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U.S. NUCLEAR WASTE  
TECHNICAL REVIEW BOARD

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



January 1, 2005, to February 28, 2006

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UNITED STATES  
NUCLEAR WASTE TECHNICAL REVIEW BOARD

2300 Clarendon Boulevard, Suite 1300  
Arlington, VA 22201

June 2006

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

The Honorable Ted Stevens   
President Pro Tempore   
United States Senate   
Washington, D.C. 20510

The Honorable Samuel W. Bodman   
Secretary   
U.S. Department of Energy   
Washington, D.C. 20585

Dear Speaker Hastert, Senator Stevens, and Secretary Bodman:

The U.S. 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.

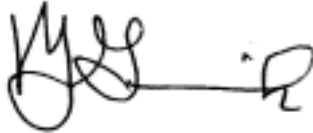
Congress created the Board to evaluate the technical and scientific validity of activities undertaken by the Secretary of Energy related to implementing the Nuclear Waste Policy Act of 1982. In this report, which covers the period of January 1, 2005, through February 28, 2006, the Board's major activities are summarized and the Board's technical evaluation of Department of Energy (DOE) work related to disposing of, packaging, and transporting spent nuclear fuel and high-level radioactive waste is presented.

The technical evaluation contained in the report focuses on six important technical issues: (1) the capability of natural barriers at Yucca Mountain to isolate radionuclides; (2) the DOE's thermal-management strategy; (3) the range of potential near-field environments and their possible effects on the engineered barrier system; (4) postclosure risk associated with the repository; (5) design and operation of surface and subsurface components and facilities; and (6) DOE plans for the waste-management system.

In the appendices to the report are Board correspondence, congressional testimony, Board performance plans and evaluations, and related materials.

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

Sincerely,

A handwritten signature in black ink, appearing to read "B. John Garrick". The signature is fluid and cursive, with a long horizontal stroke extending to the right.

B. John Garrick  
Chairman

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# NUCLEAR WASTE TECHNICAL REVIEW BOARD 2005

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# Executive Summary

The U.S. Nuclear Waste Technical Review Board (Board) was established by Congress in the Nuclear Waste Policy Amendments Act. The Act requires the Board to evaluate the technical and scientific validity of the work undertaken by the U.S. Department of Energy's (DOE) Yucca Mountain Project (Project) to develop a geologic repository system for disposing of spent nuclear fuel and high-level radioactive waste produced by the nation's nuclear defense complex and commercial nuclear power plants. The results of the Board's evaluation, along with its recommendations, must be reported at least twice yearly to Congress and to the Secretary of Energy. Between January 1, 2005, and February 28, 2006, the period covered by this report, the Board focused its evaluation on six critical technical issues. In what follows below, the Board's major findings and recommendations for each of the six areas are presented.

## *A. The Capability of Natural Barriers to Isolate Radionuclides*

Two potentially significant natural barriers at Yucca Mountain—the unsaturated zone beneath the repository horizon and the saturated zone—can isolate radionuclides that might be released from the emplaced waste packages. The Board believes that the Project has made great strides over the last few years in developing a sound understanding of the magnitude and rates of mountain-scale groundwater flow in the unsaturated and saturated zones under ambient temperatures and current climatic conditions. Although the Project should continue to evaluate new data as they become available and refine its conceptual models as warranted, new understanding is

likely to emerge in an evolutionary rather than a revolutionary manner. The Board believes, however, that additional work is needed on processes and phenomena that could significantly affect the rate at which dose-significant radionuclides are transported. Such work should include investigations into matrix diffusion, secondary mineralization, and colloid-facilitated transport.

## *B. Thermal-Management Strategy*

A key driver in the performance of the repository, both preclosure and postclosure, is temperature. The temperature of the spent nuclear fuel affects the integrity of the fuel cladding and the susceptibility of the waste-package material to localized or general corrosion. The temperature and time profiles in the near-field environment of the drift affect tunnel degradation, causing more fracture pathways, drift separation, and movement of water or water vapor in the unsaturated zone. How these temperatures are controlled is determined by the Project's thermal-management strategy, which identifies controlling criteria, including the maximum thermal loading of the waste packages, line loading in the emplacement drift, and peak temperatures and zones for pillar separation.

The Board has concerns about the technical basis underlying the Project's thermal-management strategy. First, the technical basis for the Project's choice of thermal criteria to limit temperature is not well-defined. The Board believes that the Project should articulate in a transparent way the basis for its thermal criteria. Second, the implications for thermal management of the Project's provisional decision to develop and implement

a standardized canister for storing, transporting, and disposing of spent nuclear fuel do not seem to have been evaluated fully. The Board is particularly concerned about the ability of the utilities to blend the spent nuclear fuel to the required thermal loading, given the spent nuclear fuel available in the spent-fuel pools, the increasing volume of spent nuclear fuel in dry storage at reactors, and the trend toward higher burn-up fuel. Moreover, the Board is concerned that the constraints imposed by line-load requirements during emplacement have not been fully represented or understood in terms of surface facility design and operation. Third, the Board is not persuaded that the thermal-hydrologic models being used to predict postclosure temperature, relative humidity, and vapor transport within the drifts have a strong technical basis.

#### *C. The Range of Possible Near-Field Environments that Might Occur and the Effect of Those Environments on the Integrity of the Engineered Barrier System*

The engineered barrier system consists of the spent nuclear fuel, including the cladding and the fuel pellets; the waste package, including any canister or basket holding the spent nuclear fuel or high-level radioactive waste; the waste package invert; the drip shield; and the backfill, if any. As do the natural barriers, the engineered barrier system can contribute to waste isolation.

The Alloy-22 outer barrier of the waste package will not corrode significantly unless liquid water is present on the waste package surface. The higher the temperature at which liquid water is present, the greater is the concern, because metals generally corrode faster at higher temperatures and the susceptibility of metals to corrosion generally increases at higher temperatures. Project scientists have determined that dusts from ventilation air during the preclosure period would settle on waste package surfaces and would contain salts that could form saturated brines with boiling points on the order of 200°C.

The Project maintains that potential localized corrosion of Alloy-22 at elevated temperatures can be excluded from its performance-assessment

calculations. The Board believes that the technical basis for the exclusion is not compelling, partly because only very limited corrosion data have been collected at temperatures above 150°C and partly because data showing cessation (stifling) of localized corrosion at lower temperatures may or may not be relevant to all conditions under which localized corrosion could occur in the proposed repository. The Board strongly urges the Project to continue collecting data that might justify its assumption that localized corrosion will not occur at temperatures as high as 200°C.

#### *D. The Postclosure Risk Associated with the Proposed Repository*

Beginning in 1991, the Project carried out seven performance assessments for the proposed repository at Yucca Mountain, and it is preparing an eighth assessment, which it intends to use for supporting its application for a license to construct the repository.

The Board appreciates the fact that the Project is in the midst of preparing a license application for its proposed repository system. Not surprisingly, the Project is motivated to advance a licensing case whose main—and possibly sole—objective is to demonstrate compliance with the applicable regulations via an intensely legalistic process. Consequently, when faced with gaps in understanding, “bounding” or conservative approaches are often adopted. What is difficult to assess is the degree of total conservatism that exists when scientists add their own conservatism in the chain of integrated analyses that form the performance assessment.

For that reason, the Board remains concerned that by adopting a conservative compliance-focused approach, the Project discounts the importance of letting policy-makers, the public, and the broader technical and scientific community know what the Project’s experts believe are the intrinsic capabilities of the proposed repository at Yucca Mountain. Having more-definitive information on the adequacy of the natural system and the levels of conservatism involved, for example, may well provide all interested and affected parties with important and relevant information.

Thus, the Board believes that the Project should carry out a realistic performance assessment, perhaps in parallel with its efforts to develop a compliance case. Such a realistic performance assessment would establish a “baseline” for measuring how “conservative” or “nonconservative” the Project’s licensing case might be. Although some assumptions still may be required, they, too, will need to be well justified if this realistic assessment is to be carried out credibly. Thus the Board reiterates its view that fundamental understanding is important and encourages the Project to fill in areas where significant gaps in such understanding exist.

Further, to address what now appear to be the critical radionuclides contributing to peak dose, the Board recommends that the Project prepare full and realistic process models that account for the transport of the two radionuclides in question, neptunium-237 and plutonium-242. Such an effort should trace the radionuclides from when they leave the degraded fuel pellet until they are taken up by the “reasonably maximally exposed individual.” These analyses should be consistent with the thermal hydraulic analyses used in the thermal-management strategy. The model calculations should extend until the time of peak dose or 1,000,000 years.

#### *E. Design and Operation of Surface and Subsurface Components and Facilities*

In recent years, the Project has intensified its efforts to design and develop concepts-of-operation for the surface and subsurface facilities that might be constructed at Yucca Mountain. The Board looks favorably on the Project’s provisional decision to implement the standardized transportation-aging-disposal canister concept. It believes that such an approach holds the potential for minimizing the handling of bare fuel assemblies, for simplifying the design of surface facilities, and for reducing occupational exposures. As noted above in the thermal-management discussion, the Board remains concerned that the Project has not fully evaluated the range of consequences associated with implementation of the standardized transportation-aging-disposal canister

concept. The Board recommends that the Project carry out a comprehensive formal analysis that would better specify the full effect of adopting the standardized transportation-aging-disposal canister concept. Such an analysis should take into consideration a full complement of scenarios that can evaluate various design and operational assumptions associated with waste acceptance, transport, receipt and processing at the surface facilities, and emplacement.

#### *F. Plans for the Waste-Management System*

The waste-management system consists of elements that collectively must carry out a range of functions: accepting waste at a utility or, if needed, at DOE defense-complex sites; handling, transporting, processing, and storing the waste; and, finally, emplacing the waste underground. Because the elements of the waste-management system are tightly coupled, the assessment of the behavior and performance of one element may strongly depend on or affect the behavior and performance of others.

The Board notes that the Project has begun development of the Total System Model, which has significant potential as a tool for understanding the performance of the coupled waste-management system. The Total System Model, for example, can be used to examine system throughput, identify possible “choke” points, and show where various design and operational elements are incompatible. For maximizing the value of the Total System Model, however, the input data must be based on the most up-to-date information; critical modeling assumptions also must be confirmed; there should be an ability to represent upset conditions; and all components of the waste-management system, including emplacement, need to be incorporated in the model. The Board recommends, therefore, that these enhancements be pursued actively. The Board further recommends that the Total System Model be used by designers of the surface facilities and all other components of the waste-management system to determine needs and capabilities and to eliminate problems or constraints in the future.

Because of funding constraints, much of the Project's anticipated work on establishing a transportation network has been deferred. Nonetheless, the Board believes that the Project should move expeditiously to perform a comparative risk analysis of alternative rail corridors that might be used to move spent nuclear fuel and

high-level radioactive waste to Yucca Mountain. Once that risk analysis has been completed, the DOE should inform all interested and affected parties what route(s) it prefers. In addition, the Project should develop a contingency plan for greater use of legal-weight and heavy-haul trucking.

## 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's (DOE) Yucca Mountain Project (Project) to develop a geologic repository system for disposing of spent nuclear fuel (SNF) and high-level radioactive waste (HLW) produced by the nation's nuclear defense complex and commercial nuclear power plants. The results of the Board's evaluation, along with its recommendations, must be reported at least twice yearly to Congress and the Secretary of Energy. This document is the first such report for 2006.

Between January 1, 2005, and February 28, 2006, the period covered by this report, the Board focused its attention on the Project's efforts to develop post-closure performance estimates for the repository it proposes to construct at Yucca Mountain in Nevada. The Board considered areas where the Project could improve its understanding of the capability of the natural system, the unsaturated and saturated zones in particular, to isolate the radionuclides of the SNF and HLW. The Board continued its evaluation of how the waste packages might perform if they were emplaced in the proposed repository. Finally, the Board also examined the Project's planned waste-management system that is needed to accept, transport, and handle SNF and HLW before their disposal.

The Board's mandate to review the DOE's waste disposal project is broad, encompassing the technical and scientific aspects of all of the Secretary

of Energy's actions to implement the NWPAA. During the period covered by this report, the Board continued evaluating the work that the Project is pursuing to prepare a license application (LA) for constructing the proposed repository. The LA contains, among other things, a Total System Performance Assessment (TSPA), which details the Project's technical case for how a Yucca Mountain repository might isolate SNF and HLW for many tens of thousands of years, the so-called postclosure period. The LA also contains the DOE's Preclosure Safety Analysis, which is intended to demonstrate how the performance requirements for the operational phase of the proposed repository will be met. Once completed and submitted, the LA eventually will be the subject of a U.S. Nuclear Regulatory Commission (NRC) adjudicatory hearing and determination.

At the same time, the Board continued its longstanding tradition of encouraging the Project to undertake investigations and analyses that go beyond licensing requirements so that there is greater transparency in the fundamental processes involved and to increase public confidence in the conclusions reached in the TSPA. The Board's position is that the Project's conclusions about postclosure repository performance need to be compelling, convincing, and strongly evidence-based. This position traces to the Board's beginnings. It was formally articulated in comments that the Board made, first in 1997 and again in 2000, on two Project proposals for revising its original site-suitability guidelines (Cohon 1997, 2000). Further, the Board suggested that the Project seek out multiple lines of evidence about repository performance, such as natural or

engineered analogues, that are independent of the TSPA (NWTRB 2001). On several occasions, the Board also noted the importance of increasing “fundamental understanding” to reduce the uncertainties associated with the TSPA. (See, for example, Cohon 2002.) Most recently, the Board recommended that the Project conduct a “more realistic” TSPA (Garrick 2005c, 2006).

## I. Events Influencing the Board’s Review

As President George W. Bush’s second term began in 2005, significant changes took place in the senior leadership of the Office of Civilian Radioactive Waste Management (OCRWM), which has responsibility for the Project. A new Acting Director initiated a review of the full range of activities taking place within the office. That review ultimately led to two important programmatic shifts and initiated a significant reorganization.

- The OCRWM instructed its lead contractor, Bechtel-SAIC Corporation (BSC), to devise a plan for operating the Yucca Mountain repository as a primarily “clean” or non-contaminated facility. The change in surface facility design meant that most SNF would be sent to the repository in a standardized transport-aging-disposal (TAD) canister that would not require repetitive handling of bare SNF before its disposal. Earlier plans called for shipping SNF in various types of canisters to the repository where workers would handle each of the bare SNF assemblies up to four times.
- The OCRWM designated Sandia National Laboratories (SNL) as its lead laboratory for integrating the Project’s scientific work related to the evaluation of repository performance during the postclosure period. As the OCRWM’s lead laboratory, SNL would provide management and integration services for all Yucca Mountain scientific programs, a task previously assigned to BSC.
- The OCRWM began restructuring itself to create a flatter organization. The heads of 13

offices will be expected to report directly to the Director/Principal Deputy Director, located in Washington D.C. The former distinction between “east” and “west” will be eliminated; within any given office, people can work either in Washington or in Las Vegas.

In March 2005, Secretary of Energy Samuel W. Bodman announced that “certain employees of the U.S. Geological Survey (USGS) working on the Yucca Mountain project may have falsified documentation of their work.” The documentation in question related to computer modeling involving water infiltration and climate (DOE Office of Public Affairs 2005). Separate investigations of this matter were launched by the OCRWM, and the Inspectors General of the Departments of Energy and Interior. In February 2006, the OCRWM released a report detailing the results of its investigation (OCRWM 2006). The OCRWM maintained that the net infiltration ranges developed by the USGS were “consistent with groundwater recharge rates determined by other scientists studying other arid and semi-arid regions in the United States.” Notwithstanding this conclusion, the OCRWM said that it will “replace or supplement the infiltration modeling work, as needed, and will review or verify the supporting documentation...” (DOE Office of Public Affairs 2006).

In August 2005, the U.S. Environmental Protection Agency (EPA) proposed changes to its Yucca Mountain-specific environmental standard (EPA 2005). The EPA’s proposal responded to a July 2004 Court of Appeals decision (*Nuclear Energy Institute v. EPA*) that had vacated the 10,000-year compliance period in the previously promulgated standard, 40CFR197. In particular, the EPA requested public comments on the following changes to its standard:

- The compliance period should extend to the time of peak dose but for no more than 1,000,000 years.
- For the first 10,000 years, the individual protection standard should be 15 mrem/year. For the remainder of the compliance period, the

individual protection standard should be 350 mrem/year.

- The figure of merit for judging compliance during the first 10,000 years should be the mean of the projected dose rates. For the remainder of the compliance period, the figure of merit should be the median of the projected dose rates.
- Features, events, and processes (FEP's) that have an annual probability of occurrence that is greater than  $10^{-8}$ /year must be included in the TSPA. FEP's not satisfying that probability criterion during the first 10,000 years also may be excluded in the performance assessment that is carried out for the remainder of the compliance period. However, four FEP's and their associated scenarios—climate change, seismic events, volcanic events, and general corrosion—must be included in the 1,000,000-year/peak-dose TSPA regardless of their annual probability of occurrence.

Shortly thereafter, the NRC proposed modifications to its licensing regulation, 10CFR63, so that its rule would conform to the changes that the EPA proposed and to specify how climate should be modeled during the post-10,000-year part of the compliance period (NRC 2005).

In February 2006, as part of its Advanced Energy Initiative, the Administration requested \$250 million to launch the Global Nuclear Energy Partnership (GNEP). In the Administration's vision, if fully implemented over the next several decades, the GNEP would foster the building of a new generation of nuclear power plants, would develop and deploy new nuclear recycling technologies, would design Advanced Burner Reactors to produce energy from the recycled nuclear fuel, and would provide fuel services to developing nations to reduce the risks of nuclear proliferation. The DOE has emphasized in statements to Congress and elsewhere that a Yucca Mountain repository would still be necessary even if the GNEP is implemented fully. In those statements, the DOE has maintained that one important consequence of a fully implemented GNEP would be to increase substantially the capacity of the pro-

posed Yucca Mountain repository. At this time, it is unclear what the prospects are for approval by Congress of this or subsequent budget requests or what GNEP's ultimate impact on the Yucca Mountain repository project might be.

## II. Board Review of the OCRWM's Technical and Scientific Investigations

Early in 2005, the Board developed a set of critical technical issues that it believed warranted its special attention. These priority issues, announced at the Board's November 2005, meeting, include the following:

- The capability of natural barriers to isolate radionuclides;
- Thermal-management strategy;
- The range of possible near-field environments that might occur and the effect of those environments on the integrity of the engineered barrier system (EBS);
- The postclosure risk associated with the proposed repository;
- Design and operation of surface and subsurface components and facilities;
- Plans for the preclosure waste-management system, including transportation; and
- A comparison of preclosure and postclosure human exposure to radiation.

Once these priorities were established, it became very clear that the Board needed to interact with the Project in a concerted manner that permitted in-depth technical exploration of the issues. Toward that end, small contingents of Board members and staff held eight fact-finding meetings with the DOE and its contractors between March and September of 2005. As they are obligated to do under the NWPA, Project scientists and engineers presented a number of ongoing

scientific investigations and analyses, many of which contained preliminary results still in draft form. These fact-finding meetings were productive and enabled the Board to engage in the detailed and lengthy technical discussions that are necessary to understand many of the fundamental methods of analysis employed by the Project. In addition to the meetings with the Project, several Board members and staff held separate talks with representatives of railroads, trucking companies, cask manufacturers, transportation logistics providers, and nuclear utilities. The purpose of these meetings was to gather first-hand information from key stakeholders who would be involved in designing and operating the waste-management system. Importantly, all of these fact-finding meetings were undertaken in part to improve the technical substance and relevance of the Board's public meetings.

The Board, in fact, was able to explore all but the last of its priority issues at its public meetings. In what follows, the OCRWM's technical and scientific investigations with respect to each issue, as articulated at those meetings, are described, and the Board's findings and recommendations are presented.

### *A. The Capability of Natural Barriers to Isolate Radionuclides*

Two potentially significant natural barriers at Yucca Mountain—the unsaturated zone beneath the repository horizon and the saturated zone—can isolate radionuclides that might be released from the emplaced waste packages.

#### *1. THE OCRWM'S TECHNICAL AND SCIENTIFIC INVESTIGATIONS*

*Unsaturated zone.* The ability of the unsaturated zone to isolate radionuclides under ambient conditions depends on, among other things, the amount of liquid water that flows through it, the chemical form and solubility of the radionuclides released from the EBS, the path the water takes through the rock, and the ability of the rock to

retard or retain the radionuclides mechanically or chemically.

The amount of water flowing in Yucca Mountain is determined in the first instance by climate, which affects the amount of rain and snowfall. A fraction of that water infiltrates beneath the root zone and percolates down into the rock. The topographic and geologic variability of Yucca Mountain results in some areas having relatively enhanced infiltration and other areas having relatively reduced infiltration. The belief is that water percolating down is diverted around repository drifts by physical forces rather than seeping into them. Estimating how much water is likely to be available to transport radionuclides outside the proposed repository is a key objective of the Project.

At the Board's February 9, 2005, meeting (NWTRB 2005a), one Project scientist presented preliminary data on opal growth rates over the last several hundred thousand years (Andrews 2005). According to the scientist, such growth rates depend on how much water passes through the unsaturated zone at the proposed repository horizon. Although not conclusive, these data suggested to the presenter that the repository level at Yucca Mountain is buffered from long-term transient climate states. At the Board's February 1, 2006, meeting (NWTRB 2006), another Project scientist described the approach taken in the TSPA to modeling the seepage of liquid water entering the drifts (Birkholzer 2006). In addition, new calculations not used in the current TSPA analysis indicate that water vapor present in the drifts could condense on the drip shields and waste packages (Hardin 2006). In-drift condensation occurs because a temperature gradient develops along the axis of the emplacement drift that is caused by the relatively hot waste packages at the center and cooler waste packages at the edge of a repository. This condensation phenomena typically is referred to as the "cold-trap" effect.

Once water enters the drifts either by seepage or by condensation, it is available to dissolve and transport any radionuclide released from the



waste packages. Radionuclides could be transported as dissolved species, as either sorbed reversibly or irreversibly on to colloids, or as true colloids. Two radionuclides, neptunium-237 ( $^{237}\text{Np}$ ) and plutonium-242 ( $^{242}\text{Pu}$ ), are particularly important in the projections of repository performance carried out to the time of peak dose or 1,000,000 years. Project scientists reported at the Board's February 1, 2006, meeting, that the Project had undertaken investigations and analyses to understand better the chemistry, solubility, and genesis from SNF degradation of the likely oxide forms of the those two radionuclides (Sassani and Howard 2006a). As a result of those studies, the Project concluded that the solubility of the neptunium isotope was best modeled by a reduced form ( $\text{NpO}_2$ ) inside the waste package and by a more oxidized form ( $\text{Np}_2\text{O}_5$ ) outside the waste package. In the models, the plutonium isotope is transported primarily by reversible and irreversible attachment to colloids. Work is being carried out to estimate the relevant rate constants (Sassani and Howard 2006b). Finally, investigations are ongoing to learn more about how neptunium and plutonium bond chemically with the products of SNF degradation and waste package corrosion.

The current conceptual model holds that fluid flow and advective radionuclide transport in the unsaturated zone takes place mostly through fractures. The model recognizes that diffusion into the rock matrix also is a significant radionuclide transport process. Some Project studies suggest that the magnitude of matrix diffusion for relevant scales in nature may be greater than is currently represented in Project computer models, which are based on laboratory-scale data. Underestimation of the magnitude of matrix diffusion in computer models would underestimate the amount of time required for radionuclides that diffuse into the rock matrix to be transported through the actual hydrogeologic system, resulting in earlier, larger dose projections.

*Saturated zone.* The saturated zone receives all of the water draining from the unsaturated zone and any radionuclides in that water. At Yucca Mountain, the rocks of the saturated zone are predomi-

nantly volcanic tuffs and alluvial sediment. The capability of the saturated zone to isolate radionuclides depends on, among other things, the form and quantity of the radionuclides, climate, the physical and chemical properties of the rock, the magnitude of matrix diffusion, water-flow rates and water chemistry, especially oxidation state, and the amount of sorption onto rock and mineral surfaces. As the Project's understanding of each of these variables matures, its estimates of the capability of the saturated zone could become less uncertain.

At the Board's February 1, 2006, meeting, a Project scientist described how water flow and radionuclide transport are modeled in the TSPA (Arnold 2006). Climate change is represented by scaling the computed time required for radionuclides to reach the accessible boundary, a point approximately 18 km south of the proposed repository footprint, in proportion to flux changes in the saturated zone. Matrix-diffusion calculations in the saturated zone depend on the spacing between flowing horizons in the rock, the magnitude of rock porosity, and the diffusion coefficient for the radionuclide. The scientist described the uncertainties associated with estimates of each of these variables. In particular, he noted that, as in the unsaturated zone, the effect of matrix diffusion in the saturated zone might be underestimated in the Project's models.

The sorption conceptual model also was described. It incorporated unique sorption characteristics for each radionuclide and rock substrate. Here again, the modeling had to address uncertainties, such as sorption coefficients for the tuff matrix and alluvium, dispersivity, effective porosity of the alluvium, colloid retention factor, and sorption coefficients onto colloids. As a result of a combination of natural variability and model uncertainty, the saturated zone breakthrough curves for neptunium ranged from 30 years to more than 20,000 years. The Project scientist stated that the sorption modeling presumed that the groundwater was oxidizing. He noted, however, that there were some indications that local reducing conditions may exist in the saturated zone. Reducing conditions would decrease the solubility and increase the sorption

coefficients of technetium and neptunium. In his view, such changes would increase the capability of the saturated zone to isolate radionuclides.

## 2. BOARD FINDINGS AND RECOMMENDATIONS

The Board believes that the Project has made great strides over the last few years in developing a sound understanding of the magnitude and rates of mountain-scale groundwater flow in the unsaturated and saturated zones under ambient temperatures and current climate conditions. Further, the Board considers the Project's findings regarding the chemistry of the water in the unsaturated and saturated zones under ambient conditions broadly consistent with a large body of empirical data and experience. Although the Project should continue to evaluate new data as they become available and refine its conceptual models as warranted, new understanding is likely to emerge in an evolutionary rather than a revolutionary manner.

The Board believes, however, that additional work on radionuclide transport is needed—in particular, research on secondary mineralization (Garrick 2005c). This area of investigation relates to what is more generally referred to as the radionuclide source term, the understanding of which is critical to assessing the overall performance of the proposed repository. If these investigations determine that the neptunium and plutonium leaving the EBS are captured in secondary mineral phases, the possibility exists that the natural system's capability to isolate the dose-contributing radionuclides ( $^{237}\text{Np}$  and  $^{242}\text{Pu}$ ) could be greatly increased. Further work investigating matrix diffusion, colloid-facilitated transport, or other processes that might significantly affect the rate at which dose-significant radionuclides are transported also could yield important insights. In addition, the Peña Blanca analogue site in Mexico provides an opportunity to test models and methods for predicting radionuclide migration and retention processes at Yucca Mountain. The Board encourages the Project to continue studies at that location. In short, the Board believes that it would be prudent for the Project to refine its understanding of radionuclide retardation and retention phenom-

ena to evaluate better the potential contribution that the natural system might make to isolating radioactive waste.

The Board is skeptical about the Project's claim to have found evidence of a "reducing curtain" in the saturated zone. Once oxidized water flows into a reducing zone (and becomes reduced), it cannot simply flow out "the other side" and become reoxidized. Thus the Project's conjecture that localized reducing conditions might retard some radionuclides does not seem well founded unless the entire groundwater flow path is reducing. There does not appear to be evidence to support such a claim.

Finally, the Board remains puzzled about the Project's inability to put to rest two longstanding issues: whether bomb-pulse chlorine-36 ( $^{36}\text{Cl}$ ) has been observed at the proposed repository horizon and whether the water found behind the sealed section of the cross-drift is the result of condensation or seepage. (Neither issue was mentioned in any of the Project's presentations at the three public meetings.) Inconsistencies in past studies of  $^{36}\text{Cl}$ , for example, raise questions about the technical basis of model predictions of water flow and radionuclide transport. In the case of the water found in the sealed section of the cross-drift, the Project has not developed and tested a hypothesis that explains all of the physical and chemical data collected. To enhance confidence in both the quality and the conclusions of the Project's technical analyses, the Board recommends that work be expedited to resolve both of these issues.

### *B. Thermal-Management Strategy*

A key driver in the performance of the repository, both preclosure and postclosure, is temperature. Temperatures of interest include the temperature of the SNF and HLW at the time of emplacement, the temperature on the waste package wall, the drift wall temperature, and the near-field drift temperatures. The temperature of the SNF affects the integrity of the fuel cladding (a barrier) and the susceptibility of the waste-package material to localized or general corrosion. The temperature and time profiles in the near-field

environment of the drift affect tunnel degradation, causing more fracture pathways, drift separation, and movement of water or water vapor in the unsaturated zone.

The Project's thermal-management strategy is comprised of three elements (Harrington 2005): (1) development of thermal criteria that constrain the size, age, and contents of waste packages; this in turn limits how hot the waste packages can be and how that heat will be distributed among the thousands of packages emplaced in the drifts of the proposed repository; (2) how those thermal criteria will be achieved during preclosure operations involving waste acceptance and handling, blending, staging and sequencing of the waste packages during emplacement; and (3) how the emplaced waste packages influence critical variables during the thermal pulse that relate to the near-field environment, including drift-wall temperature, seepage, in-drift transport of water vapor, chemistry, and radionuclide transport. Clearly then, the thermal-management strategy creates the most important bridge between preclosure activities and postclosure performance.

#### *1. THE OCRWM'S TECHNICAL AND SCIENTIFIC INVESTIGATIONS*

At the Board's February 9, 2005, meeting, an engineer described the Project's thermal-management strategy (Harrington 2005). He stated that during preclosure surface operations the key thermal criterion was keeping the SNF below 400°C to maintain cladding integrity. Once the waste packages are emplaced in the proposed repository, their surface temperatures cannot exceed 300°C. Cladding temperature of the SNF cannot exceed 350°C once the SNF is emplaced and throughout the postclosure period. The Project also has established the following criteria: (1) The waste package thermal power cannot be greater than 11.8kW; (2) The packages would have to be emplaced so that they would not heat the drift wall to a temperature higher than 200°C or heat the center part of the drift rock pillar to more than 96°C; (3) The maximum average thermal line load cannot exceed 1.45 kW/meter.

According to this individual, several options are available to ensure that these thermal criteria can be satisfied.

- Waste packages can be derated, i.e., not fully loaded.
- Hot SNF can be blended in the same waste package with cooler SNF.
- The packages can be spaced farther apart than the baseline design now specifies.
- The proposed repository can be ventilated for longer than the time now called for in the baseline design.
- Waste packages can be stored on the surface until they have cooled.

The Project engineer gave no indication that satisfying either the preclosure or postclosure thermal criteria would be difficult. He noted, for example, that the Project intends to construct concrete pads that would have enough room to accommodate up to 21,000 MTHM of stored SNF, or approximately 30 percent of the amount of waste allowed to be disposed of at Yucca Mountain under current law.

At one of the fact-finding meetings, officials from the Project discussed in greater detail the technical basis that supported the choice of the thermal criteria. The Board members explored how those choices constrained the design of the repository. They also reviewed the Project's efforts to model seepage into the drifts, water-vapor transport within the drifts, and condensation of water vapor in the pillars separating the drifts.

#### *2. BOARD FINDINGS AND RECOMMENDATIONS*

The Board has concerns about the technical basis underlying the Project's thermal-management strategy. These concerns manifest themselves in each of the three elements that constitute the strategy. First, the technical basis for the Project's choice of thermal criteria to limit temperature is not well-defined. For example, the 11.8 kW/waste package limit appears to have been based arbi-

trarily on the average power of a PWR SNF assembly plus 20 percent. A more technically valid approach might be to derive the maximum waste package-surface temperature limit from limits on the drift-wall temperature. A limit derived from the drift-wall temperature would likely be higher than 11.8 kW/waste package, although how much higher still is not well understood. The Board believes that the Project should articulate in a transparent way the basis for its thermal criteria. The Board will be holding future fact-finding meetings to evaluate further the technical basis for the Project's proposed thermal criteria.

Second, the implications for thermal management of the Project's provisional decision to implement the TAD concept do not seem to have been evaluated fully. In particular, the Board is concerned about the ability of the utilities to blend the SNF to the required thermal loading, given the SNF available in the spent-fuel pools, the increasing volume of SNF in dry storage at reactors, and the trend toward higher burn-up fuel. For example, assuming an 11.8 kW/waste package limit, how long would a waste package have to be stored at Yucca Mountain if its initial thermal output was substantially higher than this limit? Utilities are storing SNF at their sites in dry storage casks. This SNF is predominantly older, cooler material, which may not be available for future TAD packages. The longer the delay in implementing the TAD concept, the more SNF will be placed in storage casks. Those casks might have to be reopened at the proposed repository, thereby negating at least some of the value of the TAD concept. Moreover, the Board is concerned that the constraints imposed by line-load requirements during emplacement have not been fully represented or understood in terms of surface facility design and operation. The Board looks forward to reviewing the Project's assessment of the full range of consequences associated with implementing the TAD concept.

Third, the Board is not persuaded that the thermal-hydrological models being used to predict postclosure temperature, relative humidity, and vapor transport within the drifts have a strong technical basis. For example, the thermal con-

ductivity of the rock at Yucca Mountain is important for predicting thermohydrologic conditions in the proposed repository. Uncertainty in the thermohydrologic conditions, especially during the thermal pulse that lasts about 1500 years, arises in part from the scarcity of *in situ* measurements of thermal conductivity in the lower lithophysal rocks where approximately three-quarters of the repository might be constructed. More data on thermal conductivity could reduce this uncertainty (Garrick 2005c). In addition, further analysis of data obtained from the Drift-Scale Heater Test might be helpful in reducing the uncertainty in thermohydrologic conditions during the thermal pulse.

Finally, the Project is conducting three-dimensional analyses to complement its two-dimensional multiscale model of water and vapor flow. The Board plans to review those new analyses to determine what impact, if any, they might have on the Project's safety case. In particular, the Board would like to see how energy and mass balances are achieved and how these results are integrated into performance assessment. Due to the importance of the multiscale model, the Board also recommends that it be reviewed by independent experts.

### *C. The Range of Possible Near-Field Environments that Might Occur and the Effect of Those Environments on the Integrity of the EBS*

The EBS consists of the SNF, including the cladding and the fuel pellets; the waste package, including any canister or basket holding the SNF or HLW; the waste package invert; the drip shield; and the backfill, if any. As do the natural barriers, the EBS can contribute to waste isolation.

#### *1. THE OCRWM'S TECHNICAL AND SCIENTIFIC INVESTIGATIONS*

*Waste package.* For the last few years, the Board has explored whether localized corrosion of the Alloy-22 waste package might occur at temperatures higher than 150°C by the action of concentrated deliquescent brines (Corradini 2003a, 2003b; NWTRB 2003). After a public meeting

held in May 2004 (NWTRB 2004b), the Board concluded that deliquescence-induced localized corrosion due to calcium chloride brines during the higher-temperature period of the thermal pulse would be unlikely because of the improbability of such brines being present (Duquette 2004). Because no other plausible brines were known to exist at temperatures above 150°C, the issue of localized corrosion above 150°C due to concentrated deliquescent brines seemed to be closed. A January 2005 letter to the Board from former OCRWM Director Margaret Chu, however, reopened the issue (Chu 2005). The letter suggested that *combinations of salts* known to be present in the drifts at Yucca Mountain could deliquesce at temperatures as high as 200°C. One question that remained to be answered was whether this combination of salts might cause localized corrosion.

After considerable investigation and analysis, the Project concluded that localized corrosion was so inconsequential that it could be excluded from the list of FEP's that needed to be evaluated in the TSPA. In a pair of presentations at the Board's November 8, 2005, meeting (NWTRB 2005b), Project scientists laid out the technical arguments that led to that conclusion (Bryan 2005; Ilevbare 2005). The presentations sought to address the following logic tree:

1. Can multiple-salt-deliquescent brines form at elevated temperatures?
2. If deliquescent brines form at an elevated temperature, will they persist?
3. If deliquescent brines persist, will they be corrosive?
4. If potentially corrosive brines were to form, would they initiate localized corrosion?
5. If localized corrosion were to be initiated, would penetration of the waste-package outer barrier occur?

One scientist stated that, according to experimental data, a mixture of NaCl-KNO<sub>3</sub>-NaNO<sub>3</sub> could deliquesce at temperatures up to approximately

200°C at the relative humidities that will exist in a repository at Yucca Mountain at that temperature. Thus, the answer to the first question is "yes." Moreover, the monovalent salt brines will not degas sufficiently to dry out at elevated temperatures. Consequently, the answer to the second question also is "yes."

The scientist maintained that the answer to the third question is "no," at least for temperatures below 160°C. The deliquescent brines studied, both initially and after interacting with the waste package surface, possess a high nitrate-to-chloride ratio. Experimental evidence obtained at temperatures as high as 160°C indicate that nitrate-rich brines do not initiate localized corrosion. However, some new data at higher temperatures showed localized corrosion on creviced Alloy-22 samples. These data are still being evaluated. Depending on that evaluation, the Project may have to adjust its position on the corrosivity of NaCl-KNO<sub>3</sub>-NaNO<sub>3</sub> brines at high temperatures.

Regardless of the corrosivity of the brine, the second scientist argued that the answer to the fourth question also is "no." The Project calculated an upper limit to the brine volume of 1.8μL/cm<sup>2</sup>. (This translates into an 18μm thick layer.) The Project believes that such a limited volume would not allow the formation of aggressive solutions within the crevices. Finally, in the Project's view, processes occurring after any possible initiation of localized corrosion would limit the extent of the corrosion. Those processes include corrosion stifling, physical retention of brine in the corrosion products, and chemical sequestration of brine components in the corrosion products. The scientist presented some preliminary data to support the Project's claims about stifling and used the data to argue that the answer to the fifth question is "no" as well.

*Drip Shield.* In mid-1998, the Project decided to introduce a drip shield into its baseline design of the proposed repository system. Current plans call for the drip-shield base to be made from Alloy-22; the drip-shield shell, plates, and welds from titanium-grade 7; and the drip-shield structural supports from titanium-grade 24.

Although titanium-grade 7 generally is considered not susceptible to stress-corrosion cracking (SCC) at below-boiling temperatures in neutral or basic solutions, one set of experiments at 105°C showed apparent SCC when this material was immersed in concentrated basic saturated water (BSW). Based on this finding, the Board felt it important to pursue the question of whether titanium-grade 7 is the appropriate material for the drip shield.

At the Board's November 8, 2005, meeting, a Project scientist gave a comprehensive presentation on the potential degradation of the drip shield as a result of corrosion (Gordon 2005). He noted that experiments indicated that the titanium might be susceptible to hydrogen induced cracking (HIC) in the presence of fluoride ions. However, the aerated repository conditions and the extended period of dry oxidation likely provide a sufficient margin of protection against HIC. Further, a repetition in air rather than in BSW of the SCC experiment that prompted the Board's question gave essentially the same results as the earlier experiment. This finding suggests that crack growth observed in the BSW tests may have been due primarily to creep rupture, not to SCC.

It should be noted that the TSPA assumes that penetrations of the drip shields due to any SCC that might occur would be limited to fine cracks through which no water would flow, especially if the cracks are filled with corrosion products and mineral assemblages (Boyle and Lachman 2005). The Project has carried out preliminary experiments to support this assumption.

## 2. BOARD FINDINGS AND RECOMMENDATIONS

The Alloy-22 outer barrier of the waste package will not corrode significantly unless liquid water is present on the waste package surface. The higher the temperature at which liquid water is present, the greater is the concern, because metals generally corrode faster at higher temperatures and the susceptibility of metals to corrosion generally increases at higher temperatures. Project scientists have determined that dusts from ventilation air during the preclosure period

would settle on waste package surfaces and would contain sodium chloride, sodium nitrate, potassium nitrate, and other salts. Certain combinations of these salts, dissolved in water, could form saturated brines with boiling points on the order of 200°C.

The Project maintains that potential localized corrosion of Alloy-22 at elevated temperatures can be excluded from its TSPA calculations. The Board believes that the technical basis for the exclusion is not compelling, partly because only very limited corrosion data have been collected at temperatures above 150°C and partly because data showing cessation (stifling) of localized corrosion at lower temperatures may or may not be relevant to all conditions under which localized corrosion could occur in the proposed repository (Garrick 2005c). The Project will participate in a Board-sponsored public workshop in September 2006 to address this issue in greater depth. The Board strongly urges the Project to continue collecting data that might justify its assumption that general corrosion will not occur at temperatures as high as 200°C.

Besides the potential for localized corrosion, aqueous conditions on waste package surfaces at elevated temperatures raise other corrosion concerns. General corrosion of Alloy-22 is a very slow process, but it is the process by which waste packages inevitably will fail if they do not fail first because of localized corrosion (or because of SCC, see below). General corrosion proceeds more rapidly at higher temperatures. Some previous performance assessment models have assumed that general corrosion of Alloy-22 *does not occur above 120°C*, presumably based on the assumption that aqueous conditions do not exist above this temperature. Because aqueous conditions *can* exist at elevated temperatures—as Project researchers have demonstrated—future performance assessments should not exclude general corrosion at elevated temperatures when aqueous conditions are predicted to be present. The Board strongly urges the Project to continue to collect data to resolve the issue of whether general corrosion occurs at temperatures as high as 200°C.

Alloy-22 has been shown to be very resistant to, but not immune from, SCC under many Yucca Mountain conditions at temperatures below approximately 160°C. Although Alloy-22 can exhibit SCC under these conditions, very high stress intensities induced by pre-cracking are required, and even then cracks propagate very slowly. However, for Yucca Mountain environments above about 160°C, only limited SCC data exist for Alloy-22. Given that the susceptibility of metals to SCC generally increases with temperature, the Project will have to obtain relevant data under higher-temperature conditions, assume that SCC will occur, or use a different approach.

The Project has gathered substantial new data on SCC of the titanium-grade 7 alloy used to construct the drip shield. Nonetheless, the Board continues to believe that SCC in titanium alloys cannot be dismissed.

If the waste packages corrode to the point where water can enter them, the SNF cladding and the fuel pellets also must degrade before waste gets mobilized and leaves the package. Alternatively, the glass with which the HLW has been mixed must degrade. Although there is good understanding about what radionuclides will be present in the SNF and the HLW at the time of emplacement and how those radionuclides will decay over time, the Project's understanding of how the radionuclides interact with the SNF and glass-degradation products is much more limited. Consequently, there is considerable uncertainty about the source term incorporated into the TSPA. To address this uncertainty or lack of detailed analysis, the Project has made simplifying assumptions that need to be reviewed carefully for their effects on the fuel degradation and radionuclide migration processes.

For example, the Project has presented experimental data on SNF alteration where neptunium-uranium co-precipitation did not occur, suggesting that neptunium transport may not be significantly delayed by this process. Further, drip-test data show neptunium concentrations that are not necessarily at that radionuclide's solubility limits. The Board notes that the Project is seeking to improve its understanding of the source term

through research sponsored by its Science and Technology program. Even if such work is not incorporated directly into the TSPA, it will likely increase confidence in technical claims that will be advanced by the Project (Garrick 2005c).

#### *D. The Postclosure Risk Associated with the Proposed Repository*

Beginning in 1991, the OCRWM carried out seven performance assessments for the proposed repository at Yucca Mountain, and it is in the process of preparing an eighth assessment, the TSPA-LA. If submitted to the NRC, the TSPA-LA will be the focus of an adjudicatory hearing to determine whether the DOE will be permitted to construct a repository at Yucca Mountain.

##### *1. THE OCRWM'S TECHNICAL AND SCIENTIFIC INVESTIGATIONS*

At the November 9, 2005, meeting, the Project sought to address two general questions posed by the Board: To what extent does the TSPA rely on conservative or non-conservative assumptions? What effect do those assumptions have on projections of repository performance?

Two Project scientists advanced three key positions (Van Luik and Andrews 2005):

- The primary purpose of performance assessment is to demonstrate post-closure regulatory compliance.
- The DOE will provide a demonstration of post-closure regulatory compliance that does not underestimate dose.
- This demonstration demands the application of a cautious but reasonable approach in modeling long-term performance.

The two individuals cited NRC regulations, publications from international bodies, such as the Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development, and the Board itself in defense of those positions. Further, they suggested that the use of conservative assumptions was unavoidable

given that models have to be simplified, that needs for additional data have to be reduced, and that alternative conceptual models have to be addressed. In contrast, they maintained that in no case has the TSPA been intentionally non-conservative or optimistic.

The two scientists provided three examples of conservatism used in the TSPA. In the first example, EBS transport, they pointed to conservatisms, among other things, dealing with coupled processes in the breached waste packages, the representation of the water film on the waste form and in-package materials, and the in-package chemical conditions. In the second example, transport of radionuclides in the unsaturated zone, they noted that a cautious but reasonable approach had been adopted to propagate future climate effects and to represent site-scale matrix diffusion processes. In the third example, transport of radionuclides in the saturated zone, they observed, among other things, that permanent filtration of colloids is not considered and that potential reducing conditions were not incorporated.

They concluded their presentation by noting that the Project is able to understand the implications of using conservative representations by undertaking sensitivity analyses. This approach allows them to defend the conclusions reached in the TSPA. Although the Project continues to explore ways of making its performance assessments less conservative and more realistic, there probably are practical limits on what might be done in this area. Ultimately, the two scientists suggested, the Project is not likely to change any of its three key positions.

At the Board's February 1, 2006, meeting, a third scientist described a "scoping" performance assessment that was carried out to 1,000,000 years, which included the time of peak dose (Nutt 2006). This performance assessment contained a number of simplifications:

- Only representative FEP's that could potentially affect peak dose were evaluated.

- A constant climate state was used, which is based on an integrated long-term average. This resulted in slightly larger infiltration rates than occur during the glacial transition climate stage.
- Repository average percolation flux was set equal to average infiltration.
- Drifts were presumed to have collapsed because of seismic activity.
- Only advective radionuclide transport was considered.
- Only general corrosion processes were evaluated.
- Waste forms were presumed to degrade instantaneously once the waste packages failed because of general corrosion.
- All transport through the volcanic rocks of both the unsaturated and saturated zones was assumed to be instantaneous. Radionuclide transport in the saturated alluvium was included in the model.

The Project scientist identified three factors from the scoping study that are significant to the size and timing of the peak dose: waste package lifetime, neptunium solubility, and magnitude of water seepage. Neither igneous nor seismic events were expected to have a significant effect on peak annual dose.

The presentation did not include any quantitative performance assessment results, although they were publicly available, having been included in a document containing the DOE's comments on the EPA's proposed environmental standard (Golan 2005b). That document reports the following:

- Waste packages begin to fail at 480,000 years and continue to fail beyond 1,000,000 years.
- The drip shields begin to fail at 40,000 years and continue to fail until about 1,000,000 years. If drips shields were not deployed,



the peak dose would rise by approximately 20 percent.

- The peak dose occurs at roughly 600,000 years. Its mean value is approximately 100 mrem/year.
- If the temperature dependence on the waste package general corrosion rate was extended below 45°C to 21°C, the time of the peak dose would be pushed out beyond 1,000,000 years, but its magnitude would remain approximately the same.

At its February 1, 2006, meeting, the Board also heard a presentation on conservatism, non-conservatism, and uncertainty in radiation-dose calculations that are part of a risk-informed analysis (Ryan 2006). The presentation identified five approaches for addressing conservatisms and uncertainties:

- Extreme bounding analysis;
- Bounding analysis;
- Sensitivity studies;
- On-off calculations and comparisons; and
- Probabilistic risk analysis.

Examples of past uses of each approach were presented to demonstrate that each can play a role in dose calculations, each has strengths and weaknesses, and some may be better than others for specific applications.

## 2. BOARD FINDINGS AND RECOMMENDATIONS

Scientists and engineers are typically cautious in advancing claims. They usually prefer to wait until as much evidence as possible has accumulated before committing to a particular position. To borrow from the language that the EPA used in its recently proposed Yucca Mountain standard, this “natural tendency” is reinforced when those individuals know that their claims might be challenged in a formal regulatory process.

The Board appreciates the fact that the Project is in the midst of preparing a license application for its proposed repository system. Not surprisingly, the Project is motivated to advance a licensing case whose main—and possibly sole—objective is to demonstrate compliance with the applicable regulations via an intensely legalistic process. Consequently, when faced with gaps in understanding, “bounding” or conservative approaches often are adopted. Examples of this abound, including how the Project models the temperature dependence of generalized corrosion rates, sorption in the saturated zone, and the containment capability of some parts of the EBS. What is difficult to assess is the degree of total conservatism that exists when scientists add their own conservatism in the chain of integrated analyses that form the TSPA.

For that reason, the Board remains concerned that by adopting a conservative compliance-focused approach, the Project discounts the importance of letting policy-makers, the public, and the broader technical and scientific community know what the Project’s experts believe are the intrinsic capabilities of the proposed repository at Yucca Mountain. Having more definitive information on the adequacy of the natural system and the levels of conservatism involved, for example, may well provide all interested and affected parties with important and relevant information.

The Board believes that the Project’s “cautious but reasonable” approach to dealing with uncertainties has limits, including the fact that just how conservative the TSPA is overall is unclear. This limit is not overcome by conducting sensitivity analyses because the effects of parameter and model changes related to one component of the examined system or subsystem may be masked by assumptions about other components of the system or subsystem. Thus, the Board believes that the Project should carry out a realistic performance assessment, perhaps in parallel with its efforts to develop a compliance case. Such a realistic performance assessment would establish a “baseline” for measuring how “conservative” or “non-conservative” the Project’s licensing case might be. A realistic performance

assessment also is likely to increase confidence in the conclusion reached in the Project's compliance-focused TSPA.

To conduct these realistic analyses, scientists and engineers should be asked to give their best assessment of performance-critical parameters. The assessments should reflect not only the experts' opinions about the value of performance-critical parameters but also the uncertainties involved. Including the uncertainties in the assessments communicates the experts' confidence in their state of knowledge—an important piece of evidence. Responding convincingly to the request for such information may require increased understanding of the repository system. In addition, although some assumptions still may be required, they, too, will need to be well justified if this best assessment is to be carried out credibly. Thus, the Board reiterates its view that fundamental understanding is important and encourages the Project to fill in areas where significant gaps in such understanding exist (Garrick 2005c, 2006).

To address what now appears to be the critical radionuclides contributing to peak dose, the Board recommends that the Project prepare full and realistic process models that account for the transport of the two radionuclides in question,  $^{237}\text{Np}$  and  $^{242}\text{Pu}$ . Such an effort would involve tracing the radionuclides from when they leave the degraded fuel pellet until they are taken up by the "reasonably maximally exposed individual." These analyses should be consistent with the thermal hydraulic analyses used in the thermal-management strategy. The model calculations should extend until the time of peak dose or 1,000,000 years (Garrick 2006).

### *E. Design and Operation of Surface and Subsurface Components and Facilities*

In recent years, the Project has intensified its efforts to design and develop concepts-of-operation for the surface and subsurface facilities that might be constructed at Yucca Mountain. Many of these are first-of-a-kind facilities.

#### *1. THE OCRWM'S TECHNICAL AND SCIENTIFIC INVESTIGATIONS*

*Surface components and facilities.* At a January 20, 2004, Board panel meeting (NWTRB 2004a), a Project engineer presented plans for constructing several surface facilities for handling SNF and HLW: a transportation cask-receipt facility, a canister-handling facility, and two dry-transfer facilities (Harrington 2004). At the Board's September 20, 2004, meeting (NWTRB 2004c), another Project engineer provided an update on the Project's work on surface facility design (Craun 2004). In a November 30, 2004, letter to the OCRWM, the Board expressed concern that the operation of the planned surface facilities could result in bare SNF assemblies being handled as many as four times, amounting to close to one million handling operations for bare fuel assemblies. The Board recommended that the Project find ways to minimize the number of times that the assemblies would be handled (Garrick 2004).

During 2005, technical problems arose in the design of the dry-transfer facility including whether its atmosphere could be effectively made inert. Largely because of these problems, the Project decided to reassess its plans for building many of the surface facilities. Out of that reassessment came the TAD concept, which, among other things, aims to reduce the amount of bare SNF handling, and thus the radiation exposure of workers (Arthur 2005). As noted above, any final decision to develop the TAD could have important implications for the Project's thermal-management strategy.

At present, little information is available on the new surface facility design. The Board is awaiting design information to assess the improvements that have been made to the original design concepts.

*Subsurface components and facilities.* In the period covered by this report, Project scientists and engineers made three presentations on the drip shield's design and how it might be put into operation. At the Board's February 9, 2005, meeting, two Project scientists described how

the concept of a drip shield emerged from the multimaterial waste package concepts considered by the Project's License Application Design Study undertaken in the late 1990s (Boyle and Lachman 2005). Although both Alloy-22 and titanium were evaluated for use in this component of the EBS, titanium was selected to avoid potential material common-mode failures and to increase the level of defense-in-depth.

At the Board's November 8, 2005, meeting, a Project engineer detailed the drip shield's functional and operational requirements (Anderson 2005). The component had to be designed so that it would not preclude waste package retrieval. Further, it had to prevent seepage entering the drift from dripping onto the waste packages after repository closure and had to protect the waste packages from direct impacts from rockfall.

The drip shields would be installed by remote control just before repository closure, which could occur any time from 50 to 300 years after waste emplacement begins. A gantry would straddle a drip shield segment and lift it up. The gantry would then move the segment down the drift. Next, the drip shield segment would be positioned and aligned with a previously installed segment. The drip shield segment then would be lowered so that the two segments interlocked. To accomplish these tasks, the Project would have to design and build an emplacement gantry, a gantry transporter, a drip shield transporter, and a transport locomotive. Those designs are at their earliest stages of development.

A second Project engineer described analyses that examined how the drip shield would respond to mechanical degradation caused by potential seismic events (Board 2005). The analyses evaluated the effects of drift degradation, including rockfall and vibratory motion, as well as fault displacement. The analyses concluded that the drip shield would be structurally stable even after the collapse of the drifts. Further, the drip shields would be structurally stable even after being struck by the largest and most highly energetic rocks. Finally, the drip shields would remain interlocked under the full range of seismic shaking conditions.

Representing the State of Nevada, an engineer provided a different assessment of the drip shield's functionality (Kendorski 2005). Among the potential problems he noted were the following:

- The drip shield transport gantry may be hard to recover if it becomes inoperable in the drift.
- The tight clearances in the emplacement drift may be hard to navigate because the dusty environment can obscure the video images that are critical for remote control.
- Verifying that interlocking of the drift shield segments has been achieved successfully may be difficult. This may be particularly important because the interlocking tolerances are very small.

He concluded by observing that if the drip shield is integral to safety, there must be "an up-front and credible plan and design" for how the drip shield will be installed. Based on his review of the Project's documents, no such plan and design currently exist.

## 2. BOARD FINDINGS AND RECOMMENDATIONS

The Board looks favorably on the Project's provisional decision to implement the TAD concept. It believes that such an approach holds the potential for minimizing the handling of bare SNF assemblies, for simplifying the design of surface facilities, and for reducing occupational exposures (Garrick 2005b, 2005c). Clearly, the success of such an approach requires close cooperation and coordination among the DOE, utilities, and cask vendors. Based on its fact-finding meeting with representatives of utilities and cask vendors, the Board believes that steps are now being taken to promote that cooperation and coordination. As noted above, however, the Board remains concerned that the Project has not fully evaluated the range of consequences associated with implementation of the TAD concept, especially with respect to thermal management.

Thus, the Board recommends that the Project conduct a formal analysis that addresses, among other things, the following areas:

- What are the performance specifications of the TAD? How were they derived?
- How does the introduction of the TAD affect logistic capabilities and limits?
- What constraints on SNF blending does the TAD create?
- How does the TAD affect surface facility design and operation?
- How does the TAD affect the sequencing of waste emplacement necessary to maintain the specified line load of 1.45 kW/meter?

The Board believes that the Project needs to refine further its drip shield design and implementation approach (Garrick 2005c). Although the Project has produced some analytical results that it believes show that the drip shield interlocks will withstand seismic events, it is hard to believe that the drip shields will maintain their “as-installed” configuration even as those same events cause the waste packages to fail. Further, the Board believes that the Project needs to address issues related to in-drift operational envelopes and installation tolerances that could potentially increase the difficulty of installing the drip shields remotely. Finally, because the drip shield will not be installed until just before repository closure, which will be many years after waste emplacement has begun, the Project should evaluate now what factors will affect the final design of this EBS component and explain how, when, and by whom decisions about installing drip shields will be made, including whether to install them at all.

### *F. Plans for the Waste-Management System*

The waste-management system consists of elements that collectively must carry out a range of functions: accepting waste at a utility or, if needed, at DOE defense-complex sites; handling, transporting, processing, and storing the waste;

and, finally, emplacing the waste underground. Because the elements of the waste-management system are tightly coupled, the assessment of the behavior and performance of one element may strongly depend on or affect the behavior and performance of others.

#### *1. THE OCRWM'S TECHNICAL AND SCIENTIFIC INVESTIGATIONS*

*Total System Model (TSM).* At the Board's February 9, 2005, meeting, the manager in charge of system integration discussed the TSM, which was then being developed (Kouts 2005a). The Project intends to use the TSM to analyze and integrate the set of activities that start with the acceptance of SNF and HLW at utility and DOE sites, continue with the transportation of the waste to the proposed repository, and end with the handling and management of the material in facilities located on the surface near Yucca Mountain.

The TSM is an event-driven, real-time simulation. Objects, such as SNF assemblies or casks, can be traced from receipt to emplacement. The model can be used to simulate the actions of filling waste packages to meet thermal constraints, to evaluate alternative acceptance, transportation, or management scenarios, and to challenge existing design and operating concepts. Two sample results derived from the TSM—the cumulative receipt of commercial SNF shipping casks and the requirements for procuring large rail casks—were presented. At the Board's November 9, 2005, meeting, the same manager provided the Board with a somewhat fuller explanation of the TSM (Kouts 2005b).

*Transportation Network.* At the Board's February 10, 2005, meeting, the manager in charge of transportation gave two presentations (Lanthrum 2005a, 2005b). The first provided an update on the activities of his office. He laid out for the Board the major activities for which he had responsibility: cask acquisition, rolling-stock acquisition, development of transportation support facilities, transportation operations, construction of a Nevada rail line, and institutional relations. He explained how the various activities

are interrelated and affect each other. He noted that many activities have had to be trimmed or deferred because the OCRWM did not receive from Congress the budget that it had requested. For instance, for FY05, the OCRWM requested \$125 million for transportation but only \$25 million was appropriated or approximately 40 percent of what it had received in FY04. In FY06, OCRWM's transportation budget is slightly less than \$20 million.

Nonetheless, work continued on the Nevada Rail Alignment Environmental Impact Statement, conceptual design work for rail casks, and development relationships with four State Regional Groups. In July 2005, following the release of a U.S. Department of Transportation (DOT) study on the advantages and disadvantages of using dedicated trains to move SNF and HLW (DOT 2005), the OCRWM announced that it was "adopting a policy to use dedicated trains for its usual shipments of spent nuclear fuel to the Yucca Mountain repository site in Nevada, when the repository is operational..." (Golan 2005a). In December 2005, the OCRWM released its *Environmental Assessment for the Proposed Withdrawal of Public Lands Within and Surrounding the Caliente Rail Corridor, Nevada* (OCRWM 2005).

## 2. BOARD FINDINGS AND RECOMMENDATIONS

Because the elements of the waste-management system are tightly coupled and because the assessment of the behavior and performance of one element may strongly depend on or affect the behavior and performance of others, the Board believes that it would be a mistake to try developing the system without recognizing and accommodating these interdependencies. Thus, the Board notes that the Project has begun development of the TSM, which has significant potential as a tool for understanding the performance of the waste-management system. For example, the TSM can be used to examine system throughput, to identify possible "choke" points, and show where various design and operational elements are incompatible; it can assess the effects of delayed construction of a rail spur; and it can evaluate the conditions that contribute to efficient operation of the surface

facilities. For maximizing the value of the TSM, however, the input data must be based on the most up-to-date information; critical modeling assumptions must be confirmed; there should be an ability to represent upset conditions; and all waste-management system components, including emplacement, should be incorporated into the model.

Further, the Board recommends that the Project enhance the TSM in the following ways to increase the model's utility in evaluating the waste-management system:

- Add a system optimization module.
- Allow for stochastic processing times.
- Incorporate the effects of contingent events, such as major storms, bridge collapses, and delays in the construction of key facilities and system components.

The Board further recommends that the enhanced TSM be used by designers of the surface facilities and all other waste-management system components to determine needs and capabilities and to eliminate problems or constraints in the future.

The Project also should evaluate phased approaches to developing the waste-management system. For example, it should consider handling "normal" SNF first and exceptional fuel types at a later date. It should consider early shipments that are easy to load, use a single transport mode, travel over a relatively short distance, and following of routes used previously in shipping radioactive materials. It might also consider "bundling" plants with common practices into the same waste acceptance phase.

Because of funding constraints, much of the Project's anticipated work on establishing a transportation network has been deferred. Nonetheless, the Board believes that the Project should move expeditiously to perform a comparative risk analysis of alternative rail corridors that might be used to move SNF and HLW to Yucca Mountain. Once that risk analysis has been completed, the DOE should inform all interested and affected

parties what route(s) it prefers. In addition, the Project should develop a contingency plan for greater use of legal-weight and heavy-haul trucking. The Project also should supplement its current "top-down" route-selection efforts that rely on State Regional Groups with a "bottom-up" mode of interaction involving direct and meaningful input from potentially affected first responders and community leaders. Finally, the Board recommends that the Project manage its emergency response grant program using a systems approach that incorporates anticipated responses to accident conditions during transportation and verifies that adequate emergency response capability exists along each transportation route.

### **III. Other Board Activities**

#### ***A. Site Visits***

In June 2005, a delegation of Board members and staff visited the Peach Bottom Atomic Power Station, located in York County, Pennsylvania. The facility, operated by the Exelon Corporation, is the home to two boiling water reactors and one small experimental reactor that was taken out of service in 1974. The Board greatly appreciates the willingness of the Exelon Corporation to host this visit and to ensure that it was a productive one for the Board.

The purpose of the visit was to observe one day of a week-long activity during which SNF assemblies were removed from the reactor SNF pool and loaded into a dry storage-transportation cask. The Board delegation also viewed the transporter that carries the loaded cask to the storage pad. In addition, the visit gave the Board delegation an opportunity to understand better the critical interface between a utility and the OCRWM's waste-acceptance program.

In July 2005, a delegation of Board members and staff visited the DOE's Waste Isolation Pilot Plant (WIPP), located in Carlsbad, New Mexico. The WIPP is the only operating geologic repository for long-lived radioactive waste. Beginning

in 1999, transuranic-contaminated (TRU) waste from the DOE's nuclear weapons complex has been disposed of in the WIPP's salt formations. Waste emplacement is expected to continue for approximately another 30 years.

The purpose of the visit was to observe the operations of a repository. The Board delegation also examined the transportation casks used to bring TRU waste to the WIPP. The delegation went underground and saw where new drifts were being constructed. In addition, it observed some of the emplaced TRU waste. The Board delegation met with DOE officials to hear what lessons they believed they had learned during the course of developing the WIPP repository. The Board delegation also met with Carlsbad's mayor and other community leaders to get their impressions of events that ultimately led to the WIPP's opening. The Board thanks the WIPP officials and scientists and the leadership of the Carlsbad community for making this a constructive and valuable site visit.

In November 2005, a delegation of Board members and staff visited the DOE's Savannah River Site, where the Defense Waste Processing Facility (DWPF) had poured nearly 2,000 of the planned 5,060 canisters of glass containing HLW. The canisters produced so far hold approximately four percent of the radioactivity of the HLW stored in the tanks at the site. Also at the Savannah River Site is the L-Reactor spent-fuel pool, where all DOE-owned SNF is being consolidated. This SNF eventually will be packaged at the L-Reactor and transported to the DWPF. There it will be combined with canisters containing HLW and sent to the proposed repository at Yucca Mountain. Facilities for managing the DOE-owned SNF once it leaves the L-Reactor spent-fuel pool have not been designed. The Board greatly appreciates the DOE's willingness to host this site visit and to provide important information to aid in the Board's technical review.

#### ***B. International Activities***

The Board continues its exchanges with other national radioactive waste management programs to keep informed of developments of

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potential importance to the United States and to broaden the Board's perspective in its efforts to review the Project.

For example, the Board has an informal working agreement with the Swedish National Council for Nuclear Waste (KASAM). The KASAM evaluates the work undertaken by Swedish Nuclear Waste Company (SKB), the utility-owned organization responsible for implementing that country's nuclear waste program. In March 2005, a small Board delegation attended a seminar sponsored by the KASAM. The main purpose of the seminar was to review and discuss the SKB's latest three-year plan for waste management research, development, and demonstration.

On April 2005, the mayor and other representatives from the municipality of Oskarshamn, Sweden paid a visit to the Board's office. They were in Washington with a group of 33 representatives from municipalities in Sweden at which nuclear facilities are located. The Oskarshamn delegation visited separately with Board representatives and provided their perspectives on the site-characterization process in Sweden. Board members presented their perspectives on developments in the United States program.

In conjunction with its own meeting, the Board hosted the third meeting of the Advisory Bodies to Government (ABG) in Las Vegas on January 30 through February 2, 2006. This group was organized in early 2004 under the auspices of the NEA. The ABG's purpose is to provide a forum for organizations similar to the Board to meet and exchange information and to share experiences in their successes and setbacks in accomplishing their assigned missions. Countries that have established entities somewhat similar to the Board in purpose and scope are: France, Germany, Japan, Sweden, Switzerland and the United Kingdom.

Each of these countries sent at least one representative to the meeting to present updates on their review work, describe the status of their respective programs, and discuss issues of mutual interest. In addition, the delegates met and exchanged views with representatives from the Nevada and

California counties surrounding the proposed repository site. Many of the ABG delegates also toured Yucca Mountain, Amargosa Valley, and Ash Meadows National Wildlife Refuge.

### *C. Board Letter on Criticality*

On February 18, 2005, the Board responded to a letter about criticality from the State of Nevada's Agency for Nuclear Projects (Garrick 2005a). The Board stated that it had reviewed a recent DOE report (OCRWM 2004) on the probability of internal criticality. According to the report, the probability of the combined failure of waste packages and drip shields during the 10,000-year period following repository closure, a necessary precondition for criticality, would be well below the level of regulatory significance for the so-called nominal case, which assumes no significant earthquakes or volcanic events. The Board found this conclusion to be credible.

Subsequently, the Environmental Protection Agency proposed changes to its radiation safety standard applying to a Yucca Mountain repository in August 2005 (EPA 2005), and the Nuclear Regulatory Commission proposed changes to its regulation applying to a repository at Yucca Mountain in September 2005 (NRC 2005). The proposed changes are significant, particularly the proposals to change the period of applicability from 10,000 years after repository closure to the period extending from repository closure up to the time when peak dose is predicted to occur up to 1,000,000 years after repository closure. The proposed changes would not require the DOE to estimate the probability or consequence of internal criticality beyond 10,000 years after closure if the estimate of the probability of internal criticality during the 10,000-year period after repository closure is below the level of regulatory significance.

The final versions of the proposed changes have not been issued as of the date of publication of this report. The Board will continue monitoring all of the DOE's ongoing developments and activities related to in-repository criticality and the technical bases underlying the DOE's criticality calculations.

#### **IV. The Board in Transition**

In May 2005, Dr. Daryle Busch submitted to President Bush his resignation as a member of the Board, effective July 15, 2005. Dr. Busch, former President of the American Chemical Society, is Roy A. Roberts Distinguished Professor of Chemistry at the University of Kansas. In the short time that Dr. Busch served on the Board, he brought strong technical insights and sound judgment to his evaluation of the DOE's work at Yucca Mountain.

#### **V. The Board's Plans for 2006**

The Board will organize its work in 2006 into three major areas. The first is preclosure operations. This area includes an examination of the TAD concept and the technical basis for the OCRWM's decision on whether to proceed with implementation of the TAD. It also includes the design of surface facilities at the proposed Yucca Mountain site. In addition, the Board will evalu-

ate any comparative risk assessment of alternative transportation modes and routes that the OCRWM might conduct.

The second major area is postclosure performance of the proposed repository. The Board will continue its evaluation of the Project's investigations of the elements constituting the natural and engineered barriers. The Board intends to pay particular attention to work undertaken to understand better seepage into drifts, waste degradation, including waste package corrosion and radionuclide transport out of the EBS, and flow and transport of dose-significant radionuclides into the biosphere.

The third major area is integration of the waste management system. The Board will continue its efforts to evaluate the technical basis for the Project's thermal management strategy. It will explore how the Project trades off preclosure and postclosure risks. It will also evaluate any realistic performance assessment that the OCRWM might conduct.



# Abbreviations and Acronyms

ABG	Advisory Bodies to Government
BSC	Bechtel-SAIC Corporation
Board	U.S. Nuclear Waste Technical Review Board
BSW	basic saturated water
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DWPF	Defense Waste Processing Facility
EBS	engineered barrier system
EPA	U.S. Environmental Protection Agency
FEP's	features, events, and processes
GNEP	Global Nuclear Energy Partnership
HIC	hydrogen induced cracking
HLW	high-level radioactive waste
KASAM	Swedish National Council for Nuclear Waste
kW	kilowatt
LA	license application
MTHM	metric tonnes heavy metal
NEA	Nuclear Energy Agency
NRC	U.S. Nuclear Regulatory Commission
NWPAA	Nuclear Waste Policy Amendments Act of 1987
NWTRB	U.S. Nuclear Waste Technical Review Board
OCRWM	Office of Civilian Radioactive Waste Management
Project	Yucca Mountain Project

SCC	stress-corrosion cracking
SKB	Swedish Nuclear Waste Company
SNF	spent nuclear fuel
SNL	Sandia National Laboratories
TAD	transport-aging-disposal
TRU	transuranic-contaminated
TSM	Total System Model
TSPA	Total System Performance Assessment
USGS	U.S. Geological Survey
WIPP	Waste Isolation Pilot Plant

# Glossary

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

**advective transport** The movement of radionuclides by the bulk mass of flowing fluid.

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

**alluvium** Clay, silt, sand, gravel, or similar detrital material deposited by running water.

**analogue (analog)** 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.

**backfill** Natural or engineered aggregates placed in drifts to restrict human intrusion, to mitigate drift degradation and rock fall and the effects of seismic events on the engineered barrier system.

**barrier** A natural or engineered system that prevents or mitigates the movement of radionuclides toward the accessible environment.

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

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

**bounding analysis** Using extreme parameter estimates to project repository performance.

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

**cladding** The outer layer of a nuclear fuel rod.

**chlorine-36 (<sup>36</sup>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 1950s temporarily increased concentrations of chlorine-36. The resulting "bomb-pulse" levels of chlorine-36 can sometimes serve as a tracer to determine how rapidly precipitation from the 1950s has moved through soil and rocks such as those present at Yucca Mountain.

**colloid** A state of subdivision of matter in which the particle size varies from that of true "molecular" solutions to that of coarse suspensions with the diameter of the particles lying between  $10^{-7}$  and  $10^{-5}$  centimeters.

**conservative** Projections of repository performance using parameters and models that systematically under-estimate the system's ability to isolate and contain waste.

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

**coupled processes** The effects of heat on geochemistry and on the movement of water in either the liquid or gaseous phases.

**cross-drift** A small exploratory tunnel across the waste emplacement area of the proposed repository to enable scientists to get a preview of the geologic and hydrologic conditions.

**defense-in-depth** The use of multiple barriers in the design of the proposed repository to make the system less vulnerable to failure if a single barrier fail to function as anticipated.

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

**dissolved species** A chemical in aqueous solution.

**dose** See **radiation dose**

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

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

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

**fault** A plane in the earth along which differential slippage of the adjacent rocks has occurred.

**fault displacement** Relative movement of two sides of a fault such as that which occurs during an earthquake.

**fuel rod** An engineered structure that consists of a rod or tube, typically made of zircaloy, into which fuel material, usually in the form of uranium oxide pellets, is placed for use in a reactor. Many rods or tubes, that are mechanically linked, form a fuel assembly or fuel bundle.

**gantry** The rail-mounted transportation system used remote remotely emplacement of waste packages and drip shields.

**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 (HLW)** 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.

**igneous** formed by volcanic activity.

**infiltration** The flow of a fluid into a solid substance through pores or small openings; specifically, the movement of water into soil or porous rock.

**invert** The natural or engineered floor configuration of a tunnel or underground opening.

**License Application (LA)** 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.

**line-load** Two distinctly different emplacement strategies for waste package within and emplacement drift. A line load refers to placement such that the waste packages are virtually end-to-end or nearly touching. Point load refers to placement such that the packages separated by a least 2m.

**lithophysal** Volcanic rock containing hollow bubble-like cavities formed by gases as they cool.

**localized corrosion** Corrosion that takes place at discrete sites, for example, in waste package crevices.

**matrix** The solid framework of a porous system.

**matrix diffusion** The migration of higher concentrations of dissolved chemicals from more permeable zones to zones that are less permeable zones and that have lower concentrations of the same dissolved chemicals.

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

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

**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.

**Nuclear Waste Policy Act (NWPA)** The federal statute enacted in 1982 that established the Office of Civilian Radioactive Waste Management and defined its mission to develop a federal system for the management and geologic disposal of commercial spent nuclear fuel and other high-level radioactive wastes, as appropriate. The Act also specified other federal responsibilities for nuclear waste management, established the

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

**oxidizing** Any chemical reaction that involves the loss of electrons from an atom or ion.

**peak dose** The maximum radiation dose-rate projected to occur after the closure of the repository.

**peer review** A documented critical review performed by those who have experience at least equal to those who performed the work being reviewed but who are independent from individuals who performed the work.

**percolation flux** The movement of water through the repository horizon per unit area per unit time.

**performance assessment** A complex computer-based analysis that projects how well the entire repository system will isolate and contain waste and what the human health consequences will be if waste reaches the biosphere.

**performance confirmation** The tests, experiments, and analyses that are conducted to evaluate the accuracy and adequacy of the information used to determine with reasonable assurance that the repository performance objectives for the period after permanent closure will be met.

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

**preclosure** The 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.

**radiation dose** The amount of energy deposited in a unit of mass of a material. Also, and of several modified doses, including dose equivalent and effective dose, that more closely approximate the biological harm to humans from exposure to ionizing radiation.

**radionuclide** An atomic nucleus that is radioactive.

**radionuclide migration or radionuclide transport** The movement of radioactive materials through rock formations, typically in water.

**reducing** Any chemical reaction that involves the gain of electrons by an atom or ion.

**repository** See **geologic repository**

**risk analysis** Estimates of the probability multiplied by the consequences of a specific event or condition.

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

**seismic** Pertaining to an earthquake or earth vibration.

**sensitivity analysis** A type of performance analysis in which particular parameters are varied to obtain insights into their effect on waste isolation and containment and human health.

**site suitability** A determination by the U.S. Department of Energy that on the basis of data and analysis that a proposed repository site is

likely to meet the EPA's environmental standard. Such a determination in the case of Yucca Mountain led the Secretary of Energy to recommend to the President that an application for construction authorization be developed and submitted to the Nuclear Regulatory Commission. Congress ultimately approved this recommendation.

**Site-suitability Guidelines** Criteria set forth in 10CFR963, that are to be used by the U.S. Department of Energy in assessing the suitability of the site.

**sorption** Retardation of water-transported radionuclides as a result of their physically or chemically bonding to surfaces of geologic materials along the flow path.

**source term** The compositions and the kinds and amounts of radionuclides that make up the source of a potential release of radioactivity from the engineered barrier system to the host rock.

**spent nuclear fuel (SNF)** Fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by chemical reprocessing.

**SNF assembly** See **fuel rod**

**stress corrosion cracking (SCC)** A cracking process in materials that results from simultaneous corrosion and sustained tensile stress.

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

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

**thermohydrology** The study of coupled water and heat flow.

**Total System Model (TSM)** A tool to analyze the linkages, interactions, and synergies between the waste acceptance, transportation, and the repository. A model capable of integrating and analyzing the waste management system performance, alternative system solutions and assessing program and policy impacts.

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

**transparent** Easy to detect or observe. The use of clear language and easily understood con-

cepts and/or assumptions to arrive at credible, traceable, and logical conclusions.

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

**waste form** The radioactive waste materials and any encapsulating or stabilizing matrix. Examples include, used reactor fuel elements and borosilicate glass "logs."

**waste management system** All elements of the system involved in the management of radioactive wastes.

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





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# Appendices



## Appendix A

# U.S. Nuclear Waste Technical Review Board Members

### **B. John Garrick, Ph.D., P.E.; Chairman**

Dr. B. John Garrick was appointed to the U.S. Nuclear Waste Technical Review Board as Chairman on September 10, 2004, by President George W. Bush.

Dr. Garrick is an executive consultant on the application of risk sciences to complex technological systems in the space, defense, chemical, marine, transportation, and nuclear fields. He served for 10 years (1994–2004), 4 years as chair, on the U.S. Nuclear Regulatory Commission’s Advisory Committee on Nuclear Waste. His areas of expertise include risk assessment and nuclear science and engineering. A founder of the firm PLG, Inc., Dr. Garrick retired as President, Chairman, and Chief Executive Officer in 1997. Before PLG’s acquisition and integration into a new firm, it was an international engineering, applied science, and management consulting firm.

Dr. Garrick was elected to the National Academy of Engineering in 1993, President of the Society for Risk Analysis 1989–90, and recipient of that Society’s most prestigious award, the Distinguished Achievement Award, in 1994. He has been a member and chair of several National Research Council committees, having served as vice chair of the Academies’ Board on Radioactive Waste Management and as a member of the Commission on Geosciences, Environment, and Resources. He recently chaired the National Academy of Engineering Committee on Combating Terrorism. Among other National Academy committees he has chaired are the Committee on the Waste Isolation Pilot Plant, the Committee on Technologies for Cleanup of High-Level Waste in Tanks in the DOE Weapons Complex, and the Panel on Risk Assessment Methodologies for Marine Systems. Other Academy committee memberships included space applications, automotive safety, and chemical weapons disposal. He is a member of the first class of lifetime national associates of the National Academies.

Dr. Garrick has published more than 250 papers and reports on risk, reliability, engineering, and technology, has written several book chapters, and was editor of the text, *The Analysis, Communication, and Perception of Risk*.

Dr. Garrick received his Ph.D. in engineering and applied science from the University of California, Los Angeles, in 1968. His fields of study were neutron transport, applied mathematics, and applied physics. He received an M.S. in nuclear engineering from UCLA in 1962, attended the Oak Ridge School of Reactor Technology in 1954–55, and received a B.S. in physics from Brigham Young University in 1952. He is a fellow of three professional societies: the American Nuclear Society, the Society for Risk Analysis, and the Institute for the Advancement of Engineering. He is a registered professional engineer in California.

Dr. Garrick lives in Laguna Beach, California.

### **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 transportation safety and security, systems analysis, all-hazards risk management, and applications of advanced information technologies.

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 70 journal publications and study reports, and has appeared on National Public Radio, Fox National News, and CNBC discussing various risk management topics of national importance.

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 a 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.



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

Dr. William Howard Arnold was appointed to the U.S. Nuclear Waste Technical Review Board on September 10, 2004, by President George W. Bush.

Dr. Arnold is a private consultant. He was president of Louisiana Energy Services until his retirement in 1996. Louisiana Energy Services was a partnership of Urenco, Duke Power, Fluor Daniel, Northern States Power, and Louisiana Power and Light, formed to build the first privately owned uranium-enrichment facility in the United States. Dr. Arnold had retired from Westinghouse Electric Corporation in 1989 after 33 years in a variety of positions.

From 1955 to 1961, Dr. Arnold was senior engineer and section manager for Westinghouse Commercial Atomic Power. He was responsible for reactor physics design of the first series of Westinghouse commercial reactors. He spent 1 year with NUS Corporation as a nuclear fuel management consultant. From 1961 to 1968, he was deputy engineering manager, operations manager, and program manager for the NERVA nuclear rocket project for Westinghouse Astronuclear Laboratory. In 1968–1970, Dr. Arnold was manager of the overseas weapons department for the Westinghouse Defense Center in Baltimore, Maryland, responsible for the Mk 48 torpedo. From 1972 to 1989, he held various positions with Westinghouse in the nuclear area, including engineering manager of the pressurized-water reactor systems division, general manager and president of the Nuclear International Division, and general manager of the Advanced Energy Systems Division. He also served as vice president of Westinghouse Hanford Company.

Dr. Arnold was elected to the National Academy of Engineering in 1974 and is a Fellow and past member of the Board of Directors of the American Nuclear Society. He has participated in several National Academy of Sciences studies, including chairing the 2003 study, titled “Improving the Scientific Basis for Managing DOE’s Excess Nuclear Materials and Spent Nuclear Fuel.”

Dr. Arnold received a bachelor’s degree in chemistry and physics from Cornell University in 1951. In 1955, he was awarded a Ph.D. in experimental physics by Princeton University. He is a registered professional engineer in Pennsylvania.

Dr. Arnold resides in Macatawa, Michigan, and Coronado, California.

### **Daryle H. Busch, Ph.D.**

Dr. Daryle H. Busch was appointed to the U.S. Nuclear Waste Technical Review Board on September 10, 2004, by President George W. Bush. Dr. Busch resigned from the Board effective July 15, 2005.

Dr. Busch is the Roy A. Roberts Distinguished Professor of Chemistry at the University of Kansas. He also is deputy director of the NSF Engineering Research Center, which has the title Center for Environmentally Beneficial Catalysis.

Before going to the University of Kansas, Dr. Busch was a member of the faculty at The Ohio State University, eventually becoming Presidential Professor in 1987. His research in basic transition metal coordination chemistry fathered modern macrocyclic ligand chemistry and created the molecular template effect. He was one of the founders of the subject of ligand reactions and an early researcher and proponent of bioinorganic chemistry. He first described the phenomenon called "preorganization" in 1970. His research is presently focused on homogeneous catalysis, bioinorganic chemistry, and orderly molecular entanglements, a part of supramolecular and nanochemistry.

Dr. Busch served on the board of directors and in various capacities on local and regional sections and committees of the American Chemical Society (ACS). He was president of the ACS in 2000, and a member of the Board of Directors in 1999–2001.

In addition to some 400 scientific publications, Dr. Busch holds 11 patents jointly with 5 major industrial companies and 2 universities. Recognition of his research includes the ACS Award for Distinguished Service in Inorganic Chemistry (1976); the ACS Award for Research in Inorganic Chemistry (1963); the John C. Bailar Medal of his alma mater, the University of Illinois (1978); the Dwyer Medal of the Royal Society of N.S.Wales, Australia (1978); the Izatt-Christenson International Award for Macrocyclic Chemistry (1994); and the Basolo Medal of Northwestern University (2003). In 2003, Dr. Busch was an honorary inductee into the Chemical Society of Japan. His teaching has been recognized by the University of Kansas Louis Byrd Graduate Educator Award (1996) and an Ohio State University Alumni Teaching Award (1980).

He was recently chairman of the Chemistry Section of the American Association for the Advancement of Science and served the International Union for Pure and Applied Chemistry as chairman of the Commission on Inorganic Nomenclature and as secretary of the Inorganic Chemistry Division Committee.

Dr. Busch received a bachelor's degree in chemistry from Southern Illinois University in 1951 and master's and Ph.D. degrees in chemistry from the University of Illinois in 1952 and 1954 respectively.

Dr. Busch lives in Lawrence, Kansas.

### **Thure E. Cerling, Ph.D.**

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

Dr. Cerling is Distinguished Professor of Geology and Geophysics and Distinguished Professor of Biology at the University of Utah. He brings to the Board expertise in terrestrial geochemistry. His research interests are in the study of geochemistry processes occurring 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, the California Institute of Technology, and at the University of Cape Town in South Africa.

Dr. Cerling has served on numerous boards, panels, and committees, including the National Research Council–National Academy of Sciences Board of 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.

## **David J. Duquette, Ph.D.**

Dr. David J. Duquette was appointed to the U.S. 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 metallurgical honorary society, and has received an Outstanding Paper Award from *Acta Metallurgica*. 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 5 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.

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## George M. Hornberger, Ph.D.

Dr. George M. Hornberger was appointed to the U.S. Nuclear Waste Technical Review Board on September 10, 2004, by President George W. Bush.

Dr. Hornberger is Ernest H. Ern Professor of Environmental Sciences in the Department of Environmental Sciences at the University of Virginia.

Dr. Hornberger's work in catchment hydrology and hydrochemistry has centered on the coupling of field observations with mathematical modeling. The focus has been to understand how water is routed through soil and rock to streams and how hydrological processes and geochemical processes combine to produce observed stream dynamics. The modeling work allows the extension of work on individual catchments to regional scales. Dr. Hornberger's work in transport of colloids in geological media involves the processes affecting transport of inorganic colloids and biocolloids (e.g., bacteria) through porous media.

Dr. Hornberger's honors and awards include Virginia Chapter of Sigma Xi President's and Visitor's Prize (1986); Robert E. Horton Award, Hydrology Section, American Geophysical Union (1993); Fellow, American Geophysical Union (1994); Biennial Medal for Natural Systems, Modeling, and Simulation, Society of Australia (1995); John Wesley Powell Award for Citizens' Achievement, U.S. Geological Survey (1995); Fellow, Association for Women in Science (1996); member of the National Academy of Engineering (February 1996); Excellence in Geophysical Education Award, American Geophysical Union (1999); Langbein Lecturer, American Geophysical Union (2002); and Fellow, Geological Society of America (2005).

He has chaired the Board on Earth Sciences and Resources of the National Research Council (2003 to present); the Publications Committee of the American Geophysical Union (2000 to 2004); the National Research Council Commission on Geosciences, Environment, and Resources (1996 to 2000); the Advisory Committee on Nuclear Waste, Nuclear Regulatory Commission (2001 to 2003); the Board of Journal Editors, American Geophysical Union (1998 to 2000); the Committee to Prepare a Science Plan for a Water-Cycle Initiative (1999 to 2000); and the National Research Council Committee on the Review of EarthScope Science Objectives and Implementation Planning (2001).

Dr. Hornberger was associate editor of *Water Resources Research* from 1982 to 1984, North American editor of *Journal of Hydrological Processes* from 1985 to 1992, and editor of *Water Resources Research* from 1993 to 1997.

He received a bachelor's degree in civil engineering from Drexel University in 1965, a master's degree in civil engineering (hydrology) from Drexel in 1967, and a Ph.D. in hydrology from Stanford University in 1970.

Dr. Hornberger lives in Charlottesville, Virginia.

### **Andrew C. Kadak, Ph.D.**

Dr. Andrew C. Kadak was appointed to the U.S. Nuclear Waste Technical Review Board on September 10, 2004, by President George W. Bush.

Dr. Kadak is Professor of the Practice in the Nuclear Science and Engineering Department at the Massachusetts Institute of Technology (MIT). His research interests include the development of advanced reactors, in particular the high-temperature pebble-bed gas reactor, space nuclear power systems, improved technology-neutral licensing standards for advanced reactors, and operation and management issues of existing nuclear power plants. Dr. Kadak also serves as a member of the MIT undergraduate committee working on curriculum development and recruitment. He is president of Kadak Associates, a consulting firm specializing in management, organizational, and communication strategies for the nuclear industry.

Before joining the faculty of MIT, Dr. Kadak worked for Yankee Atomic Electric Company. He held various positions there from 1979 to 1987, including president and chief executive officer. From 1975 to 1979, Dr. Kadak was manager of nuclear information at New England Power Company. He was principal physicist for pressurized-water reactor physics at Combustion Engineering Corporation from 1972 to 1975.

Dr. Kadak was president of the American Nuclear Society from 1999 to 2000. He has served as a board and executive committee member of the Nuclear Energy Institute and the industry's Advisory Committee on High-Level Waste. He also has served as a member of the National Association of Regulatory Utility Commissioners special panel on high-level nuclear waste and the Aspen Institute's Dialogue on Nuclear Waste Disposal.

In 1995, Dr. Kadak was a member of the Advisory Committee on External Regulation of DOE Nuclear Safety for the U.S. Department of Energy. He also has conducted several audits of nuclear companies to assess their management practices and has served as chairman of a panel related to the DOE's Nevada Test Site. Dr. Kadak has presented more than 50 lectures and speeches on topics related to the technical and business aspects of nuclear power.

Dr. Kadak earned a bachelor's degree in mechanical engineering from Union College in 1967, a master's degree in nuclear engineering from the Massachusetts Institute of Technology in 1970, a Ph.D. in nuclear engineering from MIT in 1972, and an MBA from Northeastern University in 1983.

Dr. Kadak lives in Barrington, Rhode Island.

**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, 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 2004 Henry B. Linford Award from the Electrochemical Society; the 2001 T.P. Hoar Award from the British Institute of Corrosion, 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 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 was a member of the National Materials Advisory Board of the National Research Council.

Dr. Latanision lives in Winchester, Massachusetts.

### **Ali Mosleh, Ph.D.**

Dr. Ali Mosleh was appointed to the U.S. Nuclear Waste Technical Review Board on September 10, 2004, by President George W. Bush.

Dr. Mosleh is Nicole J. Kim Professor of Engineering, director of the Reliability Engineering Program, and director of the Center for Risk and Reliability at the University of Maryland. He conducts research on methods for probabilistic risk analysis (PRA) and reliability of complex systems, and he has made many contributions to diverse fields of theory and application. They include Bayesian methods for inference with uncertain evidence; analysis of data and expert judgment; treatment of model uncertainty; risk and reliability of hybrid systems of hardware, human, and software programs; methods and tools for dynamic PRA; cognitive models for human reliability analysis; and models of the influence of organizational factors on system safety.

Dr. Mosleh is the developer of the Accident Precursor Analysis methodology and many of the methods currently used for treating of common-cause failures in highly reliable systems. On these topics, he holds several patents and has edited, authored, or co-authored more than 250 publications. Dr. Mosleh has led numerous projects on risk, safety, and security assessments for the aerospace, nuclear, chemical, and information systems and telecommunication industries. He also led the design and development of more than 10 major risk and reliability analysis software programs currently used by various government agencies and the private sector.

Dr. Mosleh is a Fellow of the Society for Risk Analysis (SRA), and the recipient of several scientific achievement awards. He has been a consultant and a technical advisor to many national and international organizations on risk assessment and management. He has chaired or organized numerous international technical conferences on risk and reliability.

Dr. Mosleh received his Ph.D. in Nuclear Science and Engineering from the University of California, Los Angeles, in 1981.

He lives in Columbia, Maryland.



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## Henry Petroski, Ph.D., P.E.

Dr. Henry Petroski was appointed to the U.S. Technical Review Board on September 10, 2004, by President George W. Bush.

Dr. Petroski is Aleksandar S. Vesic Professor of Civil Engineering and a professor of history at Duke University. His research focuses on the interrelationship between success and failure in engineering design. He also has a strong interest in the nature of invention, as well as in the history and evolution of technology. Before joining the faculty of Duke University in 1980, he taught at the University of Illinois and the University of Texas at Austin and was a group leader at Argonne National Laboratory, where he was responsible for research and development in fracture mechanics.

Among the honors that Dr. Petroski has received are a Guggenheim Fellowship (1990–1991); honorary degrees from Clarkson University (1990), Trinity College (1997), Valparaiso University (1999), and Manhattan College (2003); the Ralph Coates Roe Medal from the American Society of Mechanical Engineers (1991); the Civil Engineering History and Heritage Award from the American Society of Civil Engineers (1993); and the Washington Award from the Western Society of Engineers (2006). He has received the Centennial Award as an Outstanding Engineering Graduate of Manhattan College (1992) and the Alumni Award for Distinguished Service from the College of Engineering of the University of Illinois at Urbana-Champaign (1994). Dr. Petroski is an honorary member of The Moles, is a fellow of the American Society of Civil Engineers, the Institution of Engineers of Ireland, the American Academy of Arts and Sciences and is a member of the National Academy of Engineering.

Dr. Petroski is the author of the book *To Engineer Is Human: the Role of Failure in Successful Design* (1985) and is the writer and presenter of the 1987 BBC television documentary “To Engineer is Human,” which has been broadcast on PBS. Among his other books are: *The Pencil: A History of Design and Circumstance* (1990); *The Evolution of Useful Things* (1992); *Design Paradigms: Case Histories of Error and Judgment in Engineering* (1994); *Engineers of Dreams: Great Bridge Builders and The Spanning of America* (1995), *Invention by Design: How Engineers Get from Thought to Thing* (1996); *Remaking the World: Adventures in Engineering* (1997); *Small Things Considered: Why There Is No Perfect Design* (2003); *Pushing the Limits: New Adventures in Engineering* (2004); and *Success through Failure: The Paradox of Design* (2006). Dr. Petroski also writes the engineering column for *American Scientist*, which is published by Sigma Xi, the scientific research society, and a column on the profession for *Prism*, the magazine of the American Society for Engineering Education. He has published more than 75 refereed journal articles in such publications as *International Journal of Fracture*, *Engineering Fracture Mechanics*, *Journal of Applied Mechanics*, and *Research in Engineering Design*.

Dr. Petroski received a bachelor’s degree in mechanical engineering from Manhattan College in 1963 and a Ph.D. in theoretical and applied mechanics from the University of Illinois at Urbana-Champaign in 1968. He is a professional engineer registered in Texas and a chartered engineer registered in Ireland.

Dr. Petroski lives in Durham, North Carolina.



## Appendix B

# Meeting List

- February 9–10, 2005**      **Winter Board Meeting**  
*Las Vegas, Nevada, and Caliente, Nevada*  
Topics:
- Systems integration
  - Scientific studies
  - Transportation
- November 8–9, 2005**      **Fall Board Meeting**  
*Las Vegas, Nevada*  
Topic:
- Scientific updates
- February 1, 2006**      **Spring Board Meeting**  
*Las Vegas, Nevada*  
Topic:
- Processes Affecting Radionuclide Transport



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## Appendix C

# Panel Organization

### Panel on the Natural System

Chair: George M. Hornberger  
Members: Thure E. Cerling

Staff: David Diodato\*  
John H. Pye  
Leon Reiter

### Panel on the Engineered System

Chair: Ronald M. Latanision  
Members: Wm. Howard Arnold  
David J. Duquette  
Henry Petroski

Staff: Carlos A. W. Di Bella\*  
John H. Pye  
Karyn D. Severson

### Panel on Repository System Performance and Integration

Chair: Ali Mosleh  
Members: Mark D. Abkowitz  
Ronald M. Latanision  
Thure E. Cerling  
Henry Petroski

Staff: Leon Reiter\*  
David M. Diodato  
Daniel S. Metlay  
John H. Pye

### Panel on the Waste Management System

Chair: Mark D. Abkowitz  
Members: Wm. Howard Arnold  
David J. Duquette  
Andrew C. Kadak

Staff: Daniel J. Fehring\*  
Carlos A. W. Di Bella  
Daniel S. Metlay  
Karyn D. Severson

\*Staff Coordinator



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## 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](http://www.nwtrb.gov).

*Letter report to Congress and the Secretary of Energy. December 2005.*

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

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

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

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

This letter and enclosure comprise the Board's second report to Congress and the Secretary of

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

*Report to the U.S. Congress and the Secretary of Energy. May 2004.*

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

*Report to the U.S. 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.***

This report contains information supporting the conclusions that the Board presented in its October 21, 2003, letter to the DOE concerning the potential for localized corrosion of waste packages during the thermal pulse.

***Report to the U.S. Congress and the Secretary of Energy. April 2003.***

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

***Report to the U.S. 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.

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

This letter report constitutes the Board's second report to Congress and the Secretary of Energy for calendar year 2001. The report summarizes the Board's evaluation of the DOE's technical

and scientific investigation of the Yucca Mountain site during the year.

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

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

***Report to the U.S. 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.



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***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.

***Report to the U.S. Congress and the Secretary of Energy: 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. 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 2 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. 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, repository construction schedules, and alternative approaches to licensing. Appendix F provides background on the Finnish and Swiss programs.

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***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

# U.S. Nuclear Waste Technical Review Board Correspondence with 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 three 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 is the OCRWM's response that was received by the Board during calendar year 2005. Inclusion of these responses does not imply the Board's concurrence.

- Letter from B. John Garrick to Theodore Garrish, Deputy Director, OCRWM; April 19, 2005.  
Subject: DOE's participation at the February Board meeting
- Letter from Paul M. Golan, Director, OCRWM, to B. John Garrick; December 14, 2005.  
Subject: DOE's responses to recommendations in the July 28, 2004 letter
- Letter from B. John Garrick to Paul M. Golan, Director, OCRWM; December 19, 2005.  
Subject: DOE's participation at the November Board meeting
- Letter from B. John Garrick to Paul M. Golan, Director, OCRWM; March 6, 2006.  
Subject: DOE's participation at the February Board meeting







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

April 19, 2005

Mr. Theodore Garrish  
Deputy Director  
Office of Civilian Radioactive Waste Management  
U.S. Department of Energy  
1000 Independence Avenue, SW  
Washington, DC 20585

Dear Mr. Garrish:

On behalf of the Nuclear Waste Technical Review Board, I thank you and your staff for participating in the Board's meetings on February 9, 2005, in Las Vegas and February 10, 2005, in Caliente, Nevada. The Board's comments on these meetings are summarized below.

**Total System Performance Assessment (TSPA).** Current TSPA calculations are based on a standard with a regulatory period of 10,000 years. However, the July 9, 2004, decision of the U.S. Court of Appeals for the District of Columbia Circuit, which remanded to the U.S. Environmental Protection Agency its Yucca Mountain repository standard, could result in a longer regulatory period. If the regulatory period is extended, the program could encounter technical challenges, including a need to address in TSPA relevant hydrogeologic and climatic processes that may be significant beyond 10,000 years. The Board requests that the DOE provide descriptions of technical and scientific elements of TSPA that might change if the standard is modified.

**Program Integration.** Program integration is of continuing Board interest and could potentially affect elements of the DOE's safety case. The Board endorses the DOE's use of a total system model (TSM) for planning and integrating various elements of the waste-management system. We look forward to learning more about TSM model components, structure, output metrics, underlying assumptions, and event uncertainties (e.g., weather events that may cause significant delays).

The design of surface facilities at Yucca Mountain should be an integrated part of the total waste-management system. The Board is concerned that assumptions related to receipt of spent fuel from utilities and the DOE's thermal-management strategy could result in excessive handling of spent-fuel assemblies as fuel is blended and aged before disposal. The Board believes that the DOE needs to evaluate and compare pre- and post-closure human exposure to radiation.

Specifically, the Board recommends that the DOE evaluate the costs and benefits of using dual-purpose (transportation and storage) or multipurpose (transportation, storage, and disposal) casks for transporting, storing, and disposing of spent fuel at Yucca Mountain. The use of such casks has the potential to limit the number of times that spent-fuel assemblies must be handled and, thus, the risks and radiation exposures associated with such handling. The Board also believes that

increasing communication with utilities, the railroad industry, and affected parties could improve planning for developing the waste-management system.

The DOE's focus on a mostly-rail scenario and the planned construction of a branch rail line to Yucca Mountain appear to have constrained planning for truck and intermodal transportation. Delays in the availability of a rail line to Yucca Mountain or the potential that such a line might not be built could result in a significantly larger number of truck shipments than currently anticipated throughout the system or could require intermodal shipments. Provisions for dealing with these scenarios, including cask design, cask availability, rolling stock, use of overweight shipments, and plans for loading and unloading, need to be considered explicitly in transportation planning.

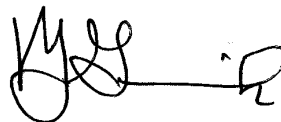
The Board believes that many activities identified in the performance-confirmation program can provide valuable information for validating modeling assumptions that form the basis of the TSPA. For example, hydraulic testing of major block-bounding faults can enhance the technical basis of the analyses supporting the license application. However, the performance-confirmation program appears to be operating independently of TSPA and of the ongoing work on repository design.

The types and structures of organizations that will design, build, and operate a repository at Yucca Mountain and the associated transportation system need to be considered. The qualifications of the participants and the need for interactions among participants, if multiple organizations are involved, could affect both the safety and the efficiency of the overall system. The Board would like to receive a draft of the DOE's implementation plans for construction, management, and operation of the repository and transportation systems.

**Science and Modeling Update.** The science and modeling update was very worthwhile. For example, the DOE presented state-of-the-art age dating of opal mineral deposits as evidence that seepage rates are unaffected by climate change. Although the large changes in the rate of growth of those minerals may have occurred hundreds of thousands of years ago and are poorly understood at present, ultimately they may provide important clues to the understanding of flow in the unsaturated zone at Yucca Mountain. Other laboratory experiments show that some oxides of neptunium may have low solubilities under a range of environmental conditions. Furthermore, the DOE cited recent reports that neptunium may be incorporated into minerals that can be stable for very long periods. Finally, DOE findings that mixtures of certain salts can raise the temperature limit for deliquescence above 160°C indicate that progress has been made in improving fundamental understanding of the conditions that could produce deliquescence. These examples illustrate the importance of a sustained science program in enhancing confidence in repository performance analyses.

Thank you again for the DOE's support of this meeting.

Sincerely,



B. John Garrick  
Chairman



## Department of Energy

Washington, DC 20585

QA: N/A

December 14, 2005

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

Dear Dr. Garrick:

Thank you for your April 19, 2005, letter providing the Nuclear Waste Technical Review Board's (Board) response to the information presented by the U.S. Department of Energy (Department) at the Board's meetings on February 9, 2005, in Las Vegas, Nevada, and on February 10, 2005, in Caliente, Nevada. I apologize for the lateness of this response.

In your letter, you asked what changes might be made in the Department's Total System Performance Assessment (TSPA) as a result of modifications to the U.S. Environmental Protection Agency (EPA) standard. As you know, on August 22, 2005, the EPA published a proposed rule to revise the "Public Health and Environmental Radiation Protection Standards for Yucca Mountain." Subsequently, on September 8, 2005, the U.S. Nuclear Regulatory Commission (NRC) published its proposed changes to its regulation, 10 CFR Part 63, "Disposal of High-Level Radioactive Wastes in a Geological Repository at Yucca Mountain, Nevada," to ensure its consistency with the EPA proposal. The Department's path forward for the TSPA will be guided by the outcome of the EPA and NRC rulemakings. Under the proposed changes, the Department's 10,000-year calculation would be extended to time of peak dose within the period of geologic stability (up to one million years) with treatment of seismic, volcanic, and climate scenarios specified.

Features, events, and processes that pertain to the effects of seismic activity on the Yucca Mountain repository natural barrier system to date have been excluded over the 10,000-year period based on low consequence. The justifications for excluding these features, events, and processes for 10,000 years are also applicable to the period beyond 10,000 years because they are not time dependent. Therefore, the Department would not plan to consider the effects of seismic activity beyond those that result in damage to the engineered barrier system. The consequences of seismic activity, properly weighted by probability of occurrence, likely will not have a significant effect on the peak median annual dose. Current analyses indicate that the magnitude and timing of the peak median annual dose depends much more on the degradation of the engineered barriers, primarily the waste package, through general corrosion.

Dike intrusion and volcanic eruption events may occur, and their consequences, properly weighted by probability, should be assessed in an evaluation of repository performance. Current analyses indicate that the mean annual probability of an igneous dike intrusion event is  $1.7 \times 10^{-8}$  per year, which is slightly higher than the  $10^{-8}$  per year regulatory limit. The probability of an

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eruption in the case where a dike intersects the repository is about 0.8. Sensitivity analyses indicate that an igneous intrusion could potentially affect repository performance over a one million-year period. However, these analyses indicate that the weighted consequences of igneous intrusion likely will not have a significant effect on the peak median annual dose. These analyses indicate that the magnitude and timing of the peak annual dose depends much more on the degradation of the engineered barriers, primarily the waste package, through general corrosion. Analyses also indicate that the greatest risk due to a volcanic eruption will occur within the first 10,000 years. The inventory of radionuclides that dominate the risk from a volcanic eruption decay significantly within and beyond the 10,000-year period following repository closure.

Analyses of past climate conditions in the Yucca Mountain area indicate that climatic conditions will change over the period of geologic stability; however, it is not possible to know or predict with certainty precisely when the climate states with peak precipitation will occur. Further, there are too many uncertainties and permutations available in trying to project a future set of climate conditions, and it is difficult to identify specific times when discrete pulses of precipitation should be included in the modeling. The Department expects to use a long-term average climate infiltration rate to address this, as specified in the proposed rules.

With regard to your comments on program integration, the Department is considering different design concepts that will allow receipt of waste as well as concepts that will streamline the handling of waste through the overall process of transportation, aging, and disposal and will keep the Board informed as these concepts mature.

The Department decided last year to proceed with planning for “mostly rail” shipments based on a Final Environmental Impact Study that considered various modes of transportation, including single mode and combined modes. Therefore, we have not undertaken any additional work on an intermodal facility. The Department does recognize, however, that even under the mostly rail scenario, a few reactor plants will be unable to accommodate rail shipments and that there will need to be truck shipments using legal weight and over weight trucks. The Department does not plan to use heavy haul truck shipments to the repository, although heavy haul shipments from reactor sites to a railhead will be considered.

The intent of the Performance Confirmation (PC) Program is to confirm the performance of the barriers and total system as documented in the TSPA for the license application; the PC Program is documented in the PC Plan. The cognizant performance assessment analysts have reviewed the current suite of activities in the PC Program to verify that the Program is focused on processes that are important to performance. Following the completion of the TSPA for the license application and associated supporting documents, additional analyses will be performed to develop parameter selection and/or recommend new PC activities such that the PC Program is contemporary with the information used to support the license application.

The Department will provide the Board with copies of any implementation plans for construction, management, and operation of the repository and transportation systems as they are developed.

The Department continues to benefit from the constructive views of the Board, and we look forward to further dialog on the repository and related issues.

Sincerely,



Paul M. Golan  
Principal Deputy Director  
Office of Civilian Radioactive  
Waste Management





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

December 19, 2005

Mr. Paul M. Golan  
Acting Director  
Office of Civilian Radioactive Waste Management  
U.S. Department of Energy  
1000 Independence Avenue, SW  
Washington, DC 20585

Dear Mr. Golan:

On behalf of the Nuclear Waste Technical Review Board, I thank the Department of Energy (DOE) staff and contractors who participated in the Board's fall meeting on November 8-9, 2005, in Las Vegas, Nevada. The Board welcomed the opportunity to review technical and scientific issues currently important to the Yucca Mountain program. Furthermore, the members were pleased with the increased technical content of the presentations, which allowed the Board to explore many important issues more fully. The Board has organized the following comments in the order that the issues were discussed at the meeting.

***Program Overview***

The DOE has announced significant changes in the Yucca Mountain program that are intended to emphasize safety and reliability and to reduce the complexity of the surface facility design and waste handling operations. The most notable change is the decision to evaluate the development of the transportation, aging, and disposal (TAD) canister system. The Board believes that this system has the potential to address the Board's previously stated concerns related to excessive fuel handling (Board letter to Theodore Garrish, April 19, 2005). However, because nuclear utilities would be responsible for loading spent fuel into the TAD canisters at their power plants, selecting the "right" standard canisters for the TAD will require close cooperation and coordination between the DOE and the utilities. To ensure total system integration, the DOE should determine first-hand the compatibility of possible TAD designs with the capabilities for storage, handling, and transportation available at each reactor site.

The success of the TAD canister system also will depend on integration of the TAD concept into a waste management system that effectively balances preclosure safety and long-term repository performance and that is based on a viable and clearly defined thermal-management strategy. Such a strategy should establish the technical basis for waste acceptance, transportation, waste handling, and emplacement of waste. Thermal criteria should result in waste handling and facility operations that are safe, flexible, reliable, and simple. In addition, key goals of a thermal-management strategy should be to enhance understanding of post-closure near-field and in-drift conditions and to ensure that these conditions do not affect adversely the long-term performance of both the natural- and engineered-barrier systems. Because of the importance of the thermal-management strategy for the entire waste management system, a

group of outside experts should review the strategy periodically during its development, just as experts have reviewed the DOE's Total System Performance Assessment (TSPA).

### *Science Update*

As usual, the Board found the science update particularly helpful; it is apparent that progress has been made since our last meeting. It seemed clear from the presentation that many large-scale, long-term tests are about to be concluded. The Board believes that much can be learned from post-test characterization, including a better understanding of some of the anomalies that have occurred and refinement in the current interpretation of test results. For example, data from the Drift-Scale Test should be used to evaluate near-field thermal-chemical-hydrologic effects. Similarly, other tests conducted behind the bulkheads in the Enhanced Characterization of the Repository Block drift and in infiltration-testing alcoves also have the potential to provide important supplemental information. It is important to complete and fully assess post-test characterization.

The Board continues to support testing in the unsaturated and saturated zones at Yucca Mountain to understand better the contribution of the natural system to repository performance. Understanding of the natural barriers at Yucca Mountain, especially over geologic time, can be increased with studies of natural analogs. For example, the Peña Blanca analog site continues to provide highly relevant data related to radionuclide migration and retention processes at Yucca Mountain. The Board encourages the DOE to continue the studies at the Peña Blanca site.

Thermal conductivity of the rock at Yucca Mountain is of fundamental importance in predicting thermohydrologic conditions in the proposed repository and the tunnel conditions that waste packages will encounter. Uncertainty in thermohydrologic conditions, especially during the thermal pulse, arises in part from the scarcity of *in situ* measurements of thermal conductivity over the range of predicted repository temperatures in the lower lithophysal rocks of the repository horizon. More thermal conductivity data collected in the repository rocks under predicted repository conditions can help reduce thermohydrologic uncertainty and thus improve predictions of long-term repository performance.

Fundamental understanding of the nature of the source term—including spent fuel oxidation, dissolution, and transport—is very important for predicting repository performance. The DOE presented experimental data on spent fuel alteration where Np-U co-precipitation did not occur. Those data suggest that Np transport may not be significantly delayed by co-precipitation. Furthermore, drip-test data show Np concentrations that are not necessarily at Np solubility limits, and thus do not strongly support the assertion that the Np solubility curves used in TSPA are conservative. Continued efforts to achieve greater understanding of the source term are important, and the Board is gratified to see this area emphasized in the portfolio of studies sponsored by the Office of Science & Technology and International.

Conspicuous by its absence was a status report on DOE efforts to determine the source of discrepancies among CI-36 studies. Inconsistencies in past DOE studies of CI-36 in Yucca Mountain create questions about the technical basis of model predictions of water flow and radionuclide transport. The Board looks forward to an update on DOE efforts to address these discrepancies and the possible presence of fast flow paths in the unsaturated zone.



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### ***Drip-Shield Design***

The DOE provided a comprehensive briefing in response to Board questions about the metals selected for drip-shield fabrication and the potential degradation of the drip shield as a result of corrosion. The Board will evaluate the substantial volume of information on drip-shield configuration, drip-shield emplacement, possible deformation—due to creep—of the drip-shield material under load, and environmental and mechanical degradation. The Board notes that a subsequent presentation by the State of Nevada raised issues about restrictive in-drift operational envelopes and installation tolerances that could potentially increase the difficulty of installing the drip shields remotely.

Because drip shields will not be installed until just before repository closure, which will be many years after waste emplacement, the DOE should evaluate now what factors will affect the final design of the drip shield and explain how, when, and by whom decisions about drip shield emplacement will be made.

### ***Localized Corrosion of the Waste Package***

The Board has continuing concerns about the DOE's technical basis for screening out deliquescence-based localized corrosion of the waste package's Alloy 22 outer barrier from Total System Performance Assessment for License Application (TSPA-LA). The Board is especially concerned about the potential for localized corrosion in deliquescent brines formed between 160°C - 220°C from airborne dust that will be deposited on the surface of the waste packages. Although the most recent corrosion data at these temperatures were alluded to, they were not presented or discussed at the meeting. The Board wants to evaluate the significance of the new data and looks forward to receiving them from the DOE as soon as possible.

The Board believes that evidence presented at the meeting supporting the screening out of deliquescence-based localized corrosion from TSPA-LA was not compelling, primarily for two reasons: First, no corrosion data were presented for temperatures above 150°C. Second, data showing stifling of localized corrosion at considerably lower temperatures may or may not be relevant to all conditions under which localized corrosion could occur in the proposed repository. The Board is assessing further the significance of the information presented by the DOE and expects to hold a corrosion workshop to discuss these important issues.

### ***Total System Model (TSM)***

The Board believes that the TSM has significant potential as a tool for understanding better the performance of the waste management system. However, it is very important to the success of the model that it incorporates the most up-to-date information (e.g., the availability of spent fuel and on-site waste handling equipment) and that the quality of all input data and assumptions is confirmed. For this reason, the Board recommended earlier in this letter that the DOE determine first-hand the compatibility of possible TAD canister designs with the storage, handling, and transportation capabilities available at the power plants. The Board also

recognizes the potential of the TSM as a valuable tool in preparing the preclosure safety analysis and in addressing important issues related to movement of spent fuel through the waste management system.

The Board would like to understand fully the capabilities and limitations of the TSM in conducting probabilistic assessments, optimizing the waste management system, and analyzing “what if” operational scenarios (e.g., how the waste management system would operate under normal, marginally normal, and off-normal conditions). In addition, the Board would like to know the role that the TSM played in the decision to pursue the TAD canister concept, in particular, the implications of the TAD system for dose, thermal management, and waste handling. We look forward to hearing from the DOE about insights that have been gained as a result of TAD-related studies and analyses.

### ***Conservatism in TSPA-LA***

The DOE believes that uncertainties related to TSPA-LA have been addressed using multiple conservatisms and a “cautious but reasonable” approach. However, the DOE does not seem to know the extent to which TSPA-LA is conservative overall. The Board believes that levels of conservatism associated with different components of TSPA-LA vary significantly and that TSPA-LA is, in general, unrealistic. The use of multiple conservatisms (and some non-conservatisms) may mask effects and obscure fundamental understanding of how the engineered and natural barriers would work together as a system to isolate waste. As a result, important constituencies (i.e., the public, the scientific community, and policy-makers) are deprived of meaningful information on which to base their opinions and judgments. The DOE’s contention that conducting sensitivity analyses of TSPA-LA would enhance system understanding has limited validity, in the Board’s view, because the effects of parameter and model changes related to one component of the system or subsystem may be masked by assumptions about other components of the system or subsystem.

The Board believes that in addition to its compliance case, the DOE should develop in parallel a realistic analysis of repository performance based on the assessments by project scientists of how the repository would behave. Such an analysis would be invaluable for fundamental understanding, for informing key constituencies, and for building confidence in the DOE’s estimates of repository performance.

Thank you again for the DOE’s support of this meeting.

Sincerely,

{Signed By}

B. John Garrick  
Chairman



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

March 6, 2006

Mr. Paul M. Golan □  
Acting Director □  
Office of Civilian Radioactive Waste Management □  
U.S. Department of Energy □  
1000 Independence Avenue, SW □  
Washington, DC 20585 □

Dear Mr. Golan:

On behalf of the Nuclear Waste Technical Review Board, I thank the Department of Energy (DOE) staff and contractors who participated in the Board's meeting on February 1, 2006, in Las Vegas, Nevada. The Board welcomed the opportunity to review technical and scientific issues important to the Yucca Mountain program.

At the meeting, Russell Dyer presented a new organization chart of the Office of Civilian Radioactive Waste Management showing program activities divided into science, engineering, transportation, operations, licensing, and eight other areas, all reporting to the Office of the Director. Because the Board is charged with ongoing review of all DOE scientific and technical activities in support of the proposed Yucca Mountain repository, not only the science program, the Board looks forward to future interaction with DOE at all program and program management levels. The Board is particularly interested in how a new organization that has all functions reporting directly to the Director will affect the technical direction and quality of the program.

In response to the technical presentations, the Board recommends that the DOE prepare full and realistic process models that account for the transport of neptunium-237 ( $^{237}\text{Np}$ ) and plutonium-242 ( $^{242}\text{Pu}$ ) from the engineered barrier system (EBS) to the biosphere over a million years, the period during which peak dose is predicted to occur. There is considerable evidence that these radionuclides are major contributors to peak dose. At the meeting, the DOE presented its current understanding of the modes of  $^{237}\text{Np}$  transport from spent fuel, an understanding that has evolved as a result of a decade of research. The presentation highlighted the limited understanding in this area and showed the importance of continuing current research, especially relating to radionuclide source term exiting the EBS as a function of time. Of continuing and particular interest to the Board are the forms of  $^{237}\text{Np}$  and  $^{242}\text{Pu}$  exiting the EBS. The presentations by the Nuclear Regulatory Commission (NRC), including the chairman of the NRC Advisory Committee on Nuclear Waste, highlighted the sensitivity of dose results to different models: for example, different assumptions on the partitioning of the dose between inhalation and ingestion. The Board continues to have an interest in a realistic dose assessment to serve as a reference point in discussions of conservatism and whether such differences in modeling as noted are rooted in simplifying assumptions that may or may not be conservative.

The Board is concerned that the methods used by the DOE in its Total System Performance Assessment (TSPA) do not properly represent the natural correlations of some specific parameters. For example, TSPA allows for combinations of physical parameters that produce extreme travel-times (a decade or less and hundreds of thousands of years) that are not considered technically credible. Another example is that peak-dose sensitivity analyses indicate that seepage of water into the drifts is significant to dose but that percolation of the water that produces the seepage is not a significant parameter—a decoupling not well explained. Improved treatment of parameter correlations can enhance the technical credibility of TSPA.

Finally, because the Board is focused on repository performance to peak dose and the DOE continues primarily to emphasize a 10,000-year compliance period, the Board is not getting the information it needs to evaluate the overall performance analysis of the repository. The Board strongly recommends that the DOE adopt a more risk-informed analysis—that is, a more realistic analysis—of the repository over a period that clearly includes the peak dose at the accessible environment.

We look forward to future meetings in which the DOE is prepared to address these issues in a focused manner.

Sincerely,

{Signed By}

B. John Garrick  
Chairman

## Appendix F

# Other Board Communications

- Letter from B. John Garrick to Robert R. Loux, Executive Director, Agency for Nuclear Projects, State of Nevada; February 18, 2005.  
Subject: Response to November 25, 2003, letter on potential criticality for waste packages.
- Statement of Chairman B. John Garrick before the Subcommittee on the Federal Workforce and Agency Organization, Committee on Government Reform, U.S. House of Representatives; April 5, 2005.
- Letter from Congressman Jon Porter, Chairman, Subcommittee on the Federal Workforce and Agency Organization, Committee on Government Reform, U.S. House of Representatives to B. John Garrick; April 14, 2005.  
Subject: Questions from the Subcommittee.
- Letter from B. John Garrick to Congressman Jon Porter, Chairman, Subcommittee on the Federal Workforce and Agency Organization, Committee on Government Reform, U.S. House of Representatives; April 29, 2005.  
Subject: Responses to questions posed in letter of April 14, 2005





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

February 18, 2005

Mr. Robert R. Loux  
Executive Director  
Agency for Nuclear Projects  
State of Nevada  
1761 E. College Parkway, Suite 118  
Carson City, NV 89706

Dear Mr. Loux:

This letter is in response to your November 25, 2003, letter to Dr. Michael L. Corradini on criticality. That letter was based primarily on an analysis by Dr. Michael C. Thorne, a consultant to the State of Nevada, of studies and documents produced in 1998 by U. S. Department of Energy (DOE) consultants and contractors. Those studies and documents were about the probability of the occurrence of internal criticalities in surface storage casks for a nominal case assuming the permanent loss of institutional control, and about the consequences of such criticalities.<sup>1</sup>

The likelihood and consequences of criticality, if it occurs, are recognized universally as important issues. The DOE has been studying such issues with respect to the disposal of spent nuclear fuel and high-level radioactive waste in a mined geologic repository, and the Board has been monitoring those DOE activities for well over a decade.

Analyses of potential criticality for waste packages emplaced in a repository should be based on representative assumptions about the packages and the conditions to which they would be exposed in a repository. There are significant differences between storage casks and emplaced waste packages that should be taken into account. The differences include the more corrosion-resistant material proposed for waste packages in the current design, the use of neutron-absorber plates or control rods in waste packages containing higher-reactivity spent fuel, and the use of drip shields over the emplaced waste packages. Such differences were not taken into account in the analysis underlying your November 25 letter.

In a recent report, the DOE concludes that the probability of internal criticality in a mined geologic repository for the nominal case during a 10,000-year regulatory compliance period is well below the threshold of regulatory significance.<sup>2</sup> We have reviewed this report and find that the conclusion drawn in the report is credible, given the credit for the integrity of the packages and the presence of the drip shields, which would prevent water from entering the packages, even with the assumption that 10 percent of the packages would fail over 10,000 years.

<sup>1</sup> An internal criticality is a self-sustaining nuclear reaction *inside* a storage cask (or waste package). A nominal case is a case that is not disrupted by seismic or igneous events.

<sup>2</sup> *Screening Analysis of Criticality Features, Events, and Processes for License Application*, ANL-EBS-NU-000008 REV 01, October 2004

The DOE's conclusion and our finding, however, generally are based on analysis that covers the first 10,000 years after repository closure.

Last year, the United States Court of Appeals for the District of Columbia Circuit rendered a decision vacating the Environmental Protection Agency standard and the corresponding Nuclear Regulatory Commission (NRC) rule to the extent that the standard and the rule incorporated a 10,000-year compliance period. Presumably, a revised standard and a corresponding rule will be promulgated to reflect the court's decision. Any significant change in the standard and its corresponding rule regarding the regulatory compliance period or the definition of the threshold of regulatory significance will necessitate reexamining repository criticality issues.

The Board's mission is to evaluate the technical and scientific validity of DOE activities related to the Nuclear Waste Policy Act, including the packaging, transportation, and disposal of high-level radioactive waste and spent nuclear fuel. Criticality clearly is an important issue related to those activities. The Board has reported on criticality issues in the past and will continue to monitor ongoing developments and activities of the DOE's Office of Civilian Radioactive Waste Management related to criticality. Thus, we appreciate your letter of November 25 and the material that was enclosed with it.

Thank you for your interest in the Board.

Sincerely,

A handwritten signature in black ink, appearing to read 'B. John Garrick', with a horizontal line extending to the right.

B. John Garrick  
Chairman

cc:

Dr. Margaret S. Y. Chu, DOE  
Dr. C. William Reamer, NRC

bjg019vf



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**Statement of  
Dr. B. John Garrick, Chairman  
U.S. Nuclear Waste Technical Review Board  
Before the  
Subcommittee on the Federal Workforce and Agency Organization  
Committee on Government Reform  
U.S. House of Representatives  
April 5, 2005**

Good morning, Mr. Chairman and members of the subcommittee. I am John Garrick, Chairman of the U.S. Nuclear Waste Technical Review Board. All eleven members of the Board are appointed by the President and serve on a part-time basis. In my case, I am a private consultant specializing in the application of the risk sciences to complex technological systems in the space, defense, chemical, marine, and nuclear fields.

As you know, Mr. Chairman, the Board was created by Congress in the Nuclear Waste Policy Amendments Act of 1987 to perform an ongoing independent evaluation of the technical and scientific validity of the Department of Energy's (DOE) efforts in implementing the Nuclear Waste Policy Act. The Board began its work in 1989 and has continuously reviewed the technical and scientific validity of DOE activities since that time. I am pleased to represent the Board at this hearing.

According to the letter inviting the Board to participate, today's hearing has two purposes. The first purpose is to question whether federal employees falsified documents related to work at the Yucca Mountain site. The second purpose identified in the letter is to examine whether sound science exists for the proposed project, in light of the allegations.

Mr. Chairman, it would be inappropriate for the Board to draw any conclusions at this time about the significance for the technical work at Yucca Mountain of the group of redacted e-mails that were posted on the subcommittee's web site on Friday afternoon. Answers to questions that might be raised by or about the e-mails should await the completion of comprehensive investigations already underway at the Departments of Energy and Interior. The Board will follow the progress of those investigations, and when they are concluded, the Board will evaluate the significance of the results for the DOE's technical and scientific work. We will then report our findings to Congress and the Secretary of Energy. In the meantime, the Board will continue its ongoing technical and scientific peer review of DOE activities. The Nuclear Regulatory Commission (NRC) is the appropriate agency to address questions about the effects on the regulatory process of possible infractions of quality assurance procedures.

As you know, Mr. Chairman, reporting to Congress and the Secretary at least twice a year is an important part of the Board's mandate. In accordance with that mandate, in late 2004, the Board sent to Congress and the Secretary a report summarizing areas of progress in the Yucca Mountain program; issues that, in the Board's view, require additional attention; and the Board's priorities for 2005. Since the second purpose of this hearing touches on technical and scientific validity, I will now summarize some of the Board's findings from that letter report.

The Board believes that over the last year or so, the DOE has made progress in several areas. For

example, a key corrosion issue raised by the Board was addressed by DOE data and analyses, indicating that tunnel conditions during the thermal pulse will likely not lead to the initiation of localized corrosion of the waste packages due to deliquescence of calcium chloride. The Board also is encouraged by DOE efforts related to making earthquake ground-motion estimates more realistic and in completing an aeromagnetic survey that could shed light on igneous activity in the Yucca Mountain area. In addition, the DOE has made headway in developing a systematic approach to planning for the transportation of spent nuclear fuel and high-level radioactive waste.

Other issues require continued or additional attention, including an improved understanding and a clear explanation of the likely conditions inside repository tunnels during the thermal pulse; other corrosion issues related to the postclosure environment of the repository; the resolution of discrepancies among chlorine-36 studies; and improvements in the modeling of volcanic consequences. The Board also will follow with interest the work undertaken by the science and technology program established by Dr. Margaret Chu.

In addition to reviewing these important issues, the Board is establishing priorities for its technical and scientific review as the DOE prepares the information necessary to submit a license application to the NRC. In identifying its priorities, the Board considers (1) if the issue is important to the safe performance of the repository, (2) if the issue is important to public confidence, and (3) if the Board has special expertise and experience, which provide new and relevant perspectives on technical issues. In particular, the Board intends to review the DOE's technical and scientific work and analysis supporting total system performance assessment (TSPA). The Board will evaluate the extent to which the DOE has used TSPA as an integrative tool and how well the assumptions underlying TSPA results are supported by technical analysis and available evidence. Other Board priorities include an improved understanding of the performance of the hydrogeologic barriers, particularly regarding the magnitude and timing of the peak dose; how the DOE's thermal-loading strategy might affect trade-offs between preclosure and postclosure risk; issues affecting the waste-package lifetime; and the DOE's continued efforts to develop an integrated waste management system, including the handling, transportation, packaging, and disposal of spent nuclear fuel and high-level radioactive waste. The Board is especially interested in scientific work and analyses that may be undertaken by the DOE in response to likely changes in the regulatory compliance period for a Yucca Mountain repository.

Mr. Chairman, let me close by saying that the Board looks forward to continuing its congressionally established role of performing an independent evaluation of the DOE's technical and scientific activities related to the disposal, packaging, and transportation of the country's spent nuclear fuel and high-level radioactive waste and reporting to Congress and the Secretary. We will be in a much better position to comment on the topics of this hearing once we have reviewed the findings of the comprehensive investigations that are currently underway.

Thank you for the opportunity to present the Board's views. I will be happy to respond to questions from the subcommittee.

TOM DAVIS, VIRGINIA,  
CHAIRMAN

CHRISTOPHER SHAYS, CONNECTICUT  
DAN BURTON, INDIANA  
ILEANA ROS-LEHTINEN, FLORIDA  
JOHN M. McHUGH, NEW YORK  
JOHN L. MICA, FLORIDA  
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CHARLES W. DENT, PENNSYLVANIA  
VIRGINIA FOXX, NORTH CAROLINA

ONE HUNDRED NINTH CONGRESS

## Congress of the United States House of Representatives

COMMITTEE ON GOVERNMENT REFORM

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April 14, 2005

HENRY A. WAXMAN, CALIFORNIA,  
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BERNARD SANDERS, VERMONT,  
INDEPENDENT

Honorable B. John Garrick  
Chairman  
Nuclear Waste Technical Review Board  
2300 Clarendon Boulevard  
Suite 1300  
Arlington, VA 22201

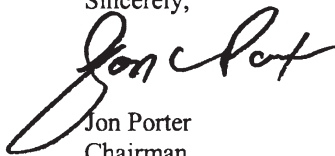
Dear Mr. Garrick:

Attached are the follow up questions to the hearing titled, "Yucca Mountain Project: Have Federal Employees Falsified Documents?" on Tuesday April 5, 2005. Please answer the attached questions, furnish any information that was requested during the hearing and return this **no later than Friday, April 29, 2005**. Please be certain to attach a cover sheet to your answers and include your name on each page of your responses.

Please return your responses no later than **Friday, April 29, 2005**, to Reid Voss, Subcommittee on Civil Service and Agency Organization, B-373A Rayburn House Office Building, Washington, D.C. 20515. Because of mail delays, we ask that you email responses to the questions for the record to [reid.voss@mail.house.gov](mailto:reid.voss@mail.house.gov) before the deadline above. Please mail all original documents as well. If you have any questions please call Reid Voss at 202-225-5147.

Thank you for your participation and cooperation.

Sincerely,



Jon Porter  
Chairman  
Subcommittee on the Federal Workforce  
and Agency Organization

**“Yucca Mountain Project: Have Federal Employees Falsified Documents?”  
Subcommittee on the Federal Workforce and Agency Organization  
Chairman Jon C. Porter  
Questions Submitted For The Record**

**Submitted April 8, 2005**

**John Garrick, U.S. Nuclear Waste Technical Review Board**

- If the allegations are proven true, what is the impact the “sound science” of the project?
- We know for certain that the e-mails in question were written during the time that DOE was rushing to prepare and submit a license application to the NRC. How many times has DOE asked for an extension in filing the license application and what reasons were given in support of an extension of time?
- Based upon DOE’s persistent quality assurance failures and in light of the recent controversy documenting employee falsification of scientific studies, what is the Board’s position regarding the current state of the scientific credibility of the project?
- Should the allegations be proven true, what is the board’s recommendation regarding the continuation of the project?
- It is my understanding that this past February (February 8, 2005) the Board called for hearings in March to review concerns over the corrosion of the titanium drip shields that are intended to keep water from leaking into casks inside Yucca Mountain. Have you held those hearings and, if so, what were your findings?
- Given the fact that DOE is self-regulated and can chose not to implement the recommendations of the Board, has there ever been a feeling among the Board that DOE uses its privilege to hide information?
- Based upon your review, has DOE come up with a plan for safely transporting nuclear waste to the proposed repository?
- To your knowledge, what has DOE done to study the transportation issues?
- If scientific studies concerning the hydrology and geology of Yucca Mountain were falsified, and if falsified reports were used as the basis for other work, how would that affect the overall reliability of the scientific studies at Yucca Mountain?

- Based on the quality of the science seen in the e-mails we have released, can we be certain that the waste stored at the site can be safely contained for even several hundred years?
- Does the NWTRB plan any particular action in response to these charges? (Such as revisit previous conclusions or more aggressive review of DOE)





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

April 29, 2005

The Honorable Jon Porter  
Chairman  
Subcommittee on the Federal Workforce  
and Agency Organization  
Committee on Government Reform  
U.S. House of Representatives  
B-373A Rayburn House Office Building  
Washington, DC 20515

Dear Chairman Porter:

Thank you very much for the opportunity to present the views of the Nuclear Waste Technical Review Board at a hearing before the Subcommittee on the Federal Workforce and Agency Organization on April 5, 2005. Enclosed are responses to follow-up questions from that hearing that were transmitted in your letter of April 14, 2005.

As you know, the Board is charged by Congress with conducting an ongoing and independent review of the technical and scientific validity of activities undertaken by the Secretary of Energy associated with implementing the Nuclear Waste Policy Act. The Board provides its technical views to help inform the consideration of issues related to the management and disposal of spent nuclear fuel and high-level radioactive waste.

Please do not hesitate to contact me or have your staff contact Bill Barnard, Board Executive Director, if you have questions related to the Board's responses or any other issue related to the Board's technical and scientific review.

Sincerely,

{Signed by}

B. John Garrick  
Chairman

Enclosure

**“Yucca Mountain Project: Have Federal Employees Falsified Documents?”**

**Subcommittee on the Federal Workforce and Agency Organization**

**Chairman Jon C. Porter**

**Questions Submitted For the Record**

**Submitted April 8, 2005**

*Answers Submitted April 29, 2005*

**John Garrick, U.S. Nuclear Waste Technical Review Board**

- **If the allegations are proven true, what is the impact the “sound science” of the project?**

Answer: It is not possible to reach conclusions about what effect, if any, there may be on the scientific program until investigations currently under way at the Department of Energy (DOE) and the Department of the Interior (DOI) are concluded. At that point, the Board will evaluate the results of the investigations to determine if they have implications for the validity of the DOE’s technical and scientific work. In the meantime, the Board will continue reviewing the technical and scientific validity of ongoing DOE activities. In accordance with its mandate established in the Nuclear Waste Policy Amendments Act, the Board will report its findings and recommendations from those evaluations to Congress and the Secretary of Energy.

- **We know for certain that the e-mails in question were written during the time that DOE was rushing to prepare and submit a license application to the NRC. How many times has DOE asked for an extension in filing the license application and what reasons were given in support of an extension of time?**

Answer: The Board’s understanding is that the DOE decides when to submit a license application (LA). Consequently, any deadline that the DOE might have had for submitting an LA would have been self-imposed.

- **Based upon DOE’s persistent quality assurance failures and in light of the recent controversy documenting employee falsification of scientific studies, what is the Board’s position regarding the current state of the scientific credibility of the project?**

Answer: The Board believes that a rigorous quality assurance program is important for this scientific program. However, deficiencies in complying with quality assurance requirements, which are monitored by the Nuclear Regulatory Commission (NRC), may or may not significantly affect the DOE’s technical and scientific findings. The Board will review this matter when investigations currently under way at the DOE and the DOI are concluded. In the meantime, the Board will continue evaluating the technical and scientific validity of the DOE’s ongoing activities and providing its straightforward assessment to Congress and the Secretary.



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- **Should the allegations be proven true, what is the board's recommendation regarding the continuation of the project?**

Answer: At this time, the Board does not know how the allegations, if proven true, would affect the DOE's technical and scientific program. In any case, a decision related to continuing the Yucca Mountain program is a matter of policy that is well beyond the Board's technical and scientific purview. Through its regular and special reports, the Board provides technical and scientific information to policy-makers, who can then use the Board's assessment when making policy decisions. As has always been the case, if at some point the Board were to determine that a condition or conditions existed that clearly made the site unsuitable, the Board would make its opinion known to Congress and the Secretary immediately.

- **It is my understanding that this past February (February 8, 2005) the Board called for hearings in March to review concerns over the corrosion of the titanium drip shields that are intended to keep water from leaking into casks inside Yucca Mountain. Have you held those hearings and, if so, what were your findings?**

Answer: No "hearings" were requested, but the Board did ask the DOE to discuss the drip shields at our next meeting. That meeting is currently planned for November 8, 2005, in Las Vegas, Nevada.

- **Given the fact that DOE is self-regulated and can choose not to implement the recommendations of the Board, has there ever been a feeling among the Board that DOE uses its privilege to hide information?**

Answer: Congress clearly intended that the Board function as a peer reviewer – not as a regulator or a program manager. While it is true that the Board was not granted authority to implement its recommendations, Congress provided the Board access to all information necessary for conducting its ongoing review, including draft documents produced by the DOE. Over the years, all the documents that have been requested from the DOE, including drafts, have been provided within a reasonable time frame. However, the Board can only request and evaluate information that it knows about.

- **Based upon your review, has DOE come up with a plan for safely transporting nuclear waste to the proposed repository?**

Answer: The DOE is developing a plan and is working on the integration of waste management activities. Although at this point the Board has no reason to believe that a safe transportation system cannot be developed, the DOE has a great deal of work to do before it can claim credibly that it has a workable plan in place for safely transporting spent nuclear fuel or high-level radioactive waste.

- **To your knowledge, what has DOE done to study the transportation issues?**

Answer: The DOE reported on its efforts to develop a transportation system at four Board meetings held in the last year and a half. Examples of DOE activities that were discussed at those meetings include developing a systematic approach to transportation planning; identifying critical transportation planning components and their interdependencies; developing tools and analyzing issues associated with ensuring safe, secure, and efficient transportation; and working on the integration of transportation activities with activities related to the transfer of spent nuclear fuel and high-level radioactive waste at generation sites and with the receipt and handling of the wastes at the proposed repository site. For much more detailed information on the DOE presentations, transcripts of Board meetings and Board letters to and from the DOE are available on the Board's Web site at, [www.nwtrb.gov](http://www.nwtrb.gov).

- **If scientific studies concerning the hydrology and geology of Yucca Mountain were falsified, and if falsified reports were used as the basis for other work, how would that affect the overall reliability of the scientific studies at Yucca Mountain?**

Answer: If data or analyses were falsified and if those data or analyses significantly affected repository performance estimates, the consequences could be serious. However, the Board has no evidence at this point to indicate that that is the case. It is not clear how a change in a single parameter would affect the DOE's estimates of repository performance, which are based on a range of values. The Board will look very carefully at this issue.

- **Based on the quality of the science seen in the e-mails we have released, can we be certain that the waste stored at the site can be safely contained for even several hundred years?**

Answer: Drawing conclusions about the quality of the science is not possible until the results of investigations currently under way at the DOE and the DOI are known. To date, the Board has seen no evidence suggesting that the containment capability of the repository would be limited to a few hundred years.

- **Does the NWTRB plan any particular action in response to these charges? (Such as revisit previous conclusions or more aggressive review of DOE)**

Answer: The Board's technical and scientific evaluation of the DOE's work is ongoing and vigorous. Consequently, the Board reviews its findings and analyses whenever necessary or appropriate. As stated previously, the Board will evaluate the results of the DOE and DOI investigations when they are available and will determine their implications for the validity of the DOE's technical and scientific work. In the meantime, the Board will continue reviewing the DOE's ongoing activities. In accordance with its congressional mandate, the Board will regularly and candidly report its findings and recommendations to Congress and the Secretary of Energy.

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## 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, climactic, 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.\*

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\*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](http://www.nwtrb.gov).



# Appendix H

## U.S. Nuclear Waste Technical Review Board

### Fiscal Year (FY) 2007

### Budget Request Submittal

#### Including Performance Evaluation for FY 2005 and Supplementary Information about the Board

#### **Summary and Highlights**

This is the U.S. Nuclear Waste Technical Review Board's performance-based budget request for fiscal year (FY) 2007. The request will support the Board efforts to achieve its performance goals for the year. The performance goals are listed in the budget document and have been established in accordance with the Board's congressional mandate: Conduct an independent evaluation of the technical and scientific validity of U.S. Department of Energy (DOE) activities related to disposing of commercial spent nuclear fuel and defense high-level radioactive waste. These activities include evaluating the proposed Yucca Mountain repository site in Nevada and packaging and transporting the waste. The Board's ongoing peer review is vital to the credibility of the DOE's technical and scientific activities.

In 2002, Congress approved the President's recommendation of Yucca Mountain and authorized the DOE to proceed with preparing an application that will be submitted to the U.S. Nuclear

Regulatory Commission (NRC) for a license to construct a repository at Yucca Mountain. Throughout this process, the Board has evaluated the technical and scientific validity of DOE work and has reported its findings to Congress and the Secretary of Energy.

The Board's performance goals for FY 2007 have been updated to reflect expected DOE activities during that period. For example, the Board will review DOE activities related to increasing understanding of the natural system, developing a radionuclide risk profile derived from Total System Performance Assessment (TSPA), analyzing the implications of DOE plans for a transportation, aging, and disposal canister system, and assessing issues relevant to thermal loading and waste-package lifetime. The Board also will review DOE activities related to planning and implementing a waste management system and designing, planning, and developing repository surface facilities. The Board is requesting \$3,670,000 to support these activities in FY 2007.

## U.S. Nuclear Waste Technical Review Board

### *Salaries and Expenses (Including Transfer of Funds)*

For necessary expenses of the Nuclear Waste Technical Review Board, as authorized by Public Law 100-203, section 5051, \$3,670,000 to be transferred from the Nuclear Waste Fund and to remain available until expended.

*(2006 Energy and Water Development Appropriations Act, P.L. 109-103)*

### **Board Budget Request for FY 2007**

#### *Background*

Approximately 2,000 metric tons of spent nuclear fuel are produced each year by nuclear reactors and are stored at more than 70 sites nationwide. By the time the presently operating reactors reach the end of their scheduled 40-year lifetimes (at some time in the 2030s), approximately 87,000 metric tons of spent fuel will have been produced. (This estimate does not include spent nuclear fuel from plants that may be granted license renewals by the NRC.) In addition, high-level radioactive waste (HLW) from defense activities has been stored at numerous federal facilities throughout the country. Disposal of the spent nuclear fuel and HLW in a deep geologic repository is the primary approach being pursued by the United States and other countries.

In early 2002, the Secretary of Energy recommended approval of the Yucca Mountain site to the President. The President then recommended the site to Congress. The State of Nevada later disapproved the recommendation. Both the U.S. House of Representatives and the U.S. Senate went on to approve the site recommendation. Since that time, the DOE has focused on preparing an application to be submitted to the NRC for authorization to construct a repository at the Yucca Mountain site. Throughout this process, the Board has evaluated the technical basis of the DOE's work and communicated Board views to Congress and the Secretary of Energy in letters, reports, and congressional testimony.

#### *The Board's Continuing Role*

The Board was established by Congress in the Nuclear Waste Policy Amendments Act of 1987 (NWPAA). The Board is charged with evaluating the technical and scientific validity of activities undertaken by the Secretary of Energy, including site-characterization activities and activities related to the packaging and transportation of HLW and spent nuclear fuel.\* Board technical and scientific findings and recommendations are included in reports that are submitted at least twice each year to Congress and the Secretary. In creating the Board, Congress realized that an ongoing independent and expert evaluation of the technical and scientific validity of the DOE's site-evaluation and other waste-management activities would be crucial to acceptance by the public and the scientific community of any approach for disposing of spent nuclear fuel and HLW.

#### *The Board's Funding Requirement for FY 2007: \$3,670,000*

The Board's budget request of \$3,670,000 for FY 2007 represents the funding needed to accomplish the Board's performance goals for the year. During FY 2007, the Board intends to continue its evaluation of the technical and scientific validity of DOE activities, including those related to increasing understanding of the natural system, developing a radionuclide risk profile derived from TSPA, analyzing tradeoffs between pre-closure and postclosure risks, assessing issues

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\*42 U.S.C. 10263

relevant to thermal loading and waste-package lifetime, and evaluating the implications of plans for a transportation, aging, and disposal canister system. The Board also will review DOE activities related to planning and implementing a waste management system and designing, planning, and developing repository surface facilities. The amount requested will support the work of the Board members who will conduct the comprehensive review described above, enable the Board to comply with extensive federal security requirements related to the Board's information systems, and allow the Board to undertake a financial audit in accordance with the Accountability of Tax Dollars Act (ATDA).

### **Performance-Based Budget for FY 2007**

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

The NWPA limited repository-development activities to a single site at Yucca Mountain in Nevada. The NWPA 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. Such activities include characterizing the Yucca Mountain site and packaging and transporting spent nuclear fuel and HLW.

The Board's general goals and strategic objectives are set forth in its strategic plan for FY 2004-2009. They have been established in accordance with the Board's statutory mandate and with congressional action in 2002 authorizing the DOE to pro-

ceed with developing an application to the NRC for authorization to construct a repository at Yucca Mountain. The Board's performance goals for FY 2007 have been established in accordance with its general goals and objectives. The Board's performance-based budget for FY 2007 has been developed to enable the Board to meet its performance goals for the year.

The Board will accomplish its goals by doing the following:

- Holding up to three public meetings with the DOE and DOE contractor personnel involving the full Board and holding meetings of the Board panels, as needed.
- When appropriate, holding fact-finding sessions involving small groups of Board members who will focus in depth on specific technical topics.
- Reviewing critical documents provided by the DOE and its contractors, including TSPA, preclosure safety analyses (PCSA), contractor reports, analysis and modeling reports (AMR), and design drawings and specifications.
- When appropriate, visiting and observing ongoing investigations, including those conducted at the national laboratories or potential analog sites.
- Visiting programs in other countries and attending national and international symposia and conferences.

The Board's performance goals for FY 2007, which are described below, are divided into four topical areas that correlate with the purviews of the Board's panels. The numbering system has been simplified, and performance goals have been updated from previous years to reflect current activities. Amounts have been allocated preliminarily to each set of performance goals for FY 2007.

## Performance Goals for FY 2007

### 1. Performance Goals Related to the Natural System

(Dollars in Thousands)

FY 05	FY 06	FY 07
839	893	917

- 1.1. Review DOE activities related to natural-system performance, including tests of models and assumptions, and pursuit of independent lines of evidence.
- 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.
- 1.3. Review DOE efforts in addressing questions related to possible seismic and igneous events and consequences.
- 1.4. Evaluate data and test results obtained from testing in the enhanced characterization of the repository block (ECRB) and other facilities.
- 1.5. Evaluate DOE efforts to analyze the source term and to estimate what radionuclides will be mobilized and transported through the natural system at what time periods.
- 1.6. Review plans and work carried out on possible analogs for the natural components of the repository system.
- 1.7. Recommend additional work needed to address uncertainties related to estimates of the rate and distribution of water seepage into repository tunnels, given anticipated infiltration rates.
- 1.8. Review DOE efforts in integrating results of scientific studies related to the behavior of the natural system into repository designs.
- 1.9. Review plans and studies undertaken by the Office of Science & Technology and International (OSTI) related to the natural system.

### 2. Performance Goals Related to the Engineered System

(Dollars in Thousands)

FY 05	FY 06	FY 07
1,006	1,071	1,101

- 2.1. Review DOE activities related to the engineered system in response to changes in the regulatory compliance period.
- 2.2. Review thermal-mechanical and rock-stability testing on potential conditions in repository tunnels.
- 2.3. 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.
- 2.4. Review the progress and results of materials testing being conducted to address uncertainties about waste package performance.
- 2.5. Review DOE analyses of facilities, systems, and component designs, including the transportation, aging, and disposal canister.
- 2.6. Evaluate the accuracy and completeness of the technical bases for repository and waste package designs.
- 2.7. Evaluate the integration of subsurface and repository designs, layout, and operational plans into an overall thermal management strategy.
- 2.8. Assess the integration of scientific studies into engineering designs for the repository and the waste package.
- 2.9. Evaluate the plans and activities of the OSTI related to the engineered system.

### 3. Performance Goals Related to Repository System Performance and Integration.

(Dollars in Thousands)

FY 05	FY 06	FY 07
671	714	735

- 3.1. Identify technical and scientific activities that are on the critical path to reconciling uncertainties related to DOE performance estimates in light of changes in the regulatory compliance period.
- 3.2. Evaluate strengths and weaknesses of TSPA.
- 3.3. Review new data and updates of TSPA models, and identify models and data that should be updated.
- 3.4. Evaluate activities undertaken by the DOE to develop a risk profile for specific radionuclides.
- 3.5. Evaluate DOE efforts to develop a realistic analysis of repository performance.
- 3.6. Evaluate DOE efforts to analyze the contribution of the different engineered and natural barriers to waste isolation.
- 3.7. Recommend additional measures for strengthening the DOE's repository safety case.
- 3.8. Evaluate DOE efforts to develop a feedback loop among performance-confirmation activities and TSPA models and data.
- 3.9. Monitor the DOE's proposed performance-confirmation plans to help ensure that uncertainties are addressed.
- 3.10. Review plans and studies undertaken by the OSTI related to overall performance of the repository.

### 4. Performance Goals Related to the Waste Management System

(Dollars in Thousands)

FY 05	FY 06	FY 07
839	894	917

- 4.1. Evaluate the integration of the repository facility, including the surface and subsurface components.
- 4.2. Evaluate the design of surface facilities, including the fuel handling and aging facilities, and how the design affects and is affected by the thermal management of the repository.
- 4.3. Review DOE procedures for ensuring that waste accepted for disposal has been suitably characterized.
- 4.4. Monitor DOE efforts to implement Section 180 (c) of the NWPA.
- 4.5. Monitor the DOE's progress in developing and implementing a transportation plan for shipping spent nuclear fuel and HLW to a Yucca Mountain repository.
- 4.6. Review DOE efforts to develop criteria for routing decisions.
- 4.7. Evaluate logistics capabilities of the transportation system.
- 4.8. Monitor progress in implementing new technologies for improving transportation safety for spent nuclear fuel, including transportation, aging, and disposal canisters and casks.
- 4.9. Evaluate DOE plans for enhancing safety capabilities along transportation corridors, and review DOE planning and coordination activities, accident prevention activities, and emergency response activities.
- 4.10. Review the potential and limits of the total system model.

## Budget Request by Object Class

### *Object Class 11.1, Full-Time Staff: \$1,724,000*

The amount requested for full-time permanent staff is based on the requirement to fund a total of 15 positions. Because the Board's technical and scientific evaluations are conducted by Board members supported by professional staff, the Board's enabling legislation authorizes the Board chairman to appoint and fix the compensation of not more than 10 senior professional staff members. This request assumes the use of all 10 positions under this authority. In addition, the chairman is authorized to appoint such clerical and administrative staff as may be necessary to discharge the responsibilities of the Board. The other 5 positions funded under this object class are support staff engaged in clerical, secretarial, and administrative activities; development and dissemination of Board publications; information technology, including maintenance of the Board's Web site; public affairs; and meeting logistics for the Board. The small administrative staff supports the very active part-time Board members and full-time professional staff.

The estimate assumes a 1.022 percent combined cost-of-living adjustment and locality raise in January 2007 for both General Schedule and Executive Schedule employees.

### *Object Class 11.3, Other than Full-Time Permanent Staff: \$376,000*

The amount requested for this category includes compensation for Board members. Each Board member will be compensated at the rate of pay for Level III of the Executive Schedule for each day that the member is engaged in work for the Board. The 11 Board members serve on a part-time basis equaling 2 full-time equivalent positions. The budget assumes that each member will attend 3 full Board meetings, 2 panel meetings, and an average of 2 additional meetings or field trips during the year. This estimate represents an average of 57 workdays per member in FY 2007. This estimate also assumes a 1.022 per-

cent increase in Executive Schedule compensation for employees in this category for FY 2007 (effective January 2007).

### *Object Class 11.5, Other Personnel Compensation: \$47,000*

The amount requested for this category covers approximately 80 hours of staff overtime and performance awards under the Performance Management System approved by the Office of Personnel Management (OPM). Most Board and panel meetings require considerable overtime for on-site meeting logistics and other preparations.

### *Object Class 12.1, Civilian Personnel Benefits: \$441,000*

The estimate for this category represents the government's contribution for employee benefits at the rate of 25.75 percent for staff and 7.65 percent for members.

### *Object Class 21.0, Travel: \$298,000*

The amount requested for this object class includes travel costs for Board members, staff, and consultants traveling to Board and panel meetings, to other meetings (including professional meetings, conferences, and orientation activities) and sites to acquire technical and scientific data, and to Yucca Mountain in Nevada to review site activities within the scope of the Board's mission. The request is based on 11 Board members attending 3 Board and 2 panel meetings and making an average of 2 other trips during the year at an average length of 3 days each, including travel time. In addition, the 10 professional staff members will travel on similar activities an average of 8 trips during the year at an average of 3 days per trip. In FY 2007, the expectation is that the DOE may increase its activities related to planning for transportation and packaging of the waste and designing the repository surface and subsurface facilities. The Board's meetings will increase commensurately and will be held in parts of the country affected by the DOE action.



***Object Class 23.1, Rental Payments to the General Services Administration (GSA): \$197,000***

The estimate for this object class represents the amount that the Board will pay to the GSA for rental of office space totaling 6,288 sq. ft. at an annual rate of \$31.34 per sq. ft.

***Object Class 23.3, Communications, Utilities, Miscellaneous: \$24,000***

The requested amount represents estimates for telephone service, postage, local courier services, video teleconferencing, FTS long-distance telephone service, the Internet, and mailing services related to management and use of the Board's mailing list.

***Object Class 24.0, Printing and Reproduction: \$22,000***

The major items in this object class are the publication of reports to the U.S. Congress and the Secretary of Energy, publication of meeting notices in the *Federal Register*, production of press releases announcing meetings and report publication, and production of other informational materials for Board members and the public. All Board meetings are open to the public, and copies of meeting materials are provided. Members of the public who live in rural areas and who do not have Web access may be interested in obtaining printed copies of Board documents.

***Object Class 25.1, Consulting Services: \$103,000***

Consultants will be hired when necessary to support and supplement Board and staff analysis of specific technical and scientific issues. This will enable the Board to conduct the kind of comprehensive technical and scientific review mandated by Congress.

***Object Class 25.2, Other Services: \$177,000***

This category includes court-reporting services for an estimated five Board or panel meetings, meeting-room rental and related services, maintenance agreements for equipment, professional development, and services from commercial sources. In addition, the Board will contract with part-time technical consultants to supplement and support in-house operations in systems management, Web site management, report production, and editing. Costs of a financial audit to comply with the Accountability of Tax Dollars Act also are included in this category.

***Object Class 25.3, Services from Other Government Agencies: \$108,000***

This category includes GSA administrative support services (payroll, accounting, personnel, etc.), legal advice from GSA, security clearances through OPM, and other miscellaneous inter-agency agreements.

***Object Class 26.0, Supplies and Materials: \$62,000***

Anticipated expenses include routine office supplies, subscriptions and library materials, and off-the-shelf technical reports and studies.

***Object Class 31.0, Equipment: \$91,000***

This estimate is for miscellaneous equipment costs, including audiovisual equipment and computer hardware, and computer-network software maintenance. In addition, funds are included to support the Federal Information Security Act, which requires federal agencies to periodically test and evaluate the effectiveness of their information security policies, procedures, and practices. The category also includes continued upgrades to IT security and continuity of operations (COOP) availability, support to e-gov telecommuting efforts, and technical support of the management of electronic records and e-mails.

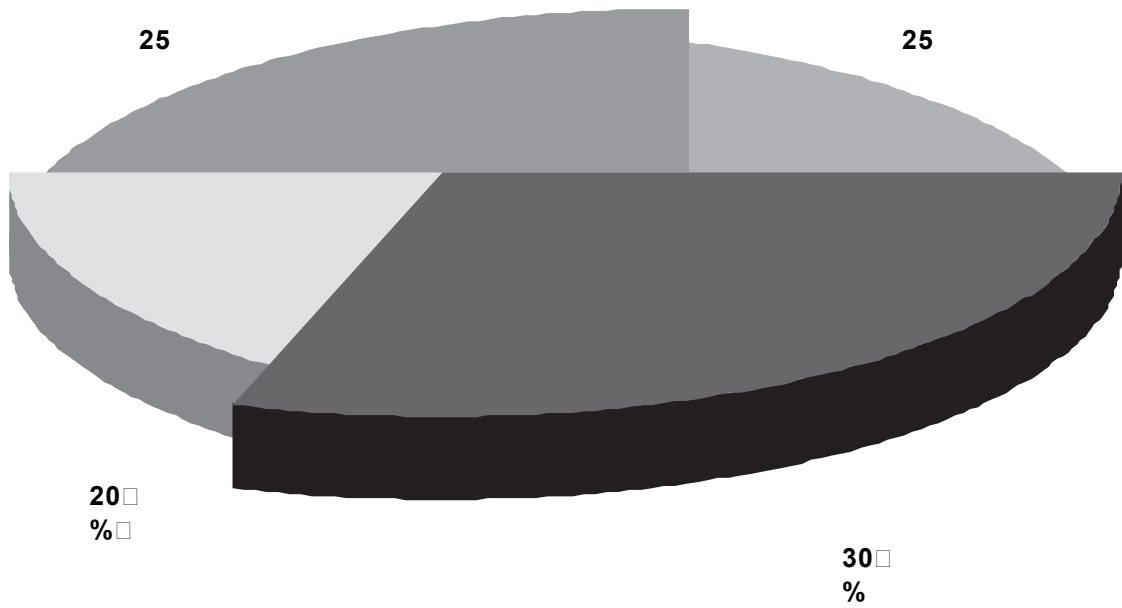
**Nuclear Waste Technical Review Board  
Projected 2007 Expenditures  
Object Classification (in thousands of dollars)**

Identification code 48-0500-0-1-271	FY 05 ACT	FY 06 EST	FY 07 REQ
Expenditures			
11.1 Full-time permanent	\$1,605	\$1,686	\$1,724
11.3 Other than Full-Time Permanent	364	366	376
11.5 Other Personnel Compensation	30	47	47
12.1 Civilian Personnel Benefits	401	430	441
21.0 Travel and Transportation	328	312	298
23.1 Rental Payments to GSA	185	184	197
23.3 Communication, Utilities, Miscellaneous	24	26	24
24.0 Printing and Reproduction	16	20	22
25.1 Consulting Services	101	103	103
25.2 Other Services	169	148	177
25.3 Services from Government Accounts	59	69	108
26.0 Supplies and Materials	42	61	62
31.0 Equipment	31	120	91
<b>99.9 Total Obligations</b>	<b>\$3,355</b>	<b>\$3,572</b>	<b>\$3,670</b>

**Nuclear Waste Technical Review Board  
Salaries and Expenses  
Personnel Summary**

Identification Code 48-0500-0-1-271	04 ACT	05 EST	06 REQ
Total Number of Full-Time Permanent Positions	17	17	17
Total Compensable Work-Years: Full-Time Equivalents	17	17	17

**FY 2007 Budget Request Resources Allocation**



■ <b>Natural System</b> (natural barriers at Yucca Mt.)	<b>25%</b>
■ <b>Engineered System</b> (engineered barriers at Yucca Mt.)	<b>30%</b>
■ <b>Repository System Performance</b> <b>And Integration</b>	<b>20%</b>
■ <b>Waste Management System</b> (Including transportation)	<b>25%</b>



# Addendum A

## U.S. Nuclear Waste Technical Review Board Performance Evaluation Fiscal Year 2005

### **The U.S. Nuclear Waste Technical Review 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 commercial spent nuclear fuel and defense high-level radioactive waste. The Act also established the U.S. Nuclear Waste Technical Review Board (Board) as an independent agency within the executive branch of the United States Government. The Act directs the Board to evaluate continually the technical and scientific validity of activities undertaken by the Secretary of Energy related to disposing of, transporting, and packaging the waste and to report its findings and recommendations to Congress and the Secretary of Energy at least twice yearly. The Board only can make recommendations; it cannot compel the DOE to comply. 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.

### **Board Performance Criteria and Method of Evaluation**

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, the Board has developed the following criteria to measure its annual performance in achieving individual performance goals.

1. Did the Board undertake the reviews, analyses, or other activities needed to evaluate the technical and scientific validity of the DOE activity identified in the performance goal?
2. Were the results of the Board's evaluation communicated in a timely, understandable, and appropriate way to Congress, the Secretary of Energy, the Office of Civilian Radioactive Waste Management (OCRWM), or the public?

If both measures are met in relation to a specific goal, the Board's performance in meeting that goal will be judged effective. If only one measure is 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 or outdated, it will be noted in the evaluation.

The Board will use this evaluation of its own performance from fiscal year (FY) 2005, together with its assessment of current or potential key technical issues of concern related to the DOE program, to

develop its annual performance objectives and to inform spending allocations in its performance-based budget for subsequent years.

## Performance Evaluation for FY 2005

The Board's performance goals for FY 2005 were developed to achieve the general goals and strategic objectives in the Board's strategic plan for fiscal years 2004-2009. The goals also were 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 U. S. 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 efforts to evaluate program activities, taking into account the interdependence of components of the repository system and the waste management system.

This evaluation will be submitted to the Office of Management and Budget (OMB), attached to the Board's budget request to Congress for FY 2007, included in the Board's summary report for 2005, and posted on the Board's Web site ([www.nwtrb.gov](http://www.nwtrb.gov)). The reliability and completeness of the performance data used to evaluate the Board's performance relative to its annual performance goals are high and can be verified by accessing the referenced documents on the Board's Web site.

### Strategy for Achieving Performance Goals

To evaluate DOE activities and achieve its performance goals, the Board engages in the following activities in any given year:

- Holding public meetings of the full Board and of Board panels.
- Reviewing the common DOE database, including scientific literature and laboratory and field data, contractor reports, analysis and model reports, and total system performance assessment (TSPA).
- Meeting with DOE contractor principal investigators on technical issues, observing ongoing tests and laboratory and field investigations, and visiting potential analog sites.
- Visiting nuclear waste disposal programs in other countries and attending national and international symposia and conferences.

In addition, in FY 2005, small contingents of Board members and staff held fact-finding meetings with the DOE, its contractors, and key stakeholders (e.g., representatives of the rail and trucking industries, the nuclear utilities, and logistics service providers). The fact-finding meetings enabled the Board to engage in concentrated discussions of important technical issues and to understand better how the DOE applies fundamental methods of analysis. Those meetings facilitated and enhanced the Board's evaluation of current issues of importance to the DOE program and helped identify additional technical issues that will be the focus of the Board's evaluation of DOE activities in coming years. In the following evaluation of the Board's performance for FY 2005, the meetings are referenced by date and the topics discussed.

For this evaluation, the Board's performance goals for FY 2005 have been organized and numbered to correlate with appropriate strategic objectives in the Board's strategic plan for FY 2004-2009.

### *FY 2005 Board Performance Goals and Evaluation*

#### *1. THE NATURAL SYSTEM*

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

- *Evaluation of 1.1.1: Effective. Explanation: During FY 2005, the Board engaged in several fact-finding meetings at which activities of the Office of Science & Technology and International (OSTI) were discussed. In its letter dated November 30, 2004, to OCRWM director, Dr Margaret Chu, the Board commented on the importance of the science and technology program. In its December 30,*

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2004, letter report to Congress and the Secretary of Energy, the Board again commented on the importance of the science and technology effort.

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

- *Evaluation of 1.1.2: Effective. Explanation: The Board held a fact-finding meeting on SZ flow and transport on September 7-8, 2005. The DOE's work related to understanding SZ flow and transport was discussed in some detail at the meeting. The Board's December 2004 report to Congress and the Secretary described studies and analyses under way indicating that the natural system might be an effective barrier against radionuclide migration and identifying a better understanding of the waste-isolation characteristics and behavior of the natural system as an area requiring more attention.*

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

- *Evaluation of 1.1.3: Effective. Explanation: The Board commented on DOE efforts to increase fundamental understanding of the Yucca Mountain site in its November 2004 letter to Dr. Chu. The Board's December 2004 report to Congress and the Secretary described studies and analyses under way indicating that the natural system might be an effective barrier against radionuclide migration and identifying a better understanding of the waste-isolation characteristics and behavior of the natural system as an area requiring more attention. In the same letter report, the Board stated that estimates of the performance of the natural barriers should be based on multiple lines of evidence. The Board held two fact-finding meetings during FY 2005, at which the SZ and the unsaturated zone (UZ) were discussed in detail.*

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

- *Evaluation of 1.2.1: Effective. Explanation: The Board commented on the DOE's progress in developing realistic ground-motion estimates in its November 2004 letter to Dr. Chu and noted that OSTI was undertaking work in this area. The Board included its comments on realistic ground-motion estimates in its December 2004 letter report to Congress and the Secretary. In the same report, the Board noted the completion of an aeromagnetic survey that could shed light on igneous activity at Yucca Mountain and commented on the need to improve modeling of volcanic consequences.*

1.3.1. Evaluate geologic, hydrologic, and geochemical information obtained from the enhanced characterization of the repository block (ECRB) at Yucca Mountain.

- *Evaluation of 1.3.1: Effective. Explanation: The Board commented on the importance of maintaining access to the ECRB in its November 2004 letter to Dr. Chu. The Board held a fact-finding meeting on June 27-28, 2005, at which issues relevant to testing in the ECRB were discussed. The Board will comment on the need to complete studies in the ECRB in its December 2005 report to Congress and the Secretary.*

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

- *Evaluation of 1.3.2: Effective. Explanation: The Board commented on the importance of completing the drift-scale heater test in its November 2004 letter to Dr. Chu. The Board held a fact-finding meeting on the UZ in June 2005 at which issues relevant to the drift-scale heater test were discussed. The Board will comment on the need to complete the drift-scale test in its December 2005 report to Congress and the Secretary.*

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

- *Evaluation of 1.3.3: **Minimally effective/deferred.** Explanation: The DOE did not report on its activities in this area during FY 2005. The Board will comment on the need to continue testing at the Peña Blanca analog site in its December 2005 letter report to Congress and the Secretary.*

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.

- *Evaluation of 1.3.4: **Effective.** Explanation: The Board discussed with the OCRWM ways to reduce technical and scientific uncertainty and make performance estimates more realistic at several fact-finding meetings held in 2005. The Board commented on the need for a clear explanation and understanding of repository conditions after closure in its December 2004 letter report to Congress and the Secretary. In the same report, the Board cited the need to address uncertainties related to the pervasiveness of capillary and thermal barriers, which will affect seepage into repository tunnels. The Board commented on the DOE's climate studies using opal dating in its April 19, 2005, letter to OCRWM director, Theodore Garrish.*

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

- *Evaluation of 1.4.1: **Minimally Effective/deferred.** Explanation: The Board discussed tunnel stability at its fact-finding meeting with the DOE on surface/subsurface facility design and operations held on September 19-20, 2005. Plans are under way for a small fact-finding meeting with the OCRWM in early 2006 to discuss research results from OSTI work.*

1.5.1. Review DOE efforts to integrate results of scientific studies on the behavior of the natural system into repository designs.

- *Evaluation of 1.5.1: **Effective.** Explanation: The Board discussed these issues with the*

*OCRWM at a fact-finding meeting on surface/subsurface facility design on Sept 19-20, 2005. The Board commented on the need for such integration in its November 2004 letter to Dr. Chu. Integration of TSPA and repository design was discussed at a meeting of the full Board held on February 9-10, 2005.*

## 2. The Engineered System

2.1.1. Monitor the DOE's performance allocation studies.

- *Evaluation of 2.1.1: **Outdated goal.** Explanation: No such DOE studies were performed in FY 2005 or are expected. This goal will be eliminated in FY 2006.*

2.2.1. Review thermal testing and rock stability testing related to potential conditions in repository tunnels.

- *Evaluation of 2.2.1: **Effective.** Explanation: The DOE's thermal management strategy was discussed at a meeting of the full Board in February 2004. The Board held fact-finding meetings with the OCRWM on thermal management on September 20-21, 2005, and on surface/subsurface facility design on September 19-20, 2005, at which these issues were discussed.*

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.

- *Evaluation of 2.2.2: **Effective.** Explanation: Several Board members participated in three fact-finding meetings with the OCRWM at which these issues were discussed. The Board commented on the corrosion resistance of Alloy-22 in magmas and the potential for stress-corrosion cracking in its November 2004 letter to Dr. Chu. In its December 2004 letter report to Congress and the Secretary, the Board noted that a major issue involving deliquescence-induced localized corrosion had been addressed by the DOE. In the same report, the Board raised several other corro-*



*sion issues that require continued attention, including the presence of ammonium ion in repository tunnels and potential stress-corrosion cracking of the drip shield.*

2.3.1. Review the progress and results of materials testing being conducted to address uncertainties about waste package performance.

- *Evaluation of 2.3.1: **Effective**. Explanation: See evaluation of 2.2.2.*

2.3.2. Evaluate DOE efforts in identifying natural and engineered analogs for corrosion processes.

- *Evaluation of 2.3.2: **Deferred**. Explanation: The DOE did not engage in such activities during FY 2005.*

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

- *Evaluation of 2.4.1: **Effective**. Explanation: At the Board's February 2004 meeting, the DOE presented information related to the integration of TSPA results into repository design efforts. Several members of the Board participated in a September 2005 fact-finding meeting with the DOE on surface and subsurface facility design at which these issues were discussed.*

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.

- *Evaluation of 2.4.2: **Effective**. Explanation: At the Board's February 2004 meeting, the DOE presented information related to the integration of TSPA results with repository design efforts. Several members of the Board participated in a September 2005 fact-finding meeting on surface and subsurface facility design at which these issues were discussed. In its November 2004 letter to Dr. Chu, the Board commented on the need to analyze engineering design using TSPA.*

2.4.3. Evaluate the integration of the subsurface design and layout with thermal management and preclosure facility operations.

- *Evaluation of 2.4.3: **Effective**. Explanation: See evaluation of 2.4.2.*

2.5.1. Assess the integration of scientific studies into engineering designs for the repository and the waste package.

- *Evaluation of 2.5.1: **Effective**. Explanation: Several members of the Board participated in a September 2005 fact-finding meeting with the OCRWM on surface and subsurface facility design at which these issues were discussed. The Board commented on the need to analyze and integrate engineering design using TSPA in its November 2004 letter to Dr. Chu.*

### **3. Repository System Performance and Integration**

3.1.1. Identify which technical and scientific activities are on the critical path to reconciling uncertainties related to DOE performance estimates.

- *Evaluation of 3.1.1: **Effective**. Explanation: During 2005, Board members participated in fact-finding meetings with the DOE designed to provide detailed information on technical and scientific issues currently important to the DOE repository program. The Board's December 2004 letter report to Congress and the Secretary provided an overview of the Board's views on areas of progress and issues requiring additional attention.*

3.1.2. Determine the strengths and weaknesses of TSPA.

- *Evaluation of 3.1.2: **Effective**. Explanation: Several Board members participated in a fact-finding meeting with the OCRWM on TSPA in August 2005 at which these issues were discussed at length. The Board commented on issues related to integration and model validation in its November 2004 letter to Dr. Chu. The Board commented further on these issues in its December 2004 report to*

*Congress and the Secretary. In its April 2005 letter to Mr. Garrish, the Board noted that TSPA will need to address relevant hydrologic processes that may be significant beyond 10,000 years and that technical and scientific elements of TSPA might change if the standard is modified.*

3.1.3. Evaluate the DOE's treatment of seismic and volcanism issues in TSPA.

- *Evaluation of 3.1.3: **Effective.** Explanation: Several Board members participated in a fact-finding meeting with the DOE on TSPA in August 2005 at which these issues were discussed. In its November 2004 letter to Dr. Chu, the Board pointed out that engineering design and operations should be analyzed using TSPA to determine the potential significance of changes on the overall repository system. The Board used as an example that if the repository is modified to mitigate the effects of igneous activity, the modifications should be evaluated for their effects on repository performance. The Board also commented on the DOE's progress in making its ground-motion estimates more realistic. The same issues were raised in the Board's December 2004 letter report to Congress and the Secretary.*

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

- *Evaluation of 3.2.1: **Minimally Effective.** Explanation: Several Board members participated in a fact-finding meeting with the DOE on TSPA in August 2005 at which these issues were discussed.*

3.2.2. Review new data and updates of TSPA models, and identify models and data that should be updated.

- *Evaluation of 3.2.2: **Effective.** Explanation: Several Board members participated in a fact-finding meeting with the DOE on TSPA in August 2005 at which these issues were discussed. In its April 2005 letter to Mr. Garrish, the Board noted that TSPA will need to address relevant hydrologic processes that may be significant beyond 10,000 years*

*and that technical and scientific elements of TSPA might change if the standard is modified.*

3.3.1. Evaluate the DOE's efforts to create a transparent and traceable TSPA.

- *Evaluation of 3.3.1: **Effective.** Explanation: Several Board members participated in a fact-finding meeting on TSPA in August 2005 at which these issues were discussed. The Board will comment in its year-end report in December 2005 that the DOE should prepare a parallel analysis that can be used by policy-makers, the public, and the technical and scientific community to understand how the natural and engineered components of a repository would work together to isolate waste and to gauge the degree of conservatism of TSPA assumptions and estimates.*

3.3.2. Evaluate the DOE's efforts to develop simplified models of repository performance.

- *Evaluation of 3.3.2: **Effective.** Explanation: See Evaluation of 3.3.1.*

3.3.3. Evaluate the DOE's efforts to identify analogs for performance estimates of the overall repository system.

- *Evaluation of 3.3.3: **Deferred.** Explanation: The DOE did not present any information to the Board on this topic in FY 2005.*

3.4.1. Evaluate the DOE's efforts to analyze the contribution of the different engineered and natural barriers to waste isolation.

- *Evaluation of 3.4.1: **Effective.** Explanation: In its December 2004 letter report to Congress and the Secretary, the Board encouraged the DOE to continue studies that will lead to a better understanding of the contribution of the natural system. The Board will comment in its year-end report in 2005 that the DOE should prepare a parallel analysis that can be used by policy-makers, the public, and the technical and scientific community to understand how the natural and engineered components of a repository would*

*work together to isolate waste and to gauge the degree of conservatism of TSPA assumptions and estimates.*

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.

- *Evaluation of 3.5.1: **Minimally effective.** Explanation: In September 2005, several Board members participated in a fact-finding meeting with the DOE on surface and subsurface facility design at which these issues were discussed. This performance goal will be modified in FY 2006.*

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

- *Evaluation of 3.6.1: **Effective.** Explanation: In its April 2005 letter to Mr. Garrish, the Board stated that program integration is of continuing Board interest and could affect the DOE's safety case. The Board will comment in its year-end report in December 2005 that the DOE should prepare a parallel analysis that can be used by policy-makers, the public, and the technical and scientific community to understand how the natural and engineered components of a repository would work together to isolate waste and to gauge the degree of conservatism of TSPA assumptions and estimates.*

3.7.1. Evaluate DOE efforts to develop a feedback loop among performance-confirmation activities and TSPA models and data.

- *Evaluation of 3.7.1: **Effective.** Explanation: The DOE updated the Board on its performance-confirmation (PC) plans at the Board's February 2004 meeting. In the Board's April 2005 letter to Mr. Garrish, the Board observed that many activities identified to be undertaken as part of PC can be used for validating modeling assumptions that form the basis of TSPA. The Board noted that rather than being integrated, PC is operating indepen-*

*dently of TSPA and of the ongoing work on repository design.*

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

- *Evaluation of 3.7.2: **Effective.** Explanation: See evaluation of 3.7.1.*

#### 4. The Waste Management System

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

- *Evaluation of 4.1.1: **Effective.** Explanation: Several Board members participated in a fact-finding meeting with the DOE in September 2005 on surface and subsurface facility design and operations at which these issues were discussed in detail. In a November 2004 letter to Dr. Chu, the Board discussed integration of the total waste management system. The Board commented on integration of the waste management system in its December 2004 letter report to Congress and the Secretary, indicating that planning and design of an integrated waste management system would remain a top priority for the Board. The DOE presented an overview of waste management-system integration at the Board's February 2005 meeting. The Board commented again on these issues in its April 2005 letter to Mr. Garrish.*

4.1.2. Monitor the identification of research needs to support improved understanding of the interaction of components of the waste management system.

- *Evaluation of 4.1.2: **Effective.** Explanation: See evaluation of 4.1.1.*

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.

- *Evaluation of 4.1.3: **Effective.** Explanation: See evaluation of 4.1.1.*
- 4.1.4. Evaluate the effects of reduced receiving capacity at the repository surface facility on the nationwide transportation system.
- *Evaluation of 4.1.4: **Effective.** Explanation: See evaluation of 4.1.1.*
- 4.1.5. Review criteria for waste acceptance for storage to ensure that accepted material has been suitably characterized for subsequent disposal.
- *Evaluation of 4.1.5: **Minimally effective/deferred.** Explanation: Some discussion of these issues took place at a fact-finding meeting with stakeholders in October 2005. The Board will review whatever activities the DOE undertakes in this area in FY 2006.*
- 4.2.1. Monitor the DOE's efforts to implement Section 180(c) of the NWPA.
- *Evaluation of 4.2.1: **Effective.** Explanation: The Board's Panel on the Waste Management System held a meeting in October 2004 at which the DOE's development of Section 180(c) programs was discussed, including reactions to the DOE efforts by state and regional stakeholders. In a follow-up letter to Dr. Chu, the Board observed that emergency planning through the 180(c) program appeared to be based on funding formulas and not enough on ensuring that adequate emergency response capacity exists along all selected routes. The issue was raised again at a fact-finding meeting with stakeholders in October 2005.*
- 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.
- *Evaluation of 4.3.1: **Effective.** Explanation: The Board's panel on the Waste Management System met with the DOE and stakeholders in October 2004. The meeting agenda was devoted entirely to this topic. The Board sent*

*a letter to Dr. Chu in December 2004 following up on issues identified at the October panel meeting. Some issues discussed in the letter included transportation planning—the Board recommended a systematic approach; security and emergency response planning; transportation risk assessment—the Board suggested a more risk-based approach; route selection; and program integration. The Board's December 2004 letter to Congress and the Secretary acknowledged transportation as an area where the DOE had made progress. Development of the waste management system was identified as a top priority for future Board review. In February 2005, the Board held a panel meeting on transportation—specifically, the Nevada branch line—in Caliente, Nevada. The Board sent a letter to Mr. Garrish on these subjects in April 2004.*

- 4.3.2. Review DOE efforts to develop criteria for transportation mode and routing decisions.
- *Evaluation of 4.3.2: **Effective.** Explanation: This topic was discussed at the Board's October 2004 panel meeting and in the December 2004 follow-up letter to the DOE. The Board indicated that it was advisable to involve state regional and tribal groups in developing the criteria. The Board noted that of particular importance was that technical issues are identified and that sound methods for addressing them are developed and applied.*
- 4.3.3. Evaluate logistics capabilities of the transportation system.
- *Evaluation of 4.3.3: **Effective.** Explanation: In the Board's April 2005 letter to the DOE, the total system model was mentioned as having potential for planning and integrating the waste management system. In its December 2004 letter, the Board suggested that the DOE work with utilities in designing the waste management system. This topic was discussed at a fact-finding meeting with transportation service providers in October 2005. In the Board's December 2005 letter to Congress and the Secretary, the Board suggested that the DOE should deter-*

*mine first-hand the logistics capabilities at the reactor sites.*

4.3.4. Monitor progress in implementing new technologies for improving transportation safety for spent nuclear fuel.

- *Evaluation of 4.3.4: **Effective**. Explanation: In the Board's April 2005 letter to the DOE, the total system model was mentioned as having potential for planning and integrating the waste management system. This topic also was discussed at a fact-finding meeting with transportation service providers in October 2005.*

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.

- *Evaluation of 4.3.5.: **Effective**. Explanation: See evaluation of 4.3.4.*



## Addendum B

# Supplementary Information On The U.S. Nuclear Waste Technical Review Board

The U.S. Nuclear Waste Technical Review Board was established on December 22, 1987, in the Nuclear Waste Policy Amendments Act (NWPAA) as an independent agency in the executive branch of the federal government. The Board is charged with evaluating the technical and scientific validity of activities undertaken by the Secretary of Energy, including the following:

- Site characterization, and
- Activities related to packaging and transporting high-level radioactive waste and spent nuclear fuel.

The Board was given broad latitude to review activities undertaken by the Secretary of Energy in implementing the Nuclear Waste Policy Act. However, the Board was not given authority to require the DOE to implement Board recommendations.\*

### Board Members

The NWPAA authorized a Board of 11 members who serve on a part-time basis; are eminent in a field of science or engineering, including environmental sciences; and are selected solely on the basis of distinguished professional service. The law stipulates that the Board shall represent a broad range of scientific and engineering disciplines relevant to nuclear waste management. Board members are appointed by the President from a list of candidates recommended by the National Academy of Sciences. To prevent gaps

\*Taken from Legislative History of the Nuclear Waste Policy Amendments Act of 1987, February 26, 1998.

in the Board's comprehensive technical review, Board members whose terms have expired continue serving until they are reappointed or their replacements assume office. The first members were appointed to the Board on January 18, 1989. Current members were appointed by President George W. Bush.

The names and affiliations of the current 10 Board members are listed below.

- B. John Garrick, Ph.D., P.E., is chairman of the Board. A founder of PLG, Inc., he retired from the firm in 1997 and is a private consultant. His areas of expertise include probabilistic risk assessment and application of the risk sciences to technology-based industries.
- Mark Abkowitz, Ph.D., is a professor in the Department of Civil & Environmental Engineering and director of the Vanderbilt Center for Environmental Management studies at Vanderbilt University. His areas of expertise include risk management, transportation of hazardous materials, emergency preparedness, and applications of advanced information technology.
- William Howard Arnold, Ph.D., P.E., a private consultant, retired from Louisiana Energy Services in 1996. He holds a doctorate in experimental physics and has special expertise in nuclear project development.
- Thure Cerling, Ph.D., is a professor in the Department of Geology and Geophysics at the University of Utah. His areas of expertise include terrestrial geochemistry.

- David Duquette, Ph.D., is professor and head of the Department of Materials Science and Engineering at Rensselaer Polytechnic Institute in New York. His areas of expertise include the physical, chemical, and mechanical properties of metals and alloys.
- George M. Hornberger, Ph.D., is Ernest H. Ern Professor of Environmental Sciences in the Department of Environmental Sciences at the University of Virginia. His areas of expertise include catchment hydrology and hydrochemistry and transport of colloids in geologic media.
- Andrew C. Kadak, Ph.D., is a Professor of the Practice in the Nuclear Engineering Department of the Massachusetts Institute of Technology. His areas of expertise include nuclear engineering and the development of advanced reactors.
- Ron Latanision, Ph.D., is a professor at the Massachusetts Institute of Technology with joint appointments in the Department of Materials Science and Engineering and the Department of Nuclear Engineering. His areas of expertise include materials processing and corrosion of metals and other materials in aqueous environments.
- Ali Mosleh, Ph.D., is professor of reliability engineering at the University of Maryland. His areas of expertise include risk and safety assessment reliability analysis and decision analysis.
- Henry R. Petroski, Ph.D., P.E., is professor of civil engineering and professor of history at Duke University. His areas of expertise include failure analysis and design theory.

## Board Staff

The NWPA limits the Board's professional staff to 10 positions. An additional 5 full-time employees provide administrative support to Board members and the professional staff. Because of the comprehensive nature of the program,

the diversity of Board member experience and expertise, and the part-time availability of Board members, the small, highly qualified staff is employed to its full capacity in supporting the Board's review of the DOE program. The Board's offices are in Arlington, Virginia.

## Board Reporting Requirements

As required under the NWPA, the Board reports to the U.S. Congress and the Secretary of Energy at least two times each year. The reports include Board recommendations related to improving the technical and scientific validity of activities undertaken by the Secretary of Energy under the civilian radioactive waste management program. The DOE's written responses to Board recommendations are published in the Board's annual summary reports.

## Board Activities

The Board and its panels sponsor meetings and technical exchanges with program participants and interested parties, including representatives of the DOE and its contractors, the U.S. Nuclear Regulatory Commission, the U.S. Environmental Protection Agency, the U.S. Geological Survey, the U.S. Department of Transportation, the State of Nevada, affected units of local governments, Native American tribes, nuclear utilities, environmental groups, state utility regulators, and members of the public. Board members and staff attend relevant technical conferences, meetings, symposia, and workshops. They participate in field trips and occasionally visit foreign programs to gain insights from the experience of other countries' repository development efforts.

Board and panel meetings are open to the public and are announced in the Federal Register four to six weeks before each meeting. To facilitate access for program participants and the public, the Board holds the majority of its meetings in the State of Nevada, and time is set aside for



public comment at each meeting. Transcripts of Board and panel meetings and all Board reports, correspondence, and congressional testimony

are available to the public via telephone or written request or can be obtained from the Board's Web site: **[www.nwtrb.gov](http://www.nwtrb.gov)**.



# Appendix I

## Nuclear Waste Technical Review Board Performance Plan Fiscal Year 2005

### Nuclear Waste Technical Review Board 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 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

(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.
- 2.4.4. 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**

(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.

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- 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)		
<b>FY 03</b>	<b>FY 04</b>	<b>FY 05</b>
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.



# Appendix J

## Nuclear Waste Technical Review Board Performance Plan

### Fiscal Year 2006

#### **Nuclear Waste Technical Review Board Goals and Strategic Objectives**

The nation's goals related to the disposal of spent nuclear fuel and high-level radioactive wastes were set forth by Congress in the NWPA. The goals are to develop a deep geologic 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 the disposal of such waste.

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 NWPAA. Such 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 set forward in its strategic plan for FY 2004-2009, have been established in accordance with its statutory mandate and with congressional action in 2002 authorizing the DOE to proceed with the development of 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 view that both the repository and waste management activities should be evaluated as systems.

The Board's performance goals for FY 2006 are listed below. The performance goals are divided into four areas that correlate with Board panel jurisdictions and have been numbered according to the appropriate strategic objectives included in the Board's Strategic Plan for FY 2004-2009. Budget amounts for FY 2006 have been preliminarily allocated to each set of performance goals.

## Board Performance Goals for FY 2006

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

(Dollars in Thousands)		
FY 04	FY 05	FY 06
868	852	903

#### *Performance Goals*

- 1.1.1. Review the technical activities and plans for 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, including tests of models and assumptions, and the pursuit of independent lines of evidence.
- 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.
- Visiting and observing ongoing exploratory studies facility (ESF), ECRB, and laboratory investigations, including the facilities at Lawrence Livermore National Laboratory, Lawrence Berkeley National Laboratory, and Sandia National Laboratories. Observing other field investigations and visiting potential analogue sites.
- Visiting programs in other countries 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 04	FY 05	FY 06
1,041	1,023	1,082

### *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 analogs 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 of the full Board 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.
- Visiting and observing ongoing laboratory investigations, including the facilities at Lawrence Livermore National Laboratory and Lawrence Berkeley National Laboratory.
- Visiting programs in other countries and attending national and international symposia and conferences.

**3. Performance Goals Related to Repository System Performance and Integration and Strategy for Achieving the Goals**

(Dollars in Thousands)		
FY 04	FY 05	FY 06
694	682	721

*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.

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- 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 performance confirmation plans 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 of the full Board 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.
- Visiting and observing ongoing laboratory investigations, including the facilities at Lawrence Livermore National Laboratory, Lawrence Berkeley National Laboratory, Sandia National Laboratories, and the engineered-barrier test facility. Observing field investigations.
- Visiting programs in other countries 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 04	FY 05	FY 06
869	853	902

### *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 transportation mode and routing decisions.
- 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 programs in other countries and attending national and international conferences and symposia.



