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1 UNITED STATES OF AMERICA
2 NUCLEAR REGULATORY COMMISSION

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4 OFFICE OF THE SECRETARY

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6 MEETING WITH ACNW

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9 Nuclear Regulatory Commission
10 One White Flint North
11 11555 Rockville Pike
12 Rockville, Maryland
13

14 Wednesday, March 17, 1999

15 The Commission met in open session, pursuant to
16 notice, at 9:08 a.m., the Honorable SHIRLEY A. JACKSON,
17 Chairman of the Commission, presiding.
18

19 COMMISSIONER'S PRESENT:

20 NILS J. DIAZ

21 GRETA DICUS

22 EDWARD MCGAFFIGAN

23 JEFFREY S. MERRIFIELD
24
25

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1 STAFF AND PRESENTERS SEATED AT COMMISSION TABLE:

2 JOHN GARRICK, Member, ACNW

3 CHARLES FAIRHURST, Member, ACNW

4 RAYMOND WYMER, Member, ACNW

5 DR. KNOPMAN, Technical Review Board

6 DR. BULLEN

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P R O C E E D I N G S

[9:08 a.m.]

CHAIRMAN JACKSON: Good morning, everyone.

DR. WYMER: Top of the morning to you, Chairman.

CHAIRMAN JACKSON: Top of the morning to you.

Before we begin, I have a very serious presentation I have to make. Given that this is St. Patrick's Day, my staff decided that we needed to honor the tradition of one of our Commissioners, so we gave him a three-leaf clover.

COMMISSIONER McGAFFIGAN: Very appropriate.

CHAIRMAN JACKSON: Good morning, again. This morning we will have the third in a series of Commission meetings on the Department of Energy's viability assessment. The DOE previously briefed the Commission on its high level waste program and viability assessment last month.

Yesterday, the Commission was briefed by the NRC staff, the State of Nevada, the affected units of local government, and the tribal governments, on their reviews and views of the DOE viability assessment for the Yucca Mountain site.

Today we will hear first from our own Advisory Committee on Nuclear Waste and then from the Nuclear Waste Technical Review Board.

The purpose, as all of you know, of the viability assessment is to provide the President, the Congress and the

1 public with information on the progress at the Yucca
2 Mountain site. Its purpose, also, is to identify the
3 critical issues that need additional study before a decision
4 can be made on whether to recommend the site for development
5 as a geologic repository for spent nuclear fuel and high
6 level radioactive waste.

7 As I mentioned yesterday, the Commission is
8 reviewing the viability assessment as part of its
9 responsibility for pre-licensing consultation with DOE. A
10 paper documenting the staff review has been prepared by the
11 staff and presently is under Commission consideration.

12 The views of the ACNW and the Nuclear Waste
13 Technical Review Board will be of great aid to the
14 Commission in its review.

15 The ACNW advises the Commission on all aspects of
16 nuclear waste disposal facilities. As an independent
17 Federal agency, like the NRC, the Nuclear Waste Technical
18 Review Board evaluates the technology and scientific aspects
19 of the DOE high level waste management program and reports
20 its findings to the Congress and to the Secretary of Energy.

21 So I welcome representatives of both organizations
22 to our meeting today and we look forward to hearing from
23 you.

24 Dr. Garrick, I understand, will begin the
25 presentation for the Advisory Committee on Nuclear Waste. I

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1 understand that Dr. Knopman will make the presentation on
2 behalf of the Technical Review Board.

3 My colleagues and I may ask questions from time to
4 time during the presentation. We'll try to be disciplined,
5 since we had an almost four-hour meeting yesterday, but we
6 may ask questions, pertinent ones, but certainly at the
7 close of each presentation.

8 I understand that copies of your viewgraphs and
9 the statement of the Technical Review Board are available at
10 the entrances to the meeting room.

11 Unless my colleagues have anything they would like
12 to add, Dr. Garrick, please proceed.

13 DR. GARRICK: Thank you, Chairman Jackson. What
14 we want to do today is share with you the committee's views
15 on our review of the viability assessment, with an eye
16 towards beyond the viability assessment and the licensing
17 process.

18 We have to note that one of our members, which is
19 25 percent of our membership, is absent today, unavoidably,
20 and we will surely miss him, but we will do our best to fill
21 in for him.

22 We are in the process of preparing a letter on
23 this subject, and so we have to view what we say today as
24 work in progress. We will be sending you a letter probably
25 next week on the subject and we're hopeful that if something

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1 comes out of this today, that we can take advantage of it in
2 the preparation of our letter.

3 We're delighted to be here and in the presence of
4 a full slate of Commissioners.

5 CHAIRMAN JACKSON: With a full slate of issues.

6 DR. GARRICK: The many times we've met with you,
7 there's been few times that we've had all five of you, and
8 we welcome the new member, Commissioner Merrifield, and we
9 welcome back Commissioner Dicus. It's nice to see you.

10 As I said, what we want to do is talk about the
11 VA, but not just from the point of view of the VA; a look
12 towards the implications with respect to licensing, the
13 progression from the viability assessment to site
14 suitability and licensing.

15 The committee, of course, has reviewed specially
16 selected parts of the viability assessment. Our overall
17 impression of the documentation is one of considerable
18 positiveness. We believe that DOE has done the best job
19 they've done so far in documenting the status of the Yucca
20 Mountain project. The clarity of the documentation has
21 realized an important step forward, in our opinion.

22 We have had the opportunity of meeting with DOE
23 and with NRC staff on the viability assessment and so we
24 believe those meetings, together with our reviews, have
25 given us a pretty good snapshot of what's going on and a

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1 basis for our comments.

2 One of the things in slide three that we wanted to
3 do was to sort of anchor our remarks to some basis that is
4 consistent with our role as advisors to the Commission. So
5 that means we want to understand what the licensing basis is
6 and present our comments and remarks therefrom; in
7 particular, we're talking about complying with the standard,
8 plus implementing regulations and guidance, and we have
9 tried to view the VA and where we go from here from that
10 perspective.

11 Of course, what that means is that there has to be
12 some basis for the measurement of performance; in this case,
13 we're talking about basically radiation risk. So we're
14 trying to keep focused on the tracking of that performance
15 measure.

16 The effort that is most effective in dealing with
17 the issue of the risk is the performance assessment. There
18 is a very strong reliance on the total systems performance
19 assessment. So we need to make sure that we understand the
20 evolution of the parameter that constitutes the basis for
21 performance measure.

22 The TSPA VA was a snapshot of DOE progress on
23 performance assessment and as far as focus is concerned, the
24 ACNW review has spent most of its time on the matter of the
25 technology attributes of the design and on the way in which

1 those technology attributes have been characterized in the
2 performance assessment that has been performed.

3 In slide four, we talk about some of the important
4 issues that were considered. As we say, we're going to be
5 talking principally about the design, number one, and,
6 number two, the logic engine for characterizing that design,
7 the performance assessment number two.

8 When we review this, we like to do it in the
9 context of specific modules and we like to do it in the
10 context of tracking what happens from rainfall to radiation
11 uptake and all of the logical modules in between. So we
12 talk about water entry to the disposal drifts, we talk about
13 waste package and cladding performance, what happens in the
14 waste mobilization process, and the development of a
15 radioactive source, sourced radionuclide source term, the
16 transport of radionuclides in the unsaturated zone, and,
17 finally, to the saturated zone and the uptake of
18 radionuclides by biode and dose to humans.

19 We have been quite tenacious on making sure that
20 the documentation, the analysis provides the modularization
21 of this mammoth project into phases or modules that seem to
22 be logical and that the interfaces and links between those
23 modules also seem to be logical and understandable.

24 So what that means is that in addition to the need
25 for a credible design, there must be a need for a way to

1 analyze that design in such a way that all of this
2 information is synthesized into some sort of a performance
3 measure that we can understand and investigate as to its
4 credibility.

5 Of the issues that are involved, and we heard a
6 lot about those yesterday, as well, the ACNW believes that
7 water entering the drifts and a credible overall performance
8 assessment requires considerable work and for the license
9 application to proceed.

10 CHAIRMAN JACKSON: Let me just ask you a question,
11 Dr. Garrick. Given that statement, do you believe that the
12 plan for additional work that DOE has described is adequate
13 for addressing your concern, particularly with respect to
14 water entering the drifts?

15 DR. GARRICK: Our preliminary review is pretty
16 positive in that respect. We want to be careful to avoid
17 overstating the case of the lack of data. We think, as a
18 committee, that there's a lot of things that they can do,
19 given the time to license, but, more importantly, and we
20 wanted to come back to this later, given the long time
21 that's involved between now and the closure of this
22 facility, that can enhance the design and the performance of
23 the repository.

24 As far as the DOE's plans, we think that most of
25 them are relevant to doing that, but we have some comments

1 on some other things that we'd like to see.

2 COMMISSIONER MERRIFIELD: Madam Chairman.

3 CHAIRMAN JACKSON: Please.

4 COMMISSIONER MERRIFIELD: I have a follow-on
5 question to that. I was down at the Center for Nuclear
6 Waste Regulatory Analysis last week and was impressed by
7 some of the parallel efforts that they're doing down there
8 to follow along and have us ready to respond.

9 Similarly, are they doing the work necessary in
10 parallel with what DOE is doing? Do we have the right
11 activities underway at the center or are there additional
12 activities you think would be appropriate?

13 DR. GARRICK: Well, it's a good question. We
14 think there could always be more. The research program of
15 the nuclear waste field is quite limited and quite
16 constrained, as you know. We think that they have given
17 that constraint within the budgets they have, they are
18 picking important and useful things to do. But whether or
19 not the research program is adequate to support the
20 preparation of the licensing process, we have some questions
21 about that. In fact, we're writing a letter on that subject
22 next week, too, or writing a report.

23 CHAIRMAN JACKSON: Please.

24 COMMISSIONER DICUS: This is another follow-up
25 question to the first two. What about time lines? Say,

1 like, from now to the possibility of a license application
2 and the work that needs to be done? Are we in trouble with
3 that, is DOE in trouble with that?

4 DR. GARRICK: I think it's awfully easy to say we
5 are, but I think one of the closing comments that we want to
6 make is that if we take advantage of the time that's
7 involved in moving from here to closure, if we can somehow
8 move the licensing process in the direction that
9 accommodates design flexibility, then we have a lot more
10 time between now and when they have to have a license.

11 And if we can pinpoint what it is they do need and
12 make that a part of the licensing process, but allow -- be
13 in a position to take advantage of the -- if there are some
14 changes that could be made, they can be made, and that we
15 can use the time between now and closure, especially given
16 that we're talking about times everywhere from 50 years to
17 300 years, depending upon the alternative that's under
18 consideration.

19 So we're not as pessimistic about the data as some
20 might be, and I think some of the comments we make will
21 illuminate that issue a little.

22 CHAIRMAN JACKSON: Dr. Garrick -- let me let
23 Commissioner McGaffigan ask a question.

24 COMMISSIONER MCGAFFIGAN: You've just made a point
25 that I -- I don't know if any of you watched yesterday's

1 briefing, but I asked about -- there's a lot of pressure on
2 DOE to get to a design that is going to be the basis for the
3 license by approximately May of this year. Yet, as you say,
4 it's going to be 50 to 300 years before the repository is
5 closed.

6 I asked whether there was sufficient flexibility
7 in our process. They cited the 6344 process in our proposed
8 rule, which is the allowance for minimal changes, tests and
9 experiments, without the requirement for a license
10 amendment, but then we would also have the license amendment
11 process to deal with suggested changes in any of the design
12 characteristics as they go forward.

13 Is there more that we need to do in the way of
14 building flexibility in than the process we currently
15 envision with the 6344 process in the proposed rule?

16 DR. GARRICK: I think that process, together with
17 the language that was picked up from Part 60 and carried
18 forward into Part 63, relative to alternatives and the
19 consideration of alternatives, probably provides the
20 mechanisms that are necessary to accommodate that.

21 But I think this is one of the important messages
22 that we wanted to carry, and you've anticipated it, and so
23 we have it sooner rather than later.

24 CHAIRMAN JACKSON: As you go along, Dr. Garrick,
25 I'm particularly interested in this issue of multiple

1 barriers and I know you're going to talk about it in
2 defense-in-depth.

3 DR. GARRICK: Yes.

4 CHAIRMAN JACKSON: But let me give you a context
5 for the interest. There appears to be a need to have a
6 discussion as to what defense-in-depth means for a
7 repository and what the interplay is between the engineered
8 features and the actual geologic environment.

9 So when you speak of the need to have design
10 flexibility and for our regulatory process to allow that and
11 you talk about a time line, I think it's important, though,
12 to posit that discussion within the context of the interplay
13 between the geologic and the engineered aspects of the
14 repository design, because if you're talking a geologic
15 environment and a design of a repository that is boring into
16 that environment, then the question of flexibility is an
17 interesting one.

18 DR. GARRICK: Right.

19 CHAIRMAN JACKSON: As opposed to the usual
20 engineered features.

21 DR. GARRICK: That's right.

22 CHAIRMAN JACKSON: So I think we need to kind of
23 amplify that.

24 DR. GARRICK: Well, if we haven't amplified that
25 by the time we get through my wrap-up, come back with that

1 question again and we will, because we agree with you 100
2 percent, and we have some specific thoughts on how to
3 display that interplay, and we will.

4 CHAIRMAN JACKSON: Dr. Fairhurst, did you want to
5 make a comment?

6 DR. FAIRHURST: Well, most of my talk has been
7 anticipated by a number of the questions now and I'm just
8 wondering at which point to start.

9 DR. GARRICK: So generally, how we want to proceed
10 from here is that I will talk a little bit about the TSPA or
11 about the concept of performance assessment and, as we said,
12 that was one of the two major issues that we want to talk
13 about, and my colleagues, Dr. Fairhurst and Dr. Wymer, will
14 identify specific design issues in the context of
15 performance and then we will try to wrap it up.

16 So with respect to the performance assessment, we
17 have, under slide number five, the words of what we need, of
18 course, is a clear, integrated, probabilistic assessment.
19 Now, I think it's important for us to indicate what we mean
20 by that.

21 And we are in agreement generally with the Coast
22 Guard report that there needs to be a simple English version
23 of the performance assessment. It's a mammoth effort. It
24 involves a tremendous amount of information and it's
25 extremely difficult for experts to get their arms around it,

1 much less the public.

2 So what we're talking about here is the need for
3 improved technical clarity, particularly with respect to the
4 model itself, and I'll deal with that in the next slide.

5 But the second thing we need is once we kind of
6 understand the pieces and parts of this model and how the
7 linkages occur from rainfall to dose, through the various
8 modules, we need to see very clearly the supporting evidence
9 to it.

10 And I like to use the word supporting evidence,
11 because sometimes when we use the word data, there is a much
12 narrower view of what constitutes the supporting basis of an
13 analysis than if you broaden it.

14 We're here talking about everything from the laws
15 of physics to laboratory measurements, to field
16 measurements, to the results that we can get in the
17 international community of which they are extensive. The
18 whole spectrum of information that one can reach for in
19 supporting an analysis.

20 So those two things are very critical. So with
21 respect to the first one, namely, technology clarity and
22 what we mean, we're always looking to try to find a top
23 review, if you wish, of the total model in such a way that
24 we can map from the components of something that is
25 reasonably comprehensible and totally in terms of it being

1 an integrated model, from that to specific components and
2 subparts of the model.

3 So one of the important requirements in projects
4 such as this, in our opinion, is to make sure that there
5 exists something that we can always fall back on as a place
6 to put things when we discover them in the details of the
7 analysis.

8 So that means there has to be clearest definitions
9 of modules, interfaces, inputs, outputs. Now, there's been
10 a tremendous amount of progress on that, but we think there
11 can be a great deal more.

12 One of the things that we look for in this era of
13 risk-informed thinking is the consistency of probabilistic
14 thinking; you know, it's not enough to think about doing one
15 part of the analysis deterministically and another part of
16 the analysis probabilistically, unless there is a rationale
17 developed that connects those two.

18 It is very difficult right now to come to complete
19 closure on that because of the complexity of the model.
20 We're certainly looking for traceability and continuity of
21 the performance measure calculation. The answer to the so
22 what question. Everything we do along the way, we ought to
23 be able to say, well, what's this got to do with the issue
24 of risk, how important it is.

25 As a matter of fact, I want to, at this point,

1 insert a backup slide that you do not have to make my point,
2 because I think an example sometimes is much better. I
3 apologize that the example is not from the waste field, but
4 rather from the reactor field. But with a little
5 imagination, I think we can translate it to the waste field.

6 It's a little difficult to read, but let me just
7 tell you what it is. Some of the -- and it's an example, in
8 my opinion, of a graphic that really is what we mean when we
9 say we're looking for tools and displays and presentations
10 that add to the clarity of what's going on and that can give
11 us insight with respect to the underlying issues, such as
12 defense-in-depth, such as the issue of uncertainty, such as
13 the issue of what are the most important contributors.

14 Here is a real result from a reactor analysis.
15 And if I can do the translation for you, let us suppose that
16 the curve that has the -- this is a probability density, a
17 series of probability density functions and the various
18 curves are risk curves as a result of certain phenomena.

19 We see a risk curve if the only contribution came
20 from seismic, we see one if the only contribution came from
21 storms or winds, we see one for fire, and then we see one
22 that's called internal, which embodies all of the things
23 inherent to the plant that could go wrong and how that
24 contributes to the total risk.

25 Now, let's, for a moment, just assume that the

1 total risk was the peak risk curve for the repository, and,
2 of course, there is uncertainty about that. This
3 immediately tell us the basis of the analysis, what that
4 uncertainty is, and we can start investigation what's behind
5 all of this as to why this uncertainty spread over two and a
6 half orders of magnitude.

7 Let's suppose that where the word internal is, we
8 have rather the waste package failure, the risk due to waste
9 package failure. And let's suppose where we have fire that
10 here we have the risk due to the failure of the natural
11 setting.

12 Now, what this tells us immediately is what kind
13 of balance we have with respect to the contribution to risk
14 as a result of the engineered barriers and the waste
15 package. Then, of course, these others, let's suppose the
16 wind is not wind, but volcanic activity. Then, finally,
17 we'll leave seismic as seismic.

18 There are several things that this kind of
19 presentation will tell you and I've already mentioned a
20 couple of them. But another thing that it tells you is a
21 great deal about how much analysis is needed. For example,
22 if you look at seismic here, here we have the seismic risk
23 is covering something like eight orders of magnitude. Now,
24 in isolation, somebody would say, well, that's terrible,
25 we've got to reduce the uncertainty from eight orders of

1 magnitude down to something more reasonable.

2 Well, the point of this whole presentation is it's
3 not terrible because it doesn't make hardly any contribution
4 to the risk.

5 So the fact that we have eight orders of
6 magnitude, as long as know that, and that's what I mean by
7 quantification, knowing what your uncertainty is, as long as
8 we know that and you have the supporting evidence behind
9 that. We know what it is, we know it's not important. And
10 so it's not taken out of context. It's not grappled in the
11 context of pure science alone. It answers the so what
12 question.

13 So I wanted to present that because I think it's
14 relevant to what I would call the movement towards how we're
15 viewing defense-in-depth, the movement towards how we're
16 viewing the impact of uncertainty, the movement towards how
17 we're going to important ranks contributors, and it's really
18 what we're pushing for when we talk about risk-informed in
19 such jargon as Monte Carlo analysis, realizations,
20 abstractions and response surfaces.

21 CHAIRMAN JACKSON: Then that raises the natural
22 question, which, in a way, goes back to my original question
23 when I was asking about water infiltration.

24 DR. GARRICK: Right.

25 CHAIRMAN JACKSON: And that is, is there a way or

1 are you examining for each of these contributions to risk,
2 can you say something about whether or what needs to be done
3 to be able to get to that so what answer and whether the
4 path that DOE is on will allow them to address that and
5 whether -- and this gets back to Commissioner Merrifield's
6 question -- whether the path that we're on in terms of our
7 own analysis will allow us to render a judgment as to
8 whether --

9 DR. GARRICK: Yes.

10 CHAIRMAN JACKSON: -- the so what question.

11 DR. GARRICK: My answer to that is that I think we
12 can do this. I think that the truth of the matter is that
13 the more I review the DOE documentation, the more confidence
14 I have that you can recast the information into these kinds
15 of presentations.

16 Now, I'm sure, as we do that, we'll find holes and
17 I'm sure that it won't all come out maybe as clearly as we'd
18 like. But I think the information is there to do this kind
19 of analysis and begin to get a risk-informed basis for
20 deciding on issues about what we should be doing with
21 respect to water seepage into the drifts and what have you.

22 So I think a lot of what we're talking about is
23 there. I think that what we're not often doing is taking
24 advantage of the fact that we need to present this with all
25 the uncertainties. Sometimes we don't want to do that

1 because we would rather hold back and have the uncertainties
2 reduced before we present them. But there is great
3 advantage, in my opinion, in doing it however little the
4 knowledge is.

5 So I'm confident that the answer to the question
6 is yes, it can be done.

7 CHAIRMAN JACKSON: But there are two pieces which
8 you seem to have essentially said. One has to do with
9 knowing what the uncertainties are, however large they may
10 be, but also knowing in terms of the so what question --

11 DR. GARRICK: Yes.

12 CHAIRMAN JACKSON: -- what the relative importance
13 is from an overall risk perspective of the particular aspect
14 of the risk with whatever its associated uncertainties are.

15 DR. GARRICK: Right.

16 CHAIRMAN JACKSON: Commissioner Merrifield.

17 COMMISSIONER MERRIFIELD: Dr. Garrick, a couple of
18 times during your presentation this morning you have
19 intimated your confidence with the research and the
20 information that's being provided by DOE. One of the issues
21 that came out of our briefing yesterday from the staff was a
22 number of concerns about the quality assurance.

23 DR. GARRICK: Yes.

24 COMMISSIONER MERRIFIELD: While you can have good
25 research, if you're not able to appropriately back that up

1 and demonstrate that it is valid, that does bring in a
2 question. I'm wondering the degree to which you've looked
3 at the quality assurance issue and whether your confidence
4 in the DOE is at all moderated by that.

5 DR. GARRICK: We have not looked at the quality
6 assurance issue to the depth that the staff has. We have
7 tried to look at the technical issues.

8 Whether or not the quality assurance template can
9 be put on a lot of the source material that they have is
10 something we would have to do more work on to be able to
11 answer.

12 I would hope that we're not in a situation where
13 the 15 years of work that's gone on has to be erased because
14 of the absence of a quality assurance program that meets the
15 standards of the NRC. So there has to be some work done
16 there to see how much of that can be recovered and captured
17 and qualified in a QA sense.

18 COMMISSIONER MERRIFIELD: AS you look at that,
19 will you also be conducting analysis as to whether you agree
20 --

21 DR. GARRICK: Oh, yes.

22 COMMISSIONER MERRIFIELD: -- with the staff's
23 determination --

24 DR. GARRICK: Yes.

25 COMMISSIONER MERRIFIELD: -- about the

1 appropriateness of the standards?

2 DR. GARRICK: Absolutely. Absolutely.

3 COMMISSIONER DIAZ: But the quality assurance
4 issue is not only looking back, but is looking forward,
5 right?

6 DR. GARRICK: Yes. But I'm a little more worried
7 about the back, capturing the work that's been done. But,
8 yes, you're absolutely right and part of the issue yesterday
9 that was discussed is that there is not enough quality
10 assurance program in place yet, even though there is a
11 dialogue going on and discussion to achieve one.

12 CHAIRMAN JACKSON: Not to prolong this, but what
13 you're really saying is that you believe that the types of
14 data exists or supporting information to make these kinds of
15 judgments, but you're not prepared to render your own
16 statement or judgment as to the quality of it.

17 DR. GARRICK: That's right.

18 CHAIRMAN JACKSON: Okay. But then that leads to a
19 second part. I think that if you're then looking at it, I
20 think it's important for us to understand or at least for
21 you to look at it and tell us that you understand where
22 quality assurance questions would have the greatest effect
23 or where one has to go at the quality assurance questions to
24 be able to put things into the proper context.

25 What I mean by that is there can be a type of

1 quality assurance in terms of the qualification of the
2 information that would affect the uncertainty.

3 DR. GARRICK: That's right.

4 CHAIRMAN JACKSON: But there is a type that could
5 affect the ability to make a judgment about the relative
6 risk or the relative importance, and I think that's where
7 one has to be able to do some bounding in both instances.

8 DR. GARRICK: I agree with you and I would hope
9 that the TSPA and the TPA of the NRC would provide a lot of
10 guidance on what aspects of the supporting evidence need the
11 greatest attention with respect to quality assurance.

12 I'm in trouble with my colleagues here because of
13 the time.

14 CHAIRMAN JACKSON: You're not in trouble with us.

15 DR. GARRICK: But let me proceed. So going back
16 to slide six and the last bullet, so what I'm suggesting
17 here, as an issue of clarity, is that we should be very
18 focused as far as the presentation is concerned on first
19 principals. We should not allow ourselves to get too
20 consumed in the mechanical details.

21 The Monte Carlo does not create probabilities.
22 It's only a method of doing probability arithmetic. What is
23 really important is to understand where the probabilities
24 come from and how they're assigned to the basic parameters.

25 Okay. With respect to the supporting evidence

1 issue, we believe that this is a critical issue in this
2 project because of the dependence on expert elicitation,
3 expert judgment, and also the issue of QA that we just
4 mentioned.

5 I think it's important for the data packages that
6 are prepared to be prepared in such a way that it's very
7 responsive to the issue of whether the information is based
8 on measurement, expert judgment, where it comes from, et
9 cetera, and we're of the opinion that more packaging,
10 better, improved packaging of the evidence base is possible
11 and that probably we're better off in the data arena than we
12 think, that where we're not so well off is in the
13 characterizing of that underlying data in a way that makes
14 it easier to understand the linkages that I have talked
15 about.

16 When we talk about expert judgment, what we want
17 to do, and to give a specific example of what we mean, we
18 want to be able to bypass the expert. We want to be able to
19 go to the supporting evidence to the expert that was the
20 basis of the expert's opinions. To me, that's extremely
21 important. If we can't do that, then I think the expert
22 elicitation process is going to receive great challenges.

23 Let me move to the issue of defense-in-depth, and
24 I think we've said almost enough about that, but there's
25 obviously some important issues here.

1 It's clear to us at least that the Department of
2 Energy has not come to terms with defense-in-depth,
3 especially in the same context as it has been used as a
4 basic regulatory tenet by the Nuclear Regulatory Commission
5 since its beginning.

6 What we mean when we talk about defense-in-depth
7 is a pervasive concept that we're talking about
8 defense-in-depth with respect to the prevention of
9 accidents. We're talking about defense-in-depth with
10 respect to, if we have an accident, being in a position that
11 we have put in procedures and equipment that we can
12 terminate it in a most expedient manner.

13 And then we're talking about if we somehow fail in
14 that, that we have mitigating systems that indeed are quick
15 response and that also have defense-in-depth. So we're not
16 just talking about redundancy, diversity, independence and
17 balance. We're not just talking about multiple barriers.
18 We're talking about a philosophy of design that is pervasive
19 through the whole process, from concept to operation and
20 beyond, from operation to accident and accident management.

21 We think that the NRC has provided some guidance
22 on this in a variety of documents. The one thing about the
23 guidance that is very critical, and we have highlighted it a
24 little bit, is that the contribution to performance should
25 come from both the natural setting and the engineered

1 barriers. At least we need to know what that is.

2 There needs to be a little greater effort on this
3 whole issue of being able to quantify the contribution of
4 individual barriers. The whole idea here is to quantify.
5 We no longer have subsystem requirements, but that doesn't
6 mean that we don't want to understand what the capability is
7 of subsystems. In fact, the emphasis is on quantifying the
8 capability of the subsystem requirements in relation to the
9 performance measures. That's the focus. That should be the
10 emphasis.

11 Some people have interpreted that the absence of
12 prescriptive subsystem requirements means that we're not
13 interested in subsystem performance. We are clearly
14 interested in subsystem performance and linking that to --
15 its relevance to system performance.

16 So with that, if there are more questions,
17 excellent, but otherwise, I'd like to move from the
18 performance assessment aspect of our presentation to the
19 design review aspect of our presentation, and the first
20 speaker will be member Dr. Fairhurst, and he will talk about
21 principally the natural setting, and the second will be Dr.
22 Fairhurst and he'll talk principally about the engineered
23 systems.

24 DR. FAIRHURST: Thank you, John, and I'm only
25 going to do the first part. Let me quickly try to

1 summarize. First of all, I certainly and I don't think any
2 of the committee found any showstoppers. That was a very
3 valuable component of reading the VA. And with respect to
4 flow and engineered design, you can summarize it almost in
5 two words, water-water, because -- and this is not a new
6 problem.

7 This is a fractured medium. Let me just say, the
8 first review, the first report ever published about the
9 problems of radioactive waste isolation was in 1957, by a
10 group of geologists and scientists, the outcome of a
11 conference of Princeton University, and they came to two
12 general conclusions.

13 If you'll excuse me, I'll just read them. The
14 first one was, "The movement of gross quantities of fluids
15 through porous media is reasonably well understood by
16 hydrologists and geologists. But whether this is
17 accomplished by forward movement of the whole fluid mass at
18 low velocity or whether the transfer is accomplished by
19 rapid flow in ribbons is not known. In deep disposal of
20 waste in porous media, it will, in many cases, be essential
21 to know which of these conditions exist. This will be a
22 difficult problem to solve." That was in 1957.

23 The second one, I'll read it and then I'll come
24 back to the first, it was "The education of a considerable
25 number of geologists and hydrologists and the

1 characteristics of radioactive waste and its disposal
2 problems is going to be necessary."

3 Now, that has happened. That problem as been at
4 the forefront not only of work in this country, but in 20
5 other countries worldwide. The STREPA project in Sweden was
6 an international project which lasted for a decade, which
7 was focused very much on this problem.

8 So when we say that the mountain scale, with the
9 unsaturated zone at Yucca Mountain, which, by the way, there
10 are 20 other countries dealing with this, the United States
11 is the only one that has to deal at Yucca Mountain with the
12 flow in the unsaturated zone. All of the others are in
13 saturated rock.

14 So we have a unique problem, but also a common
15 problem, and there is a considerable uncertainty about that
16 infiltration. It existed for 40 years plus. So it's
17 unlikely that these uncertainties are going to be reduced
18 significantly over the next two to three years, even though
19 there are some things that will definitely change.

20 There is some knowledge that over the many
21 thousands of years, the conditions will become wetter in
22 that region, and since we have a long time-frame to deal
23 with, that is being reexamined.

24 So it's unlikely that we'll see, in the license
25 application, much change from the VA analysis with regard to

1 the mountain scale infiltration problem.

2 So the first thing, water is going to get in, and
3 then from that, we have --

4 CHAIRMAN JACKSON: Let me ask you a question.

5 DR. FAIRHURST: Yes.

6 CHAIRMAN JACKSON: Can that existing uncertainty,
7 which you don't expect to be reduced much over the next few
8 years, be considered acceptable with some appropriately
9 conservative assumptions about the repository design?

10 DR. FAIRHURST: The key issue is the uncertainty,
11 yes. There are certain things that are not terribly
12 uncertain. For example, we know how much comes in pretty
13 well. Where it goes is what we don't know.

14 Now, our main concern is how much will get to the
15 drifts. So my second point was that there is water moving
16 through and we'll accept that. There is not going to be any
17 alternative to accepting it.

18 The important thing is to keep it away from the
19 drifts and find out how much gets into the drifts. More
20 specifically, we want to keep it away from the waste
21 packages, and, more specifically than that, we want to keep
22 it from getting at the radionuclides inside the waste
23 packages.

24 CHAIRMAN JACKSON: And you know the USGS has
25 recommended that there be an expert elicitation on

1 quaternary climate and on paleohydrology.

2 DR. FAIRHURST: Yes. Yes. Yes.

3 CHAIRMAN JACKSON: Do you agree with that?

4 DR. FAIRHURST: Yes. I think that is something
5 that is a very good use of expert opinion, because it will
6 -- it will probably suggest, I think, the feeling is that
7 some of the assumptions of DOE are overly conservative in
8 that regard and it will help illuminate that. It's a good
9 thing.

10 USGS is the unparalleled leader in that kind of
11 work. And so yes. And so --

12 COMMISSIONER McGAFFIGAN: Madam Chairman.

13 CHAIRMAN JACKSON: Yes, please.

14 COMMISSIONER McGAFFIGAN: Could I ask your
15 opinion? The USGS wrote a report in November about the
16 viability assessment and they dealt with this issue of how
17 much water is going to get onto the waste packages and they
18 basically say most water, in either case, I won't go through
19 the cases, most water would bypass the waste canisters.

20 Such behavior has been confirmed by experiments.
21 This is a case where they claim there's experiments in the
22 exploratory studies facility in which large rates of
23 infiltration have been artificially maintained above an
24 alcove and water entry into it observed.

25 Both theoretical and experimental results thus

1 indicate that focused flow into drifts is extremely
2 unlikely, and then they conclude it should not be assumed
3 for the TSPA. That's their view. You had the State of
4 Nevada here saying there's rapid flows and that should
5 disqualify the site instantaneously.

6 So there's a range of view here and they dismiss
7 USGS as a DOE subcontractor.

8 What do we -- how important is this to narrow by
9 2002?

10 DR. FAIRHURST: Well, you added by 2002.

11 COMMISSIONER McGAFFIGAN: By the time of the
12 license application.

13 DR. FAIRHURST: Yes. Obviously, USGS is proposing
14 what you might call a less severe situation than DOE is
15 examining and I think that is a good conservative strategy
16 for DOE. And if that turns to be -- if USGS can prove that,
17 everybody will welcome it. It actually speaks to the second
18 slide that I have, saying that the seepage into the drifts
19 with dripping onto canisters is a process of particular
20 importance.

21 However, the exact prediction of the locations,
22 the changes with time, the amount and the chemistry of
23 in-flow is not feasible. If you walk along the tunnel,
24 you'll see a thousand fractures, flow will come through one
25 and there is not a person in the world who will tell you

1 which one that was before it goes there.

2 So it's an uncertain process. But the -- so
3 performance assessment will then continue to rely on expert
4 judgment and conservative assumptions to deal with this
5 issue.

6 Now, I'm coming to the question that you asked
7 about seepage into the drifts. We feel there is an
8 opportunity for some significant improvement by doing future
9 analyses. The niche test is going on, which is the one that
10 is being done by USGS personnel, and there will be definite
11 refinements to those numerical models.

12 Now, there's a lot of work going on to this by
13 different contractors and, in fact, this is extensively
14 studied in the Swedish program, too, and there are
15 theoretical models which would suggest that if you have a
16 tunnel and a porous medium around it, that there is, through
17 capillary diversion, the water will tend to go around rather
18 than through the tunnel.

19 However, you've got a fractured medium here with
20 fractures going in it which are very sharp and how water
21 will be -- how that will affect the process. And then there
22 is another one that has not been studied by anybody really,
23 although it's being looked at somewhat in the heated drift
24 experiment, is the effect of temperature.

25 As you raise the temperature of this rock, you

1 will do an awful lot of changing around and you may know
2 something now in niche tests, but you must add the
3 consequences of high thermal load. This speaks to something
4 that I will talk about later, as to whether you talk about
5 hot or cool repository.

6 So the answer directly is yes, there is a lot of
7 activity in that, and we expect to have some refined
8 judgment certainly in two to three years, but I see no
9 reason to stop the work for that point.

10 COMMISSIONER McGAFFIGAN: But their point was more
11 -- if I could follow-up -- that, yes, there is going to be
12 seepage, but they don't think the seepage ends up getting
13 onto the waste canisters very often. In either case, most
14 water would bypass the waste canisters.

15 The previous sentences have granted there may be
16 water getting into the drifts, but they believe, reading one
17 of the prior sentences, the water tends to adhere to the
18 rock or drift mining wall and move down the wall and as film
19 flow, et cetera.

20 DR. FAIRHURST: Yes.

21 COMMISSIONER McGAFFIGAN: So that's their view. I
22 don't know whether that can be documented or how much --

23 DR. FAIRHURST: It is a view. It is a view I'm
24 sure that will be contested by a lot of people because the
25 proof is not yet there. I'm not saying it's wrong.

1 COMMISSIONER McGAFFIGAN: Right.

2 DR. FAIRHURST: And that's what we have to do.
3 Let me talk now -- just talking about following the natural
4 system. We've gone now through the unsaturated zone and
5 into the saturated zone; that is, allowing that -- we're
6 hoping to prevent any radionuclide contact of water, but we
7 have to allow that it might happen and that some of it may
8 be traveling to points where it will be -- there will be
9 uptake into human system. So we have to examine that.

10 There, again, we have conflicts, hydrology and
11 there are uncertainties. There's some potential for some
12 drilling, which will give us some new data which will
13 improve our confidence, but the uncertainties will remain.
14 And the key issue is how much dilution will occur. It's the
15 concentration and how much you take out of a well in the
16 final uptake.

17 So those are issues that are still to be resolved
18 from all the processes and so as a consequence, we will have
19 to have quite conservative assumptions and they will have to
20 be defended on that basis as conservative assumptions.

21 I've given a very quick run-through of a very
22 large subject. I have to turn to a second one now. Given
23 that water will possibly come into the drifts, how do we
24 design the repository to avoid this contact as much as
25 possible.

1 Really what you're saying is that we'll have to
2 have a very robust system of engineered barriers and that is
3 to inhibit any access to the waste.

4 And as I think you know, there's been a tremendous
5 activity on the part of DOE in the last year or so, year and
6 a half, looking at various alternative engineered designs.
7 Those engineered alternatives, there's a lot of details, but
8 in simplification, they really boil down to two; whether you
9 have a hot repository -- in other words, whether you allow
10 the rock temperature to go above the boiling point of water,
11 which that reaches about 96 degrees Celsius, or whether you
12 keep it low.

13 The aim, of course, of the hot repository is to
14 essentially put an annulus around the repository where the
15 water would -- any water that contacted it would be boiled
16 off and wouldn't be able to get in. So that was the
17 attraction of the hot repository idea and it's an
18 interesting possibility, but there are some suggestions that
19 it may be more complex to analyze. It can cause damage to
20 the rock, because the natural stresses out there are of the
21 order of ten mega pascals. By the time you get through
22 heating it up, you add about another 120. So it's a
23 significant change, although the rock will break before it
24 gets up to that temperature.

25 With the low temperature design -- I may also say

1 that a high temperature design is not all bad. One of the
2 interesting things we found, it's in one of the backup
3 slides, but I won't bother with it, is if you have a seismic
4 event during that the period that that is very hot, the rock
5 is actually clumped together, those joints, because it's
6 being pressed under thermal expansion and it won't fall out,
7 whereas if it is cold, it has a much better chance of
8 falling out.

9 So there are pros and cons. The low temperature
10 design avoids the uncertainties about the thermal effects,
11 but it allows the greater chance of humidity and moisture
12 coming to canisters and potential corrosion.

13 So there are -- the other advantage of the low
14 temperature design, although it's limited, is that every
15 other country is considering a low temperature design. So
16 you've got a lot of other people with knowledge of that, but
17 it's not all transferable, because, again, they're all in
18 the saturated zone and we are not.

19 We have a question about whether clay -- you have
20 a funny situation where you possibly may not be able to put
21 clay in there because it's too dry. It doesn't have enough
22 water to keep it expanding.

23 COMMISSIONER DICUS: I have a question, please.

24 DR. FAIRHURST: Yes.

25 COMMISSIONER DICUS: Are you leaning in one

1 direction or the other on these or are you neutral?

2 DR. FAIRHURST: At the moment, I'm interested to
3 see if there is an advocacy for the low temperature design,
4 because I know a lot more about the high temperature design
5 already. That was a standard and I'm anxious to see what
6 the arguments are for. There are also some side issues, and
7 that is whether or not the drifts are back-filled or not.
8 That does, in fact, also affect those two.

9 So I think that what will happen, by the time of
10 license application, in fact, by May, there will be a
11 decision of some preferred alternative, but it's quite
12 probable that there will be several designs that could
13 satisfy 10 CFR Part 63 over a 10,000 year period.

14 We feel, however, that there will be concerns
15 expressed, whether it's part of the regulation or not, about
16 the fact that the dose rises beyond 10,000 years and number
17 of the designs. So we want to urge -- I may modify the
18 statement that I've got there in the second bullet to say
19 that NRC should seek -- continue to seek additional
20 information that the 10,000 year safety performance will
21 provide reasonable assurance to the public to protect public
22 health and safety over the long term.

23 The other thing, there has been a recent
24 development to suggest extending the open period of
25 pre-closure to 300 years, a possibility, and this is a very

1 personal view perhaps, but I think it's shared by some
2 others, that that extension to 300 years is not a trivial
3 thing to talk -- you may say it trivially, but it
4 significantly complicates the maintenance of effective drift
5 support systems.

6 To give you an idea, in civil engineering, there
7 are lots of drift support systems, but I don't think any --
8 a lot of them are innovative and currently rock bolt and --
9 rock bolts have only been around about 30-40 years as a
10 design support system. So nobody can tell you how they will
11 last, particularly in a heated environment over 50 or 100
12 years, and to suggest to go to 300 years is not a trivial
13 thing.

14 So I would actually suggest that we stick as much
15 as possible to the 50 to 100 years and then allow the people
16 100 years hence to decide whether they want to keep it
17 another 200.

18 I was at a conference in Europe recently and
19 people were aghast at the U.S. suddenly introducing an
20 extension to 300. Nobody else wants to talk anything above
21 100.

22 So with back-fill, as I say, that reduces --
23 there's pros and cons there. That reduces the vulnerability
24 to damage from rock falls. It stops rock falls, because it
25 can't fall. And it reduces the vulnerability of seismic

1 effects, and it helps eliminate some concerns regarding
2 possible consequences of igneous events.

3 But it does increase the temperature of the waste
4 package, because it insulates it.

5 COMMISSIONER DIAZ: Let's see. On this issue of
6 the plus 10,000 years, we have a project that has
7 significant amounts of uncertainties.

8 DR. FAIRHURST: Yes.

9 COMMISSIONER DIAZ: And now you're suggesting that
10 we even try to go beyond 10,000 years -- no, that's not what
11 you're saying?

12 DR. FAIRHURST: No. I'm saying that a 10,000 year
13 standard is probably appropriate, but one should -- if there
14 are -- for example, if there are designs which would
15 indicate a better performance over a long period of time,
16 why not choose it, because it will give the public a much
17 greater feeling of confidence. There are good reasons for
18 sticking to 10,000.

19 Finally, let me talk about staff capability of
20 NRC. Just to try to put it in context, again, this effort
21 put forth by the DOE to try to come up with alternative
22 designs -- it's got several hundreds of engineers and design
23 engineers, working intensively and looking at all kinds of
24 options, and they're generating a tremendous amount of
25 information.

1 I think it's obvious that NRC staff is going to
2 have to evaluate those things proposed by DOE. And in order
3 to get somewhat, if you like, of a level playing field, the
4 issue there is that you've got a lot of people with design
5 engineering experience. We're moving from this period of,
6 40 years ago, wanting geologists and hydrologists. We're
7 now moving toward geotechnical engineers are needed.

8 And I want to emphasize that, because the question
9 that you asked about uncertainty. Geotechnical engineers
10 have a different philosophy of design than many other
11 engineers because of the complexity and uncertainty of the
12 geological media. Actually, it's called design as you go.
13 You have to excavate and when you excavate, you have to have
14 a design ready that can accommodate a variety of surprises.

15 Just to give you an example, two weeks ago, I was
16 in Yucca Mountain and they just excavated into the Solitario
17 Canyon faults and everybody was there because we were
18 learning an awful lot about whether was that a water
19 conduit, was it a water barrier, how far from that was the
20 rock disturbed, because you would not put canisters in a
21 region that was near a fault.

22 No amount of work, of theoretical work can tell
23 you that. You have to go in and find out. One has to have
24 that design as you go philosophy and that's why we believe
25 -- it's not a criticism of existing staff, it's a question

1 that one needs some augmentation of that capability in order
2 to be able to expect NRC staff to respond and analyze what's
3 being presented to them.

4 And we believe that in that context, it might be
5 useful, since this is such a rapidly evolving and changing
6 situation, you can't guess, if somebody could be hired. Six
7 months later you may need somebody different. So part-time
8 consultants --

9 CHAIRMAN JACKSON: So we have to design our staff
10 as we go.

11 DR. FAIRHURST: That's right. Well spoken, well
12 taken. It's a very nice way to finish to say that we design
13 as you go with the staff. It's very rapidly changing.

14 So with that, I think I'll leave it for any
15 questions you may have.

16 CHAIRMAN JACKSON: Thank you. Dr. Wymer?

17 DR. WYMER: I'm going to talk about engineered
18 barrier and the engineered barrier system.

19 CHAIRMAN JACKSON: Closer to the mic.

20 DR. WYMER: There?

21 CHAIRMAN JACKSON: Closer.

22 DR. WYMER: Closer.

23 CHAIRMAN JACKSON: The mic has to be closer to
24 you.

25 DR. WYMER: Oh, it moves.

1 DR. GARRICK: Flexibility.

2 DR. WYMER: We need to design as we go here. You
3 heard a lot about the engineered barrier systems. We had a
4 workshop last year, you recall, and then we had a meeting
5 here and then we wrote you a letter about it, and you heard
6 quite a bit in the subsequent briefings you've had. Even
7 yesterday you heard some more.

8 So it's a little hard for me to present something
9 new, but I'm going to try to give a little bit different
10 emphasis that might be useful.

11 First, I should say that of the designs that DOE
12 has come up with, and they've come up with five so far
13 possible designs which differ mainly with respect to thermal
14 loading, which influences the temperature the repository
15 will go to, with some additional variations with respect to
16 whether or not they have back-fill and some other minor
17 variations, but largely they're related to temperature.

18 But none of these five designs changes what are
19 the important contributors ultimately to dose that a person
20 at 20 kilometers from the repository. These contributors
21 are, as you've heard, the waste package performance and the
22 zircalloy cladding on the fuel, spent fuel degradation,
23 radionuclide transport. And nothing in the design changes
24 affects the importance of these things, although they -- the
25 design changes affect the importance in different ways, put

1 different stress on different things, depending on whether
2 or not you have drip shields and what kinds and so on.

3 As Dr. Fairhurst indicated, the robustness of the
4 whole repository system depends in large measure on the use
5 of multiple barriers and the contributions that they make.
6 So I'm going to try to concentrate on those areas.

7 COMMISSIONER DIAZ: Excuse me.

8 CHAIRMAN JACKSON: Please.

9 COMMISSIONER DIAZ: Have you seen this estimate
10 that the engineered barriers are now 99.3 percent of the
11 total -- you want to make a comment on that?

12 DR. WYMER: Yes, we've heard that. It depends on
13 what you do. In the present analysis, there certainly is a
14 great deal more emphasis, maybe it is 99 to one, between the
15 engineered barrier system and the natural environment. But
16 I don't think that's been really demonstrated and I think
17 there are ways, and I'll talk about it just a little bit,
18 ways to change that ratio substantially, possible ways, and
19 these are the kinds of things that I will suggest as things
20 that might be looked at or at least analyzed with respect to
21 whether or not they should be looked at in-depth, and I want
22 to get into that just a little bit toward the end of my
23 presentation.

24 CHAIRMAN JACKSON: You mentioned that the major
25 differences among the five designs really relates to the

1 assumptions about thermal loading.

2 DR. WYMER: Yes, that's right.

3 CHAIRMAN JACKSON: But that none of these
4 differences change the important contributors to the
5 ultimate dose.

6 DR. WYMER: That's right. They don't change that
7 list.

8 CHAIRMAN JACKSON: They don't change the list, but
9 they change the relative --

10 DR. WYMER: That's right, the relative
11 contribution.

12 CHAIRMAN JACKSON: -- contribution of those
13 contributors.

14 DR. WYMER: That's exactly right, I think.

15 CHAIRMAN JACKSON: Okay.

16 DR. WYMER: So since the multiple barriers are an
17 important compliment to those, as Dr. Garrick has pointed
18 out, they're certainly not the only compliment of
19 defense-in-depth. You do need to have a clear understanding
20 of what the contributions of the individual engineered
21 barriers are in the near field and one of the ways that the
22 Department of Energy has analyzed the importance of the
23 contribution of the individual barriers just by what they
24 call a process of neutralization, which effectively means
25 that they reduced the contribution of an individual barrier,

1 taking the barriers one at a time, to a very low value, and
2 then they see what the outcome is on the ultimate dose that
3 people receive.

4 But in reading what's written and then listening
5 to the presentations and in listening to responses to
6 questions, I don't really understand exactly what they're
7 doing, the neutralization of barriers. The reason I don't
8 is because there are a lot of coupled effects of the
9 barriers. You can't just simply take a barrier out and then
10 see what's left, because one module in the model feeds the
11 next and, in particular, this is of great importance with
12 respect to the chemistry of what goes on and the chemistry
13 is extraordinarily complex. So you can't just neutralize a
14 barrier.

15 Now, I asked the question in one of the recent
16 meetings of the DOE people, well, how do you take care of
17 these coupled effects and the interaction of these effects.

18 Well, the answer, as I understood at least, and I
19 admit that people can't present their deep understanding of
20 something in a few minutes discussion standing up at a
21 microphone, but my understanding of it at least was they did
22 sort of on the side calculations and said, okay, we realize
23 there's coupled effects here, now we're going to do a little
24 calculation to see whether or not this coupled effect will
25 importantly influence what happens with respect to

1 neutralizing these barriers and this way they are able to
2 essentially discard the coupled effects by side calculations
3 or side considerations.

4 That was my understanding and I didn't find that
5 particularly satisfactory. It didn't satisfy me, at least.
6 Now, maybe I need a little bit more detailed discussion of
7 what they have, in fact, done. I think I do. But so far my
8 understanding is that I don't think that the interaction of
9 one system and effect on the next is handled at least in a
10 transparent, easily understood way.

11 Now, on the next viewgraph, which is number 20, I
12 come down to some of the things that the horses that have
13 been beat until they're dead, having to do with timeliness
14 of being able to -- by that, I mean being able to get
15 results in time to feed the license application requirements
16 and the quality assurance of the data.

17 Those are significant potential problems. Dr.
18 Garrick has indicated that they're not necessarily
19 showstoppers, but it raises an important problem for the NRC
20 staff, I believe, in that they have to make some judgment,
21 which will be a difficult judgment, on how much data is
22 enough and how much expert elicitation is enough and whether
23 or not that is good enough.

24 Expert elicitation, for example, relies in large
25 measure on what assumptions are made, which the experts are

1 making their judgments and insofar as the assumptions
2 change, the results of the experts' opinions change.

3 And some of the kinds of assumptions that are made
4 are those with respect to, say, the composition of the water
5 that enters the drift and it drips onto package. And
6 depending on whether or not you're using the J-23 water or
7 you're actually using a new sample that you've taken, these
8 things would quite dramatically change the results of the
9 expert elicitation opinion.

10 So there are uncertainties. But anyway, the
11 principal uncertainty so far in the analyses have to do with
12 the corrosion of the waste package, and that's what I think
13 Commissioner Diaz was talking about with respect to this 99
14 to one. At least one of the big contributors was what
15 happens to the waste package. Well, it is true, as you
16 heard yesterday and you've heard before, that the database
17 for alloy-22, which is the present favorite for the
18 corrosion resistant material in the waste package, the data
19 are good and they're very encouraging and there's a lot of
20 work going on, several places, including at the center for
21 nuclear waste repository analysis, and insofar as it goes,
22 it looks okay.

23 But it's hard to get enough data on a short
24 time-frame to give you a warm fuzzy feeling about what this
25 thing will -- how this package will behave in the long term.

1 And the same thing is true of the zircalloy cladding on the
2 fuel and to a certain extent on the vitrified high level
3 defense waste. But not enough is known, although a lot is
4 known about the vitrified waste, that zircalloy cladding has
5 been looked at for a long, long time with respect to its
6 corrosion, but under quite different conditions than exist
7 in a repository and especially under conditions of
8 temperature fluctuations and temperature going up and down.

9 And then take one point in particular about the
10 alloy-22. We've heard, and it may well be true, that there
11 is a temperature regime in which corrosion will most likely
12 occur at a significant rate and above that temperature and
13 below that temperature, corrosion will be negligible; above
14 it because there is no water and below it because the rate
15 of corrosion is so slow that it's negligible.

16 So the verification of that temperature regime is
17 an important thing to be looked at and, as I understand it,
18 is being looked at, but we need data, we need information.

19 I want to talk about the chemical processes and
20 the contributions of back-fills and that will be the next
21 viewgraph and my last viewgraph.

22 There is a great deal of discussion in the TSPA VA
23 about the chemical complexity of the system and nothing I
24 can think of has not already been thought of and mentioned
25 in what has been written.

1 But what's lacking is a detailed comprehensive
2 treatment of the chemical complexity and the chemical
3 complexity is of fundamental importance because it deals not
4 only with the corrosion of the waste package and of the
5 cladding on the fuel, but it deals very importantly with the
6 rate of dissolution of the fuel material itself, which is
7 primarily uranium dioxide, and it deals with the possible
8 formation of secondary phases, which could seriously and
9 importantly impede the release of radioisotopes, actonizing
10 fission products from the waste package.

11 Now, these chemical effects have been looked at
12 one at a time and they've been considered and they've been
13 analyzed and there have been calculations made, but it is my
14 opinion or judgment that the situation is so complex that
15 nothing like the EQ3/6 computer code can deal with all of
16 the complexities.

17 For example, if you do have secondary phase
18 formation, if you don't know what the composition of the
19 solid phases are, you cannot make thermodynamic predictions
20 of what the solubility is and you can't derive this kind of
21 information from an analysis of the liquid phases.

22 You have to know what the compositions are. So
23 basically I'm saying you need a valid database before you
24 have a valid computer code that will analyze the system.
25 It's my view that the system is so complex and requires such

1 a large database, that the only true way to get at the real
2 effects are to use the real solutions, the real systems that
3 exist in nature and conduct your experiments and do
4 experiments and gather data.

5 Now, these are not hard things to do and, speaking
6 as a chemist, I bemoan the fact that we've spent ten years
7 looking at the geology and, to over-emphasize the case, two
8 years looking at the chemistry.

9 When the chemistry is of great importance with
10 respect to releases of fission products, actinides.

11 COMMISSIONER DIAZ: Excuse me. I see all of your
12 chemicals in here and I have a favorite universal solvent,
13 which is uranium. Are they modeling the uranium properly in
14 the chemistry?

15 DR. WYMER: They're doing something that I think
16 is very good and that is using the Pina Blanca analogy and
17 that gets at the -- one form of uranium, which is probably
18 very similar to what's in the fuel, although not certainly
19 identical to what's in the fuel.

20 So insofar as the uranium chemistry and the
21 uranium dissolution is concerned, yes, they're probably not
22 doing bad. What they're -- what is very difficult to deal
23 with is what happens to the uranium after it is dissolved,
24 what complexes does it form. We all know that the uranile
25 tricarboxylate complex is. It is very stable and tends to

1 solubilize things quite well. We all know that there's a
2 fluoride insoluble compound, there's chloride complexes,
3 there's sulfate complexes, silicates form solid phases.

4 It's very complex and so to say we understand how
5 the uranium will dissolve pretty well by analogies and by
6 experience, it's not the same as saying we know then next
7 what's going to happen. Those are entirely different
8 questions.

9 One thing, I don't want to get into the design of
10 the repository, since that's not the role of the NRC, but I
11 do want to say something which sort of verges on that with
12 respect to what is in the drift and what you could put in
13 the drift that would dramatically, I think, change the rate
14 of release, in particular, of technetium and neptunium from
15 the drifts, and that has to do with the amount of iron
16 that's in the drift, and there is a lot of iron in there,
17 both in the materials of construction of the drifts and on
18 the waste package, and there could be additional metallic
19 iron put in as part of a back-fill of material, such that
20 you could reduce the technetium and reduce the neptunium to
21 forms which were not nearly so readily transported out of
22 the drift and through the environment, especially if there
23 is a path through alluvium which has substantial absorption
24 properties for -- not for the neptunide ion and not for the
25 protecnotate ion, but for reduced forms of those elements.

1 And so it seems to me that there is a -- that's a
2 potential fruitful area to look at. Now, people talk about
3 and say, well, there's going to be a lot of oxygen in the
4 drift and that will oxidize the iron and it won't be in a
5 reducing state anymore.

6 Well, there are things you can do to reduce the
7 amount of oxygen that gets into the system, seal it up, for
8 example, and then the only oxygen that comes in is what's
9 dissolved in the water that comes in, and you can make a
10 pretty good case that it's easy to get enough iron to deal
11 with the oxygen that comes in and dissolved in the water for
12 five to 10,000 years.

13 So there's a lot that could be done. With that, I
14 think I'll quit. I want to say one more thing. It's not
15 necessary to have all the answers to all these questions at
16 the time you license a repository. I think you can take the
17 next 50 years or 100 years and work on these things and
18 decide whether or not you want to put in a back-fill,
19 whether or not you want to tailor that back-fill to deal
20 with some of these specific elements.

21 I don't know whether it will work or not. I just
22 think it has not adequately been addressed.

23 CHAIRMAN JACKSON: Thank you.

24 DR. GARRICK: I promise to wrap it up in a couple,
25 three minutes. The committee has indicated that the safety

1 case for Yucca Mountain probably requires greater emphasis
2 with respect to the issue of technical clarity, particularly
3 with respect to the basic structure of the model, for
4 analyzing the mountain, and, secondly, with respect to
5 displaying and making as tractable as possible the
6 supporting evidence to that modeling.

7 We consider these to be two very important issues.
8 We also consider that primary effort here is one of better
9 characterization and representation of information that is
10 largely already available.

11 The committee has identified two issues that we
12 think stand out as extremely important, obviously, seepage
13 into the drifts and waste package performance. I think one
14 of the things that could be confusing is that is the date of
15 issue, but if you deal with the date of issue in the context
16 of what the analysis is suggesting is important, and even
17 though we're not very confident about new data for the
18 saturated zone having much of an impact on the license
19 between now and licensing time, we are increasingly
20 confident about the availability of new data to address the
21 question of seepage into the drifts and the infiltration
22 part of the analysis, as well as waste package performance.

23 So the data question has to be put in context with
24 the what's important to the performance measure. And if you
25 do that, I think you see you develop a different

1 perspective, as opposed to isolating these issues and
2 talking about them in the context of what might happen in a
3 few years.

4 We believe that there probably is going to have to
5 be more guidance on implementing multiple barriers approach.
6 Part 63 talks about that performance has to come from both
7 the natural setting and the engineered barriers. I think
8 there needs to be some genuine guidance on what is meant by
9 that.

10 We have identified that it's very important to be
11 able to see clearly the impact of individual barriers to
12 overall performance and that this is not a simple problem
13 because of the fact that the chemistry is affected and, in
14 some cases, the neutralization process assumes that a
15 chemical affect is if it's there, even though, from another
16 perspective, the barrier is not there. And we need to
17 better address the question of contribution of individual
18 barriers.

19 We have talked about repository design
20 alternatives and how it imposes differing regulatory
21 considerations. Obviously, with respect to the pre-closure
22 issue, it's going to be a much different problem if we go
23 for 300 years than it is if we go for 50 years, and we need
24 to address that.

25 If we're talking about 300 years, we're talking

1 about licensing something longer than anything we've had any
2 experience with, even in the pre-closure period, much less
3 the post-closure.

4 One thing that's not on this diagram, but I think
5 you've heard a lot of from all of us, is this issue of
6 design as you go, where we think that there needs to be more
7 serious consideration of the matter of flexibility in the
8 design and how we can take advantage of the times that are
9 available before we close the repository and, at the same
10 time, not get ourselves in a position of making a commitment
11 to a project that doesn't fully comply with the reasonable
12 assurance to the safety of the public and the environment.

13 So with that, we will close our formal remarks.

14 CHAIRMAN JACKSON: Let me ask you this question.
15 So should the flexibility in design that you keep stressing
16 rest with the engineered barrier system or are you talking
17 about design within the geologic environment?

18 DR. GARRICK: Talking about the total design. If,
19 for example, we can do some things that give us a very high
20 confidence that water just isn't going to get in the drift,
21 then, of course, the uncertainties associated with the
22 saturated zone become much less of an issue and the need to
23 do a lot of research may become less, too.

24 CHAIRMAN JACKSON: Let me just ask it in a
25 practical sense. Let's imagine the schematic of the

1 repository.

2 DR. GARRICK: Right.

3 CHAIRMAN JACKSON: And it has some tunnels and it
4 has this and side tunnels and it's designed a certain way,
5 these tunnels are put in a certain part of the mountain, and
6 so forth and how you have your waste packages, your
7 engineered barrier system, and you say you design as you go.

8 Now, what are you talking about when you talk
9 about the geologic environment that you would change within
10 the 50 to 300 year period with respect to this system of
11 tunnels and where they're placed? That's what I'm really
12 asking.

13 DR. GARRICK: Yes.

14 CHAIRMAN JACKSON: Because you don't change the
15 geology.

16 DR. GARRICK: No.

17 CHAIRMAN JACKSON: All you change is the inherent
18 cavern that you're putting the things in. So explain to me,
19 when --

20 DR. GARRICK: Well, you're not changing the --

21 CHAIRMAN JACKSON: -- you talk about flexibility.

22 DR. GARRICK: You're not changing the geology, but
23 you are changing what you know about the geology. You are,
24 by making specific and selected measurements that are guided
25 by the evidence that you've put forth to date, you are able

1 to identify where you could get the best bang for your buck.
2 With respect to, for example, measuring the water flow into
3 the --

4 CHAIRMAN JACKSON: But that's a measurement.

5 DR. GARRICK: Yes.

6 CHAIRMAN JACKSON: When I talk about design, I'm
7 thinking of something you do to the repository of what's in
8 it, whether you're changing the thermal loading, the spacing
9 of things, whether you're changing what the waste package
10 looks like. You're not talking about drilling the tunnel
11 somewhere else.

12 DR. GARRICK: Right. Right. Right.

13 CHAIRMAN JACKSON: I just want to be sure that I
14 understand what you're talking about.

15 DR. FAIRHURST: You're quite right. Once you put
16 a set of tunnels in, and you've got a lot of tunnels to put
17 in.

18 CHAIRMAN JACKSON: Right.

19 DR. FAIRHURST: And you're not going to put them
20 all in right away. It is not beyond reason, and I'm not
21 saying one should do this, that you could put tunnels in
22 multiple levels. That would change your thermal loading.
23 If you go to a hot design, you could move -- make sure that
24 if you find a fault and you examine it and say we stay this
25 far away from it, you have to be allowed that flexibility.

1 But I think even more important in that
2 flexibility is the one that so many people are criticizing,
3 is the waste package design. I mean, there is no reason why
4 you can't modify that waste package design with another ten
5 years of experience. It would be stupid not to. But that's
6 flexibility.

7 CHAIRMAN JACKSON: No. All I'm trying to say is
8 that when you talk about it, let's not make it cryptic.
9 Let's be very clear.

10 DR. FAIRHURST: Yes.

11 CHAIRMAN JACKSON: Of how large a flexibility
12 you're talking about, because the statement has been made,
13 and Commissioner Diaz brought it up, that the feeling is
14 that DOE at this point is putting so much stress on the
15 engineered barrier system and one just wants to be clear.

16 DR. FAIRHURST: Yes.

17 CHAIRMAN JACKSON: And what we need to hear
18 clearly from you, that if you're really talking things to
19 the extent of thermal loading, the actual physical design,
20 as well as the waste package, then we need to be clear that
21 that's what you mean, and that's all I'm saying.

22 DR. FAIRHURST: If I could just come back to the
23 question of the USGS and other people's attitude about
24 certain things. I think the USGS has probably the best
25 sense of anybody what really exists, about where the water

1 is going to go. But the problem is, in the license
2 application, is proving it and we've got to come up with the
3 type of distribution that Dr. Garrick talked about, and
4 that's the work.

5 It is not that the geological barriers don't have
6 a role to play. It's proving and reducing uncertainties in
7 that, which is a little easier, to some extent, for some of
8 the metallic canisters, et cetera. There's a more
9 reproducible --

10 CHAIRMAN JACKSON: The VA review process, do you
11 feel that it's confirmed the soundness of the NRC approach
12 of focusing on key technical issues and using the issue
13 resolution status reports for their acceptance criteria?

14 DR. GARRICK: I think the simple answer to that is
15 yes. I think the issue resolution reports have been
16 extremely valuable and I think it has allowed the DOE to
17 make its connection between its repository strategy, the
18 safety strategy criteria, its 19 factors, and the key
19 technical issues.

20 This is something that's concerned the committee
21 for a long time, is whether or not the key technical issues
22 are really dynamic and reflective of what we're learning as
23 we proceed.

24 I think the viability assessment was pretty
25 helpful in mapping from the repository safety strategy and

1 its four basic elements to their 19 factors, to the key
2 technical issues, but we think there is a lot of work there
3 that still needs to be done.

4 CHAIRMAN JACKSON: Thank you very much.
5 Commissioner Dicus.

6 COMMISSIONER DICUS: No further.

7 CHAIRMAN JACKSON: Commissioner Diaz.

8 COMMISSIONER DIAZ: Yes. Let's see. First, kind
9 of a little request in here. You're putting a few things
10 together to send to the Commission. I think it would be
11 helpful to the Commission if you would comment on any
12 potential impact that the viability assessment has on the
13 present draft of Part 63; if there is anything you see in
14 there that we need to consider as part of the Part 63, any
15 relationship, something that we might not be aware of, but
16 the specific impact on Part 63.

17 DR. GARRICK: Okay. Thank you.

18 COMMISSIONER DIAZ: And that's one thing. The
19 other is a little more esoteric, and if my fellow
20 Commissioners allow me. I'm kind of looking at the overall
21 issues that you deal together as far as research,
22 development and engineering.

23 Of course, we all know these are not linear
24 functions. Knowledge doesn't accumulate as a function of
25 time. And the fact is it is an S curve. You put a lot of

1 effort, you get nowhere, and then you put a little more
2 effort and it starts going up and then you keep doing it and
3 keeps increasing. Then you can put in more effort and
4 you're not getting anywhere again. We all have run into
5 that quite frequently.

6 The thing that I'm kind of missing is, when each
7 and all of these important issues are put together, where
8 are we in the S curve? Because the S curve is only
9 terminated in real life by an engineering decision. We have
10 enough at this point -- we don't have it all. We're not
11 going to have it all. We keep going up another thousand
12 years, because we are in that part of the S curve. We're
13 only adding a little tiny bit of spending, enormous amount
14 of money, but not really getting much farther anywhere.

15 Obviously, there are issues in which we are not on
16 the flat part of the S curve and there are issues in which
17 we are and what the nation needs is to know which issues can
18 be intercepted by engineering and say we know enough, even
19 if the uncertainty is there, when we play it in your
20 probability curve, okay, which, by the way, is just exactly
21 as what happens when you put a fast burst of neutrons in a
22 medium and you let it go as a function of time, it's exactly
23 the same.

24 I mean, this process is repeated in nature over
25 and over again. So the issue is, where are we in the S

1 curve on the main key issues and are we intercepting them
2 with engineering at the right point, and that is a
3 tremendous issue, because that's what the nation really
4 wants to know; can engineering intercept, create a design
5 that will be effective in doing what it's supposed to do, or
6 do we still need to go further in these things.

7 And the definition on key issues of where we are,
8 to me, would be of great value.

9 DR. GARRICK: Thank you.

10 CHAIRMAN JACKSON: Commissioner McGaffigan.

11 COMMISSIONER MCGAFFIGAN: I'd first like to make
12 the point that I think Dr. Fairhurst just made a fairly
13 profound point in talking about the uncertainties in the
14 non-engineered systems and the fact that those uncertainties
15 are large and that keeps DOE focused more and more on the
16 waste package, where they can come up with new materials.

17 I am worried about over-conservatism. If I go
18 back to the chart that Dr. Garrick showed us at the outset,
19 contributors to risk, there's a danger that, in listening to
20 all this discussion, that what you end up doing is taking
21 the far element -- you know, you have all these risk curves
22 and because of uncertainties, we say, gosh, we're going to
23 -- we'll go to that point here, we'll go to that point, we
24 just take the 99th percentile of each of these elements.

25 And then I'll assume away that I get any benefit

1 whatsoever from the Yucca Mountain site and rest entirely on
2 the waste package, in which case you legitimately get
3 questions from Nevada, why isn't it in Ed McGaffigan's back
4 yard in Arlington, because you can make the standard there,
5 too.

6 And I don't think that's true, by the way, and I'm
7 not willing to engage in that experiment. But people do say
8 -- I have seen it said in the last week that 100 millirem
9 standard you can meet anywhere. I don't think that's
10 correct.

11 But the -- how do we deal with getting the sort of
12 curves that Dr. Garrick talked about as opposed to building
13 conservatism upon conservatism upon conservatism and getting
14 -- you know, the USGS says a long chain of
15 overly-conservative model elements can only lead to
16 correspondingly low probability of occurrence of the
17 resulting repository system behavior.

18 We have previously seen the climate models,
19 associated infiltration rates, seepage flow model, as
20 overly-conservative, and to this list we can add saturated
21 zone transfer model, which assumes only minor dilution of
22 radionuclides, regardless of climate.

23 All this over-conservatism is not without cost,
24 naturally. It comes in the form of engineered barriers that
25 are correspondingly conservative, so as to protect against

1 overly conservative estimates of seepage in placement
2 drifts, et cetera.

3 We can quickly turn a 25 millirem standard into a
4 25 microrem standard or a 25 picarem standard, I guess, if I
5 pile enough conservatism onto things. How are we going to
6 guard against that?

7 DR. GARRICK: I think this is a fundamental
8 question and, in my opinion, it's the question that was the
9 principal driver for thinking on a more risk-informed basis
10 and pushing for answers to what's the issue got to do with
11 risk.

12 I think the first thing that I would do is ask for
13 these curves and get that information in a form that I at
14 least know where to look to challenge it or to verify it.

15 I think this is something that is an underlying
16 basic issue associated with this kind of project. It was
17 that way in the early years of the reactor project. We
18 found we were spending a lot of time on issues that were not
19 going to eventually be the principal cause of accidents
20 later in the years.

21 One of the reasons that they weren't is we did
22 spend a lot of time on then, but on the other hand, when the
23 accident finally came around, we realized that most of the
24 problems came from the support systems which received very
25 little attention in the licensing process.

1 So all I can say about that is that we need to
2 push forward the process of doing our analysis in such a way
3 that we better expose what's important, so that we can
4 answer the so-what question.

5 That's not an easy task, but I'm convinced it's
6 doable.

7 CHAIRMAN JACKSON: Commissioner Merrifield.

8 COMMISSIONER MERRIFIELD: I have no questions. I
9 just want to express my thanks to the committee for the work
10 that it's been doing in terms of reviewing these areas. I
11 certainly look forward to the additional information you'll
12 be providing us within the next few weeks. I did have some
13 questions in those areas, so those will be of great interest
14 to me.

15 CHAIRMAN JACKSON: I want to thank the advisory
16 committee members. I also want to thank, ahead of time, the
17 very indulgent members who are here from the Nuclear Waste
18 Technical Review Board, especially since I'm going to say
19 that we will take a five-minute break.

20 [Recess.]

21 CHAIRMAN JACKSON: I think we will proceed. I
22 welcome to the table Dr. Deborah Knopman and Dr. Daniel
23 Bullen, from the Nuclear Waste Technical Review Board, and
24 we look forward to hearing your remarks this morning.

25 DR. KNOPMAN: Good morning, Chairman Jackson.

1 It's good to be back. Commissioners, ladies and gentlemen,
2 it's a pleasure to be here today. My name is Deborah
3 Knopman. I'm a member of the U.S. Nuclear Waste Technical
4 Review Board. As many of you know, all board members serve
5 part-time and most of us have other full-time jobs.

6 I am director of something called the Center for
7 Innovation and the Environment of the Progressive Policy
8 Institute, in Washington, D.C. My technical expertise is in
9 hydrology, environmental and natural resources policy
10 systems analysis and public administration.

11 With me today is another board member, Dr. Daniel
12 Bullen, who is director of the nuclear reactor laboratory
13 and associate professor of mechanical engineering at Iowa
14 State University, in Ames, Iowa. His technical expertise
15 includes performance assessment, modeling of radioactive
16 waste disposal facilities, and materials performance and
17 radiological and severe service environments.

18 Our chairman, Dr. Jerrod Cohen, who is President
19 of Carnegie Mellon University, would have liked to be here
20 today to make this presentation, but he is out of the
21 country on university business. I'm not sure what. Anyhow,
22 Dr. Cohen sends his regrets.

23 Let me begin by briefly summarizing who we are and
24 what we do. The board was created in Congress in 1987, in
25 the '87 amendments to the Nuclear Waste Policy Act, and is

1 charged with evaluating the technical and scientific aspects
2 of DOE's high level waste program. This includes site
3 characterization activities at Yucca Mountain and activities
4 relating to the packaging and transport of high level
5 radioactive waste within -- and spent nuclear fuel.

6 The board is independent within the Federal
7 Government. We're not part of DOE or any other agency. All
8 of our 11 members are nominated by the National Academy of
9 Sciences and appointed by the president. Dr. Bullen and I
10 have served as members of the board since January of 1997.

11 You asked the board to provide our views on the
12 viability assessment at Yucca Mountain that was recently
13 published by DOE. We are pleased to do so, but we must
14 preface our remarks by noting that the board's review of
15 this document is ongoing and these are preliminary views
16 that we present today and these views may evolve as our
17 review continues.

18 As you know, the purposes of VA were to summarize
19 the scientific information that had been collected over the
20 last 15 years, presents a conceptual design of a repository
21 and waste packages that might be suitable for the site,
22 estimate how well such a repository would isolate waste from
23 the human environment, identify additional studies and
24 costs, and prepare a license needed to evaluate the site,
25 prepare a license application, and then estimate the overall

1 cost of disposing of the waste.

2 It's an evaluation. The VA is an evaluation of
3 progress, on-site characterization, and it was meant to
4 provide a technical basis for deciding whether to continue
5 studying the site.

6 The VA is not and was never intended to be a
7 determination of whether the Yucca Mountain site is suitable
8 for development as a permanent geologic repository. The
9 suitability decision projected for 2001 requires the
10 completion of further site studies, repository design work
11 and analyses of repository system performance.

12 So far, neither the board's review of the VA nor
13 its other reviews of the program has identified any features
14 or processes that would automatically disqualify the site.

15 We think the VA is clearly the most significant
16 milestone thus far in the characterization of Yucca
17 Mountain. There are many parts of the VA that present
18 cutting-edge scientific analysis in a comprehensible format
19 and the board has commended and continues to commend the DOE
20 for the successful completion of this assessment.

21 In assembling the VA, DOE integrated very large
22 amounts of data and analyses, established a preliminary
23 repository design and set priorities for work to be
24 completed before decisions are made about site
25 recommendation and licensing.

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1 Most important, I think, from our board
2 perspective, the process of integration has had the effect
3 of focusing the objectives of the scientific investigations.
4 In particular, the VA highlighted the very close connections
5 between the repository design and the priority list of key
6 uncertainties about the natural system.

7 For example, such site characteristics as the
8 movement of water and vapor at temperatures above boiling
9 and the effect of high temperatures on rock stability are
10 important only because of the VA's high temperature
11 repository design. In a low temperature or below boiling
12 point design, these uncertainties would be less significant
13 and might not need to be resolved for making a suitability
14 determination. It's a very important connection and we
15 think this permeates the whole evaluation process.

16 The board concurs with the DOE that the VA is
17 simply a snapshot of current knowledge about the site that
18 Congress can use to make an informed decision on whether to
19 continue funding.

20 Today we will discuss our board's general views
21 about the site and design of the repository for the site
22 based on our review of VA. We do conclude, we have
23 concluded that Yucca Mountain continues to merit study, as
24 the candidate site for a permanent geological repository and
25 that work should proceed to support a decision on whether to

1 recommend the site to the President for repository
2 development.

3 We think the 2001 date anticipated for this
4 decision is very ambitious and much work remains to be
5 completed. At a minimum, significant progress on the work
6 identified by the board in its November 1998 report and by
7 DOE in volume four of the VA will be required to support a
8 technically defensible decision.

9 The board supports continuing focus studies of
10 both natural and engineered barriers at Yucca Mountain to
11 attain a defense-in-depth repository design and to increase
12 confidence in predictions of repository performance.

13 In November of '98, the board issues a report
14 outlining its views on the future research needed to address
15 uncertainties about the performance of the repository
16 system, including both the engineered and natural barriers,
17 and the board concluded in that report that although there
18 are economic and technical limits to reducing uncertainties
19 about the performance of the proposed repository system,
20 some key uncertainties can be reduced further over the next
21 few years through a focused research effort.

22 The board realizes there will always be
23 uncertainty about the performance of a repository far into
24 the future and that eliminating all uncertainty is not
25 possible or necessary.

1 However, the board believes that identifying
2 important sources of uncertainty, estimating the magnitude
3 of those uncertainties, reducing critical uncertainties, and
4 evaluating the effects of residual uncertainties on expected
5 repository performance are essential for supporting a
6 technically defensible site suitability decision and license
7 application.

8 The board notes that the VA relies heavily in some
9 cases on the formal elicitation of expert judgment. This
10 was necessary and we think extremely useful, given the lack
11 of field and laboratory data in certain areas and the
12 equivocal nature of some of the data in other areas.

13 However, as the experts themselves pointed out,
14 expert judgment should not be used as a substitute for data
15 that can be obtained directly from site laboratory or other
16 investigations.

17 In the board's view, every reasonable effort
18 should be made to minimize uncertainty through repository
19 and waste package design. Additional data then can be
20 sought to address uncertainties rather than relying so
21 heavily on expert judgment to support decisions about the
22 suitability of the site and a possible license application.

23 After reviewing the VA, the board concludes that a
24 significant amount of additional scientific and engineering
25 work will be needed to increase confidence in a site

1 suitability decision and license application. Alternative
2 responsibility designs should be evaluated that have the
3 potential to reduce uncertainties in projected repository
4 performance and thereby reduce the scope of additional
5 necessary scientific study.

6 Regardless of the design adopted, however,
7 long-term scientific studies will be needed to establish a
8 solid foundation for projecting repository performance
9 thousands of years into the future.

10 Let me go into this in a little bit more detail.
11 As you all know, the DOE has spent many years and many
12 dollars studying the Yucca Mountain site and designing the
13 engineered components of the repository system compatible
14 with the site. These efforts have produced a large amount
15 of data, but significant uncertainties remain about the
16 ability of the VA reference design to safely isolate
17 radioactive waste.

18 In part, this is a problem inherent in
19 extrapolating repository performance for thousands of years
20 from data acquired over a much shorter period.
21 Uncertainties also are associated with specific
22 characteristics of the Yucca Mountain site, especially the
23 difficulty in predicting the nature of water movement
24 through the fractured unsaturated rocks of the mountain and
25 the possible entry of water into repository tunnels and its

1 contact with waste packages.

2 Uncertainties like would be exacerbated by the
3 high temperatures of the reference repository design, which
4 may reduce tunnel stability, enhance waste package
5 corrosion, and perturb water movement in ways that are
6 difficult to predict.

7 Predicting the performance of waste packages,
8 which play a crucial role in the performance of the VA
9 reference repository design, is a critical area that needs
10 more study. Candidate waste package materials rely on the
11 presence of a thin passive layer to protect the underlying
12 metal from the oxidizing environment that will be present in
13 a Yucca Mountain repository.

14 I will just add, the mountain breathes, so there
15 is likely to be oxygen in that mountain all the time.

16 Improving the basic understanding of long-term
17 passivity is essential because at present, there seems to be
18 no documented natural or manmade analogs that can be used to
19 demonstrate whether this mode of protection would persist
20 over the desired period of time.

21 Research also should be continued on the
22 susceptibility of the passive layer to known modes of
23 corrosion, especially potentially catastrophic failure
24 modes, such as stress corrosion cracking.

25 The board believes that the scientific and

1 engineering work completed to date, as extensive as it is,
2 should be supplemented to improve the technical foundation
3 for evaluating the suitability of the site for preparing a
4 license application. The board agrees with a DOE
5 commissioned peer review panel which found that two types of
6 additional data are needed to improve the credibility of the
7 total system performance assessment part of the VA.

8 First, fundamental data that are essential to the
9 development and implementation of the models, and, two, data
10 sets designed to challenge conceptual models and test the
11 coupled models used in TSPA VA. There are substantial
12 uncertainties about the performance of a repository based on
13 the VA reference design that can be resolved only by
14 considering alternative repository and waste package designs
15 and by collecting additional scientific data.

16 In volume four of the VA, the DOE has identified
17 and set priorities for a suite of additional studies to
18 produce information needed for repository licensing,
19 assuming that the site is determined to be suitable for
20 development as a repository.

21 The planned studies include data collection
22 analysis and engineering design as appropriate for the three
23 major barriers discussed by the board in its November '98
24 report, and we include in that unsaturated zone, the
25 engineered barrier system, and the saturated zone.

1 Among the most important are geologic, geochemical
2 and hydrologic studies, including those planned for what we
3 call the east-west across drift, also called the enhanced
4 characterization of the repository block project.

5 These studies are aimed at understanding the
6 magnitude and distribution of seepage into the repository
7 under present conditions and under past conditions when the
8 climate was very different. They include systematic
9 analysis of the rock samples being collected, especially for
10 chlorine-36 and other indicator isotopes.

11 Flow and seepage tests at different locations
12 along the drift, moisture monitoring activities, tests in
13 the lithophysal zones that would host the majority of waste
14 packages, and studies of the Solitario Canyon fault, the
15 active fault bounding the repository, that may also serve as
16 a main conduit for percolating water.

17 Of equal importance are studies for supporting
18 projections of the performance of the engineered barrier
19 system, which, in the VA reference design, plays a critical
20 role in isolating radioactive wastes for tens of thousands
21 of years.

22 The studies identified by the DOE in volume four
23 of the VA appear to be appropriate in the sense that they're
24 technically feasible, likely to produce useful information
25 that will improve the understanding of long-term repository

1 performance. There is no guarantee, however, that
2 completion of these studies will lead to successful
3 development of a repository at the site. Studies could show
4 the site to be unsuitable.

5 They could raise new questions requiring further
6 study. On the basis of current information, however, the
7 board is pleased that volume four identifies an appropriate
8 suite of studies to be pursued in the years ahead.

9 The board is concerned that some of the planned
10 studies identified in volume four of the VA may be deferred
11 because funds are not available to carry them out in a
12 timely manner. Deferring scientific and engineering studies
13 will delay the assembly of a more credible technical basis
14 to support the site recommendation anticipated in 2001, and,
15 if the site is found suitable, license application in 2002.

16 The current VA repository design, a credible basis
17 does not yet exist.

18 For some additional thoughts on alternative
19 repository design and to complete our presentation, I would
20 like to turn my colleague, Dr. Bullen.

21 DR. BULLEN: Thank you, Dr. Knopman. High
22 temperatures in the VA repository design cause large
23 uncertainties about how the site would behave both before
24 and after repository closure. The board believes that a
25 repository design with a lower waste package surface

1 temperature merits further detailed analysis.

2 Such a design has the potential to reduce
3 uncertainty, simplify the analytical bases required for site
4 recommendation, and make licensing easier.

5 In fact, I'd like to repeat that last two
6 sentences, that the board believes that repository design
7 with a lower waste package surface temperature merit further
8 detailed analyses. Such a design has a potential to reduce
9 uncertainties, simplify the analytical bases required for
10 site recommendation, and make licensing easier.

11 Combined with improved waste package shielding,
12 the design could also simplify pre-closure performance
13 confirmation by enhancing access to tunnels, thus reducing
14 or eliminating the need for separate performance
15 confirmation drifts and permitting direct access to
16 performance confirmation instrumentation near the waste
17 packages.

18 The following factors influenced the board's
19 thinking on repository design. Lower temperatures could
20 significantly reduce coupled thermal hydrologic and thermal
21 geochemical processes. Maintaining near field temperatures
22 below the boiling point of water after repository closure by
23 ventilation of aging could reduce uncertainties about the
24 movement of water and associated geochemical processes in
25 the repository's natural barriers.

1 This could increase the confidence in the analyses
2 of repository performance required for a site suitability
3 determination. For a given environment, chances for
4 degradation of corrosion resistant waste package materials
5 would be significantly reduced if peak waste package surface
6 temperatures were reduced.

7 High repository temperatures are expected to
8 increase the mechanical degradation of repository rocks.
9 There is little, if any relevant experience to draw on for
10 predicting the long-term effects of repository heating and
11 subsequent cooling on drift stability.

12 The DOE is evaluating alternative repository
13 designs that may be appropriate as the basis for a license
14 application and the reference repository design presented in
15 the VA is expected to change as the alternatives are
16 considered.

17 The board strongly urges that analyses of
18 alternatives should not be limited to enhancements to the
19 reference design, but should give serious consideration to
20 true alternatives to the reference design, including a
21 design that limits waste package surface temperatures.

22 If Yucca Mountain is found suitable and
23 construction of a repository is authorized, the board
24 believes that there will be a need for a long-term science
25 program to reduce uncertainties about the performance of

1 engineered barriers and interaction between the repository
2 and natural processes.

3 An important goal of these studies should be
4 identification of unknown failure modes or unexpected
5 evolution of natural processes that could adversely affect
6 the performance of the major barriers of the repository.

7 Thus, these studies may be more extensive than the
8 performance confirmation activities now anticipated for a
9 repository. For example, if the waste package design
10 continues to rely strongly on corrosion resistant metals
11 protected from corrosion by a passive layer, long-term
12 scientific studies need to be carried out to improve the
13 basic understanding of the processes that could affect the
14 passive layer.

15 Long-term studies of the natural barriers also
16 will be needed primarily to verify projections of water
17 movement within the unsaturated and saturated zones near the
18 repository. For a high temperature repository design,
19 fundamental studies of coupled thermal hydrologic and
20 thermal geochemical processes will be needed.

21 For a low temperature design, a less extensive
22 program of monitoring in situ water movement may be
23 adequate. Whether the long-term scientific studies are a
24 decade-long program or a much longer will depend in part on
25 how the repository design evolves. There is no doubt,

1 however, that a program of some sort will be needed to
2 increase confidence in estimates of long-term repository
3 performance.

4 The ultimate goal of the studies at Yucca Mountain
5 is to determine that a repository at the site can safely
6 isolate wastes from the human environment. The DOE proposes
7 to demonstrate safe waste isolation through a five-part
8 post-closure safety case consisting of the following.

9 Assessment of expected post-closure performance,
10 design margin and defense-in-depth, consideration of
11 disruptive processes and events, insights from natural and
12 manmade analogs, and a performance confirmation plan.

13 The board believes that this proposed strategy is
14 an appropriate way to evaluate a Yucca Mountain repository.
15 Although each component, especially defense-in-depth and the
16 performance confirmation plan, requires significant
17 additional development.

18 Multiple lines of evidence will provide a more
19 convincing demonstration of repository safety than would any
20 individual component of the safety case. TSPA, including
21 sensitivity and uncertainty analyses, is the appropriate
22 core analytical tool of the safety case. TSPA is the
23 analytical technique that pulls together relevant
24 information about the performance of the repository system,
25 determines which features or parameters could strongly

1 influence performance, and estimates the uncertainty in
2 projections of performance.

3 TSPA has limits, however, and the DOE will need to
4 aggressively pursue the other four components of the safety
5 case. Judging how realistic the bottom line TSPA estimates
6 of repository performance are in the VA is difficult. In
7 fact, a DOE presentation to the board at its most recent
8 meeting stated that the VA's performance assessment cannot
9 be used to do the following; cannot assess compliance with
10 regulatory criteria, cannot show defense-in-depth for the
11 design of the repository system, as we saw earlier this
12 morning, cannot assess the importance of small design
13 changes, and cannot determine the suitability of the overall
14 repository system.

15 Because of a general lack of data to support
16 critical assumptions in the mathematical models, some of the
17 assumptions in the TSPA VA are likely to be overly
18 conservative and others may be non-conservative. Numerous
19 examples are presented in the recent report of the TSPA VA
20 peer review panel, which I understand is actually being
21 presented today in Las Vegas.

22 Assessing the realism or at least verifying the
23 conservatism of TSPA projections of repository performance
24 is an important goal of the additional studies called for by
25 the board. The board does not believe, however, that

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1 underlying -- that relying solely on TSPA to demonstrate
2 repository safety will ever be possible.

3 For that reason, the other four components of the
4 post-closure safety strategy should be developed
5 aggressively as compliments to TSPA. An implicit or
6 explicit sixth component of the safety strategy should also
7 be considered; designing the waste packages and the
8 repository to minimize uncertainties in projected repository
9 performance.

10 The VA concludes Yucca Mountain remains a
11 promising site for a geologic repository and work should
12 proceed to support a decision in 2001 on whether to
13 recommend the site to the President for the development as a
14 repository. The board agrees that Yucca Mountain continues
15 to merit study as the candidate site for a permanent
16 geologic repository and that work should proceed to support
17 a decision on whether to recommend the site to the President
18 for development.

19 The 2001 date anticipated for this decision is
20 very ambitious and much work remains to be completed. At a
21 minimum, progress on the work identified by the board in its
22 November 1998 report and by the DOE in volume four of the VA
23 will be required to support a technically defensible
24 decision.

25 The board supports continuing focus studies of

1 both natural and engineered barriers at Yucca Mountain to
2 attain a defense-in-depth repository design and to increase
3 confidence in predicting -- in predictions of repository
4 performance.

5 This concludes our prepared remarks and we would
6 be happy to answer any questions that you may have.

7 CHAIRMAN JACKSON: I have a comment and then a
8 question, which you may think that you've already answered.
9 It strikes me that perhaps TSPA and what it means, total
10 system performance assessment, may be a misnomer if, in
11 fact, these other four elements of what you feel should
12 comprise a safety case; that if it can't address design,
13 margin and defense-in-depth, if you can't -- it doesn't have
14 the consideration of disruptive processes and events, if it
15 doesn't have folded into it insights from manmade and
16 natural analogs, and it has no performance confirmation
17 plan, how can you make an assessment or a prediction of
18 expected post-closure performance?

19 That's my question, but let me put it another way.
20 To what extent is the DOE reference design a natural setting
21 driven design vice being a conceptual design, which is then
22 studied for the effect of the environment on it? Do you
23 understand what I'm saying?

24 DR. KNOPMAN: Yes.

25 CHAIRMAN JACKSON: To what extent is one really

1 looking at a truly coupled modeling? Because if you don't,
2 you're never going to get into the issue of design margin
3 and defense-in-depth.

4 DR. BULLEN: If you look at the history of the
5 design that we see in TSPA, you'll go back about six or
6 seven years and you will understand that at the time, it was
7 thought that the mountain was relatively dry. And since the
8 mountain was relatively dry, the waste package design and
9 the hot repository concept was thought to be a very good
10 strategy for isolating waste from the accessible
11 environment.

12 Since that time, we've built exploratory studies
13 facility, we built the enhanced characterization repository
14 block, we've discovered chlorine-36, we've changed the
15 estimate of the percolation rates that are coming into the
16 mountain, and we've also changed the prediction of what that
17 percolation rate might be in the future with the future
18 climate changes.

19 That design that was formed in the basis of the
20 multipurpose container six or seven years ago is probably
21 not the design that you would pick now had you had that
22 information six or seven years ago. So the evolution of the
23 design, which the license application design selection
24 process is currently underway, is addressing those issues.

25 And if you look at the five designs that were

1 mentioned by the ACNW, you'll see that a majority of those
2 designs don't have corrosion allowance barrier on the
3 outside, which would make sense. Engineers wouldn't put a
4 corrosion allowance barrier where there is dripping water.

5 So what we see here in the TSPA and its analyses
6 is essentially a design that was frozen a while ago and
7 analyzed and now DOE is making changes to that design to
8 address the license application and -- well, suitability
9 determination and license application in the future, based
10 on what they know now.

11 And so the evolution is taking place and that
12 design is, again, based on the environment, as we understand
13 it. So in answer to your question, the design, as we see
14 it, is evolving and the design is based on the mountain. It
15 wouldn't go into Commissioner McGaffigan's back yard because
16 we wouldn't pick that design or DOE wouldn't pick that
17 design to address the issue.

18 But the design that they see now or the evolution
19 of the design is a process that I think is important.

20 CHAIRMAN JACKSON: You were going to make a
21 comment.

22 DR. KNOPMAN: I was just going to try to answer
23 your first question.

24 CHAIRMAN JACKSON: Please.

25 DR. KNOPMAN: But did you want to add that?

1 CHAIRMAN JACKSON: No. Go on.

2 DR. KNOPMAN: I concur with my colleague on his
3 response to the second question about the natural setting
4 design. What the board is saying is that TSPA is one of
5 what should be multiple lines of evidence that feed into our
6 overall confidence in making predictions about performance.

7 It is a construct. It is a model of models, in
8 effect. But it's not the only way in which one can
9 integrate scientific information. We want it to be as rich
10 as possible. The board's comment about where TSPA is now
11 reflects TSPA VA.

12 Now, there may not be many changes in that -- in
13 the performance assessment modeling tools and strategy
14 between now and the time of a suitability determination,
15 that remains to be seen, but the fact is in its current
16 state, it is not -- should not be relied on solely as a
17 source of credible predictions. That's freely admitted.

18 But that doesn't mean it's not useful. It's
19 extremely useful in gaining insights into how the system --
20 different parts of the system may function together.
21 However, it's limited by our own understanding of those
22 coupling of processes.

23 CHAIRMAN JACKSON: Well, perhaps in the spirit of
24 plain English initiatives, I mean, it could be construed as
25 a misnomer because it really is a methodology of integrating

1 information, but within a certain boundary.

2 DR. KNOPMAN: Yes. I personally would prefer
3 partial system performance.

4 CHAIRMAN JACKSON: Yes. PSPA, right?

5 DR. KNOPMAN: I've had a problem with that all
6 along.

7 CHAIRMAN JACKSON: But let me ask you a question.
8 You've talked about that there shouldn't be an over-reliance
9 on expert elicitation.

10 Can you give the Commission a concrete example of
11 where you think over-reliance on expert elicitation could be
12 replaced, in a timely manner, by data collection and
13 testing?

14 DR. KNOPMAN: Yes. Let me start with the
15 saturated zone, which our board believes does play
16 potentially a role in waste isolation.

17 Right now there is a dearth of data about the
18 saturated zone. During the expert elicitation process, the
19 estimates by the experts were literally all over the board
20 because of that dearth of data.

21 We think that the drilling is proceeding rather
22 rapidly now with the -- Nye County has got a drilling
23 program, you may have heard something about that. Going
24 from zero to ten or 12 wells can produce some good
25 information about transmissivities and some of the -- some

1 better understanding of the properties of the flow regime.

2 So I would say that is a very good example. Now,
3 is it enough or adequate? That's to be seen. But going
4 from so little to what that Nye County program can produce,
5 I think, is a substantial advantage and possibly will allow
6 a much more confident view of what kind of dilution we may
7 be looking at, what kind of reducing environment we might be
8 looking at, the geochemistry in the saturated zone is very
9 important.

10 DR. BULLEN: In addition to what Dr. Knopman said,
11 the expert elicitation panel on waste package performance
12 and waste package degradation cited a number of experimental
13 programs which could be done in the near term to answer the
14 questions like what is the range of susceptibility of
15 alloy-22 to crevice corrosion, which was the key question
16 that was identified this morning in the ACNW presentation.

17 And those experiments can be done and, in fact,
18 the Center for Nuclear Regulatory Analysis has done those
19 types of experiments and had been actually unsuccessful in
20 making it happen below the boiling point, which is one of
21 those things that says, well, maybe this material is pretty
22 good.

23 Those experiments are underway and most of them
24 are at our national laboratory and, in fact, that's where I
25 am, to take a look at those experiments.

1 But these are questions that can be answered in
2 the short term that would greatly support evidence for a
3 suitability determination. And so that basically takes a
4 look at the expert elicitation, identifying things that
5 could be done, and then hopefully the DOE taking that
6 information and actually obtaining that data.

7 DR. KNOPMAN: I would add a third example about
8 what actually happens to moisture that possibly may enter
9 into the repository drift, and this is something we can go
10 and observe and these experiments are beginning to proceed
11 in the ECRB now, as we understand it, and they'll be sealing
12 off some parts of it.

13 So the speculation in the USGS review of VA about
14 what exactly happens to the drips, this can be -- we can do
15 some observations, it will make a big difference.

16 CHAIRMAN JACKSON: Now, you clearly have a point
17 of view, so my question is, are there any benefits that you
18 see of a high temperature design beyond the reduction of
19 water contact with the waste package.

20 DR. BULLEN: When the high temperature design was
21 proposed, with the limited infiltration rate, it was
22 probably the correct path to take. With the additional
23 information now, the board is seriously concerned that a
24 high temperature design does a number of things that may
25 pose more detriments than benefits.

1 Right now, there are significant, as you
2 mentioned, as you noticed in our testimony, there are
3 significant uncertainties associated with the movement of
4 water, the changes in the chemistry, the stability of the
5 rock, and so a high temperature design adds all that
6 uncertainty.

7 A below boiling point design improves waste
8 package performance and I would beg to differ with the
9 presentation this morning that it -- it does not necessarily
10 increase relative humidity near the waste packages, if the
11 repository is ventilated for extended periods of time.

12 Now, that is not in any of the designs long term
13 that are proposed, although the enhanced design analyses
14 does have a couple of ventilated scenarios that were being
15 evaluated. But the ventilation not only removes heat, it
16 removes water. So the longer we can keep the waste packages
17 in a benign environment and the longer we can avoid this
18 area of susceptibility in temperature, where crevice
19 corrosion of alloy-C22 or alloy-22 may be a problem, the
20 better off we are.

21 So the board feels that there is a reduction in
22 uncertainty associated with a low temperature design and
23 that there would be an improvement in performance.

24 CHAIRMAN JACKSON: What are your thoughts on our
25 staff's concern that the design may not iterate to some

1 final one by the required deadline?

2 DR. BULLEN: In reading the staff's comments from
3 yesterday, there is a significant concern that they're going
4 to carry through or carry forward a great deal of
5 information and, in fact, just the analyses of the five
6 designs is going to be a challenge for not only our board,
7 but your staff.

8 So I would tend to agree and, in fact, I would be
9 very pleased, should they focus the design down to one and
10 carry that through.

11 DR. KNOPMAN: The board doesn't have a formal
12 position on how many designs should be carried forward. The
13 board's position on the low temperature design is that it
14 requires further analysis.

15 We're not cost experts. There are many aspects of
16 design, repository systems operations that we don't analyze.
17 So we want to make it very clear that while it looks to us
18 that this would be a way to reduce some of the nagging
19 uncertainties about the geological -- the natural barrier
20 system, as well as the natural barrier system.

21 We're not investing in stock in a low repository
22 design either. I would like to see that analysis done
23 seriously in a way to provide a choice, a good technical
24 choice.

25 CHAIRMAN JACKSON: You've been very indulgent.

1 I'm going to indulge my colleagues down the line.

2 Commissioner Dicus.

3 COMMISSIONER DICUS: I don't have any questions.

4 CHAIRMAN JACKSON: Commissioner Diaz.

5 COMMISSIONER DIAZ: If I go through your testimony
6 in here, it appears to me that if I go back to my last
7 question, that you are saying that in a series of critical
8 issues, we are not at the point of the S curve that we can
9 stop and put an engineering point on it.

10 The question is, have those issues, the ones that
11 are at that point, have they been catalogued by the board
12 and communicated?

13 DR. KNOPMAN: Yes, to some extent, and your staff
14 has catalogued them and I think in the area of volcanic and
15 seismic hazards, there is closure, in some sense. There are
16 a couple of issues that have been raised having to do with
17 extensional processes at Yucca Mountain. These are not
18 confirmed, but overall those issues, we think, have been
19 dealt with adequately. So I guess I would put that.

20 The climate issue is, I think, had been thought to
21 be in that category. I think that's going to get reopened
22 and probably should. It's an important boundary condition.

23 COMMISSIONER DIAZ: But there are certain issues
24 that you said are being now addressed that could provide
25 that little bit of extra information that is needed.

1 DR. KNOPMAN: The board very strongly advocated
2 the east-west cross drift or the ECRB, precisely because we
3 thought there would be a fairly large increase in
4 information in a relatively short amount of time about the
5 repository block itself and there has been.

6 We think it's not -- hasn't been -- we still
7 haven't tapped into the full potential of that tunnel to
8 provide us with the additional information, studies. Some
9 things have gone slowly, particularly the chlorine-36
10 analyses that have been collected, but are being rather
11 slowly analyzed.

12 And I'd point out that, again, on the USGS review,
13 that the chlorine-36 evidence of fast paths wasn't even
14 mentioned in that review.

15 So these are things that can be -- that we can
16 learn a lot about in a relatively short amount of time that
17 would significantly add to our insight, I think.

18 COMMISSIONER DIAZ: And last but not least, on the
19 same point. Has the board looked at the philosophy of
20 design as you go as a potential to increase reliability of
21 the state-of-the-art design rather than the ten years ago
22 design that was no good?

23 DR. KNOPMAN: Well, our board, which includes
24 ecologists and folks from other disciplines, I think,
25 generally endorse the idea of adaptive management. However,

1 the board works very hard to not wander into the realm of
2 policy choices. So we don't have an opinion about how much
3 flexibility should be retained in the licensing process
4 within the design.

5 I'd point out, I was in Sweden last week, they're
6 wrestling with this very question, because they have a very
7 different kind of siting process and the communities that
8 are under -- the communities that are considering whether
9 they want the repository want the design nailed down now
10 before they lay themselves on the line politically to make
11 the choice for further additional site characterization
12 work.

13 So this is a big question not just for the U.S.,
14 but elsewhere, as to how much you lock in the design, but
15 the board doesn't have a position on that.

16 DR. BULLEN: I would like to emphasize one point
17 that draws on your analogy, is that different designs have
18 different sets of S curves, as you made an allusion to, and
19 I guess the board would say that the S curves for a low
20 temperature design are different than those associated with
21 a high temperature design and your level of confidence on
22 where you are on the curve is different.

23 CHAIRMAN JACKSON: Commissioner McGaffigan.

24 COMMISSIONER MCGAFFIGAN: I'll follow-up briefly
25 on the flexibility issue. It does strike me that having

1 some flexibility in our process is important, because we are
2 going to learn something over the next 50 years, if this
3 project goes forward, and I think that the general process
4 around here is license amendments, if it's a major change,
5 if they decide to put back-fill in at some point, for
6 example, and it's not in the license design, that you would
7 only do that if a safety case was made that that's an
8 improvement.

9 So I think what you could tell the public is that
10 we're building in the flexibility in in order to make safety
11 improvements.

12 If I were talking to the Swedish public, I think
13 I'd try to make that -- you know, we're going to do a
14 reference design based on what we know today, but there may
15 well be improvements in waste packages or other mechanisms
16 for making the repository even more safe, and we presumably
17 want a process that's flexible enough to adapt to those
18 sorts of changes.

19 CHAIRMAN JACKSON: But I think she's just saying
20 that that's a public policy issue.

21 DR. KNOPMAN: We, by the way, tried that on the
22 Swedes, just to say, well, wouldn't the communities
23 themselves, and they said, no, they thought it would
24 undermine their confidence in what they were being told now
25 about performance, why you need to make it more safe.

1 COMMISSIONER McGAFFIGAN: Okay. Why do we have to
2 go from MS-DOS to Windows 98? Sometimes I worry myself.

3 The other issue, on the -- clearly, I hear a
4 recommendation for -- not a recommendation, but a
5 recommendation for study of a lower temperature repository
6 and the use of -- you read twice the sentence about this
7 helping in the licensing case.

8 Are they ready to make that decision? If they
9 have to get -- there is all this pressure for them to lock
10 into a design by May, which is two months from now. Is it
11 conceivable that they could lock into a lower temperature
12 design in May if they have to go to a single design?

13 DR. KNOPMAN: I think it's not an external
14 constraint really. My understanding is they believe that's
15 -- they're trying to respond to what they think will be the
16 licensing process. But it's not any -- it's something that
17 they're making an internal judgment about, that that's when
18 they need it to happen.

19 COMMISSIONER McGAFFIGAN: But can they do these
20 other -- you mentioned operations issues that have to be
21 studied, cost issues, and somebody yesterday said this could
22 affect the total volume of waste that might be able to be
23 placed in Yucca Mountain; therefore, the issue of a second
24 repository, heaven forbid, might come up sooner rather than
25 later.

1 Can they get all that body of work done in time to
2 pursue your proposal for this May decision they have to
3 make?

4 DR. KNOPMAN: Assuming the 2001, keeping that in
5 place. I think that would have to be assessed. I don't
6 think we're really in a position to say one way or another
7 and it would be a matter of degree and comprehensibility and
8 --

9 COMMISSIONER McGAFFIGAN: I think what's probably
10 driving the May decision may well be that they have to say
11 what sort of -- in the environmental impact statement, they
12 have to have a design and that's due, I think, later this
13 summer.

14 DR. BULLEN: Having watched the license
15 application design selection review workshop that started in
16 January of this year, actually started late last year but
17 culminated actually last week in presentations that were
18 made in Las Vegas. They have done a very credible job of
19 doing what we asked them to do and saying don't look at just
20 the enhancement to the current repository design.

21 They have taken a look at hot repositories,
22 they've taken a look at cold repositories, they've taken a
23 look at different areas of mass loading and different waste
24 package configurations.

25 And so the process is ongoing and the board has

1 been following that very closely. In fact, we had members
2 at this meeting last week who talked about the five designs
3 that you have seen as enhanced design EDAs, and I forget
4 what -- assessments or whatever the word might be.

5 But they are coming to closure on that process by
6 May and they will make a recommendation or there will be a
7 recommendation made to the Department of Energy and we feel
8 that they've done a very credible job of attempting to do
9 this and it's an ongoing process and we're still reviewing
10 it.

11 So in answer to your question, yes, they are doing
12 it. How much will they get done and how credible will it
13 be? We still have to see. But they have done as we've
14 asked and sort of opened the flood gates, if you will, and
15 allowed them to take a look outside the box.

16 DR. KNOPMAN: The alternatives within the -- as
17 you know, within the EIS do include a lower thermal loading.

18 COMMISSIONER MCGAFFIGAN: I didn't know that.

19 DR. KNOPMAN: They have right now -- and they
20 designed -- you know more about EIS than I do, I think.

21 COMMISSIONER MCGAFFIGAN: You know more about EIS
22 than I do, I think.

23 DR. KNOPMAN: They've designed the environmental
24 impact statement alternatives to be flexible in that because
25 there may be -- they don't want to have to redo the EIS as

1 design changes may be made, so they have a high, medium and
2 low thermal load as there are three alternatives, plus there
3 is a no action alternative, which is another matter.

4 And so in principal, this shouldn't throw off
5 their EIS process all that much, because they were to have
6 some credible analysis anyhow for these lower thermal
7 loadings.

8 COMMISSIONER McGAFFIGAN: That's a very good
9 point. I didn't know that. We're a commenting, not a
10 cooperating agency. So I think we're waiting to get the
11 draft rather than seeing it in advance.

12 CHAIRMAN JACKSON: Commissioner Merrifield.

13 COMMISSIONER MERRIFIELD: Going back to a question
14 that the Chairman raised earlier, there is an issue about
15 the multiplicity of designs that are currently under study
16 and we are all grappling with the difficulties of that and
17 our lives would be made much simpler once the design is
18 fixed.

19 I raise this issue in the questioning we had
20 yesterday and afterwards, Commissioner McGaffigan made what
21 I thought was a very good point, and that is we can't fail
22 to recognize the fact that the decision of the EPA in terms
23 of what the appropriate standard would be is a key component
24 to this.

25 As you all know, we as a Commission decided to

1 move forward with our Part 63 and included what we believed
2 would be the appropriate standard as a place-holder, a 25
3 millirem all pathways standard.

4 Although EPA has not indicated what its decision
5 will be, there are preliminary indications that they are
6 favorably disposed toward a 15 millirem standard with a
7 separate ground water pathway standard.

8 And so my multi-part question is, number one, have
9 you all taken a look at this issue and have an opinion on it
10 and, two, if you have, do you agree with virtually every
11 national and international body that it should be a
12 multi-pathway standard or do you agree with the EPA?

13 CHAIRMAN JACKSON: You can take the fifth, if
14 you'd like.

15 DR. KNOPMAN: The board is not entering into the
16 debate on the standard.

17 COMMISSIONER MERRIFIELD: Do you have any position
18 on the fact that this -- that ultimately the decision, which
19 we'll have to abide by, does play an important part and
20 ultimately the Department of Energy, making its decision on
21 a design, and, if so, have you articulated that to the
22 President?

23 DR. KNOPMAN: Let me say, I guess, on one issue
24 related to the standard, when you think about the range
25 between what the NRC has already proposed and what we

1 believe that the EPA may propose, these are numbers that,
2 when you look at the kinds of uncertainties around our
3 performance assessment, and our projections of dose, we're
4 -- in the best of all possible worlds, I would say we've got
5 two to three orders of magnitude range of uncertainty in
6 those dose predictions.

7 So the difference between a 25 millirem per year
8 all pathways dose and a 15 millirem -- I mean, there are --
9 I'm just saying there's a lot of uncertainty in the system.

10 COMMISSIONER McGAFFIGAN: But the heart of the
11 difference, as Commissioner Merrifield has pointed out, is
12 not the 15 versus 25. That may well be something that is at
13 the margin.

14 There is a two order of magnitude difference when
15 you use the current maximum contaminant levels for things
16 like technetium-99 and you end up with a de facto .2
17 millirem standard and the case to make for a .2 millirem
18 standard, as we heard yesterday, you know, just requires an
19 enormous amount of additional data and cost.

20 DR. KNOPMAN: Right.

21 COMMISSIONER McGAFFIGAN: And .2 millirem --

22 CHAIRMAN JACKSON: Well, I think the better way,
23 rather than our preaching to them, it is better to --

24 DR. KNOPMAN: No, I understand.

25 CHAIRMAN JACKSON: -- ask them, do you see a

1 significant difference in terms of the data and the approach
2 for capturing and analyzing that data that would be needed
3 to make the safety case using the one standard vice another?

4 DR. KNOPMAN: My own view is that it puts a
5 significant additional burden on saturated zone
6 characterization and geochemical analyses. I would stop
7 there.

8 CHAIRMAN JACKSON: Thank you very much. Let me
9 just thank you and thank also the Advisory Committee on
10 Nuclear Waste. Clearly, your views are very important to us
11 and will help us in our review of our own staff's paper on
12 the viability assessment, as well as in our interactions
13 with DOE and other stakeholders.

14 So unless there are any additional comments or
15 questions, we're adjourned. Thank you.

16 [Whereupon, at 11:38 a.m., the meeting was
17 concluded.]

CERTIFICATE

This is to certify that the attached description of a meeting
of the U.S. Nuclear Regulatory Commission entitled:

TITLE OF MEETING: MEETING WITH ACNW

PLACE OF MEETING: Rockville, Maryland

DATE OF MEETING: Wednesday, March 17, 1999

was held as herein appears, is a true and accurate record of
the meeting, and that this is the original transcript thereof
taken stenographically by me, thereafter reduced to
typewriting by me or under the direction of the court
reporting company

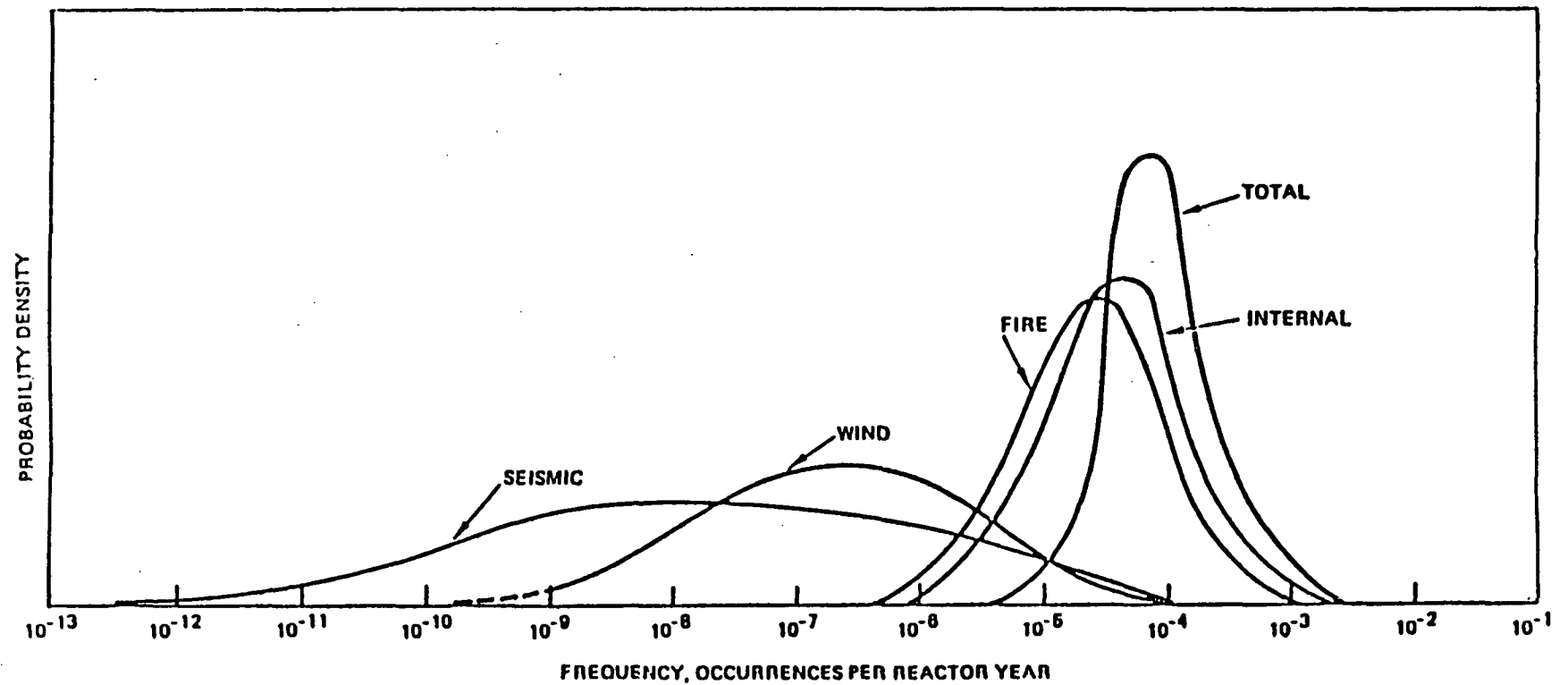
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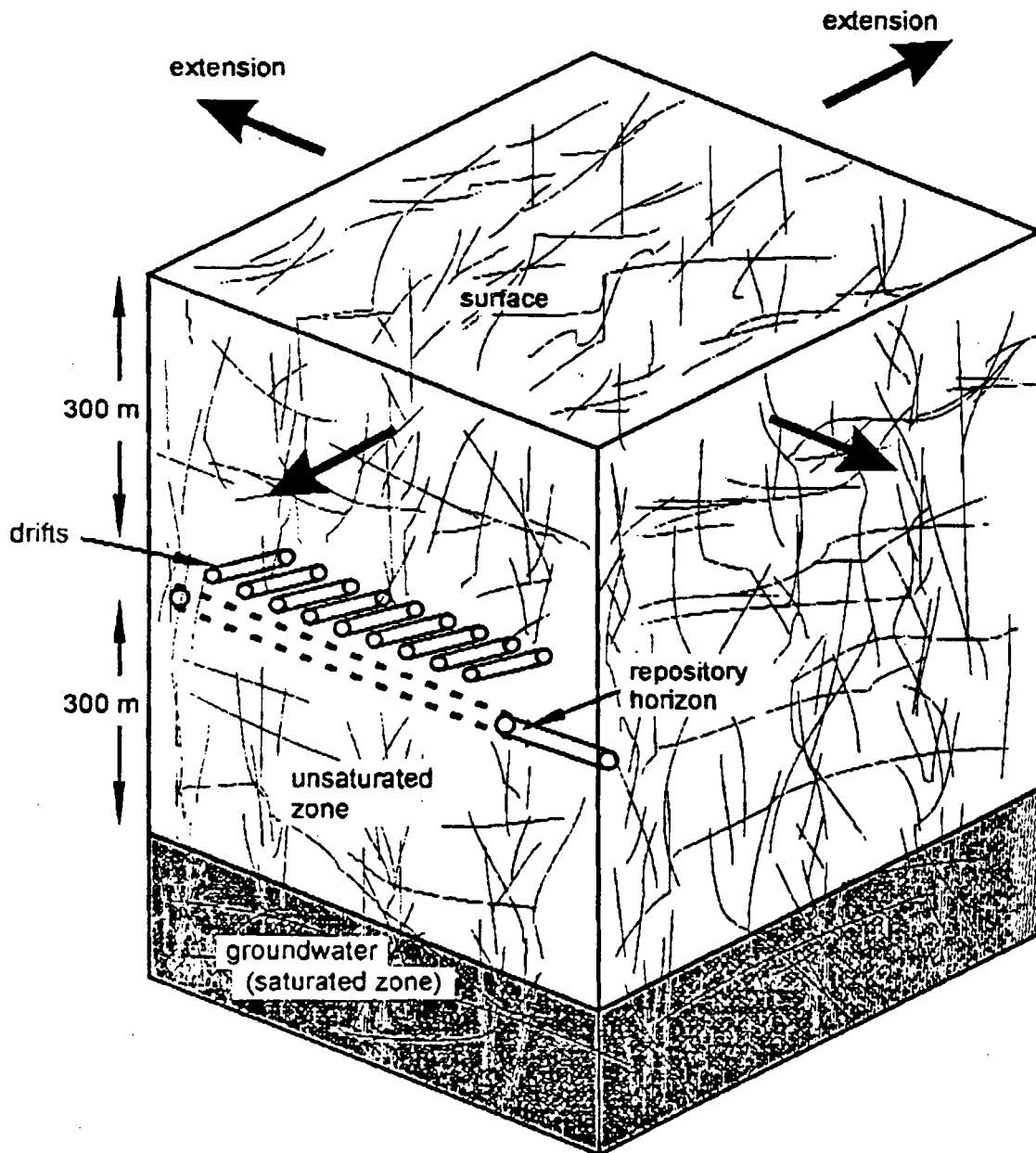
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MARCH 17, 1999**

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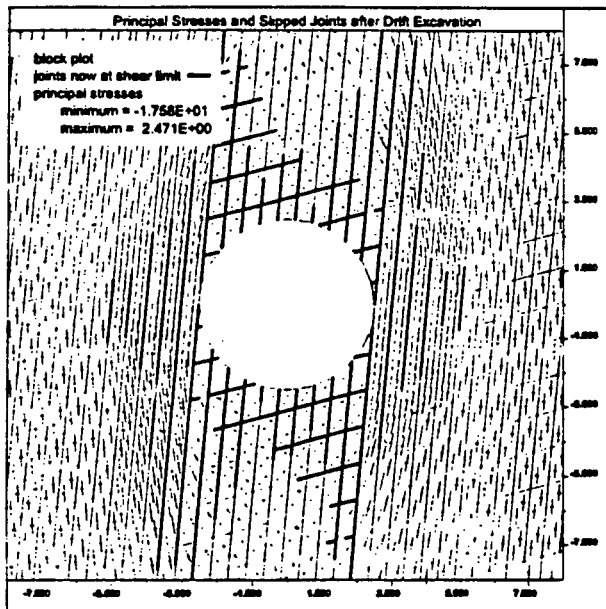
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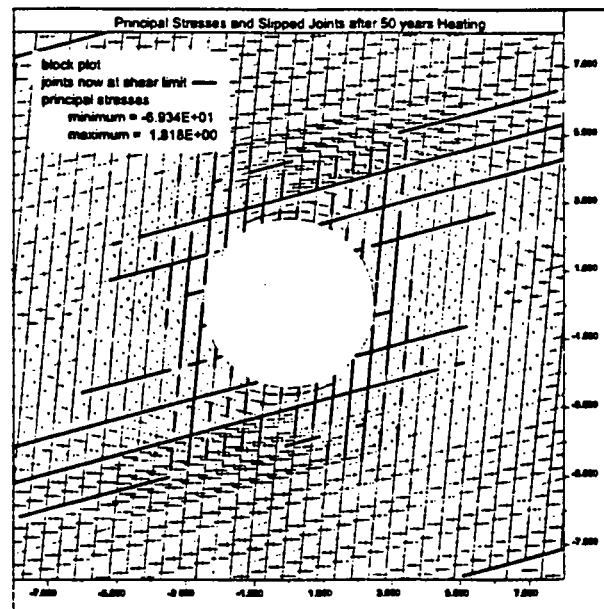
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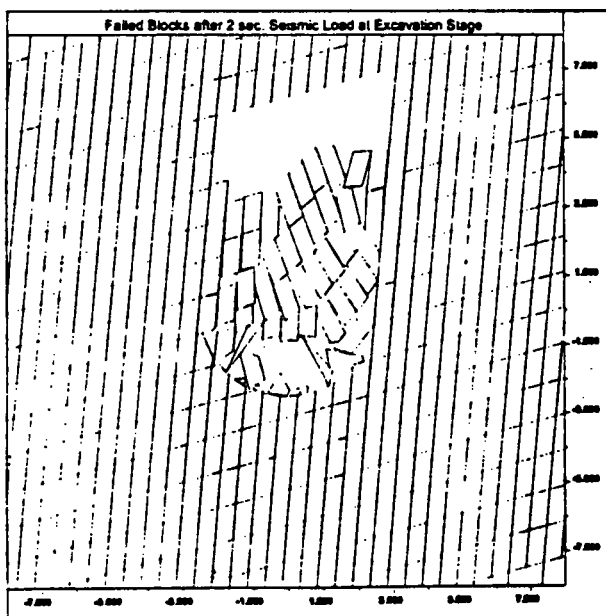
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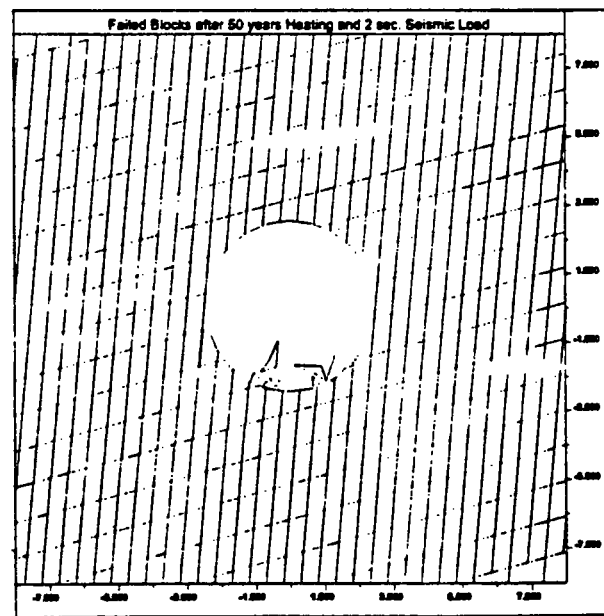
(a)



(c)



(b)



(d)

Effect of Heating (a,c) on Drift Stability and Seismic Event Before (b) and During (d) Heating

**Moving Beyond
the
Yucca Mountain Viability Assessment:
Preliminary Views**

**Dr. Debra S. Knopman, Member
Dr. Daniel B. Bullen, Member
U.S Nuclear Waste Technical Review Board**

**presentation to the
U.S. Nuclear Regulatory Commission**

***March 17, 1999
Rockville, Maryland***

Chairman Jackson, Commissioners, ladies, and gentlemen, good morning. It is a pleasure to be here today. My name is Debra Knopman and I am a member of the U.S. Nuclear Waste Technical Review Board. All Board members serve part-time, and most of us have other full-time jobs. I am director of the Center for Innovation and the Environment of the Progressive Foundation in Washington, D.C. My technical expertise is in hydrology, environmental and natural resources policy, systems analysis, and public administration. With me today is another Board member, Dr. Daniel Bullen, who is director of the Nuclear Reactor Laboratory and associate professor of mechanical engineering at Iowa State University in Ames, Iowa. His technical expertise includes performance assessment modeling of radioactive waste disposal facilities and materials performance in radiological and severe service environments. Our Chairman, Dr. Jared Cohon, would have liked to be here today to make this presentation, but he is out of the country on university business. Dr. Cohon sends his regrets.

Let me begin by briefly summarizing who we are and what we do. The Nuclear Waste Technical Review Board was created by Congress in the 1987 amendments to the Nuclear Waste Policy Act and is charged with evaluating the technical and scientific aspects of the Department of Energy's (DOE's) high-level nuclear waste management program. This includes site-characterization activities at Yucca Mountain and activities relating to the packaging and transport of high-level radioactive waste and spent nuclear fuel. The Board is an independent agency within the federal government, *not* part of the DOE or any other agency. The Board has eleven members who are nominated by the National Academy of Sciences and appointed by the President. Dr. Bullen and I have served as members of the Board since January, 1997.

Introduction

Today, you asked the Board to provide its views on the viability assessment (VA) of the Yucca Mountain site that was published recently by the DOE. We are pleased to do so, but we must preface our remarks by noting that the Board's review of the document is on-going and the preliminary views we present today may evolve as our review continues.

As you know, the purposes of the VA are to summarize the scientific information that has been collected at the site over the past 15 years, present the conceptual design of a repository and waste packages that might be suitable for the site, estimate how well such a repository would isolate wastes from the human environment, identify the additional studies (and their costs) needed to evaluate the suitability of the site and prepare a license application, and estimate the overall cost of disposing of waste at the site. The VA is an evaluation of progress on site characterization at Yucca Mountain and provides the technical basis for deciding whether to continue studying the site.

The VA is not, and was not intended to be, a determination of whether the Yucca Mountain site is suitable for development as a permanent geologic repository. The suitability decision, projected for 2001, allows for the completion of further site studies, repository design work, and analyses of repository system performance. So far, neither the Board's review of the VA nor its other reviews of the program has identified any features or processes that would automatically disqualify the site.

General Views on the VA

The VA is the most significant milestone thus far in the characterization and evaluation of the Yucca Mountain site. Many parts of the VA present cutting-edge scientific analysis in a comprehensible format. The Board commends the DOE for the successful completion of this assessment. In assembling the VA, the DOE integrated large amounts of data and analyses, established a preliminary repository design, and set priorities for work to be completed before decisions are made about site recommendation and licensing.

The process of integration has had the salutary effect of focusing the objectives of the scientific investigations. In particular, the VA highlighted the close connections between the repository design and the priority list of key uncertainties about the natural system. For example, such site characteristics as the movement of water and vapor at temperatures above boiling and the effect of high temperatures on rock stability are important only because of the VA's high-temperature repository design. In a low-temperature (below boiling point) design, these uncertainties would be less significant and might not need to be resolved for making a suitability determination.

The Board concurs with the DOE that the VA is simply a "snapshot" of current knowledge about the site that the U.S. Congress can use to make an informed decision on whether to continue to fund studies of the site. Today, we will discuss the Board's general views on the site and on the design of a repository for the site, based on our review of the VA. The Board concludes that Yucca Mountain continues to merit study as the candidate site for a permanent geologic repository and that work should proceed to support a decision on whether to recommend the site to the President for repository development. The 2001 date anticipated for this decision is very ambitious and much work remains to be completed. At a minimum, significant progress on the work identified by the Board in its November 1998 report and by the DOE in volume 4 of the VA will be required to support a technically defensible decision. The Board supports continuing focused studies of both natural and engineered barriers at Yucca Mountain to attain a defense-in-depth repository design and to increase confidence in predictions of repository performance.

Uncertainties in Repository Performance

In November 1998, the Board issued a report outlining its views on future research needed to address uncertainties about the performance of the repository system, including both the engineered and the natural barriers. The Board concluded in that report that although there are economic and technical limits to reducing uncertainties about the performance of the proposed repository system, some key uncertainties can be reduced further over the next few years through a focused research effort. The Board realizes that there always will be uncertainty about the performance of a repository far into the future and that eliminating all uncertainty is not possible or necessary. However, the Board believes that identifying important sources of uncertainty, estimating the magnitude of those uncertainties, reducing critical uncertainties, and evaluating the effects of residual uncertainties on expected repository performance are essential for supporting a technically defensible site-suitability decision and license application.

The Board notes that the VA relies heavily in some cases on the formal elicitation of expert judgment. This was necessary and extremely useful, given the lack of field and laboratory data in certain areas and the equivocal nature of some of the data in other areas. However, as the experts themselves pointed out, expert judgment should not be used as a substitute for data that can be obtained directly from site, laboratory, and other investigations. In the Board's view, every reasonable effort should be made to minimize uncertainty through repository and waste package design. Additional data then can be sought to address uncertainties, rather than relying so heavily on expert judgment to support decisions about the suitability of the site and a possible license application.

After reviewing the VA, the Board concludes that a significant amount of additional scientific and engineering work will be needed to increase confidence in a site-suitability decision and license application. Alternative repository designs should be evaluated that have the potential to reduce uncertainties in projected repository performance, thereby reducing the scope of additional necessary scientific study. Regardless of the design adopted, however, long-term scientific studies will be needed to establish a solid foundation for projecting repository performance thousands of years into the future. Let me discuss the Board's views in more detail.

Additional Scientific and Engineering Work is Needed

The DOE has spent many years (and many dollars) studying the Yucca Mountain site and designing the engineered components of a repository system compatible with the site. These efforts have produced a large amount of data, but significant uncertainties remain about the ability of the VA reference design to safely isolate radioactive wastes. In part, this is a problem inherent in extrapolating repository performance for thousands of years from data acquired over a much shorter period (years to decades). Uncertainties also are associated with specific characteristics of the Yucca Mountain site, especially the difficulty in predicting the nature of water movement through the fractured unsaturated rocks of the mountain and the possible entry of water into repository tunnels and its contact with waste packages. Uncertainties likely would be exacerbated by the high temperatures of the reference repository design, which may reduce tunnel stability, enhance waste package corrosion, and perturb water movement in ways that are difficult to predict.

Predicting the performance of the waste packages, which play a crucial role in the performance of the VA reference repository design, is a critical area that needs more study. Candidate waste package materials rely on the presence of a thin passive layer to protect the underlying metal from the oxidizing environment that will be present in a Yucca Mountain repository. Improving the basic understanding of long-term passivity is essential because, at present, there seem to be no documented natural or man-made analogs that can be used to demonstrate whether this mode of protection would persist over the desired period of time. Research also should be continued on the susceptibility of the passive layer to known modes of corrosion, especially potentially catastrophic failure modes, such as stress-corrosion cracking.

The Board believes that the scientific and engineering work completed to date, as extensive as it is, should be supplemented to improve the technical foundation for evaluating the suitability of the site or preparing a license application. The Board agrees with a DOE-commissioned peer

review panel which found that two types of additional data are needed to improve the credibility of the total system performance assessment part of the VA (TSPA-VA): (1) fundamental data that are essential to the development and implementation of the models and (2) data sets designed to challenge conceptual models and test the coupled models used in the TSPA-VA. There are substantial uncertainties about the performance of a repository based on the VA reference design that can be resolved only by considering alternative repository and waste package designs and by collecting additional scientific data.

In volume 4 of the VA, the DOE has identified and set priorities for a suite of additional studies to produce information needed for repository licensing, assuming that the site is determined to be suitable for development as a repository. The planned studies include data collection, analysis, and engineering design, as appropriate, for the three major barriers discussed by the Board in its November 1998 report (unsaturated zone, engineered barrier system, and saturated zone). Among the most important are geologic, geochemical, and hydrologic studies, including those planned for the east-west cross drift. These studies are aimed at understanding the magnitude and distribution of seepage into the repository under present conditions and under past conditions when the climate was very different. They include systematic analysis of the rock samples being collected, especially for chlorine-36 and other indicator isotopes; flow and seepage tests at different locations along the drift; moisture-monitoring activities; tests in the lithophysal zones that would host the majority of waste packages; and studies of the Solitario Canyon fault, the active fault bounding the repository that also may serve as a main conduit for percolating water. Of equal importance are studies for supporting projections of the performance of the engineered barrier system, which, in the VA reference design, plays a critical role in isolating radioactive wastes for tens of thousands of years.

The studies identified by the DOE in volume 4 of the VA appear to be appropriate in the sense that they are technically feasible and are likely to produce useful information that will improve the understanding of long-term repository performance. There is no guarantee, however, that completion of these studies will lead to successful development of a repository at the site. The studies could show the site to be unsuitable, or they could raise new questions requiring further study. On the basis of current information, however, the Board is pleased that volume 4 identifies an appropriate suite of studies to be pursued in the years ahead.

The Board is concerned that some of the planned studies identified in volume 4 of the VA may be deferred because funds are not available to carry them out in a timely manner. Deferring scientific and engineering studies will delay the assembly of a more credible technical basis to support the site recommendation anticipated in 2001 and, if the site is found suitable, a license application in 2002. For the current VA repository design, a credible basis does not yet exist.

Alternative Repository Design

High temperatures in the VA repository design cause large uncertainties about how the site would behave both before and after repository closure. The Board believes that a repository design with lower waste package surface temperatures merits further detailed analyses. Such a design has the potential to reduce uncertainty, simplify the analytical bases required for site recommendation, and make licensing easier. Combined with improved waste package shielding, the design also

could simplify preclosure performance confirmation by enhancing access to the tunnels, thus reducing or eliminating the need for separate performance-confirmation drifts, and permitting direct access to performance-confirmation instrumentation near the waste packages.

The following factors influenced the Board's thinking on repository design.

- Lower temperatures would significantly reduce coupled thermal-hydrologic and thermal-geochemical processes. Maintaining near-field temperatures below the boiling point of water after repository closure, by ventilation or aging, could reduce uncertainties about the movement of water and associated geochemical processes in the repository's natural barriers. This could increase confidence in the analyses of repository performance required for a site-suitability determination.
- For a given environment, chances for degradation of corrosion-resistant waste package materials would be reduced significantly if peak waste package surface temperatures were reduced.
- High repository temperatures are expected to increase the mechanical degradation of repository rocks. There is little, if any, relevant experience to draw on for predicting the long-term effects of repository heating and subsequent cooling on drift stability.

The DOE is evaluating alternative repository designs that might be appropriate as the basis for a license application, and the reference repository design presented in the VA is expected to change as the alternatives are considered. The Board strongly urges that analyses of alternatives should not be limited to "enhancements" to the reference design but should give serious consideration to true alternatives to the reference design, including a design that limits waste package surface temperatures.

Long-Term Scientific Studies

If Yucca Mountain is found suitable and construction of a repository is authorized, the Board believes there will be a need for a long-term science program to reduce uncertainties about the performance of engineered barriers and the interactions between the repository and natural processes. An important goal of these studies should be identification of unknown failure modes or unexpected evolution of natural processes that could adversely affect the performance of the major barriers of the repository. Thus, these studies may be more extensive than the performance confirmation activities now anticipated for a repository. For example, if the waste package design continues to rely strongly on corrosion-resistant metals protected from corrosion by a passive layer, long-term scientific studies need to be carried out to improve the basic understanding of the processes that could affect the passive layer.

Long-term studies of the natural barriers also will be needed, primarily to verify projections of water movement within the unsaturated and saturated zones near the repository. For a high-temperature repository design, fundamental studies of coupled thermal-hydrologic and thermal-geochemical processes will be needed. For a low-temperature design, a less extensive program of monitoring in situ water movement may be adequate. Whether the long-

term scientific studies are a decade-long program or much longer will depend in part on how the repository design evolves. There is no doubt, however, that a program of some sort will be needed to increase confidence in estimates of long-term repository performance.

Postclosure Safety Case

The ultimate goal of the studies at Yucca Mountain is to demonstrate that a repository at the site can safely isolate wastes from the human environment. The DOE proposes to demonstrate safe waste isolation through a five-part postclosure safety case consisting of the following.

- assessment of expected postclosure performance (i.e., TSPA)
- design margin and defense-in-depth
- consideration of disruptive processes and events
- insights from natural and man-made analogs
- a performance confirmation plan.

The Board believes that this proposed strategy is an appropriate way to evaluate a Yucca Mountain repository, although each component, especially defense-in-depth and the performance-confirmation plan, requires significant additional development. Multiple lines of evidence will provide a more convincing demonstration of repository safety than will any individual component of the safety case. TSPA, including sensitivity and uncertainty analyses, is the appropriate core analytical tool of the safety case. TSPA is the analytical technique that pulls together relevant information about the performance of the repository system, determines which features or parameters could strongly influence performance, and estimates the uncertainties in projections of performance. TSPA has its limits, however, and the DOE will need to aggressively pursue the other four components of the safety case.

Judging how realistic the "bottom-line" TSPA estimates of repository performance are in the VA is difficult. In fact, a DOE presentation to the Board at its most recent meeting stated that the VA's performance assessment (TSPA-VA) cannot be used to do the following.

- Assess compliance with regulatory criteria.
- Show defense-in-depth for the design of the repository system.
- Assess the importance of small design changes.
- Determine the suitability of the overall repository system.

Because of a general lack of data to support critical assumptions in the mathematical models, some of the assumptions in the TSPA-VA are likely to be overly conservative and others may be nonconservative. Numerous examples are presented in the recent report of the TSPA-VA peer review panel. Assessing the realism (or, at least, verifying the conservatism) of TSPA projections of repository performance is an important goal of the additional studies called for by the Board. The Board does not believe, however, that relying solely on TSPA to demonstrate repository safety will ever be possible. For that reason, the other four components of the postclosure safety strategy should be developed aggressively as complements to TSPA. An

implicit or explicit sixth component of the safety strategy also should be considered: designing the waste packages and the repository to minimize uncertainties in projected repository performance.

Conclusion

The VA concludes, "... Yucca Mountain remains a promising site for a geologic repository and ... work should proceed to support a decision in 2001 on whether to recommend the site to the President for development as a repository." The Board agrees that Yucca Mountain continues to merit study as the candidate site for a permanent geologic repository and that work should proceed to support a decision on whether to recommend the site to the President for development. The 2001 date anticipated for this decision is very ambitious and much work remains to be completed. At a minimum, progress on the work identified by the Board in its November 1998 report and by the DOE in volume 4 of the VA will be required to support a technically defensible decision. The Board supports continuing focused studies of both natural and engineered barriers at Yucca Mountain to attain a defense-in-depth repository design and to increase confidence in predictions of repository performance.

This concludes our prepared remarks and we will be happy to try to answer any questions you may have.



UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON NUCLEAR WASTE
WASHINGTON, D.C. 20555-0001

March 10, 1999

MEMORANDUM TO: Annette Vietti-Cook
Secretary

FROM: John T. Larkins, Executive Director
Advisory Committee on Nuclear Waste

SUBJECT: MEETING WITH ADVISORY COMMITTEE ON NUCLEAR
WASTE (ACNW) AND NUCLEAR WASTE TECHNICAL REVIEW
BOARD (NWTRB)

The ACNW is scheduled to meet with the NRC Commissioners between 9:00 - 10:00 a.m. on Wednesday, March 17, 1999 to discuss the ACNW's review of the Department of Energy's Viability Assessment.

INTRODUCTION - Chairman Shirley Ann Jackson 9:00 - 9:05 a.m.

PRESENTATIONS - Advisory Committee on Nuclear waste

(Presenters listed under each topic)*

1. Overview and Performance Assessment Issues 9:05 - 9:20 a.m.
- B. John Garrick, ACNW
2. Natural System and Repository Design Issues 9:20 - 9:35 a.m.
- Charles Fairhurst, ACNW
3. Engineered Barrier System Issues 9:35 - 9:50 a.m.
- Raymond G. Wymer, ACNW
4. Summary 9:50 - 10:00 a.m.
- B. John Garrick, ACNW

PRESENTATIONS - Nuclear Waste Technical Review Board 10:00 - 11:00 a.m.

*Presentation time includes discussion.

cc: ACNW Members
ACNW Staff



**U.S. NUCLEAR REGULATORY COMMISSION
MEETING WITH
ADVISORY COMMITTEE ON NUCLEAR WASTE
ON
REVIEW OF DOE'S VIABILITY ASSESSMENT**

**Rockville, MD
March 17, 1999**

ACNW Review of DOE's Viability Assessment

Overview and Performance Assessment Issues

**Dr. B. John Garrick, Chairman
Advisory Committee on Nuclear Waste**

ACNW's General Observations on VA

- **Purpose and Objectives of ACNW Review**
- **Progression from VA to Site Suitability and Licensing**
- **Overall Impressions**

Background of ACNW Review

- **Licensing Basis (Standard plus Implementing Regulations and Guidance)**
- **Performance Measure (Radiation Risk)**
- **Measure Evaluation (Strong Reliance on Performance Assessment)**
- **TSPA-VA -- a Snapshot of DOE Progress on PA**
- **ACNW Review (Technical Attributes of Design and PA in Risk Context)**

Important Issues Considered by ACNW

- **DOE must Demonstrate Credible Analyses of Design to Assess:**
 - Water entry to disposal drifts
 - Waste package and cladding performance
 - Release of radionuclides after canisters are breached
 - Transport of radionuclides in the unsaturated zone
 - Transport and dilution of radionuclides in the saturated zone
 - Uptake of radionuclides by biota and dose to humans
- **DOE must Have a Credible Overall PA (i.e., Clear, Integrated, Probabilistic)**
- **ACNW Believes that Water Entering the Drifts and a Credible Overall PA Require Considerable Work for the License Application**

Clear, Integrated, Probabilistic PA

- **Need for Improved Technical Clarity**
- **Improvements to Provide a Clear and Traceable Link Between PA and Supporting Technical Evidence**

Need for Improved Technical Clarity in PA

- **Summary of Total PA Model**
- **Definition of Modules, Interfaces, Inputs, Outputs**
- **Consistency of Probabilistic Thinking**
- **Traceability and Continuity of Performance Measure Calculation**
- **Highlight First Principles, Minimize Mechanical Details**

Need for Clear Links Between PA and Supporting Evidence

- **Processing of Input Data (Data Summaries)**
- **Clear Distinctions between Measurements and Judgments**
- **Exposure of the Basis of Expert Judgments**
- **Probability Assignments and Uncertainty Propagation**

Multiple Barriers and Defense in Depth

- **Evolving DOE Concepts and Implementation**
- **NRC views in Draft Part 63 (Natural System and EBS)**
- **Insights from other NRC Guidance on Multiple Barriers and DID**
- **Need for Guidance on Applying Multiple Barriers and DID to Waste Repositories**

ACNW Review of DOE's Viability Assessment

Natural System and Repository Design Issues

**Dr. Charles Fairhurst
Advisory Committee on Nuclear Waste**

Natural System

Unsaturated Zone

- **Mountain-Scale Flow Models**
 - **Considerable uncertainty about infiltration**
 - **Unlikely that uncertainties can be reduced significantly over next several years (although levels of infiltration during pluvial conditions are subject to reconsideration)**
 - **The VA analyses for mountain scale infiltration may not change much for SR/LA**

Seepage into Drifts

- Seepage into Drifts with Dripping onto Canisters Is a Process of Critical Importance
- Exact Prediction of Locations, Temporal Changes, Amount, and Chemistry Not Feasible
- Performance Assessment Will Continue to Rely on Expert Judgment and Conservative Assumptions to Deal with this Issue
- Models of Seepage into the Drifts
 - Opportunity for significant improvement in future analyses
 - Niche tests and continuing work with tracers (e.g., ^{36}Cl) will provide new data
 - Refinements will be made to numerical models

Saturated Zone

- **Significant Uncertainties Associated with the Saturated Zone Due, in Part, to Complex Hydrology**
- **Some New Data Will Improve Confidence, but Will Not Greatly Reduce Uncertainties**
- **The Key Quantity Is the Total Dilution (From All Processes)**
- **Computations Will Have to Be Reasonably Conservative and Be Defended as Such**

Repository Design

- **Uncertainty of Water Flow Pathways Through Unsaturated Zone Is a Major Repository Design Consideration**
- **Robust System of Engineered Barriers Is Required to Address this Uncertainty, i.e., to Inhibit Water Access to Waste**

Alternative Designs

- **Variety of Alternative Engineering Designs under Active Consideration**
- **High Temperature Designs - Keep Rock Dry, but Adverse Thermal Effects on Rock and Support**
- **Low Temperature Designs - Avoid Thermal Damage to Rock, but Repository Humidity Increases**
- **DOE Preference Should Be Given to Design That Also Offers Best Post-10,000 Year Safety Performance**

Alternative Designs and Regulatory Considerations

- **Several Designs Probably Capable of Satisfying 10 CFR Part 63 (NRC 10,000 Year Regulation)**
- **NRC Should Seek Information That Illuminates Post-10,000 Year Safety Performance**
- **Extension of Pre-closure Period Beyond Minimum Required (50~100 Years) Significantly Complicates Maintenance of Effective Drift Support Systems**
- **Backfill:**
 - **Reduces vulnerability of waste packages to damage from rockfalls and seismic effects [and helps eliminate concerns regarding consequences of igneous events]**
 - **Increases temperature of waste packages**

Staff Capability

- **NRC Staff Should Be Prepared to Evaluate Engineering Designs Proposed by DOE**
- **This Implies Augmenting Staff with Geotechnical Design Experience**
- **Part-time Consultants with Such Design Experience Could Be Valuable Aid to NRC Full-time Staff in Preparing for and Evaluating LA**

ACNW Review of DOE's Viability Assessment

Engineered Barrier System Issues

Dr. Raymond G. Wymer
Advisory Committee on Nuclear Waste

Engineered Barrier System

- **Contribution of Individual Engineered Barriers to Overall Performance
- Essential to Establish "Robustness" of Multiple Barrier Approach**
- **Waste Package Performance - Need for Supporting Data**
- **Cladding Issue - Long-term Performance in Repository Environment**
- **Spent Fuel Degradation and Radionuclide Transport Issues**

Contributions of Individual Engineered Barriers

- **Need Clear Understanding of Contributions of Individual Engineered Barriers in Near Field**
 - DOE approach for “neutralization” of barriers does not adequately address multiple interactions of barrier components
 - DOE’s qualitative treatment and discussion of “neutralization” unclear

Supporting Information for Barrier Performance

- **Adequacy, Timeliness, and Quality Assurance of Key Data Are Significant Potential Problems**
 - **Corrosion of alloy-22 (and titanium) under repository conditions**
 - **Corrosion of Zr alloy cladding under repository conditions**
 - **Importance of chemical processes**
 - **Contribution of several backfill materials**
 - **Thermal and hydrologic variables**

Representation of Chemical Complexity in Near Field

- DOE Recognizes Chemical Complexity of the Near Field, but VA Provides Inadequate Treatment of it
- Examples of Chemical Complexity
 - Waste form dissolution
 - Dissolved CO₂, chloride ion, sulfate ion, fluoride ion, and silicates
 - Colloids
 - Complex formation
 - Secondary phase formation
 - Redox reactions due to iron in drifts (WP, materials of construction) and possible effects on Np, Tc

Summary and Conclusions

- **Technical Clarity of the Safety Case**
- **Traceability of Supporting Evidence (Especially in Relation to EBS Performance)**
- **Important Technical Issues: Seepage into Drifts and Waste Package Performance**
- **Guidance on Implementing Multiple Barriers Approach**
- **Identification of Contribution of Individual Barriers to Overall Performance**
- **Repository Design Alternatives Impose Differing Regulatory Considerations**

Moving Beyond
the
Yucca Mountain Viability Assessment:
Preliminary Views

Dr. Debra S. Knopman, Member
Dr. Daniel B. Bullen, Member
U.S Nuclear Waste Technical Review Board

presentation to the
U.S. Nuclear Regulatory Commission

March 17, 1999
Rockville, Maryland

Chairman Jackson, Commissioners, ladies, and gentlemen, good morning. It is a pleasure to be here today. My name is Debra Knopman and I am a member of the U.S. Nuclear Waste Technical Review Board. All Board members serve part-time, and most of us have other full-time jobs. I am director of the Center for Innovation and the Environment of the Progressive Foundation in Washington, D.C. My technical expertise is in hydrology, environmental and natural resources policy, systems analysis, and public administration. With me today is another Board member, Dr. Daniel Bullen, who is director of the Nuclear Reactor Laboratory and associate professor of mechanical engineering at Iowa State University in Ames, Iowa. His technical expertise includes performance assessment modeling of radioactive waste disposal facilities and materials performance in radiological and severe service environments. Our Chairman, Dr. Jared Cohon, would have liked to be here today to make this presentation, but he is out of the country on university business. Dr. Cohon sends his regrets.

Let me begin by briefly summarizing who we are and what we do. The Nuclear Waste Technical Review Board was created by Congress in the 1987 amendments to the Nuclear Waste Policy Act and is charged with evaluating the technical and scientific aspects of the Department of Energy's (DOE's) high-level nuclear waste management program. This includes site-characterization activities at Yucca Mountain and activities relating to the packaging and transport of high-level radioactive waste and spent nuclear fuel. The Board is an independent agency within the federal government, *not* part of the DOE or any other agency. The Board has eleven members who are nominated by the National Academy of Sciences and appointed by the President. Dr. Bullen and I have served as members of the Board since January, 1997.

Introduction

Today, you asked the Board to provide its views on the viability assessment (VA) of the Yucca Mountain site that was published recently by the DOE. We are pleased to do so, but we must preface our remarks by noting that the Board's review of the document is on-going and the preliminary views we present today may evolve as our review continues.

As you know, the purposes of the VA are to summarize the scientific information that has been collected at the site over the past 15 years, present the conceptual design of a repository and waste packages that might be suitable for the site, estimate how well such a repository would isolate wastes from the human environment, identify the additional studies (and their costs) needed to evaluate the suitability of the site and prepare a license application, and estimate the overall cost of disposing of waste at the site. The VA is an evaluation of progress on site characterization at Yucca Mountain and provides the technical basis for deciding whether to continue studying the site.

The VA is not, and was not intended to be, a determination of whether the Yucca Mountain site is suitable for development as a permanent geologic repository. The suitability decision, projected for 2001, allows for the completion of further site studies, repository design work, and analyses of repository system performance. So far, neither the Board's review of the VA nor its other reviews of the program has identified any features or processes that would automatically disqualify the site.

General Views on the VA

The VA is the most significant milestone thus far in the characterization and evaluation of the Yucca Mountain site. Many parts of the VA present cutting-edge scientific analysis in a comprehensible format. The Board commends the DOE for the successful completion of this assessment. In assembling the VA, the DOE integrated large amounts of data and analyses, established a preliminary repository design, and set priorities for work to be completed before decisions are made about site recommendation and licensing.

The process of integration has had the salutary effect of focusing the objectives of the scientific investigations. In particular, the VA highlighted the close connections between the repository design and the priority list of key uncertainties about the natural system. For example, such site characteristics as the movement of water and vapor at temperatures above boiling and the effect of high temperatures on rock stability are important only because of the VA's high-temperature repository design. In a low-temperature (below boiling point) design, these uncertainties would be less significant and might not need to be resolved for making a suitability determination.

The Board concurs with the DOE that the VA is simply a "snapshot" of current knowledge about the site that the U.S. Congress can use to make an informed decision on whether to continue to fund studies of the site. Today, we will discuss the Board's general views on the site and on the design of a repository for the site, based on our review of the VA. The Board concludes that Yucca Mountain continues to merit study as the candidate site for a permanent geologic repository and that work should proceed to support a decision on whether to recommend the site to the President for repository development. The 2001 date anticipated for this decision is very ambitious and much work remains to be completed. At a minimum, significant progress on the work identified by the Board in its November 1998 report and by the DOE in volume 4 of the VA will be required to support a technically defensible decision. The Board supports continuing focused studies of both natural and engineered barriers at Yucca Mountain to attain a defense-in-depth repository design and to increase confidence in predictions of repository performance.

Uncertainties in Repository Performance

In November 1998, the Board issued a report outlining its views on future research needed to address uncertainties about the performance of the repository system, including both the engineered and the natural barriers. The Board concluded in that report that although there are economic and technical limits to reducing uncertainties about the performance of the proposed repository system, some key uncertainties can be reduced further over the next few years through a focused research effort. The Board realizes that there always will be uncertainty about the performance of a repository far into the future and that eliminating all uncertainty is not possible or necessary. However, the Board believes that identifying important sources of uncertainty, estimating the magnitude of those uncertainties, reducing critical uncertainties, and evaluating the effects of residual uncertainties on expected repository performance are essential for supporting a technically defensible site-suitability decision and license application.

The Board notes that the VA relies heavily in some cases on the formal elicitation of expert judgment. This was necessary and extremely useful, given the lack of field and laboratory data in certain areas and the equivocal nature of some of the data in other areas. However, as the experts themselves pointed out, expert judgment should not be used as a substitute for data that can be obtained directly from site, laboratory, and other investigations. In the Board's view, every reasonable effort should be made to minimize uncertainty through repository and waste package design. Additional data then can be sought to address uncertainties, rather than relying so heavily on expert judgment to support decisions about the suitability of the site and a possible license application.

After reviewing the VA, the Board concludes that a significant amount of additional scientific and engineering work will be needed to increase confidence in a site-suitability decision and license application. Alternative repository designs should be evaluated that have the potential to reduce uncertainties in projected repository performance, thereby reducing the scope of additional necessary scientific study. Regardless of the design adopted, however, long-term scientific studies will be needed to establish a solid foundation for projecting repository performance thousands of years into the future. Let me discuss the Board's views in more detail.

Additional Scientific and Engineering Work is Needed

The DOE has spent many years (and many dollars) studying the Yucca Mountain site and designing the engineered components of a repository system compatible with the site. These efforts have produced a large amount of data, but significant uncertainties remain about the ability of the VA reference design to safely isolate radioactive wastes. In part, this is a problem inherent in extrapolating repository performance for thousands of years from data acquired over a much shorter period (years to decades). Uncertainties also are associated with specific characteristics of the Yucca Mountain site, especially the difficulty in predicting the nature of water movement through the fractured unsaturated rocks of the mountain and the possible entry of water into repository tunnels and its contact with waste packages. Uncertainties likely would be exacerbated by the high temperatures of the reference repository design, which may reduce tunnel stability, enhance waste package corrosion, and perturb water movement in ways that are difficult to predict.

Predicting the performance of the waste packages, which play a crucial role in the performance of the VA reference repository design, is a critical area that needs more study. Candidate waste package materials rely on the presence of a thin passive layer to protect the underlying metal from the oxidizing environment that will be present in a Yucca Mountain repository. Improving the basic understanding of long-term passivity is essential because, at present, there seem to be no documented natural or man-made analogs that can be used to demonstrate whether this mode of protection would persist over the desired period of time. Research also should be continued on the susceptibility of the passive layer to known modes of corrosion, especially potentially catastrophic failure modes, such as stress-corrosion cracking.

The Board believes that the scientific and engineering work completed to date, as extensive as it is, should be supplemented to improve the technical foundation for evaluating the suitability of the site or preparing a license application. The Board agrees with a DOE-commissioned peer

review panel which found that two types of additional data are needed to improve the credibility of the total system performance assessment part of the VA (TSPA-VA): (1) fundamental data that are essential to the development and implementation of the models and (2) data sets designed to challenge conceptual models and test the coupled models used in the TSPA-VA. There are substantial uncertainties about the performance of a repository based on the VA reference design that can be resolved only by considering alternative repository and waste package designs and by collecting additional scientific data.

In volume 4 of the VA, the DOE has identified and set priorities for a suite of additional studies to produce information needed for repository licensing, assuming that the site is determined to be suitable for development as a repository. The planned studies include data collection, analysis, and engineering design, as appropriate, for the three major barriers discussed by the Board in its November 1998 report (unsaturated zone, engineered barrier system, and saturated zone). Among the most important are geologic, geochemical, and hydrologic studies, including those planned for the east-west cross drift. These studies are aimed at understanding the magnitude and distribution of seepage into the repository under present conditions and under past conditions when the climate was very different. They include systematic analysis of the rock samples being collected, especially for chlorine-36 and other indicator isotopes; flow and seepage tests at different locations along the drift; moisture-monitoring activities; tests in the lithophysal zones that would host the majority of waste packages; and studies of the Solitario Canyon fault, the active fault bounding the repository that also may serve as a main conduit for percolating water. Of equal importance are studies for supporting projections of the performance of the engineered barrier system, which, in the VA reference design, plays a critical role in isolating radioactive wastes for tens of thousands of years.

The studies identified by the DOE in volume 4 of the VA appear to be appropriate in the sense that they are technically feasible and are likely to produce useful information that will improve the understanding of long-term repository performance. There is no guarantee, however, that completion of these studies will lead to successful development of a repository at the site. The studies could show the site to be unsuitable, or they could raise new questions requiring further study. On the basis of current information, however, the Board is pleased that volume 4 identifies an appropriate suite of studies to be pursued in the years ahead.

The Board is concerned that some of the planned studies identified in volume 4 of the VA may be deferred because funds are not available to carry them out in a timely manner. Deferring scientific and engineering studies will delay the assembly of a more credible technical basis to support the site recommendation anticipated in 2001 and, if the site is found suitable, a license application in 2002. For the current VA repository design, a credible basis does not yet exist.

Alternative Repository Design

High temperatures in the VA repository design cause large uncertainties about how the site would behave both before and after repository closure. The Board believes that a repository design with lower waste package surface temperatures merits further detailed analyses. Such a design has the potential to reduce uncertainty, simplify the analytical bases required for site recommendation, and make licensing easier. Combined with improved waste package shielding, the design also

could simplify preclosure performance confirmation by enhancing access to the tunnels, thus reducing or eliminating the need for separate performance-confirmation drifts, and permitting direct access to performance-confirmation instrumentation near the waste packages.

The following factors influenced the Board's thinking on repository design.

- Lower temperatures would significantly reduce coupled thermal-hydrologic and thermal-geochemical processes. Maintaining near-field temperatures below the boiling point of water after repository closure, by ventilation or aging, could reduce uncertainties about the movement of water and associated geochemical processes in the repository's natural barriers. This could increase confidence in the analyses of repository performance required for a site-suitability determination.
- For a given environment, chances for degradation of corrosion-resistant waste package materials would be reduced significantly if peak waste package surface temperatures were reduced.
- High repository temperatures are expected to increase the mechanical degradation of repository rocks. There is little, if any, relevant experience to draw on for predicting the long-term effects of repository heating and subsequent cooling on drift stability.

The DOE is evaluating alternative repository designs that might be appropriate as the basis for a license application, and the reference repository design presented in the VA is expected to change as the alternatives are considered. The Board strongly urges that analyses of alternatives should not be limited to "enhancements" to the reference design but should give serious consideration to true alternatives to the reference design, including a design that limits waste package surface temperatures.

Long-Term Scientific Studies

If Yucca Mountain is found suitable and construction of a repository is authorized, the Board believes there will be a need for a long-term science program to reduce uncertainties about the performance of engineered barriers and the interactions between the repository and natural processes. An important goal of these studies should be identification of unknown failure modes or unexpected evolution of natural processes that could adversely affect the performance of the major barriers of the repository. Thus, these studies may be more extensive than the performance confirmation activities now anticipated for a repository. For example, if the waste package design continues to rely strongly on corrosion-resistant metals protected from corrosion by a passive layer, long-term scientific studies need to be carried out to improve the basic understanding of the processes that could affect the passive layer.

Long-term studies of the natural barriers also will be needed, primarily to verify projections of water movement within the unsaturated and saturated zones near the repository. For a high-temperature repository design, fundamental studies of coupled thermal-hydrologic and thermal-geochemical processes will be needed. For a low-temperature design, a less extensive program of monitoring in situ water movement may be adequate. Whether the long-

term scientific studies are a decade-long program or much longer will depend in part on how the repository design evolves. There is no doubt, however, that a program of some sort will be needed to increase confidence in estimates of long-term repository performance.

Postclosure Safety Case

The ultimate goal of the studies at Yucca Mountain is to demonstrate that a repository at the site can safely isolate wastes from the human environment. The DOE proposes to demonstrate safe waste isolation through a five-part postclosure safety case consisting of the following.

- assessment of expected postclosure performance (i.e., TSPA)
- design margin and defense-in-depth
- consideration of disruptive processes and events
- insights from natural and man-made analogs
- a performance confirmation plan.

The Board believes that this proposed strategy is an appropriate way to evaluate a Yucca Mountain repository, although each component, especially defense-in-depth and the performance-confirmation plan, requires significant additional development. Multiple lines of evidence will provide a more convincing demonstration of repository safety than will any individual component of the safety case. TSPA, including sensitivity and uncertainty analyses, is the appropriate core analytical tool of the safety case. TSPA is the analytical technique that pulls together relevant information about the performance of the repository system, determines which features or parameters could strongly influence performance, and estimates the uncertainties in projections of performance. TSPA has its limits, however, and the DOE will need to aggressively pursue the other four components of the safety case.

Judging how realistic the "bottom-line" TSPA estimates of repository performance are in the VA is difficult. In fact, a DOE presentation to the Board at its most recent meeting stated that the VA's performance assessment (TSPA-VA) cannot be used to do the following.

- Assess compliance with regulatory criteria.
- Show defense-in-depth for the design of the repository system.
- Assess the importance of small design changes.
- Determine the suitability of the overall repository system.

Because of a general lack of data to support critical assumptions in the mathematical models, some of the assumptions in the TSPA-VA are likely to be overly conservative and others may be nonconservative. Numerous examples are presented in the recent report of the TSPA-VA peer review panel. Assessing the realism (or, at least, verifying the conservatism) of TSPA projections of repository performance is an important goal of the additional studies called for by the Board. The Board does not believe, however, that relying solely on TSPA to demonstrate repository safety will ever be possible. For that reason, the other four components of the postclosure safety strategy should be developed aggressively as complements to TSPA. An

implicit or explicit sixth component of the safety strategy also should be considered: designing the waste packages and the repository to minimize uncertainties in projected repository performance.

Conclusion

The VA concludes, "... Yucca Mountain remains a promising site for a geologic repository and ... work should proceed to support a decision in 2001 on whether to recommend the site to the President for development as a repository." The Board agrees that Yucca Mountain continues to merit study as the candidate site for a permanent geologic repository and that work should proceed to support a decision on whether to recommend the site to the President for development. The 2001 date anticipated for this decision is very ambitious and much work remains to be completed. At a minimum, progress on the work identified by the Board in its November 1998 report and by the DOE in volume 4 of the VA will be required to support a technically defensible decision. The Board supports continuing focused studies of both natural and engineered barriers at Yucca Mountain to attain a defense-in-depth repository design and to increase confidence in predictions of repository performance.

This concludes our prepared remarks and we will be happy to try to answer any questions you may have.



POLICY ISSUE **(Notation Vote)**

March 11, 1999

SECY-99-074

FOR: The Commissioners

FROM: William D. Travers
Executive Director for Operations

SUBJECT: STAFF REVIEW OF U.S. DEPARTMENT OF ENERGY VIABILITY
ASSESSMENT FOR A HIGH-LEVEL RADIOACTIVE WASTE
REPOSITORY AT YUCCA MOUNTAIN, NEVADA

PURPOSE:

In SRM M990208, dated February 16, 1999, the Commission directed the staff to provide a paper on the staff review and comment on the U.S. Department of Energy (DOE) Viability Assessment (VA) of a potential high-level radioactive waste repository sited at Yucca Mountain, Nevada. This paper provides the Commission with staff comments on the VA that, if not addressed by DOE before the license application (LA) is submitted as scheduled in 2002, could cause the LA to be incomplete or lead to a protracted licensing review.

BACKGROUND:

The Fiscal Year 1997 Energy and Water Development Appropriations Act (P.L. 104-206) requires DOE to provide the President and Congress with a VA for the Yucca Mountain site. The VA is a management tool that will provide DOE with the basis for making an informed assessment of the feasibility of proceeding with the process of licensing and constructing a repository at Yucca Mountain. Congress required the VA to include the following elements: (1) a preliminary design concept for the critical elements of the repository and waste package;

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(2) a total system performance assessment (TSPA) based on the design concept and scientific data and analysis available by June 30, 1998, describing the probable behavior of the repository relative to the overall system performance standards; (3) a plan and cost estimate (LA Plan) for the remaining work required to complete an LA; and (4) an estimate of the costs to construct and operate the repository in accordance with the design concept. DOE issued the VA on December 18, 1998, fulfilling its statutory requirement.

In a memorandum dated December 21, 1998, the staff informed the Commission of the scope and approach for its review and committed to providing the Commission with a paper that summarizes DOE's progress and U.S. Nuclear Regulatory Commission (NRC) staff comments, and recommends Commission action. NRC does not have a statutory role with regard to the VA, which is not a licensing document. However, as the agency responsible for reviewing the LA for geologic disposal of spent nuclear fuel and high-level wastes in the proposed geologic repository at Yucca Mountain, NRC has a unique perspective for evaluating the VA and, particularly, the DOE plan for remaining work required for an LA (i.e., the LA Plan). This licensing perspective is likely to be sought by Congress, the President, or others. DOE has also sought NRC input on the VA in terms of preparing a complete and high-quality LA.

In the VA, DOE analyzed the probable performance of a Yucca Mountain repository by using a reference design. DOE used this analysis, evaluations of design alternatives, and estimates of the consequences from disruptive events to make an internal decision on the viability of the Yucca Mountain site. DOE has concluded that the site and design are sufficiently promising for a geologic repository and work should proceed toward a decision on site recommendation.

DOE's conclusions on feasibility are based on estimates of exposures arising from the disposal of radioactive waste at Yucca Mountain, consistent with the reference design and DOE's understanding of the site. Estimates are included for both base case probable performance and repository performance assuming the occurrence of selected disruptive events. In the absence of Environmental Protection Agency standards applicable to Yucca Mountain, DOE assumed a performance measure of 25 mrem/year to an average member of a critical group located 20 km from the repository over the first 10,000 years after closure. The performance measure, exposure pathway, and time frame are consistent with those in proposed 10 CFR Part 63 (64FR8640).

As part of its ongoing prelicensing consultation with DOE, the staff has interacted with DOE on numerous occasions during development of the VA. NRC has been receiving and reviewing the VA supporting documents for over a year to prepare for the VA review. The staff began its formal review of the VA in late December 1998. The focus of the staff review was postclosure performance of the repository. The staff review covered elements (1) - (3) of the VA; element (4), which consists of an estimate of the costs to construct and operate the repository in accordance with the design concept, was not reviewed.

DISCUSSION:

The VA documents significant progress in areas such as: data collection; data synthesis; performance assessment modeling; and documentation. One result of this progress is that there is general agreement between DOE and NRC staff that DOE's planned work appears adequate in several technical areas (e.g., mechanical disruption of waste packages, spatial and temporal distribution of flow). In addition, it is also positive to note that in the LA Plan DOE has

identified areas where additional data collection or analysis is needed for completing the design of the repository and developing an LA. In other areas, the staff has developed comments on the VA related to the completeness of the data, analysis, or documentation. These comments are organized in succeeding parts of this paper along the organizational lines of the VA, that is: the Preliminary Design Concept; the TSPA; and the LA Plan. The comments developed by the staff are not new in that they have been identified during earlier public interactions with DOE on the VA and were communicated to DOE in written staff documents. The comments are summarized below and described in detail in Attachment 1.

Preliminary Design Concept

DOE was directed by Congress to develop "a preliminary design concept for the critical elements of the repository and waste package." As directed, DOE developed a preliminary design concept for the repository, which was used for the TSPA and the cost estimates. However, DOE also presented several major design alternatives that differ from the VA reference design. The consideration of these alternatives is an indication that, currently, DOE is not focused on a single design concept for proceeding to LA. The DOE safety case ultimately will need to be developed around a single reference design. The diversity and ongoing evolution of design concepts currently under consideration may not converge quickly enough for a single design to emerge for an LA in 2002, or may limit the availability of data and analyses in support of the LA design. The NRC staff recognizes DOE's need for flexibility in considering alternate designs to better protect public health and safety, but this must be appropriately balanced against the need for adequate data and analysis to support the design presented in the LA.

Total System Performance Assessment - VA

DOE was directed by Congress to prepare a TSPA based on the design concept and scientific data and analyses available at the time. As directed, DOE performed a TSPA and presented the results for the probable behavior of the repository relative to an overall system performance standard. Probable behavior is defined by DOE as the behavior specified by a base case. Limited consideration of disruptive events (e.g., volcanism) was done separately. DOE estimated the peak annual dose in 10,000 years between 0.04 and 0.1 mrem/year for the base case.

The staff believes that DOE's TSPA-VA represents an advancement over earlier efforts in that it is more comprehensive. In conducting its review, the staff compared DOE conclusions with an independent analysis using the Total systems Performance Assessment (TPA) code jointly developed by NRC and the Center for Nuclear Waste Regulatory Analyses. In general, the comparison was favorable with many areas of agreement between the two analyses (e.g., waste package lifetimes greater than 10,000 years, consideration of infiltration). Preliminary results from the staff's independent analysis with the TPA provide an estimate of approximately 0.6 mrem/yr for the peak expected dose in 10,000 years. With the current set of assumptions used in the TPA code, the dominant contributor to peak expected dose in the first 10,000 years was volcanism, because long waste package lifetimes limited doses from other pathways. Although the staff's and DOE's results are within approximately an order of magnitude, it should be noted that the expected annual dose value calculated by the staff is a different performance calculation than the "expected peak dose" used by DOE in the TSPA-VA and the results are not directly comparable.

There are areas where NRC's and DOE's assessments of repository performance differ significantly, and, therefore warrant additional data collection and analysis. The performance of the waste package over long time periods, the estimation of the quantity and chemistry of water contacting the waste package as it affects waste package corrosion and waste form dissolution, the consequences of igneous activity, and how radionuclides are transported in the saturated zone including how concentrations are calculated, represent key areas where the staff believes further work is needed prior to LA, and for which the staff has developed comments in Attachment 1.

License Application Plan

Congress directed DOE to prepare a plan and cost estimate (LA Plan) for the remaining work required to complete an LA. As directed, DOE developed a plan and cost estimate for the remaining work required to complete an LA and an estimate of the costs to construct and operate the repository. The staff has commented on specific areas of the DOE LA Plan where additional work appears required to prepare the LA. The staff did not review DOE's estimates for the costs to construct and operate the repository.

Implementation of the DOE Quality Assurance (QA) program is a long-standing item of importance to the staff. DOE audits have identified that some data in the Management and Operations Contractor technical database have been determined to be not traceable to their origins and inadequately technically reviewed under DOE's own QA program. DOE recognizes the need to implement an overall data qualification strategy and has developed a management plan to direct this work. The staff is conducting a review of the management plan, and will continue to provide oversight of DOE's activities to effectively implement its QA program.

CONCLUSIONS:

NRC staff's evaluation of the VA indicates that the analyses presented are adequate to allow for an informed decision to be made regarding continuation of site characterization of Yucca Mountain and the staff agrees with DOE's decision to proceed. The staff has identified a number of comments on aspects of the reference design, total system performance calculation, and the LA Plan. The staff considers these to be significant subjects that require:

1) successful implementation of plans already in place (e.g., QA program); 2) timely DOE decisions (e.g., waste package design); or 3) additional work not identified in the LA Plan (e.g., quantity and chemistry of the water contacting the waste package and waste form) for DOE to have a high-quality LA by 2002. As described in a December 21, 1998, memorandum to the Commission, the staff will follow up on specific technical issues through periodic revisions to the Issue Resolution Status Reports (IRSRs). The staff intends to inform DOE of its comments and possible actions to address them. A draft letter to DOE is attached.

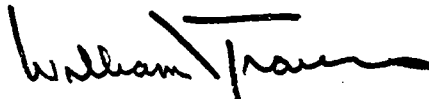
In the LA Plan, DOE has outlined a strategy for conducting additional site characterization, improving its performance assessment, qualifying models and data, and developing a design for the LA. Through a set of workshops, DOE is developing detailed plans to implement the LA Plan. These workshops may result in work plans that could address NRC staff's concerns, if the work is completed. NRC staff will continue to observe these workshops and continue its precicensing consultation with DOE.

RECOMMENDATIONS:

That the Commission approve sending the letter transmitting NRC comments on the VA to DOE.

COORDINATION:

The Office of the General Counsel has reviewed this paper and has no legal objections. There are no resource, information management, or information technology impacts associated with this paper.



William D. Travers
Executive Director
for Operations

Attachments: 1. Letter to DOE with Staff Evaluation of Significant Concerns
2. SRM M990208B

Commissioners' completed vote sheets/comments should be provided directly to the Office of the Secretary by COB Friday, March 26, 1999.

Commission Staff Office comments, if any, should be submitted to the Commissioners NLT March 19, 1999, with an information copy to the Office of the Secretary. If the paper is of such a nature that it requires additional review and comment, the Commissioners and the Secretariat should be apprised of when comments may be expected.

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**UNITED STATES
NUCLEAR REGULATORY COMMISSION**
WASHINGTON, D.C. 20555-0001

Mr. Lake H. Barrett, Acting Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy, Headquarters
1000 Independence Avenue, S.W.
Washington, DC 20585

**SUBJECT: NRC STAFF REVIEW OF THE U.S. DEPARTMENT OF ENERGY VIABILITY
ASSESSMENT FOR A HIGH-LEVEL RADIOACTIVE WASTE REPOSITORY AT
YUCCA MOUNTAIN, NEVADA**

Dear Mr. Barrett:

In December 1998, the U.S. Department of Energy (DOE) completed its viability assessment (VA) for a potential high-level radioactive waste repository at Yucca Mountain, Nevada. Although the VA is a management tool to provide DOE with a basis for making an informed assessment of the feasibility of proceeding with site characterization and the process of potential licensing and construction of a repository at Yucca Mountain, the U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the VA as part of its prelicensing consultation with DOE under the Nuclear Waste Policy Act of 1982 (NWPA). It is believed that the results of the review will facilitate DOE's development of a complete and high-quality license application (LA). NRC staff believes that DOE's analyses are adequate to make an informed decision whether to continue with site characterization of Yucca Mountain in anticipation of a potential site recommendation, and staff agrees with DOE's decision to continue site characterization.

Staff interactions with DOE over the past 18 months have facilitated the NRC staff review of the VA. These interactions focused on elements of DOE's ongoing work that formed the basis for the VA. The VA reflects substantial progress by DOE in focusing its program on the issues that need to be addressed prior to a licensing decision. It describes significant DOE progress in areas such as data collection, data synthesis, performance assessment modeling, and documentation of results. There is general agreement that DOE's planned work appears adequate in several technical areas including: mechanical disruption of waste packages; spatial and temporal distribution of flow; distribution of mass flux between fracture and matrix; and dilution of radionuclides in soil.

Staff comments on the VA are intended to facilitate DOE's efforts to focus its program and develop a high-quality LA. The staff reviewed the preliminary design concept, total system performance assessment (TSPA), and LA Plan. Supporting documents such as the TSPA-VA Technical Basis Document were also examined. In formulating comments, the staff took into account supporting information, importance to performance or licensing, and DOE's plans for addressing these topics, as documented in the LA Plan. The comments developed by the staff are not new and have been the subject of earlier public meetings and NRC staff documents.

The staff comments in the enclosure cover the reference design, technical topics related to the data or models associated with several aspects of DOE's TSPA (i.e., performance of the waste package, seepage into the drifts, saturated zone flow, and analysis of the consequences of volcanism), and the LA plan. More detailed comments on the VA will be provided to DOE through updates to Issue Resolution Status Reports, interactions, and correspondence, as appropriate. The staff will continue to evaluate these topics, interact with DOE, and provide timely feedback. It is important for the precicensing consultations to proceed in order for a possible LA to be of sufficient quality that the staff will be able to complete its review in the time frame required by the NWPA.

Sincerely,

Carl J. Paperiello
Director
Office of Nuclear Material
Safety and Safeguards

Enclosure: U.S. Nuclear Regulatory Commission Staff Evaluation of
U.S. Department of Energy's Viability Assessment

cc w/encl: See attached list

Letter to L. Barrett from C. Paperiello dated: _____

cc: R. Loux, State of Nevada
S. Frishman, State of Nevada
A. Brownstein, DOE/Wash, DC
S. Hanauer, DOE/Wash, DC
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R. Dyer, YMPO
S. Brocoum, YMPO
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A. Gil, YMPO
B. Price, Nevada Legislative Committee
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U.S. Nuclear Regulatory Commission's Staff Evaluation of U.S. Department of Energy's Viability Assessment

The U.S. Nuclear Regulatory Commission (NRC) staff reviewed the U.S. Department of Energy's (DOE's) Viability Assessment (VA) for a potential high-level radioactive waste (HLW) repository sited at Yucca Mountain, Nevada (YM). This review was conducted as part of the staff's precicensing activities and included the preliminary design, total system performance assessment (TSPA), and License Application (LA) Plan. Based on this review, the staff identified several challenges for DOE to assemble a complete and high-quality LA within the time frame envisioned in the LA Plan.

The review of the VA indicates that DOE has made significant progress in a number of areas such as: data collection, data synthesis, performance assessment (PA) modeling, and documentation. However, additional work will be needed in order for DOE to be able to prepare a complete and high-quality LA. The LA Plan provides a high-level description of where DOE believes progress is required and the priority that DOE is assigning to particular objectives.

The TSPA will be an important element in DOE's LA. The staff conducted concurrent reviews of the TSPA-VA and the LA Plan. Through these reviews, the staff identified a set of technical comments regarding the supporting data and models within the TSPA. These comments address key elements of DOE's PA, and -- based on the review of the LA Plan -- may represent challenges for DOE to develop a complete and acceptable LA. There are areas where the staff does not have major comments at this time. These areas include: mechanical disruption of waste packages (WPs); radionuclide release rates and solubility limits; spatial and temporal distribution of flow in the unsaturated zone (UZ); distribution of mass flux between fracture and matrix in the UZ; retardation in fractures in the UZ; retardation in water-production zones and alluvium; dilution of radionuclides in groundwater from well pumping; airborne transport of radionuclides; dilution of radionuclides in soil; and location and lifestyle of the critical group. The most significant staff comments are summarized below.

Enclosure

Repository Design

Comment:

The reference repository design presented in VA keeps open numerous options such that the overall concept remains fluid. Significant changes in the repository design may affect the timely availability of data to be used for repository PA that is necessary for developing a complete and defensible LA. Although appreciating the importance and need for flexibility in design, the lack of a more focused design may not permit DOE sufficient time to address all pertinent issues and prepare a complete LA within its current schedule.

Importance:

Many aspects related to the repository design, especially the thermal load and temperature alternatives; option for backfilling the emplacement drifts and its timing; ground support options and maintenance of underground facility; selection of emplacement stratum; and ventilation alternatives may be important to understanding repository performance. Design alternatives being considered by DOE could result in substantially different approaches than the current reference design. Design options being considered (U.S. Department of Energy, 1998) include different thermal loads, backfilling of the emplacement drifts, continuous pre-closure ventilation, timing of repository closure, type of ground support systems, near-field rock treatment, and repository horizon elevation. Additional enhancement features such as drip shields and Richard's barrier are also being studied. Adequate documentation of design development and traceability of design changes are very important to the completeness and defensibility of the DOE LA. It is important to establish that the data being gathered and the suite of analyses being performed are sufficient to cover all the design alternatives under consideration. It is equally important to develop analytical tools that can make quantitative comparisons of alternatives so that the preference of one over the rest could be established on a rational basis.

Status of Resolution:

The NRC staff has to date concentrated on the design control process being employed by the DOE to document designs and design changes. However, the staff has yet to review the DOE process for the design of the repository. The staff has been observing many DOE meetings and workshops where design alternatives are being discussed and compared based mostly on engineering judgement or qualitative criteria. DOE plans to complete the selection of the LA design in May 1999 and the final design in November 2000 (US Department of Energy, 1998).

Additional Background:

None.

Basis:

DOE presented its first conceptual design for the proposed repository at Yucca Mountain in its Environmental Assessment (in 1984) and then again in its Site Characterization Plan (in 1987). Over the years, the initial design concepts have undergone several iterations with many minor and some major changes to reflect newly acquired information as well as to respond to comments raised by oversight and regulatory bodies. At present, DOE is considering several design alternatives and design options that could significantly affect the repository performance; generate new demands for data and model development; and raise associated uncertainties. For example, depending on the thermal load option selected for final consideration, the technical issues that need to be addressed by DOE and evaluated by NRC could be different. Backfilling the emplacement drifts can change the WP degradation and disruption scenarios to a large extent. Considering the current DOE schedules for addressing the issue of design alternatives, there is a risk that data, models, and analysis results will not be sufficient for a complete and high-quality LA. This might result in NRC requesting additional information at the time of LA review and thus prolong the review period.

References:

- McKenzie, III, D.G. 1998. Alternative repository designs. Presented to the *Drift Stability Workshop*. North Las Vegas, NV: U.S. Department of Energy, Office of Civilian Radioactive Waste Management.
- U.S. Department of Energy. 1998. *Viability Assessment of a Repository at Yucca Mountain, Volume 4: License Application Plan and Costs*. North Las Vegas, NV: U.S. Department of Energy, Office of Civilian Radioactive Waste Management.

Waste Package Corrosion

Comment:

It is unclear whether DOE will be able to acquire sufficient data, applicable to conditions at the proposed repository, in time to demonstrate compliance with NRC requirements. This comment is applicable to the VA design of the waste package (WP) and other aspects of the Engineered Barrier System (EBS).

Importance:

Container life is an important factor in limiting the dose to the critical group and in providing defense-in-depth for the repository system. For example, DOE sensitivity analyses in the TSPA-VA show that by decreasing the corrosion rate of the inner overpack material by a factor of 60, the annual dose at 10,000 years decreases from 2 mrem to less than 10^{-3} mrem. The corrosion rate of the inner overpack material is one of the many WP parameters affecting the prediction of WP lifetime in the TSPA-VA. Several WP parameters have been defined based on expert elicitation rather than long-term test data, especially those for the corrosion-resistant material (CRM). Even if the design were fixed today, only very limited data will be available to substantiate the adequacy of the waste package design for LA.

The continued consideration of alternate designs (in all areas including the EBS and repository) further complicates this subject. It will be even more difficult to gather sufficient and applicable data in the far shorter time-frame between the next design decision (May 1999) and LA. In addition to the time required for testing new materials and concepts, and developing the appropriate modeling when different failure modes may be involved, fabrication issues -- including the problem of closure welding -- will require time for development and evaluation prior to completing the LA.

Status of Resolution:

DOE has testing programs in place for many WP parameters, particularly those relating to the CRM. NRC and DOE staff have had ongoing discussions and interactions regarding these programs and the validity of the values selected by expert elicitation. DOE has described an ambitious testing program in the LA Plan.

DOE has continued the evaluation of alternative designs for waste packages, and a decision is expected in May 1999. One alternative to the current design includes the use of Alloy-22 as an outer barrier and titanium Grade 7 or 16 as an inner barrier. Other options include a three-wall design in which nuclear grade stainless steel (i.e., 316 NG) will be used to provide structural integrity. The reverse design of that proposed in VA, consisting of Alloy-22 as an outer barrier and the steel as an inner barrier providing structural integrity, is also being considered. The issues related to the performance of the alternate designs, including data collection and fabrication issues, are currently being reviewed by NRC and will be addressed in the next revision of the Issue Resolution Status Report (IRSR) on Container Life and Source Term (CLST).

Additional Background:

There are a number of ancillary subjects associated with data collection. In addition to data sufficiency and applicability to the repository environment, there are issues associated with the qualification of data. Another issue is the appropriate role of data collected during the performance confirmation period, relative to data available at the time of Construction Authorization. Although it is appropriate for DOE and NRC to take into consideration more long-term data at later times (i.e., license to receive and possess, repository closure), sufficient data must be available to support the LA. Finally, the bulk of the long-term data used in the TSPA is gathered from expert elicitations and literature reviews, rather than measured under the environmental conditions at Yucca Mountain; including water chemistry, gamma radiation, and the variation of temperature with time.

Basis:

Sensitivity analyses indicate that the lifetime of the WPs has a significant effect on dose to the receptor group. Consequently, corrosion performance of the WPs is a critical factor that may be affected by detrimental interactions between different materials and/or prompted by a specific fabrication process. Additional testing may be required to provide support for any new design. In particular, DOE has recognized in VA that "the primary weakness of the [waste package] model is the overall reliance on expert elicitation rather than on long-term test data of corrosion rates for corrosion-resistant material."

References:

U.S. Nuclear Regulatory Commission, *Issue Resolution Status Report (Key Technical Issue: Container Life and Source Term, Revision 0)*, Washington DC: U.S. Nuclear Regulatory Commission, 1998a.

Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms

Comment:

The data and models used in the VA to calculate the quantity and chemistry of water dripping on WPs are inadequate to describe the process and extent of potential dripping under ambient and thermally-altered conditions. This is an issue because both DOE and NRC PA analyses indicate that the fraction of WPs contacted by water is the most important factor affecting dose for the groundwater pathway. Further, NRC staff considers that the current DOE testing and modeling plans are not sufficient to resolve the issue prior to LA. There are activities that DOE could complete prior to LA that would provide additional support for addressing this issue.

Importance:

The quantity and chemistry of water contacting the WP are the major factors in determining the lifetime of the WP. Radionuclide release rates from breached WPs are also dependent on the quantity and chemistry of water contacting the WPs and, subsequently, the waste forms. Degradation of WPs by corrosion and alteration of waste forms is accelerated in the presence of water and certain dissolved aqueous species. Differences in the amount of seepage into the emplacement drifts and onto WPs lead to calculated radionuclide releases that vary by several orders of magnitude.

Status of Resolution:

DOE recognizes that there are few data -- and the need for additional data -- regarding seepage into drifts, the effects of heat and excavation on flow at the drift scale dripping onto WPs, and the chemistry of water on WPs. In addition, DOE has recognized that its current PA models do not adequately capture the effects of coupled processes on the quantity and chemistry of water contacting WPs. DOE has assigned a high priority to both the data collection and modeling efforts, and is conducting a peer review on drift seepage to guide its pre-licensing scientific activities. The range of activities outlined in the LA Plan are unlikely to provide an adequate licensing basis for assessing the quantity and chemistry of water contacting WPs and waste forms. For instance, it was noted at the Drift Seepage Peer Review Meeting on January 11-13, 1999, that the niche studies that have been conducted and proposed to be completed prior to license application, do not provide an adequate basis to support the seepage abstraction (Hughson, 1999). However, two activities were suggested by members of the peer review panel (Hughson, 1999). It is likely that they could be completed prior to LA and would lead to a more defensible approach for addressing the quantity and chemistry of water contacting the WPs and waste forms. First, systematic air permeability measurements conducted in horizontal boreholes in the three repository host rock units could provide data on the scales of variability and heterogeneity in rock properties that are necessary to describe seepage. Second, additional model development efforts should focus on explaining the observed patterns of seepage in the niche experiments.

Additional Background:

The data and processes necessary to describe the quantity and chemistry of water contacting the WPs and waste forms through abstraction in a PA have been addressed in several IRSRs (U.S. Nuclear Regulatory Commission, 1998a, 1998b, 1998c, and 1998d). In addition, the importance of characterizing thermal perturbations to UZ flow fields during the heating phase and considering coupled thermal-hydrologic-chemical-mechanical processes in PAs was raised in letters to DOE (U.S. Nuclear Regulatory Commission, 1997, 1998e).

Basis:

An ongoing peer review of the DOE drift seepage approach has identified inadequacies in the data, experiments used to collect the data, the models used to describe the seepage process, and the methods used to abstract seepage into performance assessments (Hughson, 1999). Both laboratory scale heater tests and analog site heater tests have indicated the potential for liquid water to contact a heat source under heterogeneous or transient boiling conditions. Both: (1) the potential for gravity-driven refluxing during the thermal period and other coupled processes; and (2) the importance of these processes for adequately describing WP performance has been presented to DOE (U.S. Nuclear Regulatory Commission, 1997, 1998c). Drift collapse may also significantly alter effective parameters describing moisture retention characteristics of the fracture continuum, and thus result in more seepage for a given percolation flux. On the very small scale of a drift wall, the presence of surface irregularities and conducting fractures that dead-end at the drift crown will result in less capillarity and thus less diversion of percolation flux around the drift (Hughson, 1999). Many alteration products of tuff and engineered materials are likely to affect the chemistry of water contacting WPs, which in turn can affect corrosion rates, waste form alteration rates, and radionuclide solubility and speciation (U.S. Nuclear Regulatory Commission, 1998d). Although an effort was made to address this subject, there are many limitations in the data used and the extent of phases considered. Additional data and analysis of seepage under both isothermal and thermal conditions will be required for a complete LA. The amount of data required for the LA, and the need to confirm expected performance of the evolving repository system, will depend on the importance of the quantity and chemistry of water contacting WPs and waste forms to the DOE safety case.

References:

Hughson, D., *Drift Seepage Peer Review*, Trip Report, Las Vegas, Nevada, January 11–13, 1999, Center for Nuclear Waste Regulatory Analyses, San Antonio, TX, 1999.

U.S. Nuclear Regulatory Commission, *Comments on the Department of Energy Thermohydrology Testing and Modeling Program*, letter dated January 23, 1997, from M.J. Bell, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S. Department of Energy, 1997.

U.S. Nuclear Regulatory Commission, *Issue Resolution Status Report (Key Technical Issue: Total System Performance Assessment and Integration, Revision 1)*, enclosure to letter dated

December 8, 1998, from M.J. Bell, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S. Department of Energy, 1998a.

U.S. Nuclear Regulatory Commission, *Issue Resolution Status Report (Key Technical Issue: Unsaturated and Saturated Flow Under Isothermal Conditions, Revision 1)*, enclosure to letter dated October 7, 1998, from M.J. Bell, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S. Department of Energy, 1998b.

U.S. Nuclear Regulatory Commission, *Issue Resolution Status Report (Key Technical Issue: Thermal Effects on Flow, Revision 1)*, enclosure to letter dated October 1, 1998, from M.J. Bell, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S. Department of Energy, 1998c.

U.S. Nuclear Regulatory Commission, *Issue Resolution Status Report (Key Technical Issue: Evolution of the Near-Field Environment, Revision 1)*, enclosure to letter dated August 28, 1998, from N.K. Stablein, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S. Department of Energy, 1998d.

U.S. Nuclear Regulatory Commission, *U.S. Nuclear Regulatory Commission Comments on the U.S. Department of Energy Total System Performance Assessment*, letter dated July 6, 1998, from M.J. Bell, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S. Department of Energy, 1998e.

Saturated Zone Flow and Transport

Comment:

In NRC sensitivity studies, flow in the saturated zone has been shown to be an important component of the natural barrier. At this time, the saturated zone (SZ) has not been sufficiently characterized from the repository out to the proposed 20-km receptor location to adequately assess its contribution to performance. This is an issue because it creates uncertainty about the SZ flow and transport models and the SZ representation in the TSPA. Furthermore, it may render the LA incomplete because the SZ remains an integral part of the DOE repository safety strategy.

Importance:

The SZ is the primary pathway for radionuclide transport from the repository to the receptor location, and is an integral part of the DOE repository safety strategy. The SZ has been identified in the TSPA-VA as one of 19 "principal factors" affecting postclosure performance. In its 1998 report to Congress, the Nuclear Waste Technical Review Board (NWTRB) stated that it believes that the SZ "is an essential natural component of a defense-in-depth repository design for Yucca Mountain" (NWTRB, 1998, PP 45).

DOE indicates that radionuclide travel time in the SZ constitutes a significant fraction of the 10,000 year compliance period (DOE, 1998a: Vol 3, pp 6-16). In addition, sensitivity analyses performed by DOE (DOE, 1998a: Vol 3, pp 4-71-80; 5-40-43) indicate that all three SZ attributes examined in the analyses (SZ dilution, method of combining flow in the SZ flowtube model, and the alluvium fraction in the SZ flow path) have some measure of importance to repository performance, and that SZ dilution is an important parameter affecting the calculated dose for the 10,000-year simulation. Sensitivity analyses by NRC and Center for Nuclear Waste Regulatory Analyses (CNWRA) staff suggest that the SZ is a relatively important subsystem for overall repository performance (Jarzemba et al., 1998).

Status of Resolution:

DOE has low "current confidence" and a low "confidence goal" in the SZ flow and transport representation in the TSPA (DOE, 1998a: Volume 4, pp 2-20, 2-38). DOE plans to conduct additional SZ work activities to improve confidence in the SZ representation in the TSPA for the LA (DOE, 1998a: Vol 4, pp 2-47; pp 3-15, 3-16). In cooperation with DOE, Nye County will implement an "Early Warning Drilling Program," involving installation and testing of shallow and deep wells downgradient of the repository. These wells are expected to provide data about the hydraulic and transport properties of the aquifers along the flow path downgradient from the repository. The scope of the drilling program is limited, however, and may not adequately characterize the SZ, especially the alluvial aquifer. According to DOE (DOE, 1998a: Volume 4, pp 2-39, 3-13), the scope of the planned SZ work was constrained by the available time before the site recommendation (SR) decision and the LA submittal. Furthermore, DOE has assigned a relatively low priority to the planned SZ work (DOE, 1998a: Volume 4, pp 2-20, 2-39).

In addition, some of the planned work activities will extend beyond the cutoff dates for the planned refinement and update of the site-scale and regional SZ flow models. These include (DOE, 1998: Vol 4, pp 3-16): (1) downgradient alluvial hydraulic and tracer testing; (2) K_d determination of alluvium samples obtained from the Nye County wells; and (3) downgradient hydraulic and tracer testing of the volcanic rocks in the area between 5 and 20 km from the repository. DOE states that data obtained from the first two activities and early data from the third activity will be available for use in the TSPA for the LA, but it is not clear how this will be achieved.

It may be possible for DOE to implement, in a relatively short time prior to the LA, some additional field work independent of the Nye County drilling program, possibly including exploratory drilling and surface geophysical investigations to specifically delineate and characterize the alluvium along the flowpath downgradient from the repository. However, DOE currently has no plans to address this.

Additional Background:

The M&O (1998) and DOE (1998a) suggest that the SZ flow system in the YM vicinity has not been adequately characterized. There are very limited field data to characterize the SZ flow between about 5 km and 20 km downgradient from the repository (DOE, 1998a: Volume 4, pp2-38), and limited data to define the SZ transport along the SZ flow path from the repository to the receptor location (DOE, 1998a: Vol 3, pp6-36). In addition, conceptual uncertainties associated with SZ flow and transport have also been reported by the U.S. Geological Survey and others (Luckey et. al., 1996; Czarnecki et., el., 1997; D'Agnes, et., al., 1997; DOE: 1998b; Geomatrix Consultants, Inc., 1998; Gelhar, 1998; and NWTRB, 1998).

The uncertainties about SZ flow and transport at YM have been documented in two IRSRs (NRC, 1998a,b). The flow rate in water production zones has been identified by NRC staff as a key element of subsystem abstraction (KESA) in the TSPA models, and the acceptance criteria are in the Unsaturated and Saturated Flow Under Isothermal Conditions IRSR (NRC 1998a,b).

Basis:

The presence of alluvium along the SZ flow path is expected to significantly delay the arrival of radionuclides at the receptor location due to enhanced sorption and dilution; however, the location of the water table transition from tuffs to alluvium is not yet reasonably characterized. There is uncertainty as to where SZ flow enters the alluvium along the flowpath from the repository or even if flow occurs within the alluvium within 20 km (DOE, 1998a: Volume 3, pp 6-24). This is especially important considering the potentially higher sorption coefficients of some radionuclides which are key contributors to dose, such as neptunium in the alluvium (DOE, 1998a: Volume 3, pp 6-24 - 6-25).

The flow rate in water production zones is affected by the basin scale groundwater flow and may, therefore, be controlled by high permeability features or channelized flow pathways in the aquifer. The presence of preferential and/or fast pathways, due to geologic structural controls, could significantly reduce the transport time. In the YM vicinity, the faults locally control groundwater flow and may represent pathways for upward flow from the deeper carbonate

aquifer (Fridrick et al., 1994; Bredehoeft, 1997; Geomatrix Consultants, 1998). Such flow channeling along preferred pathways is common in fractured and faulted rock (Tsang and Neretnieks, 1998). Interpretation of aquifer borehole tests indicate that permeability at YM is anisotropic (Geldon, 1996). The anisotropic permeability due to structural features downgradient of YM may result in more southerly-directed flow paths than currently modeled by the DOE. The radionuclides in this southerly flow path could remain in the volcanic tuff aquifer all the way to the receptor location at 20 km, since there is no alluvium or a much reduced alluvium fraction in this direction (Frizzel and Shulters, 1990).

DOE has characterized the uncertainties in SZ flow and transport to the TSPA as "moderate", but states that the uncertainty could increase as the model more realistically accounts for processes that reduce radionuclide concentration (DOE, 1998a: Volume 4, pp 2-38). Furthermore, a "moderate" ranking of the SZ uncertainties appears inconsistent with the results of the sensitivity analyses performed by either DOE or NRC/CNWRA.

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Frizzel, V.A., Jr., and J. Shulters, 1990. *Geologic Map of the Nevada Test site, Southern Nevada; U.S. Geological Survey Miscellaneous Investigations Series Map I-2046, Scale: 1:100,000*.

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Nuclear Waste Technical review Board, 1998. *Report to The U.S. Congress And The U.S. Secretary of Energy*.

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U.S. Nuclear Regulatory Commission. 1998a. *Issue Resolution Status Report (Key Technical Issue: Total System Performance Assessment and Integration)*. Revision 1. Washington, DC: Nuclear Regulatory Commission.

U.S. Nuclear Regulatory Commission. 1998b. *Issue Resolution Status Report (Key Technical Issue: Unsaturated and Saturated Flow under Isothermal Conditions)*. Revision 1. Washington, DC: Nuclear Regulatory Commission.

U.S. Department of Energy. 1998a. *Viability Assessment of a Repository at Yucca Mountain: Total System Performance Assessment, December 1998*. DOE/RW-0508. Las Vegas, NV: U.S. Department of Energy, Office of the Civilian Radioactive Waste Management.

U.S. Department of Energy. 1998b. *Peer Review of the Total System Performance Assessment-Viability Assessment: Third Interim Report, June 1998*. Las Vegas, NV: U.S. Department of Energy, Office of the Civilian Radioactive Waste Management.

Volcanic Disruption of the Waste Package

Comment:

DOE concludes in the TSPA-VA that there are no risks from volcanism during a 10,000 yr post closure period, based on models assuming waste package resilience and limited HLW entrainment during a volcanic eruption (CRWMS M&O, 1998). NRC staff review concludes (i) these analyses are based on assumptions of physical conditions that are not representative of Yucca Mountain basaltic volcanism, (ii) data are insufficient to evaluate waste package and HLW behavior under appropriate physical conditions, and (iii) model assumptions are incongruent with those used elsewhere in the TSPA-VA, for example, in enhanced source-term analyses.

Importance:

TSPA-VA analyses may underestimate the contribution to risk associated with future igneous activity at the proposed repository site. Current NRC calculations suggest that the probability-weighted risk from volcanic disruption of the proposed repository is low (on the order of 1 mrem), however this value has sizeable model and parameter uncertainty. DOE has not identified in the VA plans to conduct additional investigations necessary to support igneous activity risk assessment. Unavailability of acceptable consequence models to support igneous activity risk assessment is an issue, in that a process with a potential to be an important contributor to total system risk would not be supported adequately in the LA.

Status of Resolution:

While the VA License Application Plan (DOE, 1998b) indicates no planned activities to resolve these issues, recent informal staff interactions, including participation at DOE workshops, suggest that workplans are being developed which, if implemented, could resolve them. These plans are expected to be completed in late March. The staff will review these plans as they become available and discuss their implementation with DOE in future DOE/NRC Technical Exchanges and other interactions (DOE, 1998a, Section 6.5.3.8) to determine if the issues can be resolved at the staff level prior to licensing.

Additional Background:

The issues associated with the DOE igneous activity program, including the relationship to Total System Performance Assessment modeling, have been raised in comments on DOE study plans 8.3.1.8.1.1 (Holonich, 1994a), 8.3.1.8.1.2 (Holonich, 1994b), 8.3.1.8.5.1 (Holonich, 1994c), numerous interactions with DOE at Technical Exchanges, Appendix 7 Meetings, meetings and workshops with the Advisory Committee on Nuclear Waste and the Nuclear Waste Technical Review Board, interactions associated with the DOE PVHA, and most recently through detailed comments in the Igneous Activity Issue Resolution Status Reports (NRC, 1997, 1998). Acceptance criteria contained in the IA IRSR (NRC, 1998) delineate an acceptable technical basis for evaluating risks associated with future igneous events.

Basis:

In the TSPA-VA, it is assumed that a waste package with >50 percent of the original corrosion resistant material thickness (i.e., >1 cm) will not fail when exposed to the extreme physical conditions of a volcanic eruption except through occasional end-cap failure. This assumption precludes any direct HLW entrainment or release from any volcanic event occurring within the first 100,000 yr post-closure (CRWMS M&O, 1998). This assumption is based on extrapolation of limited data from <430 °C to likely magmatic temperatures around 1100 °C. In contrast, similar data are used to conclude that an intact waste package will fail mechanically when exposed to magma intruded into repository drifts (i.e., enhanced source-term analysis), even when temperatures significantly below expected intrusion temperatures are used in the analysis (CRWMS M&O, 1998). The TSPA-VA analysis of waste-package resilience also does not address the dynamic force imposed on a waste package entrained into a volcanic conduit. As outlined in the IA IRSR (NRC, 1998), staff analyses of limited available data conclude waste-package breach is likely under volcanic eruption conditions. Models proposing waste-package resilience during igneous events are nonconservative and will need robust support through analyses and data that examine physical, chemical, and thermal conditions representative of likely future igneous activity in the YM region.

Another key assumption in the TSPA-VA that is not supported by available information is that magma particle sizes or particle velocities are insufficient to entrain HLW fragments (CRWMS M&O, 1998). Although the expansion of dissolved volatiles in ascending magma may be sufficient to form a two-phase flow regime at repository depths, the fragmented particles are still at temperatures around 1100 °C. Particles will be larger average size than observed at completely cooled and fragmented fall deposits, and will impact HLW fragments elastically. In addition, assumed HLW particle sizes do not account for the extreme physical conditions associated with igneous disruption. As outlined in the IA IRSR (NRC, 1998), staff concludes that HLW particle sizes will be reduced substantially when exposed to the physical, thermal, and chemical environment associated with YM igneous events. Models proposing a lack of entrainment in potential repository-penetrating igneous events will need support through analyses and data.

References:

- CRWMS M&O. 1998. *Total System Performance Assessment Viability Assessment (TSPA-VA Analyses Technical Basis Document, Chapter 10, Disruptive Events*. B000000000-0171704301-00010 REV 01. North Las Vegas, NV: U.S. Department of Energy, Yucca Mountain Site Characterization Office.
- Holonich, J.J. 1994a. Letter (February 8) to D.E. Shelor (DOE) on review of U.S. Department of Energy Study Plan "Probability of Magmatic Disruption of the Repository," Revision 2. Washington, DC: U.S. Nuclear Regulatory Commission.
- Holonich, J.J. 1994b. Letter (May 21) to D.E. Shelor (DOE) on review of U.S. Department of Energy Study Plan "Characterization of Volcanic Features." Washington, DC: U.S. Nuclear Regulatory Commission.

Holonich, J.J. 1994c. Letter (September 14) to R.A. Milner (DOE) on review of U.S. Department of Energy Study Plan "Physical Processes of Magmatism and Effects on the Potential Repository." Washington, DC: U.S. Nuclear Regulatory Commission.

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U.S. Department of Energy. 1998a. *Viability Assessment of a Repository at Yucca Mountain, Volume 3: Total System Performance Assessment*. DOE/RW-0508/V3. North Las Vegas, NV: U.S. Department of Energy, Yucca Mountain Site Characterization Office.

U.S. Department of Energy. 1998b. *Viability Assessment of a Repository at Yucca Mountain, Volume 4: License Application Plan and Costs*. DOE/RW-0508/V4. North Las Vegas, NV: U.S. Department of Energy, Yucca Mountain Site Characterization Office.

Quality Assurance

Comment:

Although NRC staff has reviewed and accepted the DOE Quality Assurance (QA) program, DOE has consistently had problems implementing the program. Deficiencies identified during DOE audits and surveillance of its suppliers raised the issue of whether the data/products produced by these suppliers will be acceptable and appropriately qualified for licensing. DOE audits have identified that some data in the Management and Operating Contractor's (M&O's) technical data base are not traceable to their origins and could not be ensured to be applicable, correct and technically adequate. The Technical Basis Document, which supports the TSPA-VA, indicates that a major portion of the data supporting VA is not qualified. DOE's LA Plan does not recognize the current situation with regard to implementation of its QA program and the activities needed to address it.

Importance:

To obtain authorization to construct a HLW repository, DOE must be able to demonstrate in its LA that data, analysis, and designs of barriers and systems important to safety or waste isolation meet QA requirements of Appendix B to CFR Part 50.

The QA program applies to all systems, structures, and components important to safety and waste isolation, including: design and characterization of barriers important to waste isolation; activities such as site characterization, facility and equipment construction; facility operation; performance confirmation; permanent closure; and decontamination and dismantling of surface facilities. Confidence in the adequacy of data, data analyses, construction activities, and other items and activities associated with the LA is obtained through a QA program.

Status of Resolution:

DOE recognizes the need to improve the implementation process to qualify data, models, and codes and has assigned a high priority to these activities based on questionable data in the M&O technical data base and its associated references. DOE has also issued Yucca Mountain Administration Procedure YAP-SIII.1Q, Revision 3, ICN0 to improve the process of qualifying unqualified data.

During the NRC/DOE QA meeting of December 9, 1998, DOE committed to the development of an overall data qualification strategy/plan by December 21, 1998. The plan should include: 1) identification of unqualified data sets approved for qualification; 2) methods of qualification and rationale; 3) technical disciplines required; 4) data evaluation criteria including size of sample to be tested, statistical method to be used, and identification of computer codes to be used; 5) criteria for changing data status from "non-qualified" to "qualified;" and 6) a schedule for completing the work. NRC staff is currently reviewing the "Data, Model and Code Qualification/Validation and Control Plan."

Meanwhile, an NRC QA Task Force was formed to conduct an independent and objective review of the DOE HLW QA program and its implementation. A Task Force review of the "DOE Management Plan and Responses to Corrective Action Request (CAR) and Status of

Implementation of Corrective Actions" document, dated January 25, 1999, is underway. The Task Force will also review, and formally comment on, the Root Cause Analysis/Corrective Action Report conducted by DOE.

Additional Background:

None.

Basis:

The NRC On-Site Representative's reports (ORRs) and Observation Audit Reports (OARs) on the Yucca Mountain Project are documented to alert NRC staff, managers and contractors to information on DOE programs for site characterization, repository design performance assessment, and environmental studies that may be of use in fulfilling NRC's role during pre-licensing consultation. As noted in the ORRs and the OARs, deficiencies have been identified questioning the accuracy, qualification and traceability of data.

References:

NUREG-1298 - Generic Technical Position (GTP) on "Qualification of Existing Data for High-Level Nuclear Waste Repositories," dated February 1998.

YAP-SIII.1Q, Revision 3, ICN0 - Yucca Mountain Administration Procedure on "Qualification of Unqualified Data," dated November 13, 1998.

"Data, Model and Code Qualification/Validation and Control Plan," dated December 1998.

"DOE Management Plan and Responses to Corrective Action Request (CAR) and Status of Implementation of Corrective Actions," dated January 25, 1999.



**UNITED STATES
NUCLEAR REGULATORY COMMISSION**

WASHINGTON, D.C. 20555-0001

IN RESPONSE, PLEASE
REFER TO: M990208B

February 16, 1999

MEMORANDUM TO: William D. Travers
Executive Director for Operations

FROM: Annette L. Vietti-Cook, Secretary /s/

SUBJECT: STAFF REQUIREMENTS - BRIEFING ON HLW PROGRAM
VIABILITY ASSESSMENT, 2:00 P.M., MONDAY, FEBRUARY 8,
1999, COMMISSIONERS' CONFERENCE ROOM, ONE WHITE
FLINT NORTH, ROCKVILLE, MARYLAND (OPEN TO PUBLIC
ATTENDANCE)

The Commission was briefed by Lake H. Barrett, U.S. Department of Energy on the HLW Program Viability Assessment. The staff is expected to provide a Commission paper on their review and comment of the Final Viability Assessment on March 9, 1999 and brief the Commission on March 16, 1999. There were no new staff requirements as a result of this briefing.

cc: Chairman Jackson
Commissioner Dicus
Commissioner Diaz
Commissioner McGaffigan
Commissioner Merrifield
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OPA
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