Department of Energy
Washington, DC 20585

October 3, 1996

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Dr. John E. Cantlon
Chairman
Nuclear Waste Technical Review Board
1100 Wilson Boulevard
Arlington, Virginia 22209

Dear Dr. Cantlon:

This letter transmits the Department of Energy's response to the Nuclear Waste Technical Review Board's *Report to the U.S. Congress and the Secretary of Energy; 1995 Findings and Recommendations,* also referred to as the Board's *Thirteenth Report,* that was issued on May 14, 1996. Our response to the Board's recommendations are found in the enclosure.

As noted in the Board's report, the Civilian Radioactive Waste Management Program made progress in 1995. In 1996, we maintained the momentum of site characterization, while we revised the Program due to a significant funding reduction and Program redirection from Congress. Our revised approach is described in the May 1996 Revision 1 to the *Civilian Radioactive Waste Management Program Plan.* This approach is based on an increased understanding of the repository from more than a decade of scientific and engineering work at Yucca Mountain, and in particular, the wealth of information gained from recent progress in site characterization. The Revised Program Plan defines a more focused and cost-effective repository program that regains a target date for a license application, if the site is suitable.

We appreciate the Board's continuing concern with the refinement of the waste isolation strategy for a potential repository at Yucca Mountain. Although a condensed version of our strategy was included in the Program Plan, we have not yet agreed on all the details of our approach. The development of the strategy is serving a useful purpose, however, by forcing real integration of the work being done and conceptual integration of the work proposed by participants. We expect that a detailed version of the strategy, including the definition of longer term information needs and work yet to be done, will be completed next year.

The Department appreciates the Board's constructive review and recommendations regarding our technical program. We look forward to receiving the Board's views on the implementation of

the Program's revised approach as we move forward in a technically sound and cost-effective manner. If you have any questions, please contact me at (202) 586-6842.

Sincerely,

Daniel A. Dreyfus, Director
Office of Civilian Radioactive
Waste Management

Enclosure

DOE Response to the Recommendations of the Nuclear Waste Technical Review Board in its 1995 Summary Report to the U.S. Congress and the Secretary of Energy, April 1996

OVERVIEW RECOMMENDATIONS

Recommendation 1:

The DOE should continue to refine its waste isolation strategy to make it more robust, to address potential failure modes, to state the strategy's hypotheses more precisely, and to specify criteria for determining when those hypotheses have been validated or rejected.

Response:

The DOE is continuing to refine its Waste Containment and Isolation Strategy to make it more robust, to address potential failure modes, and to clearly state the strategy's hypotheses. The DOE expects the Waste Containment and Isolation Strategy to evolve as additional data are collected, and as analyses and performance assessments are completed. As the Program proceeds, the DOE will evaluate the relevant hypotheses to determine the degree to which they are confirmed, including the remaining uncertainty in the data and analyses related to their evaluation. Since, in general, the hypotheses are not subject to binary "validation or rejection," the DOE plans to use Total System Performance Assessment (TSPA) and related sensitivity studies to evaluate the degree to which the hypotheses are confirmed and the effect of the remaining uncertainty on the predicted repository performance.

Recommendation 2:

The DOE should evaluate what went wrong in the preparation and NAS review of its technical basis report on surface processes at Yucca Mountain.

Response:

The DOE has evaluated the process used to prepare its technical basis report on surface processes at Yucca Mountain and the National Academy of Sciences (NAS) review of this document. Even though technical basis reports are no longer being developed, the DOE will apply the lessons learned to refine and strengthen its future license application analyses. For example, some of the lessons learned include the importance of providing an adequate schedule for the preparation and review of documents, of increasing the role of project scientists in the preparation and review of regulatory documents, and of providing more detailed documentation to support the technical conclusions contained in the document. For the Project Integrated Safety Assessment (PISA), the appropriate line organizations will be responsible for the technical content, and the review will include the Principal Investigators, as appropriate. The DOE also has provided a realistic schedule for these activities. The final PISA will provide a complete and current site description that can be used to support compliance with DOE's revised siting guidelines.

Recommendation 3:

The DOE's safety demonstration for a repository should be as rigorous and thorough as practical at the time of the initial application for construction authorization. The DOE needs to continue to work with the NRC to determine an appropriate balance between the need for data and reliance on expert judgment.

Response:

If the Yucca Mountain site is suitable, the DOE intends to provide a defensible safety demonstration that is appropriate for the initial application for construction authorization. The DOE agrees that the safety demonstration should be as rigorous and thorough as practical, and must be supported by both field and laboratory data. The approach to preparing the license application recognizes that the NRC must have reasonable assurance that the repository will meet its performance objectives prior to authorizing construction. The DOE believes such assurance can be achieved through a safety demonstration supported by a focused site characterization program that is as comprehensive as practical.

To be acceptable to Congress and other stakeholders, however, the site characterization program must provide meaningful results within rational cost and schedule constraints. Consequently, the DOE must strike a balance between the collection and analysis of site data and the use of expert judgment to address the residual uncertainty in performance assessments in a way that facilitates regulatory decisions. It is inevitable that some uncertainties will exist at the time of construction authorization and for decades thereafter. Some uncertainties are likely to remain at the time of repository closure. Long-term testing, such as *in situ* thermal tests and material corrosion tests, will continue beyond the time of the initial license application as part of a performance confirmation program. The results of this testing will enhance confidence in the assumptions that are the basis for the performance assessments and other safety arguments in the license application.

The DOE is interacting with the NRC regarding the use of expert judgment and its utility in the licensing process. The DOE will not use expert judgment as a substitute for objective, quantitative analyses based on reasonably obtainable data that would measurably affect our understanding of repository system performance. Where appropriate mechanistic models are not available or the collected data lends itself to differing interpretations, however, we will use expert judgment to support technical conclusions. The elicitation of expert judgment associated with the recently completed Probabilistic Volcanic Hazard Assessment is an example of this approach.

RECOMMENDATIONS FOR RISK AND PERFORMANCE ANALYSIS

Recommendation 1:

Building on the strengths (and filling in the gaps) shown in TSPA-95, the DOE should prepare itself for the next, and critically important, role assigned to TSPA—the Yucca Mountain site "viability assessment" in 1998. Assumptions about models and input parameters will need to be highlighted and their bases clearly laid out and open for review.

Response:

The DOE is actively preparing for the upcoming Total System Performance Assessment (TSPA) in support of the viability assessment, which has been tentatively named TSPA-VA. This TSPA will incorporate directly the latest site and design information, including process models developed and documented by the site and design organizations. For each key process model, which would address key attributes identified in the Waste Containment and Isolation Strategy, a small working group will be formed consisting of representatives from both the Performance Assessment organization

and the organization responsible for the development, substantiation, and documentation of the process model. This process will ensure that: (1) all the key performance-related issues associated with each process model are adequately abstracted into the TSPA analyses; and (2) the technical bases used in the TSPA-VA analyses are clearly laid out and open for review. A detailed plan for the completion of the TSPA-VA is being prepared in the current fiscal year. The basic elements of this plan have been incorporated in DOE's Program Plan and have been implemented in the Long Range Plan/Integrated Project Schedule and the detailed planning for Fiscal Years 1997 and 1998.

As suggested by the Board and demonstrated in the succession of completed TSPA analyses, the intent of the next TSPA iteration will be to build on the information collected during previous iterations of the TSPA, as well as comments received from interested parties such as the NWTRB, the NRC, and the State of Nevada.

Recommendation 2:

TSPA should play an integral role in refining and testing the basic tenets of the developing waste isolation strategy. TSPA, for example, could provide an estimate of the amount of percolation flux that could, in turn, require a reexamination of the current strategy. It can also clarify what kinds of data are needed to demonstrate that the safety case has been made.

Response:

The DOE has used the earlier iterations of the TSPAs for the initial development of the Waste Containment and Isolation Strategy and for refining plans in the site and design programs. However, it is important to note that some assumptions in TSPA-1995 are not tied directly to substantiated conceptual models. Care must be taken not to over-interpret the results of TSPA-1995 nor to over-utilize these results in the allocation of testing priorities. TSPA is an iterative process that relies on updated and substantiated process models to provide greater confidence in the results. The DOE agrees that the results of current performance assessments in combination with sound technical judgment should be used to evaluate the hypotheses in the Waste Containment and Isolation Strategy and to prioritize testing needs. The DOE will continue to use the results of TSPAs and related sensitivity analyses to evaluate the degree to which hypotheses in the Waste Containment and Isolation Strategy are confirmed.

Recommendation 3:

The DOE should make an early determination of which aspects of the next TSPA will require expert judgment and make clear to the technical community how these judgments will be obtained.

Response:

The DOE agrees with this recommendation. During the ongoing planning process, the DOE's TSPA staff identified the following five process models that are potential candidates for the use of expert judgment for the next TSPA: unsaturated zone percolation flux; drift-scale thermal hydrology; long-term waste package degradation; waste form dissolution; and, saturated zone hydrology. These recommendations are being reviewed by the scientific and design programs to develop a prioritized list of expert judgment activities to support the next TSPA iteration. Agreement has been reached concerning the need for an expert elicitation regarding uncertainties in the unsaturated zone percolation flux model. Planning the details of this work is now in progress. The DOE has also issued a policy statement on the use of expert judgment entitled "Principles and Guidelines for Formal Use of Expert Judgment, Revision 0" (1995).

RECOMMENDATIONS FOR GEOENGINEERING

Recommendation 1:

The DOE needs to examine both the cost and the rate of progress for excavating the ESF and compare it with planned repository construction methods when assessing the viability of the Yucca Mountain site. Additional modifications to the TBM or use of a TBM of a different design may be needed to improve excavation efficiency.

Response:

Both the cost and the rates of progress for the various ground conditions encountered during excavation of the Exploratory Studies Facility (ESF) are available and will be utilized for planning and evaluating the repository construction methods. Lessons learned from the ESF design and construction will be used to maximize the effectiveness of the repository design associated with assessing the viability of the Yucca Mountain site. These lessons learned also will be used to determine the most efficient method of excavation, including the proper design of the tunnel boring machine(s).

Recommendation 2:

The Board recommends that the DOE set up a procedure to provide timely monitoring of the response and actions of the M&O contractor to the recommendations of the board of consultants.

Response:

A board of consultants from the underground tunneling industry has been utilized to provide independent review of the ESF construction and design activities. Its recommendations were considered by the Management & Operating Contractor (M&O); the M&O produced a close out report and provided it to DOE for comment in July 1996. The final report will be transmitted to DOE by August 30, 1996. The current focus of the board is on repository design activities required for the viability assessment. When input has been received from the board of consultants, the M&O contractor actions will be tracked.

Recommendation 3:

The Board supports initiation of a long-term, tunnel-scale thermal test as soon as possible and recommends that more thought be given to how more information can be obtained from all heater tests.

Response:

The DOE appreciates the Board's support of early initiation of drift-scale or tunnel-scale thermal testing in the ESF. Implementation of the *in situ* thermal testing program receives high priority, and construction of the thermal testing facility is proceeding on schedule. Ambient temperature measurements to characterize the single-heater test block have been made and installation of the instruments is under way. On August 26,1996, the heater for this test was switched on as planned.

The May 1996 Program Plan, Revision 1, identifies that the initiation of the heat-up cycle of the drift-scale test

would occur in the July 1997 time frame. As a result of new planning assumptions, it is now expected that the drift-scale test heating phase will start toward the end of Fiscal Year 1997. The large block test at Fran Ridge, suspended at the end of Fiscal Year 1995, is planned to be resumed in Fiscal Year 1997. The heat-up cycle of the large block test will be started in February 1997. Small block tests and thermal property measurements in the laboratory will continue in Fiscal Year 1997.

The *in situ* thermal testing program has several components. The drift-scale test, by its large size, long duration, and complex suite of measurements, is intended to provide maximum information toward the understanding of heat-driven near-field processes. Plans and designs for the drift-scale test underwent in-depth Project review in recent months to ensure that Project needs have been addressed by the test. The plans and design of the test are summarized here and are followed by a description of the objectives.

- In the drift-scale test, a drift approximately 55 meters in length will be heated over a period of several years by electric heaters placed on the floor of the drift. The heaters will be similar in dimension to the waste package canisters to be used in the repository. In addition, a planar array of rod heaters, referred to as wing heaters, will be inserted into regularly spaced holes drilled in both walls of the drift at approximately the mid-height. The wing heaters are meant to simulate the presence of heated emplacement drifts on either side of an emplacement drift. They also enable a large volume of rock to be heated in a reasonable time.

- During the heating phase, the total heat output available from the canister heaters on the floor of the drift will be approximately 80kW, and that from the wing heaters will be approximately 200kW.

- After two years of continuous heating, test results will be evaluated to decide whether to continue the heating further and, if so, for how long. Heating may be continued for up to four years, to be followed by a period of controlled cooling and then natural cooling.

- The volume of rock surrounding the drift that will be heated above 100°C will exceed 30,000 cubic meters. The temperature in the drift wall will not be allowed to exceed 200°C to 250°C. The temperature in the floor immediately under the canister heaters will be higher. The rock close to the wing heaters may reach temperatures several hundred degrees higher.

- The heated drift will be similar in size and shape to repository emplacement drifts. It will be circular in cross section, 5 meters in diameter, and have a cast-in-place concrete invert. The first 35 meters of the drift will primarily be for observing thermo-hydrologic-chemical processes. Approximately 10 meters of this 35-meter length will be supported by steel sets and partial lagging. The rest will be supported by rockbolts and welded wire mesh. The next 10-meter length of the drift will be supported by a cast-in-place concrete liner, and the last 10 meters will be supported by precast concrete segments. The drift-scale test will help build a defensible understanding of the following: (a) large scale heat-transfer mechanisms including the role of convection, heat pipes, and enhanced diffusion; (b) moisture movement including the formation of dry-out and condensate zones, sub-boiling mobilization toward and away from the drift, shedding/drainage and downspout rewetting; (c) geochemical processes including return (to waste packages) water chemistry, evolution of near field water, changes in hydrologic pathways due to chemical processes, and changes in matrix transport properties; and, (d) thermomechanical processes including rock mass properties, changes in fracture aperture, new fracture formation and changes in near field stresses and displacements. More details about the objectives of the test and a brief description of the methods to achieve the objectives are given as follows:

- Prior to the installation of any instruments, the rock in the test area will be characterized. Such characterization will include mapping of all exposed surfaces; video logging all boreholes; measuring bulk permeability *in situ-,* and measuring thermal expansion, thermal conductivity, deformation modulus, moisture saturation, porosity, density, moisture imbibition potential, and mineralogic-petrologic characteristics in the laboratory.

- Various measuring systems will be installed in holes drilled from the heated drift (before heating) as well as from an observation drift parallel to the heated drift. Measurements will be made of rock temperature; movement of moisture in the rock; pressure, temperature and humidity of the air in the rock and in the drift; changes in rock-water chemistry; displacements in the rock; changes in the loads on ground support; and, changes in rock stress.

- In the drift-scale test, rock temperature, which provides the most important signature toward understanding heat-driven processes, will be measured at more than 4000 locations in the volume of heated rock at a rate of at least one measurement per sensor per hour.

- A number of different techniques will be employed to measure the moisture content of the rock as it changes with heating and cooling. The electrical resistivity tomography (ERT) method will measure the bulk moisture content of large volumes of rock. More than 1000 electrodes will be employed to make literally millions of individual resistivity measurements, and thus water contents, during the course of the drift-scale test. The well-established neutron-logging technique will be used to measure the moisture content of the rock in close proximity to 10 strategically located boreholes. If ground-penetrating radar proves effective in earlier trials, then it will also be used in the neutron logging holes to measure the moisture content of larger volume of rock. Continuous (one record per sensor per hour) measurements of pressure, temperature, and relative humidity of the air in approximately 100 chambers created using packers in 10 holes will also provide information for inferring the movement of moisture as the rock is heated and then cooled.

- Air injection tests involving injection of air in one of the "packered"chambers and monitoring the response in the others will help in understanding how the bulk permeability of the rock changes with heating and cooling. Results of the air injection tests will also help in delineating the condensate zone, if any.

- Up to 13 different chemical parameters will be monitored *in situ* at approximately 100 locations in 10 boreholes. Liquid water, if available at the sampling points, also will be collected periodically and will be analyzed from similar numbers of locations in these holes. This information, together with the mineralogic characteristics of the rock analyzed before heating and after cooling, will help in understanding the kinetics of rock-water interaction.

- Coupons of potential waste package material will be placed in the rock and in the drift, and will be subjected to heating and cooling during the entire duration of the test. In addition, the heaters will be partly constructed from candidate waste package materials. Information on the response of these coupons and materials will enable the models of waste package material degradation to be refined.

- The different ground-support systems in the heated drift are intended to provide information on how they perform under thermal stress, in an atmosphere of changing temperature and humidity, and at a drift scale, at least in size, if not time. Specifically, rock-support interaction; potential corrosion and degradation of support material; and possible debonding of concrete liners, shotcrete, and rockbolt grout will be studied in the drift-scale test. Also, approximately 100 measurements of displacements in the rock will be made periodically in approximately 15 holes. Literally thousands of rockbolt load and steel set strain measurements will be made during the course of the drift-scale test.

- The drift-scale test will not provide information to directly address the issue of condensate zone coalescence. However, data from the drift-scale test, together with model simulations, will assist in investigating the likelihood of the phenomenon of condensate coalescence.

The drift-scale test is the most important component of the thermal tests, but the other tests also contribute to the understanding of thermal processes and are part of the Project's thermal testing strategy.

The large block test provides timely information that will not be obtained in any of the other tests. The large block test has been designed specifically to create, if possible, and to observe a refluxing zone above the heaters. Formation of such a zone is not possible in the single heater test. Although refluxing is possible in the drift-scale test, the earlier results and controlled initial and boundary conditions are some of the reasons that make the large block test an important component of the thermal task. In addition, for both underground tests, rewetting after the thermal pulse decays is expected to be a slow process, with data from the *in situ* tests available only after many years. The large block geometry allows for much easier control of a forced rewetting phase, and it will provide results sooner for Viability Assessment and License Application. Furthermore, the large block test will have tracer tests to provide information on transport properties, which is not currently planned for either underground test. The only large-scale field tracer test to date has been for ambient temperature, saturated conditions at C-wells.

The single heater test also has value in that it finishes much sooner than the drift-scale test. It also fits in the Project strategy of progressing from simpler, smaller, shorter tests to more complex, bigger, longer tests. The simplified geometry of this test compared to the drift-scale test also has value in investigating thermal processes and in measuring the associated value of parameters such as thermal conductivity. One of the values of the test from a management viewpoint is that even though it is followed closely by the drift scale test, it provides valuable information on test construction, instrumentation, and coordination of the many groups involved in a complex test.

The large block test will provide the only *in situ* information of transport properties for unsaturated and/or thermally disturbed conditions. Also, there are tests conducted in the laboratory at above-ambient temperatures. The laboratory thermal tests are valuable in that they are the smallest scale, and thus the quickest and cheapest. Their scale also allows for better control of test conditions so that particular phenomena can be studied one at a time, instead of being combined as they are in larger tests. Although these small scale measurements are not representative of a drift-scale property, they can be correlated to the larger scale measurements made in the *in situ* tests. This correlation will then permit characterization of a large repository to proceed based largely on many smaller, easier tests, rather than relying solely on larger, more expensive tests.

RECOMMENDATIONS FOR HYDROGEOLOGY AND GEOCHEMISTRY

Recommendation 1:

The Board encourages the DOE to focus sufficient resources on verifying a sound conceptual model of flow in the unsaturated zone. This exploration and testing should provide the needed evidence for assigning quantitative bounds to the infiltration flux and percolation flux and should provide general support for the unsaturated zone flow model.

Response:

The DOE recognizes the need to test and refine the current conceptual model for the unsaturated zone hydrologic system at Yucca Mountain, as well as the need to establish quantitative bounds on the net-infiltration flux into the mountain and the percolation flux across the potential repository horizon. To accomplish these goals, the DOE is planning to continue and to augment current studies that are focused on these issues as follows:

- Systematic sampling within the ESF of fracture and lithophysal cavity in-filling materials for depositional-age determinations using uranium-series, carbon-14, and other techniques will be continued in order to construct a history of past water movement through the unsaturated zone.

- Systematic and feature-based sample collection within the ESF for chlorine-36 analyses will be continued. These analyses, specifically the apparent occurrences of “bomb-pulse” chlorine-36 associated with mapped

structural features in the ESF, may identify potential "fast" flow pathways through the unsaturated zone. Both the systematic and feature-based chlorine-36 sampling complement the fracture depositional age data and the interpretations derivable from the depositional ages.

- Detailed *in situ* hydrologic and pneumatic characterization of the Ghost Dance Fault will be conducted at two locations within the ESF to test the hypothesis that this feature may constitute a potential "fast" pathway for fluid flow in the unsaturated zone.

- Pneumatic, water-potential, and temperature monitoring will be continued in selected instrumented boreholes to determine ambient conditions within the unsaturated zone and to monitor dynamic changes in response to barometric fluctuations, to ESF-induced effects, and, possibly, to transient infiltration events. These data not only define conditions and processes within the unsaturated zone but they also provide data needed to calibrate the numerical predictive models of fluid flow in the unsaturated zone.

- An ESF-based field activity based on existing study plans is being designed specifically to test the prevailing unsaturated zone conceptual model and to obtain bounding estimates of the *in situ* percolation flux transiting the Paintbrush nonwelded hydrogeologic unit and moving downward across the potential repository horizon. This activity is intended to yield bounding estimates of water flux in the rock matrix and, possibly, in fractures under prevailing ambient conditions within the unsaturated zone at Yucca Mountain.

- As discussed under Risk and Performance Assessment Recommendation 3, an expert elicitation is to be conducted in 1997 to help the DOE evaluate the uncertainties in the unsaturated zone flow model.

Recommendation 2:

The DOE should place a stronger emphasis on predicting (or bounding) the release rates of important radionuclides from the EBS. Specifically, the DOE should evaluate alternative models for the seepage flux (water entering repository tunnels) and the concentration of neptunium in the water leaving the EBS.

Response:

The DOE agrees that predicting (or bounding) the release rate of important radionuclides from the engineered barrier system (EBS) is an important component that impacts the overall system performance. The DOE is evaluating a range of alternative conceptual models of seepage into the drifts. These models include using different scaling laws to correlate average "bulk" hydraulic properties to the likelihood and magnitude of seepage flux. Modeling of the effects of heterogeneity in rock properties and possible backfill properties on the possible distribution of seepage flux is also being conducted. The TSPA-1995 results illustrate the significance of the seepage flux into the drifts in controlling EBS release rates for the soluble radionuclides that may be transported in the aqueous phase. This significance has also been noted in the Waste Containment and Isolation Strategy. A number of sensitivity analyses are being undertaken in the current fiscal year to further evaluate the significance of the alternative seepage models.

The concentration of radionuclides leaving the EBS is dependent on a number of processes, including the dissolution rate of the spent fuel and the solubility of the key radionuclides in the water. Further analyses of spent fuel dissolution and neptunium solubility data (as well as numerical modeling of a range of possible solubility values) will allow alternative parameters to be used in TSPA analyses, the consequences of which will be evaluated in the current fiscal year. The validity of the range of parameters used will be the focus of ongoing analyses in Fiscal Year 1997.

RECOMMENDATIONS FOR ENGINEERED BARRIER SYSTEM

Recommendation 1:

The DOE should continue its efforts to identify engineering concepts that could help the EBS accomplish the three roles (complete containment, low mobilization, slow release) set out for it in the waste isolation strategy. Once identified, the DOE should set priorities for the concepts and decide which merit further investigation.

Response:

The DOE concurs with the Board's recommendation that it continue to identify approaches that will help the EBS accomplish its three goals and that it should determine those meriting further investigation and those that do not.

Planned work includes evaluation of the following approaches: the use of a long-lived container; the applicability of cladding credit for control of release; the addition of components such as backfill and drip shields; and the applicability of credit for the invert in controlling release from the EBS. These and other approaches need to be evaluated as part of an integrated design for the EBS. For example, backfill in the emplacement drifts might improve containment by keeping the waste packages dry, but it might also increase waste temperatures to the point that there is excessive mobilization of radionuclides in packages that breach early.

Recommendation 2:

The DOE should consider increasing the robustness of the EBS for preventing nuclear criticality after repository closure. In particular, the use of depleted uranium in filler, backfill, or invert material is a concept the program has yet to explore adequately.

Response:

Since the Board's report was written, two analyses have been completed: "Second Probabilistic Criticality Analysis: Generation and Evaluation of Internal Criticality Configurations" (1996) and "Probabilistic External Criticality Evaluation" (1996). The former deals with the consequences and, to a lesser degree, the probabilities of internal criticality events; the latter deals with probabilities of external criticality events. A third analysis, which discusses both probabilities and consequences of external criticality events, is in preparation. All three analyses indicate that both the probability and the consequences of criticality are small. In addition, recent studies that were not performed under the aegis of the Civilian Radioactive Waste Management Program have predicted that both the likelihood and the consequences of criticality events would be negligibly small. The DOE is continuing its program of criticality analysis, including the possibility of nuclear explosions, but does not expect to find any significant performance benefit in additional measures to decrease either the likelihood or consequences of criticality events. We will continue to view use of depleted uranium as one possible factor in criticality control. However, as the designs develop, the risk associated with criticality will continue to be a major determinant of their adequacy, and modifications will be considered that reduce risk without imposing disproportionate cost.

Recommendation 3:

Attempts should be made to locate data for iron artifacts to check extrapolations of corrosion models for waste packages based on short-term data.

Response:

The corrosion testing and modeling activity has been following the approach outlined in the ASTM procedure C-1174 (Prediction of Long-Term Behavior of Waste Package Materials Including Waste Forms Used in the Geologic Disposal of High-Level Nuclear Waste). This procedure provides a parallel path of testing and model development that includes both short- and long-term testing and the use of natural analogues.

The DOE has considered natural analogues and has reported its findings in a final report of the Natural Analogue Review Group entitled "Applications of Natural Analogue Studies to Yucca Mountain as a Potential High Level Radioactive Waste Repository," 1992. This document discussed what was known at the time regarding native iron and copper and metallic artifacts. The site of Santorini in Greece was specifically mentioned as an opportunity to study the fate of varied metallic artifacts buried in tuffaceous materials comparable to Yucca Mountain.

Since 1992, because of programmatic funding constraints, the budget for the natural analogue program has been limited, and little new work has been performed. A small effort was funded in Fiscal Year 1995 and partly into 1996 to examine the corrosion of candidate container materials in the geothermal wells in New Zealand; this work is currently on hold. However, the Project has followed the work of others, such as the NRC and other international programs. Funding has been identified to restart this effort in Fiscal Year 1997.

Recommendation 4:

The DOE should give a high priority to the corrosion research program for candidate waste package materials and should maintain an appropriate and consistent level of support for the next several years.

Response:

The DOE continues to recognize the importance of this effort in supporting waste package design and performance prediction. The need to confirm the performance of the candidate waste package materials, particularly those that contribute to containment, has been strongly addressed in the Waste Containment and Isolation Strategy. Long-term testing of these materials is underway at Lawrence Livermore National Laboratory following its "Activity Plan for Long-Term Corrosion Studies" (E-20-50, Rev. 2, 1995). The DOE also is performing short-term materials testing.

Recommendation 5:

The use of fillers to prevent void space collapse should be evaluated.

Response:

Since the Board's report was written, calculations have been completed on the loss of structural strength of the waste package as the containment barriers are degraded by corrosion. This work has been reported in several analyses and in a technical document. The waste package was found to have substantial mechanical integrity until the containment barriers have been severely thinned. Perforation seems likely to occur before extreme thinning. The DOE agrees that filler could provide a modest increase in mechanical support for a severely thinned container, but there are many disadvantages of filler. The cost and operational complexity of adding filler are significant, particularly for fuel that had been previously canistered. Recent results from thermal conductivity tests also suggest that even granular metallic fillers, such as steel shot, would raise internal temperatures substantially. Granular metallic fillers would be expected to

corrode and swell when the container perforates, and it is possible that such swelling would cause rupture of the container. Finally, filler would increase waste package mass. The DOE will continue to evaluate filler material as one option for enhancing criticality control or other elements of performance.

RECOMMENDATIONS FOR ENVIRONMENT AND PUBLIC HEALTH

Recommendation 1:

The DOE's socioeconomic program should expand the range of standard effects being considered to include those that will arise from increased transportation of materials, and personnel, possible social problems associated with "boom-and-bust" cycles, and the effects of controversial projects on the larger social system.

Response:

As the Board has observed, the socioeconomic program has studied and the DOE continues to evaluate potential impacts related to population change. In addition, the DOE examined the potential effects resulting from increased transportation of materials and personnel in the "Section 175 Report: Secretary of Energy's Report to the Congress Pursuant to Section 175 of the Nuclear Waste Policy Act, As Amended" (DOE/RW-0205, 1988). In an environmental impact statement for a proposed repository, that research will be addressed and an analysis will be made of issues regarding the full range of foreseeable potential impacts to human health and the environment, including socioeconomic impacts. The plans for the socioeconomic program currently do not include research of topics such as the effects of controversial projects on the larger social system, and it is unlikely that research into that issue will be pursued.

Recommendation 2:

An uncertain legal situation prevails with respect to special socioeconomic impacts. As a result, as long as the site-suitability guidelines remain in effect, the Board believes a modest research and analytic effort would be prudent. The DOE should concentrate its efforts on deriving worst-case, bounded estimates of what consequences might arise and how long those impacts might last.

Response:

The Department does not have an obligation under the site suitability guidelines to evaluate "special" socioeconomic impacts, i.e. those from perceived risk. The Department has, however, attempted to remain cognizant of the research and academic debate that have transpired in this relatively new field of inquiry, and has sponsored work by university and national laboratory professionals on this topic. While some limited, additional work may be feasible in this area, DOE must ensure any additional expenditure of resources on special socioeconomic impacts is consistent with Congressional redirection of the Program.