UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

***

OFFICE OF THE SECRETARY

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MEETING WITH ACNW

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Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Rockville, Maryland

Wednesday, March 17, 1999

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

COMMISSIONER'S PRESENT:

NILS J. DIAZ
GRETA DICUS
EDWARD MCGAFFIGAN
JEFFREY S. MERRIFIELD

STAFF AND PRESENTERS SEATED AT COMMISSION TABLE:

JOHN GARRICK, Member, ACNW
CHARLES FAIRHURST, Member, ACNW
RAYMOND WYMER, Member, ACNW
DR. KNOPMAN, Technical Review Board
DR. BULLEN

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

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

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

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

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

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

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

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

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

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

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

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

We have to note that one of our members, which is

25 percent of our membership, is absent today, unavoidably, and we will surely miss him, but we will do our best to fill in for him.

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

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

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

CHAIRMAN JACKSON: With a full slate of issues.

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

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

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

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

basis for our comments.

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

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

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

The TSPA VA was a snapshot of DOE progress on performance assessment and as far as focus is concerned, the ACNW review has spent most of its time on the matter of the technology attributes of the design and on the way in which those technology attributes have been characterized in the performance assessment that has been performed.

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

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

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

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

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

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

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

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

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

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

COMMISSIONER MERRIFIELD: Madam Chairman.

CHAIRMAN JACKSON: Please.

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

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

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

CHAIRMAN JACKSON: Please.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

DR. GARRICK: Yes.

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

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

DR. GARRICK: Right.

CHAIRMAN JACKSON: As opposed to the usual engineered features.

DR. GARRICK: That's right.

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

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

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

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

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

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

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

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

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much less the public.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

magnitude down to something more reasonable.

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

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

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

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

DR. GARRICK: Right.

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

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

DR. GARRICK: Yes.

CHAIRMAN JACKSON: -- the so what question.

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

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

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

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

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

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

DR. GARRICK: Yes.

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

DR. GARRICK: Right.

CHAIRMAN JACKSON: Commissioner Merrifield.

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

DR. GARRICK: Yes.

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

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

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

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

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

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

DR. GARRICK: Oh, yes.

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

DR. GARRICK: Yes.

COMMISSIONER MERRIFIELD: -- about the

appropriateness of the standards?

DR. GARRICK: Absolutely. Absolutely.

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

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

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

DR. GARRICK: That's right.

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

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

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

DR. GARRICK: That's right.

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

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

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

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

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

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

Okay. With respect to the supporting evidence

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

the mountain scale infiltration problem.

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

CHAIRMAN JACKSON: Let me ask you a question.

DR. FAIRHURST: Yes.

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

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

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

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

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

quaternary climate and on paleohydrology.

DR. FAIRHURST: Yes. Yes. Yes.

CHAIRMAN JACKSON: Do you agree with that?

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

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

COMMISSIONER McGAFFIGAN: Madam Chairman.

CHAIRMAN JACKSON: Yes, please.

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

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

Both theoretical and experimental results thus

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

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

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

DR. FAIRHURST: Well, you added by 2002.

COMMISSIONER McGAFFIGAN: By the time of the license application.

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

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

which one that was before it goes there.

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

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

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

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

As you raise the temperature of this rock, you

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

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

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

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

DR. FAIRHURST: Yes.

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

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

COMMISSIONER McGAFFIGAN: Right.

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

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

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

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

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

And as I think you know, there's been a tremendous activity on the part of DOE in the last year or so, year and a half, looking at various alternative engineered designs.

Those engineered alternatives, there's a lot of details, but in simplification, they really boil down to two; whether you have a hot repository -- in other words, whether you allow the rock temperature to go above the boiling point of water, which that reaches about 96 degrees Celsius, or whether you keep it low.

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

With the low temperature design -- I may also say

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

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

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

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

COMMISSIONER DICUS: I have a question, please.

DR. FAIRHURST: Yes.

COMMISSIONER DICUS: Are you leaning in one

direction or the other on these or are you neutral?

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

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

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

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

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

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

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

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

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

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

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

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

DR. FAIRHURST: Yes.

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

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

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

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

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

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

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

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

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

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

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

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

CHAIRMAN JACKSON: Thank you. Dr. Wymer?

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

CHAIRMAN JACKSON: Closer to the mic.

DR. WYMER: There?

CHAIRMAN JACKSON: Closer.

DR. WYMER: Closer.

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

DR. WYMER: Oh, it moves.

DR. GARRICK: Flexibility.

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

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

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

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

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

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

COMMISSIONER DIAZ: Excuse me.

CHAIRMAN JACKSON: Please.

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

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

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

assumptions about thermal loading.

DR. WYMER: Yes, that's right.

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

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

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

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

CHAIRMAN JACKSON: -- contribution of those contributors.

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

CHAIRMAN JACKSON: Okay.

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

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

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

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

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

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

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

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

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

Expert elicitation, for example, relies in large measure on what assumptions are made, which the experts are making their judgments and insofar as the assumptions change, the results of the experts' opinions change.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CHAIRMAN JACKSON: Thank you.

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

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

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

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

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

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

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

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

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

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

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

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

So with that, we will close our formal remarks.

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

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

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

repository.

DR. GARRICK: Right.

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

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

DR. GARRICK: Yes.

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

DR. GARRICK: No.

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

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

CHAIRMAN JACKSON: -- you talk about flexibility.

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

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

CHAIRMAN JACKSON: But that's a measurement.

DR. GARRICK: Yes.

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

DR. GARRICK: Right. Right. Right.

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

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

CHAIRMAN JACKSON: Right.

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

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

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

DR. FAIRHURST: Yes.

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

DR. FAIRHURST: Yes.

CHAIRMAN JACKSON: And what we need to hear clearly from you, that if you're really talking things to the extent of thermal loading, the actual physical design, as well as the waste package, then we need to be clear that

that's what you mean, and that's all I'm saying.

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

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

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

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

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

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

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

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

CHAIRMAN JACKSON: Thank you very much. Commissioner Dicus.

COMMISSIONER DICUS: No further.

CHAIRMAN JACKSON: Commissioner Diaz.

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

DR. GARRICK: Okay. Thank you.

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

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

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

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

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

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

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

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

DR. GARRICK: Thank you.

CHAIRMAN JACKSON: Commissioner McGaffigan.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CHAIRMAN JACKSON: Commissioner Merrifield.

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

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

[Recess.]

CHAIRMAN JACKSON: I think we will proceed. I welcome to the table Dr. Deborah Knopman and Dr. Daniel

Bullen, from the Nuclear Waste Technical Review Board, and we look forward to hearing your remarks this morning.

DR. KNOPMAN: Good morning, Chairman Jackson.

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

I am director of something called the Center for Innovation and the Environment of the Progressive Policy Institute, 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 and radiological and severe service environments.

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

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

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

The board is independent within the Federal Government. We're not part of DOE or any other agency. All of our 11 members 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 of 1997.

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

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

cost of disposing of the waste.

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

The VA is not and was never 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 requires 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.

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

In a assembling the VA, DOE integrated very 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.

Most important, I think, from our board perspective, the process of integration has had the effect of focusing the objectives of the scientific investigations. In particular, the VA highlighted the very 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 or below boiling point design, these uncertainties would be less significant and might not need to be resolved for making a suitability determination. It's a very important connection and we think this permeates the whole evaluation process.

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

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

recommend the site to the President for repository development.

We think 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 DOE in volume four of the VA will be required to support a technically defensible decision.

The board supports continuing focus 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.

In November of '98, the board issues a report outlining its views on the future research needed to address uncertainties about the performance of the repository system, including both the engineered and natural barriers, and 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 there will always 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 we think 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 or 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 responsibility designs should be evaluated that have the potential to reduce uncertainties in projected repository performance and thereby reduce 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 go into this in a little bit more detail. As you all know, the DOE has spent many years and many dollars studying the Yucca Mountain site and designing the engineered components of the 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 waste.

In part, this is a problem inherent in extrapolating repository performance for thousands of years from data acquired over a much shorter period. 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 like 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 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.

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

Improving the basic understanding of long-term passivity is essential because at present, there seems to be no documented natural or manmade 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 for 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.

First, fundamental data that are essential to the development and implementation of the models, and, two, data sets designed to challenge conceptual models and test the coupled models used in 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 four 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 '98 report, and we include in that unsaturated zone, the engineered barrier system, and the saturated zone.

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

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 lithophyssal zones that would host the majority of waste packages, and studies of the Solitario Canyon fault, the active fault bounding the repository, that may also 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 four of the VA appear to be appropriate in the sense that they're technically feasible, 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. Studies could show the site to be unsuitable.

They could raise new questions requiring further study. On the basis of current information, however, the board is pleased that volume four 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 four 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, license application in 2002.

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

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

DR. BULLEN: Thank you, Dr. Knopman. 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 a lower waste package surface

temperature merits further detailed analysis.

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

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

Combined with improved waste package shielding, the design could also simplify pre-closure performance confirmation by enhancing access to 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 could significantly reduce coupled thermal hydrologic and thermal geochemical processes. Maintaining near field temperatures below the boiling point of water after repository closure by ventilation of aging could reduce uncertainties about the movement of water and associated geochemical processes in the repository's natural barriers.

This could increase the 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 significantly reduced 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 may 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.

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

engineered barriers and interaction 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 a 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.

The ultimate goal of the studies at Yucca Mountain is to determine 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 post-closure safety case consisting of the following.

Assessment of expected post-closure performance, design margin and defense-in-depth, consideration of disruptive processes and events, insights from natural and manmade analogs, and 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 would 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 uncertainty in projections of performance.

TSPA has 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 cannot be used to do the following; cannot assess compliance with regulatory criteria, cannot show defense-in-depth for the design of the repository system, as we saw earlier this morning, cannot assess the importance of small design changes, and cannot 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 non-conservative. Numerous examples are presented in the recent report of the TSPA VA peer review panel, which I understand is actually being presented today in Las Vegas.

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

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

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

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 the 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 four of the VA will be required to support a technically defensible decision.

The board supports continuing focus studies of

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

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

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

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

DR. KNOPMAN: Yes.

CHAIRMAN JACKSON: To what extent is one really

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

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

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

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

And if you look at the five designs that were

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

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

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

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

CHAIRMAN JACKSON: You were going to make a comment.

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

CHAIRMAN JACKSON: Please.

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

CHAIRMAN JACKSON: No. Go on.

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

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

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

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

CHAIRMAN JACKSON: Well, perhaps in the spirit of plain English initiatives, I mean, it could be construed as a misnomer because it really is a methodology of integrating information, but within a certain boundary.

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

CHAIRMAN JACKSON: Yes. PSPA, right?

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

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

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

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

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

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

better understanding of the properties of the flow regime.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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final one by the required deadline?

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

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

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

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

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

CHAIRMAN JACKSON: You've been very indulgent.

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

Commissioner Dicus.

COMMISSIONER DICUS: I don't have any questions.

CHAIRMAN JACKSON: Commissioner Diaz.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CHAIRMAN JACKSON: Commissioner McGaffigan.

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

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

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

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

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

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

COMMISSIONER McGAFFIGAN: Okay. Why do we have to go from MDOS to Windows 98? Sometimes I worry myself.

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

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

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

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

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

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

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

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

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

And so the process is ongoing and the board has

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

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

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

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

COMMISSIONER McGAFFIGAN: I didn't know that.

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

COMMISSIONER McGAFFIGAN: You know more about EIS than I do, I think.

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

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

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

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

CHAIRMAN JACKSON: Commissioner Merrifield.

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

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

As you all know, we as a Commission decided to

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

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

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

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

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

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

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

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

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

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

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

DR. KNOPMAN: Right.

COMMISSIONER McGAFFIGAN: And .2 millirem --

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

DR. KNOPMAN: No, I understand.

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

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

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

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

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

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