U.S. NUCLEAR WASTE
TECHNICAL REVIEW BOARD

Report to
The U.S. Congress
And
The Secretary of Energy

January 1, 2003, to December 31, 2003

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UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201–3367

May 2004

The Honorable J. Dennis Hastert
Speaker of the House
United States House of Representatives
Washington, DC 20515

The Honorable Ted Stevens
President Pro Tempore
United States Senate
Washington, DC 20510

The Honorable E. Spencer Abraham
Secretary
U.S. Department of Energy
Washington, DC 20585

Dear Speaker Hastert, Senator Stevens, and Secretary Abraham:

The Nuclear Waste Technical Review Board submits this *Report to The U.S. Congress and The Secretary of Energy* in accordance with provisions of the Nuclear Waste Policy Amendments Act of 1987, Public Law 100-203, which requires the Board to report its findings and recommendations to Congress and the Secretary of Energy at least two times each year.

Congress created the Board to evaluate the technical and scientific validity of activities undertaken by the Secretary of Energy related to implementing the Nuclear Waste Policy Act (NWPA) of 1982. 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 of the technical and scientific validity of the U.S. Department of Energy (DOE) activities related to the disposal, packaging, and transportation of spent nuclear fuel and high-level radioactive waste. The Board held meetings and commented to the DOE on a range of technical and scientific issues, including seismicity, DOE plans for transporting the waste, the design and operation of facilities at the proposed repository site, performance- confirmation activities, and the potential for localized corrosion of waste packages during the period of high temperatures after repository closure. Correspondence and related materials from the Board to the DOE on these and other issues are included in the appendices to the report. Also included in the appendices are the Board's

strategic plan for fiscal years 2004-2009, its performance plans for 2004 and 2005, and its performance evaluation for 2003.

The Board believes that information in the Board's report will be useful as important decisions are made on managing the nation's spent nuclear fuel and high-level radioactive waste.

We thank you for this opportunity to present the Board's views.

Sincerely,

David J. Duquette
Executive Committee Chairman

NUCLEAR WASTE TECHNICAL REVIEW BOARD 2003

[1] Resigned effective January 12, 2004
[2] Resigned effective January 17, 2003

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Executive Summary

In 1987, the U.S. Nuclear Waste Technical Review Board (Board) was created as an independent federal agency by Congress in the Nuclear Waste Policy Amendments Act. The Board was charged with evaluating the technical and scientific validity of the U.S. Department of Energy's (DOE) efforts to develop a system for disposing of high-level radioactive waste and spent nuclear fuel. The Board is required to report its findings and recommendations to Congress and the Secretary of Energy at least twice a year. This document describes activities undertaken by the Board from January 1 through December 31, 2003.

In the year following Congress's approval of the Yucca Mountain, Nevada, site for development of a repository, the major focus of the Board's activity was its evaluation of the DOE's analysis of how corrosion-resistant its Alloy 22 waste package was likely to be. The Board devoted one full meeting and parts of two others to exploring this question. The Board wrote two letters to the DOE communicating its findings and recommendations. The Board also prepared a detailed 18-page technical analysis to support its conclusions.

In its October 21, 2003, letter to the DOE, the Board raised concerns about the performance of the waste package if it is subjected to conditions that are likely to arise if the DOE implements its current high-temperature repository design. In particular, the Board made the following observations.

- Localized corrosion processes are particularly insidious because initiation is difficult to predict and propagation rates can be very rapid. Data emerging both from the DOE's Yucca Mountain Project and from the Nuclear Regulatory Commission's Center for Nuclear Waste Regulatory Analyses (CNWRA) suggest to the Board that crevice corrosion of Alloy 22 is likely to begin during the thermal pulse (the first thousand years after repository closure).

- Project data show that initiation of crevice corrosion during the thermal pulse is likely in concentrated brines (with or without nitrates) formed through deliquescence processes at temperatures well below the peak temperatures on the waste package surface expected in the DOE's proposed repository design.

- Crevice corrosion, a form of localized corrosion, initiated during the thermal pulse is likely to propagate during the remainder of the thermal pulse and also is likely to continue even after the thermal pulse has passed.

- Work at the CNWRA and elsewhere indicates to the Board that welds and thermal treatment (aging) increase susceptibility to crevice corrosion. The DOE's modified waste package design has both welded areas (i.e., closure welds) and many features that offer opportunities for crevice formation. Redesign studies for reducing or eliminating areas of increased susceptibility to localized corrosion may be a worthwhile option.

- Most generalized corrosion data reported to date are for surface temperatures on the waste package of 95°C or lower. These data may constitute an adequate technical basis if the surface temperatures of the waste packages in the repository never exceed 95°C. Few data exist, however, for the higher temperatures of the thermal pulse.

- Because of the seriousness of these corrosion concerns, the Board strongly urges the DOE to reexamine the current repository design and proposed operation. The Board believes that the high temperatures of the current design and operation will result in perforation of the waste packages, with possible release of radionuclides. The data currently available to the Board indicate that perforation is unlikely if waste package surface temperatures are kept below 95°C.

- Finally, the Board believes that total system performance assessment should not be used to dismiss these corrosion concerns.

In its November 25, 2003, letter to the DOE, the Board stated that, based on its review of data gathered by the DOE and the CNWRA, all the conditions necessary to initiate localized corrosion of the waste packages likely will be present during the thermal pulse because of the deliquescence of salts on waste package surfaces, and thus the initiation of deliquescence-induced localized corrosion will be likely during the thermal pulse. In particular, corrosion experiments indicate that localized corrosion is likely to be initiated if temperatures on the waste package surface are above 140°C and if concentrated brines, such as would be formed by the deliquescence of calcium and magnesium chloride, are present. Limited data examined to date indicate that dust, which would be present in the proposed tunnels and which would be deposited on waste packages, contains calcium chloride and magnesium chloride salts in amounts sufficient for the development of concentrated brines through deliquescence. The letter concluded, "Thus, the Board believes that under conditions associated with the DOE's current high-temperature repository design, widespread corrosion of the waste packages is likely to be initiated during the thermal pulse. Once started, such corrosion is likely to propagate rapidly even after conditions necessary for initiation are no longer present. The result would be perforation caused by localized corrosion of the waste packages, with possible release of radionuclides."

In addition to its evaluation of the DOE's analysis of how corrosion-resistant its Alloy 22 waste package was likely to be, the Board evaluated and communicated to the DOE its findings and recommendations on several other issues. They included the DOE's efforts to increase confidence in its estimates of repository performance, the DOE's plans for developing a system to transport high-level waste and spent nuclear fuel from sites where those materials are currently stored to Yucca Mountain, the DOE's analysis of seismicity issues associated with repository design, and the DOE's projections of the consequences for waste isolation and containment of igneous activity at Yucca Mountain.

Board Activities

The U.S. Nuclear Waste Technical Review Board (Board) was established by Congress in the Nuclear Waste Policy Amendments Act (NWPAA) (U.S. Congress 1987). The Act requires the Board to evaluate the technical and scientific validity of the work undertaken by the U.S. Department of Energy (DOE) to develop a geologic repository system for disposing of high-level radioactive waste (HLW) and spent nuclear fuel (SNF) produced by the nation's nuclear defense complex and commercial nuclear power plants.

Between January 1, 2003, and December 31, 2003, the period covered by this report, the Board focused most of its attention on the DOE's analysis of how the waste packages might perform if they were emplaced in the proposed repository at Yucca Mountain, Nevada. In addition, the Board evaluated several DOE activities designed to increase confidence in projections of long-term repository performance. The Board also reviewed the DOE's plans for developing a transportation system that might be used to move waste to Yucca Mountain. Finally, the Board examined the DOE's analysis of issues related to earthquakes and volcanic activity.

I. Background

On July 23, 2002, President George W. Bush signed House Joint Resolution 87 (U.S. Congress 2002), formally certifying Yucca Mountain as the presumptive site for the nation's first HLW and SNF repository and authorizing the DOE to file an application with the U.S. Nuclear Regulatory Commission (NRC) for permission to construct the facility. During 2003, the DOE accelerated its efforts to prepare a license application, stepped up its work to design the surface and subsurface repository structures, and initiated efforts to create a system to transport waste from sites where it is currently stored to the proposed repository. Although the DOE's repository program entered a new phase, the Board's role remained unaltered. It continued its ongoing technical evaluation of the DOE's activities to implement the Nuclear Waste Policy Act as amended.

II. Findings and Recommendations

A. The Board's Evaluation of the Potential for Waste Package Corrosion

In its first report released in March, 1990 (NWTRB 1990) and in almost every subsequent report, the Board has raised questions about the thermal strategy that the DOE proposes to adopt for a repository at Yucca Mountain. In the early years, the Board's questions focused on the technical uncertainties that would accompany high repository temperatures, particularly temperatures above boiling.[1] Many of those uncertainties remain. For example, how might heat above boiling temperatures affect movement of water vapor in the unsaturated-zone rock where the proposed repository would be built?

[1] As will be discussed in Section III B below, this issue has arisen in other countries as well.

Over the last two years, however, data developed by the DOE and others on the corrosion of the waste package in the environment likely to be created in the DOE's current high-temperature repository design has raised several critical issues. The Board now has concluded, based on the data currently available, that all conditions necessary for penetration of waste packages by localized corrosion during the thermal pulse—the first 1,000 years after repository closure—will be present and widespread.

At its January 28, 2003, meeting in Las Vegas, Nevada, the Board heard four presentations dealing with the potential for corrosion of the DOE's proposed waste package (NWTRB 2003a). Researchers sponsored by the State of Nevada gave the first two. They described experiments and analyses designed to assess the integrity of the Alloy 22 waste package. They concluded that a wide range of corrosive conditions would be produced on the surface of the waste package, but those conditions could not be readily quantified nor could their effect on corrosion be predicted (Staehle 2003, Shettel 2003).

Investigators sponsored by the DOE gave the next two presentations. In the first one, four possible mechanisms for initiating corrosion on the waste package were evaluated: deliquescent brines from dust-water interactions, seepage brines from fracture flow, calcium chloride brines from pore water, and acid-gas evolved from calcium chloride brines (Farmer 2003a). The researcher concluded that none of the mechanisms could reasonably be expected to lead to waste package corrosion. In the second presentation, modifications made to the waste package final closure design were explained. In the DOE's view, the changes would reduce significantly the time spent welding, eliminate the need for thermal stress mitigation, reduce performance uncertainties, and achieve cost savings (Cloud 2003).

In a March 5, 2003, letter to the DOE (Corradini 2003a), the Board stated "…corrosive solutions are *possible*; the necessary pore water, decay heat from the waste packages, and in-drift conditions (i.e., high temperatures, pressure, humidity) would be present in a repository at Yucca Mountain." But the Board held that the technical basis for concluding whether the presence of those solutions was *likely* had not been established. The Board also noted that the DOE did not respond directly to a question asked at the meeting: "Would a repository with lower peak temperatures on waste package surfaces reduce the uncertainty, likelihood, or severity of the corrosive solutions?" The Board recommended to the DOE that it address that question and provide a carefully documented technical basis for its answer.

Toward that end, the Board offered the DOE broad latitude to structure as it saw fit the core of the first day of the May 13–14, 2003, Board meeting to be held in Washington D.C. (NWTRB 2003b). In response, the DOE and its contractor personnel delivered three major presentations related to in-drift thermohydrology, in-drift thermohydrochemistry, and Alloy 22 corrosion (Bodvarsson 2003, Peters 2003, Farmer 2003b).

The first presentation put forth an analysis describing why the DOE believed that there would be no seepage into the drifts of the proposed repository during the period when rock temperatures are above boiling. It also advanced the DOE's view that, if any water seeps into the drifts during that time, its chemistry would be relatively benign. The second presentation described three temperature ranges: a high-temperature regime, when rock-surface temperatures are significantly above the boiling point of water; a transition regime, when rock-surface temperatures fall between 80° and 120°C; and a low-temperature regime, when rock-surface temperatures are significantly below the boiling point of water. It also suggested reasons that neither seepage-induced nor deliquescence-induced corrosion was likely to take place. The third presentation detailed, among other things, the electrochemical analyses of waste package corrosion that had been undertaken. It also discussed results of "dip and dunk" corrosion experiments on Alloy 22. The presentation noted that there would be "zones of susceptibility" in which the environment to which Alloy 22 might be exposed would permit corrosion theoretically to occur. But it concluded that the waste package would be protected by different mechanisms in each of the three temperature ranges.

In a June 30, 2003, letter to the DOE (Corradini 2003d), the Board commended the DOE for its three presentations on the evolution of the near-field environment and on the potential for waste package corrosion. It noted, however, "…potentially significant questions remain about the technical basis for the Project's thermal analyses. These questions include concerns about the initiation of localized corrosion and the technical basis underlying Project claims about capillary and vaporization barriers. The Board is in the process of carefully evaluating the DOE's presentations from the May [2003] Board meeting and will be preparing more detailed comments for the DOE on these subjects."

At its September 16–17, 2003, meeting in Amargosa Valley, Nevada (NWTRB 2003c), the Board heard a presentation from a DOE contractor (MacKinnon 2003). It focused on how the conceptual models depicting the evolution of the near-field environment and waste package corrosion were integrated into the DOE's total system performance assessment (TSPA) and what insights were obtained. The presentation concluded the following:

- Drift seepage would not occur when [drift] crown temperatures are above the boiling point of water.
- It is highly unlikely that dust deliquescence would initiate localized corrosion on the waste package.
- If seepage water reaches the waste packages, conditions suitable for localized corrosion may occur during the thermal pulse, but the performance of the drip shield (in the nominal scenario) will prevent seepage water from contacting the waste packages, thereby making localized corrosion extremely unlikely.

In an October 21, 2003, letter to the DOE (Corradini 2003e), the Board presented its initial views about the technical validity of the DOE's claims about the potential for corrosion of the waste package. To illustrate its concerns about localized corrosion, the Board provided as an attachment to the letter copies of seven critical overheads that were shown and discussed at the Board's January and May 2003 meetings.[2] Among the key points of the letter were the following.

- Localized corrosion processes are particularly insidious because initiation is difficult to predict and propagation rates can be very rapid. Data emerging both from the Yucca Mountain Project and from the Center for Nuclear Waste Regulatory Analyses (CNWRA) suggest to the Board that crevice corrosion of Alloy 22 is likely to initiate during the thermal pulse.
- Project data show that initiation of crevice corrosion during the thermal pulse is likely in concentrated brines (with or without nitrates) formed through deliquescence processes at temperatures well below the peak temperatures on the waste package surface expected in the DOE's proposed repository design.
- Crevice corrosion, a form of localized corrosion, initiated during the thermal pulse is likely to propagate during the remainder of the thermal pulse and also is likely to continue even after the thermal pulse has passed.
- Work at the CNWRA and elsewhere indicates to the Board that welds and thermal treatment (aging) increase susceptibility to crevice corrosion. The DOE's modified waste package design has both welded areas (i.e., closure welds) and many features that offer opportunities for crevice formation. Redesign studies for reducing or eliminating areas of increased susceptibility to localized corrosion may be a worthwhile option.
- Most generalized corrosion data reported to date are for surface temperatures on the waste package of 95ºC or lower. These data may constitute an adequate technical basis if the surface temperatures of the waste packages in the repository never exceed 95ºC. Few data exist, however, for the higher temperatures of the thermal pulse.

[2] Several of the slides came from a May 14, 2003, presentation by Dr. Gustavo Cragnolino of the NRC's Center for Nuclear Waste Regulatory to the Board.

- Because of the seriousness of these corrosion concerns, the Board strongly urges the DOE to reexamine the current repository design and proposed operation. The Board believes that the high temperatures of the current design and operation will result in perforation of the waste packages, with possible release of radionuclides. The data currently available to the Board indicate that perforation is unlikely if waste package surface temperatures are kept below 95ºC.

- Finally, the Board believes that total system performance assessment should not be used to dismiss these corrosion concerns.

On November 25, 2003, the Board sent to the DOE a detailed 18-page technical report supporting the general conclusions about corrosion that it had set out a month earlier (Corradini 2003f, NWTRB 2003d). The report also contained the Board's evaluation of the technical basis underlying the DOE's claims about the evolution of the near-field environment.

Based on its review of data gathered by the DOE and the CNWRA, the Board stated that all the conditions necessary to initiate localized corrosion of the waste packages likely will be present during the thermal pulse because of the deliquescence of salts on waste package surfaces, and thus it is likely that deliquescence-induced localized corrosion will be initiated during the thermal pulse. In particular, corrosion experiments indicate that localized corrosion is likely to be initiated if temperatures on the waste package surface are above 140°C and if concentrated brines, such as would be formed by the deliquescence of calcium and magnesium chloride, are present. Limited data examined to date indicate that dust, which would be present in the proposed tunnels and which would be deposited on waste packages, contains calcium chloride and magnesium chloride salts in amounts sufficient for the development of concentrated brines through deliquescence. "Thus, the Board believes that under conditions associated with the DOE's current high-temperature repository design, widespread corrosion of the waste packages is likely to be initiated during the thermal pulse. Once started, such corrosion is likely to propagate rapidly even after conditions necessary for initiation are no longer present. The result would be perforation caused by localized corrosion of the waste packages, with possible release of radionuclides."

In its report, the Board noted that the DOE believes that the conditions in the repository would not promote significant corrosion. The Board observed that the DOE points to data, gathered using thermogravimetric apparatus (TGA), to demonstrate that the conditions necessary to initiate localized corrosion will be present only briefly. The Board, however, evaluated these data and found them inadequate to support the DOE's claim for the following reasons.

- Brines used in the TGA experiments may not be representative of those that would form on the waste packages because of deliquescence.

- The metallic coupons used in the experiments did not contain crevices.

- The TGA experiments have been run only over narrow ranges of temperature and relative humidity.

- The experimental apparatus is an "open" system that may not approximate short-term behavior of the microenvironment associated with crevices.

- The results of other experiments conducted by the DOE seem contradictory.

The Board also observed in its November 25, 2003, report that the DOE holds that the conditions under which localized corrosion might occur are extreme and unlikely. The information provided to the Board to date, however, does not form a compelling basis for that contention. For example, the DOE maintains that the presence of nitrates and an insufficient amount of calcium chloride in the proposed repository tunnels will limit localized corrosion. The DOE's own data, however, indicate that nitrate may not be protective at temperatures higher than 140°C. Furthermore, as noted above, the Board concluded that more than enough chloride would be present in the dust from the tunnels to lead to widespread localized corrosion. "Thus, the

DOE's belief that the geochemical environment on the waste package surfaces *will not* lead to corrosion lacks a strong technical basis." The Board reiterated its view that "the problems related to localized corrosion could be avoided if the repository design and operation were modified. The data currently available indicate that perforation of the waste packages caused by localized corrosion is unlikely if their temperatures are kept below 95ºC."

B. Improving Confidence in the DOE's Projections of Repository System Performance

As required by the NRC's regulations for licensing a Yucca Mountain repository, the DOE employs a complex computer-based methodology, TSPA, to project how the proposed repository might behave thousands of years into the future. The TSPA rests on a large number of assumptions, many of which are difficult to verify empirically; considerable uncertainty is attached to many of the conceptual models underlying the TSPA; and many gaps in the data used by the TSPA still persist.

Over the years, the Board has spoken often about the need for the DOE to increase confidence in its estimates of postclosure repository performance. For example, in a recent *Report to Congress* (NWTRB 1999), the Board concluded that the TSPA could be used as the "core analytical tool" for making the safety case for a repository. However, the Board also noted the limits of performance assessment and expressed doubt that relying "solely on the TSPA to demonstrate repository safety will ever be possible." Therefore, the Board recommended that additional lines of evidence, such as natural analogues, be used to overcome these limitations. Two of the four essential elements of any DOE site recommendation articulated by the Board were directed toward improving confidence in the projections of the TSPA (NWTRB 2001).

- Meaningful quantification of the conservatisms and uncertainties in the DOE's performance assessments.

- Development of multiple lines of evidence to support the safety case of the proposed repository. The lines of evidence should be derived independently of performance assessment and thus not be subject to the limitations of performance assessment.

Several times in 2003, the DOE made presentations to the Board on matters touching on confidence in the projections of repository performance. As part it of its regular update on its scientific and technical investigations at the Board's January and May 2003 meetings (NWTRB 2003a, NWTRB 2003b), the DOE discussed its efforts to reconcile contradictory analyses developed by two national laboratories related to the presence of bomb-pulse chlorine-36 at the horizon of the proposed repository. At the Board's September 17, 2003, meeting (NWTRB 2003c), the DOE informed the Board that it had approved an independent third-party study that would attempt to resolve the issue.

In a March 5, 2003, letter to the DOE (Corradini 2003a), the Board noted that the DOE has adopted the more conservative interpretation of the chlorine-36 data in developing its conceptual and numerical models of flow and transport in the unsaturated zone. Nonetheless, the Board reiterated its view that demonstrating understanding is of importance comparable to showing compliance (see NWTRB 2002). In addition, the Board maintained that discrepancies in results between two DOE-supported groups measuring the same phenomenon affect the credibility of the program. Thus, the Board "continues to believe that the DOE should persist in its efforts to reach scientific consensus on the results of the chlorine-36 analyses and the implications of those results for fluid flow in Yucca Mountain."

A potentially important independent line of evidence is the use of natural analogues to better understand how natural and engineered processes will evolve over long time periods. At its May 13, 2003, meeting (NWTRB 2003b), two speakers touched on the DOE's ongoing work at a possible analogue site at Peña Blanca in Northern Mexico. The natural uranium deposits at Peña Blanca, particularly at the Nopal 1 site, form a unique natural analogue for many of the processes that would occur at the proposed

Yucca Mountain repository. The uranium oxide deposit is in many ways similar to spent fuel. As at Yucca Mountain, it is located in oxidizing conditions in fractured, unsaturated volcanic tuff in a region of arid climate.[3]

In a June 30, 2003, letter to the DOE (Corradini 2003d), the Board observed that, on balance, Peña Blanca is an appropriate site for testing a number of important models and assumptions that underlay the DOE's analyses of Yucca Mountain and to examine alternatives to these models. Because work at Peña Blanca would likely increase understanding of important natural processes, the Board "strongly recommends continued support for studies at this unique site."

Finally, at the Board's January 28, 2003, meeting (NWTRB 2003a), a representative of the DOE's contractor discussed efforts to analyze the contributions various barriers make to the performance of the proposed repository (Swift 2003). Although this presentation was framed in the context of complying with the NRC's Yucca Mountain licensing regulation (10 CFR 63), the Board believes that such analyses also could provide important insights into the respective roles of the different barriers. Thus, in a March 5, 2003, letter to the DOE (Corradini 2003a), the Board "urged the DOE to continue this effort."

C. Development of a Waste Management System

In the NWPAA, Congress specified that one key area that the Board should review was the DOE's activities "relating to the packaging or transportation of high-level radioactive waste or spent nuclear fuel." Until recently, the DOE had undertaken very few activities related to transportation, and, consequently, the Board's review had to be limited. After Congress approved the selection of the Yucca Mountain site, however, the DOE began to devote more attention and resources to developing national and Nevada-specific transportation systems. The Board's involvement in the area also grew.

At the Board's January 28, 2003, meeting (NWTRB 2003a), the DOE presented information about the Standard Contract (10 CFR 961) negotiated between the DOE and the owners of commercial SNF, about the need to procure a transportation fleet and casks, and the process for selecting road and rail routes to Yucca Mountain from sites where HLW and SNF are currently stored (Williams 2003a). In a March 5, 2003, letter to the DOE (Corradini 2003a), the Board made three recommendations:

- The DOE's transportation planning and development effort should adopt a "systems" approach, addressing both strategic and operational considerations.

- The Board views the early involvement of external stakeholders as critical to developing a comprehensive plan for the waste management system and to building public confidence in those plans.

- Because proactive engagement of external stakeholders is a time-consuming process, the Board encourages the DOE to initiate this activity as soon as possible.

This overview was the prelude to a day-long meeting of the Board's Panel on the Waste Management System held on February 25, 2003, in Las Vegas, Nevada (NWTRB 2003f). The DOE gave a series of presentations on waste acceptance, developing a transportation plan, surface facility design and operation, and subsurface facility design and operation. The Board also invited representatives of the nuclear power industry, States through which the waste might travel, the State of Nevada, and local Nevada governments to present their views about what the DOE is doing and what it should be doing. A major purpose of this meeting was to familiarize Board members with the baseline from which the DOE will work in the years ahead.

In an April 30, 2003, letter to the DOE (Corradini 2003b), the Board conveyed the following findings and recommendations.

[3] There also are some important differences between Nopal 1 and Yucca Mountain. Scientists from the DOE and its contractors seem well aware of those differences.

- A sustained and well-thought-out effort will be needed to develop a transportation system that will engender public confidence.

- The DOE should adopt safety as a guiding principle in planning and developing a transportation system and should develop an integrated safety plan for guiding the development process.

- The DOE's strategic plan for transportation, which is being developed, should be published for public comment as soon as practical.

- The public as represented by state and local governments would like to know as soon as possible what modes and routes will be used for transporting HLW and SNF to a Yucca Mountain repository.

- The DOE should seek approaches to improving communication with utilities that will facilitate planning for the waste acceptance process.

D. Seismic Issues

Yucca Mountain is located in an area that has experienced earthquakes and volcanic activity in the past. Consequently, seismic and igneous issues have received considerable attention as the DOE characterized the site to determine whether it is suitable for repository development. Over the years, the Board has followed closely the technical work on these issues undertaken by the DOE and its contractors and generally has evaluated that work positively.

On February 24, 2003, the Board's Panel on the Natural System and its Panel on the Engineered System held a joint meeting in Las Vegas (NWTRB 2003e) to examine how the DOE is addressing a broad range of seismic issues. DOE-contractor scientists discussed the general approach taken to both preclosure and postclosure seismic issues, the basis of using particular ground-motion parameters in pre- and postclosure seismic design and analysis, and results of the preclosure analyses.[4] Finally, other DOE-contractor scientists presented analyses of drift stability and described how the response of the proposed engineered barrier system to seismic events would be incorporated in a TSPA.

To help it evaluate the information obtained at this meeting, the Board engaged the services of four experts: Alfred J. Hendron, Jr., from the University of Illinois; Peter Kaiser from Laurentian University; Art McGarr from the U.S. Geological Survey; and Anestis S. Veletsos from Rice University. Their reports (Hendron 2003, Kaiser 2003, McGarr 2003, Veletsos 2003) are available on the Board's Web site: **www.nwtrb.gov.**

In a June 27, 2003, letter to the DOE (Corradini 2003c), the Board articulated its basic concern that in estimating very-low-probability (10^{-6} per year or less) ground motions, the DOE has derived earthquake ground motions that lack physical realism and are outside the limits of existing worldwide seismic records and experience, particularly when the Yucca Mountain source and site conditions are taken into account. The Board observed that much of this critique of the very-low-probability ground motion estimates is shared by many of the individuals from the DOE and its contractor who spoke at the meeting.

The Board concluded that the estimates of very-low-probability ground motion needed to be bounded on the basis of sound physical principles. In addition, it urged the DOE to evaluate and consider the work of Dr. James Brune, the University of Nevada, Reno seismologist, who made a presentation at the February 24, 2003, meeting, as an alternative line of evidence for limiting estimates of ground motions (Brune 2003).[5] The Board also suggested how the DOE might refine its analysis of drift degradation.

[4] Preclosure refers to the roughly 100-year period after construction begins on the repository's surface and subsurface facilities. Postclosure refers to the 10,000-year period during which the repository will have to meet performance standards set by the U.S. Environmental Protection Agency and the NRC.

[5] Brune suggests using the precariously balanced rocks found on the Yucca Mountain crest to infer how much ground motion had been experienced at the site over long time periods.

The DOE defended its use of highly conservative and perhaps even physically unrealistic ground-motion estimates by claiming that the surface and subsurface facilities still would comply with applicable NRC regulations. In its letter, the Board expressed concern that "not all the assumptions in the Project's analysis of this complex, highly coupled system have been fully assessed." Thus the "true" level of conservatism may not be well specified. More generally, the Board recommended that the DOE not adopt the approach it has for six reasons:

- High levels of conservativism can lead to a skewed understanding of repository behavior and the significance of different events.

- High levels of conservatism can introduce consideration of events for which there is little or no understanding or engineering experience.

- Compounding conservative assumptions does not always produce conservative results, e.g., the worst case for drift stability is not when the horizontal and vertical stresses are both very high.

- High levels of conservatism may lead to unreasonably high costs and may have a serious effect on the eventual development of both surface and subsurface designs.

- If conservatism stems from a lack of understanding, it tends to undermine confidence in the scientific basis of the process under consideration. Physically unrealistic results, inappropriately extrapolated from physically realistic databases and analyses, could cast unwarranted doubt on much of the truly excellent work carried out in this area.

- If "unacceptable" consequences are discovered later, it may be more difficult to justify subsequent reductions of elevated ground-motion estimates previously assumed to be acceptable.

E. Igneous Issues

In 2002, the DOE chartered an independent group of technical experts to examine the issue of how igneous consequences are modeled and incorporated in the TSPA. The group's *Final Report* was released in February 2003 (ICPRP 2003). At the Board's May 14, 2003, meeting, a member of the group presented its findings and recommendations (NWTRB 2003b). To help it evaluate the issue of igneous consequences, the Board engaged the services of three scientists: Derek Elsworth from the Pennsylvania State University, William Melson from the Smithsonian Institution, and Meghan Morrissey from the Colorado School of Mines. Their reports (Elsworth 2003, Melson 2003, Morrissey 2003) are available on the Board's Web site: **www.nwtrb.gov.**

In a June 30, 2003, letter to the DOE (Corradini 2003d), the Board complimented both the DOE for initiating and supporting this peer review and the reviewers for producing a high-quality report containing much original work. The Board suggested that the DOE pay particular attention to three areas that the group explored.

- The first area is the use of upgraded modeling techniques that take into account conditions such as compressible inviscid flow that may be present at repository depth. The Board concurs with the review group that the likelihood of the generation of strong shock waves, which have been hypothesized by some investigators, is negligible.

- The second area is the need to study aeromagnetic anomalies in the vicinity of Yucca Mountain that could signify buried volcanoes. Such studies may involve additional aeromagnetic surveys (at appropriate altitudes); drilling; and dating, which could help determine the existence, age, and volume of the possible volcanoes.

- The third area is the need to address subjects that were not within the range of the Panel's expertise: i.e., waste package-magma interaction and waste entrainment in both the volcanic eruption scenario and the groundwater release scenario. The Panel confined itself to evaluating magma-drift interaction in the volcanic eruption scenario. These subjects are of great importance in any consequence analysis. The DOE should address them using the advice of outside reviewers. The DOE also

should consider experimental studies for analyzing and verifying key phenomena and parameters (e.g., chemical and mechanical effects of magma on waste packages).

III. Other Board Activities

A. Site Visits

1. Materials Testing Facilities

Board members having materials science and engineering expertise visited three major laboratories performing materials investigations relevant to the Yucca Mountain Project. The facilities were at the Lawrence Livermore National Laboratory (LLNL), the CNWRA, and The Catholic University of America (CU). Respectively, these laboratories are located in Livermore, California; on the campus of the Southwest Research Institute in San Antonio, Texas; and in northeast Washington, D.C.

LLNL is the source of virtually all the data used by the DOE to support its corrosion models for Alloy 22. Much modeling of the near-field in-drift environment also takes place at LLNL. At LLNL, Board members visited individual laboratories where data were being or had been obtained for corrosion models. They held discussions with corrosion laboratory personnel and environmental modeling personnel. The laboratory where experiments were conducted on microbially influenced corrosion particularly was impressive. Board members also toured a nearby facility where laser peening was being further developed for commercial activities. The Board members feel that LLNL's work on stress-corrosion cracking could be strengthened. They also believe that the information provided on the details of the environmental modeling and crevice-corrosion modeling was somewhat sparse. They also were disappointed in the apparent decision not to attempt to replicate CU data that recently had been made public.

The CNWRA is the principal technical arm assisting the NRC staff in the HLW and SNF areas. The materials part of the CNWRA program has produced, and continues to produce, a prodigious amount of corrosion data and associated reports. The preponderance of the CNWRA corrosion work is short term and electrochemical in nature and performed at temperatures of 95ºC or below. Some of their recent crevice-corrosion studies are done at higher temperatures but in solution chemistries different from those used by LLNL for similar studies. Modeling of the evolution of environments on waste package surfaces is performed for the NRC at the CNWRA. Apparently part of the CNWRA's environmental work is done with a modeling system (OLI) that is different from LLNL's (EQ3/6). Because modeling of high-temperature deliquescence and behavior of very concentrated brines is novel, the convergence or divergence of the results of these two modeling systems will be very important for establishing confidence.

CU is performing corrosion experiments under contract with the State of Nevada. The Board's visit was a brief one immediately after its May 2003 meeting in Washington. The evaporation of concentrated pore water to near dryness (approximately 140°C) was observed, as was the subsequent visible attack of Alloy 22 coupons by the environment thus created.

2. Peña Blanca

In May 2003, Board members visited the Peña Blanca natural analogue site, near Chihuahua, Mexico. The site is the location of an approximately 8 million-year-old hydrothermal deposit of uranium ore (as uraninite, UO_2) in older rocks. It has the following characteristics in common with Yucca Mountain: Basin-and-Range extensional tectonic setting, fractured silicic volcanic rocks, unsaturated hydrogeology, oxidizing geochemical environment, arid climate, and underlain by a carbonate aquifer. One significant difference is the presence of iron oxides coating the fractures at Peña Blanca, although iron oxides could occur at Yucca Mountain from introduced ferrous engineering materials. Another difference is that the environment at Peña Blanca was initially acidic.

The Board long has recognized the potential value of the Peña Blanca natural analogue site

and has encouraged DOE to pursue investigations there. After some initial delays, a drill rig arrived at the site to begin investigations. The new core samples and boreholes can yield a wealth of mineralogical, chemical, and isotopic information relevant to source term and radionuclide transport issues for Yucca Mountain. Mineralogical studies can address the stability of secondary uranyl phases and their chemical compositions. The stability of those minerals will ultimately control releases of much of the radionuclide inventory from Yucca Mountain. Chemical studies can inform and test reactive transport simulations. Isotope studies can be used to infer the mobility of the radionuclides and the geochemical "openness" of the system.

As noted above, the Board remains enthusiastic about the potential value of the ongoing work at Peña Blanca. It provides qualitative and quantitative insight into the character of radionuclide migration, and it provides the potential for testing process models and performance assessment tools.

B. International Fact-Finding Trips

In 2003, the Board continued to keep abreast of international scientific and technical work pertinent to the Board's mission.

For example, Board members attended the International Meeting on Clays in Natural and Engineered Barriers for Radioactive Waste Confinement held in Reims, France. Issues discussed at the conference included approaches to analyzing technical problems, integration of scientific and technical work, the time frame for evaluating repository performance, and specific topics, such as understanding pore-water chemistry, age dating of groundwater, thermo-hydromechanical behavior, analogue work, and hydrogeological flow-and-transport modeling.

Two observations from the conference are worth noting.

- Research has been done in Spain and Switzerland aimed at understanding the thermo-hyromechanical phenomena taking place in the near field and within the engineered barrier system (bentonite, granite and/or clay). Research results indicate that it is considerably easier to predict real conditions in a potential repository using models and experiments at lower temperatures. Similar conclusions were reached by the Belgians in their research on repository design at Praclay Gallery at Mol, Belgium.

- Belgium and Sweden have produced small-scale demonstration projects of their proposed repository systems. In both countries, this exercise resulted in design changes that are still in progress, even though the initial efforts in each country were considered fairly mature at the time the projects commenced.

In October 2003, a delegation from the Board traveled to Belgium, France, Switzerland, and Britain. The purpose of the trip was threefold: (1) visit sites under study as the potential location for a repository; (2) tour long-term storage facilities and transportation systems; and (3) discuss the role of the various barriers in the disposal concepts of the countries visited, with special emphasis on waste package fabrication and performance.

A brief summary of the Board's observations obtained on this visit includes the following:

- In developing a transportation system for the proposed Yucca Mountain site, the DOE may be able to benefit by using or adapting some of the equipment, practices, and facilities developed by other countries that have already established transport systems.

- Of the countries visited by the Board that have looked at repository design issues, none proposes keeping temperatures at or above boiling for as long as the DOE proposes. In changing its reference design from a high to a low temperature, the Belgian program noted that, if temperatures are kept below boiling, it will be simpler, easier, and less complicated to understand natural processes and the behavior of materials and to make predictions.

- The experience of the Belgians illustrates that repository designs and operations can and will evolve. Such evolution is to be expected. Because pressure to build a repository is not

strong in this country, the changes do not appear to be viewed as a failure of or a roadblock to the program. Rather, the changes seem to be part of an incremental learning process of developing a design that is both safe and implementable.

IV. The Board in Transition

During 2003, two Board members tendered their resignations. On January 6, 2003, Debra Knopman informed President George W. Bush that she intended to resign from the Board effective January 17, 2003. President William J. Clinton appointed Dr. Knopman to the Board on January 17, 1997. On December 30, 2003, Michael Corradini informed President Bush that he intended to resign from the Board effective January 12, 2004. President Bush appointed Dr. Corradini as Chairman of the Board on June 26, 2002. Both Dr. Knopman and Dr. Corradini brought considerable expertise and extensive experience to the Board's task of evaluating the technical and scientific validity of DOE waste-disposal activities. During the time they served as Board members, each individual made important and valuable contributions to the Board's technical and scientific review.

V. Evaluation of the Board's Performance During 2003

The Board believes that measuring its effectiveness by directly correlating Board recommendations with improvements in the technical and scientific validity of the DOE's activities would be ideal. However, the Board cannot compel the DOE to comply with its recommendations. Consequently, a judgment about whether a specific recommendation had a positive outcome for the DOE program may be (1) subjective or (2) an imprecise indicator of Board performance because implementation of Board recommendations is outside the Board's direct control. Therefore, to measure its performance in a given year, the Board has developed performance measures. For each annual performance goal, the Board considers the following.

- Did the Board undertake the reviews, evaluations, and other activities needed to achieve the goal?

- Were the results of the Board's reviews, evaluations, and other activities communicated in a timely, understandable, and appropriate way to Congress and the Secretary of Energy?

If both measures have been met in relation to a specific goal, the Board's performance in meeting that goal is judged effective. If only one measure has been met, the performance of the Board in achieving that goal is judged minimally effective. Failing to meet both performance measures without sufficient and compelling explanation results in a judgment that the Board has been ineffective in achieving that performance goal. If the goals have been deferred, that action is noted in the evaluation.

The Board uses its evaluation of its performance from the current year, together with its assessment of current or potential key issues of concern related to the DOE program, to develop its annual performance objectives and performance-based budget request for subsequent years. The results of the Board's performance evaluation are included in its annual summary reports.

On the basis of an evaluation of its performance in meeting its goals for the year and consistent with the performance measures described above, the Board's performance for FY 2003 was found to be effective overall. However, the Secretary's activities related to the waste management program were again limited in 2003. In addition, the DOE has not undertaken some long-term design activities. Therefore, several of the Board's FY 2003 goals related to design were deferred, pending DOE activities related to the goals. A detailed evaluation of the Board's performance for FY 2003 is in Appendix H of this report.

Abbreviations and Acronyms

Board	Nuclear Waste Technical Review Board
CNWRA	Center for Nuclear Waste Regulatory Analyses
CU	Catholic University
DOE	Department of Energy
HLW	high-level radioactive waste
LLNL	Lawrence Livermore National Laboratory
NRC	U.S. Nuclear Regulatory Commission
NWPAA	*Nuclear Waste Policy Amendments Act of 1987*
NWTRB	Nuclear Waste Technical Review Board
OCRWM	Office of Civilian Radioactive Waste Management
SNF	spent nuclear fuel
TSPA	total system performance assessment

Glossary

The following list was compiled to help readers understand some of the terms used in this report.

aeromagnetic anomaly A localized departure from the earth's expected magnetic field as determined by an aeromagnetic survey.

Alloy 22 A nickel-chromium-molybdenum alloy proposed for use as the material of construction for the waste package's outer wall.

analogue A phenomenon that can provide information on or add understanding to aspects of repository performance. Analogues are of two types: natural and anthropogenic. Natural analogues occur through natural phenomena. Anthropogenic analogues result from human activity. An "archaeological analogue" is an anthropogenic analogue resulting from the activities of ancient cultures.

barrier Something that prevents or retards the passage of radionuclides toward the environment.

brine A concentrated solution of one or more salts in water.

calcium chloride A highly deliquescent salt with the chemical formula $CaCl_2$.

chlorine-36 (^{36}Cl) 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 1950's temporarily increased concentrations of chlorine-36. The resulting "bomb pulse" levels of chlorine-36 can sometimes serve as a tracer for determining how precipitation from the 1950's has moved through soil and rocks, such as those at Yucca Mountain.

corrosion A destructive attack of a material by chemical or electrochemical interaction with its environment.

coupon A small, thin, flat metal sample used in corrosion testing.

crevice corrosion Localized corrosion of a metal surface at or near an area that is shielded from full exposure to the bulk environment because of proximity between the metal and the surface of another material.

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

drift A near-horizontal excavated passageway through the earth; a tunnel.

drip shield Barriers placed over and around waste packages to divert water from the packages.

engineered barrier system The constructed components of a disposal system designed to retard or prevent releases of radionuclides from the underground facility. They include waste forms, fillers, waste containers, shielding material placed over and around such containers, and backfill materials.

geologic repository A facility for disposing of radioactive waste in excavated geologic media, including surface and subsurface areas of operation and the adjacent part of the natural setting.

groundwater Subsurface water as distinct from surface water.

high-level radioactive waste Highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in 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.

high-temperature repository design An approach that allows the temperature of the waste package surface to exceed the boiling point of water for a significant period of time.

hydrogeology The science dealing with subsurface water and with related geologic aspects of surface water.

hydrothermal Of or pertaining to hot water, to the action of hot water, or to the products of the action, such as a mineral deposit precipitated from a hot aqueous solution, with or without demonstrable association with an igneous process.

igneous Formed by volcanic activity.

inviscid flow Flow in which fluid friction is negligible.

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, and a spent-fuel storage facility. A license application must be approved before the facility is constructed and before it can be operated.

localized corrosion Corrosion that takes place at discrete sites. Crevice corrosion is a form of localized corrosion.

multiple lines of evidence Varied methodological approaches used to infer the behavior of the repository system (or its major components) for extended time periods. Examples include analogues, simplified calculations, and arguments based on defense-in-depth.

near field A zone that typically extends one diameter outward from the tunnel wall. In that zone, coupled thermal, hydrological, mechanical, and chemical processes are expected to occur.

nitrate The anion NO_3^-, often used as a way to designate a salt containing nitrate.

Nuclear Waste Policy Act 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 cost of geologic disposal, authorized interim storage until a repository is available, and defined interactions between federal agencies and the states, local governments, and Indian tribes.

Nuclear Waste Policy Amendments Act The federal statute enacted in 1987 that amended the Nuclear Waste Policy Act to limit repository site-characterization activities to Yucca Mountain, Nevada; establish the Office of the Nuclear Waste Negotiator to seek a state or Indian tribe willing to host a repository or monitored retrievable storage facility; create the Nuclear Waste Technical Review Board; and increase state and local government participation in the waste management program.

peer review Critical review of a scientific report performed by experts in the subject covered in the report.

performance assessment A complex computer-based analysis that predicts the behavior of an entire repository system under a given set of conditions.

pore water Subsurface water in the voids of a rock.

postclosure The period of time after the closure of the geologic repository.

preclosure The period of time before and during the closure of the geologic repository.

process models Conceptual and mathematical models of a particular process (e.g., unsaturated-zone flow) that reflects the phenomena of interest. The models then can be abstracted (simplified) for use in performance assessments.

radionuclide transport The movement of radioactive materials through rock formations, most typically in water.

salt The compound formed by the anion of an acid and the cation of a base.

saturated zone The part of the Earth's crust in which all empty spaces are filled with water.

seepage The movement of liquid water, including dissolved chemicals, into repository drifts.

seismic Pertaining to an earthquake or earth vibration.

spent nuclear fuel Uranium-containing rods that have been withdrawn from a nuclear reactor following irradiation. Some of the uranium atoms have undergone nuclear reactions producing fission products and transuranic elements that remain in the rods.

Standard Contract An agreement between the U.S. Government and the owners in the United States of commercial high-level radioactive waste and spent nuclear fuel. It provides the framework under which the government will be paid by the owners to dispose of their high-level radioactive and spent nuclear fuel.

stress-corrosion cracking A cracking process in materials that results from simultaneous corrosion and a sustained tensile stress.

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 current repository design.

thermal stress Forces that arise in the walls and pillars between repository drifts due to the heat from radioactive decay.

thermohydrochemistry The study of components in aqueous and solid phases as influenced by heat.

thermohydrology The study of coupled water and heat flow.

total system performance assessment (TSPA) Analyses undertaken by the Department of Energy for assessing the ability of the potential repository at Yucca Mountain to provide long-term isolation and containment of radioactive wastes.

unsaturated zone Layers of rock in which some, but not all, of the empty spaces are filled with water.

waste entrainment The incorporation of buried nuclear waste into rising igneous fluids.

waste isolation Separation of the waste from the environment.

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

References

Bodvarsson, Gudmundur S. 2003. "The Character of the Unsaturated Zone." Presentation to U.S. Nuclear Waste Technical Review Board. May 13, 2003. Washington, D.C.

Brune, James N. 2003. "Precarious Rocks, Shattered Rock, and Seismic Hazard at Low Probabilities for Yucca Mountain." Presentation to U.S. Nuclear Waste Technical Review Board. February 24, 2003. Las Vegas, Nevada.

Cloud, Jack D. 2003. "Waste Package Manufacturing and Closure Welds." Presentation to the U.S. Nuclear Waste Technical Review Board. January 28, 2003. Las Vegas, Nevada.

Corradini, Michael L. 2003a. March 5 letter from Michael L. Corradini, Chairman, U.S. Nuclear Waste Technical Review Board, to Margaret S. Y. Chu, Director, Office of Civilian Radioactive Waste Management, on the Board's reactions to presentations at the January 2003 Board meeting.

_____. 2003b. April 30 letter from Michael L. Corradini, Chairman, U.S. Nuclear Waste Technical Review Board, to Margaret S. Y. Chu, Director, Office of Civilian Radioactive Waste Management, on the Board's reactions to presentations at the February 2003 meeting of the Panel on Waste Management Systems.

_____. 2003c. June 27 letter from Michael L. Corradini, Chairman, U.S. Nuclear Waste Technical Review Board, to Margaret S. Y. Chu, Director, Office of Civilian Radioactive Waste Management, on the Board's reactions to presentations at the February 2003 joint meeting of the Panel on the Natural System and the Panel on the Engineered System.

_____. 2003d. June 30 letter from Michael L. Corradini, Chairman, U.S. Nuclear Waste Technical Review Board, to Margaret S. Y. Chu, Director, Office of Civilian Radioactive Waste Management, on the Board's reactions to presentations at the May 2003 Board meeting.

_____. 2003e. October 21 letter from Michael L. Corradini, Chairman, U.S. Nuclear Waste Technical Review Board, to Margaret S. Y. Chu, Director, Office of Civilian Radioactive Waste Management, on the Board's comments on the data and analyses related to corrosion presented at the May Board meeting.

_____. 2003f. November 25 letter from Michael L. Corradini, Chairman, U.S. Nuclear Waste Technical Review Board, to Margaret S. Y. Chu, Director, Office of Civilian Radioactive Waste Management, additional Board's comments on the data and analyses related to corrosion presented at the May Board meeting.

Elsworth, Derek. 2003. "Summary Report to the NWTRB: Igneous Consequences Peer Review Report and Related Presentations of February 26, 2003." Consultant report for U.S. Nuclear Waste Technical Review Board.

Farmer, Joseph. 2003a. "Chemical Environmental Evolution on Alloy 22." Presentation to U.S. Nuclear Waste Technical Review Board. January 28, 2003. Las Vegas, Nevada.

_____. 2003b. "Materials Performance." Presentation to U.S. Nuclear Waste Technical Review Board. May 13, 2003. Washington, D.C.

Hendron, Alfred J., Jr. 2003. "Independent Consultant Report on February 24, 2003 Meeting of the Panel on the Natural System and Panel on the Engineering System Joint Meeting on Seismic Issues." Consultant report for U.S. Nuclear Waste Technical Review Board.

Igneous Consequences Peer Review Panel (ICRP). 2003. *Final Report of the Igneous Consequences Peer Review Panel*. Las Vegas, Nevada. Bechtel SAIC Company LLC.

Kaiser, Peter K. 2003. "Letter Report by P.K. Kaiser on the NWTRB Joint Panel Meeting on Seismic Issues in Las Vegas, February 24, 2003." Consultant report for U.S. Nuclear Waste Technical Review Board.

McGarr, Art. 2003. "Comments to Nuclear Waste Technical Review Board Regarding the Joint Panel Meeting on Seismic Issues, 24 February 2003." Consultant report for the U.S. Nuclear Waste Technical Review Board.

MacKinnon, Robert J. 2003. "Update on Engineered Barrier System Performance: Performance Assessment Insights." Presentation to U.S. Nuclear Waste Technical Review Board. September 16, 2003. Armagosa Valley, Nevada.

Melson, William. 2003. "Review of the Final Report of the Igneous Consequences Peer Review Panel Presented in Las Vegas, February 26, 2003." Consultant report for U.S. Nuclear Waste Technical Review Board.

Morrissey, Meghan. 2003. "Review of the Final Report of the Igneous Consequences Review Panel." Consultant report for U.S. Nuclear Waste Technical Review Board.

Nuclear Waste Technical Review Board (NWTRB). 1990. *First Report to the U.S. Congress and the U.S. Secretary of Energy*. Arlington, Virginia.

_____. 1999. *Report to the U.S. Congress and the Secretary of Energy: Moving Beyond the Viability Assessment*. Arlington, Virginia.

_____. 2001. *Report to the U.S. Congress and the Secretary of Energy, January to December 2000*. Arlington, Virginia.

_____. 2002. *Report to the U.S. Congress and the Secretary of Energy, January 1, 2001, to January 31, 2002*. Arlington, Virginia.

_____. 2003a. Winter Board Meeting; January 28, 2003; Las Vegas, Nevada (transcript of proceedings). Arlington, Virginia.

_____. 2003b. Spring Board Meeting; May 13–14, 2003; Washington, D.C. (transcript of proceedings). Arlington, Virginia.

_____. 2003c. Fall Board Meeting; September 16–17, 2003; Amargosa Valley, Nevada (transcript of proceedings). Arlington, Virginia.

_____. 2003d. "An Evaluation of Key Elements in the U.S. Department of Energy's Proposed System for Isolating and Containing Radioactive Waste." Board Technical Report. Arlington, Virginia.

_____. 2003e. Panel on the Natural System and Panel on the Engineered System. Joint Meeting; February 24, 2003; Las Vegas, Nevada (transcript of proceedings). Arlington, Virginia.

_____. 2003f. Panel on the Waste Management System Meeting; February 25, 2003; Las Vegas, Nevada (transcript of proceedings). Arlington, Virginia.

Peters, Mark T. 2003. "The Character of the In-Drift Environment." Presentation to the U.S. Nuclear Waste Technical Review Board. May 13, 2003; Washington, D.C.

Shettle, Don L. 2003. "Near-Field Environments and Corrosion;" Presentation to U.S. Nuclear Waste Technical Review Board. January 28, 2003. Las Vegas, Nevada.

Staehle, Roger W. 2003. "Continuing Investigations of Local Environments on Waste Container Surfaces." Presentation to Nuclear Waste Technical Review Board. January 28, 2003. Las Vegas, Nevada.

Swift, Peter. 2003. "Barrier Capability Analyses." Presentation to U.S. Nuclear Waste Technical Review Board. January 28, 2003. Las Vegas, Nevada.

U.S. Congress. 1987. *Nuclear Waste Policy Amendments Act of 1987* (NWPAA); 100th Congress; 1st Session, 1987. Washington, D.C.: Government Printing Office.

_____. 2002. *House Joint Resolution 87*: Approving the Site at Yucca Mountain, Nevada, for the development of a repository for the disposal of high-level radioactive waste and spent nuclear fuel, pursuant to the Nuclear Waste Policy Act of 1982; 107th Congress; 2nd Session; 2002. Washington, D.C.: Government Printing Office.

Veletsos, Anestis S. 2003. "Letter Report: Comments on the Information Pressented at the U.S. Nuclear Waste Technical Review Board (NWTRB)." Consultant report for U.S. Nuclear Waste Technical Review Board.

Williams, Jeff. 2003. "Operating the Waste Management System." Presentation to U.S. Nuclear Waste Technical Review Board. January 28, 2003. Las Vegas, Nevada.

10 CFR 63 (Code of Federal Regulations). 2001. Title 10, *Energy*, Part 63, "Disposal of High-Level radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain."

10 CFR 961 (Code of Federal Regulations). 2001. Title 10, *Energy*, Part 961, "Standard Contract for the Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste."

Appendices

Appendix A
U.S. Nuclear Waste Technical Review Board Members

Michael L. Corradini, Ph.D.; Chairman

Dr. Michael L. Corradini was appointed to the Nuclear Waste Technical Review Board as chairman on June 26, 2002, by President George W. Bush. Dr. Corradini resigned from the Board effective January 12, 2004.

Dr. Corradini is chairman of the engineering physics department of the University of Wisconsin-Madison. He brings to the Board expertise in nuclear and industrial safety. His research focuses on multiphase flow and heat/mass transfer, vapor-explosion phenomena, jet-spray breakup, and mixing dynamics, as well as on heat/mass transfer and chemical reactions involved in molten core-concrete interactions.

Dr. Corradini has 25 years of experience in nuclear engineering, including research and teaching. He was elected to membership in the National Academy of Engineering of the National Academy of Sciences in 1998. He is a Fellow of the American Nuclear Society and was a recipient of the 1990 Young Members Engineering Achievement Award. Dr. Corradini is a registered Professional Engineer.

Dr. Corradini has served as a consultant for the U.S. Nuclear Regulatory Commission's Advisory Committee on Reactor Safeguards and for the U.S. Department of Energy National Laboratories (Los Alamos National Laboratory, Oak Ridge National Laboratory, Idaho National Engineering Laboratory, Brookhaven National Laboratory). He also has participated in nationally and internationally sponsored research.

Dr. Corradini earned a bachelor of science degree in mechanical engineering from Marquette University in 1975. He received a master of science degree in nuclear engineering from the Massachusetts Institute of Technology (MIT) in 1976 and a Ph.D. in nuclear engineering from MIT in 1978. For the next three years, he was on the technical staff of Sandia National Laboratories, conducting research on severe reactor accidents. In 1981, Dr. Corradini joined the University of Wisconsin–Madison faculty. He became Associate Dean, Academic Affairs, of the College of Engineering in 1995. In 2001, he became chairman of the Department of Engineering Physics.

Dr. Corradini lives in Madison, Wisconsin.

Mark D. Abkowitz, Ph.D.

Dr. Mark D. Abkowitz was appointed to the Nuclear Waste Technical Review Board on June 26, 2002, by President George W. Bush.

Dr. Abkowitz is a professor of civil and environmental engineering at Vanderbilt University in Nashville, Tennessee, and is director of the Vanderbilt Center for Environmental Management Studies. He brings to the Board expertise in the fields of transportation, risk management and risk assessment, and emergency preparedness.

Dr. Abkowitz has served on several national and international committees, including as chairman of the National Academy of Sciences Transportation Research Board Committee on Hazardous Materials Transport and as a member of the National Research Council Committee on Disposal of Transuranic Waste at the Waste Isolation Pilot Plant. Dr. Abkowitz also serves on the board of Visual Risk Technologies. He is the author of more than 60 journal publications and study reports.

Dr. Abkowitz has been inducted into Chi Epsilon and the National Society of Sigma Xi and is a member of the World Conference on Transportation Research Society. He received the Distinguished Service Award in 1996 from the Transportation Research Board.

Dr. Abkowitz received a bachelor of science degree in civil engineering from the Massachusetts Institute of Technology (MIT) in 1974. In 1976, he received a master of science degree in civil engineering from MIT. He was awarded a Ph.D. in civil engineering–transportation by MIT in 1980. From 1976 to 1980, he worked as a project manager and research investigator for the U.S. Department of Transportation. In 1980, he joined the civil engineering faculty of Rensselaer Polytechnic Institute. During a sabbatical in 1986–87, he served as a senior analyst to the U.S. Congress, Office of Technology Assessment. He joined Vanderbilt in 1987 as Administrative Director, Vanderbilt Engineering Center for Transportation Operations and Research.

Dr. Abkowitz lives in Nashville, Tennessee.

Daniel B. Bullen, Ph.D.

Dr. Daniel B. Bullen was appointed to the Nuclear Waste Technical Review Board on January 17, 1997, by President William Clinton.

Dr. Bullen is an associate professor of mechanical engineering, Department of Mechanical Engineering, at Iowa State University in Ames, Iowa. He brings to the Board special expertise in performance assessment modeling of radioactive waste disposal facilities, performance assessment of engineered barrier systems, radiolysis effects in spent-fuel dry casks in storage environments, radiation effects on materials, and materials degradation in severe service environments.

Dr. Bullen has been teaching since 1989, and he served as Nuclear Engineering Program Coordinator at Iowa State University from 1993 to 1996 and as director of the Iowa State University Nuclear Reactor Laboratory from 1993 to 2001. He has 12 years of industry experience in nuclear engineering and materials science. He has edited and reviewed articles for such professional publications as Nuclear Technology, Journal of the American Ceramic Society, American Nuclear Society Transactions, and Encyclopedia of Chemical Technology. He has written or co-written more than 70 technical publications and reports and has contributed to three books. He is a registered Professional Engineer in mechanical, metallurgical, and nuclear engineering. Dr. Bullen's honors and awards include Tau Beta Pi (National Engineering Honor Society), Phi Kappa Phi, Sigma Xi (Scientific Research Society), Alpha Nu Sigma (Nuclear Engineering Scholastic Honor Society), a Lilly Teaching Fellowship at the Georgia Institute of Technology (1991), and two Outstanding Professor awards. He has appeared in Who's Who in Science and Engineering, Who's Who in America, and Who's Who in the World.

Dr. Bullen is a member of ASM International; American Society of Mechanical Engineers; National Society of Professional Engineers; and Minerals, Metals & Materials Society; and American Nuclear Society (ANS). He is an active member of the Education and Training Division and the Fuel Cycle and Waste Management Division of ANS and has served as Chairman of the Executive Committee of each division.

Dr. Bullen is an international consultant in radioactive waste management. As a consultant to Monitor Scientific, LLC of Denver, Colorado, Dr. Bullen has provided technical expertise to the Japanese and Swedish nuclear waste management programs on issues related to waste package degradation, performance-confirmation monitoring, and long-term performance assessment.

In 1978, Dr. Bullen earned a bachelor of science degree in engineering science from Iowa State University. He was a research assistant at the University of Wisconsin-Madison while earning master of science degrees in nuclear engineering in 1979 and materials science in 1981 and a Ph.D. in nuclear engineering in 1984. He then worked for Lawrence Livermore National Laboratory as an engineer until 1986, when he became senior engineer for Science & Engineering Associates, Inc., in Pleasanton, California. In 1988, he became president of DG Engineering Associates, providing technical consulting services to Lawrence Livermore National Laboratory. Dr. Bullen moved to North Carolina State University in 1989 as an assistant professor of nuclear engineering and to the Georgia Institute of Technology in 1990 as an assistant professor of mechanical engineering. He moved to Iowa State University in 1992 as an associate professor of nuclear engineering.

Dr. Bullen lives in Ames, Iowa.

Thure E. Cerling, Ph.D.

Dr. Thure E. Cerling was appointed to the Nuclear Waste Technical Review Board on June 26, 2002, by President George W. Bush.

Dr. Cerling is Distinguished Professor of Geology and Geophysics and professor of Biology at the University of Utah. He brings to the Board as expertise in terrestrial geochemistry. His research interests are in the study of geochemistry processes occuring at or near the Earth's surface and in the geological record of ecological change.

Dr. Cerling was elected to membership in the National Academy of Sciences in 2001. He is a fellow of the American Association for the Advancement of Science and of the Geological Society of America. He has been a visiting professor at Scripps Institution of Oceanography, Yale University; the University of Lausanne in Switzerland; and at the California Institute of Technology.

Dr. Cerling has served on numerous boards, panels, and committees, including the National Academy of Sciences–National Research Council Board on Earth Sciences and Resources, Geochemical Society Board of Directors, and the Nuclear Waste Group of the International Union of Geological Sciences. He also served on the Governor's Nuclear Waste Task Force, State of Utah, in 1981–83. In 1998, he received the University of Utah Distinguished Research Award.

In 1972, Dr. Cerling earned a bachelor of science degree in geology and chemistry from Iowa State University. In 1973, he received a master of science degree in geology from Iowa State University. In 1977, he was awarded a Ph.D. in geology by the University of California–Berkeley. From 1977 to 1979, Dr. Cerling worked as a research scientist at Oak Ridge National Laboratory. In 1979, he joined the faculty of the University of Utah.

Dr. Cerling lives in Salt Lake City, Utah.

Norman L. Christensen, Jr., Ph.D.

Dr. Norman L. Christensen, Jr. was appointed to the Nuclear Waste Technical Review Board on January 17, 1997, by President William Clinton.

Dr. Christensen is professor of ecology at the Nicholas School of the Environment and Earth Sciences at Duke University in Durham, North Carolina. He brings to the Board special expertise in biology and ecology. His research interests include the effects of disturbance on structure and function of populations and communities; comparative biogeochemical and community responses to varying fire regimes; use of remote sensing systems (such as synthetic aperture radar) to evaluate long-term changes in forest ecosystems; and pattern analysis of forest development following cropland abandonment as affected by environment, stand history, and plant demographic patterns.

Dr. Christensen has been teaching for more than 29 years and has more than 90 scientific articles and books to his credit. He has written widely on the importance of natural disturbance in the management of forests, shrublands, and wetlands, and he is interested in applying basic ecological theory and models to ecosystem management.

Dr. Christensen is the recipient of the 1977 Duke Endowment Award for Teaching Excellence, the 1991 Distinguished Teaching Award for Trinity College of Arts and Sciences at Duke, and the 1994 Distinguished Scholar-Alumni Award from California State University–Fresno. He was made a Fellow of the American Association for the Advancement of Science in 1993 and is a recipient of the National Park Service's A. Starker Leopold Award for distinguished service. Dr. Christensen has served on more than 25 national and regional panels and commissions and on the editorial boards of American Midland Naturalist, Journal of Vegetation Science, and Journal of Wildland Fire. He is currently Vice-president of the Ecological Society of American and Chairman of the National Commission on Science for Sustainable Forestry.

Dr. Christensen is a member of the American Association for the Advancement of Science, the British Ecological Society, the Ecological Society of America, Sigma Xi (Scientific Research Society), the Society of American Foresters, and the National Association of Environmental Professionals.

Dr. Christensen earned a bachelor's degree in biology from Fresno State College in 1968. He earned a master of science degree in biology from Fresno State College in 1970 and a Ph.D. in biology from the University of California–Santa Barbara in 1973. He began his teaching career as an assistant professor in the Department of Botany at Duke University in 1973. He became an associate professor in 1979 and was elevated to full professor in 1987. He was dean of the Nicholas School of the Environment from 1991 to 2001.

Dr. Christensen lives in Chapel Hill, North Carolina.

Paul P. Craig, Ph.D.

Dr. Paul P. Craig was appointed to the Nuclear Waste Technical Review Board on January 30, 1997, by President William Clinton.

Dr. Craig is Professor of Engineering Emeritus at the University of California, Davis, and is a member of the university's Graduate Group in Ecology. He brings to the Board special expertise and research interest in energy and environmental policy.

Dr. Craig has more than 21 years of teaching experience and more than 100 refereed publications to his credit. He is Chairman of the Sierra Club's National Global Warming and Energy Committee. He was a Lawrence Berkeley National Laboratory Participating Guest Scientist from 1976 to 1997 and again starting in 2002. He is a Fellow of the American Physical Society. Dr. Craig's awards include a John Simon Guggenheim Memorial Foundation Fellowship and a National Science Foundation Meritorious Service Award. He is a member of Phi Beta Kappa.

Dr. Craig earned a bachelor of science degree in mathematics and physics from Haverford College in 1954. He earned a Ph.D. in physics from the California Institute of Technology in 1959. He began his career as a staff scientist at Los Alamos National Laboratory in 1959 and moved to Brookhaven National Laboratory in 1962 as a physicist and a group leader. In 1971, he became deputy and acting director of the Office of Energy Research and Development Policy of the National Science Foundation, where he provided policy analysis support to the President's science advisor and to the Office of Management and Budget. Dr. Craig became director of the University of California Council on Energy and Resources in 1975 and professor of engineering at the University of California, Davis, in 1977. He received his emeritus standing in 1994.

Until his appointment to the Nuclear Waste Technical Review Board, Dr. Craig was a member of the National Academy of Sciences–National Research Council Board on Radioactive Waste Management.

Dr. Craig lives in Martinez, California.

David J. Duquette, Ph.D.

Dr. David J. Duquette was appointed to the Nuclear Waste Technical Review Board on June 26, 2002, by President George W. Bush.

Dr. Duquette is Department Head and a professor of materials science and engineering at Rensselaer Polytechnic Institute (RPI) in Troy, New York. He brings to the Board expertise in the physical, chemical, and mechanical properties of metals and alloys, with special emphasis on environmental interactions. His current research interests include the physical, chemical, and mechanical properties of metals and alloys, with specific reference to studies of cyclic deformation behavior as affected by environment and temperatures, basic corrosion studies, and stress-corrosion cracking.

Dr. Duquette is author or co-author of more than 200 scientific publications, primarily in environmental degradation of materials and electrochemical processing of semiconductor interconnects. Among the awards that he has received are the Willis Rodney Whitney Award from the National Association of Corrosion Engineers in 1990 and the Humboldt Prize from the Alexander von Humboldt Foundation in 1983. He has been elected an Honorary Member of Alpha Sigma Mu, the national mettallurgical honorary society, and has received an Outstanding Paper Award from Acta Metrallurgica. He is a Fellow of the National Association of Corrosion Engineers and of the American Society for Metals and is also a member of the Minerals, Metals & Materials Society and of the Electrochemical Society.

Dr. Duquette spent more than five years as a member of a scientific review group that advised the Canadian government on disposal of high-level nuclear waste. He also has been a member of a panel that advised the United States government on container design and materials selection for disposing of nuclear waste.

Dr. Duquette received a bachelor of science degree from the U.S. Coast Guard Academy in 1961. From 1961 to 1965, he served as a commissioned officer in the U.S. Coast Guard. From 1965 to 1968, he was a research assistant in the Department of Metallurgy and Materials Science at the Massachusetts Institute of Technology (MIT). In 1968, he was awarded a Ph.D. in materials science by MIT. From 1968 to 1970, he worked as a senior research associate in the Advanced Materials Research and Development Laboratory of Pratt and Whitney Aircraft. Dr. Duquette joined the RPI faculty in 1970.

Dr. Duquette lives in Loudonville, New York.

Debra S. Knopman, Ph.D.

On January 17 1997, President William Clinton appointed Debra Knopman to serve on the Nuclear Waste Technical Review Board. Dr. Knopman resigned from the Board on January 17, 2003.

Dr. Debra S. Knopman is director of the Center for Innovation and the Environment of the Progressive Policy Institute in Washington, D.C. She has more than 24 publications in scientific and technical journals to her credit. Dr. Knopman is a member of the National Research Council's Commission on Geosciences, Environment, and Resources and served briefly on the Board on Radioactive Waste Management and the Panel for the Review of the DOE Environmental Restoration Priority System before accepting a position in the Clinton Administration in 1993. She also is a member of the American Geophysical Union. Dr. Knopman was a 1978–1979 Henry Luce Foundation Scholar.

Dr. Knopman brings to the Board special expertise in hydrology, environmental and natural resources policy, systems analysis, and public administration.

In 1975, Dr. Knopman earned a bachelors degree in chemistry from Wellesley College. She completed a master of science degree in civil engineering from the Massachusetts Institute of Technology in 1978 and earned a Ph.D. from the Department of Geography and Environmental Engineering at The Johns Hopkins University in 1986. Dr. Knopman began her career in 1975 as a freelance science writer and editor in Israel and the United States. She served with the Joint Commission on Rural Reconstruction and the Yunlin Irrigation Association as a Luce Scholar in Taiwan from 1978 to 1979 and as legislative assistant for energy and environmental issues to Senator Daniel P. Moynihan in Washington, D.C., from 1979 to 1980. She was a professional staff member of the U.S. Senate Committee on Environment and Public Works from 1980 to 1983 and moved to the U.S. Geological Survey in 1984, beginning as a student assistant and progressing through being a research hydrologist to becoming chief of the systems analysis branch. In 1993, Dr. Knopman was appointed Deputy Assistant Secretary for Water and Science, Department of the Interior. She assumed her current position in 1995.

Dr. Knopman resides in Washington, D.C.

Ronald M. Latanision, Ph.D.

Dr. Ronald M. Latanision was appointed to the Nuclear Waste Technical Review Board on June 26, 2002, by President George W. Bush.

Dr. Latanision is professor emeritus of materials science and engineering and nuclear engineering at the Massachusetts Institute of Technology (MIT) and a principal and Director, Mechanics and Materials in Exponent Corporation. He brings to the Board expertise in materials processing and in corrosion of metals and other materials in aqueous (ambient as well as high-temperature and high-pressure) environments.

Dr. Latanision is the author or co-author of more than 200 scientific publications. Among the awards that Dr. Latanision has received are the David Ford McFarland Award for Achievement in Metallurgy from The Pennsylvania State University Chapter of the American Society for Metals, in 1986, and the Willis Rodney Whitney Award from the National Association of Corrosion Engineers in 1994. He was elected Distinguished Alumnus of The Ohio State University College of Engineering in 1991, and Honorary Alumnus of MIT in 1992.

Dr. Latanision is a Fellow of the American Society of Metals International and the National Association of Corrosion Engineers. He is founder and co-chairman of the New England Science Teachers and is a member of the National Academy of Engineering and the American Academy of Arts and Sciences. He has been a consultant to industry and government and has been active in organizing international conferences.

In 1964, Dr. Latanision received a bachelor of science degree in metallurgy from The Pennsylvania State University. In 1968, he was awarded a Ph.D. in metallurgical engineering by The Ohio State University. In 1968 and 1969, he was a Postdoctoral Fellow at the National Bureau of Standards. From 1969 to 1974, he worked for Martin Marietta Laboratories, first as a research scientist and then as acting head of materials science. He joined MIT in 1975 as director of the H. H. Uhlig Corrosion Laboratory. During a sabbatical in 1982–83, he served as a science advisor to the U.S. House of Representatives Committee on Science and Technology. He also served as a member of the National Materials Advisory Board of the National Research Council.

Dr. Latanision lives in Winchester, Massachusetts.

Priscilla P. Nelson, Ph.D.

Dr. Priscilla P. Nelson was appointed to the Nuclear Waste Technical Review Board on January 17, 1997, by President William Clinton.

Dr. Nelson is Director, Division of Civil and Mechanical Systems, for the Directorate for Engineering at the National Science Foundation. Dr. Nelson brings to the Board special expertise in rock engineering and underground construction.

In 1970, Dr. Nelson earned a bachelor of science degree in geological sciences from the University of Rochester. She earned master of science degrees in geology from Indiana University in 1976 and in structural engineering from the University of Oklahoma in 1979. She was awarded a Ph.D. in geotechnical engineering by Cornell University in 1983. Dr. Nelson's career has included service as a Peace Corps volunteer and employment as a field engineer for the Alaskan Resource Sciences Corporation from 1975 to 1977. She joined the faculty of The University of Texas at Austin in 1983 and became full professor and holder of the John Focht Teaching Fellowship before joining the National Science Foundation in 1996. She has served as a consultant for major underground construction projects, including for the Superconducting Super Collider project from 1985 through 1992.

Dr. Nelson has more than 13 years of teaching experience and more than 100 technical and scientific publications to her credit. She has served as a member of the U.S. National Committee for Rock Mechanics, the U.S. National Committee for Tunneling Technology, and the Board on Radioactive Waste Management, all activities of the National Research Council. She is a member of the American Rock Mechanics Association (ARMA), the American Society of Civil Engineers (ASCE), the International Tunnelling Association, the American Underground Construction Association, the Association of Engineering Geologists, the American Society for Engineering Education, and other professional organizations. She is past president of the Geo-Institute of ASCE and of ARMA. Her honors and awards include Exxon Teaching Fellowships at The University of Texas at Austin (1985–1987), the Case Studies Award from the U.S. National Committee for Rock Mechanics (1988), the Haliburton Education Foundation Award of Excellence (1991), the Basic Research Award from the U.S. National Committee for Rock Mechanics (1993), and election to The Moles, an association of the heavy construction industry (1995). At the National Science Foundation, she has received the Director's Award for Integrative Collaboration three times, and she received the Director's Award for Meritorious Service in 1997. In 1999, she was appointed to the Senior Executive Service. Also in 1999, she received the Director's Award for Superior Accomplishment from the NSF.

Dr. Nelson lives in Arlington, Virginia.

Richard R. Parizek, Ph.D.

Dr. Richard R. Parizek was appointed to the Nuclear Waste Technical Review Board on February 11, 1997, by President William Clinton.

Dr. Parizek is a professor of geology and geoenvironmental engineering at the Pennsylvania State University; president of Richard R. Parizek and Associates, consulting hydrogeologists and environmental geologists; and a registered Professional Geologist. Dr. Parizek brings to the Board special expertise in hydrogeology and environmental geology. His research interests include the hydrogeology of karst, fractured rock, and glaciated terranes; factors controlling groundwater occurrence and movement; and the relationship between land use and groundwater pollution resulting from disposal of nuclear waste and other hazardous substances.

Dr. Parizek has more than 42 years of teaching experience and numerous journal publications to his credit. His awards include a cooperative fellowship from the National Science Foundation (1960), Kurl Mason Award, Pennsylvania Department of Environmental Resources, superior achievement award from the U.S. Environmental Protection Agency (1976), the Clearwater Conservancy Award (1985), the Matthew J. and Anne C. Wilson Teaching Award (1986), the medal for distinguished service to environmental science and engineering of the Institute of Meteorology and Water Management, Warsaw, Poland (1991), M. King Hubbard Award, National Ground Water Association (1998), Award for Distinguished Service in Hydrogeology, Geological Society of America (1999), and C.V. Theis Award, American Institute of Hydrology (2001). Dr. Parizek was appointed an administrative law judge of the Atomic Safety and Licensing Board Panel of the U.S. Nuclear Regulatory Commission in 1990, a position he left upon appointment to the Nuclear Waste Technical Review Board.

Dr. Parizek is a member of the American Association for the Advancement of Science, the American Institute of Hydrology, the Geological Society of America, the National Groundwater Association, the International Association of Scientific Hydrology, and Sigma Xi.

In 1956, Dr. Parizek earned a bachelor of science degree in geology from the University of Connecticut. He earned a master of science degree in geology in 1960 and a Ph.D. in geology in 1961, both from the University of Illinois. Dr. Parizek began his career as research assistant with the Illinois State Geological Survey in 1956 and began teaching in 1961 as assistant professor of geology and geophysics at The Pennsylvania State University. He became a full professor in 1971 and continues to teach in the Department of Geosciences. Dr. Parizek also has been a visiting scientist with the U.S. Geological Survey and a visiting scholar at Stanford University, the Desert Research Institute, Changchun College of Geology and the Institute of Karst Geology in the Peoples' Republic of China, and National Cheng Kuug University in Taiwan.

Dr. Parizek lives in State College, Pennsylvania.

Appendix B
2003 Meeting List

January 28 — **Winter Board Meeting**
Las Vegas, Nevada
Topics:
- Yucca Mountain science programs
- Materials testing
- Barrier analyses

Transcript available

January 29–30 — **Board Business Meeting**
Las Vegas, Nevada
Minutes available

February 24 — **Joint Panel on the Repository and Panel on Site Characterization Meeting**
Las Vegas, Nevada
Topic:
- Seismic issues

Transcript available

February 25 — **Panel on the Waste Management System Meeting**
Las Vegas, Nevada
Topics:
- Waste receipt
- Transportation
- Repository operation

Transcript available

May 13–14 — **Spring Board Meeting**
Washington, D.C.
Topic:
- Thermal aspects of Yucca Mountain repository design

Transcript available

May 14–15 — **Board Business Meeting**
Washington, D.C.
Minutes available

September 16–17 **Fall Board Meeting**
Amargosa Valley, Nevada
Topics:
- Program update and project review
- Flow and transport in the unsaturated and saturated zones
- Updates on igneous issues
- Updates on DOE's transportation activities

Transcript available

September 17–18 **Board Business Meeting**
Las Vegas, Nevada
Minutes available

Appendix C
Panel Organization

Panel on the Natural System

Chair:	Richard R. Parizek	Staff:	David M. Diodato*
Members:	Thure E. Cerling		John H. Pye
	Norman L. Christensen, Jr.		Leon Reiter
	Paul P. Craig		
	Priscilla P. Nelson		

Panel on the Engineered System

Chair:	Ronald M. Latanision	Staff:	Carlos A. W. Di Bella*
Members:	Daniel B. Bullen		John H. Pye
	Paul P. Craig		Karyn D. Severson
	David J. Duquette		
	Priscilla P. Nelson		

Panel on Repository System Performance and Integration

Chair:	Daniel B. Bullen	Staff:	Leon Reiter*
Members:	Mark D. Abkowitz		David M. Diodato
	Thure E. Cerling		Daniel S. Metlay
	Ronald M. Latanision		John H. Pye
	Priscilla P. Nelson		
	Richard R. Parizek		

Panel on the Waste Management System

Chair:	Norman L. Christensen, Jr.	Staff:	Daniel J. Fehringer*
Members:	Mark D. Abkowitz		Carlos A. W. Di Bella
	Daniel B. Bullen		Joyce M. Dory
	Paul P. Craig		Daniel S. Metlay
	David J. Duquette		Karyn D. Severson

* Staff coordinator

Appendix D
U.S. Nuclear Waste Technical Review Board Publications

The following publications are available by mail from the Nuclear Waste Technical Review Board or electronically from the Board's Web site at **www.nwtrb.gov**.

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

This letter and attachments constitute the Board's second report to Congress and the Secretary of Energy for calendar year 2003. This 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. It also contains the Board Technical Report on Localized Corrosion.

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 Congress and the Secretary of Energy. 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.

Report by letter 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.

Report to Congress and the Secretary of Energy. 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 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 long-term 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 suitability 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.

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 under way 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: January to December 1996. 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 NRC. 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 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 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 The Office of Civilian Radioactive Waste Management's (OCRWM) 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 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 focuses on the exploratory studies facility (ESF) 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 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 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 Board's 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, reposi-

tory 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 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 15 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 Board's report provides update on the Board's activities and explores in depth the following areas: 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 EPA, the 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 Board's 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 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 Board's report sets the stage for the Board's evaluation of the 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 E

Communication Between U.S. Nuclear Waste Technical Review Board and U.S. Department of Energy

In addition to published reports, the Board periodically writes letters to the Director of the U.S. Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM). The letters typically provide the OCRWM with the Board's views on specific technical areas earlier than do Board reports. The letters are posted on the Board's Web site after they have been sent to the OCRWM. For archival purposes, the eight Board letters written during the period covered by this report are reproduced here.

The OCRWM typically responds to the Board's reports and letters, indicating its plans to respond to the Board's recommendations. Included here are the OCRWM's responses received by the Board during calendar year 2003. Inclusion of these responses does not imply the Board's concurrence.

- Letter from Michael L. Corradini to Margaret S. Y. Chu, Director, OCRWM; March 5, 2003.
  Subject: DOE's participation at the January Board meeting

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Michael L. Corradini; June 26, 2003.
  Subject: DOE's responses to recommendations in the March 5, 2003 letter

- Letter from Michael L. Corradini to Margaret S. Y. Chu, Director, OCRWM; April 30, 2003.
  Subject: DOE's participation at Panel on the Waste Management System meeting on transportation issues held February 24, 2003

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Michael L. Corradini; July 22, 2003.
  Subject: DOE's responses to recommendations in the April 30, 2003 letter

- Letter from Michael L. Corradini to Margaret S. Y. Chu, Director, OCRWM; June 27, 2003.
  Subject: DOE's participation at Panel on the Natural Systems and Panel on the Engineered System meeting on seismic issues held February 24, 2003

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Michael L. Corradini; October 8, 2003.
  Subject: DOE's responses to recommendations in the June 27, 2003 letter

- Letter from Michael L. Corradini to Margaret S. Y. Chu, Director, OCRWM; June 30, 2003.
  Subject: DOE's participation at the May Board meeting

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Michael L. Corradini; October 10, 2003.
  Subject: DOE's responses to recommendations in the June 30, 2003 letter

- Letter from Michael L. Corradini to Margaret S. Y. Chu, Director, OCRWM; October 21, 2003. Subject: Board comments the data and analyses presented at the May Board meeting

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Michael L. Corradini; October 27, 2003. Subject: DOE's responses to recommendations in the October 21, 2003 letter

- Letter from Michael L. Corradini to Margaret S. Y. Chu, Director, OCRWM; November 25, 2003. Subject: Transmittal of Board technical report

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Michael L. Corradini; December 17, 2003. Subject: DOE's responses to recommendations in the letter of October 21, 2003 and report of November 25, 2003

- Letter from Michael L. Corradini to Margaret S. Y. Chu, Director, OCRWM; December 4, 2003. Subject: Board January panel meetings

- Letter from Michael L. Corradini to Margaret S. Y. Chu, Director, OCRWM; December 16, 2003. Subject: DOE's participation at the September Board meeting

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

March 5, 2003

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

On behalf of the U.S. Nuclear Waste Technical Review Board, I want to thank you for participating in the Board's meeting on January 28, 2003, in Las Vegas, Nevada. We found your program overview and the presentations by individuals from the Department of Energy (DOE) and its contractors very clear and helpful to the Board in carrying out its responsibility to review the scientific and technical validity of DOE activities. The Board's observations and several recommendations drawn from the information presented at the meeting are summarized below.

Natural Barriers

Encouraging the DOE to develop a better fundamental understanding of the potential behavior of the natural barriers in a Yucca Mountain repository has long been a Board priority. Two presentations at the meeting dealt with issues that have relevance for such understanding.

Chlorine-36 – The Board previously has recommended that the DOE resolve the contradictory analyses related to the possible presence of bomb-pulse chlorine-36 at the repository horizon. The Board realizes that the DOE's conceptual and numerical models for flow and transport in the unsaturated zone attempt to reduce the relevance of the contradictions by assuming the presence of fast flow paths in the unsaturated zone. However, the Board believes that developing a basic understanding of key processes inside Yucca Mountain that may affect repository performance is essential. This understanding should include whether or not fast flow paths are present in the unsaturated zone and the extent of rapid water movement through the fast paths if they do exist. In addition, discrepancies in results between two DOE-supported groups measuring the same phenomenon affect the credibility of the program. The Board continues to believe that the DOE should persist in its efforts to reach scientific consensus on the results of the chlorine-36 analyses and the implications of those results for fluid flow in Yucca Mountain.

Paleosols – Field investigations and numerical modeling of heterogeneous alluvial sedimentary deposits show that even relatively thin low-permeability deposits can significantly alter directions and rates of water flow and chemical transport in the saturated zone. Ancient soils known as "paleosols" can form these thin low-permeability deposits within alluvial

sedimentary sequences and are known to occur in the Yucca Mountain region. Also, depending on their mineralogical properties, paleosols can potentially retard the chemical-transport rates of some radionuclides. Taken together, these characteristics suggest that paleosols merit exploratory investigation by project hydrogeologists.

Engineered Barriers

As noted in previous Board reports and letters, uncertainties related to the performance of the engineered barriers are extremely important, particularly given the prominence of the engineered barriers in DOE estimates of repository performance and DOE's decision to use a high-temperature repository design in its license application. Several presentations at the meeting dealt with factors that could affect the potential performance, development, or procurement of the engineered barriers in a Yucca Mountain repository.

Corrosive environments – Contractors for the State of Nevada presented experimental results showing that highly corrosive brines and condensates can be produced at laboratory scale by distillate boiling of concentrated synthetic porewaters at atmospheric pressure. However, the presentations did not include a specific sequence of events that would cause such corrosive solutions to develop in a repository at Yucca Mountain. The presentations also did not include estimates of the likelihood that such solutions would occur in a repository or of the extent of such solutions if they were to occur. Dr. Joseph Farmer gave a very informative presentation on the Project's view that the evolution of such highly corrosive environments in a repository at Yucca Mountain would be unlikely. Except in the case of acid-gas generation, however, his presentation did not include the Project's technical basis for this view (i.e., that the generation of certain highly corrosive solutions would be either implausible or so unlikely or minor in extent as to be insignificant).

Clearly, corrosive solutions are *possible*; the necessary porewater, decay heat from the waste packages, and in-drift conditions (i.e., high temperatures, pressure, humidity) would be present in a repository at Yucca Mountain. However, the Board does not know, at this point, whether a case can be made that corrosive solutions would be so likely and widespread that they would be a concern or whether a case can be made that they would be so unlikely and sparse that they would be insignificant. Presentations convey data, views, and progress, but complex hypotheses and models require carefully prepared and reviewed technical reports for their explanation and defense. Thus, we urge the Project to ensure that the analysis and model report (AMR) that deals with the evolution of chemical environments on waste package surfaces contains a defensible technical basis, including the full logic, explanations, and assumptions underlying the Project's view that widespread corrosive solutions are unlikely.

We asked at the meeting whether a repository with lower peak temperatures of waste package surfaces would reduce the uncertainty, likelihood, or severity of corrosive solutions. However, the question was not answered directly. The Board believes that the Project should answer this question, and, if the answer is "Yes," a second question, "How much?" also should be answered. The technical basis for both answers should be documented carefully and completely in an AMR.

Materials studies – The Board was encouraged by the information presented on studies of corrosion in the presence of deliquescence, seepage, and $CaCl_2$ brines, but we note that many more studies, especially at elevated temperatures, will be needed to adequately explore potential corrosion mechanisms and corrosion rates in a high-temperature repository. The Board concurs with the observation of the Waste Package Materials Performance Peer Review Panel that the Project staff needs a senior-level, visionary leader with a strong background in materials science and engineering and with very good management credentials. Such a person could develop a systematic approach for identifying needed materials studies, ensure continuity of the effort, and enhance communication with the technical community.

Prototype manufacturing – The Board is pleased that the DOE plans to procure waste package prototypes and develop welding processes. Programs in other countries that have undertaken prototyping activities have learned a great deal. In fact, some programs have encountered surprises that have taken considerable time to resolve. Manufacturing waste packages to the specifications required for a repository may require a significant development effort and corresponding lead-time before repository operations can begin. Information presented at the Board meeting did not contain detailed justification for the number of prototypes planned, but the Board concurs with the timing of the initial development effort. The Board strongly urges the DOE to begin prototype development as soon as possible.

As experience is gained, useful modifications of the waste package design may be identified. For example, the DOE may find that dual Alloy-22 lids may not be justified in light of the manufacturing complexity associated with a dual-lid design. The current plan not to stress-relieve or otherwise mitigate tensile stresses of the inner Alloy-22 closure weld also raises questions about the value of the dual-lid concept. Finally, because the trunnion-collar sleeves appear complex and their attachments to the waste package appear prone to crevice corrosion, there may be a need to reconsider these parts of the design during prototype manufacturing.

Repository System and Integration

The Board also has urged the DOE to gain a better understanding of the potential behavior of the entire repository system through continued scientific studies and through analysis of the contribution of different barriers to repository performance. Presentations at the meetings touched on these issues.

Barrier performance – The Board is pleased that the DOE continues exploring ways to determine and display the contributions of individual barriers to performance of the overall repository system. The Board believes that such analyses can provide important insights into the respective roles of the different barriers. Furthermore, there appear to be opportunities for improving both the analytical approach for analyzing the performance of individual barriers and the clarity of the presentation of study results. The Board urges the DOE to continue this effort.

On-going scientific studies – Results from scientific studies, such as experiments in the cross drift and the cool-down phase of the drift-scale heater test, may be very valuable in increasing understanding of the potential behavior of a repository system at Yucca Mountain. However, these studies will require adequate funding and the attention of management to realize

their true potential. As the Yucca Mountain project focuses on licensing activities, the temptation may be to divert resources from scientific studies to the licensing effort. The Board encourages the DOE to institute mechanisms that will ensure adequate funding and management commitments to on-going scientific studies.

Waste Management System

With the approval of the site recommendation, the DOE's plans for operating the waste management system, including waste acceptance, transportation, and operations at a Yucca Mountain repository, have become extremely important. Since funding constraints in this area have caused plans to be deferred for several years, the Board is pleased to see that the DOE will resume work on the waste management system this year. The Board views this as a very important area and will hold additional meetings to review DOE plans in the coming months.

The Board recommends that the transportation planning and development effort adopt a "systems" approach, addressing both strategic and operational considerations. The Board views the early involvement of external stakeholders as critical to developing a comprehensive plan for the waste management system and to building public confidence in those plans. Because proactive engagement of external stakeholders is a time-consuming process, the Board encourages the DOE to initiate this activity as soon as possible.

Once again, the Board thanks you, the DOE staff, and the DOE contractors for supporting the Board's January meeting. We look forward to continuing our ongoing technical and scientific review and to commenting on DOE activities in the future.

Sincerely,

[Signed By]

Michael L. Corradini
Chairman

Department of Energy
Washington, DC 20585

June 26, 2003

Dr. Michael L. Corradini, Ph.D.
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, VA 22201-3367

Dear Dr. Corradini:

Thank you for your letter of March 5, 2003, providing the Nuclear Waste Technical Review Board's (Board) perspective on information presented by the U.S. Department of Energy (Department) at the Board's January 2003 meeting.

The Department appreciates the Board's continuing review of our activities as we continue development of science, design, and analysis, including a license application, for a repository at Yucca Mountain. Our responses to the views expressed by the Board are summarized in the enclosure to this letter.

The Department continues to benefit from the constructive views of the Board, and we look forward to continuing our dialogue.

Sincerely,

Dr. Margaret S.Y. Chu, Director
Office of Civilian Radioactive
Waste Management

Enclosure:
Responses to the March 5, 2003 letter to the U.S. Department of Energy (DOE) from the Nuclear Waste Technical Review Board

Responses to the March 5, 2003 letter to the U.S. Department of Energy (DOE) from the Nuclear Waste Technical Review Board

Natural System

The Board continues to believe that the DOE should persist in its efforts to reach scientific consensus on the results of the chlorine-36 analyses and the implications of those results for fluid flow in Yucca Mountain.

Response:

The DOE agrees that it is important to resolve the discrepancies in results between two DOE-supported groups measuring the same phenomenon. As noted in our letter of January 24, 2003[1], DOE is pursuing resolution of the legacy discrepant data sets by

- having the institutions involved to date document the results to date and propose a plan to resolve the discrepancies, and
- considering an independent new validation study as a parallel, complementary effort.

Isotopic evidence of the existence of fast pathways has guided the development of the unsaturated-zone flow conceptual model which includes dual-permeability concepts that can capture the range of travel times corresponding to flow in the matrix and flow in fractures. The quantitative ^{36}Cl information has been compared with the numerical results of the model. The information is used as "supporting data" rather than as a target for model calibration. Even though the ^{36}Cl data were not used to calibrate the unsaturated flow model (CRWMS M&O 2000, Section 3.7.4.4[2]), the distribution of travel times predicted by the model is consistent with the data. The occurrence of some rapid transport has been built into the conceptual and numerical models of unsaturated-zone flow and transport to be consistent with isotopic evidence, and the TSPA calculations capture this behavior within the range of uncertainty in the existing isotopic data.

Field investigations and numerical modeling of heterogeneous alluvial sedimentary deposits show that even relatively thin low-permeability deposits can significantly alter directions and rates of water flow and chemical transport in the saturated zone. Ancient soils known as "paleosols" can form these thin low-permeability deposits within alluvial sedimentary sequences

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[1] Chu, Margaret, 2003. Letter to Michael L. Corradini responding to the views expressed by the Board on information presented in the September 2003 NWTRB meeting, with enclosure. January 24, 2003.

[2] CRWMS M&O 2000c. *Unsaturated Zone Flow and Transport Model Process Model Report.* TDR-NBS-HS-000002 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O.

and are known to occur in the Yucca Mountain region. Also, depending on their mineralogical properties, paleosols can potentially retard the chemical-transport rates of some radionuclides. Taken together, these characteristics suggest that paleosols merit exploratory investigation by project hydrogeologists.

Response:

At the January meeting, Dr. Graham Fogg from the University of California at Davis gave an interesting presentation[3] on the influence of paleosols on fluid flow and transport in complex alluvial sediments. The DOE will consider the merit of investigating paleosols in the alluvium along with other proposals for additional studies under consideration in the Science and Technology Program.

Engineered Barriers Corrosive Environments

Contractors for the State of Nevada presented experimental results showing that highly corrosive brines and condensates can be produced at laboratory scale by distillate boiling of concentrated synthetic pore waters at atmospheric pressure. However, the presentations did not include a specific sequence of events that would cause such corrosive solutions to develop in a repository at Yucca Mountain. . . . The *Board does not know, at this point, whether a case can be made that corrosive solutions would be so likely and widespread that they would be a concern or whether a case can be made that they would be so unlikely and sparse that they would be insignificant. . . . Thus, we urge the Project to ensure that the analysis and model report (AMR) that deals with the evolution of chemical environments on waste package surfaces contains a defensible technical basis, including the full logic, explanations, and assumptions underlying the Project's view that widespread corrosive solutions are unlikely.*

Response:

During the recent May NWTRB meeting, the DOE made an extensive set of integrated presentations[4] laying out why we believe that a strong case can be made for the efficacy of our current design approach. Both the in-drift environment and the corrosion resistance of the engineered barriers were discussed in detail. As usual, the interaction with the Board was very useful to us, because it brought forward issues and areas where we need to provide the Board with additional analysis and, in some cases, where we need to collect or analyze additional data to supplement the analyses and data that we presented.

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[3] Fogg, G. E. 2003. *Influence of Paleosols on Fluid Flow and Transport: Perspective on Alluvial Complexity and Hydrogeology.* Presentation to the Nuclear Waste Technical Review Board Winter Meeting, January 28, 2003. Las Vegas, Nevada.

[4] Boyle, W. 2003. *Logic for Evaluating Engineered Barrier Performance.* Presentation at the Nuclear Waste Technical Review Board Spring Meeting, May 13-14, 2003. Washington, DC; Bodvarsson, G. May 13-14, 2003. *The Character of the Unsaturated Zone.* Washington, DC; Peters, M. 2003. *The Character of the In-Drift Environment.* Presentation at the Nuclear Waste Technical Review Board Spring Meeting, May 13-14, 2003. Washington, DC; Farmer, J. 2002. *Materials Performance.* Presentation at the Nuclear Waste Technical Review Board Spring Meeting, May 13-14, 2003. Washington, DC.

The DOE agrees that documentation of the evolution of the chemical environment on waste packages surfaces should contain a defensible technical basis that clearly states the assumptions and conclusions supporting the definition of the environment. The DOE is preparing or updating several Analysis and Modeling Reports that will collectively address our understanding of the evolution of the in-drift environment and the effect of that environment on waste package and drip shield surfaces. The long-term performance of a repository as analyzed using our current approach depends on the longevity of the waste package (especially since, in our view, conservative assumptions about the natural system diminish the relative projected effectiveness of the natural barriers). While the material selected for the outer barrier of the waste package is a very corrosion resistant alloy, environments can be created in the laboratory where this material undergoes unacceptable rates of corrosion. However, in our May presentations to the Board, we provided the Project's basis for concluding that these environments will not exist in the repository itself.

The DOE looks forward to the Board's reaction to our May presentations, but more importantly to the Board's insights and recommendations. We believe that more such integrated presentations, in which we can provide a more integrated picture of the fundamental basis for the efficacy of our design, should be planned for future Board meetings.

We asked at the meeting whether a repository with lower peak temperatures of waste package surfaces would reduce the uncertainty, likelihood, or severity of corrosive solutions. However, the question was not answered directly. The Board believes that the Project should answer this question, and, if the answer is "Yes," a second question, "How much?" also should be answered. The technical basis for both answers should be documented carefully and completely in an AMR.

Response:

The DOE agrees that maintaining below-boiling rock would reduce the uncertainties related to coupled processes.

However, as we discussed in our presentations[5] during the recent May Board meeting, we believe that a higher-temperature operating mode will lead to the drifts being drier for much longer, limiting aqueous phase corrosion due to seepage. We look forward to further interactions with the Board as we explain our data and models on this aspect in more detail, and obtain more in-depth Board review and comment on them.

The DOE has clearly indicated its intention to proceed to License Application with a design that retains the flexibility to be operated in a cooler mode should that be deemed necessary. Testing and analysis are ongoing to improve the technical basis for selecting postclosure thermal conditions. This experimental program and associated analyses will continue. As additional data and analyses are completed, the DOE will re-evaluate the technical basis for the choice of postclosure thermal conditions.

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[5] Bodvarsson, G. 2003 (op. cit.); Peters, M. 2003. (op. cit.); Farmer, J. 2003 (op. cit.)

Materials studies

The Board was encouraged by the information presented on studies of corrosion in the presence of deliquescence, seepage, and $CaCl_2$ brines, but we note that many more studies, especially at elevated temperatures, will be needed to adequately explore potential corrosion mechanisms and corrosion rates in a high-temperature repository.

Response:

The DOE agrees that additional studies are needed to adequately explore potential corrosion mechanisms in relevant repository environments more fully, particularly at the higher temperatures that will exist for a certain period of time in the repository's future evolution. As we discussed during our presentations[6] to the Board in the recent May meeting, the DOE is conducting tests in highly corrosive environments such as concentrated bulk calcium chloride environments (8 to 9 molar) with and without nitrate at temperatures above 120°C to characterize high-temperature corrosion processes. Initial results show that there is little margin between Alloy 22 corrosion potential and the critical potential for the initiation of localized corrosion. However, as noted during the January Board meeting[7], and again during the May meeting[8], calcium chloride brines are unstable in open systems and are unrealistic in a repository at Yucca Mountain. The ongoing materials testing program will continue to provide additional data to strengthen the technical basis for our understanding of corrosion mechanisms in relevant repository environments.

The Board concurs with the observation of the Waste Package Materials Performance Peer Review Panel that the Project staff needs a senior-level, visionary leader with a strong background in materials science and engineering and with very good management credentials. Such a person could develop a systematic approach for identifying needed materials studies, ensure continuity of the effort, and enhance communication with the technical community.

Response:

The observations of both the Board and the Panel on the value of a senior-level, visionary leader for the materials program are appreciated, and we are taking them seriously.

Prototype manufacturing

The Board is pleased that the DOE plans to procure waste package prototypes and develop welding processes. Programs in other countries that have undertaken prototyping activities have learned a great deal. In fact, some programs have encountered surprises that have taken considerable time to resolve. Manufacturing waste packages to the specifications required for

[6] Farmer, J. 2003. (op cit.)

[7] Farmer, J. C. 2003. *Chemical Environment Evolution on Alloy 22.* Presentation at the Nuclear Waste Technical Review Board Winter Meeting, January 28, 2003. Las Vegas, Nevada.

[8] Peters, M. 2003. (op. cit.); Farmer, J. 2003. (op. cit.).

a repository may require a significant development effort and corresponding lead-time before repository operations can begin. Information presented at the Board meeting did not contain detailed justification for the number of prototypes planned, but the Board concurs with the timing of the initial development effort. The Board strongly urges the DOE to begin prototype development as soon as possible.

As experience is gained, useful modifications of the waste package design may be identified. For example, the DOE may find that dual Alloy-22 lids may not be justified in light of the manufacturing complexity associated with a dual-lid design. The current plan not to stress-relieve or otherwise mitigate tensile stresses of the inner Alloy-22 closure weld also raises questions about the value of the dual-lid concept. Finally, because the trunnion-collar sleeves appear complex and their attachments to the waste package appear prone to crevice corrosion, there may be a need to reconsider these parts of the design during prototype manufacturing.

Response:

The DOE recognizes the importance of waste package prototypes and has included prototypes as a fundamental part of the design, procurement, and fabrication strategy of the project. The DOE considers the manufacture of prototypes to be an integral part of the design process and recognizes the valuable information and knowledge that will come from a waste package prototype program. Accordingly, the DOE has planned and implemented a waste package prototype design, development, and fabrication program that started this year.

At this stage of the project, the DOE has planned for a total of fifteen waste package prototypes. These prototypes will be used in various ways:

- Several prototypes will be used to verify the closure processes and systems. The lids will be welded on the prototypes to verify the welding process, nondestructive examination processes, stress mitigation process, inerting process, leak detection process, robotic systems, and control systems, and to develop processes to repair closures that do not meet all requirements, as well as the integration of all these processes and systems.

- Several prototypes will be used for potential future destructive and non-destructive testing. Depending on the information required and requested, it is anticipated that these tests could include ring core tests, American Society of Testing Materials proof tests, drop tests, metallography, and others.

- Several prototypes will be used in the proposed training facility to demonstrate waste package handling processes.

- Prototypes will be necessary in the Operational Readiness Review process.

- Prototypes will be used in the training facility to train operators for Operational Readiness Review, start-up, and actual operations.

The manufacture of fifteen waste package prototypes will allow significant flexibility. Numerous combinations of the ten waste package configurations could be manufactured depending on the project needs. These fifteen prototypes will be manufactured over a 4 to 5 year

period starting in 2004, so determinations can be made in the future as to which configurations need to be manufactured. Furthermore, if a greater number of prototypes were necessary for any of the previously mentioned reasons (closure, training, etc.), it would be possible to manufacture several ¼ or ½ scale mockups, or even just the tops, instead of a single full-sized prototype for approximately the same cost.

The DOE agrees with the Board that, as design progresses and post-closure performance predictions evolve, it may be determined that the inner Alloy-22 lid will not be necessary. Because that determination has not yet been made, however, the first waste package prototype will include the inner Alloy-22 lid.

The DOE also agrees with the Board that the trunnion-collar sleeves may need to be reconsidered for various reasons. Fabrication of the first waste package prototype will provide valuable information that will allow decisions to be made regarding the trunnion-collar sleeves and, in fact, the trunnion-collar itself.

Repository System and Integration

Barrier performance - The Board is pleased that the DOE continues exploring ways to determine and display the contributions of individual barriers to performance of the overall repository system. The Board believes that such analyses can provide important insights into the respective roles of the different barriers. Furthermore, there appear to be opportunities for improving both the analytical approach for analyzing the performance of individual barriers and the clarity of the presentation of study results. The Board urges the DOE to continue this effort.

Response:

The DOE agrees that analysis of the contribution of the natural and engineered barriers can provide important insights into repository performance and will continue to evaluate and improve the analytical approaches for analyzing the performance of individual barriers. As noted in our January letter to the Board[9], the barrier capability analyses may include evaluations of intermediate performance measures from the Total System Performance Assessment (TSPA) and pinch point analyses that report radionuclide mass flux or concentrations at selected interfaces between model components. These approaches to evaluating barrier capability are described in section 8.3 of the TSPA-LA Methods and Approach document[10]. These analyses will focus on the capabilities of these barriers to limit movement of water or radionuclides.

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[9] Chu, Margaret, 2003. Letter to Michael L. Corradini responding to the views expressed by the Board on information presented in the September 2002 NWTRB meeting, with enclosure. January 24, 2003.

[10] BSC (Bechtel SAIC Company, LLC) 2002. Total System Performance Assessment-License Application Methods and Approach. TDR-WIS-PA-000006, Rev. 00, Las Vegas, Nevada; Bechtel SAIC Company, LLC.

On-going scientific studies – As the Yucca Mountain project focuses on licensing activities, the temptation may be to divert resources from scientific studies to the licensing effort. The Board encourages the DOE to institute mechanisms that will ensure adequate funding and management commitments to on-going scientific studies.

Response:

The DOE agrees that results of scientific studies will be valuable in increasing understanding of the potential behavior of the repository. To this end, DOE is planning additional scientific studies that will continue through the various stages of repository development, licensing, and operation as the project moves forward. This includes the Performance Confirmation program, which we expect will be the subject of a DOE presentation to the Board at a future meeting. The DOE has also initiated a Science and Technology Program with two objectives: 1) to improve existing and develop new technologies to achieve efficiencies, in terms of safety and savings, in the waste management system; and 2) to increase understanding of repository performance. An update on the Science and Technology program was presented at the May 2003 Board meeting. We look forward to continuing Board review as this new Program develops.

Waste Management System

With the approval of the site recommendation, the DOE's plans for operating the waste management system, including waste acceptance, transportation, and operations at a Yucca Mountain repository, have become extremely important. Since funding constraints in this area have caused plans to be deferred for several years, the Board is pleased to see that the DOE will resume work on the waste management system this year. The Board views this as a very important area and will hold additional meetings to review DOE plans in the coming months.

Response:

The DOE agrees that work on the waste management system is important and will be pleased to support future meetings with the Board to review DOE plans in this area.

The Board recommends that the transportation planning and development effort adopt a "systems" approach, addressing both strategic and operational considerations. The Board views the early involvement of external stakeholders as critical to developing a comprehensive plan for the waste management system and to building public confidence in those plans. Because proactive engagement of external stakeholders is a time-consuming process, the Board encourages the DOE to initiate this activity as soon as possible.

Response:

The DOE agrees with the Board's recommendation that transportation planning and development should use a systems approach for both strategic and operational concerns to ensure that the transportation system and its operation are safe, secure, and reliable. As we noted in the

February Panel meeting on the Waste Management System[11], the DOE is committed to an institutional process that includes working closely with states, tribes, and local governments affected by the transportation of Spent Nuclear Fuel and high-level waste to Yucca Mountain. The DOE will build on previous cooperative planning experience, such as our experience at the Waste Isolation Pilot Plant, in developing its transportation plan.

[11] Williams, J. 2003. *Developing a successful transportation program.* Presentation at the Nuclear Waste Technical Review Board Panel Meeting on the Waste Management System, February 25, 2003. Las Vegas, Nevada.

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

April 30, 2003

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

On behalf of the U.S. Nuclear Waste Technical Review Board, I want to thank your staff for participating in the February 25, 2003, meeting of the Board's Panel on the Waste Management System in Las Vegas, Nevada. We found the presentations very clear and helpful in carrying out the Board's evaluation of the technical and scientific validity of activities undertaken by the Secretary of Energy related to managing the disposal of the nation's spent nuclear fuel and high-level radioactive waste.

A major purpose of the meeting was to familiarize the Panel members with the baseline from which DOE work will progress in the years ahead. We think that goal was achieved. The presentations at the meeting make clear that a sustained and well-thought-out effort will be needed to develop a transportation program that will engender public confidence. Other observations and recommendations drawn from the information presented at the meeting are summarized below.

Transportation and Waste Acceptance

In the Board's view, the DOE should adopt safety as a guiding principle in planning and developing a transportation system and should develop an integrated safety plan for guiding the development process. The schedule for such transportation planning also is important, and it appears that the DOE's current timetable may be optimistic, considering the substantial amount of work to be done. For example, the DOE presentation identified a transportation strategic plan, to be issued in fiscal year 2003; a transportation project management plan, to be developed during fiscal year 2003; and transportation operations plans, to be developed in fiscal year 2005 and beyond. As the highest-level document, the strategic plan is clearly the most urgent, and public involvement in its development is essential. The Board recommends that the DOE publish a draft strategic plan for public comment as soon as practical.

During the afternoon session, several representatives of affected local governments made excellent presentations on potential issues of concern related to the transportation of spent nuclear fuel through their areas. These presentations and the comments of members of the public made clear that affected parties would like to know as soon as possible what modes and routes will be used for transporting spent nuclear fuel to a Yucca Mountain repository so that they can

begin their own preparations. The Board also is interested in this information and requests that the DOE provide its timeline for making those decisions and for issuing the "Record of Decision" for the Yucca Mountain final environmental impact statement.

The DOE presentation indicated that, because of pending lawsuits, there are few, if any, on-going interactions on waste acceptance between the DOE and electric utilities. However, it is apparent that significant coordination is needed for the waste acceptance process to be smooth and efficient. For example, no casks have been certified for transporting some of the higher-burnup spent fuel likely to be generated in the future. Coordination of cask development (and certification) with utility shipping needs and with repository and transportation-system capabilities will be important for efficient operations. The DOE should seek approaches to improving communication with utilities in a way that will facilitate planning for the waste acceptance process.

Surface and Underground Facilities

The Board would appreciate receiving additional information on two significant issues related to the design and operation of surface and underground facilities. First is the possibility that a small amount of spent fuel will be damaged during transportation to Yucca Mountain. Spent fuel found to be damaged when the casks are opened at the surface facilities will be handled in the remediation building. However, DOE does not plan to have the remediation building operational until three years after the receipt of spent fuel begins. The Board requests more information about the DOE's plans for resealing and storing damaged spent fuel during the interim period before construction of the remediation building. Second, the DOE presentation identified two potentially significant changes in the design and operation of the underground facilities: (1) use of a wheeled waste transporter and (2) location of exhaust drifts and shafts. The Board would like more details on the technical bases for these concepts.

Again, thank you for the DOE's support of this meeting. Waste acceptance and transportation are likely to become topics of significant interest in the months ahead, and the Panel on the Waste Management System anticipates holding additional meetings to review the DOE's progress in this area.

Sincerely,

{Signed by}

Michael L. Corradini
Chairman

Department of Energy
Washington, DC 20585

July 22, 2003

Dr. Michael L. Corradini
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, Virginia 22201-3367

Dear Dr. Corradini:

Thank you for your April 30, 2003, letter expressing the Nuclear Waste Technical Review Board's (Board) perspective on our February 25, 2003 meeting.

The Department of Energy appreciates and values the Board's continuing review of our activities as we proceed toward submitting a license application for a repository construction authorization to the Nuclear Regulatory Commission. Our responses to the views expressed by the Board are presented in the enclosed letter.

The Department has benefited from the constructive views of the Board and we look forward to continuing our dialogue.

Sincerely,

Dr. Margaret S.Y. Chu, Director
Office of Civilian Radioactive
Waste Management

Enclosure:
Responses to the April 30, 2003 letter to the U.S. Department of Energy (DOE) from the Nuclear Waste Technical Review Board

Michael L. Corradini, Ph.D -2-

bcc w/encl:
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Responses to the April 30, 2003 letter to DOE from the Nuclear Waste Technical Review Board

Transportation

In the Board's view, the DOE should adopt safety as a guiding principle in planning and developing a transportation system and should develop an integrated safety plan for guiding the development process. The schedule for such transportation planning also is important, and it appears that the DOE's current timetable may be optimistic, considering the substantial amount of work to be done.

Response: DOE agrees that safety should be a guiding principle in planning and developing a transportation system for shipments to a geologic repository in Nevada. We also agree that an integrated safety plan is necessary to guide the development process. Consequently, DOE looks forward to further discussions with the Board regarding the format and content of such a plan. DOE also agrees that the public should be involved in the development of the Transportation Strategic Plan and, therefore, plans to seek stakeholder input at the July 16-17, 2003 Transportation External Coordination Working Group meeting. Input received during that meeting will be addressed as DOE finalizes its Plan.

Waste Acceptance

..it is apparent that significant coordination is needed for the waste acceptance process to be smooth and efficient. For example, no casks have been certified for transporting some of the high burn-up spent fuel likely to be generated in the future. Coordination of cask development (and certification) with utility shipping needs and with repository and transportation systems capabilities will be important for efficient operations. The DOE should seek approaches to improving communications with utilities in a way that will facilitate planning for the waste acceptance process.

Response: DOE acknowledges that commercial utilities are producing higher burn-up spent fuel than was envisioned when the Standard Contract was signed. Recognizing this future scenario, DOE has considered and incorporated repository facility design features and operational scenarios to receive, package, and emplace higher burn-up spent fuel as a part of DOE's ongoing design evolution process. For example, repository surface facilities are being designed to blend spent nuclear fuel in waste packages with a combination of high burn-up spent fuel and cooler older spent fuel to manage thermal loading requirements.

Development and certification of transportation cask designs for higher burn-up commercial spent nuclear fuel is a multi-faceted endeavor requiring close regulatory interactions with the Nuclear Regulatory Commission, transportation cask design and production assessments of cask vendors, and logistical coordination with commercial nuclear utilities. DOE is examining how best to develop and manage a transportation system that would accommodate the variety and range of spent nuclear fuel that would be available for shipment to support repository operations. However, the submittal of a license application for repository construction authorization continues to be our primary program focus, especially given the exigencies of the budget process. DOE has requested funding in fiscal year 2004, and will

continue to do so in future budget requests to examine high burn-up spent nuclear fuel and other transportation and waste acceptance issues

Surface and Underground Facilities

The Board would appreciate receiving additional information on two significant issues related to the design and operation of surface and underground facilities. First is the possibility that a small amount of spent fuel will be damaged during transportation to Yucca Mountain. Spent fuel found to be damaged when the casks are opened at the surface facilities will be handed in the remediation building. However, DOE does not plan to have the remediation building operational until three years after the receipt of spent nuclear fuel begins.

Response: DOE's design process is evolutionary, and will continue to be refined and optimized. The design and operational concepts presented last February were provided to the Board as a snapshot in time. DOE realizes that specific design feature details, including the handling of off-normal operations, must be addressed in a license application. The sequencing of the functional status of the Remediation Building shown to the Board was primarily based on expected funding profiles and how construction could be adjusted to meet the expected funding scenarios. Options are now being developed to construct the remediation capabilities first and have them built into the main Dry Transfer Building instead of as a stand alone separate building. Damaged SNF could also be stored after receipt until the necessary remediation facilities are completed so as not to disrupt any proposed shipping scenarios. DOE and our M&O contractor have recently awarded a contract to enlist the services of a surface facility design contractor. Remediation capability is a major part of this present design effort.

..the DOE presentation identified two potentially significant changes in the design and operation of the underground facilities: (1) use of a wheeled waste transporter and (2) location of exhaust drifts and shafts. The board would like more details on the technical bases for these concepts.

Response: Since the February 2003 meeting, DOE has reexamined the utility of the "wheeled waste transporter." Based on a review of how the "wheeled waste transporter" would operate within the subsurface tunnel environment, DOE and the M&O have decided to pursue a conceptual design with a rail based transporter. Consistent with the evolution of the surface design approach, DOE is pursuing a modular subsurface construction approach - building underground panels of emplacement drifts in phases. Consequently, exhaust drifts and exhaust shafts will be constructed to best accommodate the sequential construction of the emplacement panels. DOE expects to have a greater fidelity of detail regarding this and other design issues as the design stabilization efforts mature.

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

June 27, 2003

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

On February 24, 2003, the Nuclear Waste Technical Review Board's (Board) Panel on the Natural System and Panel on the Engineered System held a joint meeting in Las Vegas devoted to seismic issues. As indicated in the March 10, 2003, letter sent to you by William Barnard, it was a very informative and successful meeting. This was due in large part to the Department of Energy's (DOE) efforts and its willingness to discuss difficult topics where much of the information is preliminary and final positions have not yet been established. Reports by Board consultants who attended the meeting can be found on the Board's web site.

The DOE and its contractors, the U.S. Geological Survey, the U.S. Bureau of Reclamation, the University of Nevada at Reno (UNR), and others set a high standard in the basic geological and seismological studies on which seismic hazard at Yucca Mountain was evaluated. This information was incorporated in a state-of-the-art probabilistic seismic hazard analysis (PSHA) completed in 1998. The Board's assessment of the application of the PSHA to preclosure (approximately the first 100 years) and postclosure (the first 10,000 years) is based on the results that were available at the time of our February meeting. A basic concern of the Board is that although the PSHA is, in general, sound, extending it to very low probabilities results in ground-motion estimates about which there are serious technical questions. These relate to the lack of physical realism and the implications of these unrealistic estimates for performance assessment, design, and scientific confidence. Following is the Board's evaluation of the material presented, its strengths and weaknesses, and specific recommendations to the DOE on seismic issues.

Preclosure Ground Motions

With respect to preclosure, the ground motions proposed for design at annual probabilities of exceedance (APE) of 10^{-3} to 10^{-4} appear reasonable. However, as Bechtel SAIC (BSC) consultant Robert Kennedy stated, an evaluation to see if the surface facilities meet performance goals for critical systems, structures, and components could require using ground motions whose APE is as low as 10^{-6}. If physically unrealistic, as may be the case (as discussed below), such motions could pose an undue burden on the design and operation of these facilities.

Postclosure Ground Motions

In the Board's view, the very-low-probability (APEs of 10^{-6} to 10^{-8}) ground motions proposed for use in postclosure performance assessment are generally unrealistic, physically unrealizable, or outside the limits of existing worldwide seismic records or experience, particularly when Yucca Mountain source and site conditions are taken into account. These ground motions can require unrealistic source characteristics (e.g., stress drops) and unrealistic strains, which may exceed the ability of the rock to sustain without fracturing. For example, some of the real earthquake ground-motion recordings used in the consequence analysis for performance assessment are scaled up (increased) by factors higher than 100 to reach the "target" level of ground motions (e.g., 535 cm/sec peak ground velocity at an APE of 10^{-7}), which themselves are based on extending the results from the PSHA and modifying them to take into account local site conditions. In some cases, this method of scaling yielded peak ground accelerations and velocities (e.g., 20 g peak ground acceleration and 1790 cm/sec peak ground velocity) well above already unrealistic target levels. Many DOE and BSC presenters at the meeting shared many of these same views. However, as discussed later in this letter, differences of opinion may exist between the Board and the DOE on how to proceed, given this lack of physical realism.

The very-low-probability ground motions need to be bounded on the basis of sound physical principles. The DOE indicated that it is carrying out such studies (e.g., limitations posed by source conditions and local site conditions). The studies will be challenging. Aside from an ongoing study in Switzerland, we are not aware of other recent systematic attempts to place physical bounds on earthquake ground motion. Despite these difficulties, the Board strongly recommends that the DOE complete these studies, subject them to external peer review, and implement them accordingly to limit the proposed very-low-probability ground motions.

The DOE also should evaluate and consider the work being carried out by Dr. James Brune and his colleagues at UNR as an alternative line of evidence for limiting ground motions. The evaluation of precarious rocks and other formations at Yucca Mountain suggests that during the last 10,000,000 years, ground motions that have occurred at Yucca Mountain may be substantially less than those estimated by the PSHA. Dr. Brune attributes this to the incorrect handling of uncertainty in the PSHA and other seismic hazard analyses.

The Board notes two additional areas where lack of data may affect the magnitude of the estimated ground motions: insufficient geotechnical data on the Topopah Springs Lower Lithophysal unit (Tptpll), which constitutes some 80 per cent of the emplacement rock in the proposed repository and shear modulus data at strains larger than 0.1 per cent, the range of strains induced by the proposed very-low-probability ground motions.

Drift Degradation and Other Topics

The Yucca Mountain Project has made excellent progress in assessing underground opening stability and drift degradation due to both seismic and thermal processes. Models used to predict tunnel behavior need to be calibrated against the conditions expected in the repository (e.g., information obtained from the ESF and, in particular, the cross drift). Models used to predict tunnel performance under extreme dynamic loading should be compared to nuclear test damage data and rockburst damage observed in mines with comparable rock-mass conditions. Analyses also need to account for long-term behavior (e.g., static fatigue) using representative rock-mass properties to simulate raveling and spalling processes expected during preclosure and postclosure periods. Particular attention should be focused on rock properties and analytical models to understand brittle failure and to predict the outcome of the failure process for this heterogeneous rock mass with its spatial and temporal variability in properties.

Recent studies of brittle failure in heterogeneous rocks near excavations have shown that conventional linear or curved failure criteria may not be appropriate for the Tptpll unit. The Board recommends that models be adopted and developed that can properly simulate the strain-dependent tensile spalling mechanism clearly observed in the cross drift and that drift design be based on such failure criteria. If tunnel openings have the potential to collapse, raveling and failure processes will continue until rock mass bulking substantially fills the drift. During this process, dynamic forces and nonsymmetrical rock pressures will develop on the drip shield. The potential for drip shield deformation and corrosion under these conditions needs to be analyzed.

If, after considering the consequences and the risks posed to the public, the DOE decides to modify the repository design to mitigate the effects of seismic activity, such modifications need to be evaluated in terms of their overall impact upon repository operations and performance.

Implications of Highly Conservative Assumptions

A number of highly conservative assumptions have been used in addressing seismic issues. The DOE may find conservatism attractive because it could provide a way to show regulatory compliance in the face of uncertainty. As stated above, DOE and BSC scientists agree that many of their estimates are highly conservative or physically unrealistic. The DOE maintains, however, that this is not necessarily a problem because the assumptions are consistently conservative and the repository system will still show regulatory compliance. It appears that the DOE intends to use the ground-motion bounding studies as evidence of conservatism rather than as a means of modifying the ground motion estimates themselves. Not all the assumptions in the Project's analysis of this complex, highly coupled system have been fully assessed, e.g., the effects of seismically and thermally induced drift degradation on seepage and local flow and transport, and consideration of seismically induced waste package failure modes not related to stress-corrosion cracking. These assumptions need to be evaluated. If they are important, the assumed level of conservatism could be affected.

The Board recommends that the DOE not take a physically unrealistic or highly conservative approach for several reasons: (a) High levels of conservativism can lead to a skewed understanding of repository behavior and the significance of different events; (b) High levels of conservatism can introduce consideration of events for which there is little or no understanding or engineering experience; (c) Compounding conservative assumptions does not always produce conservative results, e.g., the worst case for drift stability is not when the horizontal and vertical stresses are both very high; (d) High levels of conservatism may lead to unreasonably high costs and may have a serious effect on the eventual development of both surface and subsurface designs; (e) If conservatism stems from a lack of understanding, it tends to undermine confidence in the scientific basis of the process under consideration. Physically unrealistic results, inappropriately extrapolated from physically realistic databases and analyses, could cast unwarranted doubt on much of the truly excellent work carried out in this area; (f) Finally, if "unacceptable" consequences are discovered later, it may be more difficult to justify subsequent reductions of elevated ground-motion estimates previously assumed to be acceptable.

The Board thanks you and the DOE staff and contractors for the effort extended in making the meeting as successful as it was.

Sincerely,

Michael L. Corradini
Chairman

Department of Energy
Washington, DC 20585
October 8, 2003

Dr. Michael L. Corradini, Ph.D.
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, VA 22201-3367

Dear Dr. Corradini:

Thank you for your letter of June 27, 2003, providing the Nuclear Waste Technical Review Board's (Board) perspective on information presented by the U.S. Department of Energy (Department) on seismic issues at the joint meeting of the Board's Natural System and Engineered System Panels in February 2003.

The Department appreciates the Board's continuing review of our activities as we develop the license application for a repository at Yucca Mountain. Our responses to the views expressed by the Board are summarized in the enclosure to this letter.

The Department continues to benefit from the constructive views of the Board and we look forward to further dialogue on seismic issues.

Sincerely,

Dr. Margaret S.Y. Chu, Director
Office of Civilian Radioactive
Waste Management

Enclosure:
Responses to the Nuclear Waste Technical Review Board Comments on U.S. Department of Energy Presentations Given at the February 2003 Joint Natural System and Engineered System Panel Meeting on Seismic Issues

Michael L. Corradini, Ph.D. -2-

bcc w/encl:
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Responses to the Nuclear Waste Technical Review Board Comments on U.S. Department of Energy (DOE) Presentations given at the February 2003 Joint Natural System and Engineered System Panel Meeting on Seismic Issues

Preclosure Ground Motions

With respect to preclosure, the ground motions proposed for design at annual probabilities of exceedance (APE) of 10^{-3} to 10^{-4} appear reasonable. However, as Bechtel SAIC (BSC) consultant Robert Kennedy stated, an evaluation to see if the surface facilities meet performance goals for critical systems, structures, and components could require using ground motions whose APE is as low as 10^{-6}. If physically unrealistic, as may be the case (as discussed below), such motions could pose an undue burden on the design and operation of these facilities.

Response:

10 CFR Part 63.102[1] only requires consideration of initiating events that are reasonable, i.e., based on the characteristics of the geologic setting and the human environment and consistent with precedents adopted for nuclear facilities with comparable or higher risks to workers and the public. Given this requirement, the DOE plans to evaluate seismically initiated event sequences for preclosure safety analyses for earthquake ground motions with APEs of 10^{-4} and greater.

Postclosure Ground Motions

In the Board's view, the very-low-probability (APEs of 10^{-6} to 10^{-8}) ground motions proposed for the use in postclosure performance assessment are generally unrealistic, physically unrealizable, or outside the limits of existing worldwide seismic records or experience. . . . Many DOE and BSC presenters at the meeting shared many of these views. However, as discussed later in this letter, differences of opinion may exist between the Board and DOE on how to proceed, given this lack of physical realism.

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[1] 66 FR 55732. Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, NV. Final Rule 10 CFR Part 63.

The very-low-probability ground motions need to be bounded on the basis of sound physical principles. The DOE indicated that it is carrying out such studies (e.g., limitations posed by source conditions and local site conditions). The studies will be challenging. Aside from an ongoing study in Switzerland, we are not aware of other recent systematic attempts to place physical bounds on earthquake ground motions.

Despite these difficulties, the Board strongly recommends that the DOE complete these studies, subject them to external peer review, and implement them accordingly to limit the proposed very-low-probability ground motions.

Response:

As the Board notes, the DOE is conducting studies to bound the very-low probability ground motions. While the results may not be available in time to provide direct input to Total System Performance Assessment for the License Application (TSPA-LA), they will be available after independent technical review to support the U.S. Nuclear Regulatory Commission staff's review of the LA and provide clarification regarding the level of conservatism in the LA.

The DOE also should evaluate and consider the work being carried out by Dr. James Brune and his colleagues at University of Nevada at Reno (UNR) as an alternative line of evidence for limiting ground motions. The evaluation of precarious rocks and other formations at Yucca Mountain suggests that during the last 10,000,000 years, ground motions that have occurred at Yucca Mountain may have been substantially less than those estimated by the Probabilistic Seismic Hazard Analysis (PSHA). Dr. Brune attributes this to the incorrect handling of uncertainty in the PSHA and other seismic hazard analyses.

Response:

The DOE agrees and is considering Dr. Brune's observations as an alternative line of evidence for limiting ground motions. His observation that there is no shattered rock at Yucca Mountain as would be expected if there had been extreme ground motion during the last 13 million years is the basis for one of the ongoing studies to bound the very-low probability ground motions. Specifically, a strain threshold at which rock failure would be expected is being identified from consideration of measured rock properties. The strain threshold is then being used to establish an upper limit on ground motions that have occurred in the last 13 million years (the approximate age of the tuff units). The results of these studies may be included as *a priori* information in the development of updated ground motion distributions.

The DOE is currently negotiating with Dr. Brune and his associates at UNR to continue their studies of near-surface attenuation (kappa) and possibly conduct finite-source ground motion calculations to investigate possible limiting effects on the very low-probability (10^{-6} and less) ground motions of physically bounded source parameters.

The Board notes two additional areas where lack of data may affect the magnitude of the estimated ground motions: insufficient geotechnical data on the Topopah Spring Lower Lithophysal unit (Tptpll), which constitutes some 80 per cent of the emplacement rock in the proposed repository and shear modulus data at strains larger than 0.1 per cent, the range of strains induced by the proposed very-low probability ground motions.

Response:

The ongoing studies to bound the very-low probability ground motions are also addressing high-strain shear-modulus reduction and damping. Specifically, high-strain properties for the volcanic tuff below the repository horizon are being developed by nonlinear numerical modeling. These properties will then be input to the site response model to generate "saturated" ground motions at the repository waste-emplacement level. While the results may not be available in time to provide direct input to Total System Performance Assessment for the License Application (TSPA-LA), they will be available after independent technical review to support the U.S. Nuclear Regulatory Commission staff's review of the LA and provide clarification regarding the level of conservatism in the LA.

Drift Degradation and other topics

Models used to predict tunnel behavior need to be calibrated against the conditions expected in the repository (e.g., information obtained from the Exploratory Studies Facility and, in particular, the cross drift). Models used to predict tunnel performance under extreme dynamic loading should be compared to nuclear test damage data and rock burst damage observed in mines with comparable rock-mass conditions. Analyses also need to account for long-term behavior (e.g., static fatigue) using representative rock-mass properties to simulate raveling and spalling processes expected during preclosure and postclosure periods. Particular attention should be focused on rock properties and analytical models to understand brittle failure and to predict the outcome of the failure process for this heterogeneous rock mass with its spatial and temporal variability in properties.

Response:

The short time available for presentation at the Seismic Panel Meeting unfortunately did not allow for a detailed review of all the geomechanical studies that have been performed and are now underway that address some of the issues brought out in this comment. During the process of validation of the numerical modeling techniques used for the drift degradation models, comparison was made to the observed sidewall fracturing in the Enhanced Characterization of the Repository Block lithophysal units. Comparison was also made between the small number of observed wedge-type failures in non-lithophysal units to the model predictions. Details of the validation can be found in BSC (2003)[2].

The 3-Dimensional Distinct Element Code (3DEC) and Universal Distinct Element Code (UDEC) models used for the dynamic stability analyses have been extensively validated in other projects. The validation was against field data from high explosive testing (for the Defense Nuclear Agency) and against damage from rockbursts in deep mines (by numerous authors in the United States, Canada, and South Africa). An example of a validation exercise involving detailed comparison of the ability of a number of continuum and discontinuum numerical models (including UDEC) to simulate supported tunnels in fractured rocks can be found in Senseny (1993)[3]. We have not explicitly compared the models here to nuclear tests at the Nevada Test Site, but this would be a good confidence-building exercise, with the caveat that the characteristics of the incoming waveforms are significantly different between explosions and earthquakes, with resulting potential difference in damage mechanisms.

The project is currently addressing the issue of time-dependent rock mass degradation via a combined laboratory testing and numerical modeling program. We are conducting static fatigue measurements on tuff core samples to better understand the relationship of "time to failure" as a function of stress level. To understand the impact of lithophysal porosity, the DOE is:

1) calibrating the Particle Flow Code (PFC) model against the laboratory data to establish its ability to reproduce the basic static fatigue response of non-lithophysal tuff;

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[2] BSC (2003). *Drift Degradation Analysis*, ANL-EBS-MD-000027, Rev. 02. Las Vegas, Nevada: Bechtel SAIC Company.

[3] Senseny, P.E. 1993. "Stress Wave Loading of a Tunnel: A Benchmark Study." *Proceedings of the Symposium – Dynamic Analysis and Design Considerations for High-Level Nuclear Waste Repositories, San Francisco, California, August, 19-20, 1992*. Hossain, Q.A., ed. Pages 311-338. New York, New York: American Society of Civil Engineers.

2) investigating the impact of lithophysal voids numerically by adding porosity to the calibrated numerical rock samples, and conducting simulated static fatigue experiments to derive lithophysal time to failure plots; and

3) incorporating this logic into previously validated tunnel scale models for investigation of time-related degradation under in situ and thermal loading. The PFC model is used here to predict brittle fracturing modes of the solid matrix between lithophysae. The primary heterogeneities examined here are the lithophysae and their variability in size, shape and porosity. This work will be completed in Fiscal Year 2004.

Recent studies of brittle failure in heterogeneous rocks near excavations have shown that conventional linear or curved failure criteria may not be appropriate for the Tptpll unit. The Board recommends that models be adopted and developed that can properly simulate the strain-dependent tensile spalling mechanism clearly observed in the cross drift and that drift design be based on such failure criteria. If tunnel openings have the potential to collapse, raveling and failure processes will continue until rock mass bulking substantially fills the drift. During this process, dynamic forces and nonsymmetrical rock pressures will develop on the drip shield. The potential for drip shield deformation and corrosion under these conditions needs to be analyzed.

Response:

This comment goes to the heart of modeling of brittle rock behavior. The project is currently using the PFC program (using parallel bonds for particles) to model and understand the brittle fracturing response of lithophysal rock. The DOE has performed extensive calibration of the model against laboratory testing of large lithophysal samples and their failure mechanisms. The PFC model provides a reasonable prediction and representation of tensile fracturing during axial splitting failure of the laboratory samples. The basic failure mechanism in compression for lithophysal rock, shown by the PFC model, is tensile fracturing between lithophysae, which subsequently coalesce as the sample macroscopically yields. This process is porosity dependent, leading to reduction of strength and modulus as the lithophysal porosity increases.

The PFC model has been shown to successfully reproduce the relationship of uniaxial compressive strength to lithophysal porosity as shown in the laboratory. It appears that the model adequately represents the small-scale mechanism of tensile failure between lithophysae, leading to the larger sample-scale failure mechanisms at the laboratory and field scale. Because it is computationally difficult to examine tunnel-scale problems with PFC, the basic failure response

defined by the laboratory and field testing and supplemented by PFC has been encapsulated into the UDEC program that is used to represent tunnel-scale degradation processes. The UDEC program has been calibrated to produce an equivalent mechanical constitutive model to the PFC model and is verified by comparison to laboratory data and observations of damage in the Enhanced Characterization of the Repository Block. UDEC, which is a discontinuum model, is used to predict the tunnel degradation process, including the raveling and bulking process. The model has been used to examine drip shield static and dynamic loadings that are generally non-symmetric in nature. The load distributions on the drip shield have been supplied to the drip shield structural designers who are using them to estimate stresses and deformations.

If, after considering the consequences and the risks to the public, the DOE decides to modify the repository design to mitigate the effects of seismic activity, such modifications need to be evaluated in terms of their overall impact upon repository operations and performance.

Response:

The DOE does not expect modifications to the repository design will be required to mitigate the consequences of high-amplitude, low-probability ground motions. Even using the present, probably unrealizable ground motion estimates, it appears that the calculated consequences will be acceptable. Any proposed changes to repository design to mitigate the potential effects of seismic activity will be processed through our design control procedures to evaluate the overall impact on repository operations and performance.

Implications of highly conservative assumptions

A number of highly conservative assumptions have been used in addressing seismic issues. It appears that the DOE intends to use the ground-motion bounding studies as evidence of conservatism rather than a means of modifying the ground motion estimates themselves. Not all the assumptions in the Project's analysis of this complex, highly coupled system have been fully assessed, e.g., the effects of seismically and thermally induced drift degradation on seepage and local flow and transport, and consideration of seismically induced waste package failure modes not related to stress-corrosion. These assumptions need to be evaluated. If they are important, the assumed level of conservatism could be affected.

The Board recommends that the DOE not take a physically unrealistic or highly conservative approach for several reasons: (a) High levels of conservatism can

lead to a skewed understanding of repository behavior and the significance of different events; (b) High levels of conservatism can introduce consideration of events for which there is little or no understanding or engineering experience; (c) Compounding conservative assumptions does not always produce conservative results, e.g., the worst case for drift stability is not when the horizontal and vertical stresses are both very high; (d) High levels of conservatism may lead to unreasonably high costs and may have a serious effect on the eventual development of both surface and subsurface designs; (e) If conservatism stems from a lack of understanding, it tends to undermine confidence in the scientific basis of the process under consideration. Physically unrealistic results, inappropriately extrapolated from physically realistic databases and analyses, could cast unwarranted doubt on much of the truly excellent work carried out in this area; (f) Finally, if "unacceptable" consequences are discovered later, it may be more difficult to justify subsequent reductions of elevated ground-motion estimates previously assumed to be acceptable.

Response:

The DOE agrees with the Board that the seismic ground motions that we will be using in the LA corresponding to the very lowest annual probabilities of exceedence (APEs of 10^{-6} and below) are highly conservative and may indeed be "physically unrealizable". However, despite the various issues with using these probably conservative values, the DOE considers that using them is acceptable in the TSPA that will support the LA. To address the problems associated with using such ground motions, we are now carrying out several different studies to bound the very low-probability ground motions; whose ultimate objective is to provide a technical basis for a more realistic set of ground motions in the very-low-APE range.

The DOE agrees with all of the reasons cited by the Board as to why taking a physically unrealistic or highly conservative approach is not desirable. We are working to assure ourselves that none of the potential problems cited by the Board will actually occur for the case of the highly conservative extreme seismic ground motions that we will be using in the LA. Most importantly, we are taking care to assure that using these conservative values will actually produce conservative results throughout.

Also, we agree with the Board's concern that using these values can produce a skewed understanding of actual behavior. We have performed various analyses of the system response at what we believe are more realistic ground-motion levels, and we will be performing more such analyses in the future. Furthermore, we are very sensitive to the possibility that using the unrealistically high ground-motions

may "cast unwarranted doubt on much of the truly excellent work carried out in this [seismic] area" (quoting from the Board's letter). We will therefore take care, as we develop the text supporting this aspect of our LA, to explain how to interpret the analysis results appropriately, and why possible misinterpretations are not correct.

The implications of unrealistically high seismic ground motions as inputs to the design of both the surface facilities and the underground facilities are important to DOE. This includes not only the implications for the physical designs themselves but also the cost implications. This is one reason why we are pursuing the work to bound the very-low probability ground motions. Another reason is the important implications of these extreme ground motions on drift degradation, on seepage and in-drift transport, and on possible seismic-induced failures of the waste-packages. While the results may not be available in time to provide direct input to Total System Performance Assessment for the License Application (TSPA-LA), they will be available after independent technical review to support the U.S. Nuclear Regulatory Commission staff's review of the LA and provide clarification regarding the level of conservatism in the LA.

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

June 30, 2003

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

The Board thanks you and the rest of the Yucca Mountain Project team for participating in the Nuclear Waste Technical Review Board's May 2003 meeting in Washington, D.C. The meeting was extremely productive and informative. The first day's presentations were comprehensive, well integrated, and thought-provoking; the two large charts were especially useful integrating tools. The Board valued the extended question-and-answer periods, which allowed presenters to explain thoroughly the rationale for their conclusions. The extra effort that went into preparing these presentations was evident and, in the Board's view, worthwhile. The Board also found interesting the insights provided by you and your deputy director, John Arthur, particularly the comments related to the management challenges facing the civilian radioactive waste management program.

In this letter, the Board provides some initial reactions to the Project's technical presentations at the May meeting. The letter also conveys the Board's views on the *Final Report* of the Igneous Consequences Peer Review Panel. Last, the letter offers the Board's thoughts on the natural analogue studies being conducted by the DOE at Peña Blanca.

Initial Board Reactions to Presentations by the Project at the May Board Meeting

The Board continues to believe that the concept of a "safety case," which is endorsed strongly by virtually all the major nuclear waste management programs abroad, has considerable merit. In fact, during the meeting, Project scientists were able to verbalize why they believe that a Yucca Mountain repository would isolate and contain waste effectively. An updated written narrative description similar to those oral comments would make the Project's approach to ensuring safety more transparent and understandable.

The first day of the meeting was structured to allow the Project to describe the thermal aspects of the current repository design and operating mode, how the thermal aspects have been analyzed, and the results of those analyses. In response, the Project delivered three major presentations related to in-drift thermohydrology, in-drift thermohydrochemistry, and Alloy-22

corrosion. The subjects presented are critical for predicting the potential repository's overall performance. Other factors relevant to performance, such as drift degradation and the thermal properties of the lower lithophysal unit, however, were not addressed fully. The Board's initial reaction is that potentially significant questions remain about the technical basis for the Project's thermal analyses. These questions include concerns about the initiation of localized corrosion and the technical basis underlying Project claims about capillary and vaporization barriers. The Board is in the process of carefully evaluating the DOE's presentations from the May Board meeting and will be preparing more detailed comments for the DOE on these subjects.

The Board is pleased that the Project is committed to sponsoring long-term research on "outside of the box" scientific and technical issues. It is not yet clear, however, how data and analyses from the Science and Technology Program will be integrated into the license application process or the performance confirmation effort mandated by the Nuclear Regulatory Commission.

Board Views on *Final Report* of Igneous Consequences Peer Review Panel

At the May meeting, a member of the Igneous Consequences Peer Review Panel (Panel) presented the Panel's findings from its *Final Report*. In the Board's view, the Panel has made an important contribution to the assessment of the consequences of igneous activity at Yucca Mountain. The DOE and its contractors deserve credit for initiating and supporting this effort. The Panel's *Final Report* shows evidence of both independence and high technical quality. Much original work was conducted. Detailed reviews of the Panel's work by Board consultants can be found on the Board's Web site: www.nwtrb.gov.

The Panel agreed with much of the DOE's approach (e.g., the overall conceptual model of a rising dike intersecting waste emplacement drifts and localizing into a volcanic conduit that reaches the surface), but the Panel also recommended improvements. Because of the significance of the igneous issues, the Board recommends that the DOE give the most emphasis to three areas.

- The first area is the use of upgraded modeling techniques that take into account conditions such as compressible inviscid flow that may be present at repository depth. Past models based on incompressible flow may not give a true picture of dike behavior and magma-drift interaction. Such modeling also would help evaluate the likelihood of the so-called "dog leg" scenario as proposed by Woods and others in their 2002 article, *Modeling magma-drift interaction at the proposed high-level radioactive waste repository at Yucca Mountain, Nevada*. The Board concurs with the Panel that the likelihood of the generation of strong shock waves, as proposed by Woods and others, is negligible.

- The second area is the need to study aeromagnetic anomalies in the vicinity of Yucca Mountain that could signify buried volcanoes. Such studies may involve additional aeromagnetic surveys (at appropriate altitudes); drilling; and dating, which could help determine the existence, age, and volume of the possible volcanoes.

- The third area is the need to address subjects that were not within the range of the Panel's expertise, i.e., waste package-magma interaction and waste entrainment in both the volcanic eruption scenario and the groundwater release scenario. The Panel confined itself to evaluating magma-drift interaction in the volcanic eruption scenario. These subjects are of great importance in any consequence analysis. The DOE should address them using the advice of outside reviewers. The DOE also should consider experimental studies for analyzing and verifying key phenomena and parameters (e.g., chemical and mechanical effects of magma on waste packages).

In all of these investigations, it is very important that the DOE maintain an integrated team of field experts, modelers, engineers, and performance assessment analysts. If, after considering the consequences and the risks posed to the public, the DOE decides to modify the repository design to mitigate the effects of igneous activity, such modifications would need to be evaluated in terms of their overall impact upon repository operations and performance.

Board Comments on Peña Blanca Natural Analogue

At the meeting, two speakers touched on the Project's ongoing work at the possible analogue site at Peña Blanca in northern Mexico. Following the meeting, several Board and staff members visited Peña Blanca and observed the work first-hand. We are impressed with the progress being made.

The natural uranium deposits at Peña Blanca, particularly at the Nopal 1 site, form a unique natural analogue for many of the processes that would occur at the proposed Yucca Mountain repository. The uranium oxide deposit is in many ways similar to spent fuel. As at Yucca Mountain, it is located in oxidizing conditions in fractured, unsaturated welded tuff in a region of arid climate. There also are some important differences between Nopal 1 and Yucca Mountain, which Project scientists seem well aware of. The differences include the presence of some sulfates and iron in various forms at Nopal 1 and the relative lack of nonwelded-tuff layers. All in all, however, Peña Blanca offers the opportunity to test a number of the proposed models and assumptions underlying the DOE's analyses of Yucca Mountain and to examine alternatives to these models. They include, but are not limited to, models and assumptions related to waste form dissolution (the source term), unsaturated zone flow and transport, and the active fracture model.

The work at Peña Blanca can provide information for addressing important technical issues both in the short term and in the long term. The additional information that comes from studying this site could show that the repository system would perform better or not as well as current performance estimates now project. However, either way, these tests could increase understanding of the processes and their associated uncertainties. For this reason, the Board strongly recommends continued support for studies at this unique site.

Once again, the Board thanks you and the rest of the Yucca Mountain Project team for participating in the Board's May meeting. We look forward to continuing the Board's ongoing technical and scientific review and to commenting on Project activities in the future.

Sincerely,

Michael L. Corradini
Chairman

Department of Energy
Washington, DC 20585

October 10, 2003

Dr. Michael L. Corradini, Ph.D.
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, VA 22201-3367

Dear Dr. Corradini:

Thank you for your letter of June 30, 2003, providing the Nuclear Waste Technical Review Board's (Board) initial reactions to information presented by the U.S. Department of Energy (Department) at the Board's May 2003 Summer Board Meeting.

The Department appreciates the Board's continuing review of our activities as we continue development of science, design, and analysis, including a license application, for a repository at Yucca Mountain. Our responses to the views expressed by the Board are summarized in the enclosure to this letter.

The Department looks forward to the Board's detailed comments on the technical basis for our thermal analyses along with other aspects of the Department's licensing case.

Sincerely,

Dr. Margaret S.Y. Chu, Director
Office of Civilian Radioactive
Waste Management

Enclosure:
Responses to Initial Comments from the Nuclear Waste Technical Review Board on U.S. Department of Energy presentations in the May 2003 Full Board Meeting

Responses to Initial Comments from the Nuclear Waste Technical Review Board (Board) on U.S. Department of Energy (DOE) presentations in the May 2003 Full Board Meeting

Safety Case:
The Board continues to believe that the concept of a "safety case", which is endorsed strongly by virtually all the major nuclear waste management programs abroad, has considerable merit. In fact, during the meeting, Project scientists were able to verbalize why they believe that a Yucca Mountain repository would isolate and contain waste effectively. An updated written narrative description similar to those oral comments would make the Project's approach to ensuring safety more transparent and understandable.

Response:
The DOE agrees with the Board as to the importance of transparent communications. We are currently developing a series of technical basis reports to clearly document the Project's approach to ensuring safety of the repository system. These reports describe the various barriers of the repository system and the technical basis for performance of each barrier. In the May 2003 Board meeting, DOE presented an integrated basis for performance in the unsaturated zone above the drifts, in the in-drift environment, and in material performance. In the September 2003 meeting, we continued with this approach, addressing the detailed technical basis for flow and transport in the unsaturated zone and the saturated zone.

The Project delivered three major presentations related to in-drift thermohydrology, in-drift thermohydrochemistry, and Alloy-22 corrosion. ...The Board's initial reaction is that potentially significant questions remain about the technical basis for the Project's thermal analyses. These questions include concerns about the initiation of localized corrosion and the technical basis underlying Project claims about capillary and vaporization barriers. The Board is in the process of carefully evaluating the DOE's presentations from the May Board meeting and will be preparing more detailed comments for the DOE on these subjects.

Response:
The DOE looks forward to the Board's more detailed comments on the character of the unsaturated zone, the character of the in-drift environment, and materials performance.

As the DOE presented in the May and September Board Meetings, our technical basis continues to be based on: a) no significant corrosion above the boiling point of water because of a lack of seepage and the presence of primarily benign deliquescent brines; b) no significant corrosion at and near the boiling point of water because of the presence of primarily benign seepage and deliquescent brines and the presence of the drip shield; c) no significant corrosion below the boiling point of water because of the presence of primarily benign seepage brines and the presence of the drip shield.

The DOE has clearly indicated its intention to proceed to License Application with a design that would operate at a higher-temperature, but that retains the flexibility to be operated in a cooler mode should that be deemed necessary. Ongoing testing and analyses continue to improve the technical basis for the models used in the performance assessments over the range of possible postclosure thermal conditions. This testing and analytical program includes corrosion testing, prototype testing, near-field environment characterization using such tests as the Drift Scale Test, and unsaturated zone flow and seepage investigations. Finally, the DOE continues to develop the Total System Performance Assessment for the License Application where the above models are being integrated. This model will be used to conduct additional sensitivity analyses related to all barriers important to waste isolation, including the near-field environment and corrosion processes to better understand and communicate the technical basis for postclosure thermal conditions and impacts to total system performance. As additional testing and analyses are completed, the DOE will re-evaluate the technical bases and refine the operational parameters for the repository as needed. The DOE looks forward to continuing the discussion of the ongoing work and long-term strategy with the Board.

Science and Technology (S&T) Program

The Board is pleased that the Project is committed to sponsoring long-term research on "outside the box" scientific and technical issues. It is not yet clear, however, how data and analyses from the Science and Technology Program will be integrated into the license application process or the performance confirmation effort mandated by the U.S. Nuclear Regulatory Commission.

Response:

The Science and Technology Program is by design distinct from the mainline Office of Civilian Radioactive Waste Management (OCRWM) activity of developing the License Application. However, as the S&T Program completes various projects over the long-term, the results could impact either our

understanding of the way the repository will perform, or our repository design. In either case, the new information, including any data, models, analysis tools, new technologies, or different design approaches, will be used on a case-by-case basis either to amend the License Application or to support its technical basis. If anything adverse is discovered, it will be made available publicly as soon as feasible. However, the S&T Program does not have as an objective to support the initial License Application.

The relationship of the S&T Program to OCRWM's Performance Confirmation (PC) Program is to provide long-term technical support. Specifically, S&T will likely support some projects that could, if successful, provide better methods that the PC Program could use in carrying out its mandate. These might include developing improved measurement methods or improved instrumentation, or proving out novel proposed approaches for ascertaining whether a given aspect of repository performance is or is not performing according to expectations. If a new method or tool is successfully developed, OCRWM expects it to be integrated into an updated PC Program appropriately.

Igneous Consequences Peer Review Report:
The Board recommends that the DOE give the most emphasis to three areas.

The first area is the use of upgraded modeling techniques that take into account conditions such as compressible inviscid flow that may be present at repository depth. Past models based on incompressible flow may not give a true picture of dike behavior and magma-drift interaction. Such modeling also would help evaluate the likelihood of the so-called "dog-leg" scenario as proposed by Woods and others. . . . The Board concurs with the Panel that the likelihood of the generation of strong shock waves, as proposed by Woods and others, is negligible.

Response:
Current modeling of dike propagation uses a 2-dimensional hydrofracture code that includes free surface effects but is limited to an incompressible fluid model. Limited 2-dimensional modeling has also been done with a different code suggesting that the effects of order-of-magnitude changes in magma compressibility have a negligible effect on dike crack propagation. The DOE is considering development of a new hydrofracture code to include compressible fluids using the approach defined by the Igneous Consequence Peer Review Panel (Appendix 3.3 of the final report of the Peer Review).

The DOE intends to continue the 3-dimensional modeling completed thus far to investigate the effect of finite strike-length of the crack tip acceleration as the tip approaches the free surface. This latter activity addresses a potential non-

conservatism relevant to the "dog leg" scenario due to increased confinement as the crack tip reaches the free surface.

The current modeling presents magma flow as an incompressible viscous fluid and is expected to provide a reasonable basis for description of effusive flow from a dike into a drift. The DOE is considering 2- and 3-dimensional models that will permit better simulation of effusive flow and that will permit simulation of both pyroclastic flow and transitional flow between effusive and pyroclastic. These models will include multiphase flow with exchange of momentum and energy between phases. Inclusion of energy exchange will permit calculation of magma cooling rates in the dike, in a drift, and in a potential "dog-leg" crack growing out of a drift. Exchange of momentum is necessary for accurate portrayal of the multiphase flow.

The DOE is considering the feasibility of combining the 2- and 3-dimensional multiphase code for modeling simulation of transitional and/or pyroclastic flow in a dike to the new compressible hydrofracture code in order to develop a better understanding of the effect of such flow on dike propagation.

The second area is the need to study aeromagnetic anomalies in the vicinity of Yucca Mountain that could signify buried volcanoes. Such studies may involve additional aeromagnetic surveys (at appropriate altitudes); drilling; and dating, which could help determine the existence, age, and volume of the possible volcanoes.

Response:
The DOE has developed plans to initiate activities to evaluate potential buried volcanic centers in the vicinity of Yucca Mountain, including Crater Flat, Jackass Flat, and a section of the Amargosa Desert south of Crater Flat and Yucca Mountain. The investigations will consist of flying low altitude, combined aeromagnetic and electromagnetic surveys along a very closely spaced survey grid. These will be used to produce high-resolution aeromagnetic maps that will more accurately identify and define any potential buried volcanic centers including those anomalies identified from the 1999 U.S. Geological Survey (USGS) aeromagnetic data. A two-phased drilling program will initially drill up to six anomalies identified from the 1999 USGS aeromagnetic data. During the second phase, we will drill any new high-probability anomalies identified from the new aeromagnetic survey to confirm the presence or absence of buried volcanic centers. Chemical analyses and age dating will be performed on any basalts encountered from drilling. Additionally, limited age dating and chemical analyses will be performed on samples collected from the known volcanic centers in Crater Flat to better constrain eruptive sequences.

The field and laboratory program will begin in early fiscal year (FY) 2004 and continue through FY 2005. Information will be made available as the activities proceed, and a final report will be available in early to mid 2006. Information from this field and laboratory program will be used in an update of the Probabilistic Volcanic Hazard Assessment.

The third area is the need to address subjects that were not within the range of the Panel's expertise, i.e., waste package-magma interaction and waste entrainment in both the volcanic eruption scenario and the groundwater release scenario. The Panel confined itself to evaluating magma-drift interaction in the volcanic eruption scenario. These subjects are of great importance in any consequence analysis. The DOE should address them using the advice of outside reviewers. The DOE also should consider experimental studies for analyzing and verifying key phenomena and parameters (e.g., chemical and mechanical effects of magma on waste packages).

Response:
DOE recognizes the need to address subjects that were not within the range of the Panel's expertise. While DOE has no plans for conducting another peer review, we have developed a report, *Igneous Intrusion Impacts on Waste Packages and Waste Forms* (MDL-EBS-GS-000002). The purpose of this model is to assess the potential impacts of igneous intrusion on waste packages and waste forms, including deleterious dynamic, thermal and chemical impacts. The results (expected dynamic conditions) are corroborated by relevant experimental and industrial analogs. The models for waste package and waste form response during igneous intrusion consider the following: Zone 1, which includes the emplacement drift intruded by the basalt dike and Zone 2, which includes the emplacement drifts adjacent to Zone 1. This report combines the following assessments:

- Impacts of magma intrusion on the performance of engineered barrier system (drip shields, cladding and waste packages) in emplacement drifts in Zone 1, and the fate of waste forms,
- Impacts of intrusion-related thermal conduction/convection and emanating magma gases on the drip shields, cladding and waste packages in the Zone 2-emplacement drifts, adjacent to the intruded drift, and
- Impacts of intrusion on in-drift thermal and geochemical environments, including seepage hydrochemistry, which may affect the release, and fate and transport of radionuclides.

The results of this model study will provide inputs to the *Igneous Intrusion Groundwater Transport* and to the *Waste Form Degradation and Mobilization Sub-models* of the Total System Performance Assessment model.

Based on the numerical simulations of non-steady state heat conduction with radial flow and simulations of flow of volatile gas from cooling magma, the report concludes that thermal effects and effects of corrosive gases on waste packages in Zone 2-emplacement drifts will be negligible. The maximum expected temperature rise in the Zone 2-emplacement drifts is less than 10° C. The low-thermal conductivity and the 80-meter distance separating drifts limit the thermal effects. Constraints on the effects of corrosive gases include (1) the limited amount of initial gases that could exsolve from the cooling intruded magma and that could reach waste packages in Zone 2 emplacement drifts, and (2) the dominance of the gas phase by water.

Eventual release of radionuclides potentially trapped in the magma would be minimal because of several factors, including: (a) low dissolution rate of basalt by incoming seepage water, (b) the development of stable waste-mineral phases in the basalt, and (c) the fact that waste form solubility, and especially fissile uranium solubility, is controlled by solution pH. Solution pH for seepage water equilibrated with basalt is in a range that causes precipitation of solubilized radionuclides and sorption of waste mineral phases in the basalt. Based on the results of the preceeding analyses, DOE will consider experimental studies (e.g., chemical and mechanical studies) to the extent that they are required to support our license application case.

In all of these investigations, it is very important that DOE maintain an integrated team of field experts, modelers, engineers, and performance assessment analysts. If, after considering the consequences and the risks posed to the public, the DOE decides to modify the repository design to mitigate the effects of igneous activity, such modifications would need to be evaluated in terms of their overall impact upon repository operations and performance.

Response:
The DOE agrees that it is essential to maintain an integrated team to complete these investigations as well as any future analyses involving volcanism and engineered barrier performance. The DOE is currently evaluating the potential effects (beneficial and adverse) of using durable barriers to limit flow of magma from potential future dikes that could intersect the repository as an integrated effort that includes experts in disruptive events and waste package analyses. This and any other proposed changes to repository design to mitigate the potential effects of igneous activity will be processed through our design control procedures to evaluate the overall impact on repository operations and performance.

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Peña Blanca

. . . Peña Blanca offers the opportunity to test a number of the proposed models and assumptions underlying the DOE's analyses of Yucca Mountain and to examine alternatives to these models. They include, but are not limited to, models and assumptions related to waste form dissolution (the source term), unsaturated zone flow and transport, and the active fracture model. . . . The additional information that comes from studying this site could show that the repository system would perform better or not as well as current performance estimates now project. However, either way, these tests could increase understanding of the processes and their associated uncertainties. For this reason, the Board strongly recommends continued support for studies at this unique site.

Response:
The DOE agrees that the ongoing work at Peña Blanca provides an opportunity to examine alternative models and to test proposed models and assumptions. A scientific plan, supported by the S&T Program, is under development for expanded studies at this site in the areas of hydrology, transport, and geochemistry. This plan will be considered for funding in FY 2004.

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

October 21, 2003

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

In its June 30, 2003, letter to you, the Nuclear Waste Technical Review Board promised a more detailed evaluation of data and analyses presented at the Board's May 2003 meeting. This letter briefly summarizes our concerns about waste-package corrosion during the thermal pulse — particularly localized corrosion but also general corrosion. In addition, we are nearing completion of a report on the technical bases for these and related concerns about various thermal pulse issues. We will provide the report to you soon.

1. *Localized Corrosion.* Localized corrosion processes are particularly insidious because initiation is difficult to predict and propagation rates can be very rapid. Information on localized corrosion (e.g., pitting, crevice corrosion, stress corrosion cracking) rates in representative repository environments is critical to predicting waste-package effectiveness. As illustrated by the attached overheads provided to the Board at recent meetings, data emerging both from the Yucca Mountain Project and from the Center for Nuclear Waste Regulatory Analyses (Center) suggest to the Board that crevice corrosion of Alloy 22 is likely to initiate during the thermal pulse (approximately the first thousand years after repository closure, when temperatures will exceed 95ºC for the current repository design). Project data show that initiation of crevice corrosion during the thermal pulse is likely in concentrated brines (with or without nitrates) at temperatures well below the peak waste-package surface temperatures expected in the Department's proposed repository design. Crevice corrosion initiated during the thermal pulse is likely to propagate during the remainder of the thermal pulse and also is likely to continue even after the thermal pulse, at temperatures below 95°C.

   Work at the Center and elsewhere indicates to the Board that welds and thermal treatment (aging) increase susceptibility to crevice corrosion. As currently designed, the waste package has both welded areas (i.e., closure welds) and many opportunities for crevice formation. Redesign studies for reducing or eliminating areas of increased susceptibility to localized corrosion may be a worthwhile option.

2. *General Corrosion.* In choosing candidate materials of construction, an important line of inquiry is the general (uniform) corrosion rate. If the general corrosion rate is known with confidence, then one can determine the mass of material (or thickness) required to perform for the life of the system. In the case of the Project, one needs corrosion-rate information in representative repository environments. Most corrosion data reported to date are for 95ºC (the approximate boiling point of pure water at the altitude of the repository site) or lower. These data may constitute an adequate technical basis if the surface temperatures of the waste packages in the repository never exceed 95ºC. Few data exist, however, at the higher temperatures of the thermal pulse. Moreover, the nature of the environments in contact with the waste packages (or drip shields) is not well known under such conditions. Concentration processes of various kinds may lead to aggressive chemistries.

The concern about localized corrosion during the thermal pulse is one of the data in hand showing that localized corrosion is likely. In contrast, the concern about general corrosion during the thermal pulse is one of corrosion-rate uncertainty due to the lack of corrosion data. That the aqueous environments necessary for corrosion exist during the thermal pulse is primarily due to deliquescence of salts. In the higher part of the thermal pulse range, deliquescence can be attributed mainly to chloride salts with divalent cations.

The Project data and the Center data are consistent in that both sets of data cast doubt on the extent to which the waste package will be an effective barrier under the repository conditions that have been presented to the Board. The waste package is both a key barrier and an extremely important element in providing defense-in-depth. Given the importance of the waste package to the repository, the Board requests that the Department address the Board's concerns about corrosion, particularly localized corrosion, during the thermal pulse.

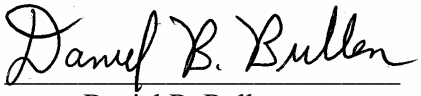
The Board believes that total system performance assessment should not be used to dismiss these corrosion concerns.

As you are aware, the Board's responsibilities include evaluating the technical and scientific validity of the Department's activities related to the repository and reporting the Board's findings, conclusions, and recommendations. Our role is that of an independent technical advisor. We know that the Department's decision-making process must take into account not only technical and scientific factors but also many others. Nevertheless, because of the seriousness of these corrosion concerns, we strongly urge you to reexamine the current repository design and proposed operation. The Board believes that the high temperatures of the current design and operation will result in perforation of the waste packages, with possible release of radionuclides. The data currently available to the Board, provided by the Project and the Center, indicate that perforation is unlikely if waste-package surface temperatures are kept below 95ºC.

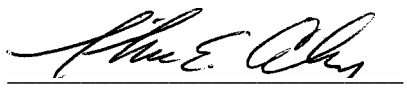
Sincerely,

Michael L. Corradini, Chairman

Mark D. Abkowitz



Daniel B. Bullen



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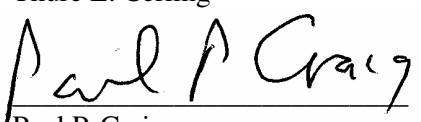
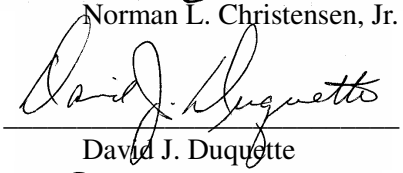


Paul P. Craig



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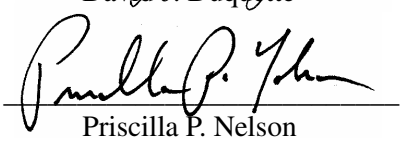


Priscilla P. Nelson

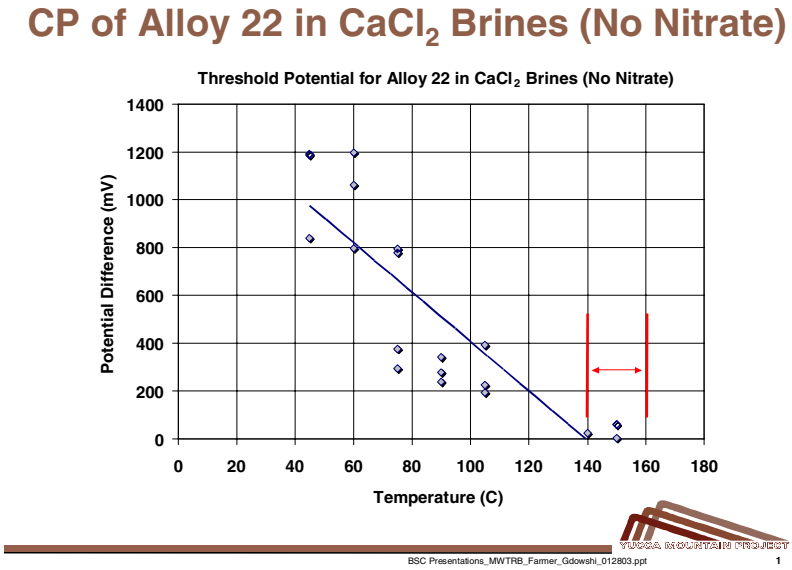
Richard R. Parizek

Attachment: Seven overheads presented at the Board's January and May 2003 meetings.

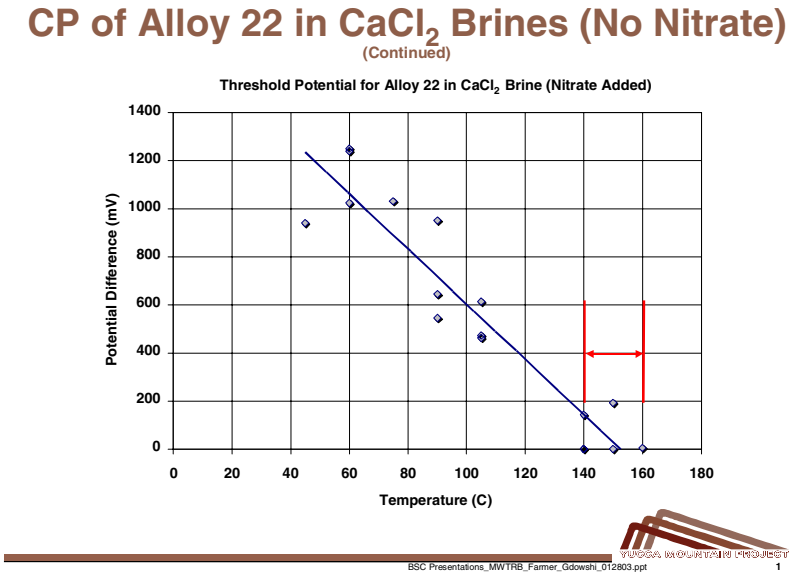
ATTACHMENT TO OCTOBER 21, 2003, LETTER FROM THE BOARD TO DR. CHU

This attachment contains seven overheads presented at the Board's January and May 2003 meetings. The first three overheads were part of presentations by Dr. Joseph C. Farmer of the Department of Energy's Lawrence Livermore National Laboratory. The next four overheads were part of a presentation by Dr. Gustavo A. Cragnolino of the Nuclear Regulatory Commission's Center for Nuclear Waste Regulatory Analyses.

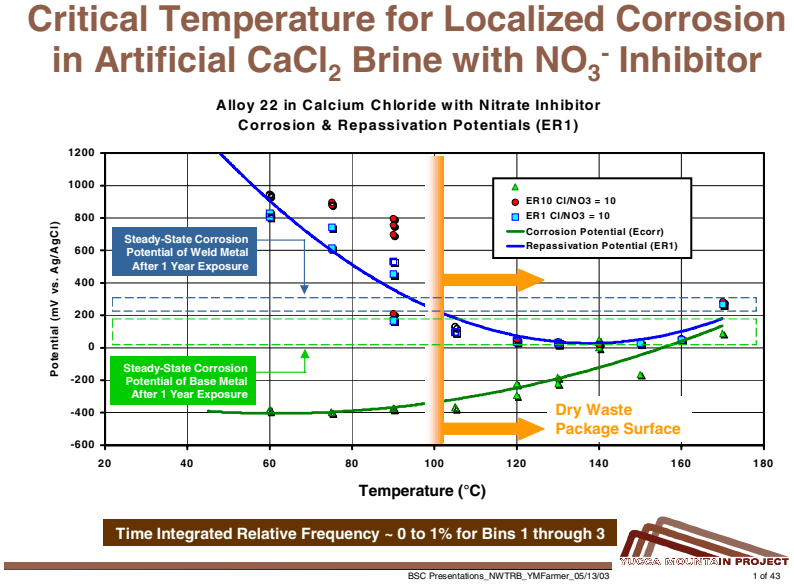
This figure is an overhead from Dr. Farmer's presentation at the January 28, 2003, Board meeting in Las Vegas. Localized corrosion is virtually certain to initiate when the Potential Difference falls below 0. For Alloy 22 in a concentrated solution of calcium chloride with no nitrate added, the overhead indicates that the Potential Difference is below 0 for temperatures of approximately 140ºC and higher. (Peak waste package surface temperatures in the current design are approximately 180ºC.)



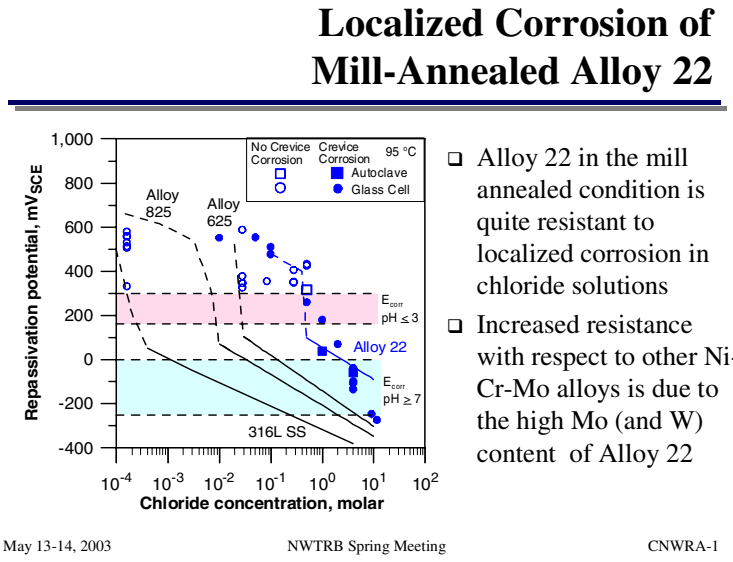
This figure is another overhead from Dr. Farmer's presentation at the January 28, 2003, Board meeting. (There is an error in the title. Instead of "No Nitrate," it should read "Nitrate Added.") Again, localized corrosion is virtually certain to initiate when the Potential Difference falls below 0. For Alloy 22 in a concentrated solution of calcium chloride with nitrate added, the overhead indicates that the Potential Difference is below 0 for temperatures of approximately 150ºC and higher.



This figure is an overhead from Dr. Farmer's presentation at the May 13, 2003, Board meeting in Washington, D.C. Note the dashed boxes. They indicate that base-metal steady-state corrosion potential moves in a noble (positive) direction with time and that welded-metal corrosion potential moves even farther in that direction with time, indicating increasing susceptibility to crevice corrosion with aging time and in welded structures. Although the overhead appears to state that waste package surfaces are dry above approximately 120ºC, deliquescence of salts in the dust on waste package surfaces can cause brines to form at temperatures up to approximately 150º-160ºC.

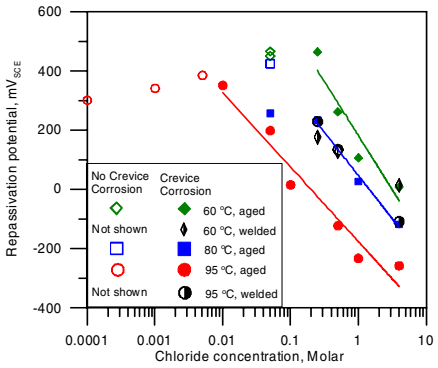


This figure to the right is an overhead from Dr. Cragnolino's presentation at the May 14, 2003, Board meeting in Washington, D.C. Note that Alloy 22 is more resistant to localized corrosion than other nickel-chromium-molybdenum alloys (alloys 625 and 825) and than a nickel-chromium alloy (316 stainless steel).



This figure is an overhead from Dr. Cragnolino's presentation at the May 14, 2003, Board meeting. It illustrates the increased susceptibility of welded and thermally aged Alloy 22 in comparison to mill-annealed material.

Effect of Fabrication Processes on Localized Corrosion

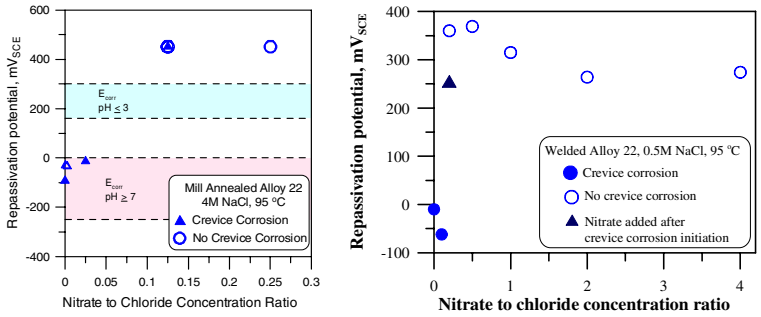


- Welding and short-term thermal aging increase localized corrosion susceptibility
- Localized corrosion observed at lower [Cl^-] and lower temperatures compared to the mill annealed condition

May 13-14, 2003 NWTRB Spring Meeting CNWRA-1

This figure is an overhead from Dr. Cragnolino's presentation at the May 14, 2003, Board meeting. It illustrates the beneficial effect of nitrate on localized corrosion susceptibility of Alloy 22 at 95ºC. There is an error in the next-to-last line. Rather than "1.2 for mill-annealed material," it should read "0.12 for mill-annealed material."

Effect of Nitrate on Localized Corrosion of Alloy 22

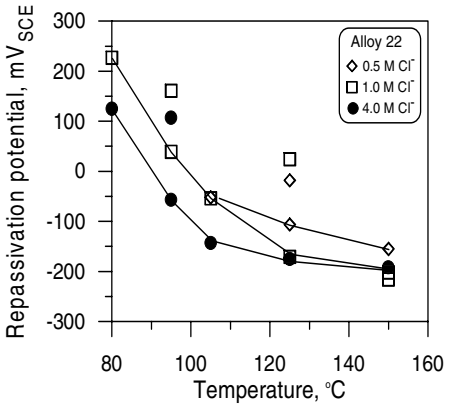


- Nitrate is an efficient inhibitor of localized corrosion induced by chloride
- Critical nitrate to chloride molar concentration ratio is 1.2 for mill-annealed material and 0.2 for welded material

May 13-14, 2003 NWTRB Spring Meeting CNWRA-1

This figure is an overhead from Dr. Cragnolino's presentation at the May 14, 2003, Board meeting. It illustrates how repassivation potential decreases with temperature.

Effect of Temperature on Localized Corrosion



- E_{rcrev} measured using creviced specimens in autoclave systems
- Significant decrease of E_{rcrev} with increasing temperature from 80 to 105 °C
- At higher temperatures E_{rcrev} values tend to level off

May 13-14, 2003 NWTRB Spring Meeting CNWRA-1

Department of Energy
Washington, DC 20585

QA: N/A

October 27, 2003

Dr. Michael L. Corradini
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, VA 22201-3367

Dear Dr. Corradini and Board Members:

I have received your letter of October 21, 2003, transmitting the Board's comments on the data and analyses we presented at the Board's May 13-14, 2003, meeting. I look forward to the report containing the detailed basis for the Board's comments, and will provide a response after there has been time to review it.

I am deeply disappointed by the premature release of the letter's contents. As a result, I am providing an immediate response so that I may register my concern about statements in the letter that, taken out of context, might be misunderstood or misrepresented. I am referring specifically to the definitive statements that crevice corrosion is "likely to initiate" during the thermal pulse, that "the data in hand [show] that localized corrosion is likely," and that "the high temperatures of the current design and operation will result in perforation of waste packages… ." I do not agree that the data cited by the Board support such definitive conclusions.

As we presented in the May meeting, the corrosion testing results cited in the Board's letter provide an incomplete representation of what we expect to occur in the likely environment inside the repository drifts. The Board's conclusions did not acknowledge the dependence of those results on the existence of extreme and unlikely environmental conditions, nor did the letter say whether the Board believes that such conditions are likely to occur. The outcome is an incorrect implication that the data show that localized corrosion and waste package perforation are "likely to" or even "will" occur.

With reference to the statement "that total system performance assessment should not be used to dismiss these corrosion concerns," I want to assure you that we will not dismiss the Board's corrosion concerns. However, as you know, the performance assessment is a required part of the demonstration of compliance with safety requirements established by the Environmental Protection Agency and the Nuclear Regulatory Commission.

Finally, I appreciate the fact that the Board's approach relates to the thermal operating conditions of the repository, and not to the ability to dispose of waste safely at Yucca Mountain.

Once again, we look forward to the Board's forthcoming report that we anticipate will provide a more complete basis and context for the Board's conclusions.

Sincerely,

Dr. Margaret S. Y. Chu, Director
Office of Civilian Radioactive
Waste Management

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

November 25, 2003

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

We are pleased to transmit a technical report prepared by the Nuclear Waste Technical Review Board (Board) that includes additional analyses supporting the Board's conclusions related to corrosion in its October 21, 2003, letter to you. Although the enclosed report touches on a variety of corrosion issues, its main focus is the potential for deliquescence-induced localized (or crevice) corrosion of the Alloy 22 waste packages in the Department of Energy's proposed high-temperature repository design. The conditions used by the Board for its analyses were presented by the DOE at the Board's January and May 2003 meetings. The report also evaluates the vaporization barrier and capillary barrier concepts that were discussed at the May meeting. Appended to the report are some additional technical comments by Dr. Michael Corradini.

Based on its review of data gathered by the DOE and the Center for Nuclear Waste Regulatory Analyses, the Board believes that all the conditions necessary to initiate localized corrosion of the waste packages will likely be present during the thermal pulse because of the deliquescence of salts on waste package surfaces, and thus it is likely that deliquescence-induced localized corrosion will be initiated during the thermal pulse. Corrosion experiments indicate that localized corrosion is likely to be initiated if waste package surface temperatures are above 140°C and if concentrated brines, such as would be formed by the deliquescence of calcium and magnesium chloride, are present. Limited data examined to date indicate that dust, which would be present in the proposed tunnels and which would be deposited on waste packages, contains calcium chloride and magnesium chloride salts in amounts sufficient for the development of concentrated brines through deliquescence. (Crevices are widespread on the waste packages, arising from their design as well as from contacts between the metal and dust particles.)

Thus, the Board believes that under conditions associated with the DOE's current high-temperature repository design, widespread corrosion of the waste packages is likely to be initiated during the thermal pulse. Once started, such corrosion is likely to propagate rapidly even after conditions necessary for initiation are no longer present. The result would be perforation caused by localized corrosion of the waste packages, with possible release of radionuclides.

The Board is aware that the DOE believes that the conditions in the repository will not promote significant corrosion. The DOE points to data, gathered using thermogravimetric apparatus (TGA), to demonstrate that the conditions necessary to initiate localized corrosion will be present only briefly. The Board has evaluated these data and finds them inadequate to support the DOE's claim for the following reasons.

- Brines used in the TGA experiments may not be representative of those that would form on the waste packages because of deliquescence.
- The metallic coupons used in the experiments did not contain crevices.

- The TGA experiments have been run only over narrow ranges of temperature and relative humidity.
- The experimental apparatus is an "open" system that may not approximate short-term behavior of the microenvironment associated with crevices.
- The results from other experiments conducted by the DOE seem contradictory.

The DOE also holds that the conditions under which localized corrosion might occur are extreme and unlikely. The information provided to the Board to date, however, does not form a compelling basis for that contention. For example, the DOE maintains that the presence of nitrates and an insufficient amount of calcium chloride in the proposed repository tunnels will limit localized corrosion. The DOE's own data, however, indicate that nitrate may not be protective at temperatures higher than 140°C. Furthermore, as noted above, the Board has concluded that more than enough chloride would be present in the dust from the tunnels to lead to widespread localized corrosion.

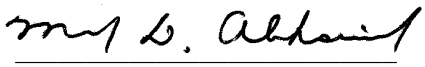
Thus, the DOE's belief that the geochemical environment on the waste package surfaces *will not* lead to corrosion lacks a strong technical basis. Absent that basis, the Board cannot ignore the clear and unambiguous implications of the corrosion and deliquescence experiments.

As stated in our October 21 letter, the Board realizes that decision-makers must take into account considerations beyond technical and scientific ones when making program decisions. However, because of the significance of the waste packages to the proposed repository system, the Board believes that the potential for localized corrosion during the thermal pulse should be addressed. From a technical perspective, the problems related to localized corrosion that are described by the Board in the enclosed report could be avoided if the repository design and operation were modified. The data currently available indicate that perforation of the waste packages caused by localized corrosion is unlikely if their temperatures are kept below 95ºC.

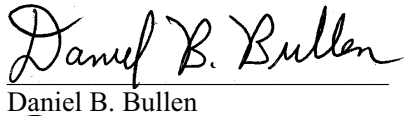
The Board looks forward to continuing its review of the DOE's investigations at Yucca Mountain, including those dealing with the integrity of the waste packages.

Sincerely,

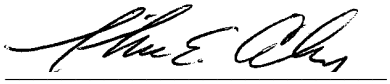
Michael L. Corradini, Chairman



Mark D. Abkowitz



Daniel B. Bullen



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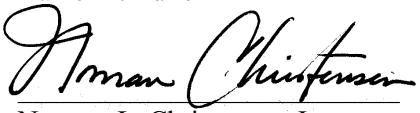
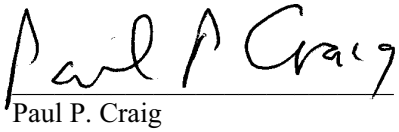
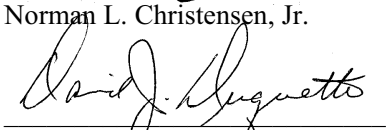


Norman L. Christensen, Jr.

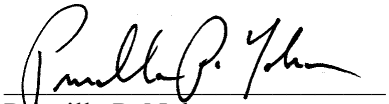


Paul P. Craig

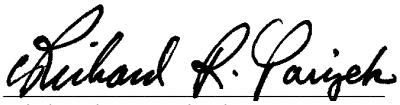


David J. Duquette

Ronald M. Latanision



Priscilla P. Nelson



Richard R. Parizek

QA: N/A

Department of Energy
Washington, DC 20585

December 17, 2003

Dr. Michael Corradini
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, VA 22201-3367

Dear Dr. Corradini:

Thank you for your letter of November 25, 2003, transmitting the Board's technical report, *An Evaluation of Key Elements in the U.S. Department of Energy's Proposed System for Isolating and Containing Radioactive Waste*. This report provides additional analyses to support the Board's October 21, 2003, letter, which summarized the Board's concerns relating to waste package corrosion during the thermal pulse. In addition, I have received your letter of December 4, 2003, announcing the Board's decision to conduct meetings of the Engineered System and the Waste Management System Panels, instead of a Full Board meeting, in January 2004.

With respect to the Board's technical report, we are in the process of reviewing this report, but I would like to provide some preliminary comments. While the Board has identified some valid issues with the technical basis for aspects of the U. S. Department of Energy's (DOE's) analysis of corrosion processes during the thermal pulse, I am concerned about certain conclusions in this report. As first noted in my October 27, 2003, letter, I am especially concerned about the Board's conclusions that under the conditions associated with our current design, "widespread corrosion is likely to be initiated during the thermal pulse" and this corrosion is "likely to propagate rapidly even after conditions necessary for initiation are no longer present." Our analyses do not suggest such results and I do not believe that the data presented in the Board's report support such strongly stated conclusions. The report also fails to acknowledge briefings on the DOE's ongoing testing and analysis program that is structured to address some of the issues raised by the Board.

I anticipate that our review of your report will be completed in February 2004. After we have completed this review, we would appreciate the opportunity to discuss the report during a Full Board meeting – perhaps in the March timeframe. The purpose of this discussion would be to develop a common understanding of the technical issues related to seepage, the in-drift environment, and localized corrosion. Instead of formal DOE

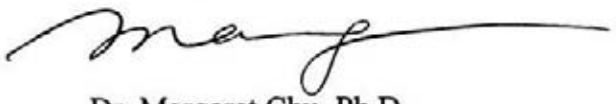
presentations, I propose a round table presentation and discussion of the issues as an appropriate forum to develop a common understanding of the Board's concerns and DOE's perspective on these issues. The Board used this approach in their meeting on multiple lines of evidence in April of 2001 and the results were well received.

The Board's letter of December 4, 2003, provides suggested topics for DOE presentations at the Board's panel meetings scheduled for January 20 and 21, 2004. With respect to the panel meeting on the waste management system, the DOE will provide the requested presentations on the status of DOE transportation planning and the interface between the transportation system and the Yucca Mountain surface facilities.

For the panel meeting on the engineered system, I believe it is premature, as noted above, for the DOE to address the Board's November report at that time. Given the critical nature of the Board's concerns, I believe this discussion should be addressed in a Full Board Meeting after the DOE has completed a technical review of the Board's report. Our respective staffs are discussing alternative presentations for that meeting.

Claudia M. Newbury of my staff will be working with Daniel Fehringer and Carl DiBella of the Board staff on the details and planning for these two panel meetings. I appreciate the time the Board has taken to develop and communicate its views, and I look forward to continuing our dialogue on important issues.

Sincerely,



Dr. Margaret Chu, Ph.D.
Director
Office of Civilian Radioactive
Waste Management

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

December 4, 2003

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

The Board has decided to conduct two panel meetings on January 20 and 21, 2004, in Las Vegas, rather than the full Board meeting that was scheduled for the same week and location. Specifically, the Board's Panel on the Engineered System will conduct a meeting on Tuesday, January 20, and the Board's Panel on the Waste Management System will conduct a meeting on Wednesday, January 21. Both meetings will be held at the Crowne Plaza Hotel. Principal topics that will be considered at the Engineered System Panel meeting will be waste-package corrosion, environment on waste package surfaces, and design. The focus of the Waste Management System Panel will be issues related to the transportation of spent nuclear fuel and high-level waste.

Since OCRWM's appropriation for FY2004 is now settled, we very much would appreciate an update from you on OCRWM's current activities and plans for the remainder of the fiscal year. Because it appears that all Board members will be at the January 20 meeting, we would prefer to have your update then if that is convenient for you.

Panel on the Engineered System

In an October 21, 2003, letter to you, the Board expressed its serious concerns about the potential of waste-package corrosion during the thermal pulse. On November 25, 2003, the Board sent you a report discussing the technical basis for the Board's concerns and other topics. We would like the DOE to take as much time as you think necessary at the January 20 meeting to address the issues in these two documents. The specific subject areas to be addressed would be up to you. They could include, for example, corrosion data obtained since Spring 2003 and plans for obtaining additional corrosion data, amplification of the deliquescence discussion at last May's Board meeting, plans for analyses of airborne dusts or ECRB dusts, responses to the Board's concerns about temperature and relative humidity calculations, etc. Time permitting, we would also appreciate updates on the waste package prototype program, surface and subsurface facility design (particularly recent changes and ground support design), waste package/drip

shield/emplacement pallet/invert/engineered barrier system design, and other design topics the DOE is prepared to discuss. Dr. Ron Latanision, who chairs the Panel on the Engineered System, will chair this panel meeting. Dr. Carl Di Bella is the staff member coordinating this meeting for the Board.

Panel on the Waste Management System

The transportation meeting will focus on strategic planning considerations related to the potential shipment of commercial spent fuel and high-level waste to Yucca Mountain. The purpose of the meeting is to hear directly from key stakeholders who could have operational or oversight responsibilities for the safety and/or security of such shipments at some point during loading, in-transit, and/or unloading activities. Speakers will be asked to address the following questions:

1. What are your key Yucca Mountain transportation safety and security concerns?
2. How have you been able to address these concerns based on the information and resources that the DOE has provided to date?
3. What concerns have you been unable to address? What does the DOE need to provide to allow this to happen?
4. How long will it take you to address these outstanding concerns once the DOE has provided what you need?

We plan to invite speakers who are knowledgeable about all aspects of a Yucca Mountain transportation system, including representatives of utilities, truck and rail operators, cask manufacturers, state and local governments, and veterans of previous shipping campaigns. We request two presentations by the DOE: one on the interface between the transportation system and Yucca Mountain surface facilities, and another overview presentation of the status of DOE transportation planning. Dr. Mark Abkowitz, member of the Panel on the Waste Management System, will chair this panel meeting. Dr. Dan Fehringer is the staff member coordinating this meeting for the Board.

We are looking forward to two days of very interesting and productive meetings.

Sincerely,

Michael L. Corradini
Chairman

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

December 16, 2003

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

The Board thanks you and the rest of the Yucca Mountain Project team for participating in our September meeting in Amargosa Valley. Your program overview and the presentations by your staff and contractors were very clear and helpful to the Board.

We were pleased to hear that you have completed your selections for key management positions within the Office of Civilian Radioactive Waste Management. It appears that you have assembled a highly qualified and competent management team.

Our observations and recommendations from this meeting are presented below.

Issues Relating to Natural Characteristics of Yucca Mountain

Igneous scenarios. According to the DOE's estimates, igneous scenarios may dominate the risk to humans from a Yucca Mountain repository. To date, it appears that the DOE intends to pursue only one of the three recommendations made by the Board in its June 30, 2003, letter—study of aeromagnetic anomalies near the Yucca Mountain site. The Board repeats its recommendation that the DOE also conduct modeling studies of compressible fluids and studies of waste package-magma interaction and waste entrainment.

Enhanced borehole studies. As plans are developed for drilling aeromagnetic anomalies near Yucca Mountain, the Board encourages the DOE to consider additional development of those boreholes as monitoring wells to obtain hydraulic head, water chemistry, and related hydrogeologic data at relatively small additional cost. Additional hydrogeologic data from these areas may resolve differing hypotheses regarding the direction of water flow in the saturated zone and may provide additional information about the ability of the saturated zone to function as a barrier to migration of radioactive materials.

Chlorine-36. The Board encourages the DOE to resolve discrepancies in chlorine-36 studies and agrees with the decision to commission a third-party review that includes integrated chlorine-36 and other bomb-pulse data to help address inconsistencies. Such an integrated

methodology should include the measurement of tritium. If an accepted integrated methodology could be developed, it could enhance understanding of hydrogeologic controls on fast-path flows into the repository and yield a conceptual model consistent with both chlorine-36 and other bomb-pulse data. The Board believes that resolving chlorine-36 discrepancies will require a "root cause" analysis that lays out each step in the procedure, how the discrepancies were addressed by each of the two analytical groups, and what each set of measurements has in common as well as what differences exist and the potential reasons for these differences and actions for resolving them.

Issues Relating to Potential Waste Package Corrosion

Microbial activity. Decreasing nitrate concentrations with depth, as shown in one of Bo Bodvarsson's slides, suggest microbial activity. A waste package design that relies on nitrate to reduce the likelihood of localized corrosion must take into account the effects of microbial activity on nitrate concentrations both before and during the thermal pulse.

Gas pressure. The maximum temperature at which brines can exist on waste package surfaces is a strong function of gas pressure. Elevated pressures allow brines to exist at higher temperatures, increasing the likelihood that corrosion will be initiated. Even transient elevated pressures could be important. The DOE should provide a careful and complete explanation of gas pressures during the thermal pulse within the drift environment.

Issues Relating to Management and Communication

Quality/schedule tradeoffs. The Board appreciates John Arthur's assurance that the license application schedule is not constraining the quality of work within the Yucca Mountain project. The Board strongly agrees with the DOE that a license application should be filed only when appropriate quality standards have been met. A schedule-driven approach to quality management can potentially compromise the safety culture surrounding the preparation of the license application, thereby making the project vulnerable to poor decision-making. The Board emphasizes the importance and inherent long-term efficiency in "taking the time to do it right."

Repository performance confirmation. With an operational period that may extend beyond repository closure, it appears that performance confirmation may be a component of the DOE's proposed radioactive waste disposal system that will span licensing, construction, and possibly operation. Thus, performance confirmation holds the possibility of enhancing confidence in repository prediction not only by "confirming" DOE models but also by testing the underlying conceptual, physical, and mathematical bases of those models. The Board encourages the DOE to have a clear understanding of what it means by performance confirmation and integrate it thoroughly with performance assessment and repository design. This includes the need to establish formal management practices that ensure that appropriate interactions occur between these system components. Moreover, the Board believes that the performance confirmation program can benefit significantly from the input of the interested public and affected parties.

Program integration and communication. The Board believes that the technical basis documents being developed for the Yucca Mountain Project have significant potential for improving program integration and enhancing program communication with the wider technical community as well as the general public. For gaining the maximum benefit from these documents, integrating their most important conclusions into a concise description of the safety case for a Yucca Mountain repository will be important. However, if the documents are not well integrated or if they contain technical errors, then communication of the safety case to the broad scientific and public audiences will be weakened. Where appropriate, the discussion of relevant analogs can be used as a line of evidence and enhance the DOE's communication.

The Board reiterates the need for early and continuous involvement of interested members of the public and affected parties in transportation planning. This involvement is critical to develop a safe and secure transportation system and to engender public confidence in system performance.

Once again, the Board thanks you and the rest of the Yucca Mountain Project team for participating in the Board's September meeting. We look forward to continuing the Board's ongoing technical and scientific review and to commenting on Project activities in the future.

Sincerely,

Michael L. Corradini
Chairman

Appendix F
Other U.S. Nuclear Waste Technical Review Board Correspondence

- Letter from Harry W. Swainston to Michael L. Corradini; October 27, 2003.
  Subject: Transmittal of "Review of the Report 'Thermochronological Evolution of Calcite Formation at the Potential Yucca Mountain Repository Site, Nevada'"

- Letter from Michael L. Corradini to Harry W. Swainston; December 8, 2003.
  Subject: Acknowledgement of letter

- Letter from Robert R. Loux, Executive Director, Nevada Agency for Nuclear Projects to Michael L. Corradini; November 25, 2003.
  Subject: Internal criticality risk at Yucca Mountain

- Letter from Michael L. Corradini to Robert R. Loux; December 8, 2003.
  Subject: Acknowledgement of letter

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October 27, 2003

Dr. Michael L. Corradini, Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Blvd., Suite 1300
Arlington, VA 22201-3367

Dear Dr. Corradini:

Enclosed you will find a copy of a document entitled "Review Of The Report 'Thermochronogical Evolution Of Calcite Formation At The Potential Yucca Mountain Repository Site, Nevada'" published under the auspices of the Siberian Branch of the Russian Academy of Sciences United Institute of Geology, Geophysics and Mineralogy, which was authored by two members of the Institute of Mineralogy and Petrography, Dr. Yuri V. Dublyansky and Dr. Sergey Z. Smirnov. The document is a review of a two part report written by UNLV coordinators, Nick Wilson, Jean Cline and Y. Amelin, of the Yucca Mountain Thermochronology Project, a project conducted in response to a suggestion by the Nuclear Waste Technical Review Board in 1998 to resolve differences in the interpretation of certain fluid inclusion and stable isotope data, which had spawned a heated controversy between scientists representing the State of Nevada and those representing the interests of the DOE (primarily the USGS) concerning the origin and ages of secondary minerals in the interior of Yucca Mountain.

Dr. Dublyansky was Nevada's representative for the UNLV Thermochronology Project. Except for DOE representatives' concession that the secondary minerals in question were, indeed, formed from heated aqueous fluids, the disagreement between the scientists, particularly the source of the heat, has persisted to the present day. The DOE aligned interests still maintain that the source of the depositing fluids was meteoric water in the form of infiltrating rainwater passing through a mountain that remained hot for millions of years. Dr. Dublyansky and a group of internationally based scientists working with him, which include many of his colleagues at the Institute, Jerry Szymanski of Las Vegas, Nevada and Dr. Tim Harper of England are convinced, based on many lines of evidence, that the secondary minerals were deposited by hydrothermal fluids driven from deep beneath Yucca Mountain and that episodes of such deposition are recent in geologic time. If hydrothermal fluids were to flood the proposed repository during its 10,000-year lifetime or even an extended period of many tens of thousands of years, steam explosions would undoubtedly result and the canisters would be breached. As the fissile material is rearranged tremendous quantities of radioactivity would be released through a variety of pathways to the biosphere, not the least of which are those created by predictable low yield nuclear explosions and uncontrollable *in situ* criticality processes.

In a letter written to the NWTRB by the Yucca Mountain Project Manager, J. Russell Dyer,

dated January 24, 2002, the lack of a consensus in the lingering rainwater-upwelling controversy was documented. Inexplicably, however, NWTRB Chairman Jared Cohon wrote a letter addressed to Mr. Lake H. Barrett, Acting Director of OCRWM dated March 11, 2002, which stated:

> At the Board meeting and in a letter to the Board dated January 24, 2002, the DOE concluded that the hypothesis of hydrothermal upwelling proposed by Mr. Jerry Szymanski had been adequately addressed and may be discounted. These conclusions were based on the DOE's positive response to a Board recommendation that a joint federal-State of Nevada project be conducted to determine the ages of fluid inclusions at Yucca Mountain. A systematic joint study was coordinated by University of Nevada-Las Vegas scientists and can be considered a model for successful resolution of some contentious scientific issues. The Board concurs with the DOE's conclusions and considers this issue resolved.

The important point to recognize with respect to the foregoing communications is that they contain nothing more than political opinion. The decision whether or not the controversy is scientifically resolved is a technical issue related to the safety of the site, which is committed to the jurisdiction of the Nuclear Regulatory Commission's licensing board. The NRC is the sole entity responsible for safety considerations concerning the licensing of the Yucca Mountain site. Furthermore, the decision whether or not the State of Nevada will raise a contention based upon the continuing controversy is a question, which rests solely with the Nevada Attorney General. The bottom line is that the controversy is resolved neither politically nor scientifically.

Other political statements such as the one attributed to you as the consequence of your recent co-authorship of an editorial in a Madison, Wisconsin newspaper that in your opinion nuclear waste can be "stored safely at Yucca Mountain" are counter productive in the effort to provide the world community with a fair and unbiased process. Since that bell cannot be unrung, an appropriate strategy for the mitigation of the effects of the dissemination of misinformation might come in the form of reopening the scientific review of the origin and ages of the secondary minerals at Yucca Mountain before the NWTRB.

An unbiased consideration of reasonable interpretations, which may be attributed to data acquired during the UNLV Thermochronology Project, is warranted. A number of questions, which were raised by Board members, regarding findings by the Thermochronology Project in a meeting of the full Board on May 9, 2001 need to be resolved. Among these were questions raised concerning the source of magnesium found in samples of secondary minerals, the source of hydrocarbons in all gas inclusions, an explanation for the high salinities in the fluids of the inclusions, the use of a constant lead correction for uranium-lead age dating, thermodynamic limitations to the rainwater hypothesis, etc.

The review authored by Dr Dublyansky and Dr. Smirnov enclosed herein and a second review authored by them: "Commentary on: 'Physical and stable-isotope evidence for formation of secondary calcite and silica in the unsaturated zone, Yucca Mountain, Nevada' by J.F. Whelan, J.B. Paces, and Z.E. Peterman" (submitted for publication in Applied Geochemistry, a peer-reviewed journal) as well as the reports of the USGS and UNLV researchers regarding their interpretations of the data produced by the UNLV Thermochronology Project can provide valuable resources to define the issues. The position of the international group of scientists referred to above will be fully discussed in a book length monograph presently in a draft format pending review, which will contain multiple lines of evidence proving without question that the deposition of the secondary minerals was caused by the upwelling of hydrothermal water.

The NWTRB has the statutory mandate in Section 503 of the NWPA, 42 U.S.C. 10263, to

evaluate the technical and scientific validity of activities undertaken by the Secretary of Energy in relation to, among other things, site characterization activities. This broad grant of authority provides the Board with the power and the duty to oversee the DOE's consideration of potentially disruptive events such as the possible flooding of the proposed repository by upwelling water and to intervene with appropriate admonitions and recommendations to the Department of Energy. It is a dereliction of this duty for the Board to disregard its mandate by leaving contentious issues affecting the performance of the proposed repository left unresolved.

The Board also has the duty to report to the Congress and the Secretary of Energy with regard to findings, conclusions and recommendations as to matters within its purview. *See* 42 U.S.C. 10268. To the extent the Board has prematurely terminated consideration of the need for a comprehensive risk assessment of potential consequences associated with the controversy discussed herein, it appears that both the Secretary of Energy and the Congress have been misled by previous reports from the Board. Eventually, evidence of the dangerous nature of the site will certainly cause the abandonment of the site. At that time certain individuals and entities will be held accountable for the expenditure of billions of dollars and, more importantly, years of lost time in the resolution of a pressing national environmental problem. There will be plenty of blame to go around. Unless the NWTRB takes steps to rectify its past nonfeasance, it will likely become the scapegoat for the misfeasance of many.

I commend the enclosed review for your careful consideration and appropriate action.

Cordially,

Harry W. Swainston

Harry W. Swainston
Attorney At Law

Enclosure
cc:
The Honorable Brian Sandoval, Nevada Attorney General, Carson City NV
The Honorable Kenny Guinn, Nevada Governor, Carson City, NV
The Honorable Harry Reid, Nevada Senator, Washington DC
The Honorable John Ensign, Nevada Senator, Washington DC
The Honorable Jim Gibbons, Nevada Representative, Washington DC
The Honorable Shelly Berkley, Nevada Representative, Washington DC
The Honorable Jon Porter, Nevada Representative, Washington DC
The Honorable Spencer Abraham, Secretary of Energy, Washington DC
Brian McKay, Chairman, Nevada Commission on Nuclear Projects, Reno, NV
Michon Mackedon, Vice Chairman, Nevada Commission on Nuclear Projects, Fallon, NV
Richard H. Bryan, Nevada Commission on Nuclear Projects, Las Vegas, NV
Larry Brown, Nevada Commission on Nuclear Projects, Las Vegas, NV
Steven Molasky, Nevada Commission on Nuclear Projects, Las Vegas, NV
Myrna Williams, Nevada Commission on Nuclear Projects, Las Vegas NV
Paul Workman, Nevada Commission on Nuclear Projects, Las Vegas, NV
Robert Loux, Executive Director, NWPO, Carson City, NV
Pricilla P. Nelson, member, NWTRB, Arlington, VA

Paul P. Craig, member, NWTRB, Arlington, VA
Daniel B. Bullen, member, NWTRB, Arlington, VA
Norman L. Christenson, Jr., member, NWTRB, Arlington, VA
Richard Parizek, member, NWTRB, Arlington, VA
Thure E. Cerling, member, NWTRB, Arlington, VA
Ronald M. Latanision, member, NWTRB, Arlington, VA
Mark D. Abkowitz, member, NWTRB, Arlington, VA
David J. Duquette, member, NWTRB, Arlington, VA
Jared Cohon, former Chairman, NWTRB, Arlington, VA
William D. Barnard, Executive Director, NWTRB, Arlington, VA
B. John Garrick, Chairman, ACNW, Rockville, MD
Michael T. Ryan, Vice Chairman, ACNW, Rockville, MD
George M. Hornberger, member, ACNW, Rockville, MD
Milton Levenson, member, ACNW, Rockville, MD
Ruth F. Weiner, member, ACNW, Rockville, MD
Nils J. Diaz, Chairman, NRC, Rockville, MD
Jeffrey S. Merrifield, Commissioner, NRC, Rockville, MD
Edward McGaffigan, Commissioner, NRC, Rockville, MD
William D. Travers, Executive Director, NRC, Rockville, MD
Bret W. Leslie, NRC, Washington, DC
Thomas J. Casadevail, Central Region Director, USGS, Denver, CO
Wayne Premo, USGS, Denver, CO
James Paces, USGS, Denver, CO
Zell Peterman, USGS, Denver, CO
Stephen Brocoum, Assistant Manager, DOE/YMPO, North Las Vegas NV
J. Russell Dyer, Assistant Deputy Manager for Repository Design, DOE/YMPO, North Las Vegas NV
Drew H. Coleman, OLANS, DOE/YMPO, North Las Vegas, NV
Donald H. Baepler, Executive Director, Harry Reid Center for Environmental Studies, Las Vegas, NV
Jean S. Cline, Associate Professor, UNLV, Las Vegas, NV
Nicholas Wilson, Calgary, Canada
Robert J. Bodnar, C.C. Garvin Professor of Geochemistry, Blackburg, VA
Yuri Dublyansky, Geochemist, IMP, Novosibirsk, Siberia, Russia
Tim Harper, President, Geosphere, Ltd., Beaworthy, Devon, Eng.
Jerry Szymanski, Geologist, Las Vegas NV
Carol Hill, Geologist, Albuquerque, NM
Charles Archambeau, President, TRAC, Boulder, CO
Mary Beth Gray, Assoc. Professor of Geology, Bucknell University, Lewisburg, PA
Arjun Makhijani, President, IEER, Washington DC
Charles D. Bowman, LANL, Los Alamos, NM
Francesco Venneri, LANL, Los Alamos NM
William J. Broad, New York Times, New York, NY

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

December 8, 2003

Harry W. Swainston, Esq.
Attorney At Law
4040 Hobart Rd.
Carson City, Nevada 89703

Dear Mr. Swainston:

Thank you for your letter of October 27, 3003 and the accompanying report by Drs. Yuri V. Dublyansky and Sergey Z. Smirnov entitled *Review of the Report: "Thermochronological Evolution of Calcite Formation at the Potential Yucca Mountain Repository Site, Nevada."* We do appreciate your direct transmittal of this report to all of our Board members. In your letter you requested that we carefully consider the Dublyansky and Smirnov report and take appropriate action. Based on input from its members, the Board will decide on an appropriate course of action.

Thank you again for transmitting copies of the report.

Sincerely,

Michael L. Corradini
Chairman

OFFICE OF THE GOVERNOR
AGENCY FOR NUCLEAR PROJECTS
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E-mail: nwpo@nuc.state.nv.us

November 25, 2003

Dr. Michael L. Corradini
Chairman
U.S. Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Suite 1300
Arlington, VA 22201

RE: Internal Criticality Risk at Yucca Mountain

Dear Dr. Corradini:

I am writing to request that the Nuclear Waste Technical Review Board ("TRB") conduct a careful review of the previously withheld, but recognized potential for internal criticality of nuclear waste residues at the proposed Yucca Mountain nuclear waste repository. We were amazed to learn, after finally obtaining some of the pertinent documents from the Department of Energy ("DOE") through the Freedom of Information Act ("FOIA"), that DOE's own studies anticipate that, if the repository operates as is now planned, *up to 60 nuclear criticalities* may plausibly occur inside the mountain, and that the conditional probability of occurrence may be greater than one in one thousand per year.

That conclusion is sharply at odds with what DOE publicly represented in its Final Environmental Impact Statement (FEIS) on the proposed facility, which assigns such events an extremely low probability of occurrence. In particular, in FEIS Volume 1 at page 5-39, DOE concluded:

> The potential for criticality of commercial spent nuclear fuel would be maximized when the internal basket was fully degraded, but with the assemblies remaining intact and no breach of the bottom of the waste package. Under these circumstances, the calculated probability of a critical event within the total inventory of the 21-PWR Absorber Plate

waste packages would be less than 2×10^{-7} in 10,000 years (after closure of the repository).

However, DOE's actual criticality studies, which were omitted (improperly, we believe) from the FEIS administrative record, tell a markedly different story. Once Nevada determined that such documents existed, we filed a series of FOIA requests, which produced some, but not yet all, of the pertinent documents. One document we did receive recently is DOE's *Criticality Potential Curve Draft Report* for the proposed Yucca Mountain repository. Nevada engaged Dr. Michael C. Thorne, an independent expert in criticality safety and probabilistic risk assessment, to study that report. He has not been able to undertake a full review at this time because DOE has withheld some of the supporting documentation, calculations and analyses performed for the preparation of this report.

However, Dr. Thorne was able to make some clear and startling conclusions. He noted that the DOE report identifies three types of potential criticality events at Yucca Mountain – "Light Bulb," "SL-1," and "Waste Package." He concluded, based on his review of previous criticality accidents worldwide, that these potential criticality events and their projected fission yields were indeed plausible occurrences in the proposed repository. The DOE report estimated the conditional probability of each of these events per cask as 5.1×10^{-3}, 2.6×10^{-4} and 2.6×10^{-4} for Light Bulb, SL-1 and Waste Package criticality events, respectively. The calculated probabilities are conditional in that they assume perforation of the cask and introduction of water to the waste, but for the long term, of course, DOE's Total System Performance Assessment assumes that all packages eventually do degrade.

Moreover, Dr. Thorne observed several non-conservative deficiencies in the probabilistic arguments used in the DOE studies, implying that higher frequencies (which he assessed as 4.1×10^{-2}, 2.1×10^{-2} and 2.1×10^{-2} for Light Bulb, SL-1 and Waste Package events, respectively) cannot be ruled out. Nevertheless, even using the conditional probability estimates given in the DOE report, because the Yucca Mountain repository would contain about 11,770 waste packages (Supplemental Science and Performance Analyses, 2001, page 7-62), and because all packages will eventually degrade, the expected numbers of criticality events over the long term are 60, 3, and 3 for Light Bulb, SL-1 and Waste Package events, respectively.

These astonishing numbers raise grave concerns about the proposed repository's safety and environmental impacts, further calling into question the legal and technical adequacy and veracity of the Yucca Mountain FEIS. A criticality occurring in the repository could severely compromise the entire facility, vastly increasing radionuclide releases and making waste packages irretrievable.

DOE's *Criticality Potential Curve Draft Report* does not discuss the timescale over which these presumed criticality events would occur. However, Dr. Thorne believes the report suggests they occur uniformly over a period beginning when a package first perforates and admits water and ends when the presumed "bathtub" wall has corroded

sufficiently to release the water. (The potential long-term integrity of the canisters is a matter to which the TRB and we are also very concerned.) According to Dr. Thorne, the period from penetration of the first package to loss of the bathtub configuration in the last is likely to extend from some point within the 10,000 years following repository closure and for some tens of thousands of years thereafter. Based on more than 60 critical events over that interval, the probability of a critical event within the whole proposed repository is thus – using DOE's own numbers – *on the order of 1 x 10^{-3} per year or higher*, with that probability applying to at least part of the interval within the 10,000-year regulatory compliance period. This value differs radically from the value of 2 x 10^{-7} per year cited in DOE's FEIS. The criticality numbers also further underscore the absurdity of limiting Yucca Mountain's safety analysis to 10,000 years.

We recognize that the values given in the *Criticality Potential Curve Draft Report* are based on a simplified analysis, though we see no reason why they should not have been prominently dealt with in the FEIS. This issue has become all the more important given recent determinations by the TRB and Nevada's experts that corrosion of the Yucca Mountain waste containers and water infiltration are serious possibilities during the regulatory compliance period, and are certain to occur over longer periods.

Finally, this month we received through the FOIA process several backup documents for the *Criticality Potential Curve Draft Report* that appear only to confirm our concerns. These 1998 documents reveal that DOE's Senior Technical Review Panel for the FEIS was likewise worried about criticality in the event of water entering a ruptured or corroded spent fuel canister, and it recommended on several occasions that DOE "quantify the consequences" if such an event "is conceivable." The documents show that DOE's own criticality analysts had "assumed that ingress of water into a storage cask, without any change in geometry of the spent fuel and/or movement of the neutron poison, *would result in a critical event,*" and that the probability of criticality was so high that DOE should not waste time analyzing it, but should proceed directly to analysis of the consequences. Unfortunately, DOE performed no such analysis. This same document concluded that "[a] criticality event could affect radionuclide release to the environment by damaging uranium and fuel matrix and cladding, so that the slow dissolution process which would normally occur is accelerated, and radionuclides are released in a short time period. Such a release would be more concentrated and the air release pathway would become significant, so an evaluation of the effects of potential criticality events is in order."

We and Dr. Thorne have also examined more recent criticality reports, in particular:

Configuration Generator Model for In-Package Criticality, MDL-EBS-NU-000001 REV 01 ICN 01; and

U.S. Nuclear Regulatory Commission, Safety Evaluation Report for Disposal Criticality Analysis Methodology Topical Report, Revision 0, June 2000.

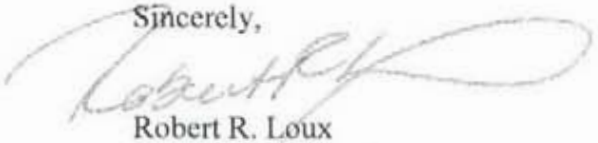
The June 2000 NRC report describes the methodology then proposed by DOE for evaluating criticality events. This methodology involved application of detailed geochemical modeling to define potentially critical configurations of fissile material both within and outside waste packages. But according to Nevada's experts, it is not clear that such geochemical modeling is feasible given the complexities of the proposed repository, the limitations of existing computer codes and the lack of appropriate data for use with those codes under proposed repository conditions. This seems to have been recognized by DOE itself, which subsequently adopted a fault tree/event tree based approach. Nevertheless, the fundamental problem remains of determining from the generalized descriptions of configuration classes used in the fault tree/event tree approach whether they can give rise to criticality events. This issue does not appear to have been addressed in DOE's proposed methodology, and it was certainly ignored in the FEIS.

In short, the documentation available to DOE at the time the FEIS was written was nowhere near sufficient for DOE to have summarily ruled out substantial numbers of criticality events occurring in the proposed Yucca Mountain repository. Indeed, the available documentation suggests internal criticality may be one of the most, if not the most, significant safety issues in repository licensing. Although subsequent work provided two alternative methodologies that, at first blush, have the potential to demonstrate lower probabilities of criticality events, more detailed examination by Nevada's experts suggests that limitations of scientific understanding, computational tools and relevant data will make it impossible to effectively deploy those alternative methodologies.

In view of the above, the potential occurrence and significance of criticality events, deliberately obscured in the FEIS, must be thoroughly analyzed and reviewed. I am requesting that the Board initiate such a review and begin by requesting from DOE a clear and comprehensive demonstration that the methodology, models and data identify the range of criticality events that could occur, quantify their probabilities of occurrence, and evaluate their potential consequences and the implications for repository operability, closure and post-closure performance.

I would be happy to share any of our documents with you, and we can put you in contact with Dr. Thorne so you can discuss this matter with him directly if you wish.

Sincerely,



Robert R. Loux
Executive Director

cc: Dr. Margaret S. Y. Chu, DOE
Dr. William D. Travers, NRC

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

December 8, 2003

Mr. Robert R. Loux
Executive Director
Agency for Nuclear Projects
1802 N. Carson Street, Suite 252
Carson City, Nevada 89701

Dear Mr. Loux:

Thank you for your November 25 letter dealing with internal criticality risk at Yucca Mountain and the attachments to the letter.

The Board's mission is to evaluate the technical and scientific validity of Department of Energy (DOE) activities involving the packaging, transportation, and disposal of high-level radioactive waste and spent nuclear fuel. Clearly criticality is one of those activities. The Board has reported on criticality in the past and monitors ongoing criticality developments and activities of the DOE's Office of Civilian Radioactive Waste Management. Thus, we appreciate your providing this material on criticality to us.

Thank you again for your letter and its attachments.

Sincerely,

Michael L. Corradini
Chairman

Appendix G

U.S. Nuclear Waste Technical Review Board Strategic Plan: Fiscal Years 2004–2009

(Revised March 2004)

Statement of the Board

The Nuclear Waste Policy Amendments Act of 1987 directed the U.S. Department of Energy (DOE) to characterize one site, at Yucca Mountain in Nevada, to determine its suitability as the location of a permanent repository for disposing of spent nuclear fuel and high-level radioactive waste. The Act also established the U.S. Nuclear Waste Technical Review Board as an independent agency within the executive branch of the United States Government. The Act requires the Board to evaluate continually the technical and scientific validity of activities undertaken by the Secretary of Energy related to implementing the Act and to report its findings and recommendations to the Secretary and Congress at least twice yearly. The Board only can make recommendations; it cannot compel the DOE to comply.

Congress created the Board to perform ongoing independent and unbiased technical and scientific evaluation—crucial for public acceptance of decisions related to nuclear waste disposal. The Board strives to provide Congress and the Secretary of Energy with completely independent, credible, and timely technical and scientific program evaluations and recommendations achieved through peer review of the highest quality.

This strategic plan includes the Board's goals and objectives for fiscal years 2004 through 2009. During that period, the DOE plans to develop an application for authorization to construct a repository and to submit it to the U.S. Nuclear Regulatory Commission (NRC). During the next several years, important technical and scientific activities will be undertaken by the DOE aimed at (a) gaining a better understanding of the potential behavior of a Yucca Mountain repository, (b) developing a repository design, (c) reducing technical uncertainties, (d) confirming estimates of repository performance, and (e) developing and implementing plans for a waste management system that includes waste transportation, handling, and packaging and repository operations. In accordance with its statutory mandate, the Board will continue its evaluation of the technical and scientific validity of the DOE's work in these areas. In conducting its evaluation, the Board looks at how components of the repository and waste management systems interact with other elements of the systems. This "systems view" of repository and waste management activities will continue to be critically important because many crucial technical and scientific decisions will be made throughout this period.

Mission

The Board's mission, established in the Nuclear Waste Policy Amendments Act (NWPAA) of 1987 (Public Law 100-203), is to "…evaluate the technical and scientific validity of activities [for management of high-level radioactive waste] undertaken by the Secretary after the date of the enactment of the Nuclear Waste Policy Amendments Act of 1987…" By law, the Board will cease to exist not later than one year after the date on which the Secretary begins disposal of high-level radioactive waste or spent nuclear fuel in a repository.

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 the technical validity of DOE activities related to implementing the Nuclear Waste Policy Act (NWPA) of 1982. The Board also provides essential technical and scientific information to Congress and the public on issues related to the disposal, packaging, and transport of spent nuclear fuel and high-level radioactive waste. The Board performs technical and scientific evaluation of the DOE's work related to (a) gaining a better understanding of the potential behavior of a repository at Yucca Mountain, (b) developing a repository design for safe and efficient repository operations, (c) establishing a program for confirming estimates of repository performance, and (d) developing and implementing plans for a waste management system that includes waste transportation, handling, and packaging and repository operations.

Values

To achieve its goals, the Board conducts itself according to the following values.

- The Board strives to ensure that its members and staff have no real or perceived conflicts of interest related to the outcome of the Secretary's efforts to implement the NWPA.
- Board members arrive at their conclusions on the basis of objective evaluations of the technical and scientific validity of the Secretary's activities.
- The Board's practices and procedures are open and conducted so that the Board's 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.

Goals and Strategic Objectives

The nation's goals related to disposing of spent nuclear fuel and high-level radioactive waste were set forth by Congress in 1982 in the NWPA. The goals are to develop a repository or repositories for disposing of high-level radioactive waste and spent nuclear fuel at a suitable site or sites and to establish a program of research, development, and demonstration for disposing of such waste.

In 1987, the NWPAA limited repository development activities to a single site at Yucca Mountain in Nevada. The NWPAA also established the Board and charged it with evaluating the technical and scientific validity of the Secretary of Energy's activities associated with implementing the NWPA. The activities include characterizing the Yucca Mountain site and packaging and transporting spent nuclear fuel and high-level radioactive waste.

The Board's general goals have been established in accordance with its statutory mandate and

with congressional action in 2002 authorizing the DOE to proceed with the submittal of an application to the NRC for authorization to construct a repository at Yucca Mountain. The goals reflect the continuity of the Board's technical and scientific evaluation and the Board's systems view of the repository and of waste management activities.

General Goals of the Board

To accomplish its congressional mandate, the Board has established four general goals.

1. Evaluate the technical and scientific validity of activities undertaken by the DOE related to understanding, testing, analyzing, and modeling geologic and other natural components of a proposed Yucca Mountain repository system. Review DOE activities related to estimating and confirming the performance of the natural components of the repository system.

2. Evaluate the technical and scientific validity of activities undertaken by the DOE related to understanding, testing, analyzing, and modeling the engineered components of a proposed Yucca Mountain repository system. Review DOE activities related to estimating and confirming the performance of the engineered components of the repository system.

3. Evaluate the technical and scientific validity of activities undertaken by the DOE related to understanding and modeling interactions among the components of the natural and engineered repository systems, estimating and confirming the performance of the proposed repository system, and integrating scientific and engineering activities.

4. Evaluate the technical and scientific validity of activities undertaken by the DOE related to planning, integrating, and implementing a waste management system, including the transportation, packaging, and handling of spent nuclear fuel and high-level radioactive waste and the operation of a repository.

Strategic Objectives of the Board

To achieve its general goals, the Board has established the following long-term objectives.

1. Objectives Related to the Natural System

1.1. Evaluate the technical and scientific validity of data and analyses related to the contributions of the natural barriers to waste isolation in a Yucca Mountain repository.

1.2. Evaluate DOE analyses and investigations related to hydrologic, geologic, geotechnical, seismic, volcanic, climatic, biological, and other natural features, events, and processes at the Yucca Mountain site and at related analogue sites.

1.3. Review DOE efforts to increase fundamental understanding of the potential behavior of the repository in a natural system.

1.4. Evaluate DOE and other studies and analyses related to repository tunnel environments.*

1.5. Review DOE integration of technical and scientific activities related to the natural system.

1.6. Review DOE efforts to confirm estimates of natural-system performance, including tests of models and assumptions and the pursuit of independent lines of evidence.

2. Objectives Related to the Engineered System

2.1. Evaluate the technical and scientific validity of DOE data and analyses related to the contribution of the engineered system to waste isolation in a Yucca Mountain repository.

2.2. Evaluate DOE studies and analyses related to the tunnel environments that will affect the performance of waste packages.*

*This is a shared objective under the natural system and engineered system.

2.3. Assess DOE efforts to increase understanding of fundamental corrosion processes in a proposed repository.

2.4. Review waste package designs, including the performance attributes and technical bases for such designs, and assess the need to revise waste package designs on the basis of the results of ongoing technical and scientific studies.

2.5. Evaluate the integration of science and engineering in the DOE program, especially the integration of new data into repository and waste package designs.

2.6. Review DOE activities related to confirming the predicted performance of the engineered system.

3. *Objectives Related to Repository System Performance and Integration*

3.1. Evaluate the technical and scientific validity of the DOE's technical basis for its estimates of repository system performance.

3.2. Review the technical and scientific validity of DOE models used to predict repository system performance.

3.3. Evaluate DOE efforts to increase confidence in its estimates of repository performance.

3.4. Evaluate the technical and scientific validity of DOE efforts to gain a more realistic understanding of the interaction of the natural and engineered components of a repository system.

3.5. Evaluate the integration of science and engineering with performance assessment.

3.6. Evaluate the technical bases for the DOE's repository safety case, including efforts to integrate the safety case with multiple lines of evidence and performance confirmation.

3.7. Review the development of DOE plans and activities for performance confirmation.

4. *Objectives Related to the Waste Management System*

4.1. Review DOE efforts related to the interaction of components of the waste management system from a life-cycle systems perspective, including at-reactor storage, waste acceptance, transportation, and repository design and operations.

4.2. Review the technical and scientific validity of the DOE's plans for safely handling and packaging spent nuclear fuel and high-level radioactive waste for transport to a permanent repository and for disposal in a permanent repository.

4.3. Review the technical and scientific aspects of the DOE's transportation plans.

4.4. Review the technical and scientific validity of the DOE's plans for developing a transportation infrastructure.

4.5. Evaluate design and engineering of the facility components or subsystems that involve innovative features, assumptions, and approaches.

4.6. Review the process through which the DOE provides technical and scientific information to interested parties and includes interested members of the public in the development of waste management plans.

Achieving the Goals and Objectives

The NWPAA grants significant investigatory powers to the Board. In accordance with the NWPAA, 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, the NWPAA directs the DOE to provide all records, files, papers, data, and information requested by the Board, including drafts of work products and documentation of work in progress. According to the legislative history, in providing this access, Congress expected that the Board would review and comment on DOE decisions, plans, and actions as they occurred, not after the fact.

By law, no nominee to the Board may be an employee of the DOE, a National Laboratory, or DOE contractors performing activities involving high-level radioactive waste or spent nuclear fuel. The Board has the power, under current law, to achieve its goals and objectives.

In conducting its ongoing technical and scientific review, the Board takes a "systems view" of the repository and of waste management activities. That view considers how one element of the repository system affects another. Consistent with this approach, the Board has established four panels composed of three or four Board members. As described in the following paragraphs, the purviews of the panels correspond to the Board's general goals.

1. *Panel on the Natural System*

   Panel Goal. Evaluate the technical and scientific validity of activities undertaken by the DOE related to understanding, testing, analyzing, and modeling geologic and other natural components of a proposed Yucca Mountain repository system. Review DOE activities related to estimating and confirming the performance of the natural components of the repository system.

2. *Panel on the Engineered System*

   Panel Goal. Evaluate the technical and scientific validity of activities undertaken by the DOE related to modeling, understanding, testing, and analyzing the engineered components of a proposed Yucca Mountain repository system. Review DOE activities related to estimating and confirming the performance of the engineered components of the repository system.

3. *Panel on Repository System Performance and Integration*

   Panel Goal. Evaluate the technical and scientific validity of activities undertaken by the DOE related to understanding and modeling the interactions of natural and engineered repository system components, estimating the performance of the proposed repository system, confirming the performance of the proposed repository system, and integrating scientific and engineering activities.

4. *Panel on the Waste Management System*

   Panel Goal. Evaluate activities undertaken by the DOE related to planning, integrating, and implementing a waste management system, including the transportation, packaging, and handling of spent nuclear fuel and high-level radioactive waste and the operation of a repository.

Much of the Board's information-gathering occurs at open public meetings arranged by the Board. At each meeting, the DOE, its contractors, and other program participants present technical information according to an agenda prepared by the Board. Board members and staff question presenters during the meetings. Time is provided at the meeting for comments from members of the public and interested parties. The full Board holds three or four meetings each year. The Board's panels meet as needed to investigate specific issue areas. The majority of Board meetings are held somewhere in Nevada.

The Board also gathers information from trips to the Yucca Mountain site, visits to contractor laboratories and facilities, and meetings with individuals working on the project. Board members and staff attend national and international symposia and conferences related to the science and technology of nuclear waste disposal. From time to time, Board members and staff also visit programs in other countries to review best

practices, perform benchmarking, and assess potential analogues.

Although the Board's information-gathering activities are carried out primarily to further the Board's review, they often have the collateral benefit of promoting communication and integration of technical information within the DOE program and facilitating the dissemination of information among interested parties outside the program. Analyses are performed primarily by Board members and the Board's staff. When necessary, the Board hires special expert consultants to perform in-depth reviews of specific technical and scientific topics.

Crosscutting Functions

Several entities and agencies are involved in developing a system for safely packaging, transporting, and disposing of spent nuclear fuel and high-level radioactive waste in a geologic repository at a suitable site. As discussed in the following paragraphs, the Board's ongoing peer review is unique among the organizations involved in managing spent nuclear fuel and high-level radioactive waste.

- *Congress and the Administration, including the Secretary of Energy,* make decisions on national policy and goals and how they will be implemented. The Board's role in this process is to help ensure that policy-makers receive unbiased and credible technical and scientific analyses and information.

- *State and local governments* comment on and perform local oversight of DOE activities. The Board's oversight activities are different in that they are (1) unconstrained by any stake in the outcome of the endeavor besides the credibility of the scientific and technical activities, (2) confined to scientific and technical evaluations, and (3) conducted by individuals nominated by the National Academy of Sciences and expressly chosen by the President for their expertise in the various disciplines represented in the DOE program.

- *Other federal agencies* (in addition to the Board) with roles in the waste management program include the DOE, the NRC, the Environmental Protection Agency (EPA), the Department of Transportation (DOT), and the United States Geological Survey (USGS). The DOE and its contractors are responsible for developing and implementing waste management plans and for conducting analytical and research activities related to licensing, constructing, and operating a repository. The NRC is the regulatory body having responsibility for licensing the construction and operation of a proposed repository and for certifying transportation casks. The EPA is responsible for issuing radiation safety standards that the NRC uses to formulate its repository regulations. The DOT is responsible for regulating the transporters of the waste. The USGS participates in site-characterization activities at the Yucca Mountain site.

The Board's role and its systems approach are unique among these organizations. The Board performs ongoing independent review and expert oversight of the technical and scientific validity of the Secretary of Energy's activities relating to civilian radioactive waste management and communicates its findings and recommendations to Congress, the Secretary, and the public. The Board's technical and scientific evaluations complement the work of other agencies involved in achieving the national goal.

Key External Factors

Some factors that are beyond the Board's control could affect its ability to achieve its goals and objectives. Among them are the following.

- *The Board has no implementing authority.* The Board is by statute a technical and scientific review body that only makes recommendations to the DOE. Congress expected that the DOE would accept the Board's recommendations or indicate why the recommendations could not or should not be implemented. However, the DOE is not legally obligated to

accept any of the Board's recommendations. If the DOE does not accept a Board recommendation, the Board's recourse is to advise Congress or reiterate its recommendation to the DOE, or both. The Board's recommendations and the DOE's responses are included in Board reports to Congress and the Secretary.

- *Legislation and budget considerations could affect nuclear waste policy.* The level of funding provided to the Board affects its ability to comprehensively review DOE activities. Funding levels for the program also may influence activities undertaken by the DOE in a given year or over time. In addition, it is not possible to predict if legislation related to nuclear waste disposal will be passed in the future or how the Board might be affected by such legislation, if enacted.

The Board will 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

The Board believes that measuring its effectiveness by directly correlating Board recommendations with improvements in the technical and scientific validity of DOE activities would be ideal. However, the Board cannot compel the DOE to comply with its recommendations. Consequently, a judgment about whether a specific recommendation had a positive outcome as defined above may be (1) subjective or (2) an imprecise indicator of Board performance because implementation of Board recommendations is outside the Board's direct control. Therefore, to measure its performance in a given year, the Board has developed performance measures. For each annual performance goal, the Board considers the following.

1. Did the Board undertake the reviews, evaluations, and other activities needed to achieve the goal?
2. Were the results of the Board's reviews, evaluations, and other activities communicated in a timely, understandable, and appropriate way to Congress and the Secretary of Energy?

If both measures were met in relation to a specific goal, the Board's performance in meeting that goal will be judged effective. If only one measure was met, the performance of the Board in achieving that goal will be judged minimally effective. Failing to meet both performance measures without sufficient and compelling explanation will result in a judgment that the Board has been ineffective in achieving that performance goal. If the goals are deferred, that will be noted in the evaluation.

The Board will use its evaluation of its own performance from the current year, together with its assessment of current or potential key issues of concern related to the DOE program, to develop its annual performance objectives and performance-based budget request for subsequent years. The results of the Board's performance evaluation are included in its annual summary report.

Consultations

In developing its original strategic plan, the Board consulted with the Office of Management and Budget, the DOE, congressional staff, and members of the public and provided a copy of the plan to the NRC and to representatives of state and local governments. The Board solicited public comment and presented its strategic plan at a session held expressly for that purpose during a public Board meeting in Amargosa Valley, Nevada, on January 20, 1998. During 2003, the Board again solicited and received comment on its revised strategic plan and performance plan. Many of those comments are incorporated in this revision. Copies of the Board's strategic plan, annual performance plans, and performance-based budget for fiscal year 2005 are available in the Board's summary report for 2003 and on the Board's Web site: **www.nwtrb.gov**.

Appendix H

U.S. Nuclear Waste Technical Review Board Performance Evaluation

Fiscal Year 2003

Evaluating the Board's Performance

The Board believes that measuring its effectiveness by directly correlating Board recommendations with improvements in the technical and scientific validity of Department of Energy (DOE) activities would be ideal. However, the Board cannot compel the DOE to comply with its recommendations. Consequently, a judgment about whether a specific recommendation had a positive outcome as defined above may be (1) subjective or (2) an imprecise indicator of Board performance because implementation of Board recommendations is outside the Board's direct control. Therefore, to measure its performance in a given year, the Board has developed performance measures. For each annual performance goal, the Board considers the following.

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The Board will use its evaluation of its own performance from the current year, together with its assessment of current or potential key issues of concern related to the DOE program, to develop its annual performance objectives and performance-based budget request for subsequent years. The results of the Board's performance evaluation are included in its annual summary report.

Board's Performance Evaluation for 2003

On the basis of the following evaluation and consistent with the performance measures described in the previous section, the Board's performance for 2003 was found to be effective overall. However, the Secretary's activities related to the waste management program were again somewhat limited in 2003. In addition, some long-term design activities have not been undertaken by the DOE. Therefore, some of the Board's 2003 goals related to design have been deferred, pending DOE activities related to the goals. Goals not fully achieved are listed at the end of their respective sections.

The reliability and completeness of the performance data used to evaluate the Board's performance relative to its annual performance goals is high and can be verified by accessing the referenced documents on the Board's Web site: **www.nwtrb.gov**.

Performance Goals for FY 2003

The Board's performance goals for fiscal year (FY) 2003 were developed to further the achievement of the Board's general goals and strategic objectives. An evaluation of the Board's effectiveness in achieving each performance goal is provided in the bullet under the goal.

1. Performance Goals Related to Site Suitability and Predicting Repository Performance

Performance Goals and Evaluations

1.1.1. Review for technical validity the technical and scientific components of the DOE's on-going site investigations (if applicable).

- Evaluation of 1.1.1: The Board held a meeting on January 28, 2003, at which it received updates from the DOE on studies attempting to resolve differences in the existence of fast paths for water flow, on work related to low permeability areas that affect water flow and rates, and on scientific studies related to temperatures in repository tunnels and work in the cross drift. On March 5, 2003, the Board sent a letter to Dr. Margaret Chu stating that resolving differences in opinion on chlorine-36 studies is essential for understanding key processes at Yucca Mountain. The letter went on to state that paleosols merit investigation, noting that ongoing scientific studies will require adequate funding and the attention of program managers. At a February 24, 2003, joint meeting of the Board's Panel on the Natural System and Panel on the Engineered System, the Board discussed in detail the DOE's work related to estimating seismic hazard and in particular ground-motion estimates. In a follow-up letter to Dr. Chu, the panels pointed out problems associated with very conservative ground-motion estimates. After meeting in September 2003, the Board sent a letter on December 16, 2003, in which it encouraged the DOE to develop boreholes as monitoring wells to obtain hydraulic head, water chemistry, and related hydrogeolgic data at small cost. In the same letter, the Board suggested that the DOE undertake a "root cause" analysis to resolve discrepancies in chlorine-36 study results.

1.1.2. Monitor the DOE's efforts to quantify uncertainties related to estimates of repository performance.

- Evaluation of 1.1.2: Duplicate. (See evaluation of 1.3.3.)

1.2.1. Monitor the results of flow-and-transport studies being conducted to obtain information on the potential performance of the saturated zone (SZ) as a natural barrier in the repository system.

- Evaluation of 1.2.1: At a meeting held on January 28, 2003, the Board discussed the significance of alluvial sedimentary deposits (paleosols) in altering directions and rates of water flow and chemical transport in the SZ. The Board sent a letter to the DOE on March 5, 2003, in which it commented on this technical issue. The Board received several updates and a presentation on flow and transport in the SZ and the unsaturated zone at its September 2003 meeting. In a December 16, 2003, letter to Dr. Margaret Chu, the Board suggested that in conjunction with the DOE's planned drilling of aeromagnetic anomalies consideration be given for developing some of the boreholes as monitoring wells to conduct studies related to water flow in the SZ and to obtain information on the ability of the SZ to function as a barrier to migration of radioactive materials.

1.2.2. Evaluate geologic, hydrologic, and geochemical information obtained from the enhanced characterization of the repository block at Yucca Mountain.

- Evaluation of 1.2.2: After receiving an update on scientific activities at its January 2003 meeting, the Board sent a letter on March 5, 2003, to Dr. Margaret

Chu noting that these studies could be very valuable in increasing understanding of the potential behavior of Yucca Mountain but that adequate funding and attention from program managers would be needed to fully realize the potential of the studies.

1.3.1. Determine the strengths and weaknesses of the total system performance assessment (TSPA).

- Evaluation of 1.3.1: In a March 5, 2003, letter to Dr. Margaret Chu, the Board suggested that the DOE gain a better understanding of the potential behavior of the entire repository system through continued scientific studies and by exploring ways to determine and display the contributions of individual barriers to overall repository performance. As part of its comments to the DOE following a February 2003 joint panel meeting on seismic hazard, the Board stated that the lack of physical realism and unrealistic ground-motion estimates had implications for performance assessment, design, and scientific confidence. The Board reviewed and commented on the DOE's technical basis documents in a December 2003 letter to the DOE.

1.3.2. On the basis of an evaluation of the natural processes at work at the Yucca Mountain site, recommend additional work needed to address uncertainties, paying particular attention to estimates of the rate and distribution of water seepage into the proposed repository under proposed repository design conditions.

- Evaluation of 1.3.2: In letters to Dr. Margaret Chu sent by the Board in March and December 2004, the Board reiterated the need to resolve discrepancies between chlorine-36 studies related to the possible existence of fast water paths into exploratory tunnels. In its November 25, 2003, technical report on the potential for corrosion of waste packages during the thermal pulse, the Board commented extensively on the DOE's active fracture model, which postulates that a vaporization barrier and the capillary properties of the repository tunnel walls will prevent water from seeping into the drifts and onto the waste packages for hundreds of years.

1.3.3. Evaluate the DOE's quantification of uncertainties and conservatisms used in TSPA.

- Evaluation of 1.3.3: In a letter dated June 27, 2003, the Board commented on the implications of using highly conservative assumptions to address seismic issues. The Board recommended that the DOE not take a physically unrealistic or highly conservative approach to addressing seismic issues for several reasons: Such an approach can skew understanding; compounding conservatisms does not always produce conservative results; unrealistic assumptions can lead to unreasonably high costs; using conservatisms in the place of understanding can undermine confidence in results; actions taken later in light of more-realistic assumptions could be harder to implement.

1.3.4. Recommend additional measures for strengthening the DOE's repository safety case.

- Evaluation of 1.3.4: At its January 2003 meeting, the Board received presentations on the contribution of individual barriers to the performance of the repository system. In a March 2003 letter to Dr. Margaret Chu following the meeting, the Board encouraged the DOE to continue its work to evaluate the contributions of the barriers and found that there appear to be opportunities for improving both the analytical approach and the clarity of the presentation of study results. In a December 2003 letter to Dr. Margaret Chu, the Board urged the DOE to integrate the conclusions from the DOE's technical basis documents into a concise description of the safety case for a Yucca Mountain repository. The Board also encouraged the DOE to include in its safety case a dis-

cussion of relevant analogs that can be used as lines of evidence.

1.3.5. Evaluate data from the drift-scale heater test.

- Evaluation of 1.3.5: The Board commented on the drift-scale heater test and other ongoing scientific studies in its letter to Dr. Margaret Chu dated March 5, 2003. The Board pointed out the value of these test in increasing understanding of the potential behavior of a repository system at Yucca Mountain. The Board noted that adequate funding and attention by managers would be necessary to realize the full potential of this scientific work.

1.4.1. Review plans and work carried out on natural and engineered analogs to the repository system.

- Evaluation of 1.4.1: The Board commented on the use of analogs in its June 2003 letter to the DOE on seismic hazard. The Board suggested that the DOE compare tunnel performance under extreme dynamic conditions in DOE models with nuclear test damage data and rockburst damage observed in mines with comparable rock-mass conditions. In its December 2003 letter, the Board suggested the use of analogs as lines of evidence in a repository safety case.

2. Performance Goals Related to the Engineered Repository System

Performance Goals and Evaluations

2.1.1. Monitor the DOE's development of analytical tools for assessing the differences between different repository designs.

- Evaluation of 2.1.1: On February 20, 2003, the Board transmitted to the DOE a compilation of its statements related to uncertainties related to high-temperature repository designs and thermal loads. The Board held a meeting in Washington, D.C., on May 13–14, that focused on the DOE's repository design and operating mode for Yucca Mountain. At the meeting, the DOE made presentations related to thermal aspects of the repository design and operating mode, how the thermal aspects were analyzed for waste isolation, and the results of the analyses. The Board noted in its October 21, 2003, letter to the DOE that data currently available to the Board indicate that perforation of waste packages is unlikely if waste-package surface temperatures are kept below 95ºC.

2.1.2. Evaluate the accuracy and completeness of the technical bases for repository and waste package designs.

- Evaluation of 2.1.2: The Board commented on the DOE's technical basis for dealing with the evolution of chemical environments on waste package surfaces in a letter to Dr. Margaret Chu dated March 5, 2003. In the same letter, the Board encouraged the DOE to document carefully and completely the technical basis for its answer to a question related to whether a repository with lower peak temperatures on waste package surfaces would reduce uncertainty and the likelihood or severity of corrosion problems. The Board also commented on the use of dual Alloy-22 lids, observing that they may not be justified. The Board devoted most of its May 2003 meeting to discussions about the technical basis for the DOE's proposed repository design and operating mode. Given the information presented at that meeting, the Board sent a letter to Dr. Margaret Chu on October 21, 2003, on the potential for corrosion of waste packages. On November 25, 2003, the Board issued a detailed technical report supporting its conclusions on the potential for deliquescence-based, localized corrosion during the thermal pulse. In December 2003, the Board combined its October letter and November technical report in a report submitted to Congress and the Secretary of Energy.

2.1.3. Evaluate the extent to which the DOE is using the technical bases for modifying repository and waste package designs.

- Evaluation of 2.1.3: The Board received updates at its meetings held in May and September 2003 on the DOE's plans to include a high-temperature repository design in a license application to the Nuclear Regulatory Commission. The Board commented in its letter of October 21, 2003, to Dr. Margaret Chu that most corrosion data are for temperatures below 95°C. Therefore the DOE's data may constitute an adequate technical basis for estimating generalized corrosion of waste packages if temperatures are kept below that level. The Board further comments that it believes that the high temperatures of the DOE's current repository design will result in perforation of the waste packages. The Board goes on to state that perforation is unlikely at temperatures below 95ºC.

2.1.4. Monitor and evaluate the DOE's progress in developing a technical basis for modified or novel design features.

- Evaluation of 2.1.4: In a March 2003 letter to Dr. Margaret Chu, the Board commented on potential modifications of the waste package. The Board observed that the dual lid of the current waste package design may not be justified. In addition, the letter goes on to state that current plans not to mitigate tensile stresses of the inner Alloy-22 closure weld raises questions about the dual-lid concept. In addition, because the trunnion-collar sleeves appear complex and prone to crevice corrosion, it may be necessary to reconsider this part of the design.

2.2.1. Evaluate data from studies of corrosion and the waste package environment on the predicted performance of materials being proposed for the EBS.

- Evaluation of 2.2.1: At its January 2003 meeting, the Board heard a presentation from contractors from the state of Nevada and from the DOE on potentially corrosive environments in repository tunnels and commented on those presentations in a March 2003 letter to Dr. Margaret Chu. In that letter, the Board noted that even though corrosive brines and condensates can be produced at laboratory scale the State presentations did not include estimates of the likelihood that such solutions would occur. The Board devoted most of its May 2003 meeting to discussions about the technical basis for the DOE's proposed repository design and operating mode. Given the information presented at that meeting, the Board sent a letter to Dr. Margaret Chu on October 21, 2003, on the potential for corrosion of waste packages. On November 25, 2003, the Board issued a detailed technical report supporting its conclusions on the potential for deliquescence-based, localized corrosion during the thermal pulse. In December 2003, the Board combined its October letter and November technical report in a report submitted to Congress and the Secretary of Energy. On the basis of data from the DOE, the Board concluded that there is a significant potential for localized corrosion of waste packages during the thermal pulse in the DOE's high-temperature repository design. The Board also found that there are questions about the repository environments predicted by the DOE.

2.3.1. Assess the integration of scientific studies with engineering designs for the repository and the waste package. In particular, monitor the results of ongoing thermal tests and evaluate DOE plans for using the test results to support models of the thermally disturbed region near the repository and for deciding on spacing between emplacement drifts, degree of preclosure ventilation, and closure date of the potential repository.

- Evaluation of 2.3.1: The Board commented in a December 2003 letter to Dr. Margaret Chu that the technical basis documents developed by the DOE have significant potential for improving program integration.

2.3.2. Evaluate the DOE's efforts in identifying natural and engineered analogs (see also 1.4.1).

- Evaluation of 2.3.2: The Board commented on the use of analogs in its June 2003 letter to the DOE on seismic hazard. The Board suggested that the DOE compare tunnel performance under extreme dynamic conditions in DOE models to nuclear test damage data and rockburst damage observed in mines with comparable rock-mass conditions. In its December 2003 letter, the Board suggested the use of analogs as lines of evidence in a repository safety case.

3. Performance Goals Related to the Waste Management System

Performance Goals and Evaluations

3.1.1. Monitor efforts by the NRC to update estimates of risk associated with transportation of spent nuclear fuel and high-level radioactive waste.

- Evaluation of 3.1.1: Board staff attended meetings of the NRC study committee and updated other staff and the Board members on the NRC committee deliberations.

3.1.2. Evaluate the operation of the entire repository facility, including the surface and subsurface components.

- Evaluation of 3.1.2: In a letter to Dr. Margaret Chu dated March 5, 2003, the Board urged the DOE to adopt a "systems" approach, addressing both strategic and operational considerations in its transportation planning. The Panel on the Waste Management System held a meeting in February 2003 that tracked the theoretical movement of spent fuel from reactor sites to the repository surface facilities and began identifying issues of concern for future Board meetings. The Board reported its findings from the meeting in a letter to Dr. Margaret Chu dated April 30, 2003.

3.2.1. Evaluate the effects of "off-normal" events at the surface facility and how the events could affect the ability of the facility to receive waste shipments.

- Evaluation of 3.2.1: The Panel on the Waste Management System held a meeting in February 2003 that tracked the theoretical movement of spent fuel from reactor sites to the repository surface facilities and began identifying issues of concern for future Board meetings. In an April 2003 letter to Dr. Chu, the Board identified two issues of concern related to the surface and subsurface facilities at the repository and asked for additional information on both. First, the Board noted the possibility that a small amount of spent fuel could be damaged in transit, requiring mitigation before the remediation facilities are planned to be constructed. Second, the Board asked for information about new underground design changes, including the use of a wheeled waste transporter and the location of exhaust drifts and fans.

3.3.1. Examine the ability of storage casks and containers, including multipurpose canisters, to serve as disposal casks and containers in a repository.

- Evaluation of 3.3.1: Board staff attended meetings of a National Academy of Sciences committee involved in studying this issue and conveyed the discussions surrounding the issues to Board members and other Board staff.

3.4.1. Evaluate logistics capabilities of the transportation system.

- Evaluation of 3.4.1: In an April 2003 letter to Dr. Margaret Chu following its February panel meeting, the Board pointed out that no casks have been certified for transporting some of the higher-burnup spent fuel likely to be generated in the future. The Board went on to state that coordination of cask development with utility shipping needs and with repository and transportation system capabilities will be important.

3.4.3 Review criteria for waste acceptance for storage to ensure that accepted material has been suitably characterized for subsequent disposal.

- Evaluation of 3.4.3: In its letter to Dr. Chu of April 2003, the Board called attention to the need to coordinate with the nuclear utilities to ensure that the waste acceptance process proceeds smoothly.

3.4.4. Evaluate the DOE's plans for enhancing safety capabilities along transportation corridors, and review the DOE's planning and coordination activities (e.g., route selection), accident prevention activities (e.g., improved inspections and enforcement), and emergency response activities.

- Evaluation of 3.4.4: The Panel on the Waste Management System held a meeting in February 2003 that tracked the theoretical movement of spent fuel from reactor sites to the repository surface facilities and began identifying issues of concern for future Board meetings. In its April 2003 letter to Dr. Margaret Chu, the Board recommended that the DOE adopt safety as guiding principle in planning and developing a transportation system and should develop an integrated safety plan for guiding the development process.

The following goals were deferred to 2004, pending the commencement of activities in these areas by the DOE:

3.2.2. Evaluate the effects of reduced receiving capacity at the repository surface facility on the nationwide transportation system.

3.2.3. Evaluate effects of human errors in risks associated with packaging and transporting spent nuclear fuel.

3.4.2. Monitor progress in implementing new technologies for improving transportation safety for spent fuel (e.g., electronic braking, wheel-bearing monitoring).

4. Performance Goals Related to Long-Term Activities
(Will apply only if the site is found suitable and a site recommendation is ratified.)

PERFORMANCE GOALS

4.1.1. Monitor the DOE's proposed plans for performance confirmation to help ensure that uncertainties identified as part of the site recommendation process are addressed.

- Evaluation of 4.1.1: The Board received a presentation on the DOE's performance confirmation plans at its September 2003 meeting and commented on the plans in a December 2003 letter to Dr. Margaret Chu. The Board noted that the operational period for performance confirmation may extend beyond repository closure; therefore, it may serve to increase confidence in DOE models by confirming their predictions. The Board urged the DOE to clearly define what it means by performance confirmation.

The following goal was deferred, pending DOE activities related to design modification.

4.1.2. Monitor design modification activities undertaken by the DOE.

Appendix I

U.S. Nuclear Waste Technical Review Board Performance Plan

Fiscal Year 2004

The nation's goals related to disposing of spent nuclear fuel and high-level radioactive waste were set forth by Congress in the Nuclear Waste Policy Act of 1982. The goals are to develop a repository or repositories for disposing of high-level radioactive waste and spent nuclear fuel at a suitable site or sites and establishing a program of research, development, and demonstration for disposing of such waste.

The Nuclear Waste Policy Amendments Act of 1987 (NWPAA) limited repository development activities to a single site, Yucca Mountain in Nevada. The NWPAA also established the Board and charged it with evaluating the technical and scientific validity of the Secretary of Energy's activities associated with implementing the NWPA. The activities include characterizing the Yucca Mountain site and packaging and transporting spent nuclear fuel and high-level radioactive waste.

The Board's performance goals for fiscal year (FY) 2004 have been developed to achieve the general goals and strategic objectives in its strategic plan. The goals also have been established in accordance with the Board's statutory mandate and reflect congressional action in 2002 authorizing the U.S. Department of Energy (DOE) to proceed with developing an application to be submitted to the Nuclear Regulatory Commission (NRC) for authorization to construct a repository at Yucca Mountain. The Board's performance goals reflect the continuity of the Board's ongoing technical and scientific evaluation and the Board's "systems view" of the repository and of waste management activities.

Performance Goals for FY 2004

The Board's performance goals for FY 2004 have been developed to further the achievement of the Board's general goals and strategic objectives. Because some of the general goals and strategic objectives relate to work and activities that will be undertaken in the future, they may not have corresponding annual performance goals in any given year. The performance goals have been numbered to correlate with appropriate strategic objectives in the Board's strategic plan for FY 2003–2008.

1. Performance Goals Related to the Natural System and Strategy for Achieving the Goals

Performance Goals

1.1.1. Review the technical activities and agenda of the DOE's science and technology program.

1.1.2. Monitor the results of flow-and-transport studies to obtain information on the potential performance of the saturated zone as a natural barrier in the repository system.

1.1.3. Review DOE efforts to confirm estimates of natural-system performance and pursue independent lines of evidence, including tests of models and assumptions.

1.2.1. Review DOE efforts to resolve questions related to possible seismic events and igneous consequences.

1.3.1. Evaluate geologic, hydrologic, and geochemical information obtained from the

enhanced characterization of the repository block (ECRB) at Yucca Mountain.

1.3.2. Evaluate data from the drift-scale heater test.

1.3.3. Review plans and work carried out on possible analogues for the natural components of the repository system.

1.3.4. Recommend additional work needed to address uncertainties, paying particular attention to estimates of the rate and distribution of water seepage into the repository under proposed repository design conditions.

1.4.1. Evaluate tunnel-stability studies undertaken by the DOE.

1.5.1. Review the DOE's efforts to integrate results of scientific studies on the behavior of the natural system into repository designs.

STRATEGY FOR ACHIEVING GOALS

The Board will accomplish its goals by doing the following.

- Holding three public meetings with the DOE and DOE contractor personnel involving the full Board, and holding meetings of the Panel on the Natural System as needed.

- Reviewing critical documents provided by the DOE and its contractors, including contractor reports, process model reports, and total system performance assessment (TSPA).

- Meeting with contractor principal investigators on technical issues, including those related to climate change, seismic and volcanic events, flow and transport in the unsaturated and saturated zones, seepage, and the biosphere.

- Observing relevant laboratory and site investigations, including those conducted in the exploratory studies facility (ESF), the ECRB, and at Lawrence Livermore National Laboratory, Lawrence Berkeley National Laboratory, and Sandia National Laboratories. Observing other field investigations and visiting potential analogue sites. Visiting countries with nuclear-waste disposal programs and attending national and international symposia and conferences.

2. Performance Goals Related to the Engineered System and Strategy for Achieving the Goals

PERFORMANCE GOALS

2.1.1. Monitor the DOE's studies related to the relative contribution of engineered barriers to repository performance.

2.2.1. Review thermal testing and rock stability testing related to potential conditions in repository tunnels.

2.2.2. Evaluate data from studies of the effects of corrosion and the waste package environment on the predicted performance of materials being proposed for engineered barriers.

2.3.1. Review the progress and results of materials testing being conducted to address uncertainties about waste package performance.

2.3.2. Evaluate the DOE's efforts in identifying natural and engineered analogues for corrosion processes.

2.4.1. Monitor the DOE's development of analytical tools for assessing the differences between repository designs.

2.4.2. Evaluate the accuracy and completeness of the technical bases for repository and waste package designs and the extent to which the DOE is using the technical bases for modifying repository and waste package designs.

2.4.4. Evaluate the integration of the subsurface design and layout with thermal management and preclosure facility operations.

2.5.1. Assess the integration of scientific studies with engineering designs for the repository and the waste package.

STRATEGY FOR ACHIEVING GOALS

The Board will accomplish its goals by doing the following.

- Holding three public meetings with DOE and contractor personnel involving the full Board, and holding meetings of the Panel on the Engineered System as needed.
- Reviewing critical documents provided by the DOE and its contractors, including contractor reports, process model reports, and TSPA.
- Meeting with contractor principal investigators on technical issues.
- Reviewing DOE documents and databases, paying particular attention to design features developed to promote drainage, control ventilation, and protect workers in the exhaust end of the ventilation system.
- Reviewing the common database (literature, laboratory, and field data) and judging the adequacy of the database for a decision on repository development.
- Observing relevant laboratory investigations, including those conducted at Lawrence Livermore National Laboratory and Lawrence Berkeley National Laboratory. Visiting countries with nuclear-waste disposal programs and attending national and international symposia and conferences.

3. Performance Goals Related to Repository System Performance and Integration and Strategy for Achieving Performance Goals

PERFORMANCE GOALS

3.1.1. Identify which technical and scientific activities are on the critical path to reconciling uncertainties related to the DOE's performance estimates.

3.1.2. Determine the strengths and weaknesses of TSPA.

3.1.3. Evaluate the DOE's treatment of seismic and volcanism issues in TSPA.

3.2.1. Evaluate the DOE's quantification of uncertainties and conservatisms used in TSPA.

3.2.2. Review new data and updates of TSPA models, and identify models and data that should be updated.

3.3.1. Evaluate the DOE's efforts to create a transparent and traceable TSPA.

3.3.2. Evaluate the DOE's efforts to develop simplified models of repository performance.

3.3.3. Evaluate the DOE's efforts to identify analogues for performance estimates of the overall repository system.

3.4.1. Evaluate the DOE's efforts to analyze the contribution of the different engineered and natural barriers to waste isolation.

3.5.1. Evaluate technical aspects of value engineering (providing a needed function reliably and at the lowest cost) and performance-related trade-off studies, including criteria, weighting factors, and decision methodologies for such studies; how technical uncertainties are taken into account; and what factors are included or excluded from such studies and why.

3.6.1. Recommend additional measures for strengthening the DOE's repository safety case.

3.7.1. Evaluate the DOE's efforts to develop a feedback loop among performance-confirmation activities and TSPA models and data.

3.7.2. Monitor the DOE's proposed plans for performance confirmation to help ensure that uncertainties identified as part of the site recommendation process are addressed.

STRATEGY FOR ACHIEVING GOALS

The Board will accomplish its goals by doing the following.

- Holding three public meetings with DOE and contractor personnel involving the full Board, and holding meetings of the Panel on the

Repository System Performance and Integration as needed.

- Reviewing critical documents provided by the DOE and its contractors, including contractor reports, process model reports, and the DOE's TSPA.
- Meeting with contractors' principal investigators on technical issues.
- Observing relevant laboratory investigations, including those conducted at Lawrence Livermore National Laboratory, Lawrence Berkeley National Laboratory, Sandia National Laboratories, and the engineered-barrier test facility. Observing field investigations. Visiting countries with nuclear-waste disposal programs and attending national and international symposia and conferences.

4. Performance Goals Related to the Waste Management System and Strategy for Achieving the Goals

PERFORMANCE GOALS

4.1.1. Evaluate the operation of the entire repository facility, including the surface and subsurface components.

4.1.2. Monitor the identification of research needs to support improved understanding of the interaction of components of the waste management system.

4.1.3. Review the technical and scientific basis of the DOE's analyses of component interactions in various scenarios, including the degree of integration and redundancy across functional components over time.

4.1.4. Evaluate the effects of reduced receiving capacity at the repository surface facility on the nationwide transportation system.

4.1.5. Review criteria for waste acceptance for storage to ensure that accepted material has been characterized suitably for subsequent disposal.

4.2.1. Monitor the DOE's efforts to implement Section 180 (c) of the NWPA.

4.3.1. Monitor the DOE's progress in developing and implementing a transportation plan for shipping spent nuclear fuel and high-level radioactive waste to a Yucca Mountain repository.

4.3.2. Review the DOE's efforts to develop criteria for decisions on transportation mode and routing.

4.3.3. Evaluate logistics capabilities of the transportation system.

4.3.4. Monitor progress in implementing new technologies for improving transportation safety for spent nuclear fuel.

4.3.5. Evaluate the DOE's plans for enhancing safety capabilities along transportation corridors, and review the DOE's planning and coordination activities (e.g., route selection), accident prevention activities (e.g., improved inspections and enforcement), and emergency response activities.

STRATEGY FOR ACHIEVING GOALS

The Board will accomplish its goals by doing the following.

- Holding three public meetings with DOE and contractor personnel involving the full Board, and holding meetings of the Board's Panel on the Waste Management System in appropriate areas of the country.
- Reviewing critical documents provided by the DOE and its contractors, including contractor reports, process model reports, and TSPA.
- Meeting with groups involved in implementing transportation plans, including the NRC, the Department of Transportation, railroad and trucking companies, nonprofit groups, nuclear utilities, and other interested parties. Visiting countries with nuclear-waste disposal programs and attending national and international conferences and symposia.

Appendix J

U.S. Nuclear Waste Technical Review Board Performance Plan

Fiscal Year 2005

Goals and Strategic Objectives

The nation's goals related to disposing of spent nuclear fuel and high-level radioactive waste were set forth by Congress in the NWPA. The goals are to develop a repository or repositories for disposing of high-level radioactive waste and spent nuclear fuel at a suitable site or sites and to establish a program of research, development, and demonstration for disposing of such waste.

The NWPAA limited repository development activities to a single site, Yucca Mountain in Nevada. The NWPAA also established the Board and charged it with evaluating the technical and scientific validity of the Secretary of Energy's activities associated with implementing the NWPA. The activities include characterizing the Yucca Mountain site and packaging and transporting spent nuclear fuel and high-level radioactive waste.

The Board's general goals and strategic objectives, which are presented in the Board's strategic plan for fiscal years (FY) 2004–2009, have been established in accordance with its statutory mandate and with congressional action in 2002 authorizing the DOE to proceed with developing an application to be submitted to the NRC for authorization to construct a repository at Yucca Mountain. The Board's goals reflect the continuity of the Board's ongoing technical and scientific evaluation and the Board's "systems view" of the repository and of waste management activities.

The Board's performance goals for FY 2005, which are included in this document, have been developed to further the achievement of the Board's general goals and strategic objectives. The performance goals have been numbered to correlate with appropriate strategic objectives, and preliminary budget amounts have been allocated to each set of performance goals.

Board Performance Goals for FY 2005

1. Performance Goals Related to the Natural System and Strategy for Achieving the Goals

(Dollars in Thousands)

FY 03	FY 04	FY 05
795	794	800

PERFORMANCE GOALS

1.1.1. Review the technical activities and agenda of the DOE's science and technology effort.

1.1.2. Monitor the results of flow-and-transport studies to obtain information on the potential performance of the saturated zone as a natural barrier in the repository system.

1.1.3. Review DOE efforts to confirm estimates of natural-system performance and pursue independent lines of evidence, including tests of models and assumptions.

1.2.1. Review DOE efforts to resolve questions related to possible seismic events and igneous consequences.

1.3.1. Evaluate geologic, hydrologic, and geochemical information obtained from the enhanced characterization of the repository block (ECRB) at Yucca Mountain.

1.3.2. Evaluate data from the drift-scale heater test.

1.3.3. Review plans and work carried out on possible analogues for the natural components of the repository system.

1.3.4. Recommend additional work needed to address uncertainties, paying particular attention to estimates of the rate and distri-

bution of water seepage into the repository under proposed repository design conditions.

1.4.1. Evaluate tunnel-stability studies undertaken by the DOE.

1.5.1. Review the DOE's efforts to integrate results of scientific studies on the behavior of the natural system into repository designs.

STRATEGY FOR ACHIEVING GOALS

The Board will accomplish its goals by doing the following.

- Holding three public meetings with the DOE and DOE contractor personnel involving the full Board, and holding meetings of the Panel on the Natural System as needed.
- Reviewing critical documents provided by the DOE and its contractors, including contractor reports, process model reports, and total system performance assessment (TSPA).
- Meeting with contractor principal investigators on technical issues, including those related to climate change, seismic and volcanic events, flow and transport in the unsaturated and saturated zones, seepage, and the biosphere.
- Observing relevant laboratory and site investigations, including those conducted in the exploratory studies facility (ESF), the ECRB, and at Lawrence Livermore National Laboratory, Lawrence Berkeley National Laboratory, and Sandia National Laboratories. Observing other field investigations and visiting potential analogue sites. Visiting countries with nuclear-waste disposal programs and attending national and international symposia and conferences.

2. Performance Goals Related to the Engineered System and Strategy for Achieving the Goals

(Dollars in Thousands)

FY 03	FY 04	FY 05
954	953	960

PERFORMANCE GOALS

2.1.1. Monitor the DOE's performance allocation studies.

2.2.1. Review thermal testing and rock-stability testing related to potential conditions in repository tunnels.

2.2.2. Evaluate data from studies of the effects of corrosion and the waste package environment on the predicted performance of materials being proposed for engineered barriers.

2.3.1. Review the progress and results of materials testing being conducted to address uncertainties about waste package performance.

2.3.2. Evaluate the DOE's efforts in identifying natural and engineered analogues for corrosion processes.

2.4.1. Monitor the DOE's development of analytical tools for assessing the differences between repository designs.

2.4.2. Evaluate the accuracy and completeness of the technical bases for repository and waste package designs and the extent to which the DOE is using the technical bases for modifying repository and waste package designs.

2.4.3. Evaluate the integration of the subsurface design and layout with thermal management and preclosure facility operations.

2.5.1. Assess the integration of scientific studies with engineering designs for the repository and the waste package.

STRATEGY FOR ACHIEVING GOALS

The Board will accomplish its goals by doing the following.

- Holding three public meetings with DOE and contractor personnel involving the full Board, and holding meetings of the Panel on the Engineered System as needed.
- Reviewing critical documents provided by the DOE and its contractors, including contractor reports, process model reports, and TSPA.

- Meeting with contractor principal investigators on technical issues.

- Reviewing DOE documents and databases, paying particular attention to design features developed to promote drainage, control ventilation, and protect workers in the exhaust end of the ventilation system.

- Reviewing the common database (literature, laboratory, and field data) and judging the adequacy of the database for a decision on repository development.

- Observing relevant laboratory investigations, including those conducted at Lawrence Livermore National Laboratory and Lawrence Berkeley National Laboratory. Visiting countries with nuclear-waste disposal programs and attending national and international symposia and conferences.

3. Performance Goals Related to Repository System Performance and Integration and Strategy for Achieving Performance Goals

(Dollars in Thousands)

FY 03	FY 04	FY 05
636	635	640

Performance Goals

3.1.1. Identify which technical and scientific activities are on the critical path to reconciling uncertainties related to the DOE's performance estimates.

3.1.2. Determine the strengths and weaknesses of TSPA.

3.1.3. Evaluate the DOE's treatment of seismic and volcanism issues in TSPA.

3.2.1. Evaluate the DOE's quantification of uncertainties and conservatisms used in TSPA.

3.2.2. Review new data and updates of TSPA models, and identify models and data that should be updated.

3.3.1. Evaluate the DOE's efforts to create a transparent and traceable TSPA.

3.3.2. Evaluate the DOE's efforts to develop simplified models of repository performance.

3.3.3. Evaluate the DOE's efforts to identify analogues for performance estimates of the overall repository system.

3.4.1. Evaluate the DOE's efforts to analyze the contribution of the different engineered and natural barriers to waste isolation.

3.5.1. Evaluate technical aspects of value engineering and performance-related trade-off studies, including criteria, weighting factors and decision methodologies for such studies and how technical uncertainties are taken into account.

3.6.1. Recommend additional measures for strengthening the DOE's repository safety case.

3.7.1. Evaluate the DOE's efforts to develop a feedback loop among performance-confirmation activities and TSPA models and data.

3.7.2. Monitor the DOE's proposed plans for performance confirmation to help ensure that uncertainties identified as part of the site recommendation process are addressed.

Strategy for Achieving Goals

The Board will accomplish its goals by doing the following.

- Holding three public meetings with DOE and contractor personnel involving the full Board and holding meetings of the Panel on the Repository System Performance and Integration, as needed.

- Reviewing critical documents provided by the DOE and its contractors, including contractor reports, process model reports, and the DOE's TSPA.

- Meeting with contractor's principal investigators on technical issues.

- Observing ongoing laboratory investigations, including those conducted at Lawrence Livermore National Laboratory, Lawrence Berkeley National Laboratory, Sandia National Laboratories, and the engineered-barrier test facility. Observing field investigations. Visiting countries with nuclear-waste disposal programs and attending national and international symposia and conferences.

4. Performance Goals Related to the Waste Management System and Strategy for Achieving the Goals

(Dollars in Thousands)

FY 03	FY 04	FY 05
795	794	800

Performance Goals

4.1.1. Evaluate the operation of the entire repository facility, including the surface and subsurface components.

4.1.2. Monitor the identification of research needs to support improved understanding of the interaction of components of the waste management system.

4.1.3. Review the technical and scientific basis of the DOE's analyses of component interactions under various scenarios, including the degree of integration and redundancy across functional components over time.

4.1.4. Evaluate the effects of reduced receiving capacity at the repository surface facility on the nationwide transportation system.

4.1.5. Review criteria for waste acceptance for storage to ensure that accepted material has been suitably characterized for subsequent disposal.

4.2.1. Monitor the DOE's efforts to implement Section 180 (c) of the NWPA.

4.3.1. Monitor the DOE's progress in developing and implementing a transportation plan for shipping spent nuclear fuel and high-level radioactive waste to a Yucca Mountain repository.

4.3.2. Review the DOE's efforts to develop criteria for decisions on transportation mode and routing.

4.3.3. Evaluate logistics capabilities of the transportation system.

4.3.4. Monitor progress in implementing new technologies for improving transportation safety for spent nuclear fuel.

4.3.5. Evaluate the DOE's plans for enhancing safety capabilities along transportation corridors, and review the DOE's planning and coordination activities (e.g., route selection), accident prevention activities (e.g., improved inspections and enforcement), and emergency response activities.

Strategy for Achieving Goals

The Board will accomplish its goals by doing the following.

- Holding three public meetings with DOE and contractor personnel involving the full Board, and holding meetings of the Board's Panel on the Waste Management System in appropriate areas of the country.

- Reviewing critical documents provided by the DOE and its contractors, including contractor reports, process model reports, and TSPA.

- Meeting with groups involved in implementing transportation plans, including the NRC, the Department of Transportation, railroad and trucking companies, nonprofit groups, the utilities, and other stakeholders. Visiting countries with nuclear-waste transportation and disposal programs and attending national and international conferences and symposia.

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