Department of Energy
Washington, DC 20585

August 13, 2007

QA: N/A

RECEIVED AUG 16 2007

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

Dear Dr. Garrick:

Your 2006 Report to the U.S. Congress and the Secretary of Energy describing the activities of the Nuclear Waste Technical Review Board (Board), as well as more recent correspondence, raised a number of technical issues to which the Office of Civilian Radioactive Waste Management has responded in the enclosed table. The table summarizes the issues raised, the U.S. Department of Energy (DOE) responses to the Board's concerns, and DOE's current work activities in these areas.

We appreciate this opportunity to communicate with the Board regarding issues of importance to the Yucca Mountain Project and look forward to future exchanges. If you have any questions concerning the enclosed table, please contact me or Russ Dyer, Director, Office of the Chief Scientist, at 702-794-1408.

Sincerely,

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

Enclosure

NUCLEAR WASTE TECHNICAL REVIEW BOARD ISSUES RAISED IN 2006 REPORT TO CONGRESS AND IN RECENT CORRESPONDENCE WITH DOE, AND DOE RESPONSES TO THESE ISSUES

BOARD FINDINGS AND RECOMMENDATIONS	DOE RESPONSE
The Capability of Natural Barriers to Isolate Radionuclides	
The Board believes…that additional work on radionuclide transport is needed – in particular, research on secondary mineralization. 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 repository. If these investigations determine that the neptunium and plutonium leaving the EBS are captured in the secondary mineral phases, the possibility exists that the natural system's capability to isolate the dose-contributing radionuclides (^{237}Np and ^{242}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.	The DOE Office of the Chief Scientist, Science, Technology and Management (OCS/STM) funds independent work in a number of "Thrust Areas". The Source-Term Thrust Area is dedicated to scientific studies relevant to spent nuclear fuel (SNF) and nuclear waste glass and the critical processes within the waste package and drifts that affect potential radionuclide release from the waste forms and from the engineered barrier system. Source Term research studies include: 1) actinide thermodynamics at elevated temperatures; 2) impact of uranyl alteration phases of spent fuel on mobility of neptunium and plutonium; 3) effect of deliquescence and decay heat on source term degradation; 4) spent fuel dissolution mechanisms and rates; 5) in-package sequestration of radionuclides; and 6) long-term corrosion of spent nuclear fuel; 7) natural sequestration of radionuclides in volcanic tuff and secondary phases; 8) in-situ spectroelectrochemical study of Np redox, dissolution, and precipitation behavior at corroding commercial spent nuclear fuel (CSNF)/Alteration phase interface; 9) migration of the release of I-129 from SNF via uptake by uranyl alteration phases; 10) actinide adsorption to U(VI) silicates; 11) direct determination of the thermo-dynamic properties of uranyl minerals important to repository performance; 12) surface charge and radionuclide adsorption characteristics of U(IV/VI) and metal corrosion oxides at 25°-150°C under repository chemical environments. OCS/STM work also includes work at the Peña Blanca natural analogue site. OCS/STM activities have been reduced in FY 2007 and will not be funded in FY 2008, due to budget constraints.

BOARD FINDINGS AND RECOMMENDATIONS	DOE RESPONSE
	The Office of the Chief Scientist, Repository Science and Integration (OCS/RSI) directs the scientific program that supports the DOE's licensing case. OCS/RSI work includes incorporation of kinetics of filtration of irreversible colloids in the unsaturated and saturated zones through the "colloid diversity model". The approach (1) recognizes variability (diversity) in the attachment/detachment rate constants resulting from differences in colloid size, mineralogy, surface charge, and characteristics of sorption sites, (2) treats these variations with a distribution of retardation factors for colloids, and (3) develops the distribution of retardation factors as a function of transport time through the UZ and SZ. This work involves an abstraction of kinetic colloid filtration into the FEHM software to replace the current equilibrium approach. New data related to the performance of the natural barrier system are evaluated on an ongoing basis. For example, results from Alcove 8/Niche 3 tests are being utilized to more realistically take into account matrix diffusion in UZ flow and transport using an enhancement factor to the matrix diffusion coefficient estimated with the dual permeability model and possibly employing the MINC (multiple interacting continua) method. More realistic accounting of the role of matrix diffusion in radionuclide transport through the unsaturated zone will be evaluated and documented in the *Particle Tracking Model and Abstraction of Transport Processes* (MDL-NBS-HS-000020) AMR.
The Board is skeptical about the Project's claim to have found evidence of a "reducing curtain" in the saturated zone.	The evidence behind the notion that there may be areas of 'reducing ground waters' in the saturated zone is discussed in the BSC 2005 report: *Impact of Solubility and Other Geochemical Processes on Radionuclide Retardation in the Natural System.* A sensitivity study is planned for this year to evaluate the impact of potential 'reducing conditions' on radionuclide transport in the saturated zone through Monte Carlo simulations using the SZ flow and transport abstraction model for a range of reducing conditions.

BOARD FINDINGS AND RECOMMENDATIONS	DOE RESPONSE
The Board remains puzzled by the Project's inability to put to rest the issues related to the bomb-pulse chlorine-36 (^{36}Cl) observed in the proposed repository horizon and to the water found behind the bulkhead in the sealed section of cross-drift. Inconsistencies in past studies of ^{36}Cl raise questions about the technical basis of model predictions of water flow and radionuclide transport. In the case of the water found in the cross-drift, the Project has not developed and tested a hypothesis that explains all of the physical and chemical data collected. The Board recommends that work be expedited to resolve both of these issues to enhance confidence in both the quality and the conclusions of the Project's technical analyses.	Work performed as part of the ^{36}Cl validation activities by the Lawrence Livermore National Laboratory, the U.S.Geological Survey, and the Los Alamos National Laboratory have been documented in a report which is available on the OCRWM web site at http://www.ocrwm.doe.gov/documents/design/35641/index.htm. An independent study of ^{36}Cl issues has been conducted under a cooperative agreement between the Department and the Nevada System of Higher Education (NSHE) Scientists have collected samples from the Exploratory Studies Facility, evaluated experimental techniques, and tested rock samples in 2006. NSHE has submitted the results of their independent study of ^{36}Cl. The results were inconclusive and the report recommended additional work. DOE has not planned additional work on the ^{36}Cl issue. The report is available on the NSHE web site.
Thermal-Management Strategy	
The Board has concerns about the technical basis behind 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. For example, the 11.8 kW/waste package limit appears to have been based arbitrarily 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 drift wall temperature. The Board believes that the Project should articulate in a transparent way the basis for its thermal criteria.	The Department agrees that the thermal management strategy must be clearly defined to provide the technical basis for waste acceptance, transportation, waste handling, and waste emplacement. Postclosure near-field and in-drift conditions affecting performance of the engineered and natural barriers are being addressed in the postclosure elements of the thermal management strategy. This includes the thermal decay characteristics of the waste and temperature limits at key locations such as the waste package wall and drift wall. The FY 2007 work scope is addressing these thermal management issues.
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 spent nuclear fuel to the required thermal loading, given the spent nuclear fuel available in spent-fuel pools, the increasing volume of spent nuclear fuel in dry storage at reactors, and the trend towards higher burn-up fuel.... Moreover, the Board is	The performance specification is being developed taking into account all the system requirements from waste acceptance to final disposal. Accordingly, it has been the Department's intent to incorporate requirements that, while ensuring that the thermal performance of the TAD canister system would be consistent with the current postclosure thermal management approach, would provide sufficient flexibility to accommodate alternative thermal management strategies. If, as a result of further analyses, the current postclosure thermal management approach is

BOARD FINDINGS AND RECOMMENDATIONS	DOE RESPONSE
concerned that the constraints imposed by line-load during emplacement have not been fully represented or understood in terms of surface facility design and operation.	altered, the Department believes that such changes can be accommodated by altering the manner in which the TAD canister system is operated, (i.e. by decreased surface aging), rather than by requiring changes to the TAD canister design. The Department is developing an updated thermal management strategy to reflect commercial spent nuclear fuel (CSNF) forecast at somewhat higher burnup and earlier time out of the reactor than previously considered. This strategy is intended to maximize operational flexibility and minimize the related need for canister thermal limits. Using postclosure process models and parameters from alternative waste streams, sensitivity analyses will be performed to evaluate effects of a broader range of variables affecting thermal performance.
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. For example, the thermal conductivity 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 last 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…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.	The geostatistical model used to calculate the thermal conductivity of the repository horizon rocks has been developed based on site-specific data including well logs and measurements of physical properties and thermal conductivity on rock cores from boreholes. Because a sequential Gaussian simulation is used, the model provides an appropriate representation of the spatial variability and uncertainty of the underlying data, especially the key input parameters (i.e., matrix thermal conductivity and lithophysal porosity). Both parameters contribute to the spatial variability and uncertainty in the model results, although the dominant influence is from matrix thermal conductivity. Whereas, *in situ* tests are useful in evaluating the effects of discontinuties such as lithophysal cavities, laboratory tests are used to measure matrix thermal conductivity, the dominant contributor to spatial variability and uncertainty. The *in situ* test results are not part of the basis for spatial variability and uncertainty in the model results. The reason is that *in situ* tests by their nature (and cost) cannot be performed over nearly as broad a range of spatial distribution and stratigraphic facies as can be performed using geophysical well logs and core samples. Thus, additional *in situ* tests would not be a practical way to improve the model treatment of spatial variability and uncertainty.

BOARD FINDINGS AND RECOMMENDATIONS	DOE RESPONSE
	The in situ thermal conductivity test results are point measurements that corroborate the geostatistical model. All test results are within the range of values derived from the model. One of the test results is slightly over 1.5 standard deviations from the model-derived mean and the others are within one standard deviation. Additional confidence in the model is gained by the methods and models used to estimate matrix thermal conductivity, lithophysal porosity, matrix porosity, and bulk density. The latter two are used to estimate the former two, which are used to obtain bulk thermal conductivity. For the Drift-Scale Heater Test, activities such as re-entry, retrieval of sample materials, collection of additional samples, and photography have been deferred for budgetary reasons. Longer term activities will include coring, rock-bolt pull tests, and investigation of spalling at the drift crown. The objectives of these activities include obtaining a better understanding of the thermal-hydrologic-chemical-mechanical effects on repository performance. The thermal-hydrologic model to predict postclosure temperature, relative humidity, and vapor transport in the emplacement drifts is being revised to support the license application. No additional *in situ* thermal conductivity tests are planned. The Department believes than an acceptable level of model validation has been achieved. While potentially useful, further *in situ* thermal conductivity tests are not necessary for this purpose.

BOARD FINDINGS AND RECOMMENDATIONS	DOE RESPONSE
[T]he Project is conducting three-dimensional analyses to complement its two-dimensional multi-scale model of water and vapor flow. The Board plans to review those analyses to determine what impact, if any, they might have on the 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.	DOE does not plan to conduct an external review of the multiscale model. The OCS/STM Program has funded an integrated in-drift/near field flow and transport model with reactive chemistry. This includes an integrated thermal hydrologic chemical model with a rigorous mass balance.
Range of Possible Near-Field Environments that Might Occur and the Effect of Those Environments on the Integrity of the Engineered Barrier System	
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.	Further work on the role of stifling has been planned for FY 2007, and will be included in planning for the long-term corrosion test facility. Collection of dust samples and studies of the role of dust deliquescence on localized corrosion are also expected to continue.
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.	In the current TSPA simulations, general corrosion of both waste package and drip shield materials is assumed to occur at all temperatures. The Alloy 22 general corrosion model is temperature-dependent and the temperature dependency is represented by an Arrhenius relationship. The titanium alloy general corrosion rate is taken to be independent of temperature in agreement with the experimental results of Smailos and Köster (1986 IAEA-TECDOC-421). General corrosion data for Ti Grades 7 and 29 (as well as some analogue alloys) has been collected at 150°C. These data were found to be consistent with the Project's existing models for Ti Grade 7. The data indicated that the Project's model for Ti Grade 29 was somewhat

BOARD FINDINGS AND RECOMMENDATIONS	DOE RESPONSE
	conservative. The Project will continue to collect general corrosion data in high temperature environments.
[F]or Yucca Mountain environments above 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.	SCC requires 1) a susceptible material; 2) a critical environment; and 3) a source of stress. The Project's SCC models assume that waste package and drip shield materials are susceptible to SCC and that a critical environment exists at all temperatures. SCC initiation is subject to a threshold stress and SCC propagation is subject to a threshold stress intensity factor. Current models use SCC initiation data acquired in solutions at temperatures up to 165°C in aggressive SCW solution. Limited crack growth rate data collected in SCW solutions at 175°C agree with more extensive data collected at 150°C. In FY 2007, testing of Alloy 22 specimens containing simulated weld flaws will be continued. These tests are used to evaluate whether SCC will initiate at defect sites. During FY 2007, Alloy 22 U-Bend specimens, exposed for times up to ~9 ½ years, will be evaluated for evidence of SCC initiation and growth.
The Board continues to believe that SCC in titanium alloys cannot be dismissed.	SCC is not expected for the as-emplaced drip shields as they have undergone stress relief treatments (no source of stress is available to drive crack growth). SCC of the drip shield materials can occur under seismic loadings. After seismically-induced cracks penetrate, only limited water flow is expected because cracks in passive materials are tight and tortuous, water would be flowing against a thermal gradient, and there is potential for crack plugging by mineral precipitation and/or corrosion products. During FY 2006/2007, Ti Grades 7 and 29 specimens continue to be tested at General Electric. These data will produce information useful in understanding titanium alloy SCC (e.g., stress and stress intensity thresholds and crack growth rates). During FY 2007, titanium alloy U-Bend specimens, exposed for times up to ~9 ½ years, will be evaluated for evidence of SCC initiation and growth.

BOARD FINDINGS AND RECOMMENDATIONS	DOE RESPONSE
	Testing of titanium alloy specimens containing simulated weld flaws will be continued. These tests are used to evaluate whether SCC will initiate at defect sites.
[T]here 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.	DOE agrees. Although the simplifying assumptions are conservative, they will be examined in light of the best available data. The OCS/STM has a number of research studies in the areas of source term, spent fuel degradation, and radionuclide migration.
The Postclosure Risk Associated with the Proposed Repository	
The Board appreciates the fact that the Project is in the midst of preparing a license application for its 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 intense legalistic process. Consequently, when faced with gaps in understanding, "bounding" 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 a 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 DOE should carry out a realistic performance assessment in parallel with its efforts to develop a compliance case. Such a realistic performance	The Department's approach to the TSPA reflects international experience and Nuclear Regulatory Commission (NRC) staff perspectives, and the unique challenge of modeling transport in partially saturated fractured rock. The Department believes that the performance assessment supporting the postclosure compliance analyses is reasonable for this application and has been developed cautiously. However, Department recognizes the Board's perspective that some aspects of the model might be considered unrealistic. Because the approach that the Department is using for postclosure performance assessment has evolved over many years through interaction with NRC staff and is reflected in the Yucca Mountain Review Plan, it is an integral part of our approach to development of the license application. The Department is currently undertaking development of a performance margin analysis of system performance. This would be used (1) as a management and communication tool, (2) to build confidence in the estimate of repository performance in the compliance-based analysis, and (3) to quantify and help understand the degree of overall conservatism in the TSPA. The Department plans to complete performance margin analyses that will use available data to evaluate the extent of conservatism and/or non-conservatism in the conservative compliance-focused analyses. These analyses will complement the TSPA for compliance.

BOARD FINDINGS AND RECOMMENDATIONS	DOE RESPONSE
assessment would establish a "baseline" for measuring how "conservative" or "non-conservative" DOE'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 occur. Further, to address what now appear to be the critical radionuclides contributing to peak dose, the Board recommends that the DOE 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 with the calculations extending until the time of peak dose or 1,000,000 years.	
Design and Operation of Surface and Subsurface Facilities	
[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 carry out 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?	The Department will continue the integrated system engineering and analyses approach to gain a greater understanding of the interrelationships between the subsystem components: waste acceptance, transportation, and repository operations. These continuing analyses are expected to provide additional insights as design details are further refined and operational scenarios are more fully defined, but will be sequenced to occur as details and scenarios are deemed mature for consideration to ensure that realistic representations of the waste management system are examined. The Department accepted the preliminary TAD performance specifications submitted by BSC. The Department is currently tailoring those specifications to support a procurement action for a TAD conceptual design which, when completed, will address the Board's questions.

BOARD FINDINGS AND RECOMMENDATIONS	DOE RESPONSE
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? ....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.	The Department has completed its Critical Decision-1 (CD-1) process which included a description of surface facility design and operation effects from the TAD. The Department has approved introduction of a canister-based system into the baseline. CD-1 authorized the preliminary TAD design which is underway.
The Board believes the Project needs to refine its drip shield design and implementation approach....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 shields will not be installed until just before repository closure,...the Project should evaluate now what factors will effect 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.	The Department agrees that it is important to evaluate factors that will influence the final drip shield design well in advance of repository closure. The Department plans to fabricate prototype drip shields to evaluate operational envelopes and design and installation tolerances in the performance confirmation drifts. In addition, a revision to the *Seismic Consequences Abstraction*, MDL-WIS-PA-000003, is planned to account for drip shield damage as a function of thinning due to corrosion and response to seismic events in intact and collapsed drifts.
Plans for the Waste-Management System	
The Board considers the Total System Model (TSM) being developed by the DOE to have significant potential as a tool for understanding the performance of the coupled waste-management system. The TSM can be used to examine system	The results of TSM analyses were used to evaluate a primarily canister-based system using TADs for commercial spent nuclear fuel (CSNF). Insights from the TSM analysis included, but were not limited to, factors such as dose, thermal management, and waste handling. The Department

BOARD FINDINGS AND RECOMMENDATIONS	DOE RESPONSE
throughput, identify possible "choke points", and show where various design and operational elements are incompatible. To maximize 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 off-normal conditions; and all components of the waste-management system, including emplacement, need to be incorporated in 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 recommends that that the TSM be used by designers of 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.	recognizes that information obtained from the utilities is important to the quality of the TSM analyses and success of the canister-based approach. The Department has provided information on the new canister-based approach to cask vendors and nuclear utilities and is evaluating technical issues raised by them regarding developing and licensing of TADs. The Department is committed to continuing the close coordination with cask vendor and nuclear utility representatives, not only in the development of the performance-based specification for TADs, but also in the subsequent design of the TADs. The Department will continue the integrated system engineering and analyses approach to gain a greater understanding of the interrelation-ships between the subsystem components: waste acceptance, transportation, and repository operations. This will be done in close cooperation with the utilities and cask vendors.
[T]he Board believes that the DOE should move expeditiously to perform a comparative risk analysis of alternate 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 DOE should develop a contingency plan for greater use of legal-weight and heavy-haul trucking.	In a Record of Decision published in April 2004, the Department selected "mostly rail" as the mode of transport, both nationally and in the State of Nevada. The "mostly rail" option includes an expectation that some truck shipments will be made. In a Supplement Analysis to the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F), the Department considered the potential environmental impacts of shipping legal-weight truck casks on railcars. This scenario involved shipments from generator sites to an intermodal transfer station that would be constructed and operated in Nevada and the subsequent transportation of those casks to a repository at the Yucca Mountain site by legal-weight trucks. In the event that the rail line is not completed when the repository begins operations,

BOARD FINDINGS AND RECOMMENDATIONS	DOE RESPONSE
	these truck transportation options would still be available for initial shipments to Yucca Mountain and will have been fully planned and ready for completion by that time. A full range of transportation contingencies is also being considered for shipment of TAD canisters in the event that the Nevada rail line is not available when the repository begins operations. However, the Department is currently planning the project, subject to available funding, to ensure that the rail line will be completed at least one year before the repository begins operation. Analyses completed for the Final Environmental Impact Statement (FEIS) considered alternative rail corridors with the contingency for some truck shipments.
Localized Corrosion	
Unlike deliquescence-induced localized corrosion, which the Project plans to screen out of the total system performance assessment (TSPA), seepage-induced localized corrosion is not screened out of TSPA. Why seepage-induced localized corrosion and deliquescence-induced localized corrosion are not treated consistently in TSPA remains puzzling to us. The important question is, "Does including deliquescence-induced localized corrosion significantly affect the dose received by the reasonably maximally exposed individual?" Even if the effect is not significant, including this phenomenon would add to the completeness, robustness, and credibility of TSPA. (Garrick, 2007)	The analysis performed by the Project to date concludes that Na-K-Cl-NO_3 (plus other dust components) will define the starting composition of the deliquescent brines that form during the thermal pulse. Any deliquescent brine will contain a temperature-dependent minimum value of NO_3:Cl. The effects of degassing will be to reduce the volume of deliquescent brine and in the limit cause dry-out, or increase NO_3:Cl and the electrolyte pH. Results from experiments conducted at temperatures up to 150°C (Reebak 2006) support the conclusion that localized corrosion will not initiate under deliquescent conditions due to the high NO_3:Cl. Localized corrosion initiation and propagation under deliquescent conditions is further inhibited by the small cathode-to-anode ratio, the lack of oxygen diffusion gradients in the dust layer, the limited quantity of reactants (namely chloride) and the absence of a physical crevice (except in the case of the waste package contacting the pallet). As identified by the Board, the conditions for which data are most limited are for temperatures between 150°C and the maximum predicted waste package temperature of approximately 205°C. Strengthening the Project's position for screening out localized corrosion during the thermal pulse can be achieved by testing under these conditions.

BOARD FINDINGS AND RECOMMENDATIONS	DOE RESPONSE
	To meet this goal the Project is pursuing a collaborative testing strategy that is being implemented at Lawrence Livermore National Lab (LLNL) and Sandia National Lab (SNL). The driver for this testing is to obtain additional crevice corrosion data under conditions that are representative of the repository during cool down. Thin-film experiments being performed at LLNL are designed to assess the crevice corrosion behavior of Alloy 22 and analogue material at temperatures up to 180°C while maintaining ambient pressure. The strategy is to put representative (or bounding) salt assemblages on the samples, and then expose the samples to RH levels sufficient to allow deliquescence at temperatures up to 180°C. Post-test examination will be used to determine if localized (or uniform) corrosion has occurred on these samples. A complementary effort at SNL involves conducting tests in repository-relevant environments at temperatures up to and exceeding 200°C. Importantly, the environmental chamber is capable of maintaining these conditions at ambient pressure and in an open flow-through system (thus preventing artifacts due to uncontrolled evolution of the test environment). Another aspect of the SNL experiments is the option to monitor initiation and propagation in-situ through the use of a direct-current potential-drop (DCPD). DCPD may be applied to both creviced and uncreviced samples of Alloy 22 and less-resistant analogues in an effort to understand the parameters that control initiation and stifling. Instrumentation may also be included that enables monitoring of deliquescence in parallel with monitoring the damage state of exposed materials.

BOARD FINDINGS AND RECOMMENDATIONS	DOE RESPONSE
Prototype testing	
As mentioned at the meeting, the efficacy of engineering designs—including operational processes—can be tested using prototyping. This is especially important in the case of the Yucca Mountain repository because many of the engineered elements are first-of-a-kind designs. Examples of specific elements that could benefit from engineering prototyping include waste package fabrication, loading, sealing, and emplacement; robotics; and drip-shield emplacement. Experience gained from engineering prototyping will enable OCRWM to identify potentially high-consequence design and operational flaws in an orderly and efficient manner. For example, contemporary industrial experience has shown that metal fabrication defects can be susceptible to localized corrosion. This has important implications for performance of the repository waste packages. Many engineering design specifications are important to TSPA calculations. Consequently, engineering prototyping can serve as an integrating mechanism and a cross-check for TSPA. Finally, engineering prototyping can be helpful as the repository program moves its focus from research and analysis to implementation.	The DOE agrees with the NWTRB recommendations on engineering prototyping and is currently prototyping various equipment. The objective of this work is to gather information to supplement the design, ensure safety requirements are met and to reduce risk for development of unique first-of-a-kind items. In the near term, prototyping is focused on waste package closure equipment and prototyping the waste package, pallet, and drip shield. Note that most spent fuel will be shipped in transportation, aging, and disposal containers (TADs); however, some fuel is expected to arrive in dual purpose containers (DPCs). These DPCs will need to be opened for transfer of contents into TADs. Existing technology for opening DPC's and for opening a sealed waste package needs to be more fully developed; therefore, DPC and waste package opening are planned for prototyping in the future. A waste package closure system (WPCS) is being prototyped. This system performs the operations required to complete closure of the waste package after it has been loaded with TAD canisters, navy canisters, DOE Spent Nuclear Fuel (SNF) canisters, or High Level Waste (HLW) canisters containing SNF or HLW. The objective of prototyping the WPCS is to design, develop, and construct the complete system required to successfully close a loaded waste package. An iterative process of revising and modifying the WPCS design will be part of the prototype process. When construction is finalized, a demonstration of closure operations will be performed on a full-scale mock-up of the waste package. The mock-up will be full diameter but not full height of a waste package. This mock-up will not contain nuclear waste but will be heated to simulate the calculated, loaded waste package temperatures. The purpose of the demonstration is to verify that the individual subsystems and the integrated system function in accordance with the design requirements and to establish closure operations procedures. This program is in progress and is also closely coordinated with the waste package design and prototype program.

References

Garrick, B.J., 2007, Workshop on Localized Corrosion of Alloy 22, Letter from B. John Garrick, Chairman, NWTRB to Edward F. Sproat, Director, OCRWM, January 12, 2007.

Garrick, B.J., 2006, Key Elements of the Safety Case, Letter from B. John Garrick, Chairman, NWTRB to Edward F. Sproat, Director, OCRWM, December 14, 2006.

NWTRB (U.S. Nuclear Waste Technical Review Board) 2006. *Report to the U.S. Congress and the U.S. Secretary of Energy, June 2006.* Arlington, Virginia: U.S. Nuclear Waste Technical Review Board.

Sproat, E.F., Letter from Edward F. Sproat, III, Director, OCRWM, to B. John Garrick, Chairman, NWTRB, May 14, 2007 with enclosure "U.S. DEPARTMENT OF ENERGY RESPONSES TO THE DECEMBER 14, 2006, LETTER FROM THE NUCLEAR WASTE TECHNICAL REVIEW BOARD".