Additional Comments by the American Nuclear Society
Preliminary Site Suitability Evaluation (PSSE)

The PSSE incorporates the most recent data from field and laboratory experiments characterizing the Yucca Mountain site for a geological repository. It examines many alternative models that have never been explored before. In many cases, models were calibrated using multiple lines of evidence. This is an important addition in addressing the soundness of the assessment. The total system performance assessment (TSPA) is a probabilistic analysis, since its conceptual models are sometimes open to alternative interpretation and its parameters are variable and uncertain. To us, the parameters look reasonable and reasonably conservative, and we are confident that the analysts have done a creditable job. Moreover, the performance assessment is well-documented and the documentation has been thoroughly peer reviewed.

The SSPA update was part of the 'unquantified uncertainty' effort. In the past, DOE just assumed fixed values (often near-bounding values) for many of the parameters and, more importantly, just one conceptual model. The ANS views this expanded approach as a significant strengthening of the suitability determination. Based on these new contributions, the ANS has high confidence that the current repository design will meet the applicable radiation protection standards established by the EPA and NRC. This success is likely because the project:

- Has demonstrated that the natural features of Yucca Mountain contribute very significantly to public health protection;
- Has adopted a highly robust engineered barrier system employing multiple, independent barriers to provide long-term confinement of radionuclides;
- Employs significant conservatism in their assessments of the future health impacts such that these impacts are probably overestimates;
- Shows substantial margin in their compliance estimates; and
- Will conduct additional research and monitoring activities over the next several decades to centuries to further bolster confidence in the safety of the repository.

Similar design strategies, relying in large part on engineered barriers, have been adopted in international repository programs focused on other types of geologic media, where less credit is being taken for desirable geologic features at the site, and increased emphasis is placed on the engineered barrier system. In the case of the Yucca Mountain design, the engineered barriers include an Alloy 22 canister, and a separate titanium drip shield. An option to then back-fill the drifts is also available, although the current analysis indicates that such backfill likely is not required.

The robustness of the engineered barrier system makes the current Yucca Mountain design less sensitive to geologic parameters and uncertainty. This explains, for example, why the predicted performance for both the high temperature and low temperature repository operating modes are now so similar (for example see figure 3-3 on page 3-10, which compares the results from the new supplemental model.) The high and low temperature operating modes result in substantially different transport processes in the geologic media surrounding the waste emplacements, but these differences have little effect on the total system performance. In both cases the radiation doses are found to be over an order of magnitude below natural background for at least one million years.

Specifically, work provided in the SSPA suggests that there is not much difference in the results between the higher temperature and lower temperature designs either in terms of the range of uncertainty or in the mean dose estimates versus time. The SSPA also provides plausible explanations as to why this is so. These explanations are largely based on the fact that the time at elevated temperature is relatively short compared to the estimated lifetime of the containers.

Section 3-82 states the drip shield role is one of defense-in-depth since one-off analyses show little change in dose with the drip shield removed. ANS suggests that the need for the drip shield in the final repository design prior to closure should be investigated with additional, long-term testing. This is due to the high cost of the drip shields. Presumably, one could buy a great deal of long-term R&D testing if it allows the drip shields to be removed, or for alternative approaches such as graded-backfill Richards barriers to be used.

The initial state of the engineered barriers can be characterized with very high certainty, and the robust nature of the individual barriers allows the long-term performance to be characterized with increasing uncertainty with time. Large safety margins are found in the preliminary calculations shown in the report. These large margins, coupled with the use of multiple, diverse barriers, makes it quite likely that the assessment will continue to show that the design meets the regulatory requirements when the detailed analysis and design is completed for the license application.

The Yucca Mountain site geology has a number of desirable features for the long-term confinement of radionuclides, such as the zeolite strata that underlie the repository and which have the capability to strongly absorb radionuclides. While these geologic features are likely to contribute substantially to overall repository performance, the current Total System Performance Assessment often does not take proper credit for them. For example, most of the groundwater flow is assumed to bypass these zeolite strata completely. This type of conservative analysis is commonly used in licensing analysis to compensate for uncertainty, in this case for the uncertainty in the detailed configuration of the rock and flow paths through the zeolite.

The uncertainty analysis has identified the dominant uncertainties. This effort is part of the overall effort at establishing levels of confidence in the analytical results. Through a combination of deterministic sensitivity studies and probabilistic analyses, it appears that a wide range of variables was considered. At this stage, enough has been done to provide adequate confidence to proceed into the licensing process.

Inadvertent human intrusion has been studied by assuming that 100 years after repository closure humans inadvertently drill a hole through the repository, passing completely through a waste canister and continuing to the water table. The drill hole, and the disruption of the waste container, provide a path for the transport of radionuclides to the water table. The analysis of this event shows that the resulting radiation doses to the public are at least a factor of 1000 less than the 15 mrem EPA licensing requirement.

The human intrusion scenarios seem reasonable only if a bounding approach is desired. That is, DOE makes several, quite conservative assumptions. The two major conservative assumptions are that: 1) a driller is even capable of drilling through both the drip shield and the container without noticing anything unusual; and 2) that a large amount of the material falls down the borehole directly into the saturated zone. Regarding 1, it is highly unlikely, using current drilling technology, that people could drill through either titanium or Alloy 22 so easily as to notice nothing peculiar. It would take a long time before both were degraded sufficiently to drill through easily. In addition, it is quite clear that the drilling operation will have a loss of circulation when it hits the open tunnel. Usually loss of circulation is an indication to the driller of something unusual. Regarding 2, DOE makes many conservative assumptions about how much material can quickly get down into the saturated zone. This would tend to maximize estimated doses. Finally, the human intrusion scenario is highly unlikely if one considers drilling within the repository footprint as a Poisson process. The cross sectional area of the containers is only a small fraction of the cross sectional area of the entire repository footprint.

ANS also agrees with the rationale as to why DOE does not further expand the human intrusion scenario in the SSPA. It is important to understand when to stop doing analysis. ANS agrees with DOE that, if one makes bounding assumptions and the results are still negligible compared to the limits, then it isn't likely to be worthwhile to expend the resources to make this part of the model more realistic.

The EPA is responsible, under the Nuclear Waste Policy Act of 1982 and its subsequent amendments, for setting the standard that the Yucca Mountain repository must meet. The American Nuclear Society and many others have questioned the EPA standard, in particular its application of the separate ground water standard (see ANS to EPA dated November 24, 1999). Begging the question of the acceptability of this standard, the most important part of this site evaluation is how well the repository can be expected to meet the EPA standard of 15 mrem/year at 18 km and 4 mrem/year in groundwater. The method for this determination – a method agreed upon by both EPA, the standard-setting agency, and NRC, the licensing agency – is performance assessment of the total system.

As Figure 3-3 shows, even with assumptions and parameters that ANS believes to be excessively conservative, estimates of repository performance meet the regulatory requirements. The more realistic supplemental models, both high-temperature and low-temperature, are well within the regulatory limits, as the figure demonstrates.

The dose limit of 15 mrem/year is considerably less than the natural background of 410 mrem/year in Southern Nevada. The dose limit is also applied to a 'reasonably maximally exposed individual' (RMEI) and not the general population, so the degree of protection is even larger. Based on analyses provided in the SSPA, it appears that the dose rate estimate due to early container failure is about one part in one million of natural background. This means all the containers could fail and doses would still be below natural background levels. Peak dose rates at 1,000,000 years are still less than background. This information should provide additional confidence that the geologic repository at Yucca Mountain is acceptable.

Perhaps the best summary of the long term impact of the repository can be found on Table 2 of the Executive Summary of the PSSE. It shows that DOE has approximately two orders of magnitude margin in terms of the individual protection standard. The MCL numbers in Table 2 require clarification since it is not clear how much additional exposure is contributed by Yucca Mountain, since footnote 'e' indicates what is listed in Table 2 is only the natural contribution. On page xxxiii, DOE says that "Nearly all of the curie concentrations (pCi/L) (for comparison to the first two groundwater protection standards) shown come from natural background." However, on page xxxiv, DOE shows how minuscule the Yucca Mountain contributions are compared to contributions from natural sources. This should have been made clearer in the presentation of Table 2.

The current TSPA includes analysis of both hot and cold repository options over a one-million year period. Because the engineered barrier system now adopted for Yucca Mountain is so robust, very little difference is seen between the two cases. This is because the details of the different transport processes away from the waste emplacements remain largely unaffected by different thermal operating modes, and the amount of time the near field experiences elevated temperatures in the higher temperature design is relatively short. To provide further confidence in the current DOE conclusions regarding the relative performance and uncertainties of the higher and lower temperature operating modes, however, the ANS recommends emplacing spent fuel with at least two different storage densities as part of DOE's long-term R&D and performance confirmation program.

Summary statement

Both the preclosure and post-closure assessments of the proposed Yucca Mountain repository indicate that the combination of site and design features provide public health protection with a considerable margin of safety in meeting the regulatory standard. Thus, we have high confidence that Yucca Mountain is a suitable site, and recommend that DOE proceeds with the next stage of repository development – application of a license for repository construction.

Certainly this site is not perfect, as would be the case for any site. But the purpose of the Nuclear Waste Policy Act was not to direct DOE to look for the impossible, but to select and characterize a site that, with appropriate engineering design and operation, can meet with high confidence the regulatory standard for public health and safety. The PSSE shows that the site can meet the postclosure standard, and the analyses indicate that preclosure health and safety protection are more than adequate.

Specific Comments on the PSSE report:

Page 3-7

DOE notes that the SSPA "is considered to more realistically represent the repository's performance…". However, DOE also notes that the SSPA analyses "support the conclusion that the TSPA-SR provides a reasonable estimate of the overall system performance". This seems contradictory. What this actually shows is that the TSPA-SR is not likely to have underestimated the doses of interest – not that it provides a 'reasonable estimate'. It shows that the TSPA-SR deliberately provides an *unreasonable* (deliberately conservative) estimate of system performance. DOE needs to be clear that what they mean by 'reasonable' is something very different from 'realistic'.

Page 3-66

SSPA analyses continue to underestimate the SZ performance– even after refinements in the models. This is not what EPRI found in their studies of fracture/matrix interaction. EPRI believes that fracture/matrix interaction is likely to be more significant in the SZ than DOE is taking credit for. However, for DOE to be able to do this, it seems, DOE will need to conduct further flow studies at more refined intervals in the boreholes extending into the SZ. This, therefore, seems like an opportunity for a performance confirmation activity. For example, on page 3-81: "However, at the less conservative end of potential [SZ] barrier performance, the saturated zone is found to significantly delay the transport of neptunium-237 and lower the expected annual dose". This suggests that DOE thinks it might be possible to significantly improve SZ characteristics in the future.

Page 3-77 to 80

This subsection provides a concise description of the four major 'natural' and five major 'engineered' barriers. Table 3-5 is a particularly concise description. DOE should consider whether to include the 'natural' feature of geochemistry that leads to solubility limitations. While this is not the typical physical barrier commonly thought of when one attempts to identify barriers, it does contribute mightily in the reduction of hazard for the many solubility-limited radionuclides (e.g., Np, Pu, Am).

Page 3-164 to 165

The Thermo-Hydrologic–Chemical (THC) drift-scale analysis concludes "fracture porosity would decrease by less than 1 percent of its initial value in the host rock near the drifts." DOE also concludes that "mineral precipitation will not affect flow around the drifts to an extent greater than that which is already represented by the natural variability in hydrologic properties." These hydrologic properties vary by several orders of magnitude. DOE also states that fracture sealing, while it has been demonstrated in the laboratory to occur, is not relevant once the "appropriate temporal and spatial scaling of the liquid flux and thermal gradient" has been taken into account. ANS suggests that DOE check these statements to confirm that the laboratory results have been incorporated in the model and that the conclusions are valid. We would also recommend checking the chlorine concentrations for the higher temperature repository design.

Page 3-173

DOE states that scoping calculations have found that carbonation of the cement will be complete in roughly 40 years. This means that all the earlier concerns about the high pH of cement liners were probably unfounded. This suggests that DOE has even more flexibility in design of the ground support system, and could drop or scale back use of steel sets if they wanted to in the future.

Transportation of SNF and HLW

Although transportation is not a part of this particular comment period, it has been commented on by many members of the public. The ANS is therefore adding its comments to these.

Transportation in Type B casks – the transportation method for both SNF and HLW -- has an admirable safety record. In the 30 years that records have been kept[1] not a single accident involving a Type B cask has resulted in release of any radioactive material or even damage to the cask, although 90 incidents and accidents involved Type B casks. Testing done at Sandia National Laboratories show that the casks withstand collisions into a concrete barrier at 60 mph, railroad grade crossing accidents, engulfing fires, and drops from helicopters. The videos of these tests have been shown at many public hearings.

10 CFR Part 71 Subpart E describes the accident conditions that these casks must withstand in order to be licensed by the NRC. Recent analyses[2] show that impact speeds of more than 90 mph and fire temperatures of more than 750^{o}C must be attained before there is a significant release of radioactive material or even a loss of lead shielding. Even attack by modern high-explosive weapons would result in at most two holes in the cask. Better than 99.99% of the accidents that a SNF cask might undergo would not result in a release of radioactivity larger than that allowed by 10DCR Part 171 (NUREG/CR-6672, Sprung, et al, 2000, Sandia national Laboratories). The most likely accident that would involve a release has conditional probability of 0.00005, an average probability of 1.5E-11 (accident statistics from Saricks and Tompkins, 1999, Argonne National Labs) and could release about 0.6 Ci (from the Yucca Mountain DEIS, 1999).

Finally, although all of these casks emit radiation externally, the external dose to an unshielded individual by the side of the route is, at most, about 0.2 microrem per shipment, even if that route is a city street and the truck is moving at about 15 mph. The data clearly shows that the risk attendant to spent nuclear fuel transportation are far lower than other more conventional shipments in terms of public health and safety. The average dose per shipment to a bystander along the highway or rail route is about 1E-8 rem (0.00001 mrem). For the 50,000 estimated truck shipments, if they all went by the same person, this would be about half a millirem over a 24-year period. If the 50,000 truck shipments passed through the same urban area of 3200 residents/square km. (about 26,000 people within a half-mile of the route, the collective dose would be about 13 person-rem in 24 years , resulting potentially in 0.007 excess fatal cancers in this population (if we assume the LNT theory). This assumes no shielding at all by buildings, etc. This is all calculated in the Yucca Mountain DEIS (1999).

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[1] Radioactive Materials Incident Reports, Sandia National Laboratories, 1999

[2] NUREG/CR-6672, Sprung, et al, *Re-examination of Spent Fuel Shipment Risk Estimates*, USNRC, 2000.