Statement for the Record

Dr. John E. Cantlon, Chairman
Nuclear Waste Technical Review Board

before the

Committee on Energy and Natural Resources
United States Senate

March 2, 1995

Chairman Murkowski and members of the Committee. Thank you for this opportunity to submit a statement for the record. I am John Cantlon, Chairman of the Nuclear Waste Technical Review Board.

As you are aware, in 1987, through the efforts of this Committee, the Congress established the Nuclear Waste Technical Review Board. The Board is charged with reporting to the Congress and the Secretary of Energy on the technical and scientific validity of the Federal government's program for the management of civilian spent nuclear fuel and some defense-related high-level radioactive wastes. Our scientific and technical conclusions are reflected in semi-annual and special reports to the Congress and the Secretary and letters to the Department. This testimony will summarize our most recent communications, but I request that a list of the current Board members and the text of our most recent communications appear in the record along with my testimony.

As noted, the Board's charter is to review the scientific and technical validity of the Federal government's civilian radioactive waste management activities. As it has reviewed the DOE's approach to site characterization and repository development, the Board has adhered to several basic scientific and technical principles that I would like to share with the Committee.

Our most recent efforts, Mr. Chairman, encompass those activities related to the DOE's new program approach to determining the suitability of the Yucca Mountain site for locating a permanent underground high-level waste repository. Our review also includes activities related to

- surface-based studies and underground site characterization and testing,
- interim storage and transportation, and
- waste package and repository design.

In many cases, however, we have found that before we could undertake a meaningful evaluation of the technical and scientific aspects of the program, we needed to acquire a general understanding of the related nontechnical factors, such as management, that were affecting the program.

As I will discuss later in my statement, among the critical institutional factors of concern are schedules and program funding as well as the question of when the DOE will be in the position to begin accepting spent nuclear fuel from nuclear utilities, and in what form it will be accepted.

Although outside the principal purview of the Board, these nontechnical factors have, important implications for the scientific and technical integrity of the Federal program. The Board believes the Committee should be aware of their potential implications for the technical program, so I will discuss them in my closing remarks.

As the Committee is aware, beginning with the 1982 Nuclear Waste Policy Act, the Federal government's civilian radioactive waste program has been driven by overly optimistic schedules. Following enactment of the 1987 Amendments, the DOE's Office of Civilian Radioactive Waste Management (OCRWM) proposed a comprehensive set of site-characterization activities with an expectation of large budget increases. However, the DOE did not ask for, nor did the Congress appropriate, the necessary funds to accomplish the scope of tasks that the DOE had set out for itself, in part, out of general concern for the Federal deficit.

With each budget cycle, the backlog of inadequately addressed, but important, technical and scientific activities steadily increased. Furthermore, a large share of the appropriations that the program did receive went to fund overhead and infrastructure rather than direct project costs.

The Board is encouraged by the changes that the DOE has initiated over the last year and hopes that the program's managers will be successful in eliminating the duplication of effort among contractors that seems to have occurred over the years. However, we would observe that the number of contractor organizations remains quite large and staffing continues to grow. For example, in the first four months of this fiscal year, there was an increase 330 full-time equivalent contractor personnel at OCRWM — up to 2,946 FTE's — or a 12.6 percent increase.

On several occasions, our Board has criticized the DOE's own allocation of resources as fundamentally inconsistent with their optimistic work schedule. Among the Board’s recommendations for completing DOE-scheduled activities were (a) establish priorities and intermediate goals based on a thorough understanding of the overall waste management system; (b) allocate more money to scientific studies and less to overhead and infrastructure costs; and (c) set realistic target dates for achieving important intermediate goals, such as beginning underground excavation and testing and determining site suitability.

The Board wishes to commend the current Department and OCRWM leadership for its recognition of these problems and its willingness to tackle a job made more difficult by unrealistic schedule deadlines and years of overly optimistic budget assumptions that did not

materialize as actual budget requests. Since Dr. Dreyfus took over as director of the OCRWM last fall, significant progress has been made in dealing with this legacy. The December 1994 *Program Plan* is an earnest *first* attempt by the DOE to refocus its resources on what are perceived as those activities required for determining site suitability.

I repeat, for the *first* time the DOE has the elements of a mission statement for its civilian radioactive waste management program that are reflected in the current *Program Plan.* This plan is geared to three intermediate milestones. First, the DOE anticipates a decision in 1998 about the technical and scientific suitability of the Yucca Mountain site. Second, if the site is found suitable, in 2000, after evaluating environmental, transportation, and socioeconomic issues through the development of an environmental impact statement (EIS) for the proposed repository, the Secretary of Energy would recommend the site to the President for development as a repository. And, third, if approved, the DOE would then submit in 2001 an application to the Nuclear Regulatory Commission for a license to begin repository construction.

Currently, the Board is reviewing the December 1994 *Program Plan.* The results of our initial review will be addressed in the Board's 11th report which will be provided to you in about three weeks.

I would like to take the opportunity at this point in my testimony to provide the Committee with the Board’s perspective on the improvements and progress that have been made in this program since Dr. Dreyfus assumed responsibility for it, and some concerns that still remain.

As we are all aware, the determination of site suitability is the first major milestone in repository development under the new approach. If the DOE finds the Yucca Mountain site suitable, the DOE's efforts to successfully *demonstrate* that it can per recent edits to 11th report construct a safe radioactive waste repository become critical. If the DOE does not present its case clearly and convincingly to the Nuclear Regulatory Commission (NRC), the DOE may be faced with costly and time-consuming delays during the licensing process.

From what we now know, it is our preliminary view that there are risks as well as opportunities associated with this new approach. Among the risks are the increased technical and scientific uncertainties that will be created because less data and analysis than previously planned will be provided *upfront* for determining site suitability and for applying to the NRC for a license to construct a repository. Among the opportunities is the chance to refocus and

streamline the program and to establish clear, near-term goals against which real progress can be demonstrated, although achievement of the objectives of the new approach will not be seen for many years. The Board is very concerned about the limited time available to collect and analyze the necessary data by the 1998, 2000 and 2001 scheduled dates.

As chairman of the Nuclear Waste Technical Review Board, I would like to highlight some of the recommendations that the Board will be making in its upcoming report. Some of them were made in past reports in some form but remain pertinent.

First, there is a need to look at the management of high-level radioactive waste as a system and set priorities accordingly.

Before this can be accomplished there is need for a clear and coherently articulated waste isolation strategy that takes into account the salient characteristics of the Yucca Mountain site and the ability and desirability of specific repository engineered barriers to enhance waste isolation. This is particularly important given the need to evaluate the DOE's tentative repository thermal management plans and the additional programmatic emphasis that is being placed on engineered barriers, extended retrievability, and postemplacement monitoring.

The waste isolation strategy also needs to be robust enough to accommodate possible changes in the basic criteria that will be used to assess the performance of the proposed repository and the standards and regulations that will be used to license the repository, which are currently undergoing review.

There also is need for a management and organizational commitment by the DOE to develop more systematic and effective ways of using iterative total system performance assessments to guide site characterization and to review priorities at Yucca Mountain. The use of performance assessments — based on a coherent waste isolation strategy — becomes even more critical now, if the program increases its reliance on postemplacement confirmatory testing — as opposed to providing comprehensive data and analysis to support a license to construct the proposed repository. The Board suggests that the Department examine closely the manner in which performance assessment was and is being used at the WIPP facility in New Mexico.

In the past, the DOE has not given adequate consideration to the interdependent nature of the elements of the waste management system, from the generation of the waste through its storage, transport, and ultimate disposal. A clear understanding of the waste management system and all its linkages is essential to developing a coherent and integrated program.

Second, the DOE should examine carefully the experience of others during the site-assessment process; particularly the influence of nonscientific and nontechnical factors.

In 1994, the Board decided to examine the experiences of others in assessing potential sites for critical or highly controversial facilities, such as low-level radioactive waste repositories, hazardous waste facilities, nuclear power plants, and other large engineering projects. Much can be learned from this experience.

Several commonalities emerged that are applicable to the Yucca Mountain project: (1) the importance of having clear strategies for site assessment, site-suitability determinations, and licensing; (2) the significance of uncertainty and the use of expert judgment; (3) the inevitable occurrence of surprises as site investigations proceed; (4) problems caused by technical and institutional overconfidence; and (5) the importance of independent technical review, quality control, and clear regulations.

But, equally important, political and process-oriented issues were found to be critical — *often overriding technical concerns.*

Third, the DOE needs to place greater emphasis on accelerating the underground exploration and testing program.

Getting underground to look at the site's complex geology is critical in determining whether the site is suitable for repository development. This recommendation, which was first made by the Board in 1991, remains pertinent. Therefore, in its December 6, 1994, letter to Dr. Dreyfus (which is attached), the Board indicated a need for substantially more underground excavation than currently is planned.

Fourth, unrealistic schedule deadlines that cannot be achieved also serve to increase frustration and erode confidence in the program. The DOE should establish realistic schedules for achieving its important intermediate milestones, and these should be reflected in current statutory deadlines.

We believe that schedules are vital if program momentum is to be maintained and progress measured. We also believe that important technical and scientific activities that were previously considered critical, not suddenly be truncated or eliminated under the combined pressure of arbitrary schedule deadlines and budgetary constraints. Without sufficient surface-based and underground data and accompanying analysis, the DOE will be forced to rely heavily on expert judgment and bounding assumptions, which may be less effective in winning public

confidence. The existing schedule may not provide sufficient time to complete the necessary site - exploration; for example, excavation across the block to explore known, and possibly unknown, faults at the repository level.

The Board thus continues to be concerned that, under the current schedule, important long-term, and perhaps more expensive, activities (e.g. an east-west excavation across the block at the repository level, initiation of in-situ thermal testing, and excavation below the repository in the Calico Hills formation) may be delayed or replaced by other, less efficacious, shorter duration activities.

An equally important concern of the Board is that the current schedules allow little time to accommodate the kinds of surprises that are often encountered worldwide in underground projects.

The Board recognizes the demands being placed on the program by overriding concern for meeting the 1998 and 2001 deadlines. Nevertheless, the Board is very concerned that important program decisions are being driven by unrealistic deadlines at some risk to the program.

Fifth, the DOE should allocate more of its resources to research and development of engineered barriers, and a robust, long-lived waste package.

Since it issued its first report in March 1990, the Board has underscored the importance of research related to the development of engineered barriers, including a robust, long-lived waste package, to help reduce uncertainties and enhance the long-term safety of the repository system. It appears that the DOE plans to increase funding for waste package development; we hope this happens; it is a move the Board strongly endorses.

Before closing, I would like to comment on the Board's perspective regarding legislation currently pending before the Committee. The Board views its role as one of providing technical and scientific information to policy makers, such as this Committee, as these bodies conduct their oversight of the Federal government's civilian radioactive waste management program and make their important policy recommendations as amendments to the Nuclear Waste Policy Act.

The Board itself has not taken a position on the need for legislative action. Of course, if the Committee so desires, the Board can, and is prepared to, evaluate the technical and scientific implications of legislative proposals under consideration by the Congress.

In this regard, in its October 1993 *Special Report,* the Board observed that the *urgent task*

of providing safe storage of spent fuel does not appear to present any substantial technical problems.

Currently, there are approximately 25,000 metric tons of spent fuel stored at reactor sites around the country, and this amount increases at the rate of about 2,000 metric tons per year. By 2030, approximately 87,000 metric tons of spent fuel will have accumulated. Therefore, even if a repository is constructed according to the DOE's schedule, substantial amounts of spent fuel will remain in storage at reactor sites for decades. To date, the implications of this extended interim storage have not been addressed by either the DOE or the utilities. In the next few months the Board will complete its technical review of the situation. The result of this technical review of the interim storage of spent fuel will be communicated to the committee and the Secretary when it is completed.

As part of our technical and scientific evaluation of the program, the Board has discussed the need to ensure that, in the interest of safety, adequate funding needs to be guaranteed during the full retrievability period both to complete the additional testing requirements and to cover the costs of retrieving the waste for any purpose, should that need arise. Given the DOE's new program approach, one important area that the Committee may wish to explore is the adequacy of funding over the very long term for the testing, monitoring, and possible spent fuel retrieval that is envisioned by the DOE for approximately 100 years once the waste has been emplaced in a repository.

In closing, I would like to observe that the Board believes that there is currently no convincing evidence that the Yucca Mountain site is not technically suitable for a well- designed repository. The Board also believes that the current Departmental leadership should be commended for recognizing the fundamental inconsistency among the schedule, the amount of work planned, and the funds made available to the program.

Immediate opportunities do exist to improve many aspects of the DOE's program. Among the opportunities listed in our December 6 letter are increased emphasis on site suitability, the clear articulation of a waste isolation strategy, the setting of priorities, and the allocation of funds to focus on the development of a long-lived waste package. This (mid-course correction) also provides an opportunity to improve the interface between the DOE and the NRC so as to capture the full potential of the DOE's programmatic changes.

As the specifics of the Department's new program approach evolve the Board will

continue to assess their technical and scientific implications. The Board also will be taking a close look at the timetables for important site-characterization activities as they are continually being updated, including timetables for underground excavation and testing and the determination of site suitability.

The results of these ongoing reviews will be communicated to the Congress and the Secretary as they are completed. However, whatever the outcome of our scientific and technical evaluation, the Board wishes to emphasize how critical it is for the DOE to set priorities within the waste management system that are based on a coherent waste isolation strategy — not on how much testing can be accomplished within the constraints of the current schedule and available appropriations.

Thank you, Mr. Chairman, for this opportunity to convey the Board's appreciation to you and your Committee for its continuing leadership on this vital national program.

Attachment: December 6, 1994 letter to Dr. Daniel A. Dreyfus, Director, Office of Civilian Radioactive Waste Management, from Dr. John E. Cantlon, Chairman, Nuclear Waste Technical Review Board.

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
1100 Wilson Boulevard, Suite 910
Arlington, VA 22209

December 6, 1994

Dr. Daniel A. Dreyfus, Director
Office of Civilian Radioactive
Waste Management
U.S. Department of Energy
Washington, DC 20585

Dear Dr. Dreyfus:

During the past six months, the Nuclear Waste Technical Review Board has met on several occasions with representatives of the Department of Energy (DOE) to gain a better understanding of your new program approach to developing and licensing the nation's first spent fuel and high-level waste repository. Ideally, one should be able to discern in the program a direct linkage among a waste isolation strategy, key decisions, technical activities, budgets, and schedules. Although the program has not yet reached this level of integration, the Board is encouraged that the program seems to be moving in this direction. It is in this spirit that we offer our comments on the evolving civilian radioactive waste management program.

The Board understands that many details of the program approach have yet to be worked out; however, we have some concerns that we believe should be brought to your immediate attention. The points listed briefly below are discussed in more detail in the enclosed document.

- A clearer definition of "technical site suitability" is needed now to establish a sound basis for future program efforts.

- The DOE should continue to develop a waste isolation strategy to provide an improved technical basis for deciding which site-characterization tests will be completed, deferred, or deleted.

- Perhaps the single most important goal in characterizing the site is predicting (or placing bounds on) the amount and significance of water that could reach the repository, corrode waste packages, and transport radionuclides to the environment.

- The effects of waste heat on repository performance must be understood well enough to permit confident predictions of (or bounds on) repository performance for alternative thermal loadings.

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- A few alternatives for the thermal loading of a Yucca Mountain repository should be carried forward until a better technical basis has been developed for choosing a preferred loading.

- The Board believes that substantially more underground excavation will be needed for a technical site-suitability decision than currently is planned.

The enclosed document also summarizes the site studies and other activities that the Board believes are most important for reducing cunent uncertainties about the suitability of the Yucca Mountain site.

In closing, let me emphasize that the Board views the new program approach as an excellent opportunity to streamline the scope of site-characterization activities and to improve the technical bases for program decisions. However, completing the necessary site studies and repository design efforts within the current schedule will be a significant technical and managerial challenge, especially considering the need for external reviews by and coordination with the Nuclear Regulatory Commission, the National Academy of Sciences, and other groups. The Board looks forward to continued interaction as the program evolves.

Sincerely,

John E. Cantlon
Chairman

Enclosure:
Recommendations for
Evaluating Site Suitability

Recommendations for Evaluating Site Suitability

Two recent meetings of the Nuclear Waste Technical Review Board, in October and November 1994, focused on the U.S. Department of Energy's (DOE) plans for evaluating the suitability of the Yucca Mountain candidate repository site and the technical studies (especially thermal testing) to be conducted at the site. As a result of those meetings, the Board has reached three conclusions that require your attention. These conclusions are discussed in the following paragraphs. The Board then identifies the areas of technical uncertainty that it believes are most important for evaluating the suitability of the Yucca Mountain site. Finally, this document offers some general recommendations for exploration, testing, and analytical activities needed to produce a technically defensible evaluation of the suitability of the Yucca Mountain site, as well as some areas where current efforts could be reduced.

The Board is unable to say that these activities are absolute requirements, nor can the Board guarantee that these activities will prove sufficient. In fact, revisions to plans for site characterization will be inevitable as information from the exploratory studies facility and other surface-based and laboratory activities is collected and evaluated. However, based on today's knowledge of the site, on the anticipated legal and regulatory requirements for further repository development, and on the current uncertainties about the specifics of the DOE's waste isolation strategy, the Board believes that the activities identified in this document represent a prudent suite of studies for evaluating technical site suitability.

Conclusions from our recent meetings.

1. *A clearer definition of "technical site suitability" is needed.* The DOE needs to identify the technical requirements for its technical site-suitability decision and the additional requirements for the licensing stage of repository development. Clear definitions of "technical site suitability" and other program goals are very important if the DOE is to develop a streamlined program of site-characterization activities that will produce all necessary technical information within existing budget and schedule constraints. A clear definition of technical site suitability is also important because the DOE's site recommendation decision will presumably initiate a politically important and potentially controversial sequence of activities that may include a Presidential recommendation to develop a repository at the site, a state veto of that recommendation, and a congressional override of the state's veto. Uncertainty about what the DOE means if it declares the site "technically suitable" may adversely affect the nation's efforts to move forward with repository development.

2. *Development of a waste isolation strategy should continue.* The Board was pleased to learn that a waste isolation strategy, or waste disposal concept, is beginning to emerge within the DOE's program. The waste isolation strategy should identify and

quantify the roles of the repository features and/or barriers that will provide waste isolation, and should be based on the defense-in-depth philosophy that has long been a fundamental aspect of repository planning. The strategy can then provide one of the major bases for planning and prioritizing tests. However, two important parts of the strategy are still needed: (1) a decision on the extent to which engineered barrier system features outside the waste packages will be used and (2) a definition and quantification of the features and functions of the geosphere that can serve as essential natural barriers to release of waste. The strategy presented to the Board by J. Younker needs to be clarified and expanded.

Ideally, one should be able to discern in the program a direct linkage among a waste isolation strategy, key decisions, technical activities, budgets, and schedules. The waste isolation strategy is particularly important because it can provide a more technically defensible basis for deciding which site-characterization studies will be completed, deferred, or deleted. For example, one of the more important decisions that requires an improved technical rationale is the sharply reduced scope of surface-based drilling to be completed before the technical site-suitability decision. Results of total system performance assessments, in conjunction with a clearly articulated waste isolation strategy, should be used to determine the amount of surface-based drilling that is needed. Prioritization of other site studies should similarly be linked to the waste isolation strategy through performance assessments.

3, A few thermal management alternatives should be carried forward. The DOE has made a tentative decision to seek an initial license for a Yucca Mountain repository based on a low thermal-loading design, while retaining the option to amend the license at a later time to increase the thermal loading. The basis for this decision is the expectation that it will be easier to obtain regulatory approval for designs with lower thermal loadings. There is no clearly articulated or documented technical basis for this decision. The DOE needs to more clearly define its concept of a "low" thermal-loading design and needs to document the technical rationale for its selection.

The technical information and analyses currently available are inadequate to select a preferred thermal-loading strategy. Therefore, the Board recommends that the DOE preserve the option to further develop a few alternative thermal-loading strategies, such as the extended-dry concept, the base case in the site-characterization plan, and a below-boiling design. Preserving these alternatives may be the only practical way for the DOE to reach technically defensible decisions within the program's current schedule since the long-term in-situ thermal tests required to select a preferred strategy cannot be completed before the 1998 scheduled date of the technical site-suitability decision, or even by the 2001 target date for the license application for construction authorization. Our concept of preserving thermal management alternatives does *not* require a significant engineering design effort for each. However, the DOE should develop appropriate measures to ensure that decisions regarding design and testing activities will not preclude the adoption of any of the alternative thermal management strategies in the future as better technical information becomes available.

Most important technical uncertainties

One of the most important features of the Yucca Mountain site is the deep water table and the apparently minimal amount of water present in, and moving through, the unsaturated zone. The presumed dryness of the site is a pervasive factor in the DOE's developing waste isolation strategy because the dryness influences the performance of both engineered and natural barriers. Perhaps the single most important goal in characterizing the site is predicting (or placing bounds on) the amount and significance of water that could reach the repository, corrode waste packages, and transport radionuclides to the environment. This determination must include both spatial and temporal variations in hydrologic properties, the influence of fractures, and the potential for processes or events (e.g., climate change) to alter the hydrologic conditions, at least to the extent that waste isolation might be affected.

A second major concern is the effect of heat generated by radioactive waste on repository conditions. Heat can significantly alter hydrologic conditions by vaporizing liquid water and by inducing convective movements of air and water vapor. Heat can also alter rock properties either directly through thermally induced mechanical, chemical, or mineralogical changes or indirectly through interactions with water (e.g., dissolution, transport, and eventual precipitation of dissolved minerals when the temperature changes or when water vaporizes). The kinetics of reactions affecting engineered barrier performance (e.g., waste package corrosion and radionuclide dissolution) are likely to be temperature dependent. It is important that the effects of waste heat on repository performance be understood well enough to permit confident predictions of (or bounds on) repository performance.

The third major area of concern at Yucca Mountain is the extent of fracturing and faulting, and the transmissive properties of fractures and faults, in the repository block and in overlying, underlying, and neighboring strata. If high-permeability faults or fractures represent conduits for the movement of water, especially episodic flow after high-precipitation events at the surface or reflux of water mobilized by radioactive decay heat, highly fractured portions of the repository block may be unsuitable for waste emplacement. If faults are found that are capable of movement following waste emplacement, it might also be necessary to restrict waste emplacement to areas where mechanical damage to waste packages is less likely. A moderate amount of fracturing or faulting may not be a cause for concern. In fact, under certain conditions, faults or fractures could serve as "drains" to channel water away from waste packages. However, if the repository contains extensive faults and fracture systems with hydrologic significance, there may be so little useable waste emplacement area that the site might be judged unsuitable. Underground exploration, characterization, and testing in the repository block must be sufficiently extensive to determine whether there will be adequate emplacement space for the projected inventory of waste, given the thermal-loading strategy ultimately adopted for the repository.

Specific recommendations

Based on current knowledge of the major features of the Yucca Mountain site, the Board recommends the following as the minimum suite of site-characterization studies needed to produce a technically defensible evaluation of the suitability of the site. It is important to emphasize, however, that the following paragraphs are not intended to be a comprehensive study plan for characterizing the Yucca Mountain site. Additional studies may be needed to produce information for licensing or to provide greater confidence that the site can be shown to be suitable. Changes to planned studies also may be warranted as site information from surface-based testing and underground exploration is acquired and its significance evaluated through the iterative performance assessment process.

Hydrogeology & geochemical tests. Hydrologic studies to support the technical site-suitability decision should emphasize identification of potential fast flow paths, the significance of those fast paths for waste isolation, and the significance of perched water within the unsaturated zone. The DOE's planned studies of hydrologic and geochemical conditions, including moisture content, composition, and age-dating for water in the rock matrix and in fractures, seem generally appropriate. However, more emphasis on isotopic studies is needed because age-dating of ground waters through those studies provides the most valuable information available about potential fast flow paths and pneumatic pathways. More schedule flexibility also may be needed to permit completion of an adequate scope of tests. The DOE recognizes that more extensive studies of the radionuclide dilution potential of the saturated zone may be needed to evaluate compliance with a dose-based standard for repository performance, if such a standard should be developed by the U.S. Environmental Protection Agency. The Board recommends that the scope of planned studies be reviewed as the form of the repository performance standard becomes clearer.

Thermal testing. The DOE presently plans two sets of in-situ thermal studies — relatively short-term, accelerated tests to provide early information to support an application for construction authorization in 2001 and longer-term tests to provide information needed to apply for a license to receive and possess waste in 2008. The planned 1998 technical site-suitability decision will be based on information from early G-tunnel studies and from later laboratory and, if available, large-block heater tests. As now planned, preliminary results of the accelerated in-situ heater tests may be available in 2000 to support a recommendation of the Yucca Mountain site for repository development.

Ideally, several years of in-situ thermal test data should be available to support a technical site-suitability evaluation. The Board recognizes that the data available to the DOE at the time it plans to make a technical site-suitability decision are not likely to include in-situ thermal testing results. However, it is possible that the more limited data to be produced by the DOE's planned large-block heater tests, combined with very preliminary information from accelerated in-situ tests, could be sufficient *if* the DOE were to conduct analyses to identify the thermally induced physical and chemical changes that could cause failure of the repository system *and* could show convincingly that such

changes are not credible or can be prevented by appropriate waste package/engineered barrier/repository design. Analyses of the effects of heat on repository performance should be initiated immediately, should continue throughout the site-characterization process, and should be used to identify (or modify) thermal tests to be carried out from site characterization through repository performance confirmation.

Finally, data from the accelerated tests *cannot* be presumed to provide positive confirmation of present theories on thermal effects. Information may prove to be inadequate. Or, test results could diverge significantly from the results of laboratory tests, large-block heater tests, or the conceptual/failure mode studies mentioned above. Under any of these circumstances, it may be necessary to delay the recommendation to the President for repository development until better information from the long-term tests can be obtained.

Underground excavation. The Board believes that substantially more underground excavation will be needed than currently is planned by the DOE. Sufficient underground exploration is needed to confirm at repository depth the continuity and orientation of structures already identified by surface investigations, to identify structures not evident at the surface, and to permit testing of structures and formations to determine their significance for long-term waste isolation. The influence of geologic structures and formations on the hydrologic properties of the repository block is the primary issue of concern. To the extent that faults serve as potentially fast water flow paths or may be capable of movement following waste emplacement, determination of an appropriate offset distance for waste emplacement will be necessary. Specifically, the Board believes that the following excavation is needed for a technical site-suitability determination.

1. As now planned, excavate the north ramp to the repository level and excavate a "main drift" through the center of the repository block in an approximately north-south direction parallel to and just west of the Ghost Dance Fault zone.

2. Explore faults and structures in the central portion of the repository block east of the main drift. The planned intersection of the Ghost Dance Fault at two locations with small diameter drifts is appropriate. An eastern extension of one of these drifts is needed to fully cross the Ghost Dance Fault zone. Further extension of the drift into the Imbricate Fault as far as the eastern boundary of the block may be needed unless adequate information about the Imbricate Fault can be obtained from the north ramp.

3. Explore faults and structures in the repository block to the west of the main drift, particularly in the area of fracturing and suspected faulting identified by Scott and Bonk. Most of the proposed repository area is located to the west of the main drift, and at least one tunnel is needed in the area of suspected faulting extending west to the Solitario Canyon Fault to evaluate the suitability of that portion of the repository horizon.

4. Excavate a thermal test area in a suitable zone of the Topopah Springs formation at or near the repository block. For the best understanding of the effects of heating on mechanical and hydraulic conditions near the excavated surface, machine excavation of the test area is needed.

5. Excavate into the Calico Hills formation from a portal separate from the existing north portal. This excavation should cross the Ghost Dance Fault zone at least once at a location immediately below one of the crossings at the Topopah Spring level.

It is unclear whether the DOE is developing a thorough waste isolation strategy that includes reliance on the Calico Hills formation as a barrier to release of waste. However, because the Calico Hills may be one of the most effective geologic barriers at the Yucca Mountain site, the Board believes that exploration into the Calico Hills formation (and incorporation of the Calico Hills as a possible barrier in the waste isolation strategy) would be prudent. Exploration in the Calico Hills may help to resolve hydrologic and structural geologic uncertainties that cannot be studied adequately using only surface-based testing.

Completion of this tunneling within the DOE's announced schedules may require (1) more aggressive schedules for operating the current tunnel boring machine than the present planning suggests, (2) simultaneous excavations with additional smaller machines, (3) contracting for large sections of tunnel rather than buying more equipment, and (4) faster and more economical acquisition of equipment for small-scale excavation of alcoves (e.g., by lease by contractors rather than purchase by the DOE). In addition, we have recommended before the establishment and use of a geotechnical engineering board by the DOE. We continue to believe that such a board would help the DOE more quickly resolve the problems that inevitably occur during major underground construction projects.

Depending on the waste isolation and thermal-loading strategies chosen and on the results of initial tunneling, additional underground exploration may be required. For example, if the DOE's repository design is based on a low thermal-loading strategy that requires use of "expansion areas" outside the existing repository block, exploration of those areas also will be required. Plans for additional exploration should be developed now so that those excavations can be carried out quickly if they become necessary.

Source term. A realistic representation of the source term — the release of radionuclides from the engineered barrier system — must be developed for a range of alternative thermal loadings. For example, for the unsaturated conditions expected at Yucca Mountain, data are needed on the effects of temperature on radionuclide solubilities and retardation factors, on the applicability of retardation factors obtained from batch tests, and on the importance of colloid mobility. Also, for the large, drift-emplaced waste package, those portions of the engineered barrier system outside of the waste package have been essentially ignored. Concepts such as the use of backfill or

waste package fillers to modify the thermal, chemical, or hydrological environment or the use of capillary barriers should be evaluated.

Additional studies. Although not of the highest priority in terms of timing, additional studies are needed for a technically defensible site-suitability decision. Some of these include:

1. Studies of disruptive processes and events (especially volcanism) are needed to evaluate compliance with the siting guidelines and to support the probability estimates required by a total system performance assessment.

2. Ongoing detailed surface mapping of faults should be completed and the potential for displacement on faults found within and near the repository block should be determined. As appropriate, this information should be used to help guide underground excavation to the areas of most importance for waste isolation.

3. At least three years of long-term corrosion research, under conditions relevant to design of waste packages and engineered barriers, should be completed prior to the technical site-suitability determination. The Board believes that approximately 10 years of corrosion research will be necessaiy to support a licensing decision to permit repository operations. The waste isolation capabilities of engineered barriers other than the waste package (e.g., capillary barriers) should also be evaluated to support a license application.

4. Expert judgment will be especially important in many areas such as identifying conservative bounding assumptions that are an important part of the DOE's planned site-suitability evaluation. Procedures for eliciting and using expert judgment should be defined, fully analyzed, and shown to be acceptable for licensing.

5. A method needs to be defined for dealing with conceptual model uncertainty, such as a weighted combination of available models or use of bounding analyses.

6. Since an environmental impact statement will be required to make a site recommendation, studies should be completed to support its preparation including measurements of soil moisture uptake by desert plants for at least two years under a variety of seasonal, soil, and other conditions; examination of shrub cover along areas of faulting to help determine the role of fracture-rooted plants in evapotranspiration where soils are thin and underlying rocks are fractured; and completion of at least two years of study of the ecosystem response to soil and fractured rock heating.

7. To establish a better understanding of the steep hydrological gradient to the north of the proposed repository site and to evaluate its potential to affect water table depths under the repository, at least one more suitably located deep well will be needed.

Areas where emphasis can be reduced

As the DOE's waste isolation strategy becomes more fully developed, it should be possible to identify areas of on-going study that can be assigned a lower priority or eliminated entirely. Candidate areas that might be considered for a lower priority now include the following.

1. Earthquake shaking should *not* be an issue for evaluating the technical suitability of the site since the repository and its critical structures can readily be designed to withstand any design seismic loading that is likely to be specified for the site. In the Board's view, designing for shaking is well within current engineering capabilities.

2. New studies of volcanic rock dates are not likely to change probability estimates for volcanism.

3. For the technical site-suitability evaluation, it should *not* be necessary to measure the in-situ thermomechanical response of rocks in the range of temperatures associated with the thermal-loading strategies under consideration by the DOE. Conservative assumptions for designing a repository will adequately compensate for uncertainties caused by lack of geomechanical testing in the thermal test area. However, thermomechanical effects on rock stability are important considerations in repository design. For repository licensing such measurements should, as much as possible, be integrated into the thermohydrological tests.

The Board does not believe that a complete understanding of Yucca Mountain is possible or necessary for licensing a safe geologic repository. What is required is an understanding that is sufficient to confidently demonstrate that waste disposal at the site will be safe. The Board urges the DOE to develop a clearer waste isolation strategy as soon as feasible and, consistent with that strategy, to aggressively seek opportunities to further streamline and prioritize its planned site-characterization studies.