's repository design will result in some waste-package surface temperatures that far exceed the boiling point of water during the first 2,000 years after repository closure. The results of laboratory studies performed by the U.S. Geological Survey (USGS) and presented at the Board meeting show that heating of dust on waste package surfaces in a Yucca Mountain repository may diminish nitrate concentration. Consequently, the Board strongly encourages DOE to make use of the USGS dust data as the program endeavors to characterize the evolution of likely waste package environments after repository closure.

Thermal-Loading Strategy

At the Board meeting, DOE clarified its thermal-loading strategy for meeting the following four upper thermal limits related to repository performance and operations:

- mid-pillar temperature of 96°C
- drift-wall temperature of 200°C
- waste package outer-barrier temperature of 300°C
- commercial spent nuclear fuel cladding temperature of 350°C

DOE's analysis indicates that the 96°C mid-pillar thermal limit is controlling (i.e., if it is not exceeded, the other limits also will not be exceeded). However, the Board has questions about the technical basis for the 96°C mid-pillar temperature limit. The Board would like to see a better justification for this thermal limit and its relationship to the water movement and the assumed drainage of water in the mid-pillar area during the thermal pulse. If the 96°C mid-pillar temperature limit were eliminated, the 200°C drift-wall temperature would be the controlling thermal limit; this could increase flexibility in thermal loading of the repository and waste package sequencing. The Board also recommends that DOE investigate the feasibility and technical advantages of determining the thermal conditions at repository closure and varying the duration of the ventilation as needed to achieve thermal limits. Because DOE's current thermal limits will produce waste package surface temperatures that exceed 150°C, the potential for deliquescence-induced localized corrosion should be analyzed.

Surface-Facility Throughput

In reviewing DOE's analysis of surface-facility throughput, the Board notes that DOE addresses each facility independently and assumes that all transportation system input (e.g., loaded transportation casks and empty waste packages) will be available on demand and that output (e.g., empty transportation casks and loaded waste packages) can be moved efficiently through the system. However, it seems highly likely that the amount of waste arriving at repository surface facilities will fluctuate, depending on factors such as the availability of transportation casks and transportation, aging, and disposal (TAD) containers. Fluctuations also may be caused by the ability of different utilities to load TADs and transportation casks and the timing of the loadings. More realistic modeling assumptions and a more integrated analytical approach may show, among other things, that additional transportation equipment and surface facilities will be required to achieve the desired throughput or that more waste will have to be stored on aging pads. These changes could significantly affect facility-design and operating costs as well as throughput. The changes also could affect safety because of the need for additional handling of the waste.

In DOE's letter to the Board dated April 11, 2008, DOE maintains that the design basis for the TAD-based repository includes "a certain amount of operational and design contingencies to account for uncertainties in the mix of TAD canistered to non-TAD canistered CSNF." DOE also states that the TAD concept is fully integrated into the waste management system and that the primary focus should be on evaluating potential event sequences and consequences associated with operation of the surface facilities at the *maximum* capacity and *maximum* rate of receipt, as required by regulation. At this point, the Board has not seen studies performed by DOE that demonstrate sufficient flexibility in the incoming waste stream, nor has the Board seen an integrated analysis of surface-facility systems that evaluates operational and safety risk. Moreover, confidence in the performance of surface facilities can be enhanced by analyzing surface facility operations under conditions of *minimum* capacity and a *maximum* rate of receipt, because the system will be most severely tested under these conditions. Accordingly, the Board recommends that an integrated throughput analysis be performed that includes all the surface facilities as a single, holistic system, uses realistic assumptions about transportation input and output, and demonstrates the robustness of the surface facility design to handle variations in the timing and characterization of the arriving waste shipments.

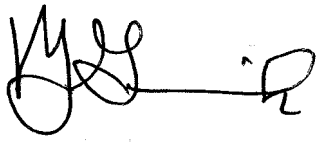
Transportation

DOE representatives confirmed at the meeting that developing a waste management system using TADs makes the Nevada rail line necessary. As acknowledged in DOE's April 2008 letter to the Board, constructing a Nevada rail line will present significant institutional challenges. The Board, therefore, reiterates its recommendation that DOE initiate contingency planning to identify alternatives to rail that can be implemented if significant delays are encountered during construction of the rail spur. In addition, the Board understands that DOE has initiated a review of the capability of short-line railroads to move loaded TADs from utility sites to mainline connections. The Board looks forward to reviewing this evaluation.

In accordance with its congressional mandate, the Board will continue its ongoing review of the technical validity of DOE's activities related to DOE's implementation of the Nuclear Waste Policy Act. The Board remains especially interested in DOE's work that is related to localized corrosion and the in-drift environment and how these two issues could affect DOE's thermal strategy for emplacing waste in a Yucca Mountain repository.

Thank you again for your participation in the Board's January meeting.

Sincerely,



B. John Garrick
Chairman

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

September 4, 2008

Mr. Edward F. Sproat III
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue SW
Washington, DC 20585

Dear Mr. Sproat:

The U.S. Nuclear Waste Technical Review Board appreciates the participation of the U.S. Department of Energy (DOE) in the Board's meeting in Las Vegas, Nevada, on May 29, 2008. The central focus of the meeting was the Total System Performance Assessment for the License Application (TSPA-LA). Consistent with its statutory mandate, the Board has continuously evaluated the technical validity of DOE activities related to developing TSPA-LA and related analyses, which are the basis for DOE estimates of repository performance at Yucca Mountain.

The Board considered this an excellent meeting. The presentations conveyed the expertise of the analysts and the challenges of estimating repository performance for one million years after waste emplacement and repository closure. The Board's observations and comments on the material presented at the meeting are summarized below.

TSPA-LA Assumptions, Methods, and Results

TSPA-LA may be the most complex and ambitious probabilistic risk assessment ever undertaken. Clear from presentations at the meeting is that the dedicated work of numerous highly capable scientists and engineers over many years has significantly advanced the understanding and representation of the natural and engineered systems at Yucca Mountain. As discussed below, however, there are notable uncertainties related to TSPA-LA calculations.

DOE analyses show that the engineered barrier system (EBS) contributes very significantly to overall repository performance. The drip shield is intended to prevent water and rocks from falling on the waste package, thus extending waste package lifetime. The drip shield therefore plays a significant role in predictions of repository performance. According to DOE analyses, in the nominal scenario, none of the drip shields fail before 265,000 years and, on average, more than 99 percent of waste packages containing civilian spent nuclear fuel remain sealed at least 500,000 years after repository closure. The extent to which the drip shield reduces calculated doses by extending waste package lifetime is uncertain because it has not been analyzed.

DOE sometimes uses what it considers conservative assumptions about the features or processes being modeled while taking an opposite approach in other instances. Because the system modeled by TSPA-LA is highly complex, simplification and abstraction of features, events, and processes are necessary. As a result, some of the simplifications and underlying assumptions in TSPA-LA may overestimate radioactive dose. For example, rather than trying to predict the location and extent of an igneous intrusion, DOE assumes that such an intrusion will damage all 11,629 waste packages in the repository. This seems to be a very (unrealistically) conservative

assumption. On the other hand, an important waste package failure mechanism that does not seem to be treated conservatively in TSPA-LA is the potential for damage of the Alloy-22 waste package by deliquescence-induced localized corrosion, which has been eliminated from performance estimates through a screening process. Deliquescence-induced localized corrosion, if it were to cause penetration of the waste packages, would have potentially significant performance implications. The Board reiterates its view that DOE should strengthen the technical basis for screening out deliquescence-induced localized corrosion. Because DOE's assumptions are not always conservative, the overall degree of conservatism of the assumptions in TSPA-LA is difficult to assess.

Assumptions and methods in TSPA-LA are not consistently well-supported. For example, estimates of the character of mountain-scale water flow in the unsaturated zone are consistent with scientific understanding. On the other hand, results of infiltration model calculations were adjusted to make them more consistent with field measurements. The Board has stated that the statistical modification of infiltration model results does not have a strong technical basis.

Enhancing Confidence in TSPA-LA Assumptions, Methods, and Results

The Board believes that some of the aforementioned uncertainties can be addressed by undertaking some or all of the specific actions described below. Addressing the uncertainties could enhance confidence in TSPA-LA methods and results.

Improve the technical basis for screening out deliquescence-induced localized corrosion. The Board believes that an appropriate experimental program could be performed to address the potential occurrence of this phenomenon and has recommended such a program in previous letters to DOE. Alternatively, the Board's opinion is that maintaining surface temperatures of the waste packages below approximately 150°C could eliminate the possibility that deliquescence-induced localized corrosion would initiate. If the technical basis for screening out deliquescence-induced localized corrosion cannot be improved, then that could have significant implications for repository design and loading.

Develop prototypes of novel engineered systems. You and I testified on July 15 at a hearing before the House Subcommittee on Energy and Air Quality, Committee on Energy and Commerce. In my testimony, I stated that in the Board's view, DOE's assumptions about drift degradation and repository tunnel tolerances may make installation of the drip shields, as currently designed, problematic. Prototyping of drip-shield fabrication and emplacement can help reduce uncertainties associated with this critical engineered component of the repository.

Continue to enhance fundamental understanding of the geologic environment. A sound fundamental understanding of the geologic environment is important for predicting both the environmental controls on EBS degradation and subsequent radionuclide transport. The Board believes that DOE should continue to develop such understanding. Although the possibility of very-long-term sequestration of radionuclides in secondary mineral phases suggested by analogue observations has not been supported so far by laboratory investigations, this process and others investigated in the Science and Technology Program of OCRWM's Office of Science and Technology and International (OSTI) are likely to be important for increasing confidence in the plan for the proposed Yucca Mountain repository. Consequently, in the Board's view many of the study areas previously supported by OSTI merit renewed support.

Thank you again for DOE's participation in the Board's May meeting. The Board looks forward to continuing its technical review of DOE activities.

Sincerely,

{Signed By}

B. John Garrick
Chairman

Department of Energy
Washington, DC 20585

QA: N/A

September 18, 2008

RECEIVED SEP 2 3 2008

B. John Garrick, Ph.D.
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

Dear Dr. Garrick:

Thank you for your September 4, 2008, letter, in which you provided the U.S. Nuclear Waste Technical Review Board's (NWTRB) observations and comments on the Total System Performance Assessment for the License Application (TSPA-LA) presentations that the U.S. Department of Energy (DOE) provided during the May 29, 2008, meeting in Las Vegas, Nevada. In that letter, the NWTRB recommended specific actions for DOE to take to enhance confidence in the TSPA-LA methods and results.

On September 8, 2008, the U.S. Nuclear Regulatory Commission (NRC) formally docketed DOE's License Application (LA). The docketing of the LA commenced the NRC licensing proceeding for Yucca Mountain. As part of the proceeding, the NRC staff will conduct an extensive technical and safety review of the LA, including the TSPA-LA. If, during the review, NRC has questions about the LA including the TSPA-LA, the NRC staff will issue Requests for Additional Information; and DOE will respond. Also, as part of the proceeding, the Atomic Safety and Licensing Board will hold evidentiary hearings on issues raised in contentions on the LA. As you are aware, the NRC licensing proceeding provides a very structured process for raising and resolving LA-related issues. As such, DOE does not intend to formally respond to issues regarding the LA raised by the NWTRB or others outside the context of the NRC licensing proceeding.

If you have any questions regarding this matter, please contact William J. Boyle at (702) 794-5506 or e-mail william_boyle@ymp.gov.

Sincerely,

Edward F. Sproat, III, Director
Office of Civilian Radioactive
Waste Management

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

October 1, 2008

Mr. Edward F. Sproat III
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Mr. Sproat:

The Nuclear Waste Technical Review Board has received your September 18, 2008, letter concerning the Board's observations and comments on the May 29, 2008, Board meeting. It is unfortunate that the Department of Energy (DOE) feels that it is so constrained by its involvement in an adjudicatory regulatory proceeding that it "does not intend to formally respond to issues regarding the [license application] LA raised by the NWTRB or others outside the context of the NRC licensing proceeding."

In establishing the Board, Congress directed it to provide ongoing peer review of the technical and scientific validity of DOE decisions and to provide advice to Congress on whether DOE activities have a solid technical and scientific foundation. In particular, Section 503 of the Nuclear Waste Policy Amendments Act (NWPAA) instructs the Board to "evaluate the technical and scientific validity of activities undertaken by the Secretary of Energy" after the passage of that Act.[1] The legislative history related to the NWPAA speaks to the scope of the Board's mandate. The House *Report* on the bill, for example, states that the NWPAA gives "the Board broad latitude to examine activities undertaken by the Secretary of Energy to implement the Nuclear Waste Policy Act."[2] In floor debate, Representative Philip Sharp, who introduced language creating the Board, observed that the Board "will have full authority to review the technical and scientific validity of all [the Secretary's] activities."[3] By authorizing the Board to remain in existence "no later than one year after the date" when disposal of radioactive waste in a repository begins, it can be inferred that Congress intended that the Board should continue its broad technical and scientific peer review throughout the licensing period.[4]

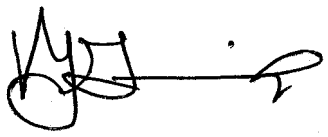
Although there may be issues that overlap with those raised in the Nuclear Regulatory Commission's adjudicatory proceeding, the two agencies, as you know, have very different responsibilities. Given its broader mandate, the Board provides oversight on numerous issues

[1] 42 USC 10263.
[2] House Report on 100-425, page 27.
[3] 133 *Congressional Record* H11975.
[4] 42 USC 10270.

not part of the regulatory process. Importantly, DOE's obligations to the Board do not change as a result of DOE's submission of a License Application to the NRC.

The Board's responsibilities under the law require it to continue its evaluation of the technical and scientific validity of the *full range of activities* undertaken by the Secretary of Energy to implement the Nuclear Waste Policy Act and its Amendments. The Board intends to continue to hold public meetings and fact-finding inquiries to gather information from DOE and others that will enable the Board to meet its obligations to Congress and to the Secretary. The Board expects DOE to engage candidly and productively with the Board on technical issues so that both our agencies can fulfill our responsibilities under the law.

Sincerely,



B. John Garrick
Chairman

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

November 5, 2008

Mr. Edward F. Sproat III
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue SW
Washington, DC 20585

Dear Mr. Sproat:

The U.S. Nuclear Waste Technical Review Board appreciates the participation of the U.S. Department of Energy (DOE) in the Board's meeting in Las Vegas, Nevada, on September 24, 2008. The central focus of the meeting was the integration of waste acceptance, transportation, and repository operations to determine the feasibility of the system for operating as planned. Participation in the meeting by individuals from DOE, the nuclear industry, and the State of Nevada provided the Board with a broader perspective of how the system will operate and the challenges that DOE will face during implementation. The Board's observations and comments on the material presented at the meeting are summarized below.

Program and Project Overview

In his presentation on the project's status and the licensing process, Dr. William Boyle, Director of the Regulatory Authority Office in DOE's Office of Civilian Radioactive Waste Management, indicated that the relationship between DOE and the Board would not change as a result of the Nuclear Regulatory Commission's (NRC) docketing of DOE's license application (LA) in early September.

Integrated System Operations

Panel discussions were held on waste acceptance and transportation and on the integration of these functions with repository operations. The discussions included representatives from DOE, the State of Nevada, and the nuclear industry. Apparent from these discussions is that DOE has analyzed a single scenario based on certain optimistic assumptions, such as receiving 90 percent of commercial spent nuclear fuel (CSNF) in transportation-aging-disposal (TAD) canisters, an optimal waste receipt schedule (both CSNF and DOE canisters), and the absence of any upset conditions. The Board understands that actual operations will begin many years from now but believes that DOE should perform additional analyses to determine the effects on the system if conditions differ from those presently assumed. In particular, the following scenarios should be addressed:

1. Delay in construction or inability to construct the Nevada rail line.
2. Delay in deployment of TADs beyond 2013.
3. Less than 90 percent of CSNF arriving in TADs.
4. Seasonal variation in the receipt rate of CSNF.
5. Delay in receipt of DOE waste, or DOE waste not received in the order needed.

6. Less than 75 percent availability of the surface facilities.
7. Occurrence of upset conditions in any part of the system.
8. Some utility sites without usable short-line rail connection to a main rail line.
9. Provisions DOE is making to ship spent fuel that is in storage casks at utility sites.
10. Provisions DOE is making regarding dual-purpose spent fuel storage systems to avoid repackaging into TADs at Yucca Mountain.

Performing such analyses now would give DOE a better understanding of system robustness and flexibility and would allow modifications, if necessary, early in the design process.

Surface Facility Design

The nature of the presentations on surface facility design seemed to reflect a lack of understanding of the design's technical basis. The presentations did not illustrate how the facilities would work and showed only the potential flow of material through buildings. For example, there were no clear explanations for (1) why the building walls need to be 4 feet thick, (2) the percentage of design completeness, and (3) how the fuel pool cooling and cleanup system operates. Moreover, many of the design elements of the wet handling facility appear to be nonstandard, suggesting that few lessons learned or industry input were incorporated into the design.

The entire issue of seismic design basis needs to be reevaluated for consistency with commercial nuclear facilities built for the same purpose. Clarity of the design requirements for surface facilities needs to be addressed to avoid what appears to be excessive design for meeting seismic effects of the surface facilities that will not need to last for hundreds of thousands of years.

Repository Site Operations

The Board continues to believe that DOE needs a comprehensive integrated throughput model for the surface facilities with time steps compatible with the task durations. The assumption that input for each facility will be available when needed and that output will be removed when processing is complete do not represent a realistic situation, nor was any justification for the 75 percent availability provided. The Board is looking forward to DOE's providing a plan for implementing a realistic surface facility throughput model that can be used to evaluate the design and determine the effects of off-normal events, including safety implications.

Equipment and Facility Testing Program

The equipment and facility testing program described by DOE reflected a broad understanding of program components. However, the Board is concerned that the feasibility of several unique components or operations (drip shield fabrication and installation, waste package fabrication, emplacement vehicle operation, etc.) has not been confirmed, yet the items have been included already in the design. The Board seeks assurance that these unique components will function as designed and requests a schedule for implementing the prototyping and testing program.

Thank you again for DOE's participation in the Board's September meeting. The Board looks forward to continuing its technical review of DOE's activities in accordance with its congressional mandate.

Sincerely,

{Signed by}

B. John Garrick
Chairman

Department of Energy
Washington, DC 20585

QA: N/A

February 17, 2009

RECEIVED FEB 2 0 2009

B. John Garrick, Ph.D.
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

Dear Dr. Garrick:

Thank you for your November 5, 2008, letter providing the Nuclear Waste Technical Review Board (Board) observations and suggestions on information presented by the U.S. Department of Energy at the Board's meeting on September 24, 2008. Our responses to your observations and comments are enclosed.

If you require further clarification regarding any of these issues, please contact me at (202) 586-6850, or Abraham E. Van Luik, at (702) 794-1424.

Sincerely,

Christopher A. Kouts
Acting Director
Office of Civilian Radioactive
Waste Management

Enclosure

Integrated System Operations

Board Observation and Comment:

The Board believes that the Department of Energy (DOE) should perform analyses to determine the effects on the system if conditions differ from those presently assumed. A number of scenarios were suggested that should be addressed to give better understanding of system robustness and flexibility and would allow modifications, if necessary, early in the design process.

DOE Response:

DOE has used a Total System Model (TSM), initially developed in 2005, for numerous systems analyses similar to those recommended by the Nuclear Waste Technical Review Board (NWTRB). The results of those systems analyses have been made available in published TSM reports, fact finding meetings with the NWTRB staff, and DOE briefings at NWTRB meetings.

DOE performed detailed modeling of individual facilities using the TSM. The modeling has the capability to include upset conditions, such as those recommended by the NWTRB. However, DOE is focused at this time on the support of the license application (LA) during the detailed technical review and preparation of a Safety Evaluation Report by the U.S. Nuclear Regulatory Commission (NRC) and the adjudicatory hearing process. Additional studies are not planned at this time as a result of severe funding limitations.

Surface Facility Design

Board Observation and Comment:

The nature of the presentations on surface facility design seemed to reflect a lack of understanding of the design's technical basis. The presentations did not illustrate how the facilities would work and showed only the potential flow of material through buildings. The issue of seismic design basis needs to be reevaluated for consistency with commercial nuclear facilities built for the same purpose. Clarity of the design requirements for surface facilities needs to be addressed to avoid what appears to be excessive design for meeting seismic effects. Three specific items were identified: why building walls need to be four feet thick, percentage of design completeness, and how the fuel pool cooling and cleanup system operates.

DOE Response:

1. Four-Foot Thick Walls

Design of the Important to Safety (ITS) nuclear facility structures must meet two requirements:

- ACI-349 code requirements for the seismic forces resulting from Design Basis Ground Motion-2 (DBGM-2), corresponding to a mean annual probability of exceedance of $5x10^{-4}$ (or 2,000 year return period) and has a peak ground acceleration of 0.45g, based on site-specific seismic data.

  Demand-to-capacity ratio was set at 0.5 to 0.6 as a prudent margin for preliminary design which also facilitated meeting the performance requirements. The shear walls of the surface facilities were determined, in general, to be four feet thick.

- Adequate margins to meet the performance requirements of 10 CFR Part 63 for ground motions beyond the design basis.

  The ITS structures must assure that unacceptable seismic performance of the structure is less probable than one in 10,000 over the preclosure period. This translates to a performance factor of 2×10^{-6} /year for a preclosure period of 50 years. Per NRC Interim Staff Guidance HLWRS-ISG-01, Review Methodology for Seismically Initiated Event Sequences, the performance factors are demonstrated to be met by performing a "convolution" of the hazard probability density function with the building fragility cumulative distribution function. Earthquake levels beyond 10^{-7}/year are included in the convolution to obtain an accurate mean probability of building unacceptable performance.

These two requirements are similar to those imposed on operating commercial nuclear power plants. Both safety related power plant structures and the repository ITS structures are designed to code for specific design basis seismic loads. Additionally, both need to demonstrate adequate margins when evaluated against design basis seismic loads (e.g., the reference earthquake level in a seismic margin analysis).

Design of the nuclear facility structures is within a prudent margin to meet the ACI-349 code and 10 CFR Part 63 performance requirements. Additional information on the seismic design of the ITS structures is provided in Safety Analysis Report (SAR) Section 1.2.2.1.6.3.

2. Design Completeness

The design, as of March 2008, is complete to the point where the safety case has been demonstrated in sufficient detail to support the LA, submitted in June 2008, and to be docketed by the NRC in September 2008. Approximately 1,350 documents (drawings, calculations, and specifications) have been issued for the ITS surface facilities, 125 documents have been issued for the balance of plant surface facilities, an additional 350 documents have been issued for the subsurface facilities and waste packages, and 46 preclosure safety analysis documents comprised of approximately 12,000 pages have been issued. Of the total, 335 documents have been issued since April 2008 and include the finite element structural analyses of the nuclear facilities, completion of the waste package configurations, and performance specifications for mechanical handling equipment. These 335 documents are the result of advancing the design from the LA design towards detailed design while maintaining both configuration control and the safety case in the SAR. Other than those documents that have been classified as official use only, these documents are available on the Licensing Support Network.

3. Fuel Pool

The design of the pool water treatment and cooling system (PWTCS) conforms to the requirements identified in ANSI/ANS 57.7-1988, Design Criteria for an Independent Spent Fuel Storage Installation (water pool type), to the extent appropriate given the facility's purpose. The PWTCS is depicted on Piping and Instrument Diagrams 050-M60-PW00-00101-000 through 050-M60-PW00-00106-000.

Pool water is drawn through one of three treatment trains. Each treatment train consists of a pump strainer, pump, and two stages of filtration followed by an ion exchange vessel. Each train is sized to turn the pool's volume over within 72 hours (350 gpm). The PWTCS can draw from multiple locations in the pool including the Dual Purpose Canister (DPC) cutting area, which helps isolate potential crud bursts. After flowing through a treatment train, pool water is fed back into the pool or cooled depending on the temperature of the pool. Boron, in the form of boric acid, is added to the pool water in the return line of the PWTCS. The boron concentration is maintained at approximately 2,500 mg/L.

The unit operations employed in the waste handling facility (WHF) are comparable to pool treatment system operations at commercial nuclear power plants such as Harris, Diablo Canyon, and Hatch, but are not necessarily in an identical processing configuration. The main reasons for the differences are a reduced heat load from spent nuclear fuel (SNF) in the WHF pool, the flexibility to receive multiple types of SNF, and the increase in the frequency of operations occurring in the WHF pool.

Design features, system configurations, and redundancy for system reliability/ maintainability were compared to SAR sections of several commercial power plants for the pool treatment system for both pressurized water reactor and boiling water reactor. In addition, information gathered from plant visits (including Hope Creek, Salem, Limerick,

Vogtle, Shearon Harris, Diablo Canyon, and Palo Verde) has been compared to the WHF design, and in some cases, incorporated during the design development.

Additional information on the PWTCS is provided in SAR Section 1.2.5.3.2.

Repository Site Operations

Board Observation and Comment:

The Board is looking forward to DOE's providing a plan for implementing a realistic surface facility throughput model that can be used to evaluate the design and determine the effects of off-normal events, including safety implications.

DOE Response:

DOE has performed detailed modeling of the operations within the individual surface waste handling facilities in order to determine facility throughput and optimize waste handling operations. Using that detailed modeling as input, the TSM approximates the waste handling facilities, using eight-hour time steps, with sufficient fidelity to provide an integrated, systems analysis from the waste generator sites to emplacement of waste packages in the repository subsurface.

Equipment and Facility Testing Program

Board Observation and Comment:

The Board is concerned that the feasibility of several unique components or operations (drip shield fabrication and installation, waste package fabrication, emplacement vehicle operation, etc.) has not been confirmed, yet the items have been included already in the design. The Board seeks assurance that these unique components will function as designed and requests a schedule for implementing the prototyping and testing program.

DOE Response:

Prototyping is being done or will be done for the following:

1. Waste Packages, Waste Package Emplacement Pallets, and Drip Shields to investigate or confirm items, such as fabrication methods (including assuring attainment of desired material properties and capabilities) and assuring there will be qualified vendors. Goals include:

    a. Confirming welding techniques, including desired residual stress distribution for the Outer Corrosion Barrier of the waste package.

b. Confirming effectiveness of nondestructive examination (NDE) methods.

c. Informing, through the lessons learned, the definitive design of the components from prototyping.

d. Providing specimens for operational training—including demonstrating assurance that the waste package may be handled in a manner consistent with ensuring adequate long-term performance.

The prototyping program for the waste packages is described in greater detail in the *Testing Strategy for Waste Package Prototypes,* 000-30R-WIS0-00400-000-001. The procurement strategy for the various prototypes is described in the *Prototype Procurement Strategy for Waste Packages, Pallets, and Drip Shields,* 000-30R-WIS0-00500-000-003.

2. Waste package closure system to demonstrate functionality/reliability. A mockup of the waste package closure cell has been constructed, and test welds have been made using prototype equipment (subsystem testing started about April 2008). Testing of the completed welds will be performed to validate the process, demonstrate/validate NDE techniques, and demonstrate/validate stress mitigation techniques.

3. The DPC cutting machine to demonstrate functionality and ability to remotely perform this process.

Factory acceptance testing will be done for standard and nonstandard mechanical handling equipment, such as overhead cranes, trolleys, the emplacement vehicle, the canister transfer machine, and the drip shield emplacement gantry. While some of this equipment is configured specifically to perform Yucca Mountain Project cask/canister handling functions, it is designed and specified to be comprised of standard, proven components. Nuclear industry codes and standards are directly applicable to the design, fabrication, and testing of this equipment. Testing will ensure that interface requirements are met, such as by the use of mockups of interfacing equipment or use of actual equipment. First equipment tests are currently scheduled for 2012.

See SAR Section 5.5 for information on preoperational and start-up testing. This testing includes dry runs of equipment using mockups of waste containers. The plan is to use the Initial Handling Facility for initial operator training, since it will be available prior to the other nuclear facilities coming on line.

2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

April 6, 2009

Mr. Christopher A. Kouts
Acting Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue SW
Washington, DC 20585

Dear Mr. Kouts:

The U.S. Nuclear Waste Technical Review Board held its winter meeting on January 28, 2009, in Las Vegas. The participation of management and technical personnel from the Office of Civilian Radioactive Waste Management (OCRWM), OCRWM's lead laboratory, and the U.S. Geological Survey (USGS) at the meeting contributed significantly to the meeting's success.

In keeping with the Board's long-standing practice, we offer feedback that is based on the meeting's presentations and discussion. The Board realizes that implementation of the recommendations presented in this letter is subject to funding and to Administration and Congressional direction.

Yucca Mountain Program Status Update

The Board appreciated the discussion of contentions recently submitted by potential parties to the Nuclear Regulatory Commission's (NRC) licensing proceedings for Yucca Mountain and of the NRC's "Requests for Additional Information" (RAI) submitted to OCRWM. The Board is not a party to the licensing proceedings and does not intend to become one. Nevertheless, most of the contentions and RAIs deal with technical matters and therefore are of interest to the Board.

Emplacement Drift Stability

Approximately 85 percent of emplacement drifts would be located in lithophysal tuff, which contains a highly heterogeneous size and spatial distribution of cavities. The Board has greater concern about the behavior of this rock than about the behavior of the nonlithophysal tuff, which constitutes the other 15 percent and is stronger, much more uniform, better characterized, and much better understood. The Board has no doubt that sufficient data exist for confidently designing a ground support system for repository tunnels in the preclosure period, although questions remain about how drift inspection and maintenance would be carried out. However, behavior of the lithophysal rock during the thermal period immediately following repository closure still presents uncertainties. No direct or indirect tensile-strength tests have been done on rock of sufficient size to be representative of lithophysal rock. Furthermore, laboratory testing and numerical simulations of basic rock behavior have focused on intact lithophysal rock, not on tuff with abundant preexisting interlithophysal fracturing, typical of the

Tptpll zone and representing 81 percent of all drift emplacement rock. OCRWM should conduct full-scale or near-full-scale thermomechanical testing of fractured lithophysal tuff to help validate the novel project models and estimates.

Criticality

Burnup credit for actinide depletion and for the presence of fission products is necessary for repository disposal of most commercial spent fuel in waste packages containing many spent-fuel assemblies. OCRWM should continue following its comprehensive technical work plan to obtain the additional data and to perform the additional analyses needed for obtaining full burnup credit. OCRWM also should continue working with NRC to reduce or eliminate the requirement for burnup measurements to obtain burnup credit.

A representative of the Electric Power Research Institute (EPRI) discussed a recent EPRI report on the direct disposal of dual purpose canisters (DPCs) that have been loaded with commercial spent nuclear fuel. A conclusion that can be reached from the report is that some or many of the several hundred already loaded DPCs may have sufficiently low potential for criticality to permit direct disposal in a repository. The EPRI report also demonstrates that the potential for criticality of a loaded DPC can be affected by the pattern of placement of spent fuel assemblies in the DPC. In particular, loading more-reactive assemblies toward the periphery of a DPC reduces the potential for criticality. Such loading involves tradeoffs, however, because shielding also could be improved but temperatures at the DPC centerline could increase. The operational practicality of making individual calculations for each DPC rather than using the more conservative "loading-curve" approach for criticality control also should be reevaluated.

The license application does not include direct disposal of DPCs, and current OCRWM funding constraints preclude the development of license innovations. Nonetheless, when budgets permit, the direct disposal of DPCs warrants OCRWM's investigation because of the significant safety and cost advantages it offers. DOE's current plans are to cut open loaded DPCs and repackage their contents into TAD (transportation, aging, disposal) canisters — a process that would involve possibly needless fuel-handling risks as well as costs of the TAD canisters and disposal of the emptied DPCs, which are likely to be contaminated and not reusable. In addition, if DOE were to provide guidance to the utilities about recommended loading strategies for DPCs, the direct disposal option could be achieved more easily.

The Board recommends that DOE aggressively pursue burnup credit and guidelines for loading DPCs.

Welding – Waste Package Closure System Prototype

The Board was interested in hearing about the welding and other work that is nearing the point of a full-scale continuous demonstration of all of the steps necessary for closure of a loaded waste package. Development of this complex prototype system, which has been underway at Idaho National Laboratory (INL) for approximately seven years, is a signal accomplishment for which the personnel involved at INL, BSC, and OCRWM deserve credit. The time, money, and technical effort necessary to integrate all the steps in a higher-than-ambient-temperature,

radiation environment have been substantial. This is true despite the fact that the technology for each individual step except low-plasticity burnishing is backed by years of commercial experience in less hostile environments. The Board notes that the prototype system includes steps for evacuating the inner, stainless-steel waste package and filling that space with inert gas (helium). Because the inner waste package will contain a sealed and inerted canister, the Board would like to understand better the need for or advantages of evacuating and inerting the inner waste package. In addition, the tolerances for the dimensions of the narrow groove between the Alloy-22 lid and the Alloy-22 waste package seem very tight, which may cause problems during the remote placement of the lid on the waste package.

Science

The Board was pleased to have a science update again after a hiatus of two years. Although the performance-confirmation scientific activities discussed at the January meeting are necessary, they are not a substitute for scientific investigations that can lead to better understanding, alternate lines of evidence related to repository behavior, and increased confidence, or suggest safety or cost improvements. OCRWM's long-term corrosion testing program presented at the Board's meeting in January of 2008 is an example of such scientific activities. Another example — presented at the meeting — is the scientific investigation of precarious rocks and surface rocks at and near the Yucca Mountain site to help date and corroborate predictions of seismic activity in the repository area. The results of this investigation by USGS scientists also may be used to constrain the maximum ground motions that Yucca Mountain has experienced in its 12-million-year history. In addition, the geotechnical work in and around the area where the repository surface facilities are planned to be located enhances confidence and understanding. Because of the value of such scientific investigations, the Board is hopeful that conditions will permit resumption of OCRWM's Science and Technology Program in the near future. When possible, significant further enhancements to scientific understanding and confidence in predictions of repository performance can be gained through monitoring of fundamental physical conditions in the Exploratory Studies Facility and the Enhanced Characterization of the Repository Block tunnels.

Corrosion

The Board is particularly interested in the experiments conducted by USGS that show that nitrate can be lost and chloride retained upon heating of atmospheric dust. The implications of these results have not been integrated with respect to the laboratory work completed on the corrosion of Alloy 22 in nitrate-chloride brines. The discussion that ensued at the Board meeting appears to indicate that DOE is no longer relying on the presence of nitrate and loss of chloride through acid-gas devolatilization as a localized-corrosion exclusion argument, but is now emphasizing an argument based on a prediction that the volume of any brine formed will be too small to have any effect on corrosion. DOE's prediction of the volume of brine apparently does not take into account that the volume of brine that forms shortly after closure will be greater than that which will exist at the time of peak postclosure temperature and can spread on the metal surface. In addition, DOE's concept of the statistical rarity of mutual deliquescence salts occurring on adjacent particles that supports the prediction of a very small brine volume has not been substantiated. A brine-volume analysis that follows the temperature-time trajectory and

takes into account chemical composition should be conducted that is directed at predicting the potential for localized corrosion of Alloy 22. Many facets of the prediction of the physical and chemical environment appear to be evolving that DOE does not recognize. The Board would like to hear a comprehensive and encompassing discussion of the status of dust-deliquescence-induced localized corrosion of Alloy 22.

The Board places high value on OCRWM's participation in our meetings. Thank you again for the participation of OCRWM and its contractors in the Board's winter meeting.

Sincerely,

{Signed by}

B. John Garrick
Chairman

QA: N/A

Department of Energy
Washington, DC 20585

June 1, 2009

B. John Garrick, Ph.D.
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3383

Dear Dr. Garrick:

Thank you for your April 6, 2009, letter providing the Nuclear Waste Technical Review Board (Board) observations and suggestions on information presented by the U.S. Department of Energy (DOE) at the Board's meeting on January 28, 2009. Responses to your observations and comments are enclosed.

If you require further clarification regarding any of these issues, please contact me at (202) 586-6850, or Abraham E. Van Luik at (702) 794-1424.

Sincerely,

Christopher A. Kouts
Acting Director
Office of Civilian Radioactive
Waste Management

Enclosure

RESPONSES TO THE NUCLEAR WASTE TECHNICAL REVIEW BOARD'S APRIL 6, 2009, LETTER FROM DR. B. JOHN GARRICK, CHAIRMAN

Emplacement Drift Stability

Board Observation and Comment:

The Board believes that the Department of Energy (DOE) "should conduct full-scale or near-full-scale thermo-mechanical testing of fractured lithophysal tuff to help validate the novel project models and estimates." This is to address Board concerns over uncertainty concerning the "behavior of the lithophysal rock during the thermal period immediately following repository closure." The Board agrees that enough is known to allow the design of a preclosure ground support system, but that there are concerns about the ability to monitor and maintain drifts, if maintenance is needed, prior to final closure.

DOE Response:

DOE disagrees that it would be beneficial to have additional data on the lithophysal rock portion of the repository in terms of response to thermal stresses after closure, because DOE has concluded that rock fall after closure of emplacement drifts in the lithophysal zone will not impact system safety or regulatory compliance. Potential rock fall in the lithophysal area of the repository could occur more often than in the non-lithophysal zones of the repository, however, the smaller size of any falling rocks in the lithophysal area makes them less likely to cause drip shield damage.

Although a full-scale thermo-mechanical test in lithophysal rock would contribute to additional confidence in prediction of drift stability during the thermal period, the existing data and models provide conservative estimates of the drift response. DOE's modeling of drift stability in the lithophysal rock mass is based on a methodology used in mining, civil, and petroleum engineering industries for more than 20 years, and the approach has been calibrated for this application to ensure that it over-predicts thermally induced damage and rockfall in drifts.

Moreover, the stability of the existing mined openings is being monitored on a regular basis. This permits DOE to evaluate potential differences in the response of lithophysal versus non-lithophysal rocks on an ongoing basis over time.

Criticality

Board Observation and Comment:

The Board would like to see the work planned to increase understanding in the area of burnup credit carried to completion. In addition, the Board would like to suggest that the current fleet of Dual Purpose Canisters (DPC) ought to be considered for direct disposal, and that prescribing loading strategies for new DPCs could minimize the criticality issue associated with DPC disposal.

DOE Response:

DOE believes that burnup credit and criticality safety are issues that cut across all areas of nuclear fuel management and handling and suggests that some of the planned Office of Civilian Radioactive Waste Management (OCRWM) work in this area could be picked up by parties outside OCRWM.

The Board notes that DOE's repository surface facilities will have the capability to reopen DPCs and move their contents into transportation, aging, and disposal (TAD) canisters. However, the Board raises legitimate issues from a cost, efficiency, and worker safety perspective regarding the handling of DPC's which would require DOE to put in place a research effort. The current Administration policy that Yucca Mountain is not a workable option and our budget constraints do not allow the implementation of such an effort.

Welding – Waste Package Closure System Prototype

Board Observation and Comment:

The Board complimented DOE, the Idaho National Laboratory, and Bechtel-SAIC, LLC, for a job well done in demonstrating the prototype waste package closure weld robotic system. The Board questioned current plans to evacuate and inert the inner waste package with helium since the TAD canister, inside of which the waste is located, is sealed and already inerted with helium. The Board expressed concern over the narrow groove between the lid and the waste package wall which may result in problems for the placement process.

DOE Response:

DOE agrees that this work was well done, and has led to significant insights that will be implemented, and was well worth the investment. Much was learned that will be directly applied in designing the waste package closure system and in writing the system operations manuals.

The inerting of both the TAD canister and the void-space in the waste package around the TAD serves to provide enhanced thermal conduction from the TAD to the package inner wall. However, the Board raises a valid technical issue that may need to be addressed in future activities that raise the same issue.

Science

Board Observation and Comment:

The Board was pleased to have an overview of the science work still in progress and recently completed. The Board made several suggestions for continued work in terms of monitoring the existing mined openings now, and in the future perhaps a resumption of the forward-looking Science and Technology Program.

DOE Response:

The current Administration policy that Yucca Mountain is not a workable option and our budget constraints do not allow the implementation of such an effort.

Corrosion

Board Observation and Comment:

The Board was interested in the U.S. Geological Survey (USGS) work on the loss of nitrate from dust at elevated temperatures. The Board was not convinced by DOE's argument concerning the low likelihood of forming corrosive brines, and the low likelihood of sufficient brine volumes to be meaningful from a corrosion perspective. The Board suggested that some additional laboratory work could be useful in addressing this question.

DOE Response:

DOE considers its assessment concerning limited brine volumes to be justified and defensible. NRC has asked a question similar to that posed by the Board concerning implications of the USGS work on nitrate to chloride ratios in dust. DOE's response to NRC's Request for Additional Information (RAI) can be viewed in NRC's ADAMS database under accession number ML091140365 (RAI Volume 3, Chapter 2.2.1.3.3, Number 16).

2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

August 13, 2009

The Honorable Steven Chu
Secretary
U. S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Secretary Chu:

The Nuclear Waste Policy Amendments Act of 1987 established the Nuclear Waste Technical Review Board as an independent agency in the executive branch. The Act charged the Board with evaluating the technical validity of U. S. Department of Energy (DOE) activities regarding the management and disposal of high-level radioactive waste and spent nuclear fuel. The Board held a public meeting on June 11, 2009, in Las Vegas, Nevada. The purpose of this letter is to provide feedback from that meeting.

The Administration has proposed a significant change in national policy for managing and disposing of high-level radioactive waste and spent nuclear fuel. I acknowledged that change in my opening remarks at the June meeting and articulated plans for the Board to continue providing independent and objective technical advice to Congress and the Secretary of Energy in accordance with the Board's mandate. The Board anticipates that its technical evaluations will be useful not only to Congress and the Secretary but also to a "blue ribbon" commission that may study options for managing nuclear waste.

The Board has established the following objectives to facilitate its evaluations:

1. To the extent that DOE engages in technical work related to the management and disposal of high-level radioactive waste and spent nuclear fuel, the Board will continue to monitor and evaluate that work and report on the technical validity of the work to Congress and the Secretary.

2. The Board will continue developing and compiling objective technical information to inform Congress, the Secretary, and a blue-ribbon commission. In developing such information, the Board will look broadly at an integrated waste management system and potential waste management alternatives and will provide its objective view of technical questions and issues that need to be addressed.

3. The Board will draw on its extensive experience, including knowledge gained from observing efforts in other countries, to develop and provide technical information and technical "lessons learned" about the U. S. nuclear waste management program, including the operational and safety risks of alternatives for managing high-level radioactive waste.

The following findings, conclusions, and recommendations reflect information conveyed at the Board's June meeting and are within the context of the three objectives noted above.

Very-Long-Term Dry Storage: Technical Issues

The Administration has announced that it intends to terminate the Yucca Mountain project and convene a blue-ribbon commission to develop and examine alternatives for the management and disposal of spent nuclear fuel and high-level radioactive waste. Any alternative is likely to require dry storage of spent nuclear fuel and high-level radioactive waste for extended periods. There appear to be no technical factors that would prevent designing and safely operating dry-storage systems for at least several decades — providing that there is regular monitoring. However, whether the current technical basis is adequate for designing and operating dry-storage facilities for very long periods is not clear.

At its meeting, the Board convened a panel of experts to discuss research and data needs for very-long-term dry storage ("very long term" was defined for purposes of discussion as 120 years or more). The panel included a representative of nuclear utilities, a representative of a firm that designs and manufactures dry storage systems, and a representative of the Electric Power Research Institute. The purpose of the panel was to brainstorm potential technical issues that might be associated with the storage of waste for a very long period.

On the basis of discussions among panelists and Board members, the technical basis for designing and operating dry-storage systems for a very long term warrants improvement. Potential issues and the need for technical data may differ, depending on the location of the storage facility (e.g., coastal or desert), the environment (e.g., humid or arid), and the materials of construction (e.g., carbon steel, stainless steel, concrete). What is most important is the condition of the spent fuel in the canisters because it must be shipped, possibly repackaged, and eventually disposed of (or reprocessed) after a long period of dry storage. The U.S. experience in examining the behavior of spent fuel in dry storage is limited to very few spent fuels having burnups significantly lower than current practice. The Board is preparing a white paper on technical needs for very-long-term dry storage.

Future Dry Cask Storage Systems

DOE has contracted with manufacturers of dry-storage systems to develop designs for transportation, aging, and disposal (TAD) canisters for transporting commercial spent fuel, storing commercial spent fuel at reactor sites or other sites, or disposing of commercial spent fuel in a Yucca Mountain repository. Dry-storage and transportation canister-based systems that are already widely used by nuclear utilities have significantly higher capacity in terms of numbers of assemblies and heat load than DOE's TAD canisters do, and the trend is for even higher future capacities. A decision to terminate the Yucca Mountain project and the low capacity of TAD canisters are likely to hinder significantly the acceptance of TAD canisters by nuclear utilities. The Board has recommended in the past that DOE modify its waste package system to allow direct disposal of loaded dual-purpose canisters without repackaging the spent fuel. This would require full burnup credit and a slight increase in the diameter of waste packages.

Drip Shield

In June 2008, DOE submitted to the U. S. Nuclear Regulatory Commission a license application for constructing a repository at Yucca Mountain. At the Board's June 11 meeting, a State of Nevada representative stated that, on the basis of the "drip shield early failure" case in the license application, the U. S. Environmental Protection Agency dose standard would be exceeded if drip shields were omitted from the repository.

The license application contains many modeling assumptions. Some of them include the composition of water seeping onto drip shields from the roofs of emplacement drifts, the initiation and propagation rate of waste-package localized corrosion due to seepage, the size and shape of any penetrations due to seepage-based localized corrosion, the degradation of the waste form once it is contacted by water, and the mobilization and transport of radionuclides from the degraded waste form. The cumulative effects of these modeling assumptions may result in a lack of realism about how barriers and waste would behave in a repository. In other words, depending on the assumptions and the model chosen to represent the degradation mechanisms, the performance of the drip shield may or may not be as represented in the current model.

The Board continues to urge DOE to develop more-realistic models. In addition, as the Board has pointed out in past letters and reports, DOE has not developed prototypes, or even scale models, for the drip shield. Just as important, if not more so, is that prototypes have not been developed for the equipment that would emplace, monitor, inspect, adjust, or, if necessary, retrieve the drip shields. Both the drip shields and the equipment for emplacing them are simple in concept, but they are unprecedented and, in our view, require prototypes. DOE has had a program for drip shield and related equipment prototypes on its books for years but has never implemented it.

Fuel-Cycle Research

One speaker at the June 11 meeting raised the subject of DOE's proposed fuel-cycle research and development program for fiscal year 2010. We note that the justification for the proposed program is almost entirely related to waste management and that the program would be undertaken largely to improve options for waste storage and disposal, reduce the amount or longevity of waste, or promote safe and secure management of waste. In accordance with its enabling legislation, the Board will evaluate the technical validity of activities undertaken within the fuel-cycle research and development program to the extent that they relate to the management and ultimate disposal of spent nuclear fuel and high-level radioactive waste. In particular, the Board will be holding a public meeting in the Washington, D. C., area on September 23, where this issue will be an important topic of discussion.

DOE-Owned Spent Nuclear Fuel and High-Level Radioactive Waste

DOE owns more than 2,000 metric tons of spent nuclear fuel and the equivalent of more than 7,000 metric tons of high-level radioactive waste. Almost all of this waste has accumulated as a byproduct of the nation's defense activities. These waste materials are stored primarily at Hanford, the Savannah River Site, and Idaho National Laboratory. Although much of the spent fuel already is in solid form in dry storage, most of the high-level waste is stored as liquid or sludge in large tanks. With only a few possible exceptions, these wastes appear to have no current or future value; they must be disposed of eventually.

A representative of DOE's Office of Environmental Management presented an overview of the inventory of DOE-owned spent fuel and high-level radioactive waste at the June 11 meeting. The Board visited the Hanford site last month and plans to visit the Savannah River Site in January 2010 and Idaho National Laboratory in June 2010 to observe and discuss first-hand the management of spent fuel and high-level radioactive waste at each site. We expect to issue a report shortly after visiting the last site and hope that the technical information in that report will be useful to Congress, the Secretary of Energy, the public, and the blue-ribbon commission.

Sincerely,

{Signed by}

B. John Garrick
Chairman

2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

October 16, 2010

The Honorable Warren F. Miller, Jr.
Assistant Secretary for Nuclear Energy
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585

Dear Dr. Miller:

The U.S. Nuclear Waste Technical Review Board held a public meeting in Idaho Falls, Idaho, on June 29, 2010. The principal topics were (1) management and ultimate disposition of the spent nuclear fuels (SNF) and high-level radioactive wastes (HLW) that are the responsibility of the U.S. Department of Energy's Idaho Operations Office (DOE-ID) and the Naval Nuclear Propulsion Program and (2) future technologies and activities that could affect the amounts and forms of SNF and HLW that will require management and disposal or could affect the radioactive hazard levels of the SNF and HLW over time.

Several of the 11 people who made presentations at the meeting were employees of DOE's Office of Nuclear Energy (DOE-NE). We greatly appreciate their participation and the quality of their presentations.

The Board was established as an independent federal agency in the 1987 amendments to the Nuclear Waste Policy Act. The Board's statutory role is to review the technical validity of activities undertaken by the Secretary of Energy related to implementation of the Nuclear Waste Policy Act. The Board reports its findings and recommendations to Congress and the Secretary of Energy at least twice a year. According to the legislative history, the Board is expected to make its recommendations before decisions are made, not after the fact. Thus, the Board established a practice many years ago of sending a follow-up letter after each of its public meetings to the appropriate DOE program managers. This letter continues that practice.

Extended Storage and Subsequent Transportation of SNF

When a repository or storage location for SNF will be available is not known at this point, and that uncertainty may continue well into the future. The Board believes that studies should be undertaken to identify and plan for actions that are needed for preventing problems from occurring during the transportation, repackaging, or disposal of SNF following *extended* periods of dry storage. Studies of the safety, cost, and technical issues associated with various alternatives for managing, packaging, and transporting the SNF also would be invaluable to the Blue Ribbon Commission for America's Nuclear Future, to the Office of Environmental Management for its long-term planning, and to the Board in setting priorities for its technical peer review.

DOE-NE's Used Nuclear Fuel Disposition Program

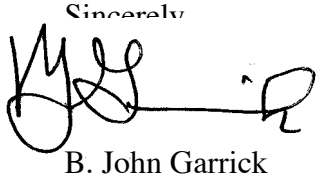
The Board realizes that the Used Nuclear Fuel Disposition Program is still in its formative phase and may be affected by congressional direction and funding for fiscal year 2011. A program that identifies alternatives and conducts scientific research and technology development to enable and optimize storage, transportation, and disposal of SNF and HLW generated by existing and future nuclear-fuel cycles would be helpful to decision-makers and technology-implementers. Each element of the program should have clear objectives and be integrated with other DOE-NE programs, particularly those of the Office of Fuel Cycle Research and Development.

Some aspects of DOE-NE's Used Nuclear Fuel Disposition Program proposed for fiscal year 2011 appear similar to the Science & Technology (S&T) Program that DOE's Office of Civilian Radioactive Waste Management (DOE-RW) established in 2003. The S&T Program was explicitly distinct from the mainline DOE-RW activity of developing an application for a license to construct a repository at Yucca Mountain. The goals of the S&T Program were to (1) improve existing technologies and develop new technologies for achieving efficiencies and savings in the waste management system and (2) increase fundamental understanding of repository performance. Although intended to be permanent, the program was suspended in 2008, just when it had assembled several teams of highly qualified engineers and scientists who were producing significant results. The Board strongly endorsed the S&T program. In the Board's view, the need for a similar effort, such as the one being defined by the Used Nuclear Fuel Disposition Program, is even greater now because the scope of scientific and technical options has grown substantially. However, the experience of the S&T program demonstrates that a fully successful program requires continuity.

According to the proposed fiscal year 2011 budget for the Used Nuclear Fuel Disposition Program presented at the meeting, $12 million is allocated to "science programs transferred from RW to NE." Because the level of science activity in the fiscal year 2010 DOE-RW program appears much smaller, the Board would appreciate receiving more information about the science programs that will be transferred from DOE-RW to DOE-NE.

Thank you for helping make the Board's meeting in Idaho Falls a success.

Sincerely



B. John Garrick
Chairman

2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

October 21, 2010

The Honorable Inés R.Triay
Assistant Secretary for Environmental Management
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585

Dear Dr. Triay:

The U.S. Nuclear Waste Technical Review Board held a public meeting in Idaho Falls, Idaho, on June 29, 2010. The principal topics were (1) management and ultimate disposition of the spent nuclear fuels (SNF) and high-level radioactive wastes (HLW) that are the responsibility of the U.S. Department of Energy's Idaho Operations Office (DOE-ID) and the Naval Nuclear Propulsion Program and (2) future technologies and activities that could affect the amounts and forms of SNF and HLW that will require management and disposal or could affect the radioactive hazard levels of the SNF and HLW over time.

Several of the 11 people who made presentations at the meeting were employees of DOE-ID. We greatly appreciate their participation and the quality of their presentations.

The Board was established as an independent federal agency in the 1987 amendments to the Nuclear Waste Policy Act. The Board's statutory role is to review the technical validity of activities undertaken by the Secretary of Energy related to implementation of the Nuclear Waste Policy Act. The Board reports its findings and recommendations to Congress and the Secretary of Energy at least twice a year. According to the legislative history, the Board is expected to make its recommendations before decisions are made, not after the fact. Thus, the Board established a practice many years ago of sending a follow-up letter after each of its public meetings to the appropriate DOE program managers. This letter continues that practice.

DOE-ID Spent Nuclear Fuel

Much of the SNF under the jurisdiction of DOE-ID already is in dry storage, and plans are under way to move the remaining SNF to dry storage. The Board has not identified any immediate technical issues with dry storage of this SNF. However, the Board recommends that the as-built lifetimes (as opposed to the design lifetimes) of all SNF dry-storage systems under DOE-ID's responsibility be assessed because it is not known at this point when a repository or storage location outside Idaho will be available, and that uncertainty may continue well into the future. In addition, the Board believes that studies should be undertaken to identify and plan for actions that are needed for preventing problems from occurring during the transportation, repackaging, or disposal of SNF following *extended*

periods of dry storage. Studies of the safety, cost, and technical issues associated with various alternatives for managing, packaging, and transporting the SNF also would be invaluable to the Blue Ribbon Commission for America's Nuclear Future, to the Office of Environmental Management for its long-term planning, and to the Board in setting priorities for its technical peer review.

DOE's National Spent Nuclear Fuel Program carried out extensive work in developing packaging systems that would be acceptable for disposal in a repository at Yucca Mountain. Whether the size, materials of construction, or other attributes of packaging developed for the Yucca Mountain repository would be suitable for other geologic disposal media is not known. Consequently, analysis of the issues associated with disposing of DOE-ID and other DOE-owned SNF in geologic settings other than unsaturated tuff would be appropriate. The Board recommends that DOE undertake such studies. This would include reexamination of studies performed more than 25 years ago in the United States as well as examining more-recent geologic disposal efforts of other countries.

DOE-ID Calcine

Virtually all of the liquid HLW at Idaho National Laboratory was calcined years ago into a solid granular form and is being stored in shielded bins. The design lifetime of the bin storage system is asserted to be 500 years. Designing a civil system made from ferrous alloys and concrete for such a period is unprecedented. The technical basis for the design lifetime estimate should be examined in detail, and the results of the examination — including any assumptions regarding inspection and maintenance frequencies — should be conveyed to the programs within DOE carrying out research on very-long-term dry storage. The results also should be transmitted to outside entities now carrying out such research, including the Electric Power Research Institute and the U.S. Nuclear Regulatory Commission.

In December 2009, DOE decided to treat the calcine by hot isostatic pressing before transporting it off the site. The decision was based in part on a cost estimate comparing various treatment alternatives. A key technical assumption affecting this decision was that treated calcine would be loaded into "standardized canisters" (2 feet in diameter by 10 feet or 15 feet long) that would subsequently be loaded into larger outer containers for storage, transportation, and disposal. This assumption may not be necessary for some treatment methods yet may increase the number of containers requiring storage, transportation, and disposal. In addition, it is not clear whether the operational risk of various treatment options was taken into account or whether probabilistic risk assessments (PRAs) were performed on the safety of the various alternatives after disposal in a repository. The Board believes that another cost comparison should be conducted that takes into consideration appropriate technical assumptions and the aforementioned risks.

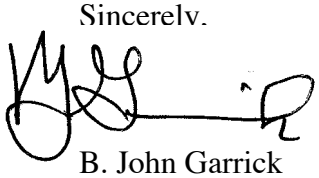
DOE-ID Sodium-Bearing Waste

Whether sodium-bearing waste (SBW) is a high-level waste remains an open matter that appears to be more of a regulatory issue than a technical one. Perhaps a risk assessment could help in the determination. In any case, we agree that changing the SBW from its current liquid form to a solid form is necessary.

More technical detail would be helpful in understanding and evaluating the basis for the selection of steam reforming for treating SBW. Although steam reforming is not a new technology, using it to treat SBW is a novel application. If SBW is classified as a high-level waste, the characteristics of the final waste form resulting from treating SBW with steam reforming and the final disposition of the resulting solid would be of particular interest to the Board.

Thank you for helping make the Board's meeting in Idaho Falls a success.

Sincerely,



B. John Garrick
Chairman

2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

July 26, 2011

Mr. David G. Huizenga
Acting Assistant Secretary for Environmental Management
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585

Dear Mr. Huizenga:

The Amendments to the Nuclear Waste Policy Act (NWPA) charge the U.S. Nuclear Waste Technical Review Board with evaluating the technical and scientific validity of activities undertaken by the U.S. Department of Energy (DOE) in implementing the NWPA. The Board also is charged with reporting the findings, conclusions, and recommendations from its evaluations to Congress and the Secretary of Energy.

In discharging these responsibilities, the Board holds several public meetings each year, and it is customary for the Board to provide feedback to DOE from the presentations and discussions at the meetings, together with other points that arise from them. In the first half of this year, we held two public meetings and a workshop. The first public meeting was focused on issues related to the work of the DOE Office of Nuclear Energy, so in this letter, I am reporting to you on relevant issues from the second public meeting and the workshop.

Comments from April Meeting

The Board's second public meeting this year was held in Amherst, New York, on April 27. The meeting dealt exclusively with past, current, and planned activities at the Western New York Nuclear Service Center (referred to below as West Valley) and focused on the West Valley Demonstration Project (WVDP), which is being conducted by your office. The WVDP includes decommissioning and waste management activities at West Valley, following the permanent closure of the only U.S. commercial reprocessing facility that operated on the site between 1966 and 1972. The Board's findings and observations from that meeting are presented below.

- In March 2011, DOE issued a draft determination* that contained a preliminary determination that the melter from the vitrification plant at West Valley can be managed and disposed of as low-level waste. That conclusion was based on criteria in DOE Manual 435.1-1, *Radioactive Waste Management Manual*. Because this appears to be the first time that these procedures have been applied to a melter, the experience and outcome in the West Valley case will set an important precedent for the many melters at Hanford

* *Draft Waste Incidental to Reprocessing Evaluation for the Vitrification Melter, U.S. Department of Energy, West Valley, New York, March 2011.*

and Savannah River that will require disposal. The Board therefore recommends that DOE take this into account in finalizing the determination of the appropriate method of disposing of the melter from West Valley.

- The Board understands that a key element of the planning basis for the project for relocating the canisters of vitrified waste at West Valley was the assumption, at that time, that a repository at Yucca Mountain would be available to receive the waste within the planning horizon. Currently, however, there is uncertainty about when a U.S. repository will be available and about whether a repository other than the one planned for Yucca Mountain would be able to accept waste packages as large as those necessary to contain the 5-canister or 7-canister MPCs, which are planned for use at West Valley. Because of these uncertainties, the Board recommends that plans for the relocation project should be flexible enough to adapt to future changes in repository design and schedule.

- The Board believes that it is important to preserve, and share on an ongoing basis, program data and experiences among entities involved in waste management and is concerned about the apparent lack of attention currently being paid to this matter at West Valley. We would like to invite representatives of your office to participate in a future Board meeting to discuss the procedures in place within DOE-EM for sharing decommissioning experiences among facilities and preserving decommissioning information. The Board is particularly interested in discussing plans for the preservation of information from decommissioning activities that will assist in minimizing future generation of high-level radioactive waste. The Board also has made a recommendation to DOE-NE that it should ensure that the necessary level of contact exists between its staff and DOE-EM staff to maximize the benefit to future DOE fuel-cycle programs of information available from the WVDP.

- Two members of the Board staff attended the regular monthly meeting of the West Valley Citizen Task Force during the evening of April 27. It is clear that this long-standing organization is involved, interested, and informed and that it is well-supported by DOE, the New York State Energy Research and Development Authority, and their contractors. We commend and encourage DOE's ongoing interaction with this well-informed group and other members of the interested public. In that regard, the Board recommends that DOE consider the use of all available information platforms, including electronic social media, to maintain and enhance the level of transparency in its operations at West Valley and other DOE sites.

Workshop on Benchmarking Analytical Results

The workshop organized by the Board was the Workshop on Evaluation of Waste Streams Associated with LWR Fuel Cycle Options. It was held in Arlington, Virginia, on June 6 and 7, 2011, and was arranged to provide a forum for developers and users of computer models, codes, and analytical tools to benchmark their results from analyzing and comparing a set of standard fuel-cycle scenarios. The Board has developed an analytical tool called the Nuclear Waste Assessment System for Technical Evaluation (NUWASTE) to assess the effects of different nuclear power program assumptions and fuel-cycle options on programs in the United States for managing spent nuclear fuel and high-level radioactive

waste. Although DOE-EM does not have the need for a computer model to analyze fuel-cycle scenarios, the presentation on the systems dynamic model that DOE-EM has developed to show the waste management operations at the Savannah River Site was a significant addition to the workshop. As we continue to develop the capabilities of NUWASTE, we may request the support of your staff in determining how to best represent the characteristics and quantities of DOE-generated high-level waste to give a complete representation in NUWASTE of the wastes to be managed under the Nuclear Waste Policy Act.

Finally, the Board appreciates very much the participation of DOE-EM staff and other representatives at the meetings we have held so far this year. We particularly thank Mr. Bryan Bower, who managed the arrangements for the Board's visit to West Valley in April, and Ms. Terry Tyborowski, who presented the DOE-EM waste management model at the workshop in June.

Sincerely,

{Signed by}

B. John Garrick
Chairman

cc:
Dr. S. Chu, Secretary of Energy
Dr. P. Lyons, Assistant Secretary, DOE-NE
Mr. B. Bower, DOE-EM, West Valley
Mr. P. Bembia, NYSERDA, West Valley

2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

July 26, 2011

The Honorable Peter B. Lyons
Assistant Secretary for Nuclear Energy
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585-1290

Dear Dr. Lyons:

As you know, the U.S. Nuclear Waste Technical Review Board is charged with evaluating the technical and scientific validity of activities undertaken by the U.S. Department of Energy (DOE) in implementing the Nuclear Waste Policy Act and with reporting its findings and recommendations related to the management and disposition of spent nuclear fuel (SNF) and high-level radioactive waste (HLW) to Congress and the Secretary of Energy.

In discharging these responsibilities, the Board holds public meetings each year. It is customary for us to provide feedback to DOE from the presentations and discussions at these meetings, together with other points that arise from them. In the first half of this year, we held two public meetings and a workshop. In this letter, I am conveying to you important issues identified by the Board from each meeting.

Comments from February 2011 Board Meeting

The first public meeting this year was held on February 16 in Las Vegas, Nevada. The presentations and discussions focused on three main areas: DOE's activities related to the back end of the nuclear fuel cycle, technical experience gained from DOE's past SNF and HLW management efforts, and work currently being undertaken by Sandia National Laboratories related to geologic disposal options in the United States.

DOE Activities Related to the Back End of the Nuclear Fuel Cycle

Dr. Monica Regalbuto, Deputy Assistant Secretary for Fuel Cycle Technologies, and Dr. William Boyle, Director of the Office of Used Nuclear Fuel Disposition Research and Development, opened the meeting with presentations on DOE's *Nuclear Energy Research and Development Roadmap*, which was published in April 2010. The presentations covered fuel-cycle technology research and development (R&D) being undertaken by DOE's Office of Nuclear Energy (DOE-NE). The Board has a particular interest in the implications for waste management of the fuel-cycle options being studied by DOE, including the effects on the quantities and the volumes of waste that would be generated. Of primary interest to the Board in this area is work that DOE is planning related to the once-through fuel cycle and limited recycling because other options do not appear to have the potential to be deployed in the next few decades.

Dr. Boyle's presentation included work that DOE is undertaking related to SNF storage, transportation, and disposal, all of which fall under the Board's statutory mandate. From his presentation, we understand that DOE's near-term objectives in these areas are providing expertise to decision-makers on issues related to managing SNF; developing a comprehensive understanding of the technical conditions necessary for long-term storage, transportation, and disposal of SNF and HLW; and developing computer models for evaluating disposal-system performance for a variety of repository concepts.

The time available for the presentations by Dr. Regalbuto and Dr. Boyle was limited. As a consequence, the information presented was not very detailed. However, it appeared that, although the R&D program was directed at appropriate fields of activity, it was not focused on specific goals and defined objectives related to helping DOE develop a program for managing SNF and HLW. The Board believes that every aspect of the R&D program should have defined goals and should be coordinated to ensure that the overall program is integrated, focused, and managed effectively.

Since the February meeting, the Board has requested and has been provided with more-detailed information on the program, including implementation plans and funding levels for activities included in the *Roadmap*. We have invited Dr. Regalbuto and her staff to make more-detailed presentations on DOE's R&D program related to management of SNF and HLW at the next Board meeting, which will be held on September 13 and 14, 2011, in Salt Lake City, Utah. I am pleased that Dr. Regalbuto and her staff have agreed to attend, and we look forward to a full discussion of the program at that meeting.

An issue that will likely come up at the meeting is the extent to which burnup credit is being taken into account in planning the development of handling, storage, and disposal facilities for SNF. This is an important issue for SNF management, and we commend the efforts we understand that DOE has made recently to develop a technical basis for taking burnup credit in the design of equipment and facilities.

Technical Experience Gained to Date from Repository Programs

The Board held a meeting at Dulles, Virginia, on October 26, 2010, at which we started a discussion of technical experience gained during DOE's efforts over the last two decades related to developing a program for managing and disposing of SNF and HLW. That meeting included panel discussions involving former Yucca Mountain program managers, representatives of local governments that would be affected by a repository at Yucca Mountain, and representatives of international waste management programs.

We continued this theme at the February meeting in Las Vegas with a panel of three former managers from the Yucca Mountain Project: Lake H. Barrett, former Acting Director of the Office of Civilian Radioactive Waste Management (OCRWM); Christopher Kouts, former Acting Director of OCRWM; and George E. Dials, former General Manager of TRW Environment Systems, the management and operating contractor for the Yucca Mountain Project, and former manager of the DOE office in Carlsbad, New Mexico. Information and technical insights from both meetings and all the panels proved very useful as the Board prepared its report on technical advancements and issues that is discussed in the last section of this letter.

Geologic Disposal Options in the United States

The third topic covered during the February meeting was work related to options for geologic disposal in the United States. Technical presentations were made by Dr. Patrick Brady, Dr. Ernest Harding, and Mr. Andrew Orrell, all of Sandia National Laboratories. Professor Hank Jenkins-Smith, professor of political science at the University of Oklahoma, presented by telephone the results of recent surveys of how technical information related to the management of SNF and HLW is perceived by the broader U.S. population.

Dr. Hardin's presentation made clear that many geologic media in the United States would be suitable for geologic disposal. He indicated that considerable academic study has been completed on deep borehole disposal, and the information that he and Dr. Brady presented indicates that it may be appropriate to begin field investigations, including a test drilling program and emplacing surrogate SNF and HLW in a borehole. If such a program is to be developed, however, the Board believes that it is essential that it is coupled with a program for developing the appropriate facility designs and for evaluating the necessary operational requirements for a borehole disposal program.

To follow-up on the presentations at the February meeting, the Board would like to know more about the progress being made regarding borehole disposal and other geologic-specific disposal programs that are under consideration. We are planning to make this a central part of the Board meeting we are planning for the spring of 2012 and will be contacting you or your staff regarding this in the near future. In this regard, we are particularly interested in work directed at optimizing the characteristics of the waste forms intended for disposal in specific geologic media.

From the technical presentations made at the meeting, it appears that at this point DOE has not developed a siting strategy or a plan for defining the siting criteria for a future repository for SNF and HLW. The Board understands that to some extent this results from an expectation that recommendations to be made by the Blue Ribbon Commission on America's Nuclear Future may affect the basis for developing such a siting strategy or criteria. Despite this possibility, however, the Board believes that there is technical merit in preparing for disposal of SNF and HLW on an early timeframe, and it encourages DOE to begin these activities.

Comments from April 2011 Board Meeting

The Board's second public meeting this year was held on April 27 in Amherst, New York, and followed a site visit to the West Valley site the previous day. The primary focus of the meeting was the management of HLW from the West Valley Demonstration Project (WVDP), and most of the issues from that meeting related to the DOE Office of Environmental Management (DOE-EM), rather than to DOE-NE. However, one item from the discussion at that meeting also is relevant to the fuel-cycle R&D program being developed by DOE-NE. During the meeting, the Board was not able to establish the extent to which "lessons learned" information from the decommissioning project is being made available to DOE-NE staff and support contractors so that it can be taken into account in developing plans for potential fuel-cycle options that include reprocessing and recycle operations. The Board recommends that DOE-NE ensure that the necessary level of contact exists between its staff and the staff of DOE-EM to maximize the benefit of this information to future DOE fuel-cycle programs.

Following the meeting in Amherst, two members of the Board staff attended the regular monthly meeting of the West Valley Citizen Task Force during the evening of April 27. I have passed on to Mr. David Huizenga, Acting Assistant Secretary for the Office of Environmental Management, the Board's commendation regarding DOE's ongoing interaction with this well-informed group and other members of the interested public. In that regard, the Board has recommended to Mr. Huizenga, and also recommends to you, that DOE consider using all available information platforms, including electronic social media, to maintain and enhance the level of transparency in its operations.

Comments from Workshop on Benchmarking Analytical Results

The third event organized by the Board this year was the Workshop on Evaluation of Waste Streams Associated with LWR Fuel Cycle Options, which was held in Arlington, Virginia, on June 6 and 7. The workshop was arranged to provide a forum for developers and users of computer models, codes, and analytical tools to benchmark their results by analyzing and comparing a set of fuel cycle scenarios. The scenarios defined for this workshop were only for benchmarking purposes and were not intended to be realistic scenarios that would necessarily be implemented in the United States. The Board has developed an analytical tool called the Nuclear Waste Assessment System for Technical Evaluation (NUWASTE) to assess the effects of different nuclear power program assumptions and fuel-cycle options on the U.S. programs for managing SNF and HLW. Dr. Steven Piet from Idaho National Laboratory (INL) presented the results of INL's assessments of the standard scenarios performed using the VISION code that was developed by INL. The other participants who presented the results of their analyses were from MIT, AREVA, and the National Nuclear Laboratory in the United Kingdom. The transcript from the workshop is available on the Board's Web site (www.nwtrb.gov). The final results of the analyses of the standard scenarios by the participants will be posted to the Board's Web site soon.

Preserving Technical Experience, Data, and Documents from Repository Efforts

The Board has finalized and issued a report titled *Technical Advancements and Issues Associated with the Permanent Disposal of High-Activity Wastes: Lessons Learned from Yucca Mountain and Other Programs*. Copies have been sent to you and to other key DOE officials. It also is available at www.nwtrb.gov. Our objective in preparing this report was to ensure that the information it contains will be available to Congress and the Secretary; DOE management, staff, and contractors; and stakeholders with roles in managing the nation's SNF and HLW, now and in the future. We believe that a substantial body of knowledge and experience exists among DOE and contractor staffs who have worked on the Yucca Mountain repository program that remains to be recorded. We encourage DOE to capture as far as possible this additional information that may be useful in developing SNF and HLW management and disposal programs in the United States in the future. We believe that this would represent an invaluable technical resource.

Toward that end, I also am pleased to report that the Board is close to agreement with DOE's Office of Legacy Management (DOE-LM) regarding the Board's role in providing independent review of DOE-LM's plans and implementation of the plans to preserve the documentation and electronic information generated from the Yucca Mountain Project. As mentioned above, we believe that this information will be of significant value in the future, and ensuring that it is available is extremely important.

The Board appreciates very much the participation of DOE-NE staff and other representatives at these Board meetings. We look forward to continued DOE-NE participation in our meetings and to following up on the issues raised above.

Sincerely,

{Signed by}

B. John Garrick
Chairman

cc:
Dr. S. Chu, Secretary of Energy
Mr. D. Huizenga, Acting Assistant Secretary, DOE-EM

December 8, 2011

Dr. Monica Regalbuto
Deputy Assistant Secretary
Fuel Cycle Technologies
Office of Nuclear Energy
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585-0620

Dear Dr. Regalbuto:

On behalf of the U.S. Nuclear Waste Technical Review Board, I am pleased to provide comments on the draft report, *Gap Analysis to Support Extended Storage of Used Nuclear Fuel,* which was prepared by National Laboratory staff for the Used Fuel Disposition Campaign of the U.S. Department of Energy (DOE) Office of Nuclear Energy and issued on June 30, 2011.

As you know, the Board issued its report, *Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel,* in December 2010. In it, the Board recommended that a number of topics related to the safety of spent nuclear fuel (SNF) after extended dry-cask storage and subsequent transportation of the SNF be addressed in future research. The lack of data related to the storage and transportation of high-burnup SNF was noted in particular. The Board believes that the draft *Gap Analysis* report identifies issues that should be addressed in establishing a technical basis for safe extended dry-cask storage and retrieval of SNF and, in general, sets appropriate research priorities for resolving the issues. More-detailed comments and Board recommendations are presented in the following paragraphs.

The Board understands the utility of the approach used in the draft *Gap Analysis* report for assigning research-priority designations of low, medium, or high to identify the essential and urgent data gaps. However, the Board considers it important that the methodology, including the priority-setting process, be applied to the important technical questions. The Board notes that the transportation element of SNF management was not included in this gap analysis; thus we look forward to a similar assessment of research needs for transportation of SNF in an integrated research program covering both storage and transportation.

Our review of the draft *Gap Analysis* report indicates that the significant research priorities identified in the Board report relating to degradation mechanisms and "cross-cutting" research needs[1] were designated in the draft *Gap Analysis* report as medium or high research

[1] For example, the "cross-cutting" needs for determining fuel-temperature profiles over time, better quantifying the amount of residual water present after drying, carrying out additional cask-demonstration and fuel-inspection projects with representative dry-stored fuel, developing concepts for fuel-transfer options, and developing advanced monitoring and instrumentation of casks.

priorities. The Board is interested in learning more about why the delayed hydride cracking degradation mechanism was set as a medium and not a high research priority.

The Board agrees with the high priority assigned in the draft *Gap Analysis* report to developing the technical basis for taking burnup credit.[2] This crosscutting issue plays a very important role in all aspects of SNF management, including storage, transportation, and disposal.

The U.S. Nuclear Regulatory Commission and cask vendors currently depend on results from the CASTOR V/21 Dry Cask Storage Characterization Project[3] at Idaho National Laboratory for technical support in considering license extensions for dry-cask storage. The draft *Gap Analysis* report states that the CASTOR V/21 cask and fuel conditions differ in significant ways from those typical for fuel in dry storage. In particular: the fuel was loaded into the demonstration cask dry (and not in a SNF pool as is typical). Consequently, the cask did not require drying and did not have the large temperature swings that occur during vacuum drying; the retention of residual water after drying; and the loaded SNF had assembly average burnups of approximately 36 GWd/MTU, which is lower than is typical. The Board thus supports the caution stated in the draft *Gap Analysis* report that the CASTOR V/21 demonstration results may not represent the cask and fuel conditions of all the commercial fuel currently in dry-cask storage in the United States.

This situation underscores the need to carry out additional cask-demonstration and fuel-inspection projects. The Board supports the recommendation to reexamine the CASTOR V/21 cask and contents along with the REA-2023 cask system stored at Idaho National Laboratory. The Board also recommends examining other representative dry-storage cask systems or developing a cask-demonstration project where a number of representative fuel assemblies of interest (including various burnups) are placed in dry storage under typical storage conditions, followed by periodic inspection to monitor changes in the state of the fuel and the storage system's components.

The Board would like to make several related recommendations. The Board report points out the importance of characterizing SNF before dry storage to establish a baseline against which to monitor changes in fuel condition during drying and extended storage. The Board recommends that a sample of representative fuel assemblies of various burnups be characterized to the extent possible before they are loaded in different casks. The casks then should be opened and inspected periodically during the storage period at a facility capable of such inspections to identify changes from the baseline conditions.

The Board report also discusses the possibility of degradation mechanisms that interact or mechanisms that may occur simultaneously. Because coupled effects are difficult to model or fully anticipate this is another reason for opening and examining representative dry-storage systems periodically. In addition to investigating the work on storage gap analysis being done in other countries, the Board encourages DOE to collect international data on SNF that has been stored in casks or canisters and examined after periods of storage to develop a more complete

[2] Burnup credit was beyond the scope of the Board Report.
[3] After more than 14 years of dry storage, when the CASTOR V/21 cask was opened, almost no degradation of PWR fuel rods, cask, or internal cask parts was observed.

centralized database of the condition of stored SNF and storage systems. The collection of the international database might affect the research needs and priorities.

The Board notes that the draft *Gap Analysis* report identifies a degradation mechanism involving cladding oxidation that occurs during high-humidity conditions in the cask. The draft *Gap Analysis* report indicates that a high-humidity condition could be caused by insufficient drying before cask sealing, the loss of helium cover gas and subsequent replacement with humid air, or mistaken filling with humid air. Not clear from the discussion in the draft *Gap Analysis* report is which scenarios are considered likely to lead to the potential fuel-side cladding degradation in storage systems. In its report, the Board emphasizes the importance of ensuring the presence of the helium cover gas to limit degradation mechanisms and recommends the development of technologies for monitoring the presence of helium in the canisters or casks over time. Accordingly, the Board supports research by DOE to quantify the amount of residual water that remains in casks after drying and to develop and implement new monitoring instrumentation. When monitoring instruments become available, they could be installed and tested as a part of the new characterization program for dry-cask storage.

The draft *Gap Analysis* report cites a number of references to the Board report and indicates that the Board report does not discuss degradation mechanisms for several named components located within welded casks or bolted containers. Although the Board report does not specifically address these mechanisms as individually applied to specific components, it does consider them in the discussion of general categories of metal and nonmetal internal components of a dry-storage system. The Board notes and endorses the need to investigate these degradation mechanisms separately for distinct types of internal cask components as is done in the draft *Gap Analysis* report.

Finally, the Board understands that a revision of the draft *Gap Analysis* report is planned for FY 2012 that will include identification of research priorities related to transportation of SNF following extended storage. The FY 2012 revision also will include a more comprehensive evaluation of technical issues raised in gap-analysis reports issued by the NRC, EPRI, the Board, and other organizations. The Board looks forward to the opportunity to review those future revisions to the draft *Gap Analysis* report and supports DOE in identifying the research and priorities necessary to develop an improved safety case for extended dry-cask storage, retrieval, and transportation of SNF.

Sincerely,

{Signed by}

B. John Garrick
Chairman

cc:
Dr. Peter Lyons, Acting Assistant Secretary for Nuclear Energy
Dr. William Boyle, Director, Office of Used Nuclear Fuel Disposition, Research and Development

December 30, 2011

The Honorable Peter B. Lyons
Assistant Secretary for Nuclear Energy
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585-1290

Dear Dr. Lyons:

On September 13 and 14, 2011, the U.S. Nuclear Waste Technical Review Board held a public meeting in Salt Lake City, Utah. The majority of the meeting was devoted to presentations by U.S. Department of Energy (DOE) officials and technical experts from six DOE National Laboratories. Those talks provided the Board with a solid overview of the activities being funded by the Office of Used Nuclear Fuel Disposition Research and Development (NE-53).

In addition, the Board heard from an official of DOE's Office of Legacy Management (LM) and from three panels. The first panel discussed the draft *Report to the Secretary* by the Blue Ribbon Commission on America's Nuclear Future (BRC), the second described work undertaken by the Extended Storage Collaboration Program (ESCP), and the third explored some of the waste-management implications of using mixed-oxide fuel (MOX).

This letter conveys Board comments and recommendations related to work being sponsored by NE-53 within the Office of Nuclear Energy and other DOE activities discussed at the meeting.

Activities Sponsored by the Office of Used Nuclear Fuel Disposition Research and Development

Three topics were addressed by DOE officials and technical experts:

- Exploration of generic disposition options
- Studies of specific technical issues associated with developing a repository either in crystalline rock (granite) or clay/shale
- Research directed toward understanding the issues associated with extended storage and subsequent transport of spent nuclear fuel (SNF)

Generic Research on Options for the Disposition of High-Level Radioactive Waste (HLW) and SNF. Representatives from the NE-53 team, Dr. William Boyle, Dr. Peter Swift, and Dr. Mark Nutt, detailed efforts to develop that organization's strategic direction. Dr. Boyle provided an overview of his unit's administrative structure and budget, spoke about the major accomplishments to date, and set forth both short-term milestones and long-terms goals. Dr. Swift described the technical basis for selecting four disposition options that NE-53 will focus on in the near term: deep-mined geologic repositories embedded in salt, granite, and clay/shale formations as well as deep borehole disposal. He also briefly identified several areas of research and development (R&D) that

NE-53 supported during the 2011 fiscal year. Dr. Nutt described the elaborate process, grounded in systems engineering techniques, used to construct the NE-53 "Research and Development Roadmap" to identify knowledge gaps and opportunities that offer the greatest potential contribution to achieving the national goal of disposing of high-activity nuclear waste in a deep geologic repository.

The Board understands and appreciates the rationale that motivated NE-53 to undertake these planning exercises. The results reported by Dr. Swift are consistent with work being undertaken by national waste management programs abroad that has already identified salt, granite, and clay/shale as the most promising host rocks in which to place a mined deep geologic repository. Given the wealth of relevant experience that has been gained in other countries, the Board strongly urges NE-53 to strengthen its technical interactions with the organizations that are responsible for waste management programs in those countries. This might enable DOE to learn from those programs and avoid duplicating their research. DOE also may be able to share costs with other programs on future work, which could free up funds that could be reallocated to other elements of the R&D program, such as research supporting development of the technical basis for extended dry storage of SNF.

In establishing research priorities, the Board believes that when compared with mined deep geologic disposal, the development of deep borehole disposition as a potential waste management option should be given a lower priority. The Board will address issues related to geologic disposal at its meeting planned for March 7, 2012, in Albuquerque, New Mexico, and the potential for deep borehole disposal will be discussed in more detail at that time.

Dr. Nutt's explanation of the "roadmap" was clear and detailed; however, the rankings were not truly quantitatively derived. They were, as Dr. Nutt acknowledged, based essentially on qualitative expert judgments. Learning more specifically on what basis this "living document" might evolve would have been valuable.

Studies of specific scientific and technical issues. Dr. Scott Painter from Los Alamos National Laboratory presented early results on discrete fracture network modeling undertaken in collaboration with the Swedish implementer, SKB. Dr. Jens Birkholzer from Lawrence Berkeley National Laboratory discussed investigations for supporting disposal of HLW and SNF in clay or shale host rocks. He focused on a key technical issue: the evolution of the thermal-hydraulic-mechanical-chemical disturbed zone surrounding the waste package following emplacement. He also described the possibility of validating the results of these studies against field data from studies that might be conducted in Switzerland or Belgium. The Board believes that both these efforts represent cutting-edge R&D. Moreover, both areas of work underscore the Board's view that NE-53 should intensify its technical interactions with other national programs.

Extended storage and subsequent transportation of spent nuclear fuel. Dr. Brady Hanson from Pacific Northwest National Laboratory presented the results of DOE's analysis of knowledge gaps related to extended storage of SNF from the current US fleet of light-water reactors before transportation to a centralized storage or reprocessing facility or a repository site. The Board's comments on this analysis, together with observations and recommendations concerning the R&D program that DOE proposes to support a program of extended dry storage, are recorded in the Board's December 8, 2011, letter to Dr. Monica Regalbuto concerning DOE's draft gap analysis report.[1]

[1] *Gap Analysis to Support Extended Storage of Used Nuclear Fuel*, prepared by National Laboratory staff for the Used Fuel Disposition Campaign of the U.S. Department of Energy (DOE) Office of Nuclear Energy, June 30, 2011.

Mr. Paul McConnell from Sandia National Laboratories discussed the R&D priorities identified in the draft gap analysis report as being required in the near term, medium term, and very long term to support transportation of SNF following extended storage. He also identified the lead National Laboratories for the main program components. Dr. John Wagner from Oak Ridge National Laboratory outlined the engineering analysis required to support extended storage and subsequent transportation of SNF, including an integrated approach to addressing safety issues.

Our December 8 letter to Dr. Regalbuto notes that the Board's report[2] on extended storage of SNF identifies R&D requirements similar to those included in DOE's draft gap analysis report. However, the Board believes that there are other issues associated with extended storage of SNF that also should be addressed by DOE in developing an integrated approach to the management of SNF under the Nuclear Waste Policy Act. Three such issues are described below.

- The potential for operations being undertaken today that limit future options in managing SNF and HLW. One example of this is the continued use of a wide range of SNF container designs for dry-storage systems. As was the case in the design of the fuel-handling facilities for the Yucca Mountain repository, the lack of a standardized container design, or at most a small range of designs, can result in additional complexity at later stages of the waste management system.
- The dose and cost implications of the need to repackage SNF. An initial assessment by the Board indicates that there necessarily would be a significant additional dose to operators from the need to repackage fuel after storage and before repository disposal. Reducing the need to repackage SNF before disposal would unquestionably reduce the dose to plant operations staff. Estimating the dollar cost of repackaging is beyond the Board's mandate, but an appropriate observation is that there inevitably are significant costs associated with repackaging SNF, and to the extent this can be avoided those costs can be reduced.
- The implications of a requirement for early removal of SNF from reactor storage pools, in response to the events at the Fukushima site in Japan in March 2011. The Board believes that a careful review of the implications of such a change for the nation's long-term SNF management system should be undertaken. Among the factors that should be considered are the current trend toward larger dry-storage containers and higher fuel burnups that will require longer onsite storage before transportation to a reprocessing or disposal facility and the practicality of establishing the industrial capacity needed to manufacture the large number of additional dry-storage systems that would be required. The Board estimates that moving all SNF that has been discharged for more than 10 years into dry storage, for example by 2020, would require a significant increase in fabrication capacity for dry-storage systems. Once the backlog has been dealt with, however, demand would fall again to a level that matches the actual rate of discharge of SNF. It may be difficult for vendors to respond to this relatively short-term increase in demand, both in terms of the fabrication requirements and in managing the accompanying increase and decrease in the size of the production workforce, the training requirements, and an increase in the need for quality assurance staff. As mentioned above, estimating the dollar cost is beyond the Board's mandate, but an appropriate observation is that there would inevitably be significant cost implications from the need for vendors to recover over a period of only 10 years the capital investment for establishing increased production capacity.

[2] *Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel – Executive Summary*, U.S. Nuclear Waste Technical Review Board, December 2010.

Office of Legacy Management's Preservation of the Documents from the Yucca Mountain Project

> In its May 24, 2010, response to the Yucca Mountain licensing board, DOE stated that [It] had contacted the Nuclear Waste Technical Review Board about the NWTRB's interest in providing independent oversight of DOE's actions in preserving the scientific information that has been developed by OCRWM [Office of Civilian Radioactive Waste Management]. The NWTRB could thus review the planned disposition of the relevant scientific information before its disposition in accordance with National Archives and Records Administration approved schedules. NWTRB has expressed interest in such an arrangement, and DOE and NWTRB will discuss how such oversight could be accomplished.[3]

Those discussions have been ongoing for more than a year as OCRWM documents have been transferred from Las Vegas, Nevada, to Morgantown, West Virginia, for preservation. Mr. John Montgomery, Site Manager of the Legacy Management Business Center, and his staff lead, Mr. Edwin Parks, briefed the Board on the status of their efforts. Members of the Board staff intend to visit Morgantown in the coming months to carry out a high-level observation of LM's activities and, subsequently, to issue at least one report containing findings and recommendations.

Panel on the Draft *Report to the Secretary* by the Blue Ribbon Commission on America's Nuclear Future

The Board invited Mr. John Kotek, Executive Director of the BRC, to summarize the major conclusions and recommendations in the draft *Report*. They included the following:

- A new approach to siting and repository development
- A new, single-purpose organization with the responsibility for transporting, storing, and disposing of HLW and SNF
- Changes in the way funds from the Nuclear Waste Fund are appropriated so that management of the program is not affected by limited access to funding
- Expeditious development of a deep geological repository for HLW and SNF
- Expeditious development of a centralized interim storage facility

In addition, the Board asked Mr. Ward Sproat, former Director of OCRWM, to reflect upon those key conclusions and recommendations. Mr. Sproat noted that the process used by the BRC was thorough, the draft *Report* generally addressed the major issues, and a number of the recommendations were specific and appropriate. He did observe, however, that the draft *Report* ignored some lessons learned from the Yucca Mountain experience as well as important political realities associated with the siting process. At the end of his presentation, Mr. Sproat urged the BRC to recommend that the Yucca Mountain licensing process be completed and to provide more-specific guidance on how to structure efforts for identifying candidate locations for a repository or a centralized interim storage facility.

[3] *U.S. Department of Energy Answers to ASLB Questions from Order Dated April 21, 2010*, May 24, 2010, pg. 37. In *House Report 112-118, Energy and Water Development Appropriations Bill, 2012*, the Board was directed to "provide support to the Department of Energy … to archive and preserve all Yucca Mountain-related documents and physical materials of scientific value."

The Board subsequently provided the BRC with comments on the draft *Report*. The Board's comments are available on the Board's Web site, www.nwtrb.gov.

Extended Storage Collaboration Program

Because of the uncertainty surrounding the future of the Yucca Mountain Project, SNF is now likely to remain in storage for a longer time than previously anticipated. Several groups, including the Board, have begun to explore the implications of this situation. (As mentioned above, the Board released a report, *Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel,* in late 2010.)

The Electric Power Research Institute (EPRI) has organized an international effort, Extended Storage Collaboration Program (ESCP), to establish the technical bases for continued safe, long-term SNF storage and future transport. The Board is, along with DOE, the Nuclear Regulatory Commission (NRC), the Nuclear Energy Institute, nuclear utilities in the United States and abroad, and nuclear vendors, closely following the work of this collaboration, whose objectives include:

- Reviewing current technical bases and conducting gap analyses for SNF storage and transportation systems
- Conducting experiments, field studies, and additional analyses to address gaps
- Coordinating research that results in a program documenting the performance of a dry-storage system loaded with high-burnup (greater than 45 GWd/MTU) fuel.

During the panel discussion on these issues, Dr. John Kessler from EPRI observed that there appears to be an emerging consensus that more attention needs to be focused on corrosion of the stainless steel canister, especially in marine environments, on the bolted-cask metallic seals, and on delayed hydride cracking of the cladding. Mr. Adam Levin from Exelon Generation Company stated that the demands for R&D could be simplified significantly if changes were made to the established regulatory framework so that the storage canister is considered the waste form for storage, transportation, and disposal rather than just for storage. He also noted that there would be significant benefit from taking full credit for burn-up and encouraged that this be pursued. Finally, Dr. James Rubenstone from the NRC described two on-going activities: (1) establishing a firm technical basis for regulations related to extended storage of SNF and (2) providing support for a potential extension of the waste-confidence decision to more than 60 years beyond the life of a commercial nuclear reactor. Although these activities are complementary, they are not identical.

The Board believes that ESCP is an extremely valuable undertaking and strongly endorses DOE's continued active participation in the collaboration. As noted above, the Board recommends that DOE provide adequate resources to support ESCP's objectives. In that regard, the Board understands that with the decommissioning of the Test Area North Hot Cell at Idaho National Laboratory, opportunities for conducting potentially important investigations on SNF at a National Laboratory may have been foreclosed. If this is so, the Board urges DOE to evaluate other options that might allow those experiments to be conducted.

Implications for Waste Management of Using MOX

Over the last few years, increased attention has been paid to the possibility that the United States might adopt a closed fuel cycle involving reprocessing of light-water reactor SNF and recycling the extracted plutonium in the form of MOX fuel assemblies and perhaps recycling the reprocessed uranium as well. DOE originally investigated this possibility as part of its now-defunct

Global Nuclear Energy Partnership. DOE's Office of Fuel Cycle Technologies continues some of the same work today. To understand better the waste-management implications of using MOX, the Board invited three practitioners to report on lessons learned by their organizations.

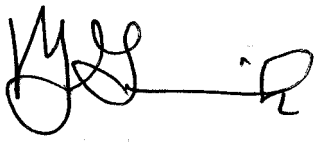
Mr. Daniel Stout from the Tennessee Valley Authority described the process that his utility is employing to determine the implications of using MOX fabricated surplus-weapons plutonium at one or more of its reactors. He noted that the decay heat of a spent MOX fuel assembly would be between 1.3 and 1.7 times higher than that for an equivalent spent-uranium fuel assembly. Consequently, the used MOX would need to be kept in dry cask storage for an additional 56 years to have the same thermal impact on a repository at the time of emplacement. For certain repository designs, that difference could be consequential.

Mr. Patrice Fortier from Transnuclear International, a division of AREVA, indicated that casks have been approved in France for transport of spent MOX and for HLW generated during commercial reprocessing of SNF.

The most detailed technical discussion was provided by Dr. Wolfgang Faber from the German utility EON, which operates eight reactors that have burned MOX. He noted that the use of MOX complicates the on-site management of both unirradiated and irradiated fuel, in part because of the increased security burdens. MOX fuel also requires longer post-discharge cooling time before removal from the spent-fuel pool, and there are other difficulties associated with the intermediate storage period after discharge. In investigating the potential consequences for U.S. utilities of introducing reprocessing and recycling of plutonium and possibly uranium, the Board recommends that DOE take account of the full range of implications for utilities and not just the perceived value of extracting the energy remaining in the spent fuel.

The Board appreciates the effort that NE-53 made to prepare lucid and candid presentations for the September meeting, and we look forward to continued interactions with DOE in future. We would be pleased to meet with you to discuss any of the issues raised in this letter.

Sincerely,



B. John Garrick
Chairman

January 6, 2012

Dr. Monica Regalbuto
Deputy Assistant Secretary, Fuel Cycle Technologies
Office of Nuclear Energy
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585-0620

Dear Dr. Regalbuto:

On behalf of the U.S. Nuclear Waste Technical Review Board, I am pleased to respond to your request to the Board for comments on *A Management Proposal for Salt Disposal Investigations with a Field Scale Heater Test at WIPP* (SDI proposal), which was prepared by the U.S. Department of Energy (DOE) Carlsbad Field Office and issued in June 2011.

As you know, Dr. Mark Nutt recently presented to the Board[1] a rationale for using features, events, and processes (FEPs) to identify research and development (R&D) issues that are linked to a generic safety assessment, and setting R&D priorities based on the importance of the issues to the generic safety case. The Board supports such "generic" R&D tasks in the context of geologic repository program development, as long as they: (1) are based on realistic concepts of host rock geology, (2) identify and evaluate significant FEPs and constitutive relationships, and (3) can be demonstrated to reduce uncertainties and adverse risk related to technical and scientific generic repository objectives.

The SDI proposal cites an approach similar to one presented by Dr. Nutt for evaluating knowledge gaps and data needs, and setting R&D priorities to support development of a generic repository safety case:

> *The core concept is the systematic reduction of uncertainty in models through the iterative process of model development, experimental studies, and repository modeling to assess geologic disposal viability… Therefore, residual uncertainties propagated through a generic model of a repository must be quantified, bringing in other relevant considerations and processes (e.g., scenario development, regulatory criteria, subsystem models) in order to fully define a Performance Assessment analysis. These results, vetted at regular intervals with stakeholders, are used to inform modification of the science program*[2]*…*

However, the Board notes that the SDI proposal does not adhere to such an approach, nor does it specify the basis for the proposed work. Instead the proposal identifies gaps in experimental work and modeling and proposes R&D activities that do not appear to be ranked by their importance in meeting generic repository objectives. The Board believes that not presenting an explicit evaluation

[1] Mark Nutt, "Used Fuel Disposition Campaign Disposal R&D Roadmap Overview," NWTRB Fall 2011 Board Meeting, Salt Lake City, Utah, September 13, 2011.
[2] SDI proposal, p. 13.

of generic salt information needs in the context of a relevant uncertainty and risk assessment is a significant shortcoming of the proposal. Two additional specific comments on the content of the proposal are discussed in the following paragraphs.

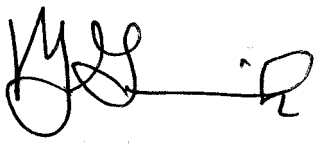
First, it is difficult to assess the importance of work in salt relative to other possible host rocks without knowing the basis for the selection of salt. Field tests are expensive, and a decision to proceed hastily with salt R&D might constrain resources for equally important, or more important, work in other geologic media. The Board cannot make a proper evaluation of the proposed work without knowing what alternatives are under consideration.

Second, the proposal includes references to salt formations and salt domes, but it is unclear whether the proposed tests at WIPP are intended to investigate the suitability of generic salt as a medium for disposing of heat-generating radioactive waste or if the tests are focusing only on the potential of bedded salt for such a purpose. In either case, the Board suggests that the proposal also should provide the technical basis for performing the proposed testing at WIPP.

The comments above raise questions about whether decision-makers have sufficient information to make the necessary decisions concerning prioritization of work related to R&D on salt. The presentation of the SDI proposal makes it appear to be essentially a qualitative list of information needs along with the proposed laboratory, field, and modeling tasks identified to supply the information. How important the individual tasks are to the engineering and science objectives is not addressed, and whether the work as proposed fits the stated objective of the SDI proposal to be "as productive, integrated, and efficient as can be achieved"[3] is unclear.

As you know, the Board is planning a trip to WIPP on March 6, 2012, in conjunction with our public meeting in Albuquerque, New Mexico, on March 7, 2012. If you would find it useful, we could use that opportunity to arrange a discussion of the SDI proposal with staff from your office and the DOE Carlsbad Field Office. As you also know, the public meeting is focused on geological disposal, so a discussion at that time may be particularly appropriate.

Sincerely,



B. John Garrick
Chairman

cc:
Dr. Peter Lyons, Assistant Secretary for Nuclear Energy
Dr. William Boyle, Director, Office of Used Nuclear Fuel Disposition, Research and Development
Mr. Jeff Williams, Deputy Director, Office of Used Nuclear Fuel Disposition, Research and Development

[3] SDI proposal, p. (v)

March 28, 2012

The Honorable Peter Lyons
Assistant Secretary for Nuclear Energy
Office of Nuclear Energy/NE-1
U.S. Department of Energy
1000 Independence Avenue, SW
Washington DC 20585

Dear Dr. Lyons:

It was a pleasure to have you participate in the Board's January 9, 2012, meeting held in Arlington Virginia. Among the issues discussed at that meeting was integration within the Department of Energy's Office of Nuclear Energy (DOE-NE), including the Office of Fuel Cycle Technologies. I am writing to provide the Board's feedback on those discussions and on information presented by you and your staff. This letter also contains Board comments on deep borehole disposal based on information presented by representatives of DOE-NE and Sandia National Laboratories at the Board meeting held in Albuquerque, New Mexico on March 7, 2012.

The Board found informative your discussion of the mission of your Office and your candid response to questions at the January meeting. Clearly the focus of DOE-NE continues to be the development of reactor and fuel-cycle technologies. However, the transfer to DOE-NE of many of DOE's responsibilities under the Nuclear Waste Policy Act provides real opportunities for integrating DOE work across the nuclear fuel-cycle. Even though this arrangement may eventually change as a result of, among other things, the recommendations of the Blue Ribbon Commission on America's Nuclear Future (BRC), the Board recommends that DOE-NE place a particular emphasis on integration, both within its own programs and with other DOE programs that will have an impact on the management of spent nuclear fuel and high-level radioactive waste in the United States.

Fuel Cycle Integration and Evaluation

The technical and institutional complexities of integrating activities throughout current as well as possible future nuclear fuel cycles were well illustrated in Deputy Assistant Secretary Dr. Monica Regalbuto's presentation. For example, the mix of public organizations and private sector firms that may be responsible for various elements of the fuel cycle presents challenges for effectively integrating the entire enterprise that are less daunting in countries such as France and Sweden.

Consequently, the Board strongly encourages DOE to engage the nuclear utilities regularly and fully as it maps out approaches for managing the backend of the fuel cycle as currently configured and as it investigates and considers other potential strategies for managing the backend of the nuclear fuel cycle. The importance of this engagement was reinforced in talks by Dr. Roald Wigeland, Mr. Jeffrey Williams, and Dr. Ernest Hardin. Each of these speakers described strong interdependencies among various elements of the nuclear fuel cycle and the need to ensure that the "pieces" fit together well. Dr. Wigeland detailed the early stages of a comprehensive fuel-cycle evaluation project that is not expected to be completed for more than two years. Because of the study's current status and the time constraints imposed by the meeting schedule, this talk could not address many key issues that are necessary to evaluate the study's technical validity. These include (1) criteria used to determine whether a fuel cycle is "promising;" (2) metrics developed to operationalize the criteria; and (3) trade-offs made among outcomes, some of which will inevitably conflict.

Based on information published by DOE-NE[1] as well as other documents the Board has reviewed, the Board offers the following words of caution.[2]

- *There seems to be a risk that comprehensiveness will be purchased at the price of relevance*. Many potential nuclear fuel cycles are conceivable in the abstract, but few seem to have been developed to the extent that their attributes can be evaluated effectively, and even fewer appear to have the potential to be deployed at commercial scale in the next 50 or so years. Although the study concluded that approximately 25 percent of the initial number of groupings were not promising and thus could be eliminated from further consideration, the Board believes that opportunities exist for additional reductions without serious risk of losing options that offer significant benefits in comparison with the ones retained.
- *Simplifying the analysis would have the added benefit of increasing the timeliness of its results*. This could be particularly useful to DOE-NE in preparing the administration's response to the recommendations of the BRC.
- *The methodological challenges to carrying out this type of evaluation are significant*. Developing appropriate metrics for some of the evaluation criteria, such as proliferation risk, institutional issues, and even waste management considerations, raises serious measurement and conceptual issues. These challenges should carefully be considered by DOE-NE as it moves forward with this analysis. In addition, the metrics that are developed and how they are traded off should be exposed to broad stakeholder review.
- *Only a very abbreviated description of the study is available publicly*. Because the conclusions developed from this work are dependent to a great extent on the evaluation criteria adopted, early publication of these criteria and exchanges with interested and affected parties would be valuable.

[1] "A Screening Method for Guiding R&D Decisions: Pilot Applications to Nuclear Fuel Cycle Options," Department of Energy, Office of Nuclear Energy, August, 2011.
[2] These are broadly consistent with the comments presented at the June 15, 2011, meeting of the Nuclear Energy Advisory Committee and those prepared by the study's internal peer review group.

- *The conclusions of this study should not be pushed beyond what can reasonably and conservatively be inferred.* The results of this study should be used as one of many decision-aiding tools and inputs as DOE-NE makes investments in fuel cycle research and development.

Effects of Waste Package Sizes

The paired presentations by Mr. Williams and Dr. Hardin on waste package sizes and repository thermal analysis, respectively, conveyed an essential message: Decisions about waste packaging and storage that have been or are being taken may have a profound effect on repository design. For, example, disposing of the large waste packages currently being loaded by utilities may require substantial operational and engineering interventions[3] to avoid exceeding repository temperature limits, especially in a geologic repository constructed in clay/shale or crystalline rock formations.

As we heard at the meeting, the prospect of having to repackage spent nuclear fuel is not a welcome one, especially if the repackaging has to be carried out at reactor sites. The Board believes that DOE should consider the existing and expected inventory of spent nuclear fuel in storage as a waste form that needs to be accommodated in a geological repository. By doing so, the costs and risks associated with repackaging a substantial amount of spent nuclear fuel could be avoided.

Work to Prepare for Geologic Disposal

As you know, the Board, along with most other commenters, strongly concurs with the finding by the BRC that deep geological disposal is the most promising and accepted method currently available for safely isolating high-level radioactive waste and spent nuclear fuel. Because of this strong consensus, the Board believes that work on the following activities can and should begin without delay.

- Generic repository site-selection criteria are clearly needed. As a starting point for this work, it is very important that DOE-NE take into account past efforts to specify siting criteria in this country and abroad. The Board is considering publishing its own survey of past siting initiatives worldwide later this year.
- Regardless of what geological formation will host this country's repository, it remains essential that there is a realistic understanding of the radiation source term, particularly with respect to the processes involved in mobilizing the waste. Such fundamental understanding is a prerequisite for evaluating the effects of the release of dose-contributing radionuclides.
- Because of the prospect that spent nuclear fuel will remain in storage for extended periods, fuel-degradation mechanisms, especially for high-burnup fuel, need to be better understood, both with respect to the requirement for transportation from reactor sites and as input to analysis of the radiation source term.

[3] These might include extended cooling at the surface, greater spacing between packages in the repository, and selection of a mix of hotter and cooler fuel assemblies for loading into containers for repository disposal.

DOE Activities Related to Deep Borehole Disposal

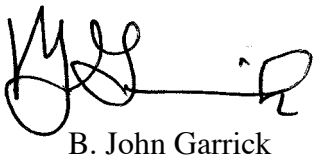
At the Board's March 7 meeting in Albuquerque, Dr. Bill Arnold of SNL and Dr. Steven Ingebritsen of the United States Geological Service participated in a panel on deep borehole disposal. This was a most interesting panel and resulted in considerable discussion within the Board.

The Board has recommended in recent reports and correspondence that consideration be given to using different methods of geologic disposal for different high-activity wastes, depending on the potential for reuse of materials that can be recovered from the waste. For example, deep borehole disposal could prove to be a suitable option for disposing of long-lived minor actinides or vitrified fission products, which have no apparent reuse value. The Board understands, however, that there may be significant complications in using deep borehole disposal for other wastes. For example, current technology for borehole construction would require spent fuel to be repackaged into smaller diameter containers to fit the borehole and this increased handling of spent fuel would be, at best, highly undesirable.

In the Board's view, research related to deep borehole disposal should not delay higher priority research on a mined geologic repository. However, if that condition can be met, the Board believes that DOE should continue its research on deep borehole disposal. This should include an analysis of the real costs of activities associated with deep borehole disposal, including a realistic assessment of the site-characterization effort that would be needed and an accounting of potential additional exposures to workers from the increased fuel handling that would be required to consolidate and repackage fuel rods. This information would provide a realistic basis for comparison with other geologic disposal options.

Once again, I would like to record the Board's appreciation for the participation of DOE-NE and SNL staff at the Board's meetings in January and March.

Sincerely



B. John Garrick
Chairman

December 11, 2012

Dr. Peter Lyons
Assistant Secretary for Nuclear Energy
Office of Nuclear Energy
U.S. Department of Energy
1000 Independence Avenue SW
Washington DC 20510

Dear Dr. Lyons:

On behalf of the U.S. Nuclear Waste Technical Review Board, I want to express its appreciation for your Office's outstanding support of the Board's meeting in Idaho Falls, Idaho on October 16-17, 2012.

Members' comments on the site visit to the Idaho National Laboratory were uniformly positive. They were pleased with the presentations and with the efforts that were made to prepare informative "poster talks" on research currently being conducted on, among other things, the physical properties of spent nuclear fuel (SNF). Moreover, notwithstanding the inclement weather, the tours of the various facilities provided opportunities to understand the scope of analytic and computational research activities being carried out at the laboratory. The participation by your team in the public meeting was equally valuable. The willingness of Dr. Monica Regalbuto to answer questions candidly and to interact informally with members of the Board and public throughout the meeting was especially appreciated.

As you may have learned, the meeting began with a valuable free-flowing discussion among Jim Williams, from the Western Interstate Energy Board, Earl Easton, from the NRC, and Jeff Williams from your Office. The discussion focused on how State Regional Groups could play important roles in working with the Department of Energy when substantial shipping campaigns of high-level radioactive waste (HLW) and SNF begin. The Board strongly recommends that your Office continue and strengthen its interactions with those groups.

As is its usual practice, in the following paragraphs, the Board provides its feedback on the information presented at the public meeting by members of your staff.

Transportation, Storage, and Disposal System Analyses

As indicated by several comments from the public at the meeting, transportation of HLW and SNF remains a major concern. It is by no means clear to those individuals that transporting this material, especially to a consolidated storage facility, will actually reduce risks. The Board

notes below that DOE needs to remain sensitive to this concern and address it in a candid and transparent fashion.

Dr. Mark Nutt discussed ongoing work to develop an integrated system architecture for managing commercial SNF from acceptance at reactor sites to disposal in a geologic repository. Such an architecture would recognize the realities of the current situation in which the disposition pathway for the widely used dual-purpose canisters is highly uncertain and where interest in standardized canisters is growing.

In the Board's view, the modeling results presented appear to be rudimentary accounting calculations that as yet do not yield particularly deep insights. Uncertainties in material flows do not seem to be represented. In addition, potential upsets in the flows are not incorporated into the modeling. The possibility of developing multiple sites, either for consolidated storage facilities or for the final repository, also is excluded from the architecture. The Board expects that these issues will be addressed as the system analyses mature.

Mr. Jeffrey Williams explained the circumstances surrounding stranded SNF at shutdown reactor sites. The information he presented has been available for many years. Providing photographs and "Google Earth" images of the each site, however, highlighted and made clearer the context and details of the geography adjacent to the facilities. The Board will be interested to hear more on this work as it progresses and will invite presentations on results at future meetings.

Mr. Williams described options for transporting the material once DOE accepts it for disposal, although he did not explain how challenges would be overcome to ready the fuel, which is today largely held in storage-only casks, for shipping. Those challenges include, but are not limited to, ensuring that the shortline rail spurs leading to some sites have been upgraded and, where necessary, loading the SNF into casks that have been certified for transportation. There also is some question about whether even the SNF currently stored in dual-purpose casks will need to be repackaged prior to shipment. One of the figures in Mr. Williams' presentation indicated that all of the transportation licenses for those casks will expire by May 2014 and that several transportation casks have not been fabricated at this time. These will be needed eventually. Although transportation cask *licensing* is not DOE's responsibility, the Board urges DOE to put a high priority on developing a comprehensive plan for ensuring that cask licenses and the yet-to-be-fabricated casks will be available to support DOE's transportation requirements and schedule.

Finally, an important issue of system integration was raised by the Board at the meeting. Many of the dry storage system designs presently in use contain material that may not meet the current criticality-control requirements for disposal. This situation raises the possibility that these storage systems may have to be opened and the fuel assemblies transferred into containers that conform to criticality-control regulations for disposal. The Board recommends that DOE evaluate the disposal criticality control of the dry storage systems presently being loaded.

Evaluations of Canister and Waste-Package Temperatures

Dr. Harold Adkins and Dr. Ernest Hardin made related presentations. Dr. Atkins' talk included an analysis of the thermal evolution of waste packages placed into dry storage. He developed a model for how the fuel cladding temperature would change over time and benchmarked it against data from SNF stored at the Calvert Cliffs Nuclear Power Station. Dr. Hardin, following up on his presentation to the Board in January, 2012, explored disposal conditions in "open" generic geologic repositories, where the emplacement media was salt, clay, and granite. In an open repository, there is an opportunity to ventilate the drifts (tunnels) containing the waste packages to remove some of their heat prior to repository closure. By removing some of the heat, larger sized packages could be disposed, especially if the thermal constraints are loosened.

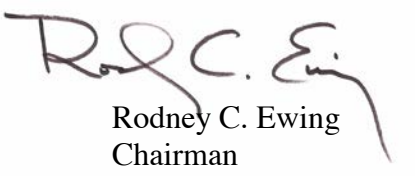
Both these presentations were technically refined and valuable. Together they suggest that there may be more flexibility in terms of waste-package size than had previously been presumed. The Board believes that this work should be continued. In particular, the two research strands should be coupled to provide temperature predictions of SNF cladding in a waste package that has been emplaced in a drift. Understanding such thermal evolutions could be important, if, for example, a package had to be retrieved.

The Importance of DOE Fully Engaging Stakeholders and Being Clear and Transparent

The Board was pleased to see mention made of communication issues in the presentation by Monica Regalbuto. The consent-based approach recommended by the Blue Ribbon Commission will require effective communication. In place of top-down models of communication that were common in the past, the Board believes that future efforts would benefit from an iterative, collaborative model that fully engages and involves stakeholders from start to finish. Having broad, meaningful stakeholder input throughout the process ensures that informational materials and communication products are informed by, and responsive to, the concerns and information needs of the public. In developing a plan to engage stakeholders early on, the Board urges DOE to draw upon the extensive body of literature on risk communication (particularly recent work on radiation risk communication) as well as important exemplars from successful health and environmental risk communication programs. By doing so, DOE would be able to ensure that its efforts are consistent with a consent-based approach, clear and transparent, and have a sound technical basis.

Once again, I would like to thank your team for its support of the Board's meeting. In the Board's view, it was a productive and, hopefully, a mutually beneficial gathering.

Sincerely,



Rodney C. Ewing
Chairman

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