UNITED STATES

NUCLEAR WASTE TECHNICAL REVIEW BOARD

REPOSITORY PANEL MEETING

Alexis Park Hotel
375 East Harmon
Las Vegas, Nevada
January 25, 1999

BOARD MEMBERS PRESENT

Mr. John W. Arendt
Dr. Daniel B. Bullen
Dr. Paul P. Craig
Dr. Priscilla P. Nelson, Chair
Dr. Richard R. Parizek
Dr. Donald Runnells
Dr. Alberto A. Sagues

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I N D E X

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P R O C E E D I N G S

NELSON: Good morning. Welcome to the meeting of the Repository Panel, which is a subset of the Nuclear Waste Technical Review Board. My name is Priscilla Nelson and I am the chair of this panel. Other panelists are Dan Bullen, John Arendt, Alberto Sagues and Don Runnells, who are sitting here, and we are joined by Richard Parizek, who is our ex officio member, we adopt him whenever he shows up. And during the day I expect two additional board members, Jeffrey Wong and Paul Craig will join us here.

The Board is organized into several--five panels to consider concentrated efforts in certain areas of the project. This particular panel that deals with the repository is associated with two staff members, who are over here to my left, your right, Russ McFarland and Carl Di Bella. And we are also joined by Leon Reiter and Bill Barnard.

We are here to hear today from DOE about its ongoing consideration of the repository design, an effort that began in the summer of 1998, last year, and is scheduled to be concluded in May. Today we'll hear about the enhanced design alternatives under consideration that were derived from an intense workshop that was held during the first two weeks in January. Tomorrow, the Board will be meeting in full and we'll hear about the Viability Assessment document.

The format for today--I hope you've all seen a copy of the agenda--includes a sequence of speakers from DOE and contractors, and we've arranged it so that there's a presentation period and then a question-and-answer period following. The questions and answers immediately following each talk will be restricted to the Board and staff members and what dialogue may derive from those questions and answers. At the end of the morning, we will have a 15-minute public commentary period, and those of you who wish to make comments, I encourage you to sign up right where you signed up where you entered so that we can know how many and who have registered their wish to speak.

In the afternoon--in the morning we're going to hear about the process that's been involved in considerations of the enhanced design alternatives. In the afternoon we'll hear about the concepts that came out of that workshop and about the future plans of DOE to continue the considerations through the May time frame. At 4 p.m. we've arranged a roundtable discussion where we will invite the presenters and a few others who have had involvement with the project in recent panel activities to discuss from 4 to 4:45 what we've heard today. And then we will have a second period, 30-minute period, of public commentary at the end of the day.

Okay, therefore, I'm happy to welcome you to this meeting of the Repository Panel, and I'd like to begin pretty much on schedule with our first speaker. The title of the presentation is "Introduction to the License Application Design Selection Process," and our speaker is Richard Craun from DOE. Rick is a mechanical engineer by training and he has a present position as senior technical advisor to the project. He has had past involvement with Rocky Flats and a history of about 15 years in the commercial nuclear industry. And I'd like to invite Rick up to the presentation place to begin his talk.

CRAUN: What I'm going to do today is try to frame the License Application Design selection activity process.

UNIDENTIFIED SPEAKER: Is your mike on?

UNIDENTIFIED SPEAKER: There you go.

CRAUN: Oh, I can hear myself now. Great. Then if we can get this to work. Modern technology, I love it, I love it.

I have a little bit of a head cold today, so if I sound a little froggy throughout the day, that's what it is. I will--if anybody needs any cough drops, I've got a whole bag of cough drops on my table.

Okay, let's go ahead and get started. We've been working on an activity called License Application Design Selection. We're going through that activity to select the design that we will carry forward--or designs that we will carry forward--into site recommendation and license application. Now, I mentioned design or designs simply because LADS isn't restricted to come out with just a design. It can come out with a design or two. It can also come out with a design and some options.

So with that let me kind of back up and talk a little bit about some terminology. We have things called "features," we have design options and Enhanced Design Options. Prior to the workshop we developed over the last--I guess our first presentation to the Board on Alternative Designs was in October of '97, the second one was in June of '98. But we identified 26 features and 8 options, and we've analyzed those and brought them forward into this process called LADS, License Application Design Selection, and there we will select an enhanced design alternative. And that's the purpose of that. So we're going from features and alternatives to an enhanced design alternative.

The LADS effort will produce a report, and that report will be a series of recommendations from the M&O contractor. They will be due to--that report will be due to DOE on April 15th. That report will address several things. It will identify the evaluations done on each of the features and alternatives to get ready for the workshop that Priscilla mentioned that was from January 4th to January 15th. It will also identify the features that are integral to the enhanced design concepts that they're going forward with, supporting features, and also the features that were not selected. In addition, the report will discuss the criteria for evaluation. We will rank each of these enhanced design alternatives to a series of evaluation criteria. So that report will address all of those.

Following the issuance of the report in April, DOE will review it, and they're scheduled for that review to complete on May 28th.

And as mentioned earlier, we just completed our current status, we just completed a two-week intensive workshop. That was from January 4th to January 15th. We had several observers involved in that workshop.

Some of the Pre-Workshop activities were the evaluations of all of the features and alternatives. In addition to that we had--we formed an Independent Review Team, and we wanted to have a review team come in and look at the objective nature of the LADS effort, the transparency and the defensibility of the effort. We had people like Wendell Weart, Peter Morris, Joe Payer, Sal Levy, Angelo Giambusso, Chris Whipple and Terry Surles. They were all members of that board. We met on the 14th, gave them a complete overview of all of the activities that were taking place to get ready for the workshop, and then they came back with a series of recommendations or ideas. And they had four basic concepts that they shared with us.

One is they thought that the criteria we were using for evaluation was too complicated. We had nine criterion elements for the Pre-Workshop activity, and they suggested that we consolidate that, simplify that a little bit. They thought it would make our process of selecting an EDA a little bit easier.

They also talked to us about the level of design decisions that we need to make. If you think of a level of a design decision as a conceptual level, one of the highest levels would be a high-temperature versus low-temperature. Very basic, different design concept. If you go with a low temperature, you might go the next level down design decision you might need to make, is it a line load or is it a point load? Are you going to use a large areal mass loading or distributed areal mass loading or are you going to use ventilation or blending? How will you try to accomplish that design? So they suggested that we look very carefully at what level of design decision we're trying to make in this effort to make sure that we don't go too far down.

They also talked to us about the need for transparency. We had a lot of information that we presented to them in a short period of time. In that information it became apparent that we have to really focus on our documentation of this process to make sure somebody can come in after the fact, read through it, and make sure they understand it.

Now, during the initial phase of the workshop, the first few days were associated with presenting what we called "One-Off" analyses. We took the VA base case, the reference case that was presented in the Viability Assessment, and we did one-off's from that. Basically, all a one-off is, for example the base case in the Viability Assessment does not include a ceramic coating on the waste package. So a one-off would be the inclusion of a ceramic coating on the waste package. A one-off would be maybe a dual corrosion resistant material for the waste package instead of a carbon steel on the outside and a corrosion resistant material on the inside.

So we took one-off evaluations of the 26 features and 8 alternatives and compared them to the VA base case. Now, what we found in the initial stages of the workshop was that those evaluations, because they were limited to one-off's, the synergism that one would expect to see between some of the features never really came to the surface other than during the discussions. The workshop brought out those synergisms quite nicely.

And in addition, the other part, there was a TSPA analysis on most of the features and most of the alternatives. Not all of them, some of them really didn't warrant a TSPA analysis. And there we brought out what the limitations of that analysis were, what we were seeing in the variation and the TSPA results, was it real, was it significant, was it worth kind of paying attention to.

The balance of the workshop--that was the first three days of the workshop--the balance of the workshop was the development of the enhanced design alternatives. And in order to do that, what we did was we broke off into three teams. We had a high-temperature team, a low-temperature team and an enhanced access team. Now, we did that to ensure diversity, to make sure that we had a diverse set of enhanced design alternatives coming in.

The low-temperature team--oh, excuse me, those three teams went out, and the first day that they went out and they did some brainstorming, like value engineering processes, if you've ever seen that, and just some general brainstorming processes where they took the features and combined them together and built their EDA's. We built--on that first Thursday we built 23 EDA's.

As we started bringing the EDA's together and started talking about them, it became apparent that they were too complicated. For example, one EDA might have a backfill, one might have a drip shield, one might have a surface modification feature, one might have rod consolidation. And so what we decided to do is to peel the EDA's back so that they basically--so that we could identify those features that are integral to the implementation of the design.

For example, a low temperature, integral features to a low-temperature design would be areal mass loading, would be aging, age the fuel on the surface, ventilation underneath, and there's several different features that one can combine that will give you effectively a low-temperature repository. That allowed us to separate those features from a variety of other features, for example a drip shield that one might add to help in the Defense-in-Depth argument. We separated those out so that we could then make a comparison of the EDA's. That comparison process was simplified by doing that, and it made it much easier to compare. We found that there was some overlap.

And I think I just timed out, I talked too long. Is Tom here? Does that mean I've got to talk faster? Could be a sign.

NELSON: Either that or more slides.

CRAUN: Or more slides, or more slides.

Let's see, which one am I? "Process is Working". No, that's the conclusion. There we go.

During the development of the EDA's we had four or five central themes keep coming back to the surface, so I put these up on the board here for you. And throughout the day Dennis Richardson and Kevin Coppersmith and others will address some of these issues. And they're important. We've had a lot of discussion during the workshop on these activities--or on these issues, we've had some post-workshop discussions, and we will have more post-workshop discussions on these.

The first one is the adequacy of Defense-in-Depth approach to address the uncertainty in variability in the natural systems and uncertainty in the engineering systems. How do we use Defense-in-Depth? In other words, if you're trying to increase your Defense-in-Depth on preventing moisture from getting to the waste package, do you add a drip shield, do you add a Richards Barrier? Those are the concepts of Defense-in-Depth. There's an analysis method that Dennis Richardson will talk about afterwards, but that whole discussion of trade-off of uncertainty with feature addition was discussed quite a bit.

Technical bases for decisions. During the workshop we found that since we had one-off analysis to work with, when we went to look at some of the combinations of blending and aging and ventilation on the low-temperature repository design, we found we quickly ran out of analysis, we quickly ran out of information, so we had a limitation of available information. What we found ourselves doing is backing up to the next higher conceptual level, characterizing the problem, characterizing the issue, and then asking for analysis to be done. So there's an issue of availability of both analysis and technical data. That also plays into what level of design decision you expect to make in the last process.

The independent team that we had, as I spoke to earlier, said that we need to simplify the evaluation criteria. I believe we had--and I've timed out again--we had ten--or nine, excuse me, criterion elements to begin with and we went down to five. So we are looking at consolidating evaluation criteria from nine. I believe currently we're aiming toward about five to simplify the comparison process.

Again, I've already talked about the level of design recommendation and the transparency of the process. The process is we're putting a lot of work, a lot of effort into this process, we've got a tremendous amount of work to be done between now and the April 15th date, and the documentation quality needs to be very high in order for us to be transparent.

Process is Working. It was fun from my perspective to watch the workshop. The Pre-Workshop activities, I was a little concerned with some of the evaluations because they did not really fully address the biases of the one-off--or excuse me, I don't know that "bias" is the right word, but the perspective of a one-off analysis. The workshop was very open. They discussed, we discussed, the limitations of the analysis, the limitations of the modeling, and the limitations of a one-off analysis versus a synergistic combination of feature analysis. So that was I think a very positive process.

The design concept teams, the three, the high, low and enhanced access, really became sponsors for their designs. They really championed their designs in the discussions. And so some of the discussions got quite heated and it was fun to see them really start championing their designs.

The workshop did end, we were able to consolidate the 23 down to 8, and so the workshop did end with 8 going into Phase II. There is some discussion you may hear about later where the enhanced access may turn out to be not an option but a feature. That may come out a little bit later. But that wasn't decided in the workshop.

With that, I'll save myself from this technology. Now I can answer any questions.

NELSON: Great. Thanks, Rick.

CRAUN: Okay.

NELSON: Let's open the questions on the general process to anyone on the Board. Have a question? John.

ARENDT: Yes, a simple question. Who organized the workshop, who was responsible for it, the single person?

CRAUN: The single person, Dick Snell is the responsible M&O manager for the workshop, it's an M&O activity. DOE has Paul Harrington involved with the workshop, he's the line organization responsible on the DOE side. And then I from

Steve Broucoum's side from a strategy standpoint was involved. Those are the three. But Dick would be the working level manager.

ARENDT: Do you expect to--what was the number of EDA's that you expected to come out of the workshop, did you have any idea? You were going from 23 to 8, did you have some number in mind before you started?

CRAUN: We were really looking at the workshop somewhere between five and ten. I prefer the smaller number because there's a lot of follow-up activity. The larger that number gets, the more activity you have to do between now and April 15th to do a complete or a thorough evaluation. So the smaller the better in my mind. But the goal initially, I believe, was five to ten.

ARENDT: All right.

NELSON: Dave Bullen.

BULLEN: Bullen, Board. Rick, you mentioned that the follow-up to this would be to carry forward one, possibly two or more, designs into License Application, and I'd like you to comment on the resources necessary to do that, and do you think that the resources are available or is it going to be a real challenge? And I guess one of the questions that would be the follow-on to that would be, does it then dictate that you're going to end up with just one design because the resources are limited?

CRAUN: Well, we have no restriction placed on us. Obviously if we try to recommend three designs, I think it's going to be very, very difficult from a resource standpoint. What I really imagine that will come out of this is a basic concept with some options that can be brought forward so that for example if we go down the process of building our--going through and developing our site recommendation and we find that we don't have sufficient information to support our cladding degradation models--I'm just picking that at random --we would want to have other features that we carried along so that in case what if that didn't work out for the site recommendation we have other things to bring forward. I really suspect that we'll end up--it's just a guess on my part, it's not a requirement--but I suspect that we will end up with a design concept with some options.

Now, there was quite a bit of similarity between some of the highs and lows. It would be nice, for example, if we had a high that could be at a later date brought back into a low if necessary. So there's some overlap there that we're really trying to look for so that what we do carry forward we have as much overlap in the design world as possible, okay?

BULLEN: Thank you.

NELSON: Let me ask about the issue of biases.

CRAUN: Yes?

NELSON: Can you elaborate a little bit on what you mean by biases associated with the one-off?

CRAUN: Well, it's a word I promised people I wouldn't use and it slipped out and I couldn't retract it. As we did the one-off analyses, the best example I can give you is the ceramic coating on the waste package. It was done as a one-off analysis, so that meant it was applied to a carbon-steel substrate. Now, moisture gets to a carbon-steel substrate, it will spall and crack the--spall the ceramic coating off. So its analysis showed a performance I think life of about 600 and some odd years, a very, very, very short lifetime for ceramic coating on a waste package. That one-off analysis biased that information because if you put it on a corrosion-resistant material, it may have different performance characteristics and a different lifetime. So that's really the bias that I was referring to.

NELSON: Okay. Any other Board questions?

(No response.)

NELSON: Any from the staff? Bill Barnard.

BARNARD: Barnard, Board staff. Rick, when you began your presentation you used a couple--well, I could say three or four terms. Could you run through those again just to make sure that we're on the same wavelength?

CRAUN: Sure.

BARNARD: You have design options, alternatives, enhancements--

CRAUN: Okay.

BARNARD: --features.

CRAUN: We have features and alternatives and enhanced design alternatives, EDA's, so we really have three. And if I mentioned four, I made a mistake already.

NELSON: Options.

CRAUN: Option, it's really a feature, I interchanged the two.

NELSON: Features are really I'll say add-ons. They're for example modular construction--oh, no, that's not a good one. Ceramic coating on the waste package is a feature that can be added to most any designs. Dual CRM is a feature that can be added to most any design. And I cheated and brought my list, I never remember all 26. Drip shield is another one. A feature basically can be added to the design. Now, a drip shield and/or backfill, another feature, backfill can effect the design. For example, depending on when I put backfill on, it will raise the waste package temperature, it may affect cladding temperature, performance characteristics, those sorts of things. So it's not as if it doesn't have any impact on the design, it's just not typically integral--necessarily integral with the design and it can be added to the design.

Options, on the other hand, the ones that we considered of the eight--I'll just mention a couple--is a low thermal load. Compared to the VA, which was a high areal mass load and high thermal load, this was an entirely different concept that took several features to add together to come up with an alternative.

An EDA, enhanced design alternative, is really just the next generation. It's really trying to look at the synergism between the features that one would develop. For example, the synergism between aging and blending, depending on how much blending and how much aging affects and how much ventilation I need. So there's a bunch of synergism, they play off of each other. So that's what we were looking for.

BARNARD: Thank you.

NELSON: Just one final question I guess. Can you define "blending"?

CRAUN: Sure, sure. The VA design has--the spent nuclear fuel has various different kilowatt ratings of the fuel rods. And in the VA design, the 21 PWR waste package has a maximum rating of 18 point something or other KW. The average kilowatt rating is about 9-ish or 10-ish, and the low kilowatt rating is I believe around 2, 1 or 2, something like that. Blending just compresses that down so you don't have as low of low and you don't have as high of high. So we try to blend the fuel into the waste packages so that in fact we have a narrower ban on the power rating of the waste package.

And that really helps in the low-temperature area. It keeps your peak temperatures as you go down the drift, it keeps them a little lower.

NELSON: Carl Di Bella?

DI BELLA: Just to help on the definition of what a feature is, could you explain whether ventilation is a feature or an option?

CRAUN: Well, let me look at my cheat sheet here. I would call it a feature. Now, we had a continuous postclosure ventilation as an option, and that's a bow-tie configuration. But the ventilation as such is a feature, I believe. If anybody knows that I'm not telling the truth, let me know. Raise your hand.

DI BELLA: Well, in the case of ventilation it's a feature, which implies--which means by definition it could be added on.

CRAUN: That's right.

DI BELLA: But in fact if you were to ventilate the repository, you would want to have a much--continuous preclosure ventilation, you would want to have a much different design than you have right now. So I don't quite follow how it is a feature.

CRAUN: The layout of the repository itself, depending on how aggressive of ventilation--you're right, Carl--depending on how aggressive of ventilation you want to go for, might require some more shafts and ramps in order to get the air exchange necessary. So it can be added on to the basic concept for low temperature, it's an integral feature. Does it change the layout of the repository a little bit? Yes, absolutely. Absolutely. It's not as if a feature doesn't have an impact. It's like backfill, can backfill have an impact on cladding temperatures? Absolutely. But it's still an add-on feature.

NELSON: Okay. Russ McFarland?

MCFARLAND: Yes, Rick, you look at the VA design, it is fairly detailed. Now we're entering an era where we're looking at alternative designs. You established a delivery point, the end of May, I believe--

CRAUN: Yes.

MCFARLAND: --May 28th--

CRAUN: Yes.

MCFARLAND: --that you will take to management a recommendation. What level of detail do you expect to have by the end of May on a preferred option or options? Will it be anything approaching that of the VA--

CRAUN: No.

MCFARLAND: --or will it be--perhaps you can speak to that.

CRAUN: Obviously the VA had a lot of work put in it. I mean, there's been a lot of analysis work placed on the VA.

You're touching on an issue that I was going to touch--what I was going to address in this afternoon's session, and that's an issue of how the DOE will evaluate the recommendations supplied by the M&O on April 15th.

We've developed--we've formed a group called LADIG --we love acronyms also--License Application Design Integration Group. The LADIG group is similar to what we used in the VA, the VA Integration Group, VAIG. We used the VAIG group to make decisions, to focus issues, to make decisions quickly. I would suspect that the LADIG group will be used in the same way to characterize exactly what form the recommendation will take. We'll be providing quite a bit of guidance to the M&O from that group so that the activities from now until April 15th can be focused in enough to give us the information in a manner that we can use it within the DOE.

So I'm going to try to hold off just a little bit because I've got a whole presentation this afternoon on that very same issue. It's a good question.

NELSON: Okay, thank you very much, Rick.

CRAUN: Thank you.

NELSON: Let's move on and hear more about what is the Phase I of this process of consideration of design alternatives, and I'd like to introduce Richard Snell, Dick Snell, and indicate that he will at some point hand off to

Kevin Coppersmith. They are scheduled together in the next increment of the meeting. Dick Snell is the executive project director and has an expertise in operations management and project and engineering management from the nuclear industry. And Kevin Coppersmith is principal geologist and vice president at Geomatrix Consultants and has really developed the performance assessment operating unit within Geomatrix and has been extensively used by the project in performance assessment workshop and expert elicitation activities.

So turn it over to you, Dick. Morning.

SNELL: Good morning. Let me get this to a location where it picks up. Can you hear me now? Any sound out of the mike now? Okay?

UNIDENTIFIED SPEAKER: Yes.

SNELL: Okay?

UNIDENTIFIED SPEAKER: Okay, yes.

SNELL: Good. Good morning again. I'm going to talk a little bit about the design process overall, trying to give you some perspective from some of the questions here. I think because we have so many acronyms and definitions and so on things are a little bit difficult to follow sometimes.

A little bit of background first of all. There was a Repository Design Alternatives Working Group that was chartered in December of '97 and it operated until about May of '98. Rick referred to a VA Integration Group, and that group was the one that initiated some effort on alternatives selection.

The group that I'm involved with now, the so-called LADS Group, the License Application Design Selection Group, we're really looking at design alternatives for SRLA, so the acronym is a little bit misleading. That group started in June of '98, it continues to the present, and in May of this year we will have reached the conclusion of this design alternatives activity.

The chart's a little hard to read on the screen, you have it in your handout, but this is the group that I have working with me that's involved in this design selection process. And the names that you see on the right-hand side of this organization chart are people that are dedicated to license application design selection, or SR/LA design selection activities. That's their only role right now. The people on the left-hand side of the chart are people that are in the various operations areas for the M&O. There are so many things that we're doing that cross-cut the entire organization that we need a representative from each of the various operations areas. So those people on the left-hand side of the chart are representatives from all of the M&O activities that are involved in this design selection work. The actual studies, reports, calculations, analyses and so forth are done in various operations areas: waste package design, subsurface design, and so forth. There's a representative from each of those groups here on the team. The team meets weekly, we have a weekly coordination meeting, and then we have ad hoc meetings as needed in order to carry out the process.

A little background on the design selection process that we're going through, and it really is complicated and I sympathize with you and it's clear from some of the questions that it is indeed difficult to follow. But referring to that Design Alternatives Working Group again, when that group began, they started looking at 10 CFR 60 as a place to begin because there are a number of places in 10 CFR 60 where a request or a requirement is laid on to look at design alternatives, various aspects thereof. Many of those have to do with individual elements or topical elements in the designs, they're not broad based. Some are more broad based. But if you look at 10 CFR 60, we captured about 30 plus requirements of one kind or another in 10 CFR 60 that ask for alternatives evaluations. That group distilled that to kind of a combined list of about 10.

And that Design Alternative Working Group, the old group, was chartered to look at a diverse group of design alternatives. They came up with a set of five, and they are listed here: thermal loading, generally, as a category of design; ventilation treatment of the designs, another category; enhanced access to the repository was another; various waste emplacement modes was another; and waste specific containment or arrangement. And what that refers to is the motivation or the approach of taking various types of waste, defense high-level, for example, commercial high-level, and putting them in places in the mountain that are best suited to those waste forms. Notionally, one might put defense high-level waste in one section of the repository, commercial high-level in another if you can characterize the mountain sufficiently and if there are natural conditions that make that a good choice.

The team that we now have, the LADS Team, started with that information. That list of ten issues was expanded, and this is particularly important because the long list of alternatives and features that we seen now stems from comments, critiques, questions and so forth that we've received over a period of time. We started with those ten items and this Board and the Board Staff have made a number of comments and questions about what we were doing over the past several months. The NRC has a list of ten key technical issues which are of great interest to them. The TRC has undergone, as you all know, a series of peer reviews, and out of those peer reviews have come a set of questions and we have attempted to capture those. Nye County has had some input with regard to the use of ventilation approaches and techniques. The DOE, of course, in reviewing our work has asked a number of questions and identified some concerns that they have. And we have a Repository Consulting Board that was chartered initially by DOE, now by the M&O, and that Board comes in and reviews what we're doing on designs periodically. For a while it was about ever three months, more recently it's been on about a six-month time frame. But that began as a tunneling consulting board and gradually was converted to a design board, and it consists of a group of people with substantial experience in underground design and nuclear facilities design.

We have taken the comments that all of those groups have generated, particularly those that were published in the various reports, in your reports, for example, and we have a matrix that lists the basic concern, identifies it. We've given it a number and we track those against the various design alternatives and design features which we're now considering. But the goal is not to miss anything. We don't want to have people make comments of a significant nature and somehow not address them.

The set of five alternatives that the Design Alternatives Working Group identified was expanded. We came up with, when we began this LADS work, a total of eight fundamental alternative designs, and that included the VA design, the VA design with options, a version of a design which deals in particular with surface facilities, modular design, modular construction of the facility, and five other design concepts, which include thermal considerations and so forth. I won't read them here, but at the back of your handout in this presentation there's a list of the alternatives and a list of all the design features. It's the last page in the handout.

The Conceptual Design Process they were using involved the preparation of a report. This is an internal report in M&O, but it's a documentation of each design alternative. There's an evaluation of each, a so-called 3-5, that's a quality assurance designation for the report, a 3-5 Report for each alternative, and a report for each design feature so that we have a documented record of what was done in terms of evaluation and we have referenceable material for all of what we're doing.

Those reports were the basis for what went into that workshop that we just held that went from January 4th through January 15th. The people that participated in the workshop used data from those reports to generate material and conduct the workshop.

That workshop--and you'll hear more about this from Kevin--but that workshop concluded what we referred to as Phase One of what we're calling a two-phase process. And

Phase One involved, again, looking at the types of alternative designs that could be used, types of design features that could be applied to those. And as Rick said, the alternative designs--down at the bottom there--is the next step, but the alternative designs are a fundamental repository layout. A design feature is an element that could be applied to one or more of those designs.

Now, along with the question that was--or the comment that was made earlier, we've used vehicles for analogies, it's not quite as simple as saying, "Well, I want to put a luggage rack on my van." It could be that simple when you apply a feature to a design, but it might be more complex. It might be, "I want a four-door instead of a two-door sedan," and to do that you have to build the car a little bit differently. The same thing is true on the design alternatives. Some of the features are comprehensive and they require a little more elaborate incorporation into a design.

In any event, the goal of that Phase One activity was to select a set of these enhanced design alternatives, and that's a basic design along with a set of selected features.

Phase Two, then, is to take what came out of that--there were eight of them I think we've mentioned already came out of the workshop, reduce those further to a little bit more manageable set, probably four or five, we're not sure exactly. From that reduced set we think we can select a very few designs that look good for performance for license ability, operability and cost. Now, we don't think that one design--it might be serendipity, but we don't think that one design is going to have the best of all of those considerations. We're probably going to find that one design may be best for performance and not necessarily the best on cost and so forth. Nonetheless, we will look for designs that have those characteristics and we will try and produce as good a design in each of the alternatives that we have or each of the EDA's that we have with regard to those criteria. From that very small set, then, we expect to be able to make a recommendation in May of '99, just a few months off.

Some comments on the design process we're going through, some perspectives, if you will. This is--we're baking a cake here, this is design work in progress. That's what you're looking at right now and that's what you're hearing about. We're using what I refer to as the "building block" concept. It's kind of like having a bunch of Legos on the table and some of the Legos are partially assembled into what we're calling design alternatives. Some of the Legos are individual pieces, they're just laying there. And what we're doing, we're taking those DA's, the partially assembled sets, and combining them with the individual parts and building designs.

We're at a conceptual or a very early preliminary stage with this work. The VA, of course, was a much more advanced piece of work, a good deal more effort had gone into the Viability Assessment design. Some of the features and some of the other alternatives we're looking at are not as well developed. So what we really have here is a set of information that's in a very early stage, and one of the challenges that we have is to make sure that we use the information appropriately, and that's what these last three points are directed towards.

We want to use comparable levels of detail when we make these evaluations. You get some--or can get some strange results if you have one item with lots and lots of information and another which is very, very, very conceptual. It's difficult to make comparisons adequately. So we want to use a consistent level of detail when we make the evaluations, we don't want to give undue emphasis on those that are fully developed, and we don't want to fall victim to the grass is always greener, something you don't know very well looks really good until you investigate it further. We have to avoid that as well. It's a balancing act, if you will, on design.

You're going to hear some subsequent presentations now. Application of Defense-in-Depth is one of the important elements as we go forward on these designs. Dennis Richardson will talk about those. You're going to hear about the Performance Assessment work that we're doing to evaluate these designs. Rob Howard will tell you about that.

You're going to get presentations later in the day on the various design concepts, that is for low temperature, high temperature and enhanced access design. And as Rick mentioned briefly, enhanced access may not be an exclusive design concept, that is access to the repository can be achieved in any of those areas. A low-temperature design does not preclude access, neither does a high-temperature design. There are ways and means of doing it. So enhanced access is a consideration for all the designs.

Also, with the design features, as you will see, certain of the features are used in all three of these conceptual approaches--ventilation, backfill, drip shields and so forth. They have multiple applications and they are tailored to suit individual design approaches.

This is the list I was talking about. I won't try and read them, but it's in your handout, and again, on the left a full list of the design features that we have currently under consideration available for use, if you will, in building designs, and on the right a set of the basic alternatives that we're currently looking at.

Now you'll have to tell me what I've done with the presentation material. Oh, all right. We're okay, the next one is up, I guess, right?

NELSON: If anyone has any very burning questions right now, specifically for Dick, otherwise we'll hold questions for the discussion after Kevin. Any burning questions?

Let me ask just one thing, Dick. Concerning blending and blending through time, when you talk about blending for the most part, it was always in the context of blending at the point of waste package emplacement to obtain uniform temperatures. But during time you'd expect a lack of uniform temperatures to develop because of the contents of the different waste packages. So blending refers specifically to the time of emplacement, trying to even out the peak temperatures, and does not refer to blending for some time in the future of waste package temperatures.

SNELL: You're correct. Blending is an attempt to take fuel assemblies of varying ages and varying burn-ups and combine them within a single waste package in order to achieve a uniform heat output, a relatively uniform heat output, and radionuclide source term so that--it's important to the design concept because you will hear later that when you look at low-temperature designs, for example, it may be highly desirable to have a relatively smaller waste package or a waste package with relatively lower outputs in order to implement that particular design concept.

The facility would always have some sort of receiving storage, that's a normal operational requirement for the facility. So there's an opportunity when wastes come in from the various utilities, for example, or from the defense program, to have some sort of holding capacity, receiving storage, and then be able to select from that holding capacity the various pieces that you want in order to produce a waste package that has 18 kilowatts or 10 kilowatts or 5 kilowatts as a nominal output.

NELSON: Question from Dan.

BULLEN: Bullen, Board. Just a quick question, Dick. You made a comment that one design may not be the best with respect to all criteria. And so that begs the question about the criteria development and the weighting that's used on those criteria. Could you comment a little bit about the ongoing development of criteria and how you expect to have a process to develop the weighting factors that would be used for those criteria?

SNELL: I'll give you a very brief comment on it. Kevin will talk a little bit more about criteria, and Rick will talk more about it again this afternoon. As I say, it might be serendipity, we might be fortunate and find that one design is head and shoulders above the rest, one concept, across the board, and that would be simple. But what we're trying to do is first of all we're trying to take the designs in the various topical areas, low temperature, high temperature and so forth, make them as attractive or as efficient or effective as we can make them individually, that's the starting point, and then we'll rate them. And I think the first look will be on an even up basis, that is no relative weighting factors one greater than the other, we'll simply look to see is there one design that looks best for operability, cost, performance and so on, and see how they stack up. What sometimes happens is you get one design that's not the best in every category but it may be near the best in every category, and that's generally something that produces a pretty good result, too. It may be number one, if you will, in a couple of categories and rank second or third in a couple of others. When you add them up, it still looks like a pretty good design.

I don't want to get too far ahead because Rick's going to talk about the--

BULLEN: That's fine. I'd be happy to wait.

SNELL: --final recommendation process later.

NELSON: Fast one from Alberto.

SAGUES: Yes, Sagues.

SNELL: Yes?

SAGUES: I'm a little bit confused as to the last transparency that you showed, the overview of design selection process. Now, is that where you started with or that's where you are now?

SNELL: That's what we started with. Essentially that's the sackful of parts or goodies or the tools, if you will, or the elements that we have to work from.

SAGUES: But now you are beyond this?

SNELL: We're beyond that point now, yes. Those are still available to us, but as you will hear later, we have found that certain of the features, for example, appear to have merit, much more merit, for the designs that we're now considering. Some of the features really don't look like they're all that attractive and they'll be put aside.

NELSON: Okay?

SNELL: Okay.

NELSON: We'll continue with Kevin. Thank you, Dick.

SNELL: Thank you.

COPPERSMITH: Thank you. It's truly a pleasure to be here, not only because I get a chance to talk but because I get a chance to attend a meeting that I don't have to facilitate. I think the other times I've spoken to this group has been largely to report on expert elicitations and the numbers of workshops and so on that we've had, the results of those. I think this ten-day workshop took the cake. It was not only the longest but one of the most intensive sessions that we've had yet. I think some of the decisions made that we'll hear about were very fruitful in the course of that, and we're not done yet, we're still underway.

I'm going to talk about the process that's being followed. My role on this project is one of officially decision analysis consultant support I think I'm listed. There's a decision team that includes Tom Cotton, Steve Hora, Allin Cornell that assist with this decision process. Mainly what I want to get across is the procedure that's being followed, the overall process in Phase One, I will then have a discussion of some of the conclusions and things that have come out of that analysis, and then Phase Two, where we go from here, and we'll talk about that at close.

The so-called two-phase process is shown here. In each case we're dealing with the development of alternatives for evaluation--this is in the large sense--evaluation criteria to evaluate those alternatives, and the development or the evaluation step. So across the top are the three steps that occur in Phase One, across the next line is Phase Two. And we can see that the process that we've followed, this occurs--I don't know if there's a pointer up here somewhere--but this process is basically a two-week workshop, and at the end of that we have developed a new set of alternatives.

Thanks, Jim.

So this is Phase One we'll be spending our time on today as well as the development of the enhanced design alternatives, and we'll talk about what will happen in Phase Two.

I want to show--this is the list of design alternatives and design features. We have two lists in here. They should be identical. One of the things you'll notice first of all, there are some numbers that are missing, like Design Alternative Number 7; what happened to that? Well, I guess during the period of development of this Repository Alternative Working Group a set was developed and then it turned out that some of those were combined, so some of these numbers don't appear. That doesn't mean they're missing, it's just due to the fact that they were combined into other alternatives.

The distinction--we all draw analogies to explain this design alternative/design feature. The design alternative is a basic alternative design concept. We picture that as vehicles, as an RV, a Jeep or a sedan. And the design features are options on that, tinted glass, luggage racks, roll bars and so on. That's fine in general, it may help think about it, but specifically don't worry about the distinction. Ultimately, when we develop the enhanced design alternatives and evaluate those, this distinction will not make any difference. So if we find that in fact there are two alternatives that look like they would do well together to accomplish a goal, for example to have a low-temperature design, they can be combined. So this designation simply helps in the process of laying out the Lego blocks that will be used to develop and build up a design. So it helped organize things, it certainly helped in the evaluation in Phase One, but the distinction in terms of whether or not they were categorized one way or another doesn't make any difference to the overall project.

The other thing is that there is opportunity, continues to be opportunity, for the injection of new ideas. For those who attended the workshop saw that in fact there were some ideas that were brought forward and put on the table at that time for evaluation or consideration in developing the EDA. So that process can happen all along, too. So if we've missed something along the way that isn't listed as a DA or a DF in this process, there's always the opportunity to consider it ultimately in the development of these designs.

So the distinction isn't so important. But I think one of the messages in looking at the lists of alternatives and features that in fact there's a large number of possible concepts that have been incorporated or at least considered throughout the Phase One process. Every one of these was subject to an evaluation. There was a lead design engineer associated with each of those. There were reports developed against a set of evaluation criteria that I'll discuss here.

Let me talk about the evaluation criteria that we used to evaluate the design alternatives and design features in Phase One. These are listed here in a brief form. First is postclosure performance. Rob Howard will talk about the analyses that were done here. Remember that the context for all of these Phase One evaluations was such that design alternatives were considered in their stripped down version, if you will, the same way you'd say, well, that defines-- these are the basic characteristics that separate a sport utility vehicle from an RV. So they were in a stripped down version, they weren't necessarily enhanced with features that might help their performance, give them more Defense-in-Depth, more licenseability, etc.

And secondly, the features themselves were done in a one-off sense. In other words, they were associated with the VA reference design. So if we were dealing, as Rick talked about, with ceramic coating, we would assume that that ceramic coating was put on the VA reference waste package. And likewise with other aspects related to let's say repository drift or other things, we would assume that the waste package for the VA reference design was the waste package. So everything else was held constant, vis-a-vis the VA reference design, and one thing was changed in these evaluations. And that can be limiting, of course, in doing the performance assessment. Perhaps we would do better if we were able to get to pull three features together and evaluate them. But that will be done in the second phase in looking at enhanced design alternatives.

So postclosure performance is a key measure, and Rob Howard will talk about that.

Preclosure performance deals with the issues primarily around the so-called design basis events. We're evaluating these features and alternatives relative to their ease with which they are able to address design basis events. These events are events related primarily to worker safety issues, the number of lifts and carries and possibility of accidents that might occur during the preclosure period.

Another evaluation criteria in Phase 1 is so-called assurance of safety. This is a--again, it's a qualitative, a judgment-type of measure. Some of these that you'll see here are either quantitative, they're on a so-called natural scale, many of the others were on a constructed scale, a 1 through 5-type evaluation where you either have a high level of assurance of safety or a low level. These evaluations are combinations of both quantitative and qualitative type assessments.

In looking at assurance of safety, we are looking for whether or not these features support the attributes of the repository safety strategy. Remember the four attributes that keep water off the waste that extend the waste package lifetime that retard release of radionuclides or they dilute, essentially, the concentrations away from the repository.

We also are looking at the significance of uncertainty in postclosure performance and our ability to reduce uncertainties in the time frame of the LA. The assessments of postclosure performance are essentially central estimates of performance. We need to also consider the uncertainties, the uncertainties in how long-term performance will actually occur, how uncertain are we about the performance of this feature and what changes it will make that will either enhance the performance or hurt the performance. All of that has uncertainty, some of which is captured in the PA analysis, some of which isn't. And this criterion is an opportunity to consider some of those uncertainties.

A fourth criterion is engineering acceptance. And there's a number of facets to this evaluation. In general, this would be this design, how would it be accepted in the engineering community relative to a number of features? How easy is it to communicate the functions of each of the elements? Do you follow accepted methods? Can you demonstrate the postclosure function? Is there precedence, regulatory engineering precedent, for this type of design? These are the types of considerations that went into the evaluation of engineering acceptance.

The next criterion is construction, operations and maintenance. This is looking primarily at some of the issues you see here, reliability, availability, maintainability, is it easier with the design or harder to perform performance confirmation activities, and so on.

Schedule is the next assessment. We're looking at, in this case, the time associated with each of these phases, site characterization, design, licensing and construction. Looking at those in the sense of how do they compare to the VA reference design in terms of the years required to carry out each one of these particular phase. And you see, for example, if they have a design that incorporates a much larger piece of real estate than the present VA reference design, there might be more time involved in the site characterization phase than for the VA reference design. And likewise other aspects. If it looks like a very difficult design to license, there may be more years involved in the licensing phase to carry it out.

Cost in this Phase 1 assessment was in terms of the total cost for the repository system. And again, these are fairly high-level design concepts, these are ballpark types of estimates, you know, rounded off to plus or minus 50 percent, so they are just for the purposes of making overall comparisons of each of the features and alternatives.

And finally, environmental considerations. This was not used as a discriminator among the designs but the environmental considerations for each of the features was evaluated by the EIS contractor.

Let me talk also that besides the basic evaluations against all these criteria, we also looked at confidence, the confidence with which each of the lead design engineers was making these assessments. These are evaluations that are designed to get at the issues of uncertainty. These obviously are professional judgments, these are engineering judgments and not quantitative measures of confidence. These aren't confidence intervals, for example, these are evaluations of the confidence that that engineer has when he's saying that "This is my cost estimate," or "This is my measure of engineering acceptance." This is an opportunity to look at how supportable the designs are, how defensible they would be, what's the level of uncertainty that we have.

These were elicited from each of the lead design engineers based on the information they have available and so on. Again, this is an opportunity to incorporate some of the aspects and availability of information that exists for the different designs at this time.

And it is an opportunity to look at not only the interplay of the engineered system--we are dealing with engineered components in most cases--but also the uncertainties associated with the natural system. As a geologist, I want to be sure that of course the uncertainties in the natural system are part of the process of developing an engineered system. Much of what we do in the engineered system is to mitigate against uncertainties in the natural system. So if we're using these engineered components to do that, we need to understand uncertainties in the way the natural system works.

Let me talk just a minute here about the EDA Development and Enhanced Design Alternative Development Methodology. They're design concepts that have been enhanced with various design features. So we're now looking at the possibility of having multiple features to support and enhance the performance of a particular design.

We're dealing with a process that's more of a build-up of the EDA's that have a high probability for success in Phase 2 rather than taking all of the possible combinations of features and screening and eliminating, eliminating, eliminating. The process is more one of build-up. Early on in the process someone did a calculation, I'm sure it was one of the members of the decision team, of the possible combinations when you have 25 design features, 8 design alternatives, and you put them together and you get jillions squared numbers of possible combinations. That isn't the process that we're following of developing those all and screening down. We're instead building up designs against a set of criteria that look like they have the highest potential for success in the subsequent evaluation.

As Rick mentioned, we are looking for five to ten EDA's for the Phase 2 evaluation. We're also looking for a set of diverse designs. We don't want a set of EDA's that in fact all are clustered towards one particular type of design, they're all high-temperature designs with some minor perturbations. In fact, we want a diverse set so we have an opportunity to see how a range of design types would actually operate.

We're taking advantage of the evaluations, all the evaluations that were done in the first phase, but we're also in this process, and in the process of the workshop, number one, taking advantage of the experience and judgment of the engineers that they have from previous work that really comes into play in this. I think it's important to remember that aspect. These are design concepts, and much of what is developed in the EDA's you'll hear about today comes from the judgment that these things will work in this combination. And that engineering insight is very important in the development process.

I think that's the nature of this last bullet. We couldn't and don't intend to layout a handbook that says, "This is the way you develop and enhance design alternatives, this is the way you develop a repository design. In fact, we have a set of criteria for evaluating it, but we allow a creative process to work to allow the engineers to put together the pieces and develop the design concept.

I want to talk a little bit about the workshop. As was mentioned earlier, we spent--and I'll show a little bit more on the schedule--we spent the early part of the workshop reviewing all the Phase 1 analyses that have been done against all the features and all the alternatives. And then we broke into breakout teams and these teams went through a process of evaluation, and they were centered around three basic design concepts: low-temperature designs, enhanced access designs--these are designs that would allow human access into the repository--and high-temperature designs. And members of those teams were representatives from the larger LADS team, the organization chart that Dick Snell showed, so we had all of the core team members who are dedicated to this project plus members from the operations areas as part of the breakout teams.

And one of the advantages, for those that have organized workshops, of a breakout team is that in fact you can get a lot of work done. This was a working workshop. I think someone--I think Dick referred to the process as we're making bread, and that's kind. I think early on I said we're making sausage. And the process is one of really--of work, rolling your sleeves up and saying, "Okay, what do we have, what's the information we've got in front of us, what are our goals that we're trying to achieve for this type of design and going forward and developing a design concept?"

For the more creative members of the breakout team this was a wonderful process. For those who were worried about meeting schedule and a certain number of EDA's, like myself, when we saw that we had 23 at the end of the first breakout, we were a little bit nervous. By the end of it we ended up with 8. But the process was definitely one of allowing some creativity to come in and allow people to begin to put things together for the first time on a project.

The leads for the--the lead design engineers who had done the work related to the design alternatives and design features served as resources to all of the teams throughout the project.

I won't go through all of the details of the workshop. Just wanted to point out some of the basic steps. Again, my concern here is process and I want to be sure that people understand the process followed.

The first three days entail the presentations that were done for all the features and all the alternatives against all the Phase 1 evaluation criteria. So this was an opportunity to hear that discussion, but it also was an opportunity for the LADS core team--and I should point that out, the decision-maker in this process is the LADS core team--so it was an opportunity for them to ask questions and to probe those engineers about the analyses and evaluations that they had done, what uncertainties they had and so on. So it was a good opportunity to do that.

We then had a series of three breakouts by the teams, the first tier. We'd then come back into general session again, second, and then back into general session. We looked at--met with the representatives from Performance Assessment, Defense-in-Depth and cost people to get some ideas about those aspects of these designs. And then met finally, again, in a general session that lasted for two days. And that general session was designed to get down to a set of enhanced design alternatives that would be carried forward from that point.

What happened, I have this slide up here as sort of a lead-in to the discussions you'll hear of the results of the workshop. We'll have three representatives from the core team talk about the results of the enhanced design alternatives that came out for high temperature, low temperature and enhanced access.

We'll have a description of the basic design concepts, and then focus on the elements of these designs that are integral. As Rick said, it became very useful in the course of this evaluation to really separate things into whether or not a particular component was integral to that design--this is what makes the design work--versus those things that were more independent could be applied to other designs. For example, many of the features that might enhance Defense-in-Depth, like putting in a drip shield, or doing other types of things that would keep water off the waste package might be applicable to a variety of designs, and we want to keep those in an independent type of basket that we can use them as needed to help enhance designs. But there are other components that are integral to making that design work. So we'll have that distinction in the discussions that we have later this morning and this afternoon. As I mentioned, this is--we try to identify those features that could be applied to other designs.

We also identified the features that were not selected. Naturally, when you have a table full of Legos and you build some things and you're then going to move on, some things are left on the table, and some of these features were not selected in this process, and of course that needs to be documented why they were not selected. Some of the times it had to do with cost or licenseability or just whether or not it would in fact fulfill the function given the uncertainties that exist at the present time.

Okay, I think that's the end of my discussion, and I'll be back to talk about Phase 2 later on.

NELSON: Great. Thank you, Kevin. And let's begin discussion to include both Dick and Kevin as makes sense.

Let me just ask you one what I think might be a broad question overall. In the wish to have balanced consideration of the EDA's as you move forward on this compressed schedule that you've got, you talked about and Rick talked about moving things up to a high level of consideration for evenness so that you don't have an overwhelming quantity of detail in a certain area for a certain option and less so in others and make it difficult to balance the consideration. But during this next period it has to come down to a lower level of consideration in order to really evaluate the EDA's that are still on the table. And this implies potentially resource allocation impacts in terms of trying to develop those additional details and assess the certainties or uncertainties and develop PA models, things like this, where it is people and time and funding resource allocation, both in the next three months and up to LA considerations. Is that being considered at all, that process, in the three-month period, the resource allocation consideration? How is that being taken into account?

SNELL: First of all, the first priority or the principal activity for the M&O engineering organizations is this alternative's effort at the present time, and it will be through the month of May. So we do have access to all the resources that the various operations areas can provide, the various design areas, PA, so forth. They're not being diverted by other engineering tasks, so that's helpful.

In terms of the information that we have available to us, for the purposes of evaluation and decision-making, we will drive the designs down to as low a level of detail as we can. In other words, we'll get as much insight as we can in each of the technical areas. I said we'd keep it at a high level. That's a relative term. A good deal of analysis has been done in several forms. I mean, work was done on the VA, for example. A lot of the analytical work that was done for the VA and analytical work that's been done for various studies is applicable to more than one design.

Take thermal analysis for example. We have a number of models that have been developed, 2D and 3D models that will depict temperature variations in the emplacement drifts with various waste package loadings and so forth. So we can use that sort of engineering information across the board. It provides insights for us on a number of the alternatives and features that we have under consideration.

We clearly have a challenge in completing this by May, and we clearly have to provide sufficient detail in order to make the results--to satisfy ourselves, first of all, that we have acceptable results and then to be able to satisfy those who would review and critique our work that we've got sufficient information to support the decisions.

So I don't know that there's any absolute answer except to say that based on what's been done so far, I think between the work that's already been accomplished and the fact that we have the M&O resources dedicated to this process over the next two or three months, I believe that we can get to a level of detail that's sufficient to support a decision and also provide adequate technical backup for the decision.

NELSON: Okay, let me just follow up a little bit on the criterion for licensability which we heard discussed. That has to do with regulatory process but also the information that can be assembled to the time of LA, and that includes resource allocation and work to be done. So both of those are included in the concept of licensability as a criterion?

SNELL: Well, licensability--they're both involved, yes. Licensability as we're using the term here has to do with based on what we understand of what will be the licensing requirements today, will these alternatives satisfy the licensing requirements. And also, by the time of license application submittal or site recommendation license application, will we be able to provide a set of technical information that provides a supportable application. In other words, have we got enough detail to deal with the uncertainties to address the questions we come up with regarding the various designs, is there enough analytical work to demonstrate that the design will be safe, will satisfy the rules.

And from my perspective it isn't just a case of satisfying the licensing rules, it is a case of satisfying ourselves that when we make a recommendation for a design we are convinced, we have convinced ourselves first, that that design or that design with some features that would carry them along really is workable, sufficient, adequate, the best that we can come up with. If we have done that and we have addressed the licensing requirements, why I believe we can get there.

To do this, to make the recommendation by May and to support a site recommendation with the dates that we now have, again, is a challenge, but I believe we have resources sufficient to do that right now.

NELSON: Dick?

PARIZEK: Yes, Parizek, Board. Dick Snell, you said the Board of Consultants were first pulled together for tunneling advice and now their job has been expanded to deal with license with design assistance.

SNELL: Yes.

PARIZEK: Did the membership of the board change to reflect the different responsibilities or it's the same old guys giving the same old advice?

SNELL: It did change. I did not comment on that. When the board was originally set up, I think we had I believe there were five consultants. They're all world-class underground construction and tunneling consultants. The constituency of the board changed somewhat when it was moved into a repository consulting role and then we added waste package, and finally the board actually was changed into two --it had two sub boards. One was waste package design and the other sub board was repository design. We added several new members, particularly with regard to waste package design. We retained the same chairman, Bart Bartholomew, but we did materially change the makeup of the board, yes.

PARIZEK: Now the meeting schedule, say, has drifted off to about every six months. At the pace that this process is going, is that helpful or do they need to be involved in a more active way than once--you know, twice a year?

SNELL: We have the option of making it more often. The next meeting of that board is in February. The last meeting I think--I've forgotten exactly, but it was summer. We were meeting about quarterly for quite a period of time, and I think a combination of changing the approach on the project a bit and the press and a number of other activities has caused us to stretch out those meetings a little bit. But we have the option of scheduling it more frequently if we choose.

PARIZEK: All right. Then there was a question about transparency which Rich Craun brought up. Obviously the importance of understanding the process that you're following and when you drop out some of the features, there's some justification why you drop it out, and that's going to be very clearly expressed. But it's still not clear to me that when you include a feature that you really know how it affects performance of the repository. So do I understand that as you go through this process you will run a VA kind of analysis or performance assessment analysis to say these attributes result in this sort of performance and you have that as part of the transparency record? Or is it expert judgment. I'm an expert engineer, my professional judgment says, hey, we always line tunnels. And I say but do you line hot tunnels for a thousand years? And if you do, you know, will they perform under your experience level in the way you think? Because it's a whole new problem that we face in engineering.

COPPERSMITH: I would say yes to both. As you'll see when I talk about Phase 2, the evaluation criteria that are being used include postclosure performance, which obviously will involve calculations of that performance.

PARIZEK: Between now and May. That's I think the thing--

COPPERSMITH: Right. But also many of the aspects are engineering judgments in terms of--

PARIZEK: Yes, has to be.

PARIZEK: --what precedent exists for this and how licensing it would be. Just basically how does it work. On some of these issues related to construction operations and maintenance, many of these issues of operability are engineer judgments. I've seen this type of system before, it's worked well or it may not because there's going to be a number of processes that go on. Many of those are more on the engineering judgments. So it's a range from the more quantitative measures to judgment-type measures.

PARIZEK: Yes, so that's what's going to be part of the credibility or transparency--

COPPERSMITH: Right.

PARIZEK: --at the end since, you know, professionals agree.

COPPERSMITH: Right.

PARIZEK: But it's nice to have the backup of calculations and--

COPPERSMITH: Right.

PARIZEK: --through the performance assessment approach. Thank you.

NELSON: Don.

RUNNELLS: Runnells, Board. I'm new on the Board so I have a couple of questions about structure, I don't have a clear picture. For example, how was the May date set? Was that backed out of some other deadline that you face? It seems--you mentioned it's a challenging date, I will certainly endorse that. That's a very kind word for that particular date. It's a tough date, and I'm curious how it was set.

SNELL: The May date was selected I think in conjunction with an overall schedule review for the project that was conducted about--well, several months ago, about eight months ago or maybe a bit longer. And in selecting the May date, consideration was given to the dates associated with license application submittal, site recommendation, production of the Viability Assessment report, and so forth. And the date I think is a result of trying to come up with a logical sequence of these various activities and suitable integration.

RUNNELLS: Backing toward us from some future deadlines, future dates. Along that same line, and maybe it's a very easy answer here, how many people, how many engineers are involved in this? An easy answer would be, how many people attended the workshop, perhaps.

COPPERSMITH: Well, there may be a difference, because we had a number of observers at the workshop. I think any given day in the general session we were somewhere between 50 and 70 people at the workshop. That included a lot of observers. I don't know if you have an estimate on total involved in the project.

SNELL: I'll quote some numbers, you know, approximate numbers. I'm not sure they're exactly right, but I think the subsurface design group has on the order of 60 or 70 or 80 people, something like that; surface design a smaller number, 40 or so; waste package design probably I think about 50 or so people; performance assessment a larger number in total, but those especially focused on this activity Rob probably has a better number, but I'll--

HOWARD: It's about 30 to 40 depending on which EDA we're looking at.

SNELL: Right. Licensing has a smaller group. Dennis can address that, but what, three or four or five people, perhaps?

RICHARDSON: Probably that's about right right now, and that will obviously increase as we get closer and closer to making this decision and doing the licensing evaluation.

SNELL: Okay. And there's a cost group, a number of estimators and so forth involved. I think probably eight or ten in the area of estimating, something like that. That will give you a rough idea.

RUNNELLS: Yes. That's very hopeful. Thank you.

One last question, Priscilla, and a little more substantive, perhaps. In talking about the process of the workshop, the design selection process, you talked about engineering and engineers, and yet, Kevin, when you gave some introductory remarks, you talked about uncertainty, much of which is geologic and hydrologic.

COPPERSMITH: Right.

RUNNELLS: In the selection process, let's talk about the workshop, how did the actual uncertainties that are geologic and hydrologic and geochemical feed into a group that apparently was largely engineering design people?

SNELL: If I may--

RUNNELLS: Could you comment on that?

SNELL: --interject, I gave our scientific community short shrift, and I'll apologize. The natural environment group has a substantial number of people involved on this activity as well, and they especially go to the area that you just mentioned. And I'm reluctant to mention an exact number of people, I honestly don't know the exact count. If we've got--Jean, would you have a feel for--

UNIDENTIFIED SPEAKER: I'd say 10 to 20, Dick.

SNELL: At least 10 to 20 people out of the scientific community directly involved in this activity, a substantially larger number involved in generating information that we're using in this evaluation.

RUNNELLS: I'm a little bit familiar with that larger group that is generating the information. How did all of that feed into the two weeks of the workshop that were largely engineering-oriented?

COPPERSMITH: Well, the context, of course, of any design is the environment that you're putting it in and the degree to which you change that environment. So as you'll see when we talk about some of the enhanced design alternatives, for example the low-temperature designs, when Carl Hastings talks about those, one of the first things he'll talk about is what is the goal of this type of design. And for example, on low temperature, one of the goals was to increase the predictability of the performance of the repository. And that predictability plays directly into the issue of coupled thermal hydrologic processes. Predictability and second key goal of that type of design is to place the waste package in a more benign environment, and more benign relative particularly to temperature conditions. So in most cases, the actual goal of the repository designs that you'll hear are to deal with the environment, usually a thermal hydrologic environment.

We have an opportunity also, as you see in the Phase 2 criteria, to really look at the uncertainties. Many of those uncertainties--I've spent the last couple of years on this project helping to quantify uncertainties and inputs to the TSPA and waste package degradation models, thermal hydrologic coupled processes, percolation flux issues--those uncertainties are key, as you know, to the performance assessment calculations. The degree to which we're able to develop process models that help incorporate and quantify those uncertainties are in good shape. But much of what we know about the natural environment is not presently quantified, or not quantified well, in our analyses. But that doesn't mean we can't consider them and shouldn't consider them in this evaluation.

So some of the criteria you'll see that deal with the uncertainty and our ability to mitigate the uncertainties are directly a function of what we--uncertainties and things like seepage into the drifts, where will it occur, how frequently will it occur, basically that is part of all of these design concepts. They're basically looking at the potential for dealing with the ambient conditions, thermal hydrologic conditions, and changes that any one of these designs would make in terms of changes in the thermal properties, the amount of moisture on the waste package, the seepage into the drifts, and so on.

RUNNELLS: Thank you.

NELSON: Bullen.

BULLEN: Bullen, Board. I saw in the evaluation that Kevin gave, the evaluation criteria for Phase 1, and they were the eight bullets that were delineated, but Rick mentioned early on that there was an option for flexibility. And I was just wondering where flexibility in the design or the enhanced design alternatives comes into play with respect to the evaluation criteria. How do you incorporate flexibility?

COPPERSMITH: They're in--they're prominently displayed in Phase 2.

BULLEN: Okay.

COPPERSMITH: And I'll talk about those. We have a flexibility criterion that takes into account the potential for programmatic changes, which of course never happen on this program, and many of those new unanticipated natural findings, natural features and finds and so on. But I'll spend as much time as you want on that. But they are part of the Phase 2 criterion.

BULLEN: I'll defer to that, then, that's fine.

COPPERSMITH: Okay.

NELSON: Alberto?

SAGUES: Yes, suppose that May arrives and a design is indeed identified and selected and in August there is some new finding that comes out from basic science that would affect the design, what happens in that case?

COPPERSMITH: I can think of a couple things, and Dick may be able to respond differently. But my--number one, there is, as we just mentioned, we are looking for designs that are flexible, that would allow for so-called unanticipated types of findings as well as just basic changes in our design concept.

Secondly, I think it's important to remember that even when this is done in May we're still dealing with a conceptual design that has not been detailed. Many of the features that will define it will occur during that period from the end of this process, the subsequent period of time to LA or SR. There is an opportunity during that, obviously, to in fact detail it and incorporate, you know, these types of new findings. But we have to remember that this is still conceptual design that we finish with in May, and even though there will obviously be a push to give sufficient detail such that a decision can be made, it is still conceptual design.

SNELL: I would just add that a lot would depend, of course, on what sort of a change or a surprise we got, if you will. But we would have to evaluate the nature of the change against the design when it occurred, and I guess the message I would like to convey is that we are not in a situation where a substantial change of some sort would be only partially addressed in order to maintain schedule. I don't want to hang crepe over anything, but you know, it's absolutely necessary to come up with a design which has the necessary attributes, it's sufficiently robust and so forth. And if we got a change that was really substantial and raised questions about the design, with sufficient flexibility, we could respond better, if you will. But if we had to do some new investigations or some new tests or something as a result of the information that became available, I think we are obligated to say that's what you need to do in order to have the right assurance that you're doing the right thing. You can let yourself be schedule driven to an unreasonable degree. You've got to maintain a substantial design.

NELSON: Let me ask a question about in creating the EDA's for Phase 2 and beyond, whatever moves on, how long--constraints, former constraints, such as cover or stand-off from zeolites or generally the location, elevation, configuration of the repository, how much are those opened up in the consideration for really developing alternatives in the mountain for different high-temperature or low-temperature concepts?

SNELL: I'll make a brief comment. Kevin, you may want to add. But I think the thing that we're trying to convey to all the people that are working on the alternatives is don't be unnecessarily constrained. I mean, there are a number of constraints or goals that have been identified, like minimum cover and so forth. Some of them are what I would characterize as somewhat arbitrary in nature, others have their basis in law or regulation. So what we're asking everyone to do first of all is simply recognize when a design concept runs up against a constraint or some kind of a limitation and not to avoid developing that alternative simply because there's a constraint or a limitation there. We're saying go ahead, if you've got an alternative that looks really attractive, you think it would be especially effective or efficient or best from a performance standpoint, and there is a constraint that applies that would affect that, let's see what that alternative looks like and tell us what the constraint is and then let's see whether or not we want to see about possibly changing the constraint. But we're asking them not to rule out viable alternatives simply because there's some sort of a limitation there which may be arbitrary.

NELSON: Any questions from staff? Carl Di Bella?

DI BELLA: Please, Kevin, help me just a little bit in clarification of when Phase 1 ends, or ended, and when Phase 2 starts, and I particularly am interested in when Phase 1 criteria were applied and when Phase 2 criteria were applied. Your first slide indicates Phase 1 was over before the workshop began, and therefore implies that the Phase 2 criteria were used for the selection process in the workshop. And thus this afternoon when we hear of the criteria and the alternatives that were retained and the alternatives that were rejected, it will be against the Phase 2 criteria that that was done; is that not--

COPPERSMITH: No.

DI BELLA: No. Okay.

COPPERSMITH: Basically, the dividing line is arbitrary. It was midnight on--and if you didn't get your tax returns in, you're late. No, from my point of view, it's a continuum, obviously. But let's say that it ended at the end of the day of the last day of the workshop. Okay, on the 14th of January we had in our hands eight EDA's. They all had developed based on the analysis that had gone on of all the individual design alternatives and features against all the Phase 1 criteria, and we put them together into a series of EDA's.

Now, Phase 2 has a different set of criteria. I'll talk about them in my second talk. They're essentially the same, they've been consolidated, but we've added some very important aspects. We've added Defense-in-Depth, which again requires multiple diverse barriers. Our first phase analysis we were essentially doing very stripped down versions, as you remember, so we wouldn't expect any of those to do well relative to Defense-in-Depth. And secondly we've added flexibility, the whole issue of programmatic changes and a number of other things that I'll talk about. Those are part of Phase 2 criteria.

Now, what you're going to hear after me, first we'll have a discussion of Defense-in-Depth, that's to get you ready for Phase 2. Okay, it hasn't been applied yet. An example that Dennis will show is we've looked at Defense-in-Depth at the VA reference design just to show that in fact it can be done and it works and to explain the process. Then we'll have Rob Howard will talk about the Phase 1 performance assessment calculations that were done against these features in a one-off sense and the stripped down design alternatives. Then we'll have the three representatives from the breakout teams and their focus on what was done at the workshop and what we arrived at at the end of the workshop. So that all is Phase 1 activity.

DI BELLA: Okay.

COPPERSMITH: Then we'll talk about where do we go from here, what are the new criteria, what will we go--what will be the process, ultimately selection at the end.

NELSON: Russ McFarland?

MCFARLAND: Kevin, not to belabor it, but when I look at the engineering acceptance criteria for Phase 1, it's a list that's fairly fluid, it's very qualitative, perhaps even subjective. Would you expect these criteria to continually--the definition to improve become almost quantitative as we move to Phase 2, into Phase 2?

COPPERSMITH: I don't think so. I think that if--well, for people who are well versed in decision analysis, there's a process of either using a natural scale of something that's directly measurable, like cost and dollars. The units of dollars work well in describing cost. But there are also constructed scales, like the type that we've used here, that deal more with subjective and judgment type issues, and there are also what are called proxy or surrogate scales that basically say, "Well, this isn't exactly what we're after, but we'll use a count or a quantitative measure to get there." So for example for dealing with things like worker safety, a surrogate for that, rather than just say a constructed scale is 1 through 5, being very safe to unsafe, we'll look at the number of lifts and moves and some other surrogate, something we can actually count and make quantitative to help us get at this worker safety issue. And sometimes, though, you might have multiple quantitative measures that get at the same issue.

We're looking at that to see if there are some surrogate or proxy scales that could help us in making these assessments, particularly the operability issues and these engineering acceptance issues. But again, from my point of view, from a decision point of view, they're both acceptable. They need to be explained and defined. There's going to be a judgment involved in either way, even if you have a nice proxy surrogate scale. We don't kid ourselves into believing that that measure, that quantitative measure, is the end-all, and there aren't any uncertainties in it. So regardless there will have to be some description and documentation of the judgment that went into the assessment.

DI BELLA: Thank you.

NELSON: Leon?

REITER: Leon Reiter, staff. Kevin, some more questions about the criteria. I'm not quite sure, was this done in a formal way, like you have sort of a utility function, you weighed it and everybody provided input and looked at the weighting at the end, or is it sort of--were these criteria just sort of considerations that you looked at and somebody chose?

COPPERSMITH: In terms of the development of the criteria themselves or their--

REITER: How were they used?

COPPERSMITH: --implementation?

REITER: How were these criteria used?

COPPERSMITH: They are used--the Phase 1 criteria were used by each of the engineers for each feature and each alternative. So they--and I haven't given all the detail on the scales to be used and so on, but they use them individually. So they each sat down--I'm doing backfill is my alternative, and I have a description of the design and how it would work and how it would be implemented and so on. Then they go through each one of those criteria.

REITER: Okay.

COPPERSMITH: And apply those. And in many cases they are--in Phase 1 they are compared to the VA reference design. So is this in terms of operations, constructability, how does this compare to the--is it advantageous or disadvantageous relative to the VA reference design. And other issues are cost and schedule, and they basically make evaluations against those criteria.

REITER: I guess what I'm after was that were all these inputs by the engineers these numerical or scale factors that put in some sort of function, compared and weighed it, and that's how you chose the eight--the--

COPPERSMITH: No. No. At the present time--again, there's limitations to doing it the way we've done it because by necessity those features have to be, for example, associated in a one-off sense just for the VA reference design. So there's engineering judgment involved of, well, if I took this ceramic coating that didn't do well on top of 10 cm of carbon-steel, what if I put it now on top of Alloy 22 or I put it on top of some other waste package material? That evaluation that was done, based on the VA reference design, may not provide the insight and the information that you need to apply it somewhere else.

REITER: Can I--

COPPERSMITH: That requires some judgment.

REITER: What I'm getting at, was there like a formal elicitation, whether it was judgment or calculations, or are these just--so did some group then just look at these or brainstorm it in the end and come up with your eight?

COPPERSMITH: Yes, that's what the two-week--

REITER: Okay.

COPPERSMITH: That's exactly what the two-week process was.

REITER: Okay. A couple questions here. You mentioned --somebody mentioned the word "licensability". I didn't see that appearing at any one particular--

COPPERSMITH: The licensability, what we'll call safety or license probability, is a Phase 2 criteria.

REITER: Okay, it's not a Phase 1 criteria?

COPPERSMITH: Right. The closest thing in the Phase 1 is assurance of safety. Assurance of safety basically deals with the uncertainty in postclosure performance and how well we can mitigate those uncertainties.

REITER: What is the difference between postclosure performance and assurance of safety, Team 1 and 3, I think?

COPPERSMITH: One deals with the central estimate of performance and assurance of safety deals with the uncertainty in that assessment.

REITER: Okay. Was diversity a criteria?

COPPERSMITH: In terms of--diversity was a criteria for putting together the set of eight EDA's. In terms of that type of diversity, we had diversity of design concepts.

REITER: So that was in putting together that part of Phase 1 which--

COPPERSMITH: Exactly.

REITER: Okay. And finally, I know Bob Budnitz and I think the whole TSPA peer review panel has come down on this term called "analyzability"; is that--that's sort of buried here somewhere. How important is that?

COPPERSMITH: I have had some discussion with Bob. I still do not have a clear definition of what is meant by "analyzability" other than if we're in a position ultimately to evaluate let's say the Phase 2 designs, the EDA's that we go ahead with, are we able to analyze their performance and other issues or to make that clear, to communicate that clearly so that we can make a decision. Do you have a different definition?

REITER: Well, the ability to demonstrate one way or the other that what you have may sound like a nice idea, can it be demonstrated analytically, I guess also in other ways.

COPPERSMITH: I would hope that these would have that characteristic. We are trying to instill the concept of simplicity. It's been called elegance, but also it's been called the KISS principle of trying to keep these designs as simple as possible. There is a--right now under engineering acceptance we're looking at--it's a positive--those aspects that allow for a highly simple type of a design that has a lot of precedent, we've seen it a lot before, it's easy to analyze. Those issues actually will help get a higher score in terms of the engineering acceptance.

NELSON: Okay, Bullen.

BULLEN: Bullen, Board. Just a quick follow-up question to the application of the criteria. Are those calculations or evaluations included in the 3-5 Reports, is that where we see them? And do the 3-5 Reports tell us how you selected each of them, and are the 3-5 Reports done or are they involving, I guess is the question.

SNELL: The evaluations are in the 3-5 Reports. I think we put them in an appendix if I--

COPPERSMITH: Yes, they're all in a separate--

SNELL: --remember correctly.

COPPERSMITH: --appendix for each report.

SNELL: I would mention the confidence assessments were also done. Those will be--those are not documented in the 3-5 Reports on individual features or alternatives but will be documented in the report that our group puts out in the April/May time frame.

BULLEN: Okay, so the 3-5 Reports are all done, though? I mean, have we--or are they still evolving?

SNELL: The 3-5 Reports are done in the sense that some of them have not finished final checking yet, but they are complete. Some have been completely through checking. There are a few, I think, that are still undergoing the last stages of the checking and review process.

BULLEN: Okay, so in answer to Leon's question, we could actually go back and look at a 3-5 Report for each of the criteria or enhancements and see how the criteria were evaluated or how they were applied?

COPPERSMITH: Right.

SNELL: Yes.

BULLEN: Okay.

NELSON: Okay, thank you very much. The process that I had the opportunity, and so did other Board members, to watch was extremely interesting and open, and I appreciate the opportunity to observe it.

I'm trying to put together now, what we've got is Legos that are somehow made into sausages that are baked like a cake in the shape of a car?

SNELL: I think you've captured it about right, yes.

NELSON: And as of now we are going to take a break and eat some cake, and then we shall come back and find out more about the tools which will be used to tell whether the car will run and how well it runs. So we break until 12:15.

UNIDENTIFIED SPEAKER: 10:15.

NELSON: 10:15, 10, 10. Sorry.

(Whereupon, a break was taken.)

NELSON: Thank you, welcome back. I want to identify that Paul Craig has joined us and is somewhere as a board member. Not a member of the panel but an interested member of this proceeding. And Rick Craun really did succumb to the disease that was inflicting him, and he is--his chair is currently occupied by Paul Harrington of DOE to answer any questions that may come from that direction.

Continuing on, we're going to listen to a presentation on postclosure Defense-in-Depth and the design selection process. It's going to be made by Dennis Richardson, who is the manager of the Repository Safety System Engineering, MK in the M&O organization. Dennis is an aerospace engineer, a mechanical engineer and a mathematician, which is an intimidating array of things to be, in addition to which we can add an MBA. So we welcome Dennis to presentation at the Board, and thank you for rolling with the punches and using the hand mike, because we understand the lavaliere mike is not working right now.

RICHARDSON: Thank you very much Priscilla. I hope this is working, it's hard to tell from here.

The presentations here are a very good example of Defense-in-Depth, as Larry pointed out. We have a digital network here, and if that breaks down, we have Tom that runs up and fixes that. And if both of that goes, we have the hard copy. So right there is my pitch.

NELSON: We're not going to let you get away with that one.

RICHARDSON: Okay. Defense-in-Depth you probably certainly recognize as one of the key elements of the repository safety strategy for making the safety case. And Defense-in-Depth is an old term, it's been tried and true for the last 35 years in the commercial nuclear industry. Of course there it's a little bit different story. You know, we have these very active systems along with the passive systems and we have a very short operational life and we have very reasonable means of assuring that everything is functioning the way it should.

So then when you think, well, how do we apply this to a repository design for postclosure, we're working mainly with passive natural barriers and passive engineered barriers over extreme long periods of time. So we had to come up with a different way of approaching the topic of Defense-in-Depth and how to use it.

In postclosure, what we're really looking at now is using a multitude of barriers and to try to ensure that the failure of any single one of these barriers does not mean failure of the entire system. That's kind of the bottom line basis for Defense-in-Depth.

In the licensing case, the Department of Energy will probably be required to identify all the principal barriers that are depending on and to show a transparent way of analyzing the performance of those barriers and how everything plays together in the total performance of the system.

So the approach we've chosen here for Defense-in-Depth is to both support what the Department of Energy will have to do in terms of licensing and also to show how we come up with a robust design and to illustrate the contribution of various barriers in both the engineered and of course the natural barrier system.

You've heard Kevin talk a little bit and you'll hear more this afternoon about the criterion that will be imposed on the final EDA evaluations. And of course Defense-in-Depth will be a major player in that criterion. We wanted to have an analytical approach that will provide some type of measure for comparison for each of the EDA's, one that we can simply look at and get some recognition of how they play against each other with respect to Defense-in-Depth. And we'll show that a little bit later on.

Now, of course this resembles a little bit the total system performance analysis, but it doesn't replace that or anything like it. It's a different way of looking at the systems and it really focuses on the multiple barriers, the redundancy of the barriers, and really to mitigate uncertainties. And a little bit later on I'll show you how we have a one, two punch for addressing uncertainties. The

Defense-in-Depth is one of those, and we'll talk about the other.

Of course this type of methodology does not replace TSPA, it's hand in hand with that. The focus on this approach is barrier neutralization. And what we're trying to do here is to show the basic contribution of each barrier and to total TSPA and determine the bottom line is a total system of the natural and engineered barriers to allow for a resilient system against the uncertainties the various barriers have.

I wanted to show this--leave this up here a little bit. I'm not sure how good you can see these slides from the back. And that one didn't show up too good, either.

UNIDENTIFIED SPEAKER: Focus.

RICHARDSON: But anyway, the approach we have for Defense-in-Depth is a rather simple four-step process that I'll walk through, and then you'll see later on how we used this process to evaluate the VA design for practice.

First step is to identify the principal barriers of the system. Of course this is very dependent on the enhanced design alternative that we're looking at because you'll have different barriers based on how the design turns out. And the way we define the principal barrier, we didn't want to look at every single nuance in terms of the system, but we wanted to have those barriers that would meet one of the following two criteria. One would be to delay the water where the radionuclides were at least 1,000 years, or limit their fractional rate or release of release to less than 10^{-4} per year. So any individual barrier that would meet one of those two criteria we would initially define as a principal barrier of the particular design.

Secondly, we want to assess the principal barriers to see what type of combinations we should consider. And here you have to look at any potential common mode failures or sources of uncertainty to determine whether or not you really have what would be two independent barriers for the time frame you're interested in or if they should be considered as a single barrier when you go into the analysis of them.

And then once we do that, we want to go into where we neutralize each of the barriers. And by neutralization we mean we would assume ineffective in limiting movement of the water or the radionuclides for that particular barrier. In all other aspects the barrier is still considered to be there physically, but it is basically ineffective in performing that particular function. And again, the object here is to determine the contribution to various barriers compared against the base case performance when that barrier is completely neutralized.

And then finally we want to evaluate the overall system performance and be able to compare that to other design alternatives. And we want to see whether or not the overall system performance is dependent on a single barrier performing as we think it would. And we want to try to come up with a design where it's not dependent on any single--whether it be a natural or engineered--barrier.

And again, our bottom line here, our acceptance on this is that the design, whatever design we come up with, should permit the repository performance objective to be met even though you have any single barrier failing to perform its function.

I'm going to run through a quick example here of what we did for the LADS workshop, is where we applied this methodology to the base VA reference design. And just to--the little picture on the side here shows the--basically the bare bones VA reference design. It has a drift lining, has the waste package with the corrosive material on the outside, the CRM on the inside, has an invert, and of course all the natural systems and barriers are in place. No drip shield, no backfill, no nothing else, just bare bones VA reference design.

Walking through, then, our methodology, the first part was to identify the principal barriers of the VA reference design, look for common modes among them, and to come up with the barriers that would be neutralized. And in terms of the VA reference design, you can see we had all the overlying rock layers, the overlying flow barriers, into one common barrier. That was considered as one barrier. The UZ barriers were put into one barrier. The saturated zone barriers were made into one barrier, and mainly because all of us view this common flow and transport models throughout that, and so we considered all of those as one barrier. The waste package, even though it's made up of two different materials, has the corrosive material on the outside and the corrosive resistant material on the inside, we consider that as a single barrier working together. And then we also had the spent fuel cladding as a barrier and the invert layer.

So then the idea here, once we have these principal barriers identified for this design, would be to go through and then neutralize each one of these and to see the impact that has on the--compared to the Base Case Performance. And you can see here, if we were looking at any other enhanced design alternative, we might certainly come up with a different list of principal barriers.

The first part of this, you have to have something to compare with when you neutralize each of the barriers. So we wanted to show the example of the Base Case Performance, which would have all the barriers working as expected in the TSPA analysis. And you can look at different time frames of this. For the purposes of this exercise, we'll focus more on the first 10,000 years, but you could certainly pick other time frames to look and compare to see the contribution to the various barriers and the effect in case they weren't operating as expected. And so this would be the base case analysis that all other neutralizations will be compared to as we walk through.

The first case--and I hope that's coming through back there, I hope you can see that okay, it's in the handouts--but this is neutralizing the overlying flow barriers. And what we mean here is that the overlying rock structure does not really inhibit the flow of water to the waste package. So we assume that all the seepage through the mountain is basically equivalent to the precipitation that would be assumed. In the long term, that would be about 300 mm per year. We also assumed that all the waste packages will get wet in this illustration.

Now, the rock structure is still there, it still does provide the thermal conditions, the same thermal conditions, the same chemistry conditions, it's just that the function of inhibiting the water is no longer present for this. And when we do that, you can see the red, the curve in red, shows the impact on the total system performance of the base case, when we do neutralize this particular barrier. And in looking at this you can see, if you'd focus just on the first 10,000 years, you see we still do meet our criteria, so the uncertainties in this particular barrier would not drive us above the base case or the criterion for the 25 mrem. However, it doesn't mean that this barrier is not important, because this barrier would also be there to provide resilience against other barriers failing and as a backup and also its total contribution to the performance of this.

But when I see this type of a curve, it does tell me that there is resilience in the design for the uncertainties in this particular barrier, and what we hope is that all the neutralizations would come well under the total performance.

Look at another barrier here. This is one where we'd neutralize the unsaturated zone. And again, here we would assume that the unsaturated zone would not inhibit the flow of water or radionuclides. And you can see on this one this approaches very closely to the Base Case Performance. And again, as you'll see, it doesn't meant that this barrier is not important, because it's highly infective in backing up other barriers. And in fact later on you would see if I were to combine this perhaps with the saturated zone you might see a great impact of both of these together. But again, here this is showing that the uncertainties just with this single barrier are being backed up by other barriers, whether it be engineered or the saturated zone.

Next example is for the neutralization of the waste package. And neutralization here means that the corrosive resistance material of the waste package is assumed to be degraded very early in time, within the first year, for all the waste packages. Now, the cladding is still in place and all the other barriers are performing as expected in the base case. But in this example you can see we get a very large spike in the first 10,000 years, we exceed the proposed regulatory criteria, and what this would tell me is that there is not enough resilience in the system, there's no other barriers that are in there to back up the uncertainties that we may have in this engineered barrier system. So on this illustration, this would come up as certainly a weakness in the particular design that's being looked at.

Next example is neutralization of the spent fuel cladding. And the way this was neutralized was assuming that there were 100 percent infant failures on all of the cladding of the fuel. Now again in this example, the waste package, all the natural barriers are performing as expected. You can see we get a fair increase in the performance, but there apparently for this example is enough backup in the system from the other barriers so that we don't exceed the criteria during the first 10,000 years. But we do get a fairly large increase in the performance.

The next example is neutralizing the invert transport barrier. You can see here there's very little change throughout the time frame as compared to the base case.

And finally, once we look at neutralization of all those barriers, we want to make a total assessment of that particular design. One way of doing that is a simpler plot. a simple histogram to show how each of the barrier plots. Now, some of the lines didn't come out good here, but you have to watch, it goes like this (indicating). So this is the waste package, this corresponds to the cladding, and so on. And you can see on this we have some rather large spikes in terms of the performance. And what we really want to do when we come up with a final design is have a case where when we neutralize all the barriers we get a very low, even performance right across here. You know, no large spikes anywhere. We want to be sure that the system performance isn't being dependent on either a natural--a single natural or engineered barrier, which means that the uncertainties of that barrier would be highly important, and we want to mitigate that.

So for illustrative purposes, just looking at the bare case VA reference design, this is what we would learn from that. It would help to drive where we see weaknesses in the system and the types of features we may want to add.

Now, if you try to figure out well what does all this mean with respect to licensing, with respect to design, first of all, the analysis here is just for illustration purposes only on a VA design. We would walk through this type of methodology and this type of analysis for each of the EDA's, as you'll see in the Phase 2 work when Kevin discusses that this afternoon.

Now, this type of approach is really tailored to understand what each of the barriers is doing in terms of performance, in terms of backing up other barriers, and also in terms of how its particular uncertainties may play in terms of the overall performance and in terms of overall licensing capability for the design.

I said before we have a two-phase approach to addressing uncertainties. Okay, the first way we go about this, obviously, is to try to reduce the uncertainties as much as humanly possible, as much as is reasonable. And of course on the natural barriers that means doing the scientific research, collecting the data, looking for analogs to support the models that we have, doing everything we can to reduce the uncertainties on others. On engineered barriers, you also have procedures in place for construction, for acceptance, quality assurance practice, those tools of the trade that are used to reduce uncertainties of engineered barriers.

Then Defense-in-Depth comes in place to give you your second throng approach at mitigating all of those uncertainties. And again, what we tried to do is come up with a design that as we neutralize each of the barriers it levels the playing field, we get no major spikes anywhere in terms of any single barrier being neutralized, which means that we have mitigated the uncertainties as much as reasonably possible.

So between reducing uncertainties, mitigating the uncertainties, together they play in terms of coming up with a very strong design, a strong licensing case that we can move forward with when we go into the licensing.

This approach is also a good way to--what I think is a fairly simple way of illustrating step by step how we understand each barrier and the transparency of understanding that can be defined.

The work that was done here, by the way, was led in part by Larry Rickersen with a team of the PA folks working with us to learn how we go about doing this. And so it was very useful in not only hoping to prove out our methodology but also in getting set for all the work that will have to be done for the criterion evaluation in the second phase of the EDA's.

So this is how we see Defense-in-Depth being played for the repository postclosure design. And again, it's quite different from if you're used to commercial nuclear, but it's how we see the approach being used on this. And we do think it will help us come up with a very sound, licensable design that plays hand in hand with addressing the uncertainties that we have in either the natural or the engineered barriers.

So take some questions at this time.

NELSON: Thanks, Dennis. Let me ask you just one question off the top. I want to make sure that I understand about natural barriers. According to your definition, would the low rainfall, fairly dry climate that's present here be considered a barrier or not?

RICHARDSON: I don't know if I'd call that a barrier, but certainly the repository site allows us to put a very good bond in terms of the initial input, the initial conditions that we would see in terms of rainfall. I don't consider that as a barrier per se, but it does allow us to bound the data that would have to be input into the total system performance analysis, and that's a very good thing to have.

NELSON: Um-hum.

RICHARDSON: Just like the site also bounds that we don't have to worry about tsunamis or tidal waves or things like that. So the characteristics of the site that allow us to bound certain input data is extremely important.

NELSON: Okay. And the issue about neutralizing and what that means, going from on to off, I have one scenario which I could envision, which is the existence of the capillary barrier, which is a little bit different from the rest of the UZ flow, and I expect based on your definition here that you're incorporating the capillary barrier as part of the UZ flow system.

RICHARDSON: I believe that's right. I'll ask Larry Rickersen to address that, he knows a lot more about it than I do.

RICKERSEN: Larry Rickersen from the M&O. The neutralization considered common sources of uncertainty and decided that the whole UZ flow system, which included capillary effects, was subject to the same uncertainties for this simple analysis. And so the capillary barrier, the effect of the rock, whether the flow was in the matrix or in the fractures, all of that was considered to be neutralized. So basically there is no effect when we neutralize the overlying rock units in this particular case. Clearly a non-physical thing, but from the point of view we're trying to see the importance of the UZ flow system in its entirety, this is how you get at it in this particular analysis.

NELSON: Okay. And in following up on that, though, I could imagine a case where if the capillary barrier does not exist as a barrier, then in fact the tunnel would start to act as a drain, in which case it would concentrate flow. And this is not covered by that neutralization concept, but it's actually almost a change in mechanism from what's part of the UZ concept to really functioning differently in a far more close to saturated environment. That judgment has to kick in in order to be included in DID, someone's got to realize it in terms of that kind of a--we could have more flow in than what I anticipate if we just made the flux equal to the precipitation.

RICHARDSON: Yes, you bring up some very good points, and this is why we definitely wanted to get a head start on how to do this neutralization, how to define it, with the PA folks well before we had to actually use it on EDA's. There may be some points where we need to neutralize in a slightly different direction or to enhance what we're doing and take a second look at it, and of course that will--we certainly have to do that over the next few weeks.

RICKERSEN: Let me add one thing to that. The question of that type has to be answered, in my opinion, for the system, and I believe that that does get answered when you look at the full performance assessment. There will be performance assessments that will--sensitivity analysis in the performance assessment. This looks like one, but it has a little bit different flavor. You look at physical effects of that type, concentrations of flows in that sensitivity analysis. So it does get covered when you do a full and complete performance assessment.

The issue here is how much for the base case does a particular barrier contribute. When you do the sensitivity studies, one barrier may be masking another, and you can't really tell exactly what the roles are. It's very difficult, as you know, to unravel that kind of stuff. So this is an additional unraveling that is complementary to the full performance assessment of the type of effects that you're talking about.

NELSON: And real important to the transparency and--

RICHARDSON: Yes.

NELSON: --the engineering profession buying into the process.

RICHARDSON: Yes, we really believe that this methodology does allow for more unmasking of the contribution and the effect of the barriers in different ways. And that's kind of a side benefit that we should get form this.

NELSON: Dr. Sagues.

SAGUES: Yes, just make sure that I understand this correctly, first of all, that the bar chart there corresponds actually to the effect sometime during the first 10,000 years.

RICHARDSON: Yes, this would be the measurement during the first 10,000 years. And as I said, you could do this for the first 100,000, whatever you chose.

SAGUES: Sure.

RICHARDSON: For illustrative purposes, we chose the first 10,000, and that's the peak that we would see.

SAGUES: Right. So then for the neutralizing the waste package, that actually--that bar would correspond to about Year 3000 or so, which is when--

RICHARDSON: I believe so.

SAGUES: --it peaks.

RICHARDSON: Yes, sir.

SAGUES: And that would correspond to basically replacing the waste package with something that has the same thermal characteristics and the like, but really it's like you can drill and you drill it so that there's basically a sieve that lets the water through but in the middle of the drift at the same height and so on as otherwise. And so that's of course very interesting, because at least during the first 3,000 years in that particular case, that is by far the largest effect.

If you were to make that chart into a linear chart, then the only thing you would see would be the waste package--

RICHARDSON: You're absolutely right. There's different ways of illustrating this using RSS or whatever. This is a very simple approach to illustrating this, and--

SAGUES: Yes, I'm sorry.

RICHARDSON: Go ahead.

SAGUES: But of course that doesn't look like Defense-in-Depth at all, right, it looks like we're learning just one component of the system.

RICHARDSON: Exactly. I'm glad you said that, that's exactly the point on this one. See, if I were looking at this design and making my Defense-in-Depth evaluation, I would say that this particular design does not do it, it would not have enough Defense-in-Depth. And what I would demand in a design is something where I get the very level low playing field where each barrier is backed up by some other barrier or combination of barriers, and I don't want to have a design where I am dependent on the uncertainties of one barrier. You're absolutely right.

SAGUES: Right. But the other thing is you don't want to do a design that just simply elevates all the others up, because that would give you a false impression of Defense-in-Depth. In other words--

RICHARDSON: Right.

SAGUES: --all the components would be bad, and perhaps that could satisfy Defense-in-Depth, the definition of Defense-in-Depth, but--

RICHARDSON: Yes, well, not quite.

SAGUES: --satisfy the requirement.

RICHARDSON: Normally what you see, as we look at the addition of--logical addition of additional features of barriers, it will have the tendency to drive everything down. I mean, once you have something up and you add in another principal barrier of some sort, that will by its very nature drive everything down and hopefully get rid of any spikes or peaks that we may have.

SAGUES: Right. Thank you.

NELSON: Dick Parizek.

PARIZEK: Parizek, Board. Remind me on page 17, your View Graph 17 was invert transparent barrier. What was the invert? You neutralized the invert transport barrier. I forget what that is.

RICHARDSON: The concrete invert.

PARIZEK: Okay, that's what it is?

RICHARDSON: Yes.

PARIZEK: Concrete. All right, I just needed to be reminded of that. And then on all of the plots that show red and black comparisons, to what extent are the red lines dependent upon uncertainties in the black line? I mean, obviously that's the base case.

RICHARDSON: Yes. They would certainly be dependent on the very same uncertainties, because everything is the same as the base case except for the one barrier being neutralized. So the uncertainties you would have in the base case would be the same uncertainties you would have here except for that barrier being neutralized. There the uncertainties are driven to where it's totally taken out of the picture.

PARIZEK: So the black line could have a certain spread to it at any one moment in time, which also would affect the red line, and so you could--

RICHARDSON: Oh, you bet.

PARIZEK: --go over that 25 mrem criteria.

RICHARDSON: Right. Right now the black line is basically--I hope I'm saying this right, but I believe it's close to what would be the expected value, the mean of the TSPA, and likewise this was done. Now, you could also perform this, say, looking at the 95 percentile or looking at 100 cases on, you know, that type of sort. But this was a fairly simple approach.

PARIZEK: Right, so the tighter the black line plot is and everybody's confident that that's reality, that improves your analysis.

RICHARDSON: Yes.

PARIZEK: So we really need to make sure we understand the processes that go into the black plots and the uncertainties--

RICHARDSON: You bet. You know, in that black plot, every one of those principal barriers that help make up how that black plot is obviously have their own uncertainties.

And what we want to do here in terms of mitigating those uncertainties is to look at each barrier one at a time and make sure that its particular uncertainties couldn't drive the results of the performance.

PARIZEK: Yes. Thank you.

RICHARDSON: And if that's the case, then we would say there's not enough Defense-in-Depth in that particular design. And of course as you can see on this design, that's the case with both the waste package and it's also the case if I would, say, put the UZ and the SZ zone into one barrier because maybe of a common flow model. If I neutralize both of those together, I also get a very large spike. And so it really gives you a fair amount of insight with respect to areas that may have weaknesses and where you might want to consider, hey, I need to do something about that in terms of an additional feature.

NELSON: Dennis, what would a strategy be to increase UZ?

RICHARDSON: I'm sorry, what?

NELSON: What would a strategy be to increase UZ in that plot?

RICHARDSON: If I were to make the waste package less effective, you would see all of these would come up higher.

NELSON: But is there an action you can take with respect to the UZ itself?

RICHARDSON: Well, as we looked at this particular feature, when I did neutralize the UZ's, of course you didn't see much of a performance spike, but if I would neutralize both the UZ and the saturated zone, you would see a very large spike. So the strategy there is, I know I have some uncertainties in both of these, I know I have uncertainties in how I model them. I want to do everything I can to reduce those uncertainties through scientific data, through analogs on my models, anything I can do to verify what I know. Then the other thing I want to do is to mitigate the importance of that uncertainty as much as possible by additional features that will keep that spike as low as possible in case I am wrong in how I model or understand that natural barrier.

But the only way--only thing I can do with a natural barrier is, one, reduce the uncertainties as much as reasonably possible through scientific research, and two, to mitigate the importance of that uncertainty through the additional engineered barriers. And so we need to do both.

And in this case, if you just look at that barrier all by itself, it seems like even the VA design does a fairly good job at mitigating those uncertainties. But again, I said, if you consider duplicate uncertainties between UZ and SZ, I get a very large spike. And it's on one of the figures there.

NELSON: Paul Craig.

CRAIG: Craig, Board. This Figure 15 that you just showed, which has the same information here on this one, with regard to the waste package--don't put it up, we know what it said. I'd like you to help me to understand the concept of a geological repository, which is, after all, what Yucca Mountain is billed as. When I look at this curve, this one that you have up here, that looks like an engineered repository, not like a geological repository. Why is that an incorrect conclusion, or is it a correct conclusion?

RICHARDSON: I think it's incorrect. I like to consider this as a repository that is made up of natural barriers--SZ, UZ, overburden--and the engineered barriers--waste package, cladding. They all work together to give the results that we come up with in either performance or Defense-in-Depth.

Now, if I look at just the natural barriers in themselves, they do a pretty darned good job, but they don't do the whole job. So I include additional engineered barriers to help support the natural barriers in terms of reducing water on the waste form with the waste package, perhaps a drip shield to keep water off the waste package. But again, all the barriers are working together, they all have their own set of uncertainties, and what we're trying to do here in Defense-in-Depth is to look at all the barriers, natural barriers, engineered barriers to assume that if I am uncertain how one performs or if a particular barrier falls to perform it function. I want to make sure that I have enough resilience in the system, in other words enough backup, due to other barriers so that I won't do anything to degrade the public health and safety.

CRAIG: Craig, Board. I guess I go back in my thinking to what the TYMS people said about a reasonable standard, which was 10 to 30 milli r per year at the time of peak exposure.

RICHARDSON: Right.

CRAIG: And you're focusing on 10,000, which is I guess okay for starters--

RICHARDSON: Sure.

CRAIG: --but we need to bear in mind that they said something rather different. And even at 10,000 years, in fact even at 3,000 years, it looks like you're close to two orders of magnitude above that kind of a level.

RICHARDSON: Yes.

CRAIG: In the case where you've neutralized the waste package.

RICHARDSON: Right.

CRAIG: And that leads me to wonder, if you can't even come close with the mountain, you absolutely require engineered things in order to come close to that guideline, then you really are relying almost entirely on an engineered barrier and not very much on the mountain.

RICHARDSON: Well, again, I wouldn't agree with that because the mountain and the environment and the location really helps me to bound a lot of the conditions that I have to assume in terms of rainfall, in terms of being able to have an unsaturated zone and being able to have a stable environment over a long period of time. All these types of conditions and constraints I'm allowed to--I know I have because of the natural system. Without the natural system, there would be a lot of questions in my mind to how to bound different effects that I know would attack the engineered barriers. So to my way of thinking, the natural--the mountain itself is very, very important because it allows me to bound a multitude of conditions that I have to consider just like the environment around a nuclear power plant allows me to bound a lot of the conditions I have to assume for my DBA's. Likewise here, the natural system does that very same thing for me. And again, the natural barriers do help to mitigate performance of the engineered barriers.

RICKERSEN: Dennis, could I add something to that, would that be all right?

RICHARDSON: Yes.

RICKERSEN: Larry Rickersen from the M&O again. What we found in doing these analyses is a very interesting result. We found that for almost all of the radionuclides, almost all of them, there were a large number of barriers in the system that worked. For example, for plutonium, both the unsaturated zone and the saturated zone separately handled those radionuclides in these analyses. Other barriers, engineered barriers, also did. So it was highly redundant with regard to most of the radionuclides. In fact, when you figure it out, it's the vast majority of the radionuclides. So this system is highly redundant for those radionuclides. The natural system works entirely--works fine in these calculations, of course, for those radionuclides.

What you have contributing to these spikes is a few small--a very small fraction of the radionuclides, those that are mobile. So that's Iodine 129, Technetium 99, and Neptunium 237. Those are the only ones contributing here, although we looked at a large number of radionuclides. What's happened is, with regard to a very small fraction, you need some engineering. With regard to the vast majority of radionuclides, the site works all by itself.

RICHARDSON: I'd show, for example, you saw the spike for the waste package. This is a particular slide I didn't show, but it might be useful here. This shows the effects if I neutralize both the UZ and the SZ transport barriers, consideration might have some commonality in terms of the models and some of that uncertainty as you go with that. And you can see here this is where I have the full waste package, the cladding, everything else. But all that wouldn't be enough to make up for potential uncertainties if I consider these as one barrier. You see, I would exceed the 25 mrem. And so I can get different insights when I go through this in terms of the importance of different uncertainties, importance of certainties perhaps in the modeling, my understanding of the natural system. And you can see all this is highly important. And I have to have--I have to have a system of both natural and engineered barriers working together, I believe, to come up with a very defendable case that I have addressed the uncertainties and I'm protecting the health and safety of the public.

And again, you point out a good fact, we're just looking at illustration, you know, we looked at D-in-D in the first 10,000 years, and we can look at different time periods, too, to see the robustness of the system through that viewpoint also.

NELSON: Okay, leave that up there because I know Dan wants to ask a question there, and then Alberto.

RICHARDSON: You told me you weren't going to let Dan ask anything.

BULLEN: Bullen, Board. As I understand this one, the little blip on the black curve is essentially the juvenile failure of one package?

RICHARDSON: Right, 1,000 years.

BULLEN: So when you neutralize the UZ and SZ for transport, is that dose that you go above 25 mrem at, I don't know, 1,100 years, or whatever that number turns out to be, is that all from one package failure or do you accelerate package failure and--

RICHARDSON: No.

BULLEN: --so you have contributing other--

RICHARDSON: No, the package, the waste package, every other barrier works exactly as it's defined and expected for the base case. The only thing done here is the neutralization of these two barriers for mitigation of water and radionuclides. Every other barrier works as expected.

BULLEN: So essentially it's the ground water transport very quickly of whatever is available from one waste package that gives you that dose?

RICHARDSON: Yes, sir.

BULLEN: Okay. Then just one quick follow-up question. You defined a principal barrier, or principal barriers, as either having 1,000-year contribution to lifetime or one part in 10^4. Were those numbers just a fraction of the 10^5--one part in 10^5 and the 10,000-year time frames, or is there a reason that you came up with those numbers? How did those numbers come about?

RICHARDSON: Basically, your answer is yes. We had to have some kind of a cut off that seemed reasonable, and the factor of 10 seemed somewhat reasonable for the initial identification of any barrier that might be considered as principal as a starting point so that we would kind of limit the playing field on this.

NELSON: Dr. Sagues.

SAGUES: Yes, I see your argument when you indicate--when you show the effect of the geologic barriers. And indeed the effect shown in that fashion, it looks dramatic. Now, again, it may be instructive to look at these graphs also on a linear scale, as we were saying earlier, because still we are talking about one gram per year effect of removing of the waste package very early on the life of the system. And that is--I think that's a different quality than, say, 10, 20, 30 mrem, okay. So that's something that I think has a different meaning.

And also it's happening very early, it's happening only after 3,000 years. And I don't know exactly, are you using--or are you considering the time scale as an important issue on deciding the effect of eliminating different barriers?

RICHARDSON: Yes, I'm--that's a very good question, and I think you'll see later on this afternoon we look at a multitude of time scales to be sure that, you know, just because we looked at one time frame, we don't want to have a big spike coming up immediately after that.

SAGUES: Sure. But what I'm--

RICHARDSON: And so it is in my mind very important not only to look at the--say the 10,000-year--if that turns out to be the criteria--time frame but also time after that to get an understanding what happens in that, say, first 100,000 years or so and where we may get peaks and impact on those peaks with respect to different design options. So we do--we won't have the ability to focus on those different time frames with a great transparency through the methodology.

SAGUES: Right. But what I meant specifically was, are you considering it worse than the peak appears at 3,000 years than it would appear after 30,000 years, or are you given those--

RICHARDSON: Oh, certainly, we want to move the peaks out as far as we can. So certainly a peak at 3,000 to me is much more concern than the peak out at 30,000 years, especially with respect to the regulatory time frame.

SAGUES: Is that quantitatively expressed in some fashion, like you're saying so many points if it happens after 3,000 years and a different number of points if it happens after 30,000?

RICHARDSON: Not explicitly like that. There's a couple things that will--and again, this afternoon you'll see not only Defense-in-Depth but how safety margin also plays into this. And by safety margin I mean if you look at your base PA case, we want to have a large factor underneath that, just for safety margin, for things that may go bump in the night or new data that may come in.

Then along with that is the Defense-in-Depth to be sure that we're flat with respect to performance, even if we're somewhat wrong about any particular barrier or a logical combination of areas in terms of where the uncertainties may be linked.

Now, our first concern obviously would be for the regulatory time frame, the 10,000 years, to make sure we have a very solid case there for the health and safety of the public. Then after that we might look at the next 100,000 years or so to see how are things reacting there, what's our Defense-in-Depth look like during that time frame. And then thirdly we may look to see what's the effect on timing of the actual absolute peak as well look out in time frame of the PA and everything. These all have slightly different considerations. I don't think we have an explicit model how we weigh each of them, but certainly each of them would be a consideration in terms of how we feel about the final design and how we would go in with our licensing case.

NELSON: Okay, we're going to be continuing this discussion throughout the day, but I know both Dick and Paul had quick questions. Go ahead.

CRAIG: Yes, you just said the regulatory time frame of 10,000 years, and I just want to be careful about this, to the best of my understanding, EPA has not yet emitted a regulatory time frame.

RICHARDSON: Well, certainly, you know, I'm just going on our knowledge right now, and that's why we have to be flexible on this.

PARIZEK: Yes, Parizek, Board. My question here has to do with what I assume to be the red plot on that figure was all 300 mm of precipitation percolates through the mountain, hits every waste package; is that what I--

RICHARDSON: No, no, the overlying rock acts as expected on this to reduce the seepage, okay. Remember, I'm not--this is only the neutralization of those two barriers. If I would also neutralize the overlying rock, like you saw in the first one, you get yet another major increase on this. This is only the two, UZ and SZ barrier.

NELSON: Okay, any burning questions from the staff?

(No response.)

NELSON: Okay. Thank you very much, Dennis.

SNELL: Priscilla?

NELSON: Yes?

SNELL: Dick Snell. Could I throw in a couple of quick comments, please.

NELSON: Okay.

SNELL: Not much time. But from some of the comments and questions you're making, I think one of the things you're looking for is some sort of balance between the natural and the engineered barriers, and I think the appearance that there may be an unbalance on the side of the engineered barriers is partly because of the way this is constructed. They almost said it, both Dennis and Larry, and that is that the site itself has some characteristics which are not included in this particular model, namely it is remote, it is dry, it has a stable geology and a suitable geology. Those considerations which are very, very important for the natural barrier are not portrayed on those charts directly, so you tend to get kind of an uneven picture. This was set up, however, as a tool for use in Defense-in-Depth, so it may not give you the picture that you might look for.

The other comment I would make is that it's a sample or an example, and it's based on the VA design. And, you know, other designs would give you somewhat different pictures. But you might remember this is the VA concept only.

NELSON: Right. Thank you, Dick, and we look forward to the continued evolution of this as a tool. I think both in log space and in linear space in many cases.

I'd like to welcome Rob Howard, who is another eclectic engineer who in between engineering degrees took a master's degree in English. So we expect higher levels of articulation here, Rob. He's been on the project since 1992, and we welcome you. Thanks, Rob.

HOWARD: Thank you. You invited me here today to talk about the role of performance assessment in the LA design selection, so I'm going to try to give you some information regarding that.

First of all note that PA is not totally dependent on computers to do their work. Here is one example of someone from performance assessment struggling without a computer. I hope you can read crooked, I'm not going to bother with that anymore.

The objective here is to provide some insight to the decision-makers and the engineers about how features, alternatives, options, whatever you'd like to call them, might perform in a postclosure performance assessment.

We subscribe to the idea that we're looking for insight, not numbers. If any of you are familiar with the book by Richard Hamming on numerical methods, you're probably familiar with that philosophy. So when you see results for these evaluations, it's important to keep in mind that it's the insight, not the absolute value.

The level of detail that we had in the analysis is consistent with the conceptual designs that were presented. The analyses are not intended to give you--or develop a safety case, what they are intended to do is help the designers move forward with the design selection process.

We used expected values. I'm going to show you the TSPA base case curve later. Results were compared to the base case at different time frames. We looked at 100,000 years--or excuse me, 10,000 years and a million years. We also looked at the timing of the peak dose. That was important to the engineers for Phase 1, so we gave them that information. Again, we're looking for orders of magnitude of difference and changes in direction of those doses, not absolute values. So if we did a calculation that showed a difference in dose of a mrem between two different features, we wouldn't consider that a significant postclosure performance contributor.

Since these are conceptual designs, the models are simple, they're consistent, at least to the extent we can make them consistent with--this is terrible. Some features we didn't explicitly model because there wasn't enough information to warrant it or we understood that postclosure performance would not necessarily be an issue. We didn't do a postclosure performance assessment, for example, of a modular design for surface facilities, as we knew that wouldn't have a big play in how the system performed.

Several features had been analyzed before, and several other features, where we didn't have process models, we had to make some basic assumptions about how that feature might perform in the system, and we documented those assumptions.

To get at the issue of traceability and transparency, I know that you brought that up before, and Dick Snell brought that up. We want to make this decision process transparent. We documented our results, we documented our assumptions according to our quality assurance procedures, and we make those available to the designers for incorporation into their reports.

We had to change some of the TSPA component models, or the process models that fed them in some cases. Thermal hydrology is a good example. Temperature dependencies are pretty important to us, specifically temperature dependencies inside the drift. We were looking at the waste package environment and how that waste package was going to perform under different thermal conditions. Cladding degradation has a temperature dependency, and in a lot of cases we try to build abstractions to these features that allowed us to take into accounts of degraded cladding performance because of elevated temperatures. Obviously, waste package degradation, temperature, relative humidity dependencies, material properties had to be changed to evaluate some of these features. EBS transport, sorption in the waste package and in the concrete invert, or we might have removed the invert in some cases to change those.

Just to give you an idea of--or remind you if you're familiar with how we do modeling and performance assessment--there's several parameters we can change at several different stages during our evaluation. At the process level, we can change thermal hydrology by different thermal inputs to the system and different loading schemes. We calculate temperature and relative humidities and saturation profiles that we can feed into our geochemical model so that there's some temperature dependencies on how we develop the geochemical inputs into the drift. Obviously waste package performance, waste form degradation is dependent on the incoming water, the composition of the water, and so we changed in some cases the input parameter to make sure that we had some sort of level idea of how the system would perform based on changing inputs to the design.

Again, cladding, there's a temperature dependency there that we used for this level of analyses for certain cases like backfill. And of course we changed some properties in some cases in the unsaturated zone based on what we did in the drift. If we put a lot of concrete in the drift, for example, one of the ways we analyzed the natural system response to it was to look at how a highly alkaline plume might influence the sorptive capacity of the unsaturated zone.

We tried not to change too many basic assumptions that were in the TSPA. We didn't change the biosphere model, for example, we didn't change the well pumping, we didn't change the saturated zone model. We didn't think that that was important in this case because, again, we were looking for orders of magnitude changes as a result of changes that we had in the engineered system not absolute values of what the peak dose might be at any particular given time frame.

Some of the features we did not carry all the way through to dose. We did interim analyses to see if there was going to be a significant change one way or another in performance. An example of that was we did some interim calculations for blending, to look at the effects of blending, on the VA design. And we ran our calculations all the way out through waste package degradation and found that there wasn't significant effects on how the corrosion resistant material performed over the time frames of interest. And we terminated the calculations at that point because we believed that we couldn't provide the engineers any more insight by doing a total system calculation where waste package failure rates were essentially the same as they were for the total--for the Viability Assessment design.

We didn't have to calculate performance for all of the features and all of the options because some of those had been done in the past. Some of them are documented in the technical basis for the Viability Assessment. Examples of this were changes in incoming chemistry to include the effects of concrete. That analysis and its effect on performance is documented in the technical basis document. Ceramic on the waste package is another example where those analyses had already been documented in previous calculations.

An issue with data and the level of design, Rick Craun told you about that earlier this morning. Some of these designs, one of the serious issues with data is the service life of the system. Where we didn't have enough information to justify the use of a single expected service life, we did some sensitivity analyses showing how the system might perform if the service life of the feature changed. And I'll show you an example of that with the Richards Barrier in a couple minutes.

I brought four examples with me this morning: drip shield and backfill, which is interesting as it gets to the repository safety strategy of limiting water contacting the waste package; dual corrosion resistant material waste package, which is another interesting example, is that gets to long waste package lifetime, which is part of the repository safety strategy; the Richards Barrier, which, again, its function is to limit water contacting the waste package; and apatite getters, which gets to the slow release of radionuclides out of the engineering system.

Some of the assumptions that were driving the performance assessment evaluation of the drip shield. The drip shield assembly is a 2 cm thick corrosion resistant material. We assumed material properties to be essentially the same as those of Alloy 22. We emplaced this drip shield at closure, which for Viability Assessment was 100 years. We backfilled that closure, and the drip shield failed by general corrosion only.

As you can see, at 10,000 years, if you look at the TSPA expected value case and the use of the drip shield, there's a measurable difference in performance that we could calculate in this case. And the differences here are due primarily to, if you look at--this is for just one waste package assumed to fail juvenile. You've got both advective and diffusive releases for the base case. With the use of a drip shield, you can knock down those doses by just limiting releases to diffusion control rather than advection controlled as well.

Definitely also includes along with the expected dose at 10,000 years the time to peak dose. The curve for your performance is a little bit more gentle than it is for the expected value case for the Viability Assessment. The time to the peak comes out significantly later, about three-quarters of a million years. But you can see that even for this feature there's not much you can do out in the million-year time frame. The system does come to a I'll call it quasi steady state out at those time frames.

Dual Corrosion Resistant Waste Package design that was evaluated for Phase 1, the design that we were asked to look at we assumed the thermal hydrology was the same as it was for the Viability Assessment. We used the same temperature and relative humidity profiles that were in the Viability Assessment. The waste packages that are dripped on 100 percent of the time we assumed that they're constantly wetted by the drips. So if it gets wet, it stays wet.

The Allow 22 outer barrier on this case--it was Alloy 22 on the outside, titanium on the inside--was subject to general corrosion only--that was an assumption that was driving it. And the titanium, which is a Grade 7 material, was subjected to general corrosion only after we had a breach of the outer barrier.

Now, the other things to keep in mind for this analyses were that we didn't look at any other failure mechanisms for the titanium. So we didn't look at stresses that might have been induced on the welds and how they might fail, we didn't look at hydrogen cracking. We also didn't look at radiolysis effects. This is a much thinner waste package than the VA design waste package, so there are failure modes here that we did not evaluate for this case that if they're going to pursue this design, you know, we've talked to the engineers about it, these are things that we have to address in the future to make sure that if we go forward with it we address the correct failure modes and have reasonable answers for how the system is going to fail and what the failure looks like.

Again, at 10,000 years, pretty good performance, definitely measurable for what we were doing for Phase 1. You can see that after you get the first juvenile failure you don't have any more failed waste packages coming on line, which starts the slope of the base case when you've got failures of the waste package coming on at around 7 or 8,000 years. It's just a juvenile failure only that's contributing to dose, and it tapers off at the 10,000-year time frame.

This curve looks similar to the curve I showed you before with the drip shield. You can see the behavior of the system. We're looking at side building limits of neptunium coming out of a single waste package here, and you don't see the failure of all the other waste packages coming on line till much later time frames, again, given the assumptions that we had for this analysis.

Richards Barrier was one that we struggled with for service life. How do you define how long this thing is going to last? If you could figure out how long it's going to last, it makes the analysis much easier. We couldn't come up with a service life for Phase 1. It's something that would have to be evaluated if these things were going to be carried forward. So we made some assumptions about when this system failed, or when this particular feature failed, and we calculated our dose based on that. We also included higher temperatures resulting from putting the fill on at 100 years would create elevated temperatures on the waste package surfaces, would also create elevated temperatures inside the waste package. And so we assumed that there was a larger percentage of fuel rods that went above our 350-degree goal limit in the VA design and thus had higher failures for cladding. But we reduced the cladding failure due to rock fall in this case because we assumed that the Richards Barrier or any kind of fill would protect the waste package from that kind of mechanical failure over time.

Again, you could see where design life drives performance. Different scale than I've shown you in the past here, but for all of these features you can see where essentially the same behavior as you would for a Richards Barrier--or excuse me, a Dual CRM waste package or a drip shield where the only thing you have until the system fails is essentially that release of neptunium from one single waste package.

Apatite getters, we got some design input from the waste package designers and from the scientists on the project, the process modelers on what the sorptive capacity of an apatite getter might be. There were issues that we had to assume that the mass of the getter was available when it was needed again. That's a design life or a service life issue. If in fact that getter material is not there at the out years, these barriers wouldn't perform as well as we show in the calculations. We evaluated two design configurations based on the thickness, and we had to reduce the thickness of the drift invert to accommodate adding a thicker getter material.

Because your other releases are primarily iodine and technetium and the sorptive capacity of apatite for technetium isn't all that great, performance of this particular design feature isn't all that impressive at the 10,000-year time frame. You do see that based on the material thickness and assuming that the getters are actually going to be there in out years, you would get a measurable performance at later years depending on the thickness of the material.

The features that dress the repository safety strategy will influence postclosure performance. That tells us that, you know, we think we've got the right strategy. If we look for design features and alternatives that address that strategy, we're going in the right direction.

Features that address water contacting the waste package or long waste package lifetime really show significant improvements in performance, but you have to define the service life of those as well.

The uncertainties and assumptions regarding the feature and the data that's used can drive performance calculations. And if they're going to be further evaluated, you know, we've got to subject these to further analysis and scrutiny so that the designers are making the best decision possible as they go through the LADS process.

We expect to continue to work with the designers in Phase 2, and the process modelers. We're going to develop models based on the new EDA's. I haven't seen the final versions of them yet, but I'm sure we'll get hammered with them later this week. It's certainly the right thing to do. Working with the designers during the development stages I believe is a good thing. It gets us talking about issues early, we're not waiting till the end to start doing our evaluations, it helps us develop our models a little earlier in the evaluation period. I suspect we'll have to do more sensitivity analyses for those designs to get carried forward, and of course if anything gets carry forward, carried to site recommendation, we're on the hook to do the postclosure evaluations for that as well. But we'll have a leg up on it, I believe, because we're working with the designers and the process level modelers so closely on the early development of these designs.

We think we've given the designers some insight into how their features can perform. We've given them one part of--or one piece of the information they need to make their decisions for those EDA's that are going to be carried on to Phase 2. We've identified where if we're going to carry a feature or alternative we have to get additional data to develop a defensible representation for use in future PA's.

NELSON: Great. Thanks, Rob. Let me ask you real quickly, in the past we've been given to understand that PA and the results of analysis from PA have been used as at least one criteria, if not a main criteria, in deciding where to allocate resources for obtaining additional data or model development costs. Do you anticipate that to be the case during this next three months as well where you in the PA process would be giving feedback that could have an implication like that?

HOWARD: Well, if you're asking me if I need help will I ask for it, the answer is yes, and will I get it, the answer is yes as well.

NELSON: And I mean more than working through the analysis but identifying places where an investment in resources would address some of the uncertainty issues effectively and allow the creation of better models. Am I asking the question at all clearly?

HARRINGTON: I'll help. Or maybe not. I'll try. I think she's focusing not just on within--this is Paul Harrington, DOE.

NELSON: This is Paul Harrington. Thanks, Paul.

HARRINGTON: Not just within POE but the use of PA as a tool to better focus the design activities, as you're doing your preliminary analyses, are we able to weed out potential design features without having done a full-blown PA analysis?

HOWARD: I don't know if that--she's frowning, so I'm not sure if that's the same question, but--

NELSON: Yes, my face is transparent. People have told me that. It's more like there are some components of the PA, in looking at the new EDA's, that really haven't been investigated as thoroughly as others. And in order to get them to the point where you can make best decisions about it, there may be some funding, some experimental work, some other things that need to get done. That has been a feedback loop that has happened in the past regarding experimental work in the field, for example, what goes on and what doesn't go on. Do you expect this process to be continued where the PA is giving feedback about what priorities could be established for such investments?

HOWARD: Well, I'll give you my answer. We'll give them what we think we need. Of course, you know, I don't have the world view of what the resource allocation should be, but we'll give them as much information as we can about where we think we could use more data or more process level models to improve the performance assessment. That will have to be weighed against other priorities of the project. But we've been fairly happy in the past with how that's been done, and I don't expect that to change at all.

NELSON: Okay. Well, that was a pretty good answer, Rob.

HOWARD: Do you want to add to that, Paul?

SNELL: I might add a comment if I may. One aspect of what we're doing now with the alternative selection is making relative comparisons of options, and that's sometimes easier to do than coming up with absolutes. The question you're asking has to do with both, but especially I think it bears on demonstrating performance in the absolute sense or the, you know, final answer. And I think what you're asking about is going to play a major role in things as we go ahead. We are trying to map test results from test programs that are already ongoing against performance assessment to look and see just how solid, how sound and how well supported our models will be as we go ahead. And as we develop the alternative designs, the strengths and weaknesses of those designs will highlight areas where we need additional data or additional work to be done. We'll take advantage of those insights that are provided. And if you look ahead even further to SRLA and you look at what sort of defensibility and other aspects you need for--ultimately for licensing, for selecting, first of all, for the site and then licensing a design, that's going to suggest also areas where resources need to be applied. I think we use all of those things to help us.

NELSON: All right, I guess seeing something like that in overall process, like the Phase 2 process and beyond, that loop would be useful, that's why I was asking, there isn't a loop for what you're learning from that--

SNELL: Okay, we'll try and provide something a little more specific--

NELSON: Great.

SNELL: --in that regard--

NELSON: Thanks.

SNELL: --try and give you a better view.

NELSON: Thanks. Now, Dan's going to kick me unless I let him speak, and then Paul.

BULLEN: Bullen, Board. I think I want the answer to Paul Harrington's question, which was, is PA used specifically to help in the design selection? And maybe the key there is, if there are certain uncertainties that you see that can't be reduced, or those uncertainties are something that are going to require insurmountable model development or additional data, are those designs going to be left by the wayside, maybe rightfully so, because you don't know that you can narrow the uncertainties associated with that and you might follow a path that is more certain?

HOWARD: Well, I can give you an answer to some of the features that we looked at and I haven't seen put back on the table for EDA's. Surface modifications is one where we did some performance assessment evaluations, at least some interim evaluations, and we showed scraping alluvium, for example, off the surface was a non-starter as far as postclosure performance goes. You look at that along with the cost of doing it and you ask yourself, well, why would I carry this forward? You know, that has to be documented somewhere. But performance assessment is used in that case to look at it.

On the other hand, we have to be really careful that some things don't get thrown out just because they don't show any postclosure performance with respect to the Viability Assessment design. Blending is one of them, and there may be some very good reasons why we would want to blend our wastes and put them and make them a more uniform heat source for certain aspects. In that case, I don't think that they're going to say, "Well, just because you showed insignificant postclosure performance assessment delta, we're going to take this off the table." Again, we're done with respect to the Viability Assessment.

BULLEN: I guess the follow-on question would be, it appears that if there's an extremely uncertain characteristic, or something that you couldn't reduce the uncertainty on, such as thermal hydrologic response that you have difficulty dealing with, and yet you have a cool repository design that has less uncertainty, is there going to be a case where PA is going to be used to make the decision? I mean, to make the hard decision and document it that that's the one you decide to carry forward? And how will that be done? And that's probably more a question to Dick than to you, Rob.

HOWARD: Thanks.

SNELL: If we have an alternative with some serious uncertainties, first of all, yes, we will use PA to help us assess those uncertainties, there's no question about it. One way the PA can help us in addressing them is to give us an idea as to whether or not we have a way of bounding those uncertainties. It might be possible in some case to use PA let's say in a worst case sense, and if the worst case sense is something that does have greater confidence, we could say, well, we can use that. If we recognize that we've got a worst case scenario, we're able to bound it and we can select an alternative that goes to the bounding situation and we can get past the uncertainties. There are some design features, perhaps, where we will use PA to help us understand the uncertainties. If we find a situation where the uncertainties are irreducible by any reasonable means that we can see in any kind of a near term, then we may be forced to conclude that the use of that feature may simply not be feasible for us, I suppose.

BULLEN: Thank you.

CRAIG: Craig, Board. I have this physicist's view that I kind of have a feeling that things ought to be transparent and there ought to be backup envelope calculations that will give me a flavor for what's going on, so these questions are along that line. Can you throw up Figure 16? I have two figures I want to ask you about. 16 is the one that talks about Richards Barriers, one of the ones. And the question on that one is that when you throw in your Richards Barrier and you let it fail after 2K years, you get an increased dose at a certain time.

HOWARD: Right.

CRAIG: Why is that?

HOWARD: Flushing. I think it's flushing. I'd have to go back and look at the inputs, but I believe what you're getting is you're getting flushing at that point.

CRAIG: Okay. Good, it makes sense. Figure 11, that one is one where you've added some more C-22 as a drip shield, and the thing that makes C-22 particularly interesting is that all of the defense depends on this few hundred angstrom thick passivated layer. Quite remarkable.

Now, as I recall, the canister itself in your design has about two centimeters of C-22 on it; is that correct?

HOWARD: That's correct.

CRAIG: The main canister. And now you've added another two centimeters of C-22 as a drip shield, which has the possibility of some common mode failure. But that's not the question. What I'm trying to understand is why it is that you get what looks like about three orders of magnitude change in dosage after a couple hundred thousand years when all you've done is to double the amount of C-22. What's causing a three-order of magnitude shift?

HOWARD: You talking about this spike right here (indicating)?

CRAIG: I'm not talking about a spike. If I go out to 200,000 years, the base case has about 10^{2} milli r per year, and now you're down to 10^{-1}, which is three orders of magnitude reduction in dose, which results entirely from putting in another two centimeters of C-22. Admittedly in a different configuration, different engineering, but still only two centimeters of C-22. So there's some extremely non-linear effect going on, and the question is, what is that effect?

HOWARD: That's a real good question. I can't answer that without going back--

BLINK: Rob, can I help?

HOWARD: Of course you can help, Jim.

BLINK: Jim Blink, M&O. The base case has only a few waste package failures that are driving those doses. The average lifetime, or the mean lifetime, of two centimeters of Allow 22 in the base case is around 150,000 years. So you have very few packages that the does that's rising there is rising from the tail of the packages. In the drip shield case, you have an independent failure mechanism between the package and the drip shield. So the drip shield is keeping water off almost all of the packages for a long time, 150,000 years, perhaps. And then you have to have the failure of the second layer, and you don't have any advective releases until the drip shield is gone, is perforated. So I think it's kind of like a Defense-in-Depth, you need to have both fail.

CRAIG: Let me try what I think is a rephrasing of what you said, and you can correct me if I'm wrong. YOU've got one juvenile failure that takes place at a time, if I remember, of 1,000 years. When does it fail, is that correct?

HOWARD: 1,000 years, yes.

CRAIG: 1,000 years. One juvenile failure at 1,000 years. With the drip shield, presumably you don't have any juvenile failures on that, so in effect what you've done is to eliminate the juvenile failure element completely. If that in fact is what's going on, that would explain the phenomenon we're seeing here, but it raises a whole set of rather interesting technical questions.

HOWARD: Yes. That's actually not correct. We assume that that waste package fails regardless of whether there's a drip shield there or not. In other words, it could fail by assuming that there was some lousy weld or some other unknown failure mechanism. So that you can see going back to the early time frame, there is the early failure of the waste package, but again, it's a diffusive release out of the waste package rather than an advective release.

CRAIG: So you're assuming that the drip shield continues to work even after the package has failed, and somehow in this early time frame some water is getting underneath the drip shield and causing a release--

HOWARD: Yes, there's--

CRAIG: --is that correct? How does it get under there?

HOWARD: We just assume that there's moisture there that's available to diffuse through it. You know, we had to make an assumption, we're not--

BLINK: Rob, that one's condensation.

HOWARD: That's right, it would be condensation. We didn't explicitly model it of what the temperature and relative humidity and what the actual saturation would be underneath that drip shield for this phase of the evaluation. It's a pretty complex process and we just had to assume that there was going to be something there, and that was--rather than trying to paint a rosy picture and say no releases, we said there's going to be something there. If there's something there, we can get it out.

NELSON: Okay, last question. Alberto.

SAGUES: Yes, taking into consideration the potential temperature differences between the drip shield and the package, assuming that the drip shield is cooler and that's why those two centimeters of C-22 on the drip shield are so much better than the two centimeters on the package, is that where some of the difference comes from?

HOWARD: No, it's aqueous corrosion only.

SAGUES: Right, but aqueous corrosion will be less severe at lower temperatures. Are they taking that--

HOWARD: That's correct.

SAGUES: --into consideration, is that what it is?

HOWARD: Yes. That complexity has not been built into this evaluation yet. You know, we didn't look at water movement underneath the waste package or between the waste package and the drip shield for this case, we just assume there was enough water there for diffusive release. If we're going to carry this one forward, that's a process that we need to look at as far as the saturation, the water movement, temperatures and relative humidities. We just assumed that the temperature and relative humidity calculations for the base case we just superimposed them onto the drip shield.

SAGUES: And the drip shield is assumed not to fail by any form of localized corrosion?

HOWARD: That's correct.

SAGUES: However, the package has a certain susceptibility to localized corrosion?

HOWARD: That's right. The package will still fail, there's still pitting in it, there's still that crevice because it's the carbon-steel over the Alloy 22 inner barrier.

SAGUES: I see. But they don't assume any crevice effects to the aggregate or they're still in contact with the drip shield.

HOWARD: That's correct.

SAGUES: And that's assumed to have no detrimental effects.

HOWARD: Right. General corrosion only, no crevices.

SAGUES: I see.

NELSON: We now move into a 15-minute period that's been reserved for comment by people from the audience. We have three people who have signed up for this time interval, and since we have 15 minutes, we invite each about on the order of five minutes. And we invite people to take this podium or to take a microphone that's in the audience as they feel comfortable with.

First person who signed up is Sally Devlin. So, Sally, would you like here or there?

DEVLIN: Here.

NELSON: Great.

DEVLIN: Hello, everybody, I'm Sally Devlin from Pahrump, Nye County, Nevada, and I live in the shadow of Yucca Mountain and I've been doing this stuff for five and a half years. I want to thank you all for coming, and it's so much fun to see so many familiar faces and so many handsome and beautiful new faces.

But I have two quick questions for you, and that is you're talking about the licensing of a repository. And I'm fortunately living in Nye County, and they asked me what this meeting was about and I go back to Nye County to the few people in Bahi, Amagosa and Parumph who can read and are interested, they will kill me. Therefore, I am requesting, and I'm facing the Board, unlike the NRC meeting who sat for two days with their backs to us, and that's why I'm standing here. And that is I would like the documentation, the time table and all the rest of it on how this licensing procedure proceeds. So you understand what I am faced with.

The other question I know this brilliant, charming, handsome, gorgeous Board can answer is where did you come up with the 25 mrems, where did you get the number, and from whom? I know NRC can't give it to you. Who gave it to you?

And I'd like it documented who gave it to you.

NELSON: We'd be happy to talk--I don't think either one of those--either the licensing steps nor the 25 mrem criterion are Board specified in any way, shape or form. So I'm sure that the licensing sequence of steps has been mapped out by DOE and by the project, and that can be supplied, Paul? I mean, Paul, do you want to take this?

CRAIG: Yes, I would. You know, we ought to talk about this off line. But I do want to mention what I think is the best and easiest to read source that talks authoritatively about this problem, and that's the technical standards for Yucca Mountain, the so-called TYMS Report that I mentioned earlier on. And it makes explicitly reference to international practice, which is in the range of 10 to 30 milli r per year, and says that based on international experience that's a reasonable range to go in. They also make some explicit statements about how Yucca should perform with respect to maximum dosages and when the maximum dose should be determined.

But on your specific question there's a very nice discussion in there with some references, and I'll tell you precisely how to get that book. In fact, I'll even get you a copy.

DEVLIN: Remember we don't have the internet.

CRAIG: I'll get you--

DEVLIN: --and we are not on line and we are barely born in Nye County. Thank you.

CRAIG: Sally, I will personally deliver a copy to you.

NELSON: And there will be additional discussion of this at the Board meeting starting tomorrow.

Paul, did you have any additional comments, Paul Harrington from DOE?

HARRINGTON: Paul Harrington, DOE. Sally, we can get with you and we'll share what we see as the licensing process.

NELSON: Okay, the next person to sign up is Judy Treichel from the Nevada Nuclear Waste Task Force.

TREICHEL: Okay, you already said who I was and I don't have to say that again. This discussion today started out with two things in mind, and I would say that as far as the public is concerned, one of them is far more important than the other, although the meeting has focused on the other. And Rick Craun's first view graph talked about the design selection, defining and updating designs for site recommendation and license application. And the public is--particularly in Nevada, but there's an awful lot of people in all different places. As many of you know, there was a huge letter that went into the Secretary of Energy from over 200 groups, and that probably represents hundreds of thousands of people asking that the site be disqualified. There were also letters from Governor Miller and now Governor Gwynn for the same thing. So the site recommendation part of this is right up on the top of the scope in the public.

And in what you've been discussing here for the license application and design alternatives and selections of designs, it was said that we'd probably wind up with one design alternative and optional features when you get to the license application, and the features can fill in for the uncertainties. But it seems to me with all of this sort of fluid characteristic of this thing, where you've got features either being described as part of Defense-in-Depth or features that are "integral" to design, or the term has been used "mutual dependency," that it's very difficult to see where you would wind up with the sort of redundancy and Defense-in-Depth as was pointed out over here, where you've got the little computer deal and you've got the prehistoric one where neither one of them has anything to do with each other but you're all set if you have a failure. And I don't see anything like that with any of these.

And when it comes to using any of this for site recommendation, I don't think it's appropriate. I think what you're proving possibly, or what you're trying to prove, is engineering adequacy rather than anything that leads to a site recommendation. So I don't see any of this as being appropriate to determining the suitability of the site.

If you had a terrific site, what the public would consider to be a good site, a suitable site, a great site, almost everything you're talking about here would be features that could then be Defense-in-Depth or whatever. If the geology really did it--and it doesn't, as you saw with the graph that we've discussed so much--that you're looking at a waste package, you're looking at engineered stuff and maybe making this site work. And you get into the idea that it can only leak this much, so therefore you have to engineer rather than if it's going to leak that much just because of its inability--Yucca Mountain's inability to isolate and contain waste, then the site isn't suitable. And in many cases, although they talk about the attributes of this site, the site itself presents challenges. And it's almost like a patient that's being overmedicated. You start to have drug reactions that you're fixing with other drugs, and you get into a really crazy chase. And I would imagine the exercise that we've heard about this morning was a very ambitious undertaking.

And Dick Snell also was talking about how we're looking for balance between the natural and the engineered barriers. Well, you may be, but the public isn't. When the public is told that Yucca Mountain--we're at Yucca Mountain because it's such a great site, or it has the potential to be such a great site, that's what they're looking at, is just the natural.

And when you mentioned that there were characteristics of Yucca Mountain that weren't--as a part of the mixture weren't brought up here, weren't on the charts, like it being very dry and very remote, those aren't necessarily great characteristics. It's very dry, so you have to irrigate. You have to irrigate your lawn, you have to irrigate if you're farming, which is what they do down gradient from Yucca Mountain. It's remote, so you do have farms, you do have the kind of lifestyles and activities going on out there that you wouldn't otherwise have.

So I think for site recommendation that's a different discussion. I think you're talking strictly about licenseability here and how you can sneak into that and be able to get it on somehow, against all odds. And I'd love response if you disagree with this, and you probably do, but it's easier to be real quiet.

NELSON: Anybody want to respond? Oh, someone in the audience.

HARRINGTON: Paul Harrington, DOE. The one curve we put up there that generated the most response had the apparently heavy reliance upon waste package. That's the one I think you were referring to.

TREICHEL: Yes.

HARRINGTON: Yes. That curve is not surprising given that we have designed a waste package that's intended to last essentially 10,000 years. We may have done ourselves a disservice by not providing similar curves for the out years. Paul Craig had made the comment earlier correctly that we shouldn't be concerned just with a 10,000-year period if that's what the regulatory period turns out to be. We are wanting to consider peak releases. If we had drawn those curves for beyond 10,000 years, there wouldn't be that significant delta between features.

Additionally, that has one bar for all of the waste package, all the engineered barrier features. A more effective approach might be to describe just what performance you get from various parts of it. I think we'll probably be looking at that in the future.

TREICHEL: Well, you're kind of splitting hairs, and I also certainly am not a scientist, but it seems to me in that presentation, page 13 plus page 14 do not equal page 19. And we can maybe talk about that, because it doesn't work for me. But at the time that Yucca Mountain was selected as the only site to be investigated, when there were three sites and that one was selected, there was obviously an overzealous director of this program here, but his assertion was that you could toss this stuff down that hole naked and there it would stay. And so there's a lot of hair splitting and a lot of changing going on at this point.

HARRINGTON: Paul Harrington, DOE, again. We're certainly not trying to split hairs. I guess I would say that we have learned an awful lot over the past five and ten years and even two and three years and we're trying to develop a design that can work in concert with the mountain as we find it.

TREICHEL: You're trying to make it work. Thank you.

NELSON: Okay, our third and final speaker registered for the public comments session is Perry Montazer. Is he here?

MONTAZER: Hello, I'm Perry Montazer. Most people know me as Parvis. I just have two quick comments, one which is to kind of follow up on what Judy has been saying and is related to Dennis Richardson's presentation. The problem that I see--and Dennis touched upon that, but I don't think the importance of this was conveyed or was received very well. The importance of these--what is really affecting those curves is the amount of uncertainty that we're putting in the performance of each one of those components. The way I see it, and going back historically, we used to give very little confidence in the performance of the waste package. And geologic component in the unsaturated zone, we had a lot of confidence in it. And today, the way I see it, we're putting a lot of confidence in performance of the waste package and we're taking away the confidence in the performance of the geologic repository.

Just as an example, look at Calico Hills. Ten years ago, if we put a lot of--actually, today, if we put a lot of confidence in performance of Calico Hills, we don't need any waste package for the system. Calico Hills can handle by itself, basically retard or prevent the release of the radionuclides. The problem we're having, and I see it, and that's something that the whole project needs to look at when you do these analyses, change the uncertainty and see if you can come up with the support. What we have as far as waste package is all the material--the oldest material that I think is being used in the waste package is less than 100 years. That is, to our experience is less than 100 years in the waste package design. C-22 is--I'm not an expert in this--no more than ten years. Therefore, I don't understand how we're putting so much confidence in the performance of C-22 over 10,000 years. That is something that I think you need to think about.

The other thing that relates to the Richards Barrier, the next presentation, Richards Barrier as a barrier is a misnomer. I've worked on this problem for the past 15 years, analyzed it for the landfills, and etc. The only advantage you get from Richards Barrier in this system in the protection against the rock fall. There's no hydraulic advantage that you're going to get from the Richards Barrier, because if the water can drip into an open drip, it's definitely going to be a lot more attractive by any kind of coarse material that you put in the tunnels. Therefore, I don't think Richards Barrier is going to perform hydraulically in your benefit. So you need to rethink that and basically just go back to the literature. I don't even think that we need to analyze that.

That's all I have.

NELSON: Well, thank you very much. The three people who made comments now, if you are interested in making comments also at the end of the day, please let us know so that we'll know to keep you on the list.

We have an outside chance that someone in the audience might have a TYMS Report, and if you do, and we promise to replace it, we would be happy to give that to Sally or arrange a connection and then replace it if that works out. Please come up and see Paul Craig, he's the one who wants to do it.

Okay, this afternoon we're going to hear about the three teams who were considering different varieties of EDA's, hearing about the final closeout vision for Phase 2 as a process, and then have a panel discussion of what we've heard today. So hope you all come back. We're adjourned now until 1:00.

(Whereupon, a luncheon break was taken.)

A F T E R N O O N S E S S I O N

NELSON: The Panel on the repository is reconvening for the afternoon session. And our first presentation will be by Carl Hastings, who is a metallurgist as a friend of mine would say, who has worked on the project here since early 1995. It must be about your four-year anniversary?

HASTINGS: Yes.

NELSON: He is a member of the TRW Senior Technical Staff and has been with TRW for the past 16 years. And he's going to speak on the first of the EDA concept teams, the low temperature concept. Good afternoon.

HASTINGS: Hey, good afternoon. I have the dubious distinction of addressing you right after lunch, and I'm going to try to get your adrenalin flowing about ten percent of what mine is right now. I had a professor back in school who for his classes that he had right after lunch he had a particular technique for getting people's attention. And what he would do is give us a little pop quiz each day we came back after lunch, and believe me, that worked very well.

So I've got a little pop quiz that I'm going to give you here, a short one, to get things started. One thing I would ask you is you heard Rick Craun and Dick Snell talk about the work we had done in getting down to eight EDA's, and you had heard them talk about the evaluation that was going to go on in the second phase and use of the criteria in the second phase. And now we're going to be presenting eight EDA's to you, my talk and the next two, and my question to you is, which EDA's are going to go through that evaluation and be written up in Phase 2? And I'll tell you the answer.

It's not going to be the eight that we're about to talk about. The eight that we're about to talk about came out of that workshop. That was our tasking to report to you on the results of that workshop. This last week and the early part of this week we started with those eight and the other Lego building blocks and we are creating a set of EDA's that we will take forward that we will be doing the detailed evaluation on and will be reporting. So we are going to give you the results of our workshop, but don't be surprised if in a week or so you hear that we're doing detailed evaluation and reporting on four, five or six EDA's and they may bear some differences from what you heard at this session.

The second thing that I--second question of the pop quiz is, how long do we have to do the detailed evaluation of the EDA's that we take forward? And I'll give you the answer to that one as well. We have this period of time in this box, that one right there. This is the second workshop that happens the first week of March, and then after the first week of March we have this period of time out to the 20th of May to get it all documented, reviewed, approved, both at the

M&O and the DOE level. So we have a very short period of time, essentially this right here (indicating), to complete the evaluations that we have to do.

So now that I have your attention, I'll go on and give you the results of what happened at our workshop with regards to the low-temperature repositories.

First thing I want to share with you is, again, I want to make sure there's no misunderstanding, we're talking about low-temperature repositories. If any of you have been exposed to the EIS work or previous work, you may have heard mention of a low thermal repository, low thermal, medium thermal, high thermal loads, those kind of things. Those were referring to the total mass of the uranium or the equivalent of the spent fuel and how it's spread out over the mountain, and it's more of a mountain scale look at the spreading of the thermal load. A low-temperature repository is not necessarily a one-for-one correlation with a low thermal load. We can achieve a low-temperature repository with compacting all the fuel into a fairly tight space and then blowing refrigerated air over it and come up with a low-temperature repository.

So what I'm going to be talking about here are some design concepts that address the low temperature repository, how can we get the temperature within the emplacement drifts down to a relatively low temperature. It's not a cold repository, but relative to the others, it's a low-temperature repository.

And when we were given that particular assignment, that wasn't defined for us. There's no definition of what do you mean by low-temperature repository. And so one of the first things we had to do as a breakout session is come to grips with what are our goals, what's motivating us, what do we want to accomplish with this thing called a "low-temperature repository". And we came up with these four goals and there was a whole lot of discussion and understanding that went behind those, and I'll try to share some of that with you.

For instance, the first one there that's addressing the defensibility of our capability to predict what's going on, that's trying to get at an understanding of what are our uncertainties, what are the processes that are going on out in the rock between the rock and the water and the steam, and that sort of thing. And so one of our objectives was, how can we make our predictions more defensible? And that was something that we felt we could take a major step forward in coming up with a low-temperature repository.

The other one had to do with the more benign environment of the waste packages. There's a general rule of thumb or a general understanding, not really a rule, that says you have a very aggressive corrosion environment if you're approximately between 80 and 100 degrees C and if your relative humidity is above 80 percent. And so if we could find a way to either stay out of that regime, the warm, wet regime, or to spend just a very little time in that regime, then we felt we could have a more benign environment for the waste packages.

The other one had to do with the preservation of the natural environments. When you start pumping a lot of steam, superheated steam, hot kind of stuff into the natural environment, into the rock, there's a lot of questions about just what's going on there, what are the coupled processes, the thermal, the mechanical, the chemical, that sort of thing. And so we thought one of our goals would be to try to reduce or mitigate some of those processes and thereby protect the natural barriers.

And lastly, we were thinking if we can keep things cold, relatively cold--I would say "warm" is probably a better term--that we would have better access into the emplacement drifts or up to the waste packages if there was some unforeseen event that took place that dictated we needed to get people in there fairly quickly. If you start from a low temperature, we could blast cool and get it down to a reasonable tolerable temperature in a very short period of time. So that was also wrapped into our goals.

So once we had established our goals, then our next step was to say, "Okay, how do we convert those into some kind of a design objective?" and we wrestled with that a little bit. And you can see the four possibilities that we came up with here. One, we played with the boiling point, or the boiling isotherm, and we looked at going out into the rock about 10 meters and establish the boiling isotherm out at that point. A second possibility was to go right here to the drift liner wall and establish the boiling point isotherm at that point. We could even pull it in a little bit further right to the surface of the waste package, and we could take a step further and say that we want the surface of the waste package to be significantly below that boiling isotherm.

So those were some ideas we played with. We developed a number of candidate EDA's based on each one of those, and towards the end of the workshop we came down to this one (indicating). We were going to focus on trying to keep the surface of the emplacement drift at or below boiling. So that's what we took forward.

We came out--we started off with a number of candidate EDA's, but then through various processes we boiled them down to these two. One is identified as a line load and the other one's a point load, and for those of you that have heard that term but aren't sure really what that means, I've tried to stick in some pictures here. A line load refers to how closely spaced the waste packages are in the drift. If you get them close enough, then you have a thermal communication from one package to another. The other thing it does for you is it allows you to spread the drifts further apart. And so since all the waste packages are lined up in a nice tight line, that's referred to as a line load. The other option looks at a point load. That's where the packages are spread relatively far apart, there's very little communication, thermal communication, between the waste package, so each waste package kind of works as a point source of the heat going out into the rock. And in that case the drift are typically spaced a little closer together. So when we refer to the point load and the line load, that's what we're talking about. And then I'll go into more detail as to what the particular characteristics of those are.

We did make some assumptions on both of those particular designs, design concepts. One of them had to do with blending. In our case, when we talk about blending, we're talking about blending the fuel assemblies within the waste package. That term is not unique to waste package blending, but that's how we used it here. When we take--in this particular case that's a picture of a waste package that will accommodate 21 PWR fuel assemblies. And so when you--if you just fill that package with the waste as it came in the door, there would be a possibility that the total power output of that package could reach as high as 18 kilowatts.

If you took some time and looked at and understood the thermal output from each fuel assembly and you blended them, you put some hot ones with cold ones in the same waste package, and if you did that perfectly across the whole repository dealing with all the waste, then the average power output for those waste packages would be down around 9 or 10 kilowatts.

And what we're saying here is for 20 percent variance and perfect blending, we're saying it's unreasonable to assume we're going to have perfect blending, so let's back off a little bit. Instead of 9 or 10 kilowatts per waste package, the hottest one may be about 12, which is significantly lower than the 18, and the cooler ones could be down around 4, 5 and 6, that sort of thing.

So that's what we meant when we talked about the plus or minus 20 percent variance on perfect blending.

The second assumption we made is that we would be able to get all the waste that we're dealing with within the primary area. Primary area, what is that? Well, here's a picture that shows the ESF, the north and the south portal. The upper block is this end right here (indicating), and you'll find out tomorrow that that's where the VA design resides, is entirely within that upper block. There's something called a lower block that's on the other side of the Ghost Dance Faults. We also have fairly well characterized that area is readily available, it would just take more tunneling to get to it. But this whole area we're referring to as the primary area. And our assumption is that for both of our cases we would be able to get all the waste that we're interested in within that primary area.

The third assumption is that we're using in-drift emplacement. That's the picture I showed you on the previous page. It's a waste package sitting in the middle of a drift. That essentially says we looked at borehole emplacement, we looked at other options, and this was the one we decided to go with.

Okay, looking at those two particular designs, this one is the line load. It's spread out over 1300 acres, which essentially fits in the upper block of the primary area. The drift diameter, we can go a little bit smaller than the VA. The VA is 5.5. Our initial thinking is we could take that down to about 4.5 without any detrimental problems. The spacing is 25 meters, and again, just for reference, tomorrow you're going to find out from VA that their drift spacing is about 28, so we're further spacing in our drifts.

The waste package, I show two of them here just for relative size. When we talk about 12 PWR assemblies in a waste package, that's a somewhat smaller waste package. That's this one up here (indicating), it will hold 12. When I get to the next slide, you'll see where we go to the larger one, the 21 PWR. I put it on this slide so that you can see the relative size between the two. So the one for the line load would use this smaller package, it would have the corrosion resistant material, or the nickel-based alloy, on the outside of the package. The carbon-steel makes up the inside layer. That would be the corrosion resistant layer there, and that would be the corrosion allowance or the carbon-steel on the inside.

We have some operating aspects of this particular design. One I talked to you about, blending within the waste packages to keep the maximum thermal output down to a lower level.

Two other aspects, one has to do with aging up to 30 years. If we do the blending and we get several hot assemblies into a waste package and so we're dealing with a waste package that has a thermal output around--in this case, because we're going with the smaller one, our worst case thermal output would be on the order of 5 kilowatts. If we get one of those, then we would age it on the surface for up to 30 years. If we put all those assemblies into the waste package and it comes out around 2 or 3 kilowatts, we could put that right into the ground, we wouldn't have to do any additional aging. So this is talking about the potential for aging to get the thermal output down.

And then we go into--put it in ground, and in ground we have a preclosure ventilation. This is, again, just to put things in perspective, the VA that you're going to hear about tomorrow has some preclosure ventilation, but it's a very small amount, it's just a whisper that goes through there once you've loaded up a drift. Prior to loading up the drift there's a fairly good amount of air flow through there to keep the temperatures down. And if after closing up the drift you need to get back into it, the VA design has a capability of what they call "blast cooling". They can open up one drift and send a hurricane through there, if you will, and get the temperatures down fairly quickly.

What we're talking about here is there would be a continuous flow of ventilation air through the emplacement drifts even after they're loaded something on the order of one or two cubic meters per second, and that will be enough to achieve our design goal of keeping the emplacement drift surface at or below the boiling point.

The second design that we had I said was dealing with a point load. This one, because of the larger waste packages that we're going to, requires a little more acreage, but that is still within the primary area. It will most likely use both the upper and the lower block to emplace the waste. You can see a little bit diameter, that's the same size as the VA option. Spacing of 60 meters is quite a bit bigger than the VA and a little bit bigger than the line load.

It's the same waste package that we described for the line option and the same characteristics down here for blending, aging and preclosure ventilation. A slight difference in the period of time. We may have to age on the surface for up to 50 years to get the initial temperatures down to a point where we can put them in the ground and not have to do a tremendous amount of preclosure ventilation.

So the integral characteristics of these designs are identified here. It's a relatively low thermal load. The VA is at about 85, these are talking about 45 to 50 MTU. aging, blending, preclosure ventilation are all integral aspects of these designs. Timing of the repository closure could be an integral aspect. We age on the surface to get it down to a certain temperature, we put it under ground, we had the preclosure ventilation. If you closed real early, you wouldn't get the advantage of that preclosure ventilation. So that would be something we'd have to look at. I've talked about the drift and waste package spacing and the waste package with the corrosion resistant material on the outside.

Other features that could be used in these designs that we can allow the designers to do sensitivities on would include enhanced access. I already talked about we have the temperature relatively low, take a little bit of blast cooling to get it down so a human could get in there. We can look at other ways of shielding the waste packages from a radiation standpoint so that humans can get into the drifts.

Drift diameter, we can play with that a little bit for the one that looks like we can get it down to 4.5, and so that's something that we can look at further.

Canistered assemblies, that's looking at instead of putting those fuel assemblies directly into the basket inside the waste package, you can canisterize them. If the utilities are to be done at the repository, you can canisterize each individual assembly or you can canisterize several of them and then put those canistered fuel assemblies into a waste package depending on the selection of material that can give you some additional performance, postclosure performance. So that's a possibility to look at. It has no effect on whether we're talking about a high-temperature repository or a low-temperature one, but if we're looking for ways to improve performance, that's a possibility.

Drip shields, backfill and Richards Barrier as well as ceramic coating are all options that we can look at to improve performance.

Rod consolidation is where you take each individual rod out of the assembly and you package them all tightly packed together inside of a canister and then you put that canister in the waste package. That's a possibility, as are additives and fillers, which are things that you put in the waste package to give you a little better performance in one aspect or another.

So those are the integral parts, and then these last few charts are to help explain some of the terms that we're using. The ceramic coating, that's just an extra coating that goes on the outside of the waste package. The drip shield you saw an earlier picture, but that's a metal shield that fits over the top of the waste package and it's set off from the waste package, it's not in direct contact with the waste package. We could use that in combination or independently with backfill that's shown here. You can put that either over the drip shield or directly over the waste package.

And then the term "Richards Barrier" is shown down here. That's where we'd have kind of a coarse sand which would go right on top of the waste package, and then a finer sand would go over the top of that. The grain size of those two would be such that the fine sand will not flow down into the coarse sand. But that gives us a particular feature that pushes the water, the water goes down through the fine sand, reaches that interface and will flow off to the side instead of flowing through the coarse sand. So when we referred to the Richards Barrier, this isn't the only way to construct the Richards Barrier, but this is typically the Richards

Barrier that we're referring to whenever we use that term in this context.

So that was all I had for you.

NELSON: Great. Thank you very much, Carl. Can you give me an idea on these lower power output packages what the temperature profile looks like with time? How well is that known? Like if you backfilled at 50 years or at 100 years, would it stay low temperature or is that early enough to compromise?

HASTINGS: No, it most likely would stay the low temperature, particularly if we're talking about the boiling point isotherm at the drift wall temperature. If you backfill the waste package, it will keep--it will act sort of like a thermal blanket on the waste package. The waste package itself may go up a little bit, most likely would go up a little bit, but the drift wall temperature would not be affected as much. In the worst case situation, there may be some fraction of the waste packages that would be at the 3 kilowatt range, and so there may be a few points in the repository that would be right at that limit, but a large number of the other packages would be significantly lower.

NELSON: Okay. Bullen.

BULLEN: Bullen, Board. Just a quick question to follow up on that. If you keep the drift wall temperature below the low temperature isotherm that you're trying to look for, does that then take away the thermally activated processes and the uncertainties associated with that, or are you still going to be moving water?

HASTINGS: No, you're still going to move water, but what it's trying to do is stay out of the steam, or the superheated steam, regime. Even at room temperature you're giving off water vapor. There's still going to be heat out in that rock, but it's not going to be the excessive heat that would tend to boil the water, so you're not eliminating those coupled processes. But we're trying to keep them down to a range where the uncertainty isn't as great. And if we're addressing processes that have to do with steam interaction, we by and large eliminated the steam aspect. We do have higher temperatures, and so you have to deal with the coupled processes that have to do with the higher temperatures.

BULLEN: Okay, but I'm still a little bit confused here on your low-temperature repository goals. If you do backfill, then you don't have a more benign environment for waste packages, do you?

HASTINGS: If you do backfill, you don't have--

BULLEN: And you raise the temperature in near field, then the goal of keeping a benign environment for the waste package has been compromised, hasn't it?

HASTINGS: That's right, that's right. Our goal was to provide a more benign environment for the waste package, and for that period of time, you'd be in the warm-wet. You could very well be in the warm-wet. But looking at the time frame on it, you pass out of that regime within the first thousand years, depending on the particularly waste package. So you're spending a relatively short amount of time in that warm-wet for some of the extreme packages. For other packages, other cooler packages, you never get into it.

BULLEN: Well, a thousand years isn't a short amount of time in everyone's estimate.

HASTINGS: Okay. That's fair.

NELSON: Alberto.

SAGUES: Yes, the question is somewhat related to what Dan Bullen asked a moment ago. What are the projections for the temperature for the surface of the packages? How long of a time would the average package experience between 80 and 100 degrees--

HASTINGS: I'm going to give you our best numbers right now. We haven't run the detailed calculations for this, but we've looked at other similar calculations and we've extrapolated into this particular regime, and our best thinking is that that would be somewhere within the first 500 to 1000 years, that somewhere in that period, between 500 and 1000 years, we would pass out of the warm-wet regime. Was that your question?

SAGUES: So starting about year 100 until about 500 to year 1000, the package will be going from between about 100 degrees Centigrade down to 80 or so?

HASTINGS: Down to below the 80.

SAGUES: And do these projections from the point of view when they take into consideration the water extraction that will have resulted from the air flow during the initial 30 or 50 years?

HASTINGS: Again, we have not done the specific calculations for this particular setup, but looking at other calculations that have been done and extrapolating to this situation, we think that there is a reasonable basis for assuming that within that period of time, 500,000 years, we'll be out of that aggressive region. Those other calculations did take into consideration the drying out that goes on due to the preclosure ventilation. So to the extent that we can look at those and extrapolate to this situation, that's what we based our current thinking on.

SAGUES: How will this compare with the base case?

HASTINGS: The VA case--

SAGUES: Right.

HASTINGS: --for that one it's more aggressive, you have higher temperatures early, but you've driven off the water. Then when the temperatures come down, the water comes back. So I don't recall--Jim, can you help me with that one? How long are we in the warm-wet with the VA?

BRINK: You enter the warm-wet between 3 and 5,000 years, and you pass out of it around 8 or 10,000 years.

SAGUES: So I guess it will be several times longer than what this case would be, isn't it?

NELSON: Several. Paul?

CRAIG: Craig, Board. Carl, I've got a couple of questions about the timing--

HASTINGS: Sure.

CRAIG: --of the research of the engineering program. As you know, there are a number of people who feel that the warm repository really has problems in terms of analyzability and are looking to salvation in the low temperature, so your stuff here is potentially really important. And if I understood your timing--

HASTINGS: Thank you.

CRAIG: It's true.

HASTINGS: Did you hear that, Dick?

CRAIG: It's true in my judgment. If I understood your timeline correctly, and I probably didn't, I estimated that you had a grand total of 23 working days if you start tomorrow in order to do this job. And the hot repository has had a lot more time than that. You've laid out a bunch of issues here which look to me like doing them in 23 days is not going to be so easy, and it's really quite important, in the judgment of some of us, that that be done properly. Aren't you on an impossible timeline to do the job that needs to be done?

HASTINGS: I don't really think I'm qualified to answer that question. I'll pass that off to either Paul or Dick.

SNELL: I'll give you my answer, anyway. Impossible, no, challenging, yes. The thing that really helps us in this regard is that a fair amount of work has been done prior to what we've gone through here in the events leading up to the workshop and over the next month. So we're able to take advantage of a substantial number of analyses, and specifically the development of models, basic thermal models and so on, has already been accomplished, to a large degree. A lot of the model runs that were made prior to getting into this alternative effort are available to us. There were some study efforts, a waste package size study, for example, that was done earlier for which some thermal alternatives were evaluated. We have those results available. And I think the combination of the results from prior work, results of model evaluations and interpretations during the work leading up to our workshop, including what's in the 3-5 Reports that I referred to earlier, plus whatever we're able to do over the next month or so, will allow us to produce comparative evaluations and reasonable results, I believe.

Yes, Paul just mentioned we did some work in connection with engineering information to support the EIS activities as well, and those model results and data are available to us also.

NELSON: Now, at the end of this 23-day period of fun and joy, you don't expect to have a design at that point, you expect to have defined the EDA in order to make a decision, you have more time to--

SNELL: That's correct.

HASTINGS: Yes. We're looking at probably just the conceptual, only at a conceptual level, certainly not a preliminary and absolutely not a final design level.

SNELL: If we've done our work well, the concept that we come up with, or the concepts that we come up with, will be sufficiently defined so that we won't have any major conclusions overturned. If the fundamental approach and the fundamental concepts are reasonably defined and supported, from that point forward it becomes a matter of amplifying or embellishing that concept.

NELSON: Okay. Let me ask you one thing. You indicate the first goal being the predictability of the thermally activated processes is more defensible, therefore perhaps better understood than, less uncertainty than?

HASTINGS: Better understood and in some cases where we can take certain processes off the table. If there are distinct differences between the interactions of steam, superheated steam, in the rock compared to warm water and the rock, this one would tend to put us in that regime where we're dealing with the warm water and not the steam.

NELSON: Right. But as this relates to something like Defense-in-Depth, which is--I'm not sure how I would expect to see such an improvement in understanding or--

HASTINGS: Okay.

NELSON: --reduction in uncertainty--

HASTINGS: Okay.

NELSON: --to be reflected in the DID.

HASTINGS: Okay.

NELSON: Because I really see that a lot of the natural processes aren't really going to go away.

HASTINGS: Right.

NELSON: I mean, the mountain will not go away.

HASTINGS: Right.

NELSON: But it may be better understood, and I'm not sure how that improvement is going to show up in the DID analysis.

HASTINGS: Okay. Let me see if I can help you there. We're taking a lot of measurements for the in situ situation out there. As we add heat, we get further and further away from that natural environment, and we start introducing other processes and we have to extrapolate further, rely more on our models. And the PA community, as you go up the temperature scale, the uncertainty that goes along with that continues to grow. So when we would ask PA to do some calculations for a repository that had relatively low temperatures, then our uncertainties would be smaller. If we asked them to do calculations where our temperatures were up around 200 degrees C, our uncertainties are bigger.

So if you're just looking at the midpoint, or just the basic expected values, you probably won't see a whole lot of difference. But if you also fold into that what is the one sigma or two sigma response, then you're going to start to see some of those benefits showing up.

NELSON: I can see that in the PA, but in DID the way it was presented here, it's not really clear to me how we're going to see that.

HASTINGS: Okay. The DID that was presented here relies very strongly on the PA. They do a number of calculations, PA calculations, where they neutralize one barrier or another. And so it would be the uncertainty that would go along with that. Say if I neutralized this barrier, my expected value is this, my uncertainty associated with that would come along with it. So if we do our DID where we start looking at not only the expected value but at least get some sense of the uncertainty that goes along with it, then we can start to fold that into the DID.

NELSON: Okay. I'll try to think harder on that.

Don.

RUNNELLS: Don Runnells, Board. In the month or so that you have to work on this, to what extent will the low-temperature enhanced design be interfaced, connected to, related to some of the geologic, hydrologic, mineralogic aspects of the repository? For example, I'm thinking of the one design I've seen, one concept I've seen hydrologically that the water will go between the drifts and drain down. Is that going to be part of this analysis in the period of time that you have available to you?

HASTINGS: Yes, to the extent that our models capture that and that those models have been properly abstracted into the PA, we would expect to see that in this period of time. We're dealing with lower temperatures here on a continuum that goes from ambient up to 200 degrees or so that we're carrying for the VA. And so we would be dealing down in the lower temperature regime and would expect to see those kind of things. But if there was some new process or very important process that we would identify that has not been captured, that we don't have modeled and we have not captured that in the PA, then it would be very challenging, if not impossible, to get that modeling work done, get it into the PA framework and checked out in time to support this analysis.

NELSON: The PA in the first 10,000 years as opposed to the far PA. There's been a lot of development in the PA models to include the capability of seeing what's happening or evaluating what's happening in the first 10,000 years?

HOWARD: Yes.

NELSON: This is Rob Howard.

HOWARD: Rob Howard, M&O. Yes, the time steps that we use and the models we use, actually our resolution in the first 10,000 years is better than our resolution in the out years. The models are the same, essentially, except for the heat policies change, obviously, with time, and so as you go through time and you get heat, the processes we assume in our current models become closer and closer to ambient. So if the question is can we analyze in the first 10,000 years as well as we can beyond 10,000 years, the answer is I think yes, that we analyze and we understand those processes a little bit better.

NELSON: Okay. We had a question from Russ McFarland on the staff?

MCFARLAND: Russ McFarland, Board Staff. Carl, several years ago a white paper was generated in the M&O on multi-level repositories. Would you speak to that white paper with regard to a low-temperature concept?

HASTINGS: Okay, that paper was looking at achieving a low-temperature repository while at the same time coming up with a mountain-level thermal load that was about the same, about the 85 or so MTU. That was a fairly short study that looked at what some of the possibilities would be from the standpoint of being able to construct such a repository, and if it could be constructed, what kind of estimates did we have on its performance.

There were no PA calculations of significance that were run against those. Again, it was taking existing calculations and that was using PA results that are several years, I think it was about three or four years older than what we have to use today, and do some back-of-the-envelope type calculations to see what kind of temperatures we could achieve in the drifts and what kind of mountain-scale loading we could get. The essential concept for that was to again look at the primary area, the upper block and lower block that I was talking about there, and you kind of stagger the different layers. You don't put them right on top of each other, but they're staggered a little bit off to the side so that there is some but limited vertical thermal interaction between the drifts. The conclusion at that time, as I recall, was that there was no significant performance improvement over the single layer and that there would be significant cost penalties to create that multi-layer layout. But there was not an objective of that study to look at the temperature loading within the emplacement drifts and trying to get that down to some goal.

MCFARLAND: Will this be part of the effort between now and Phase 2 or is this beyond Phase 2?

HASTINGS: To look at a multi-layer repository?

MCFARLAND: Yes.

HASTINGS: Probably not, because we can get all of the waste in a single layer within the primary area that we're talking about so that we really didn't see a benefit to that. If we were looking at trying to accommodate a significant increase in the total amount of waste that we had, then it would be a trade off as to whether you go to layers or go out into the expansion area, areas that have not been characterized.

MCFARLAND: Thank you.

NELSON: Okay, we're just about out of time, but Carl Di Bella.

DI BELLA: Thank you, Carl Di Bella, staff. I surmise from your presentation that you had some limits on the total duration of the aging period that you would allow and/or the preclosure ventilation period. If that's so, what were those limitations and why did you have them, and do you know if the other groups had the same ones?

HASTINGS: Okay. We did not have any hard, fast limits. We were trying to do some balancing. On the one hand, if we did all of the work by preclosure ventilation, our concern was that we may have to put in a lot more fans and shafts and drifts and that sort of thing to take care of the early phase of that heat. On the other hand, if we tried to do the whole job with aging, we would have to tie up a surface area for a significant period of time, 50 to 100 years, before we put it under ground. So it was kind of a balancing act. If we use surface aging to take care of the early heat spikes and then we use a reasonable underground ventilation to take care of the latter time/temperature aspects of the waste packages, that that seemed like a reasonable balance.

The other thing we were dealing with is we were given some consideration to being able to close the repository in 50 years. Again, that was not a hard and fast requirement, but we were asked to give that some consideration. And so we looked at the amount of time that we could age things reasonably and then put them underground and expect to get some benefit from preclosure ventilation. With the line load we felt we had an excellent chance of getting closure within 50 years. For the point load, that would be a little more challenging. We may not be able to achieve that particular goal, but we haven't done the detailed engineering calculations to confirm that.

NELSON: Okay. Great. Thank you very much, Carl.

Moving on and keeping on schedule, our next presenter is Dr. Jim Blink, who's the lead for Integrated Design Performance Review. Jim's from Lawrence Livermore

National Laboratory, working in the M&O organization.

And, Paul, he got his PhD from the University of California at Davis, so I hope that doesn't represent a conflict of interest for you.

Jim is going to talk about the high-temperature concepts that have evolved in the EDA workshop.

BLINK: While he's programming the computer, I feel a little uncomfortable with Carl being the salvation from the designs that I'm looking at. My approach here is to say heat is my friend, what can I do with it? So we've got to get away from the salvation stuff.

We came up with a set of goals similar to the other group, but again, from the other viewpoint. The top three goals are very oriented towards this high temperature idea. One is we want to drive the water away from the engineered barrier system and waste package for as long as practicable. However, that water must be shed or removed by ventilating air.

NELSON: I want to point out this is not a perfect example of DID because all things rely on electricity here.

BLINK: I call that the Bill Gates screen saver. I see that a lot.

I guess you could see most of it that way. We're trying to drive the water away, but we want to get it away permanently, shed it, remove it in ventilation, or imbibe it into the matrix of the rock in other regions of the repository. If we just hold it in fractures above the heated area, that's not acceptable.

The second goal is to avoid extended periods of warm, moist conditions, and I have numbers that are slightly different than what Carl quoted, 80 to 100 degrees C temperature of the waste package, and the relative humidity on the waste package greater than perhaps 90 percent. There's some uncertainty or debate amongst the experts as to what humidity you need to have an aqueous film on the metal. Some of the people I talk to say it's got to be above 95 percent. For TSPA/VA we sampled between 85 and 95 for that. I just picked a number of 90 here, but that's not a hard and fast number.

The last three that we have, these three down here, are goals that the high-temperature approach--they're goals for the whole repository for any design, but they're goals that the high-temperature approach might make it easier to achieve.

One is to have long-term performance even if one or two barriers are compromised, the Defense-in-Depth that Dennis told you about. This one high probably has an advantage to have capacity within the primary area for all of the waste, even beyond 70,000 tons, should Congress direct us to take a higher level.

And finally, to limit cost. If we can pack things tighter together in bigger waste packages, we have the potential to save costs both on the waste package side and the underground excavation side.

So now we have to find a way to put those goals into play. And I've got a series of about five charts that walk you through one process a person might go through in trying to invent high-temperature designs that perform well, that meet the various criteria that Kevin told you about.

The first one is we want to limit the drift wall temperature so that we limit the ground support loads. In this kind of rock, if you run up to the neighborhood of 225 degrees C or higher, the crystobalite in the rock has a phase transition to a material that's expanded relative to it, and that would greatly increase the loads. Or another way to say it is the coefficient of thermal expansion climbs fairly steeply beyond 225.

Right now in the CDA, the Control Design Assumptions document, we have a limit on ourselves of 200, but we said for this study, looking at the data, that we might agree to push to 225, the difference between the thermal expansion coefficient not being too large between those temperatures.

Another thing we can do is we can use blending and line loading to produce more uniform temperatures along the drifts, considering that a lot of our limits are limits on the highest temperature item as opposed to on the average temperature item, be it waste package or drift wall region.

So that was our first step.

The second step is now we have to figure out how to remove water from the system. We would drive the near field to above 100 degrees C to mobilize that water, we would extend the superheated region of rock and/or the reflux region above it--that's that nominally 96 degrees--several to many drift diameters above the repository horizon, creating a large dried out volume of rock. Remember that rock right now is about 10 percent water by volume, so if we can get rid of that water and have 10 percent of pores, empty pores, gas-filled pores, that's a sink for water that comes later as percolation flux. We would limit the temperatures such that the mobilized water can shed before the pillars reach above-boiling temperatures. So in a low-temperature design they're going to keep their pillars open at all times. We're going to go maybe a step more complex than that, we're going to try to use those pillars to get rid of that water we mobilize, then let them close for some period of time, and then they will be opened again as the heat dissipates and as water percolation flux comes down and kind of burns its way through.

Finally, one additional thing we can do is to use postclosure ventilation to move additional water, additional percolation water, to the footprint periphery. That is, if we run air through the drifts and let it have passage somewhere else where there are no waste packages, and then come back to the drifts again in a closed loop, we can preferentially move water from the drift region, percolating water that's working its way down, to the periphery region, where it can condense and then be shed into the rock. And I'll show you a little bit of that later.

The next step is to avoid seepage of new percolation flux while the waste packages are still hot, because we want to avoid this warm-wet business. We'll do that by designing such that the pillars cool below boiling before the flux integral exceeds the mobilized water volume. So if we integrate the percolation flux in time, we want to make sure that before that total amount of water that comes, before that water exceeds the space that we've created by mobilizing the water and shedding it, that the waste packages have cooled.

The VA design--I'm going to go the other way now, let's turn it off, since we're already here--the VA design seeks to do that, but after we came up with the thermal loading for the VA design, the changes in the properties of the mountain, the changes in the understanding of the properties, made us go away from that. So in the VA design, actually, the water comes back before the heat goes down. But there is a way--there may be ways to juggle your design variables so that doesn't happen for a broad range of properties.

The second way that one can do this is to design it such that the repository footprint as a whole sheds the water around its overall periphery, sort of a thermal umbrella over the whole repository. Obviously you don't do both of these at the same time.

The next step is to limit your waste package temperatures so that you don't exceed the cladding temperature limit for extended periods. Short periods might be okay, we have to look into that.

One way to do that is to preclosure ventilate to just below that limit for the design basis waste packages. And preclosure ventilation and aging are sort of interchangeable in this design space, although it has a significant impact on operational considerations and cost. So you'd probably optimize from those viewpoints.

If you're going to backfill, you want to delay the closure until the waste package thermal power has decayed. That's very important. Studies have shown that if you backfill at around 50 years you have temperature spikes on the waste package that are between 120, 150 degrees Centigrade. If you backfill at 100 degrees, those temperature spikes may be to only 75 degrees. So when you look at backfilling, even in the low-temperature designs, you're going to have to accept that you're not going to be around boiling that 110. The goal you're really trying to beat is the 350 on the cladding. And the delta t between the waste package and the cladding might be of the order of 90 degrees. So you can just add the backfill delta t and the cladding delta t from what you start at to see if you hit it.

The final step is to consider these zeolites. The natural system has performance in a hydrologic sense and a geochemical sense. The zeolites right now in the Control Design Assumptions document, we protect them to 170 meters below the repository horizon. That is, we do not allow ourselves to exceed 90 degrees C above that elevation. But when we looked at the zeolites from all the borehole data that we have and the underground exploration data, it turns out that in the north region, where there are a lot of zeolites, burning another 100 meters deeper with 90 degrees C, we still have plenty of zeolites left below that.

In the sough region, the zeolites are much less prevalent, but the zeolites that we have there are already deeper. So the bottom line is, if you look across the repository footprint, the minimum thickness of pure zeolite that we have from the repository horizon minus 170, the layer that we protect to, to 50 meters into the water table, is 25 meters of zeolites. We have 25 meters of equivalent zeolite thickness in our thinnest place, in our most sparse place. If we heat the repository harder so that another 100 meters of rock is heated above that level, that number does not change. The average number changes, but the minimum number stays about the same. So we believe that we could go to the 270 below the repository horizon and still not compromise our zeolite performance.

So those are the steps. Thinking of all of those, and then some of them it was only conceptual, it wasn't with calculations, we came up with three enhanced design alternatives that take advantage of that. This is a summary of the three, and I'm going to walk through them one at a time. The important parts about this are 85, 150 and 170 MTU per acre in the region of the loading. Two of them are line loads, as was the case in one of Carl's, and one of them uses this postclosure ventilation scheme.

And I'm just going to let you have that for reference in your charts and walk through the other items as we go through the individual concepts. And in each case I'm going to start out with the layout, and in each case what I've done is I've shown you the VA layout, and in the east side--east being up on this chart--in the east side I've shown you the VA emplacement drifts, about 100 emplacement drifts and about another 5 extra drifts for maintenance or air flow. And then the bottom half, the west side, I've shown you the drifts that we would have in the enhanced design alternative.

And in this 85 MTU/acre line load, first of all, we have gone to 32 PWR waste package capacity, so we have fewer waste packages total. In VA we have 10,200, and in this one we have about 8,200, so we saved ourselves a couple thousand waste packages. The drift space is 70 meters as opposed to the 28 in the VA. We only have 40 emplacement drifts as opposed to the 100 drifts in the VA. And this layout isn't exactly perfectly to scale, but it's not too bad.

The 32 PWR SNFA WP. That's a long acronym, an acronym with two spaces in it. This waste package fits within the diameter and weight envelope of the current ensemble of VA waste packages. It's no heavier than the Navy fuel waste package and it's no larger diameter than the five glass log co-disposal package. So from the viewpoint of handling it shouldn't give us any additional problems. And you can see there's 32 slots in there for the assemblies, and we've shown you some of the other details about the thermal shunts and the basket structure.

To summarize this concept, we've put an improved drip shield on this concept. By improved, it's a little better than the one that we used in Phase 1. In this case, because our waste package is dual CRM--Alloy 22 over Titanium Grade 7--we've chosen to put a sealed ceramic coating on a metal substrate as the drip shield so that we have three separate metals--or three separate long lifetime materials in our design for Defense-in-Depth. We have backfill to protect the drip shield, we have preclosure ventilation, and we'll take advantage of the effect of the concrete in sorbing some of the radionuclides to use a concrete invert and ground support.

What happens if you want to close this design at 50 years? If you do, you will spike the temperature in the waste package and overheat your cladding. So there's really two options that we came up with.

The first option is go ahead and install the backfill and accept the fact that your cladding and your highest power waste packages, each rod will get a single pinhole in it until the pressure is relieved, and then the creep will stop. As long as the waste package still is sealed at that point in time and remains sealed until the temperature falls below 200 degrees C, that cladding will not unzip. So what you've cost yourself is a pinhole in every rod, but you still haven't exposed much fuel.

The other alternative is just don't install the backfill if you decide to close that early. And in that case what happens is you don't have to worry about spiking the temperature of the cladding, but you do have to worry about rock fall. So now you have to make the case that rock fall on your drip shield or your waste package or even a ceramic coated drip shield doesn't reduce your performance as much as having those cladding pinholes would reduce it.

So this is a design trait and we'll have to look into that quantitatively before we can really say what's the right way to go.

As we went through this process, we tried to use those Lego blocks to build Priscilla's sausage car, and we divided those Lego blocks into ones that we called integral to the design and then everything else we just put in the "Other" bin.

In this case, there were only two of those Lego blocks that were really integral to this design. One was using that preclosure ventilation to limit the temperature so that you didn't overheat the drift walls and cause early collapse of them. And the other was the line load to reduce the cost and levelize the temperatures. And these acronyms out here (indicating) are the design feature number that link up with the list that was at the back of Dick Snell's talk.

The other ones, we had a major concept in this one, a design alternative that we wanted to start with the VA and make changes. So this was kind of like a perturbation design. We used an improved drip shield, we'll blend to preserve the thermal goals as much as we can, we'll delay the closure beyond 50 years to improve performance if that is permitted, we'll improve the waste package for Defense-in-Depth going to the dual CRM waste package rather than the carbon-steel over a CRM, we'll use a concrete invert for sorption, and we'll use a higher waste capacity waste package to reduce the waste package cost without increasing the subsurface cost.

Let me go on to the next one, which is the 150 MTU/acre line load. And in this case there's the VA (indicating), and this is the footprint for the west side of that one. You see, we've now gone to a design that looks much more like a square than a long, elongated rectangle. In this case we only have 40 drifts as opposed to the 100, 40-meter drift spacing, we're using the 32 PWR size waste package, so we have 8,200 waste packages rather than 10,200. And again, it's a line load.

Some more information about that design is we're not sure exactly what thermal loading to use. We have done some parameter studies. The picture I showed you was about 150, but we're looking in the range of 120 to 170. Again, we'll use preclosure ventilation to keep the pillars below boiling for centuries before they close, allowing this water that's mobilized to shed. And we want to maintain the cladding below 350 degrees C basically for the entire life of the repository, so we never want it to spike.

We want to increase the edge load protection. The problem with a high thermal load design always is the edges look like a lower thermal load just because of the 3D heat transfer out there. And so in this case what we decided to do was to either close up the drift spacing on the north and south ends, making a higher thermal load there, or to use ceramic coated drip shields on the edge waste packages only. That turns out to be about 10 percent of the waste packages would need that drip shield. But if the drip shields cost you $2 or 3 billion, if you could just shield the ones that you think are going to have the most stressed environment from seepage, you save yourself $1.5 to 2 billion.

Again, the dual CRM waste package, the dual corrosion resistant material waste package, the higher capacity waste package and the concrete invert.

I do have one set of pictures to show you--well, in a minute.

Again, the integral features that are in here, the ventilation and the line load, the other features are the improved drip shield, blending, delaying the closure beyond 50 years, improved waste package, the concrete invert for sorption, and the higher capacity waste package, essentially the same list as the other one, just a different way to go at it.

This design was trying to see how much heat we could pack in there to see if it does us any good. We're in the same boat that Carl is in that this is not a very well analyzed situation. In fact, we may be a little bit worse off as far as schedule, because there is this body of studies that Dick described for the lower thermal load, but there have been very few studies up at this level, at the high level.

Here's some conduction only calculations that the subsurface people were able to run. These are 2D calculations and they don't include the movement of water or the heat that's moved by water. This line down at the bottom is the VA reference with that set of calculational assumptions, and you can see that it crosses below boiling somewhere in the neighborhood of 5 or 6,000 years. And I believe the VA designs with the more sophisticated models have it crossing there in the 3 to 5,000-year range. So its pushed things out a little bit.

And then these curves are exactly the same design for 50-year, 100-year, 200-year and 300-year time of the repository remaining open with ventilation. The ventilation may not be super aggressive, but there has to be some ventilation to remove the heat.

Just to give you a perspective on that, the current VA ventilation of only .1 cubic meters per second removes something like 20 percent of the heat that's released from the waste packages in the first 100 years. If you increase that to 10 cubic meters per second, which is feasible, you can remove over 80 percent of the heat that's generated in the first 100 years.

You can see that the peak temperature goes down if you can keep it open longer. And if you consider a 90-degree delta t between the cladding peak and the waste package peak, you can see that the 100-year closure probably makes that okay and the cladding will be fine. And the 50-year closure is marginal for that. If you put backfill on when you close it, then you will spike the cladding too high.

The third design I want to show you is the postclosure ventilation. We call this bowtie, and I'll show you a picture in a little bit to tell you why. So here's the VA and here are the drifts for the ventilated system (indicating), and these drifts should be spaced a little farther apart so they reach the same distance. There are 66 drifts versus the 100, the drift spacing is 42 meters, it is a line load, but we're only going to load this region that I'm surrounding right now, this middle region (indicating), the middle half of each drift with waste packages. We will not load the outer half because that's the region where we're going to dump the heat and the water.

We're going to use even higher capacity waste packages in this design, waste packages that take 42 assemblies, twice as much capacity, as our VA standard waste package. But in the same size package because we'll use rod consolidation. So two assemblies worth of rods go into each slot in the waste package.

Show you the reason why it's called Bowtie. There are two perimeter drifts that go around the repository. Here's a section of the west and here's a section of the east (indicating), just as in the VA, in the same location. Now we imagine that we drill a second perimeter drift going all the way around the periphery of the repository, just directly below the other one, about 30 meters vertical separation. And we make the emplacement drifts, instead of just connecting either the two upper or the two lowers, they connect a lower with an upper in a zigzag fashion. So this one, say it's an odd numbered drift, connects the lower west with the upper east, and this one, the even numbered one, connects the lower east with the upper west.

The air flow in this follows the arrows that are here. The air flows up the odd numbered one, along the main for a little ways, down some vertical raises that we put between the drifts, and then up an even numbered drift until it gets back to where it started. So that zigzag flow along the lines of the bowtie can basically continue forever without any resort to connection with the surface. This is a totally closed system.

In the preclosure period, you don't have to do it that way. In the preclosure period, you could bring the air in in the lower mains on both sides, let it come up the emplacement drifts to the upper and then exhaust out the upper to the surface.

But when you close, you go ahead and open these raises up that you've kept artificially closed during the preclosure, and maybe you put in some blockages between every second set of drifts in the mains to minimize cross talk between these loops.

I'll show you the first set of calculations in the performance of this. This scheme, by the way, was invented by a Professor Danko at University of Nevada-Reno, and he's been analyzing it for us in these last few months.

This is a picture of the 45 PWR waste package, and it basically looks just like our 21 PWR package, 1.6 meter diameter, 52-ton capacity, and it's got the 21 slots in it, but each slot is a canistered set of two assemblies worth of rods. In order to make this work right, we probably would have to have that canisterization done at the utilities, and it just can't be any sets of rods, they will have to do some blending at that end so that we don't end up with some packages that are--if we use the VA numbers, that would be 36 kilowatts, with the average being 18.

This is the concept description of this. We have 170 MTU/acre in that center east-west part of the drifts.

The average across the footprint, though, the excavated improved area, is the same 85. Preclosure ventilation is essential to this. Rod consolidation at the utilities would be used. Again, the dual CRM with blending at the utilities, and the concrete invert.

Paul, I made this chart for you last night just because I knew you would be here. This is like the ones that I showed the TRB about a year and a half ago for a series of high and low AML designs with and without backfill. In this case, the region of vulnerability is much smaller, 80 to 105 degrees C--I went up to 105 for enhancement of the boiling point by salts or capillary forces--and humidity is 90 percent to 100 percent in the region where crevice corrosion, or localized corrosion, of the corrosion resistant material of the waste package could initiate.

This is 100 years for the coldest waste package in the coldest part of the drift, and this is 5,000 years. The dotted line, this is 100 years to 5,000 years for the hottest waste package in the hottest part of the loop of the bowtie. And you can see it looks like these curves miss that region entirely.

Now, should we believe this calculation? This is only the first calculation, and it assumes that those drifts are open for 5,000 years. And if you have rock fall, the amount of air flow goes down, although it doesn't shut off completely. So we have a fair amount more work to do on this before we could say that it's real, but the first look at it was promising.

The integral features of this are postclosure ventilation and preclosure ventilation, line loading to increase the thermal load. Other things that we've added are the blending to help preserve as much of the thermal goals as we can, rod consolidation to increase the heat source for ventilation, improved waste package for Defense-in-Depth, the concrete invert, and the higher capacity waste package to reduce costs and also to get more driving heat for this ventilation.

One of the things we have to look at for this one is that the temperatures look so good with the ventilation because the water, the percolation flux water, was coming down and being pulled into those drifts, then being moved to the outside edge of the drifts where it was condensed and shed. That's how the calculation worked.

One of the things we have to look at if we continue to work this is what happens if you have 100 years or 1,000 years where percolation flux is very low and then some time where percolation flux is high? What if the percolation flux isn't really steady? So we have more work to do on it, but the original steady state calculation didn't look too bad.

To summarize, we have three high-temperature designs that were developed as candidates. We've done calculations to determine compliance with the high-temperature design approach. The 85 MTU/acre line load is really based on the VA calculations and is just an extension of those, as well as some calculations that were done in our Phase 1 last fall. The initial results for the 150 MTU/acre line load are promising. It looks like we can come up with a scheme that doesn't violate the drift wall goal. And the initial results for the bowtie postclosure ventilation case also were promising, and I should point out that those calculations were using the 21 PWR packages, not the 42's. We haven't done any higher capacity calculations yet.

Phase 2 calculations will have to be more comprehensive and will have to evaluate each aspect of the design approach. I listed all the aspects for you, but I didn't carry you through any but the first one or two.

NELSON: Okay. Thank you, Jim. Okay, we're a little bit late, but we'll talk very fast as we ask questions. One question I have for you is this: have you considered the impact of blast loading on stability in these openings? Do you think there is any?

BLINK: Yes, we have thought about that. I really hate the idea of putting the rock into multiple cycles of fatigue. One of the things that the LADS group has done that's different than what was in the VA design is we don't plan to routinely blast cool for performance confirmation. In the VA design, every year or two they were planning to blast cool each drift and send a vehicle in and out. And we'll have to find a better way to do that. So yes, we are thinking about that.

NELSON: Okay. And in a similar vein, but not really, I have a question about the capillary barrier. I have a suspicion that I'm not absolutely certain in my mind that the capillary barrier will reset up the way people think it will at a low-temperature environment because of normal moisture removal and retreat of moisture in the fractures to form the capillary barrier; that when you have a really dry rock condition and the reentry of water, is there consideration as to whether that capillary barrier will indeed set back up under this condition of the thermal pulse, drying out and then moisture coming back in?

BLINK: I have to be sure that I understand your question. Are you talking about the barrier between the near field rock and the drift opening, the so-called air gap, or are you talking about rewetting the pores of the rock that you've dried out?

NELSON: Well, you can talk about both of them if you want, but the capillary barrier is actually--at least as I've seen if painted--is one associated with the air-water interface that exists in the fractures and addresses fracture flow, is the capillary barrier.

BLINK: Okay, so you're talking about rewetting the pores of the rock.

NELSON: The question about rewetting. It seems to me, you know, in having an actual barrier associated with capillary, I guess to me, if there's any musings or calculations relating to that or any information about resetting that up after a major thermal pulse like that, I'm just curious about that.

BLINK: Several of the labs have done bench scale testing of rock where they've dried it all the way out in an oven and then rewet it. And the rewetting curve doesn't exactly follow the--

NELSON: That's mostly intact rock as opposed to rock mass, or lithophysae rich rock. So I guess, in any event, I'm curious on that.

BLINK: Yes, I'm not sure they've done it with lithophysae, they usually do it with the middle non-lith.

NELSON: I know, everybody's done it with non-lith, yes.

Okay, Richard.

PARIZEK: Parizek, Board. The bowtie idea is new to me, and if you had a pluvial condition and actually had a lot of water starting to get into these incline emplacement drifts, although the air flow is up during the normal circulation period as you imagine it, but suppose you then have free water running down slope and it puddles down at the lower end. Are you going to overload the unsaturated zone below the repository and screw up the whole performance? Whereas before it was sort of it leaks on this canister and it sort of goes down through the floor, then it's spread out over the footprint of the repository. Here you could concentrate the flow on the down slope sides and really overload the rocks.

BLINK: You could. I think the calculations and measurements show that the rock has enough permeability to take something on the order of a fire hose.

PARIZEK: Yes, I don't mean the permeability, it's the sorption, you know, all of the retardation mechanisms that you'd like that rock to perform for you. Some are more worried about that then--I know it will take the water, it's just a question of whether it's going to help screen out the radionuclides.

BLINK: Sure. As long as the scheme is working and a lot of water is coming and is being drained on the periphery, I don't much care about that water overloading sorption because it won't have the radionuclides in it. However, once the system fails and water's coming through, then this thing degenerates to a high-temperature design without moving the stuff to the outside, so now you've got--you probably have the opposite condition where you've got a plume that's more tightly bound in that center half of the repository. But certainly that's something that we need to look at.

This scheme depends a lot on that ventilation working. If it doesn't, you know, we have to in the Defense-in-Depth point of view turn that off, but leaving the waste packages in that same compressed high-capacity state and see what happens to it. And that's something that we need to do. But your point is well taken about the transport. The transport calculation is a different calculation.

PARIZEK: Right, because it's kind of a timing problem between when pluvial conditions set up, when the whole thing cools down and when free water flow down the slopes could cause a new problem after some breachings occurred.

BLINK: Right. And the first set of calculations were done using the current day climate, not the long-term average climate.

NELSON: Dan?

BULLEN: Bullen, Board. Just a couple quick questions, Jim. When you use a dual CRM, did you mention what the thicknesses of those were or have they not been--

BLINK: I didn't mention it, but I think waste package in their studies has pretty well fixed on 5 1/2 centimeters of Alloy 22 and 1 1/2 or 2 centimeters of Titanium Grade 7.

BULLEN: And that provides the structural support necessary to lift it up and move it and heft it around?

BLINK: Yes, that's how they settled on that, was structural.

BULLEN: Okay.

BLINK: But the downside of that one is the surface contact dose outside that is high enough that you have some problems with transporter design.

BULLEN: Okay.

BLINK: And so we're currently looking at that side of it. But from the viewpoint of picking it up, it's not a problem.

BULLEN: What is the surface dose rate of those, do you have an idea? And I guess the follow-on question then is, does radiolysis come into play when you start worrying about moist air environments near a high radiation field?

BLINK: For these designs I don't think it's a problem because the dose rate is high enough for you to do some radiological processes with that air. But if you don't have the water, I don't think you're going to make your acids that cause you the problem. Later, when water comes back, I think the dose rates are down far enough by then that it probably doesn't matter.

BULLEN: I would believe later when the water comes back, I'm just not convinced that the water's all gone.

BLINK: Well, if it's well above boiling you're not convinced?

BULLEN: We'll see.

BLINK: Okay.

NELSON: Di Bella.

DI BELLA: Thank you. This is Carl Di Bella, Staff. I wonder if you could comment a bit more about the utilities loading the 42 PWR packages, doing rod consolidation and blending, and tell me what sort of basis you might have for suggesting that they would be somehow willing to do this.

BLINK: There's a 3-5 Report on this in Phase 1, and I basically gathered that information from the briefing. It turns out that if the utilities do the consolidation, you have many fewer shipments to transport, because it's compacted, and that saves a considerable amount of money. Now, whether the utilities would be willing to do that or not I think is a matter of economics. And that goes--there's two aspects of this economics. One is if it increases the probability that they get to start sending their waste to a repository sooner, that's certainly a positive. The other one is if there's enough cost savings on the repository side for this, it may be that the DOE pays them to do that. It's certainly technology that already exists, and in his report they talked about having a set of equipment that moves from utility to utility, or a few sets, as opposed to each one having to develop that capability separately.

HARRINGTON: Paul Harrington, DOE, I'd like to add something to that, too. Obviously there's a great deal of sensitivity about doing additional work or requiring work to be done at utilities that isn't currently called for under the standard contract. This is an attempt to think out of the box. As you saw, that is not inherent, it's not a fundamental part of this high-temperature approach, it's just one of the things that we're considering.

BLINK: Thanks, Paul.

NELSON: Alberto?

SAGUES: Yes. Based on the other various incubation schemes for long periods of time, does this involve recirculated air or is it constant fresh air from outside?

BLINK: On the bowtie one? That's a closed system.

SAGUES: And how about the others?

BLINK: The preclosure it's open air. The low humidity of air in that region really helps you remove heat. It pulls water out of the rock. We've done measurements in the ESF and the ESF is pulling out the equivalent of 200 mm per year of flux through the ventilation system.

SAGUES: Okay. Now, the air velocities are smaller, at least as part of the total, but that's precisely where the tiniest particles could still become airborne. Has anyone looked at what will be the effects of, say, 30 to 50 years of fresh air circulation on deposition of particles on the surface of the packages, including bio matter?

BLINK: You're thinking of dust on the packages?

SAGUES: Right.

BLINK: We have looked at it, but probably not enough. One of the things to note is that the emissivity of tough rock and presumably dust is about the same as the emissivity of these metal packages about Point 8. So I don't think it would change the heat transfer very much.

SAGUES: Well, I was concerned about the hygroscopic effects, and in the case of organic matter, of course, the deposition of other things.

BLINK: We have looked a little bit at microbiological induced corrosion, but again, not very much in depth. I think you have a good point, we need to keep looking at it.

NELSON: Okay. Thanks, Jim.

Our next speaker is Robert Dulin. Robert Dulin is a civil engineer. He's a member of the LADS core team, which is a terminology developed for the people who are making the decision about the EDA's that are going to move on forward. And our previous two speakers have also been members of the LADS Team. Robert Dulin has been an employee of Duke Engineering, Duke Energy, for 30 years engineering experience in the design of nuclear facilities. And we welcome you and invite you to begin.

DULIN: I guess we've abandoned the technology.

These other teams that just presented their concepts were focused on the temperature of the repository, and we were the other group. In other words, we didn't focus on the temperature of the repository, and in fact we were told to look at designs that might allow us the flexibility to access the repository with humans.

And as we proceeded with that task, we got into our breakout group, and the first thing we decided to do was to figure out what that really meant. So we came up with a goal here. Basically, we decided that we needed to really look at this. We had asked our feature and alternative leads to look at this particular aspect in a couple of their areas.

We had people that had looked at providing access on the basis of normal entry by people on a routine basis. We had certain features and alternatives that looked at that. As we studied that possibility, we said that's really not what we want to do, we want to provide only off-normal access. We don't want to as a routine put people into these drifts.

We know that the VA design as it has been sent out in the VA report basically provides a means to empty the drift without human access. We know that major events are set up to be handled by remote equipment. So we said that the human access that we're talking about would be for unanticipated events, things that you might make an individual trade-off at that time whether you would send a person in or you would have a remote piece of equipment that could do that same piece of work. But you'd be able to make that decision, give you that flexibility at that time.

We'd have to do blast cooling to allow that access, and we would provide shielding to allow them a limited stay time. That is, we aren't going to set up a campaign to keep people in that drift a long time, even for an anticipated event.

So that's the premise of these access designs.

We came up with three concepts. We decided we would put the title of them so that you would understand what we were talking about. But the first is basically a design in which the waste package provides the access to the drift, that is provides most of the shielding that's necessary. The second one would be one where the waste package and the emplacement mode, that is how we put the drifts in, would provide that access. And the third would be an emplacement mode which didn't require extra shielding on the waste package to provide that access.

In our studies, the feature studies that we had performed, our waste package operations folks came up with a waste package which was one of the alternatives they recommended to us which had an Alloy 22 corrosion material on the inside, around that was a thick stainless steel material for structural stability, and then an outer layer of ceramic coating. We decided that this was the waste package that we wanted to look at in terms of having a waste package that would provide all of the shielding for our--for this access. So what we would do in this particular case is thicken the stainless steel. In this case, it's ASTM-316, the nuclear grade stainless steel. We'd thicken that, and the actual thickness has not been calculated, but it would be somewhere between a 20 and 30 cm thickness of stainless steel to provide enough shielding that we could have access by eliminating the gamma dose with this waste package, basically getting that down to a tolerable level. Then we would have the portable neutron shield, which we would emplace in the drift to provide shielding from the neutron dose. Again, those are lighter weight, and again, it's off-normal, so it's not something we would anticipate doing, it's unanticipated.

Our concept of how we would do this repository is that we would keep basically the VA layout that we started with. And again, in the point load configuration, and we would put these packages in basically in the same time schedule that VA has, which is basically a loaded as it comes in type approach. And then when we're ready to close this particular design, we would go ahead and put a drip shield over this for Defense-in-Depth and backfill. So that's the basic, probably the simplest, of these concepts.

Looking at what's integral about this concept, it is really this gamma shielding and the portable neutron shield. Those are the two features that make it unique. The other features that we're talking about, the rest of the waste package and the drip shield and backfill, are really things that could be varied depending on how those designs flowed. But using the waste package for shielding on an off-normal basis, this is the design that we came up with.

The second EDA that we developed used the concept of having a waste package that provided some shielding and also an emplacement mode which enhanced the access to those waste packages and to the drift. In this case, we would again use an overall repository layout which was similar to VA, but we would go to a short cross drift layout. I have a schematic of that. But basically, where we now have drifts at 28 meters on center, we would in between those cross drifts would drill cross drifts which had about seven waste packages each in those drifts. These would be line loaded, as you heard that concept before. And the reason we would go to this for access is because you would only have a small number of waste packages to access at any one time and you'd have closure doors at each end so that you could access these drifts normally, and then on an off-normal situation be able to enter those short cross drifts.

Another unique aspect of this design is the waste package concept. In this case we decided because we wanted to be different that there was probably more than one way to do a waste package, and in this case we wanted to provide the gamma shielding with the waste package. So we decided that a single layer of carbon-steel, A516, with integral filler would potentially provide all of that gamma shielding, provide some simplicity for us in terms of fabricating that waste package, and perhaps save us some cost.

The last item in the second line, "canister bad actors," let me explain what that means a little bit. One of the other features that we evaluated dealt with the canisterization of the fuel assemblies. We know that there is some of the fuel in stainless steel fuel rods, and some of it has some--there's some failed fuel which can be determined ahead of time. And in this case, to give better performance, we would decide to canister those particular assemblies up front.

Concept of operations, again, is fairly simple. We'd use a neutron shield when it was necessary for emplacement, we would put the--the emplacement timing would be similar to VA, that is as it comes in we would emplace it, and then at the closure we would put a backfill and a drip shield for Defense-in-Depth.

I saved the most interesting design for last. Some people might call it something other than interesting, but we decided that for at least one of these designs we wanted to see what we could do to add as much to the engineering features involved as possible to make the engineering design the most robust thing that we could think of and provide this access.

So we looked at taking the VA footprint and using a trench emplacement, which is another type of access design that we had studied, basically building that trench from marble, leaving the trench open while we had the preclosure period, and basically then you would--as you came to closure, you would end up putting on a marble top on that trench. This would be providing some degree of chemistry control in addition to the enhanced access that you want. We would use the trench with a concrete cover when we did need access to that particular drift. Again, those concrete covers will be brought in on an as needed basis for the off-normal.

Our waste package concept, again, we wanted the most robust case we could make here, so we put the dual CRM waste package in. One of our concept of operations here, however, is that we know this marble is an expensive item, we know that the dual CRM waste packages are expensive items, so we wanted to go with something that would allow us to optimize both of those features, and so we would do a significant quantity of aging with this particular concept. We'd emplace only the low-temperature waste in this particular case, low temperature being in the 4 to 5 kilowatt range. And looking at the aging, it would take 50 to 100 years, in that time frame, to get most of the waste down into that kind of operating range so that you could emplace it in the 21 PWR waste packages as we had previously used.

In order to do that, then, you could institute a policy of just-in-time purchase of waste packages, drifting and emplacement so that you could minimize your expenditures. The other thing that you can do is potentially look at what advances we might make in the waste package design over a period of 50 years of aging, and perhaps there is ultimately a ceramic waste package that might better serve us than the dual CRM that we currently have designed, which we don't have technology to currently fabricate.

One other feature is because we're going to emplace only low-temperature waste, there is a significant quantity of low-temperature waste which could be emplaced early. We would limit the amount of that that we would emplace, but we'd emplace enough to have our performance confirmation program begin early. So right now we have a very fairly extensive performance confirmation program dialed into the VA which deals with all the drifts. In this case we would limit it to the early emplaced waste, get our performance confirmation program so that we understand how the drifts are going to act with that waste there, and then be able to make our case to emplace and backfill and close the other low-temperature waste as we get ready to perform that campaign.

And again, these features--these three alternatives haven't really dealt with temperature to any great extent, and it's not, as you see, what we would consider an integral feature of any of these. So we think that the only integral features of this particular emplacement mode are the trench liner and top to provide chemistry control and to act as a drip shield and then this temporary concrete shielding on the trench for access.

The other features are there to either increase the cost--decrease the cost and move the costs further out in time or to give us a better performance confirmation program and provide Defense-in-Depth.

I have one picture of the emplacement mode for this trench as we have it in one of our reports, and that's approximately to scale if you use a 12 PWR waste package. Again, that was how we would envision making this enhanced access. And I don't know the guy's name that's out there in the trench, but--

I hope I have gotten us pretty close to back on schedule with that.

NELSON: Thank you very much, and you've certainly convinced me that you guys were thinking outside the box.

DULIN: That was our aim.

NELSON: Okay. I noticed on the waste package and emplacement mode provide access you switched from an incline herringbone arrangement to a perpendicular arrangement of the connector tunnels. Is there any reason why? I mean, am I wrong? It seems like at the workshop it was presented as a herringbone.

DULIN: I think it's the drawing. Basically, the one that was studied for the alternative design that gave us this particular mode was a 45-degree herringbone design. I think this picture just probably doesn't represent it very well. So it wasn't intended to be a perpendicular. The herringbone is there so that you don't have to make the drift larger to emplace that waste package.

NELSON: I was wondering how big the drifts had to be in order to make those right-angle package--

DULIN: Yes, the drift would have to be much larger if you went in a 90-degree angle.

NELSON: Okay. Alberto?

SAGUES: Yes, what's the rationale, again, for the marble feature at the bottom of the drift?

DULIN: The which?

SAGUES: For the marble.

DULIN: It is a chemistry control. Basically, although we don't expect acidic conditions to occur in the repository, the marble, being a calcite material, would provide a calcium carbonate so that it would buffer any acidic water that did enter the repository. That's why we're looking for a chemistry control there.

SAGUES: And why not, say, limestone or--

DULIN: It's a different kind of material, but it's the same basic chemical constituent, yes. You can do either one.

SAGUES: I see.

DULIN: Both are available.

BULLEN: Bullen, Board. I guess the question that I have is sort of twofold. In the 20 to 30 centimeters of 316 or A516, do you really need additional neutron shielding when you've gone that thick? I thought I was under the impression that you've got enough neutron shielding there based on what you had with those set of thicknesses, and it was sort of the 10 to 15 centimeters that you had to worry about adding extra neutron shadow shields?

DULIN: No, we looked at that again and there really is still a need for a neutron shield even when you get up in the 20 plus range as far as what we have in terms of a source term.

BULLEN: And there's neutron shield that if you were to put it into the standard emplacement drift, are you going to shield the entire drift for neutrons or are you going to put up a bulkhead and, you know, cut the tunnel in half, or what's the--

DULIN: We haven't gotten into the detail of exactly how we would do that, but obviously there's going to be more than one way to potentially do that.

BULLEN: Okay. And I guess the follow-on question to that is what's the radiation dose that you expect at the surface of the dual CRM material in the marble trench?

DULIN: At the surface of the dual CRM material?

BULLEN: Yes.

DULIN: I don't recall that exactly, I don't know if anybody has it, but I think it's around 6 rems or something like that.

BULLEN: Wow, that seems pretty low.

BLINK: I have in my notes 6,000 r per hour.

BULLEN: Yes, 6,000 r per hour is pretty toasty, and if you're in an environment where it's not going to be hot, or not exceptionally hot like Jim Blink, you're going to have a moist air radiolysis environment, and so you'll need all the buffering capability you can get from your marble because you'll be dripping nitric acid onto it. And so one of the concerns that you might want to worry about is, how long is that marble going to last, and maybe your natural analog is the acid rain on the Parthenon or something like that. I mean, it's just something that you want to consider as you carry forward enhanced design alternatives that may have an Achilles heel or two.

DULIN: Well, that would be the Achilles heel for that dual CRM in any case.

BULLEN: It might be.

NELSON: When we left the workshop, there was a discussion about the fact that the focus here was really on access after placement, long-term after placement, as opposed to ensuring access during placement operations in the event of an accident or something where you're not talking about the emplacement, you're just really having an ability to get in there and work a problem--

DULIN: Right.

NELSON: --that might happen during placement. And I understood that last week there was going to be some additional thinking about what was meant by "enhanced access," to include that. Has there been?

DULIN: We've thought through that and have developed some additional guidance about exactly what that means, and there have been a number of considerations put on the table here over the past week. I don't have those at hand, but Dick, do you want to--

SNELL: We have got a draft statement developed for what the enhanced access ground rules should be, and it is indeed the ability to provide access, personnel access, for upset or accident considerations. And further, it's expected that the access would be fairly limited time for relatively minor items, it would provide enough time so that you could make repairs or fixes. But for any major accidents or upsets, for example if you had a substantial ground support failure due to a seismic event, something like that, the personnel access would be sufficient to allow personnel to go in and make an assessment of repairs, but the repairs themselves would have to be handled on a campaign basis. In other words, it would be a decidedly off-normal event, it would require some sort of major undertaking in order to handle the repairs.

BULLEN: Bullen, Board. Along those lines, does it drive you to one of the three enhanced access alternatives as you look at that? I mean, as you look at the upset events during emplacement, if I have an exposed trench without a cover on it and for some reason I've had ground support failure so I can't get the cover on there, then I'm really limited with respect to what I can send into the drift, aren't I?

SNELL: I suppose so. I have not really thought through what kind of combination of accidents and circumstances as you just described might occur.

BULLEN: Yes. Bullen, Board, again. I guess in evaluating those you might want to look at what you think the off-normal scenarios might be and that might help you in your selection of the alternatives to carry forward.

SNELL: Yes. So far we've defined them as a problem with the handling of the waste package. In other words, we drop it or it tilts or there's some malfunction with the placement of the waste package in the drift. Another event is some difficulty with the transporter, comes off the rails or there's a rail problem which keeps the transporter from moving as it should, or some power problem on the transporter, or a minor, emphasize minor, ground support problem or some kind of localized water leakage, something of that nature for which repairs or fixes would be relatively minimal.

NELSON: Carl Di Bella?

DI BELLA: Bob, frankly, I'm a bit surprised that something like horizontal borehole or horizontal alcove alternative didn't come up. And I assume it did come up in the deliberations of your group and for some reason it was rejected. Could you explain what that--if it did come up what that rationale was?

DULIN: The borehole concept requires a significant--I think it's like a fourfold or more increase in the number of waste packages to be handled, and that was one of our key considerations. We're talking 5 PWR assembly waste package. I think we could get up to 12 if we aged it. But basically we had a large increase in the number of waste packages. It was definitely a thing that caused us not to consider that further.

The alcove is the one you asked?

DI BELLA: Horizontal alcove, yes.

DULIN: Horizontal alcove and this short cross drift were basically two items that did the same kind of function. You basically isolated a part of the waste stream into a smaller area and allowed the access about the same way. So it really worked kind of commensurate type emplacement modes. So we chose the short cross drift.

NELSON: And following up on that short cross drift, what it did was I remember Chris Whipple, who's in the audience and will probably raise this issue again, introduces something which occurs to me really strikes at the heart of Defense-in-Depth, which is providing a connectivity between drifts that really didn't exist before. And so I was sort of surprised to see that come through as a connected herringbone arrangement. Was there consideration about that or do you think there needs to be?

DULIN: As I recall, that comment was made at the end of the Friday workshop, and--

NELSON: Yes.

DULIN: --so these represent what we did by the end of Friday.

NELSON: I know, but it's fair game to talk about what's happened since.

DULIN: Well, I can tell you that the short cross drift doesn't look like something we're going to carry forward into the actual scrubbed EDA's.

NELSON: Well, I always thought of the short cross drift as sort of like a larger horizontal borehole.

DULIN: Yes.

NELSON: You just made it so large that--

DULIN: They're somewhat similar, yes.

NELSON: --it crossed over, you know. So the maybe there's some redeeming features about it that don't need to get thrown out with the wash.

DULIN: If you look back in the history of this short cross drift, there actually was a down select to the short cross drift a couple years or three years ago in the history of the program. I'm not really familiar with exactly how that was done, but compared to some other emplacement modes, this one was a favored mode at one time.

NELSON: Any other comments from the Board? Stop? Okay. At that point we are coming right up on 3:00, and so we're on schedule for a 15-minute break, and that's what we shall have now. Reconvene at 3:15.

(Whereupon, a break was taken.)

NELSON: Okay, we are reconvened as a meeting of the Panel on the repository, and now we've got a 30-minute presentation by Dick Snell and Kevin, which Kevin is--Dick will answer questions and Kevin will make the presentation?

COPPERSMITH: Exactly, that sounds great.

NELSON: Okay, sounds good.

COPPERSMITH: Proper division of labor.

NELSON: And we've seen these two people earlier today, and so we don't need to introduce them again.

Kevin, it's yours.

COPPERSMITH: Okay.

NELSON: See, we keep having these examples of Defense-in-Depth, don't we?

COPPERSMITH: I think it's actually better example of the KISS principle, we're keeping it simple and stupid and using the old-fashioned overhead projectors.

I'm going to talk about the Phase 2 process, what is envisioned, what will happen over the next few weeks. And I should remind everyone that since Phase 1 ended at midnight on that Friday that Phase 2 has begun. So we had a week of Phase 2, and I will refer a little bit to what has gone on in this process. There's no rest for the wicked, so we have continued to forge ahead with this process.

The steps I'm going to talk about are these (indicating). Now, the first is refining the evaluation criteria for Phase 2. Secondly, strengthening and specifying the EDA's. This is to in light of these evaluation criteria make sure that our enhanced design alternatives have a high probability of success as we go through the second phase analysis. Thirdly, evaluating the EDA's against those criteria, ranking them against each criterion, and recommending a design, with possible options, as you've heard, and of course documenting the process.

In terms of terminology, as I understand it, the Management & Operations contractor makes a design recommendation and DOE makes a design selection. So I'll talk about both of those.

Actually, we had a tag team match where I end with the discussions of the recommendation, Rick Craun on selection, and I think Paul Harrington will be sitting in for Rick on that.

HARRINGTON: Yes.

COPPERSMITH: Let me talk first about the Phase 2 evaluation criteria. We referred to them a little bit in the earlier discussions. We've divided these into two types of criteria. The first we're calling screening criteria. These are criteria that we would expect any of our enhanced design alternatives to meet. And I'll go through what they are. First is to meet the 10,000-year peak dose rate. We're using an anticipated regulatory level of 25 mrems per year. Again, this is the 10,000-year performance measure. Defense-in-Depth, again, for 10,000 years following the procedure that Dennis Richardson talked about this morning, we expect any EDA to go through that process and be able to stay below the 25 mrems per year. And finally, environmental effects, no unacceptable environmental effects. This would be relative to things like drinking water standards and so on.

These criteria, again, screens would I think provide an opportunity to do the analysis and to see how they perform, but they are minimum level criteria. Just passing through this screen would not in my mind assure success of these designs in the subsequent evaluation.

In terms of actual evaluations, once they have survived the screen, these are the evaluation criteria that we're looking at in that time period. The first overall we're calling "Safety/License Probability". This is a series of issues that we've touched on, but let me explain some of them to you.

The first would be design margin, and the concept here is basically the idea that the performance of a particular design is less than let's say the 10,000-year limit of 25 mrems per year. We want to take into account how much less, how much better does it do than that criterion. And the idea is that there is a margin, then, say two or three orders of magnitude potentially, better than that standard. And this would be an opportunity to look at that difference between the standard and how well this design would actually do.

Likewise the degree of Defense-in-Depth. This is kind of the idea that well, if we have--do we have one barrier to--if we move that barrier we have an opportunity to see how it would perform. What about if we have additional barriers? What if in fact when we move or neutralize a barrier there's very little change. These are differences that are actually a degree of Defense-in-Depth that we can take into account in the Phase 2 evaluation.

Very important aspect that we've talked about I think throughout the course of the day at one time or another is we need to now look at the uncertainties in postclosure performance. All of the analyses that we've talked about for 10,000-year and for longer time periods performance are central estimate types of evaluations. There's uncertainties, not only those that are captured within the present TSPA, but uncertainties that exist in just our basic understanding of processes that also need to be taken into consideration. If, for example, these uncertainties in postclosure performance are such that they are significant, they're large and they're irreducible for a particular design, that's different from the opposite case where they're manageable, they're relatively small, or even reducible in the time frame, let's say, of LA. So this is a chance to look at those uncertainties. These are uncertainties in the natural system as well as in the engineered barrier system.

Another evaluation or part of this criterion is looking at performance beyond 10,000 years out to a peak dose rate, let's say within a million years type of evaluation.

So this is the chance and this is the place where we explicitly consider longer term performance. This allows us to make it a separation between a design that does very well for 10,000 years and then we get a large increase in peak dose versus one that maintains a long-term performance over hundreds of thousands of years.

And finally, the aspects of engineering acceptance. These are the same ones that--basically the same issues that were covered in the Phase 1 criteria will be considered as well.

So that's the first criterion.

In Cost and Schedule we're looking at more than we did in Phase 1. We're looking at the time and costs associated with several phases of the operation: site characterization and licensing, construction, operations, monitoring and closure. We'll also in this process be looking at issues like the annual funding profile or net present value costs so we get some realistic view of funding over a time period rather than just total costs as was done in Phase 1.

Construction, Operations and Maintenance is very similar to the Phase 1 evaluation. I won't repeat all of the issues there.

But we have a fourth criterion here that is very important in making this evaluation of the enhanced design alternatives, and that's the issue of what's called "flexibility". Is this design capable or in fact easily flexible to handle some other issues, some of them programmatic issues like the need for additional storage capacity, a longer preclosure period, a shorter time period to closure, and so on. Can the design handle these types of potential programmatic changes? Same thing with design changes. Is it potential for this design, for example, to go from essentially a low-temperature design to a high temperature, and vice versa? Does that flexibility exist?

And finally, the issue of unanticipated natural features or findings. I have a difficult time using that terminology "unanticipated". If we're in fact able to anticipate at some extent, then we're able to plan for it. But nature always has managed to show us that in fact things can happen maybe at the tail of our distributions and maybe sometime even beyond the tail of our distributions. Can the design handle that? Is it the type that has the flexibility of saying, for example, if flux rates are much higher than we had thought before, can it handle that? And so on. This is the type of flexibility that we're talking about here.

So these are the criteria that we're looking at, what are we going to do with the EDA's that came out of the workshop? Well, the process has already been done, and that's what I'll call strengthening and specifying the enhanced design alternatives. What the engineers and the performance assessment and cost estimators and everyone need in Phase 2 is a set of designs. Again, they're all design concepts, but they're sufficiently specified that they can in fact tie a cost to them or do performance calculations and so on. So we need a level of specification that allows for that to happen without in fact getting into any type of detailed design.

We want to strengthen them so that in fact when we go into Phase 2 none of them have any significant weaknesses. We looked at the designs that were discussed previously, the eight EDA's that came out of the workshop. We want to look at those and make sure that there are no parts of those that will do particularly poorly relative to our Phase 2 criteria. In other words, some of them that might have difficulty in licensability or are very expensive or have difficulties in other aspects of their design. So the strengthening process is really designed to make sure that we don't put something into Phase 2 that we know is not going to do well. We'd like to eliminate those or strengthen them at this point. So we're calling that basically the process of high grading or cherry picking to basically get the best aspects of those eight designs that you heard about.

This is the process of making that comparison. We're strengthening the weaker elements and then specifying them sufficiently for analysis. That's always a difficult process because we need to in fact make some assumptions about their anticipated behavior and how they would actually operate.

The evaluation will occur after that, and this is actually the process of doing calculations and engineering analyses to address the criteria. Very similar to Phase 1 where the lead design engineers were responsible for that. From a procedural point of view, the way we're going to be going through this will be there will be a lead for each one of the enhanced design alternatives, a lead design engineer, there will be also a lead from a member of the core team for each one of the EDA's to help shepherd that process through. We also will have what are called curatorial leads. For each one of the evaluation criteria, there will be an individual who is responsible for making sure that in fact that criterion is consistently applied design to design. We need to go through this process as clearly and consistently as we can and document the steps along the way.

So calculation, engineering analyses that will undoubtedly keep Rob Howard and others busy, cost estimators and others as well. We'll be using a specific design. In fact, they have to have some design that they can evaluate. But we leave open the latitude to optimize some of these design attributes. For example, in the analyses that Carl, Bob and Jim talked about, we did some preliminary analysis, and in some cases real-time analyses, during the course of the workshop to look at, for example, the benefits for low-temperature design if we do 50 years of aging and do this type of areal mass loading and this type of layout, what will be the impact in terms of the drift wall temperature. and calculations were done in real-time to help us with that. Clearly, when we go back and look at it more specifically, that 50 years of aging might become 40, and some other aspects may change. So we leave that latitude to optimize those designs in Phase 2 such that it will work better. The temperature goals, for example, and other goals that were discussed will help that process. But we want to allow the engineers to do their engineering and to try to optimize those designs. So there is latitude in the second phase to revise and refine those as appropriate as they move forward.

The summary and documentation of each EDA, of course, is going to be very important. This will include the engineering analyses and basically the evaluation against all of the criteria.

The final step in all of this is one of ranking and evaluation. This process right now as we see it will involve looking at the evaluation criteria. If, for example--this is just shown for example--we have Designs A, B, C and D and it looks like it would be a useful tool at this point to look at how they rank relative to each of these evaluation criteria, how are they coming out relative to those criteria. As Dick said, if the world were perfect and stochastic dominance holds Chris Whipple, we in fact will see that one design, B, will do well across all four. I think Chris and Tom Cotton and others who have looked at this have said that stochastic dominance never works and in the real world we'll be trading off issues of this one's the cheapest and this one gives us better performance but it's more expensive, and so on. So we expect those types of differences to occur throughout this process.

Now, going from this process of having a set of ranked designs against the criteria to a selection of a single criterion is one that obviously involves some of the trade-offs between these criteria, and that's where there will be interaction and involvement of both the M&O and DOE in the process. A group called the License Application Design Integration Group will be integral in helping to assure that that communication as we talk about the trade-offs among these different criteria, and Paul will talk about that in just a minute.

Let me just show the overall timeline. If there's anyone here who forgets that in fact all of this is tied to a timeline, let me just remind everyone. We're in the process of developing these EDA's and evaluation criteria and applying them. We will have a workshop in the first week of March to go through the evaluations that have been done up to that point and the ranking that will come out of those evaluations. And then we go into a process of documentation and review that will end at the end of May. So this is the conclusion of our Phase 2 process.

The conclusions, the things that we're basically going to do and have begun to do, the evaluation criteria are being refined. I went through those. There will still be, I'm sure, some minor modifications to occur before they're applied. We'll have EDA's that have a high potential for success, we'll have high graded the EDA's that we have now and will carry forward.

One thing I want to impress is the fact that we are looking for a diverse set of designs. Diversity has continued to be an important part of this all the way throughout. When we started after the first breakouts, we had 23 designs and we worked it down to 8 by the end of the workshop. We get to a smaller number now. We still want to look at diverse designs. We still want to have an opportunity to see how different design concepts would work rather than focusing in on just one or two. So we are giving high regard to the concept of diversity as we go through the analysis.

The detailed evaluations will go through that March

1 to 5 workshop. It doesn't end prior to the workshop. For anyone who has witnessed this process, we are working continuously, even in workshops, to develop decisions. So I anticipate that that decision-making process will go right through that workshop. The EDA's will be ranked by criterion, then the design recommendation will be made that considers all of the criteria. And I think Paul will give--

HARRINGTON: Yes.

COPPERSMITH: --a wrap-up of the overall decision process using the License Application Design Integration Group. But I'll stop here and field questions.

NELSON: Is it more logical for you to make your comments now and then to open up questions?

HARRINGTON: That would be fine, it's fairly short.

NELSON: Why don't you do that?

HARRINGTON: Kevin's already--

NELSON: That would be good. I'm not sure I'm going to introduce you correctly, but Paul Harrington--

HARRINGTON: Well, actually, I wrote something out, if you'd like.

NELSON: Good job. Paul Harrington was in the commercial nuclear industry for 17 years, got his degrees from the University of California-San Diego, at DOE for 7 years, and past was at Rocky Flats in engineering as division acting director, and he's a Yucca Mountain line organization engineering lead. Does that make sense? And this is not Rick Craun.

HARRINGTON: I'm not Rick. Unfortunately, I think I gave Rick what has caused him not to be here, though. Oh, well.

We have wrestled for some time with what is the result of this whole alternative design exercise look like and what does the DOE do with it. We have developed a number of evaluation criteria over the past several months, we have scrubbed those down, but we still need to close on just what criteria we will use for the final evaluation for SR design, what the relative merits of that are. That's not something that an individual or small group can do by themselves. It has not just project but program implementations.

So we decided to take a similar approach to what we had done during the VA to help address policy issues that came up. There we had created a Viability Assessment Integration Group. We've done the same thing for the license application design, created an integration group. The members of that include Steve Brocoum, he's the chairman of it, Dick Spence from the DOE line organization, Office of Project Engineering, Dan Wilkins, Jack Bailey, Rick Craun, myself, Jean Younker, Dick Snell. And from the MTS we have Bob Fish from the engineering organization and Mike Kline from the regulatory organization, and Harris Greenburg is the secretary. So it's fairly broad based, encompassing DOE, M&O and MTS.

What we want to do is be a resolution process for the major technical issues that come out of the LADS process. As we talked earlier, that would include the relative criteria, also give a methodology for providing issues back to headquarters.

Our product is an M&O document that gets delivered to the DOE on April 15th, as Rick said. The DOE has to review that and agree with that. The level to deliverable is a DOE project to program deliverable. So the DOE is heavily involved in this ongoing LADS effort. The workshop was an M&O workshop, but the DOE needs to own the process and the results.

These are some examples of issues that have been raised. Gee, unfortunately, I was out sick for the first meeting, so the waste package and cladding treatment I can't speak to very well. There was a decision made and guidance provided to the LADS Team on those, though, as to how to treat them in the LADS process. The EDA ranking, as Kevin discussed a moment ago, is something that the LADS Team will provide guidance to the--or the LADIG will provide guidance to the LADS Team as to how to treat that in the report. There's been several approaches that we could have taken to the report. Is it a very strict rank ordered here is number one, two, three, etc., or is it something that is a little more fluid, here are groupings, here are the various approaches to design solutions that we looked at, the relative merits of those and how they stack up given the criteria that we've applied to them. We expect this product will be more toward the latter than the former.

This is an M&O recommendation to the DOE, but as the last line says, we need to approve it and accept it. This, too, is work in progress. The LADIG team has met twice. We still have a number of issues that we will need to deal with.

Questions to Kevin and myself?

NELSON: Your report that's coming out on April 15th is going to be the M&O recommend report?

HARRINGTON: Yes, it's one LADS report that actually goes into M&O internal review in mid-March, makes the cycle through the M&O corporation, then delivery to the DOE is April 15th as a Level 3 deliverable. The DOE has a month to review it, comment on it, and then the M&O has about two weeks to incorporate those comments. And May 28th is the delivery of that report from Russ Dyer to Lake Barrett.

NELSON: Okay. Thank you. John?

ARENDT: On, Kevin, your View Graph Number 7--

NELSON: It's John Arendt, Board.

ARENDT: --your goal is to carry strong EDA's into Phase

2 with no significant weaknesses. And then your third bullet is strengthen weaker elements. I'm wondering why waste time --if there are significant weaknesses in the eight that you have selected, why spend time in strengthening them? Is eight a magic number or could you weed it down to four and maybe do better if you spend time with four? I'm just wondering what's your rationale for that.

COPPERSMITH: This is Coppersmith, M&O. I would say that in fact, no, there is no magic. We've done research and it turns out that there have been successful studies that had more than eight alternatives, so we're assuming that there is no magic in the number 8. But what we're saying is, when we look at those that came out, are they in fact--do they have a single weakness such that that could be strengthened and the design goes forward, or do we instead say, "This just isn't going to fly on a number of counts," and therefore we put a halt to that particular EDA and move on to others.

I would hope, and my goal in being the facilitator here, is that we can get to a minimal set that maintains diversity. Those that have to do a number of analyses after would sorely love to see a few designs carried into Phase 2. But I think we need the diversity. So there's a dynamic back and forth. We had said that we wanted a goal of five to ten to carry into Phase 2. If we can get closer to five than to ten, I think that would be excellent.

NELSON: Let me just ask, what happens after May 28th, what's the rest of the good news on the schedule?

HARRINGTON: That's one of the things that the LADIG Team needs to work out with headquarters. And what happens is the product, the report, goes back to headquarters for review and acceptance by the program. But we need to close with them on exactly what form that will take.

The way the acceptance criteria were written for the report, it's basically a single recommendation. As we're in this process, we're learning that we may not have a technical basis for making a down select to a single design. So that's one of the things that we need to close on with them.

NELSON: Bullen.

BULLEN: Bullen, Board, to both Kevin and to Paul. I'll reiterate the question I asked this morning, which was the weighting of the criteria that you use, and maybe more specifically, how are you going to weight it and who finally decides and in what time frame will this all be done? Now, the straw man that you put up was essentially an alphabetic weighting which, you know, it looks like we get a C average and we'll probably pass. But I guess the question that I have is that there might be a little more emphasis on safety and less on cost or more on manufacturability and less on flexibility, or how do you decide, I guess is the key question, how are you going to weight that? Right now it looks even, so--

COPPERSMITH: Okay, let me start--again, Coppersmith. I can't say it as fast as "Bullen, Board," but this is Coppersmith, LADS Team, this time. "Bullen, Board," boy, that has a nice ring to it.

Number one, what's showing on here is that A, B, C and D are different designs, okay, so that would be EDA Number 1, Number 2 and Number 3, okay. And as we rank them--again, these are just ranked from first through fourth for each of these criteria--those would be relative to the evaluation criteria that I discussed. Again, that doesn't get to the heart of your next question is, okay, at some point we have to look at the trade-offs between flexibility versus cost, etc. And that evaluation is one that we intend to use the LADIG Group as the vehicle for making those trade-offs, because it represents M&O management and DOE management in going through the process.

HARRINGTON: Harrington, DOE. I'll infer from your question that you're almost looking for something that's a formula that you can plunk in and say, "I will assign this particular value to this set of criteria." I think that's one of the reasons that we haven't been able to do that yet, it doesn't really lend itself to something so strictly graded. If I misinterpreted what you were saying--

BULLEN: No, I would love to have that, but I know I'm not going to get it.

HARRINGTON: Okay.

BULLEN: I guess--this is Bullen, Board, again--the key here is that we as a board have to understand how you selected what you finally chose to carry forward and why you didn't select the others. And maybe it's indicative of my experiences in the past working with your organization that I don't always get that answer until after the decision is made, and I'd really like to know that before the decision is made this time because this appears to be a very critical decision with respect to the long-term success of the program.

HARRINGTON: I understand.

NELSON: Bill Barnard.

BARNARD: Barnard, Board Staff. This morning both Dick Snell and Kevin Coppersmith provided a list of eight design alternatives. I was wondering if you could tell me how many of the eight qualify as high temperature and how many low temperature?

COPPERSMITH: This is Coppersmith. Number one, I'd just like to make the point that I think the designation of design alternatives and design features was a very useful tool for basically dividing up the work in Phase 1 so that the analyses, the engineering analyses as well as the evaluation against the criteria could be accomplished.

When we went into the workshop, the first three days were devoted to presentations of those analyses, what had been done, how they had evaluated, what confidence was associated with that evaluation, and so on. And I think from that point on basically the handcuffs were removed. If the teams wanted to combine, mix and match various alternatives, they could do that. If they wanted to choose an alternative that was midway between a high temperature or a low, for example, they were free to do that as well. So I think the designation, or being able to map back to those design alternatives, loses some value.

I should say, though, that the end product of the EDA's and the high graded EDA's that will be coming from that will maintain a diversity along the line of high temperature to low temperature. We see that as integral to the concept of diversity, that at least along that axis we want to see a diversity in design concepts so that we're able to evaluate those in Phase 2. So that will occur in Phase 2 for sure.

HARRINGTON: Harrington, DOE. The question was of the eight how many were high temperature and how many were low temperature and how many were enhanced access?

BARNARD: Well, enhanced should fall under either high or low according to your definitions for high and low, shouldn't they?

HARRINGTON: That's where we took it. Just as a straight scrub, we had said there were 23 initially, we scrubbed that down to 8, 3 of those ended up coming from the high-temperature group, 2 of them from the low-temperature group, and 3 of them from the enhanced access group. But in looking at that, as we said earlier, the enhanced access features could really be applied to either a high or a low or something else. That's why Kevin was saying that the consideration of them as one versus another is becoming less important to us. But the source of the 8 was the 3, 3 and 2.

NELSON: Richard?

PARIZEK: Yes, Parizek, Board. It's on Rich Craun's last page, page 3, it's criteria evolution for post-10K year performance. Can you elaborate on what's involved there?

HARRINGTON: Yes, we had talked to--this is Harrington again, DOE--we had talked about how long should we be evaluating performance. If the performance standard period does turn out to be 10,000 years, how long should the project be evaluating performance. Well, that was that discussion.

PARIZEK: That way you drop off all of the analyses after that period. Because if it goes to a million years, we're all in trouble it seems like. I mean, from all of the performance standards, say 25 mrems per year, in a million years you're in trouble on all the plots that we were shown earlier, TSPA, VA shows that, and so on. So if that ends up being a requirement, what kind of design options do we have available to us?

HARRINGTON: Well, no, we weren't saying, or I wasn't trying to say, that we would take the 10,000-year standard criteria and apply that to a million years, but rather how long would you run your PA's and look at whatever the peak release is.

PARIZEK: You'd like to stop at 10,000 years, but I say if you had to run to a million, it doesn't look good.

HARRINGTON: Well, actually, at the LADIG meeting last Friday we decided we had had a 100,000-year period in there at the start of the discussion, and at the end of the discussion had decided to move it off to a million years, if I remember the discussion right.

Secretary, did I get that right?

(No audible response.)

HARRINGTON: Okay. So we're back to looking at a period of a million years to see what sort of releases we get over that rather than truncating at 100,000 or something less.

NELSON: Di Bella.

DI BELLA: Carl Di Bella, Staff. I know that ever since the site characterization plan was issued, perhaps before also, you've tried to maintain close touch with NRC's thinking and expectations to the extent that you can interpret them, and you do that by way of Appendix 7 meetings, by technical exchanges, by management meetings, and so forth. But over the years I've noticed that most of this seems to be aimed at long-term performance, and I've seen relatively little communication in the preclosure area, things like performance confirmation expectations, expectations for how MSHA and OSHA rules are to be followed, other worker safety rules, and so forth. Is it just that I haven't noticed this or do you feel really--you understand pretty well what it is they're going to expect in this area and you don't need to have the communications?

HARRINGTON: Harrington, DOE. With respect to some features, I think we have been having a lot of dialogue with the NRC for preclosure issues. DBE work particularly comes to mind. We've had a number of Appendix 7 and technical exchanges with them to try and ensure that we have a mutual understanding of what's expected there. Performance confirmation, it's good you used that example because that came up in the workshop last week. One of the NRC staff who was there suggested that we may be taking a different perspective, possibly more comprehensive, than they were looking for. So we took an action out of that meeting to schedule a follow-on meeting with them to try and close on what our relative expectations for the performance confirmation are.

Criticality, certainly we've had a lot of discussions with them pre- and postclosure. We have just sent in a topical report for review on that. In summary, we've had quite a bit of preclosure NRC interaction, but there's more to be done there.

NELSON: Leon.

REITER: Leon Reiter, Staff. During the day we've heard the application of TSPA to problems such as Defense-in-Depth, and Rob Howard talked about it, people have alluded to that. And I was wondering whether--but of course TSPA is based on a range of assumed models and assumed ranges of uncertainties. And of course particularly important we come based on expected values. I wonder if there's any attempt, or systematic attempt, to look at any conclusion that you draw and say to what extent is dependent upon certain models or assumptions or assumed ranges of uncertainty, and therefore to what extent do we expect this to be a robust conclusion or something that might change as our knowledge changes.

COPPERSMITH: Paul, do you want to answer that first? I have some comments.

HARRINGTON: You can go ahead.

COPPERSMITH: Okay, let me make a comment relative to the workshop as an example of the consideration of those issues. I was impressed by the fact that when we had discussions, the first three days we had the lead design engineers talk about their evaluations they had made of say the particular design feature and walk through the evaluation relative to the licenseability and engineering acceptance and so on. And when we came to the discussions of its representation or effect on performance, we had both the lead design engineer talk about how the feature would work but also had PA people stand up and talk about how they were able to capture it. And I think that in the course of those discussions, I think we're very frank and open. The uncertainties associated with both sides of how it's represented or how I think this will operate, how I've been able to capture it in the performance assessment, really open the door to areas where in fact perhaps the models do not capture a range of processes or the analyses to accomplish this are simplified.

Rob Howard, for example, on each evaluation for each feature and each alternative, his first side was, "Here's our assumptions, this is what we assume," so that everyone can see what it is that was assumed to be able to carry out this calculation. And there were a lot of discussions about that, "Gee, that assumption may not be correct." But it was made very clear how these were carried out.

So the goal, I think, from the standpoint of the analysis or the evaluation, is to develop these EDA's in light of not only the calculated results and the insights that we might get but really those true uncertainties and our ability to capture what this feature might mean in the short term or uncertainties that exist now and might exist in the next couple of years so that we'll have our eyes open when we deal with this, we want to use this feature in our design. Its performance enhancement characteristics might be largely a function of how it was evaluated, and there might be significant uncertainties in that.

NELSON: Did you want to add something, Paul?

HARRINGTON: No, I had the some thought of that was really the fundamental tenet, or one of them, of the whole workshop, was what is the performance basis of these various features. That's what the PA folks had been looking at prior to the workshop and were able to bring in discussions for those that were relevant. I mean, there were a few things, like surface facility, staging that's not really a PA issue. But that was inherent in the whole process.

SNELL: Dick Snell. I might add a comment or two. Before we complete this process, that is through the end of May, a clear understanding of how PA portrays the designs obviously has to be available. And there are several things that will pertain.

For one thing, the PA model as it's currently constructed has a number of elements. Rob Howard covered them in his presentation. But some of the elements in the current PA models are not discriminators with regard to various designs. That is, the PA portrays some of the behavior of the site, for example, which would be the same regardless of which of the alternatives are selected. So that's important from the standpoint of predicting overall repository performance, but less important with regard to discriminating among alternatives that are available to us. We need a clear separation of which ones are big influences on design and which were not.

When you go to the ones that portray designs, while this isn't universally true and we'll have to review it very carefully before we finish, generally speaking, in the PA models where you have an element, a model element in PA, which portrays the design or the enhanced design alternatives that we're currently considering and there are significant uncertainties with regard to how the modeling should be conducted, PA has generally opted for what I would call a conservative assumption in the model.

And the uncertainties that we're dealing with probably fall into two categories. One category would be uncertainties where we have a pretty good understanding of directionally what could happen to us and therefore we're able to make a conservative assumption. The other kind of uncertainty would be where we simply don't have a good fundamental understanding of an item. And the uncertainties could throw us either way, and it's much more difficult to select a bounding or a conservative consumption. We'll have to understand both.

I think the high percentage--and Rob can correct me or Bob Andrews can if I'm wrong--but in most cases they've selected one that's on the conservative side. We've got a reasonable understanding of the process, but a less well defined understanding of just how the process may move when, again, we've picked a conservative assumption.

I think one of the challenges we'll have is that in looking at the designs we'll need to understand how much of that conservatism in the PA models we wish to carry forward, because they represent time, cost and other resource commitments for us. And also we'll have to understand which of those are most important or most beneficial to us in understanding designs and in selecting designs. We don't want to spend what time and resource we have on the elements that are not particularly productive for us. We do want to focus on those where we think there's substantial benefit to further attention.

So all of those things I think are going to be things that we're going to have to address over the next two to three months. Again, clearly a challenge, but all things considered, I think we're in a fairly reasonable position right now.

NELSON: Final questions?

(No audible response.)

NELSON: Okay. Thank you, Paul, and thank you, Kevin.

We're to the point in the agenda where we're looking towards a roundtable discussion. And Dr. Tor Brekke has indicated to me that since he hasn't been able to hear most of the discussions presented here today that he'd rather not be a part of the roundtable. But I would like to invite Chris Whipple to come up and join us and--as one of our observers--Russ, what did you have in mind? You have to come up and do it.

(Whereupon, there was casual conversation regarding setup for the roundtable.)

NELSON: Chris Whipple, I do want to introduce him to you. Chris is an employee of ICF Kaiser Engineers. He's the chair of the Performance Assessment Peer Review Panel that has had quite a long standing involvement with the project, and most recently has taken on the additional responsibility of being a member of the EDA Independent Review Team, which has been doing quite a bit of intense work. So he sat in on at least some of the days of the workshop that we've been referring to throughout here. So we've invited him to make some comments that he's pulled together as he wishes.

And then I'll turn it over to Dan Bullen to whip you all into shape.

BULLEN: Chris, you want to go ahead?

WHIPPLE: All right, thanks, Dan, thanks, Priscilla.

As Priscilla mentioned, I was part of a seven-member--there's so many acronyms running around for this activity that one can't keep up. I think we were called the Alternatives Evaluation Review Group, not to be confused with the Enhanced Alternatives Design and LADS and LADIG and so forth. There were seven of us. Wendell Weart is here today, he was a member of that panel as well.

And our initial involvement was a one-day meeting the middle of December to go over the proposed criteria for this activity, which Kevin presented to us. And we basically drew heavily on what Kevin had presented and we did a little I like to think simplifying and rearranging from the items on his list. And I think we brought to the front shop a little more in what was proposed, the question of the licenseability of the design from both an operations point of view and postclosure, less reliance on fundamental measures of performance, such as dose and such things, under the presumption that the EPA and NRC are capable of doing their jobs and that DOE doesn't need to do anything that might be interpreted as kind of regulating itself or auditing itself. So that seemed to us to be kind of a more focused question. Can it be licensed, is a key one. And then the issue of flexibility, which we I think as a group all felt was a very favorable aspect to consider.

What we had in mind were not only how the understanding of the site might change in the future, and certainly it has in the past several years, but also we have to recognize that the final standards that will apply to the repository are not yet set. And design alternatives that give you a wider range of likelihood of being licensable across an unknown standard was seen as a virtue in this activity.

I might mention, my own perspective, not the panel's, is that this activity is, while it's undergoing a terribly compressed schedule--and I admire how much work has been done in so short a time--I think the reasons for it are fairly clear. It's been perhaps three or four years since the estimates of the infiltration rate through the mountains have started to rise. And as they started to rise, the one design change that's been implemented has been to go with C-22 as the inner liner of the waste package. I've forgotten, it was some corrosion resistant material but less robust than that in its previous design.

UNIDENTIFIED SPEAKER: It was A25.

WHIPPLE: A25. But in terms of going back and saying, "Now that we think the mountain is wetter than we previously thought, how would we do things differently" is a good question to ask. And the fact that the TSPA/VA is out the door and is an available tool to help dig into that question and it's a much more sophisticated tool than existed in say TSPA 95. Those two things taken together I think make this timely and it's been a very good activity.

In terms of the criteria I hear, while we wrote those down, the same list that Kevin presented today of what the decision criteria and drivers would be, in the two-week workshop that I attended I guess three days out of that, what in fact was the driver as far as I could tell was engineering judgment. Could we build it, would it improve things or make them worse? And let's not censor ourselves, let's not throw out alternatives ten minutes after somebody dreams them up because we can fault some detail of them. Let's carry them forward, let it have a chance to be improved by the group, and let's do the hard job of editing in Phase 2. But Phase 1 should be kept as the inventive phase of the project. And I think the spirit of the meeting in that sense was remarkable.

Candidly, I expected people to be defending the reference design. In fact, the order of the day was, can you beat the reference design, can you improve on it. And it was a really pleasant activity to witness.

Anyway, as I mentioned, the criteria were applied in a qualitative sense more than in a quantitative sense. I think all the candidates would pass the 25 mrem at 10,000-

year test and that the TSPA against the default projected assumed standard was not a discriminator. But in addition to the TSPA calculations, the organization of the approach was clearly driven by the four attributes that are part of the program strategy. First, to keep water away from the waste; second, to have a durable waste package; third, when the water gets through the waste package, contacts the waste, to have a slow release rate; and then finally, to reduce concentration through retardation, dilution and transport.

And I think the project took those four attributes as the starting point for different ideas. For example, my take going in was that there's nothing you can do in an engineering design that would affect the saturated zone. In fact, one of the options that was kicked around along the way was to split the repository into six separate subdivisions so that you spread the stuff out more over the water table and you perhaps enhanced dilution that way and ground water transport. So they were really tackling all four of those approaches.

We heard a lot about Defense-in-Depth at the workshop, and it was a--I'll say it was a concept more than a well understood set of procedures to follow. It's not been defined in a licensing process for a repository yet. A number of people in the process have familiarity with it from experiences in the reactor business. And it's worth worrying about, but I have a sense at times that the way the project was interpreting it would not necessarily be the way the NRC would interpret it, but only time will tell. And then of course the final thing is, is it feasible from the practical standpoint of what's the cost schedule and so forth, can we build it and operate it.

A couple points before I--I've got a few comments on the three general characters, but to jump to a question Dan has asked a couple times on so how do you optimize based on your criteria, what are the weights you use, how do you figure that? I think that the Phase 2 activity will not start with that question, or at least I hope it won't. There's a different decision rule besides optimization, it's called elimination by aspects, all right. I mean, if I'm going to go buy a new car, I know right off the bat I eliminate all that cost more than X, okay, and so on. I think in this case the first question will be, "Can we license it?" It's a novel idea, but can we prove it will work with reasonable assurance to the NRC? And if the answer is no, then the panel I suspect is going to just that this is not an idea to be carried forward. It may have merit, but if you can't reach reasonable assurance, it's not worth spending a lot of time and money on.

So I think there will be some of those. If it requires, you know, a half inch of gold on the outside of the waste package, I think you can rule that out. I mean, there's a lot of bases by which you can eliminate some of the proposals, all right. And I think that Phase 2, how that gets done, will be interesting.

Down to the design review. It was interesting how at least to me the people who were simply assigned to one of these three groups became advocates for that design approach. I think just it was kind of a friendly, competitive spirit. Secretly, they may go home and say, "I had to pretend that I liked hot designs when really I'm a cold," and vice versa. But it laid out in very stark terms the fundamental philosophic difference between hot and cold designs. And one of the presentations earlier today, I think Carl's, mentioned that the analyses tends to show similar means, but the uncertainty bands go up with the hot designs.

My own concern is that it's worse than that, which is it's not just the uncertainty bands go up, but the ability of the modeling to pass reassurance becomes increasingly in doubt. That is that the sense that we really understand and can model and project the performance of the system under prolonged--you know, 10,000 years at 200 C. What it might do to the materials I think is a very difficult question. And the issue there is not performance, it's acceptable uncertainty in performance. And of course there's no clear guidance on that, but that will be the driver.

Conversely, you know, the hot designs have the benefit of requiring fewer waste packages, fewer miles of drift. You can engineer them pretty much to keep the whole place above boiling for 10,000 years. To my surprise, those designs did not come out to be estimated to be any cheaper than the current reference design, even though there were fewer packages and miles of drift. And I guess I don't--you know, intuitively, I would think that miles of drift plus number of waste packages would correlate more with cost. But as someone commented to me at the meeting a week and a half ago, the current design has really been worked over pretty hard from a cost and operations point of view.

The third area, the enhanced access, I guess my sense of that was that the reasons you'd want to send some poor sole into a loaded drift were not sufficiently well defined to evaluate the alternative ways of doing that. In thinking through what those reasons might be--Dick listed some today--I guess the one that seemed most reasonable to me was to do something having to do with replacing or fixing failed instrumentation. I mean, you're not going to have somebody go in there and lift a waste can back on its cradle. You're not going to have them spackle the ceiling, I don't think. And I just thought there were probably clever non-human intrusion ways to meet the same ends.

And I think the design trade-offs that came out of that enhanced access group were very interesting. Because of the need for shielding for human access, and both built into the waste packages and also applied at the time of entry into a drift, you tended to get extra thick waste packages. In one case I think the design called for, what, 30-inch thick stainless steel?

UNIDENTIFIED SPEAKER: 30 centimeters.

WHIPPLE: Oh, it was 30 centimeters. Excuse me. I mean, someone at the time said, "Geez, could you weld that?" Of course I don't know the answer to that. But the push was towards lots and lots of metal to absorb gamma.

The push in the other two directions, and particularly in the hot repository, was towards more use of corrosion resistant materials. And the trade-off of using a corrosion allowance material as a radiation shield without even a sense of the likelihood that you're going to want to reenter the drifts seem to me to--I must say I was doing a worse job than the rest of the folks at not filtering out the ideas and trying to pick the winners as we went. But I think that was the interesting aspect of how that design objective appeared to change the nature of the waste package design. And then the problem, of course, of making it thick and multiple corrosion layers gets to be cost. So they all interact.

All right, with that, let me quit and take questions.

BULLEN: Okay. Any questions for Chris Whipple from the Board? Alberto?

SAGUES: I guess that the question to Chris may also involve some of the other presenters as well. But I've been reflecting upon all the presentations and upon what you presented, which is a pretty good summary of the main issues that are faced in here, and I was saying if someone were writing the history of the project at some time, 10 years from now, 20 years from now, whatever, would come up saying things such as, "Well, this was a very well structured effort," the one looking at the different alternatives, "very well structured, very well organized, there's no question about it, everything nicely documented." But four months were spent to make a million-year decision about durability of the system or the performance of the system. And this concern has been expressed by other members of the Board, and I'm sure many other people as well. It's just too accelerated of a decision-making process. Are those in the project taking time to make a judicious weighting of all the possibilities? We're pushing this too fast.

The main concern that exists when one sees this is that, well, we are just looking at a few ideas, we are discovering some others, and we're just concentrating on this and we're picking to hold them together. Well, then finally some product comes out and then we'll say, "Well, now we're going to the next task." But I don't know if that's the best way to decide what to do. All of us who have been involved in research and design and any engineering or science activity know that you can only consider so many ideas in a certain amount of time. Sometimes the best thing to do is to stop working on something and come back two weeks later or two months later.

So considering that we are dealing with something quite unprecedented with a large number of unknowns, this tight schedule, highly structured approach in a very short time, has a very good chance of coming up with something very different from what may be the best decision. I know that there are other constraints, but that doesn't mean that if one follows the constraints he's going to come up with what needs to be done. Or in other words, sometimes the best that can be done just may not be good enough. And then all of this may have to be redone again.

So I think that we have to think about the implications that following the schedule are going to have on the final product. So anyway, that's the general comment.

And I have a couple of specific issues, which I'm just going to mention at this moment. Perhaps after others have an opportunity of discussing other matters maybe I can come back to those if there's time. And the issues are that most of these options seem to be thinking in terms of drip shields and backfill, and these items are relatively new. They have been considered as possibilities in the past, but now they seem to be pretty much on the way of becoming pretty much a reality in the overall design. And I think that there's a lot of questions about the pros and cons that are vital that have not been addressed in anything other than from the point of view of educated speculation, but very little more than that.

So anyway, those are the comments I wanted to make at this moment. And in a way, they're questions.

BULLEN: Yes. Anyone care to respond, I guess, is the first call? Paul Harrington.

HARRINGTON: Paul Harrington, DOE. We've been looking at this obviously for a lot longer than four months. The four months that you referred to really will be sort of the culmination of many years of acquiring data, a number of different design approaches. This project has evolved from the conceptual design report through the advanced conceptual design report to the Viability Assessment Design to the various designs that you're seeing on the table here. So I don't really feel that we're trying to slam dunk something in a very short period that doesn't have quite a bit of history of looking at many of the components of this earlier. Likewise, we're trying to take to heart a lot of the guidance that we've gotten that says don't make more of a decision than is warranted.

If you'll look at the VA Design--I think this was one of the earlier comments today--the VA Design is fairly detailed, even in the surface area. I would not expect this LADS product to be anywhere near the level of design detail that you'd find in the VA. We'll probably be in a position to make some pretty fundamental choices, but beyond that I don't expect a lot of detail.

BULLEN: Any other comments? Chris?

WHIPPLE: Yes, let me pick up on the aspect of Alberto's question about the desirability of having more time to think. Some of the design alternatives that were discussed and proposed have a very extended time sequence for operations. For example, you wouldn't install a drip shield until after 50 or 100 or 200 years of active ventilation. Or perhaps passive, but some sort of ventilation to move heat and water out of the mountain. And the specification of what the drip shield would be made out of and how it would be shaped and how it would be installed and all of that would probably have to be defined for a license application, but that doesn't mean that it couldn't be modified over time as people have better ideas about how to install it and backfill and whatever you need to do. There was some consideration given to the flexibility that approach would add.

Similarly, it showed up favorably on the cost down. If you're putting your money for the corrosion material into a drip shield and you don't have to buy it until 75 years from now, it doesn't take much of a discount rate to make that a lot cheaper than having to buy it today.

So those things were considered to some degree by the team, but how that interplays with the need to go forward into a license application with a design that's sufficiently well spec'd to be reviewable by NRC is an uncertainty that I don't know the answer to.

BULLEN: This is Bullen, Board. I actually have a problem with that discount argument, and the example that I'll use is the nuclear power industry. I used to be able to buy a reactor for about $400 million, and now I have to pay $4 billion. And I had to go back and, you know, redo the seismic analysis for my pipe hangers for every plant and retro fit it to meet the needs of a changing regulatory regime. So if I do the same kind of thing for a repository that I'm designing and building, I'm not sure I save any money even though I wait 75 years to buy a drip shield. That drip shield may be gold plated by the time I need it, and so it's not going to cost me any less. And I have difficulties. I understand the time value of money, but the issue here may be a bad example of what happened in the nuclear industry where I used to be able to buy, you know, a 500-megawatt plant for a reasonable price and now I can't. And the same kind of regulatory regime could jump in. I mean, tell me I'm wrong.

HOWARD: You're wrong.

BULLEN: Okay, Rob has told me I'm wrong. Paul Craig.

CRAIG: Paul Craig. Yes, the economics in the nuclear area is always kind of weird and one just has to add in the other side, that gee, just store the stuff for 100 years and postpone everything and discounting will clearly make it cheaper, unless Bullen is fantastically right. But so the economic argument for delay seems to be overwhelming. But that's really not the issue that we're interested in. And in fact one of the things that's bothered me about the discussion today is that there has been a reference to the cost of it a lot. There's no question that once you go ahead with the system over the many decades that you've got there will be all kinds of wonderful ideas that will come along that will make all kinds of sense.

The problem that we face at the present time isn't that. The problem that we face at the present time, it seems to me, is that there is no design that looks, to use the term that I heard a hundred times when I was out at the conference, the slam dunk concept. It seemed to be the favorite word during the workshop. There is no slam dunk concept. There is no concept which even comes close to it.

If you're going to go through licensing, you've got to have, I would hope, some concept that's really going to make it, that really does have Defense-in-Depth. And then later on, once you've got it, then you can go off and begin to modify it with more experience.

And, Chris, I'd like to get your feeling as to whether you think there is any concept which has a chance of making it through the regulatory environment at the present time. And if there isn't--if there is, well and good, but if there isn't, then the kind of argument that Alberto was making about taking more time in order to do it right, or at least better, becomes enormously powerful.

WHIPPLE: Okay, well, Paul, let me answer in two parts. First is, can you license any given design right now? In terms of the performance requirements proposed in Part 63 and as are likely to be proposed by EPA, I think that there's a number of designs that can meet those. It's a 10,000-year standard. I think that defending a 10,000-year waste package is feasible. And not to say that the other parts of the system don't contribute, but they may be harder to analyze and obtain a performance credit for.

But the rest of the question of is it licensable based on post-10,000 performance where the dose curve is still rising, the interpretation of Defense-in-Depth, I don't know enough about how those will be done to know if you can propose a repository that would answer those questions. I certainly think that the move towards the more robust waste package materials coupled with a cooler repository design to put you in a known regime of material performance and keep you there and to keep the characterization data you have on the site relevant to how the site will perform without altering it in an unknown but possibly substantial way has the greatest chance of being licensable.

Whether, you know, say a dual CRM waste package coupled perhaps with backfill after 100 years and ventilation and so forth would need a Defense-in-Depth measure because, you know, how do you count, is the waste package one layer or two, I don't know the answer to that. If you have a waste package and a drip shield, is that two barriers as opposed to one even if they're leaning against each other and it looks pretty much like a two-layer package? I don't know how you interpret that. I think people have to chase down whether there's reasons to believe that there's likely to be performance advantages with one or the other rather than to apply kind of a simple rule of what Defense-in-Depth is.

BULLEN: Any other questions from the Board? Actually, I have one, but I waited a little bit here.

NELSON: Well, you don't have to have questions, you can have discussion.

BULLEN: Well, this is discussion, true, but-- In the presentations this morning about PA--and this is sort of addressed to Rob here--is there anything that you sese as extremely difficult in allowing you to reduce the uncertainty? I mean, in any of the eight alternatives that you're carrying forward, are there a few that, you know, you just look at them and you scratch your head and you say, "Boy, I just don't see any way," or "It's going to be extremely difficult without additional data, additional time"? And so do any of them sort of fall off the radar screen naturally, or is it that you're not far enough along to be able to do this? Then the follow-on question to that is, if you're not far enough along, when will you be far enough along to know whether they can fall off the radar screen or not?

HOWARD: Rob Howard, M&O. The answer to your first question, you know, do any of the eight fall off the radar screen, the level of analysis that I can provide to the engineers is only as good as the conceptual design information they give me. If I don't know how, let's take for example the marble, fails, or if I don't understand that well enough, I can't do a calculation. You know, those sorts of things I just have to go back and ask for more information. I'm not going to provide them an analyses that doesn't make sense to the Performance Assessment Team. Whether or not they decide to carry that design forward is certainly not up to me. We can only provide them information that says, "Well, we don't have enough information to give you an analysis beyond what we've already done."

As far as when will we be there, again, I can make forecasts about performance, but I'm not very good about predicting the future. Those are very difficult things to do. You know, that's more of a programmatic question, so I guess I'll defer to Dick Snell on that one.

BULLEN: Actually, that's a good follow-on to Dick. I mean, are the resources available for Rob and his group to come up with the support necessary for you to winnow down and make the correct decision or--and I know this is a--I can see the answer's going to be yes, you're going to give him everything he needs. But in real time, are you going to be able to get the analysis necessary? And then I'll come back to Rob for another question, but go ahead.

SNELL: Presuming that we work smart, I think the answer is indeed yes. Clearly we can't do everything that we might like to do. We've got a limited time frame here and some activities are only compressible to a degree in terms of time, they don't respond to money or resource. So we do have a limited time to work, and we therefore have to work smart.

So what we've got to do, as I was alluding to a little earlier, is put our effort where either the most serious concerns lie or where the greatest benefits appear to be offered up to us. And that's what we'll be doing over the next few weeks.

BULLEN: Okay. I guess the question that comes back to Rob is, do you have the capability in your models to show sensitivities to the uncertainty of the thermal hydrologic regime for a hot repository versus a cold repository? And how do you manifest or express the uncertainties that rely on each of those? I mean, how do you quantify the less certainty of one or the other?

HOWARD: Well, we probably should separate to some extent uncertainty with the issues of analyzability.

BULLEN: Okay.

HOWARD: Obviously if we look at just water and flow through the mountain, how the system responds, the lower temperature design concepts obviously where you're eliminated the energy equation from the equations that you have to solve makes it a lot easier to analyze. Of course if we don't put any energy into the system, we probably haven't solved a national problem. So the low-temperature designs, just from a computational perspective, you know, when you eliminate or reduce the dominant terms from the energy equation, make it easier to analyze.

Uncertainty, you know, there's uncertainties in our conceptual models, uncertainties in our processes, uncertainty in the timing of when things happen. All of those things to some extent can be reduced by more study. Obviously if you gather more data you can build confidence in your uncertainty and in some cases narrow the bands. I think that tomorrow you'll be hearing more about uncertainty analysis, how it was done in the Viability Assessment, and that's probably the direction we're going to go for site recommendation and license application. But will we be doing multi-realizations in this time frame? I think that that's still up for discussion on what Dick Snell wants us to provide him. In those cases where we don't have distributions, I can't do that.

So that may not be exactly the answer that you needed, but you know, that's just the truth of where we stand right now.

SNELL: Could I--

BULLEN: Dick, go right ahead.

SNELL: Could I go back for a moment to the question that Alberto put about--

BULLEN: Sure.

SNELL: --four months to make that million-year decision? Just a couple of observations. As Paul said, we've been working on it for a longer period of time, but I'm always struck by the fact that the task that's been set is huge and it's a little presumptuous to make any kind of a decision that we think is going to last for a million years no matter what. The pyramids have been around for, what, 6, 7,000 years, something like that, and I've always wondered if the pharaoh said the pyramid builders, you know, in Egyptian, of course, "You going to guarantee this thing is going to be around in 10,000 years or 50,000 years," or whatever. I don't know whether they had the nerve to answer or not. But I guess the point I wanted to make is that it is a very large task.

Some of the decisions or the answers to questions that are being raised are going to come as a result of the review process which we're going through right now. And while we're operating on a schedule, I think there will always be schedules and we'll find ourselves always trying to work to schedules. I would just suggest that, you know, the kinds of questions that you are asking now, the kinds of questions and decisions that will have to be made by DOE at the headquarters level and others at that level over the next few months after we submit a recommendation in May are a part of the process of judging whether or not we think we've assembled enough information and provide enough insurance and there's enough credibility to let the process go forward.

When you talk about licensing, the ultimate test is submit the application and let the NRC begin the process. And I fully appreciate the discomfort, believe me, that goes with putting together a package which is supposed to substantiate a facility which is intended to last for, you know, thousands or hundreds of thousands of years and get it licensed. I think allowing the process to run its course is part of the way that you get there.

Well, enough said, I should probably stop there.

BULLEN: Thank you. Don Runnells.

RUNNELLS: Runnells, Board. I guess I have sort of an unease with the sort of thing we've heard from Alberto and others, the hurry up because we have to meet a deadline that has been established by somebody else. It's not been established by the scientists or by the engineers. And I understand that, I mean there are expectations, there are lawsuits, there are laws, there are all kinds of things that drive this. The unease I feel, though, is I continue to catch bits and pieces of things that aren't known that could be perhaps so significant that they're irreversible.

As an example, the concrete lining on some of the tunnels, or on the drifts, that sort of thing is a huge decision to be made. Will the drifts be lined with concrete or not? That may approach being irreversible in terms of cost and change in it if it's the wrong kind of decision. In listening to people like my friend Priscilla who works in that field, I'm not convinced that we have enough information to make a decision of that magnitude on something that may in fact approach being almost irreversible.

Another example, will rock bolts and mesh to support the back be detrimental to the waste package? We hear a lot about ferric ions and chloride and all of that stuff causing corrosion. If it's bad to leave rock bolts and steel supporting mesh in the tunnels and the drifts, that's something that we have to know very, very early, and I don't have the feeling that we know that at this point in time. Now, I know there are people working on that, but I don't have the feeling that we know it in the context of knowing whether or not a design will have a certain kind of support for the back and for the walls of the tunnel, concrete or rock bolts and steel mesh.

I heard my colleague Dan say that radiolysis will cause nitric acid to drip and that will dissolve the marble. We should call it limestone, limestone's a lot cheaper than marble, so dissolve the limestone. You know, maybe you just pulled that out of the air, maybe it's for a particular configuration, or maybe it's something we don't understand. And if it's something we don't understand, I have a profound unease about it.

Don't answer, I'm just listing.

BULLEN: Okay. That's fine. Sure.

RUNNELLS: From a geochemical point of view I've heard modeling efforts, hopes, thoughts that the movement of moisture away from the walls of the drift due to the heat and then the later reentry of that moisture carrying dissolved components will cause cementation, precipitation of minerals, and that would be hugely beneficial or hugely detrimental, I'm not entirely sure which one, but it's the kind of thing that approaches being irreversible.

So with that long sermon from a chair, not from a mount, but just with that long sermon, I'm wondering, is there anything in the design, in the workshop and so on that in the context of having to go forward in the next few months is irreversible or approaches being irreversible and therefore has caused certain designs to be discarded at this early stage? Or, perhaps more importantly, with this long list of possible unknowns and possible problems, should these things cause certain designs to be discarded in the next four months?

Now, let me invite comments or answers on the irreversible concept.

BULLEN: Comments on that?

SNELL: Yes, I'll--

BULLEN: Dick.

SNELL: Initial comments anyway, if I may. First of all, I'm glad you brought it up, I'm glad you raised the question in those terms. I've phrased it differently in talking about it internally, but one of the things when you're doing any design that you like to avoid is coming up with a design or suggesting a design where you've built yourself into a corner, so to speak. That is, where you have committed to a design which has irreversible aspects to it. And if that occurs or, you know, if the worst happens, Murphy's Law prevails, you have no escape, no alternative, no way out.

And our approach is to try and avoid designs which would leave you in such a situation. That is, where you commit to an approach for which there is a risk that you may encounter a bad and an irreversible situation. The idea that you can always avoid a situation like that is one to ponder, because it depends on how much information you have, how intelligent folks are, the breadth of everyone's experience, and so forth. So as a goal, it is a very, very important aspect of how we go forward, taking a look at whatever it is we're recommending and trying to do a critique from the standpoint of are we taking any steps with this approach that puts us into a situation that we can't escape from if the worst happens. And do we even understand what the worst might be. That's part of the equation.

Without going into detail, I'll just comment on a couple. Concrete, for example, does raise serious questions. There are some things we've already encountered which suggest that that may not be the thing to do for ground support. Rock bolts and mesh are under consideration as an alternative. Radiolysis still requires further attention. All of those things are things that are on the table along with a number of others where we have to ask ourselves, you know, can we do something wrong here and not find a way out?

Good question, no magic answer, but a very high priority item as we go forward.

BULLEN: Other comments? Don, did you want to respond? No?

RUNNELLS: Just very, very briefly.

BULLEN: Please.

RUNNELLS: The analogy with the pyramids, that's a good one and I've thought about that also. The problem with it is that the pharaoh probably didn't say, "Will it be around for 6,000 years"--well, he may have said that, that's what he cared about, but the question he should perhaps have asked, had he cared, was "Will it collapse and kill the people who have to walk by it?"

With respect to the moon shot that John and I were just talking about, had we debated endlessly about whether or not we could go to the moon, we would have never gone to the moon. The difference is it didn't have the potential for harming people. And that's the difference that we face here, it seems to me. It would harm a few people, very brave astronauts, but not the general population. So I think some of these other things that we think about in terms of going forward despite these uncertainties are not entirely parallel, not entirely comparable.

BULLEN: Okay. My chairman who relinquished the microphone to me says I have two minutes to wrap it up, so I'm going to ask Alberto to finish up, and then I'll say a couple words.

SAGUES: Very limited question. This would be for Carl Hastings. What would it take to have a design that would limit the package wall temperature to less than boiling, let's say less than boiling? How big would the footprint have to become or how much preconditioning would it take to do that?

HASTINGS: Off the top of my head, I'd say one of the simpler things we could do would be to derate the hotter packages. The basic design that I presented, a large number of the packages--I can't tell you what the fraction is, but a large number of the packages would not be at that high design level. Those that approach the higher temperatures you could derate those and just increase the number of packages, increase the number of drifts to put those packages into, and you'd probably make some significant progress towards keeping the temperature down.

Other things to consider are just keep the repository open beyond the 50 years so that you continue to ventilate and you continue to move down the time temperature curve could also be effective in keeping those temperatures down. If you're really interested in looking at the temperature of the surface of the waste package as opposed to the temperature of the drift, then you probably would not want to use a backfill or Richards Barrier, something that essentially puts a thermal blanket over the package. You'd look at going inside the package with canisterized fuel inside the package to get an additional barrier there, or you'd look at other aspects of the safety strategy, looking at delaying the transport of the radionuclides through the near field with a getter or something like that underneath the package.

So there are a number of options that could be looked at. Nearly all of them would cost money, and so you'd have to play that trade-off as well. Did that answer your question?

SAGUES: Yes, and the question of course was moderated by the belief which I think is shared by many of my corrosionist colleagues that every degree, see, that you come down on that particular parameter would increase the expectation of good performance dramatically.

BULLEN: Thank you, Alberto, and thank you, Carl.

This is Bullen, Board. Actually, it's really nice when everybody always precedes you in the summary because the points have already been made. I'd like to express appreciation to Chris Whipple for bringing up the point that I wanted to make about cooler being potentially more robust, more relevant data available, and it might be a simpler design to analyze. I'm appreciative also to Don and to my colleague Paul to talk about irreversibility and maybe there's no slam dank.

As I mentioned in the closing of the workshop when we were asked to sleep, there are a couple of things that I think are most important with respect to the alternative design aspects. First and foremost is essentially the same thing that Chris said with respect to licensability, that being reducing the uncertainty. In the reduction of uncertainty, you actually increase or enhance the potential for licensability, and also maybe the potential for transparency, which again is the acceptance of not only members of the NWTRB and the NRC but the general public.

The other thing that you're very well aware of is the ability to enhance waste package lifetime. If that be driving all the water away as one of the options, if you can analyze that, or reducing the temperature so the corrosion rate goes down, enhancing waste package lifetime is one of the very important parameters.

And finally, and maybe foremost with respect to the previous two points, is the KISS principle. If you can keep it simple, it's going to be analyzable, it's going to be licensable, and it's going to be an option that you'll be able to carry forward potentially without any irreversible consequences in what you do.

With that, I'll just close this session. I realize I am seven minutes late, and I turn the chair back over to Madam Chairman Nelson, who's going to talk about public comment, I think.

NELSON: Yes. Thank you very much, and your penalty for that is that you have to stay longer.

BULLEN: I would never leave for public comment.

NELSON: I know you wouldn't. Okay, we have a total of nine people who have signed up for public comment, including the three who spoke before lunch, so I talked to them, everybody except for Perry. Is Perry Montazer still here? Okay. What I'd asked is that the people who spoke immediately before lunch can be the last three speakers and we'll go to the people who did not speak before lunch first.

MONTAZER: I don't want to speak.

NELSON: You don't want to speak anymore?

MONTAZER: No.

NELSON: Okay. All right, in which case what we have is eight speakers now, and we've set aside an available 30 minutes, which means we're in the neighborhood of three and a half to four minutes statement is what we're requesting. The first person to sign up under these rules is Anthony

Hechanova. Did I say it correctly?

HECHANOVA: Yes.

NELSON: And Anthony is from UNLV. And feel free to use that mike or here, whichever one you feel comfortable with.

HECHANOVA: I'll use this and I'll try and be real quick. I just myself learned that this is just a portion of the Board, actually a panel, not the full Board, so I'll save some of my general comments for tomorrow. Real quick question. It sounds like a lot of interesting reports are going to come out about evaluation of these various design options. Are those going to be available to the public, in particular the Nevada public? And if so, is there a point of contact or a person that we can find out?

HARRINGTON: Paul Harrington, DOE. We'll be making the Viability Assessment and these sorts of documents available on the internet.

BULLEN: Bullen, Board. Paul, I think maybe the more specific question, are the 3-5 documents going to be available to the public, are the design and decision analysis documents going to be available to the public, is probably a better question than just the VA.

HARRINGTON: I don't know that we've decided one way or the other on 3-5's. I don't know that we have said yes. We might.

NELSON: Okay, next person who signed up is Bill Quapp.

Am I saying that correctly, Quapp? Member of the public.

QUAPP: Well, I didn't know I had to sign up this morning, so this comment would have been more timely following the two speakers just prior to lunch, but I want to compliment those folks doing the importance analysis. I think that's a critical thing that has been shown in the world of post TMI reactor safety evaluations to be a very important set of insight on what we should worry about and what we should worry less about.

And that leads me to another comment, though. I think one of the things we should worry less about is things that are in the 100,000 year/million year domain. I like to think of benchmarking a new time scale along the bottom of your time clocks that might be units of the history of mankind. In other words, we have about 5,000-year history of mankind, and I think predicting and justifying and analyzing the performance of engineered and natural barriers for one or two or three or four multiples of the units of mankind's history is a very credible if ambitious undertaking. I think looking at time frames in the 100,000/million year domain is ludicrous. I mean, you might as well put Ice Age events down there. And my god, you know, let's don't even spend CPU time or plotter time going out that far because all of a sudden we may find ourselves beginning to believe it. And we've heard about decisions being evaluated on the post-10,000-year performance. And I just would like to, after a little sanity check, is let's get back to worrying about maybe the first 50, 100, 300, 500 and some more rational number we could even have other time units like the history of America. That's 250 years, or thereabouts. And, you know, doing things in the time domain of those sorts of intervals are critically important to me as a taxpayer who happens to have spent 30 years or so in the nuclear business, too.

So I just caution you, you've done a great amount of work, but let's not let the availability of CPU time lead us into believing that kind of nonsense out in the 100,000/million year time domain, because you're never going to convince the skeptical public of it, even if you might convince a few engineers that you have done honest and noble computations.

NELSON: Our next commenter is Englebrick von Tiesenhausen from Clark County Comprehensive Planning.

VON TIESENHAUSEN: As Dan Bullen mentioned earlier, a lot of the comments I wanted to make have been overtaken by events, so to speak, and not only at the meeting here but also with the Phase 2 effort that's going on with the enhanced design alternatives. But I'm going to repeat them anyway.

DOE has I think made a reasonably credible effort to look at alternatives for repository and engineered barrier design. While the box of VA design has been opened, the design alternatives under consideration still could move a little further away from the mental constraints of the VA design.

I have to agree with everybody the two most important considerations would be decrease in uncertainty, and to me that also means an increase in drift stability.

The two low-temperature alternatives, while greatly reducing the possible effects of coupled processes, are still not aiming at a temperature that is low enough to get out with the area of concern for corrosion. Alloy 22 may in fact be re-interlocalized pitting at that temperature, but the issue of stress corrosion cracking is still unaddressed.

The issue of tunnel stability could be improved by using smaller diameter tunnels. I understand that one of the perceived constraints on tunnel diameter is the notion that a gantry must have adequate clearance to lift one waste package over another one. This is not a valid constraint when considering alternative repository layouts that are supposed to be out of the box.

Having a preference for low drift temperatures and smaller diameter tunnels, I find it difficult to see any advantage to a high intermediate temperature thermal loading with a waste package that has a 30-centimeter thick carbon-steel liner. Any liner that has a corrosion resistant material as part of its system would be preferable to one that has only a corrosion allowance material.

A better understanding of the natural geologic and hydrologic environment in the ambient conditions may in fact lead to a different choice in design and attempt to make up for a lack of understanding. And I quote this as lack of data by adopting apparently robust engineering solutions. And this is one extremely important reason to continue to work on trying to gain an understanding of the natural system and the effects of authentication of that system by the emplacement of spent fuel and high-level waste.

In addition, there is little Defense-in-Depth if all the performance allocation is placed on the engineered barrier system, especially if they are common failure modes.

In addition, I have here an article I'd like to give to Dr. Blink on radiation effects on environmental cracking or stainless steels, which I promised him earlier.

Thank you.

NELSON: Thank you. Thank you Englebrick.

Our next commenter is John Kessler from EPRI, Electric Power Research Institute. John.

KESSLER: Thanks, Priscilla.

In the talks I've heard all day today I was struck by the lack of clarity in what Defense-in-Depth means in terms of how it's going to be applied to the repository system and what the benefit of uncertainty reduction really is. Both issues certainly underscore the need for regulations. We could learn a lot by having some more input from NRC on both issues.

In terms of Defense-in-Depth, there's one thing that I found very curious about one of Kevin Coppersmith's slides. That is we're saying one of the screening criteria for all the EDA's is going to be for Defense-in-Depth to neutralize barriers and stay below 25 mrem per year. And I don't really understand that. Is the assumption that there's a reasonable probability that the barriers will fail completely? If so, then I can understand adding that criterion and I can understand how it comes out of reactor space where there are some barriers, you can call them that, or some features of an active repository system that you can understand could fail completely, and that's why you have certain redundant systems.

In the case of Yucca Mountain, is DOE really saying there's a reasonable probability that every single container fails early? Is there a reasonable probability that an entire natural barrier completely disappears? If that's the case, fine, then it seems reasonable to keep that Defense-in-Depth criterion. If not, why are you doing this to yourselves? I don't really understand. So it's something that would require more clarity in terms of what you mean for

Defense-in-Depth, and I encourage John Austin if he's not otherwise going to when he talks tomorrow about NRC issues if he could provide any clarity on what Defense-in-Depth means to NRC when applied to Yucca Mountain, that would be greatly appreciated.

Regarding uncertainty, we've heard a lot about yes, there are great benefits to reducing uncertainty. Yes, that sounds good, and I think I would generally agree that there are benefits to reducing uncertainty, but we've heard when Dan asked an excellent question and Rob's response was, "Well, gee, there's uncertainty in what we know about the uncertainty and there's going to be uncertainty about what uncertainty is left after we try to reduce uncertainty." Now that's fine, I can understand that, and NRC had the foresight, even in Part 60, to say that we realize we're going to be proceeding at risk when we're talking about the kind of time frames we are. We can say yes, we may understand material properties better if we keep things below 80 degrees C or whatever. We're still talking about 10,000 years or more, there's still going to be uncertainty. We need to, before we make any decisions about yes, this is the way to go because we can reduce uncertainty, yes, hurray, understand what it's really buying us before we make such a leap into a decision like that.

Thank you.

NELSON: Anybody want to respond?

(No response.)

NELSON: Okay. Our next commenter is Tom McGowan, a member of the public and known to most of us.

MCGOWAN: I see many fascinating faces here, many of whom--I should assert that I hold all of you in the highest esteem, admiration, respect. That is, most the people. You can guess who, the rest of you can argue about it.

Ladies and gentlemen--the rest of you know who you are, thank you, Milton Berle--Madam Speaker--Madam Chairman, I beg your pardon--is this Republican, Democrat or what?

NELSON: Yes.

MCGOWAN: Bipartisan?

NELSON: Yes.

MCGOWAN: All right, there' a reason for the relaxation on my part, because I had the good fortune to miss the entire meeting today. I just now arrived and I found public comments so far which fascinated me. I really mean that. It indicates the quotient of assimilation and probably the quotient of fascination on this entire presentation.

Is that Mr. John Greeves of the Nuclear Relaxation Commission? How do you do? You're forgiven, because you're not alone. As a matter of fact, it wasn't your idea in the first place. I believe the unscientific Congress came up with something called the NUPAA Mission Mandate. And they direct you to do everything except to think. And I don't mean that so, you know, disparaging. Let me put it this way: there's two ways to get this pen to the floor, isn't there? At least two. One is to throw it, exert that energy. The other one is to release it and let something called gravity do it.

I have a question for Dr. Bullen, who is not a hydrogeologist, is that correct?

BULLEN: That's correct.

MCGOWAN: But you are something to do with the surface materials of the canisters. So where are they hydrogeologists. Dr. Pascagula, are you here? Thank you. You, English?

UNIDENTIFIED SPEAKER: Yes, sir.

MCGOWAN: Okay. Where does the water originate from that impacts the repository? Simply where within the unsaturated zone? And if you say directly above the repository, we're going to have a problem. So where does it originate from? Where is the four-dimensional map of the hydrogeology of the entire region? Okay. Okay, the object is to keep the water out. Is it conceivable that the best attenuator for the emplacement drift to impact the consequences of dripping water would be a water shield? Why not immerse them in water?

Second question--they didn't answer the first one--

why are the emplacement drifts arranged in a horizontal frontal manner? Why? Is that the same thing when you get in a ship, instead of facing the prow into the wind, you face it like this, sideways? In other words, the largest area that will be impacted is the one you have facing the oncoming water. What if it doesn't come from above the repository? The water is not the key determinant of the problem. Neither is the nuclear waste. The key determinant is gravity, coupled with the context and configuration of the unsaturated zone by the geologic domain. Anybody agree with that? Which is more impactive upon the canisters, static water or--

BULLEN: Bullen, Board. In response to Mr. McGowan's question, actually, it's the near field water however it gets there, and since I'm not a hydrogeologist I can't tell you how it gets there. But when it's near the waste package is when you're the most concerned about it.

MCGOWAN: What if we're not allowed to get there in the first place, what would you be concerned about then except where to get more paper to print more stuff? And don't get me wrong, I appreciate the New York phonebook worth of information, I really do. The thing I'm concerned with is, the pathway and the singularity apparently is the one between the ears, because here you are with a repository horizon, which is fabulous. That's career preservation. In fact, that's what you were told to do. Not your idea at all. The whole point is, the water is out there on original scale, accumulating, coming your way. How long does it take that water to get there? How long did it take the Chlorine 36 to get to the repository horizon from wherever it came from? Anybody.

BULLEN: Less than 50 years.

MCGOWAN: What?

BULLEN: Less than 50 years.

MCGOWAN: Less than 50 years.

BULLEN: Right.

MCGOWAN: What is the rate of advance and descent, anybody know?

BULLEN: Pardon?

MCGOWAN: The rate of advance and descent. What is the rate of advance laterally and descent vertically, or near vertically?

BULLEN: I'll defer to my hydrologic experts.

MCGOWAN: Okay, fine. Or does it go in a descending arc, okay, which it probably does? So the water above the repository is going to miss the repository. The water coming from let's say Yucca Flats, or north-northwest came down slope, and it's going to get here a lot faster than you think. It's going to leave here a lot faster than you think, too. Because by the time it gets to the ground water, it will accelerate, and it may not stay in a dense, easily detectable mass, it may expand to a plume that you're not going to find again until you drink the water.

You've been very, very generous with the time. How much time is left?

NELSON: Zero.

MCGOWAN: Pardon me?

NELSON: Zero.

MCGOWAN: Then I can't tell you how nice you've been, no time for that.

NELSON: I wasn't going to win that one.

MCGOWAN: But anyway, I'll be back tomorrow. That's a warning. And probably will speak around lunch.

There are three prerequisites in a safe, secure repository. You're addressing none of them. But they're available, they always have been. I'll tell you what they are tomorrow. Sleep well.

NELSON: Thank you, we can't--we will look forward to it.

Okay, our next commenter is Steve Frishman from the State of Nevada by way of Texas.

FRISHMAN: I only came up here so I can see all of you.

I have just a few questions and sort of related comments to them. I'm not expecting that they be answered, but I want to pose them just for purposes of the Board thinking about whether they're questions that they may want to further consider.

First one is, I'm wondering why this very rigorous design alternatives activity is going on right now, and the only conclusion that I can come to and why it wasn't done before and in a much more systematic way throughout the consideration of Yucca Mountain as a repository. The only thing I can think of is that it's required by 10 CFR 60, and they're getting close enough to where they have to do something because they're on a track for a license application. And I guess the question that follows to me is, if the new Part 63 doesn't require this same thing, what kind of commitment is there to this very, very important exercise? And that could happen essentially any time and not finalized before this May deadline, but it could happen soon enough to where the commitment to this exercise may change only because it's not driven by regulation.

And these are sort of disconnected points that just come to mind but I think need to be thought of in the context of this meeting.

A question, what's the rationale for only one juvenile failure at 1,000 years? The 1,000 year part I can understand because Part 60 requires 1,000 years of substantially complete containment. The one juvenile failure, remember, used to be zero. It was this Board that talked about juvenile failures, and my impression was the

Department didn't believe there would be any, so they gave you one. And I think from looking at the TSPA runs you can see the effect of just that one. What if it were two or three? So I think that needs to be examined when you're talking about design. And remember, we're talking, what, about 11,000 containers? So one juvenile failure? I don't know a better number, but one doesn't sound like a good one to me, especially when I see the impact of just that one in performance.

I didn't hear anything today at all about seismic design. And if you look at the VA you can see about a 10^{-4} per year chance of something probably greater than .5g. I don't think that's just commonplace seismic design, I think it's going to take some real doing to convince people that you're designing two events like that. So I think that's a realistic element to include whenever you're looking at alternatives in design.

Oh, and just as an aside, we had another one of those unusual events at the test site today, 4.5 in Area 5 followed an hour later by a 3.5. And DOE people said they were surprised. At least that's what they told the press.

We're seeing a large range of uncertainty in the things that Performance Assessment says really matter. And I recall seeing the Department's own assessment of the lifetime of the container. It has about three orders of magnitude uncertainty and it's unlikely that it can get any better than that.

This seems to be needing to be accounted for in some of the assessments that we see relative to alternative designs. Because we saw that one chart that caused so much discussion where the container lifetime so overshadows everything else that it seems that when you have a range of uncertainty that large, you need to account for it somehow, or at least account for it in terms of not confining the presentation. I know the analysis may have been better, but I don't see evidence of it. Not confining it to just mean values. You need to know, for instance, if there are three orders of magnitude of uncertainty there, how does that relate to the other features that it so far overshadows? Well, in most cases it's probably small compared to some of the other uncertainties. But I think it needs to be displayed, because that chart told me, I guess fulfilled some of maybe my worst fears, about the real level of reliance on that container. And if we're talking performance allocation, in other areas, for sensitivity for instance, if you have that level of reliance there, or that level of impact there, and you have something like the unsaturated zone, in all other parts of your sensitivity analysis you say the unsaturated zone is so small we don't even care, we're throwing it out, we won't even consider it. But in this case you have to, so it sits there. But it's far overshadowed.

Another thing, some of you I think have been listening to me long enough talking to this Board where you remember probably four or five years ago I asked the question, is the MPC driving the repository design? And it appears that the answer has become yes. But the real question, and the reason I asked the question, is--and I think is important in this alternative design--is did the MPC driving repository design, and especially driving the waste package, did that create a system where we're not even looking for what may be a safer design? We talked a lot about money, but we are locked into this big in-drift container, and it only got there because of the MPC. Now, are we stuck with it or are we courageous enough to ask the real question, is this the safest design? And I think that question needs to be asked. If you're worried about costs, you've trapped yourself using this sort of MPC approach, you've trapped yourself into, what, 11,000 containers at probably a minimum of $400,000 a pop. So we're talking big money. And it may be that a little more thought just on design and safety, and then come back and follow it up with a cost analysis, is warranted only because you inherited a design and you don't seem to be willing to get off of it long enough to even look at it again.

There is some talk about the 10,000 year period, and I think that--it's a design factor, it affects how you evaluate designs. And that's one element that came--or that the Technical Bases Panel looked at and said 10,000 years is the wrong period. The Department somehow has chosen to like the 10,000 years anyway.

Let's go to another one that came out of that Technical Bases Report that the Department is using and is not questioning anymore, and that's the 20 km. That's a design feature, too. Evaluate your designs for what they look like at the edge of the repository. Will you have a successful design? I don't think so. Evaluate them at 5 km, you might see some real differences in the alternatives. Twenty kilometers, in spite of the rationale that the NRC staff has attacked to why 20 km is right, I wholly reject that and disagree with it, and I'm going to give them some good reasons for it pretty soon. But you should be looking at something other than 20 km because there's absolutely no rationale for 20 km right now.

And I think that's probably it, I've covered the larger pieces. But all of these I think should go into your considerations and maybe your further questioning when you start looking at the design alternative study that's going on and just the approach that's being taken. There are things that are being taken as given and they are variable. And they should be variable unless there's a rationale.

NELSON: Okay, we have two more commenters. Sally, did you want to make additional comments?

(No audible response.)

NELSON: Okay. Sally Devlin, member of the public.

DEVLIN: Thank you. Thank you, Madam Chairman, members of the Board and friends. The reason I'm making another comment is I have the attitude that if I died today did I do the best I can and did I get it all out so everybody knows. And I am going to talk about what happened at the NRC conference because this was in Amagosa, and when I was there the naval representative said, "Sally, because you're so upset about the mixed waste with the naval spent fuel that we will declassify it for you." And this young, handsome tall thing, I looked at him and I said, "You know, you're talking to your grandmother. How dare you give me this privilege. Make me fill out all those papers for a report I wouldn't even begin to understand that I'd have to go to a chemist with," and so on. And of course I came with three different definitions of mixed waste. And my concern is, and I say to this Board this poor man was so shocked and I called the Navy arrogant and I referred to Lake Barrett's report, that they want 3 to 800 canisters at a million or two apiece, and if you read that report--you know I read every report--I had a fit. So I called the Navy arrogant and so on.

And I want to be reassured, because this is really not funny, nobody can top Tom McGowan, but I'm just saying that I'm really trying to make an impression on you that I'm terribly concerned about mixed waste with the Navy. And I want to be formally reassured that there is no mixed waste going in with their spent naval fuel, which is hotter than nuclear fuel.

The other thing--do I get a yes? Come on, guys, you've been sitting on your sense of humor since 7 this morning. Let's hear it, do I get a yes?

BULLEN: This is Bullen, Board. Yes, Sally, actually, John Arendt and I are both involved in an evaluation on naval fuel, and we have taken the tours and seen the sites and evaluated the fuel, and in fact are attempting to incorporate in our next report a comment about naval fuel. But in answer to your question, with respect to mixed waste, what we understand with respect to naval fuel, there is no mixed waste in naval fuel.

DEVLIN: Then why do they want 3 to 800 canisters?

BULLEN: Well, the understanding that we have is there will be about 300 canisters of spent fuel from naval reactors that will be disposed and it will have essentially the same engineered barriers as all the other waste packages. And do the only difference being how the waste form, the spent fuel itself, degrades. And from my understanding of how the waste from the--from the way the fuel is made, it is significantly more robust because it has to have a much more aggressive environment, battle conditions and the like, and so in response to that, the Board will make a few comments. But basically, in answer to your question, there is no mixed waste in the spent fuel.

DEVLIN: You solemnly swear? Okay, I believe you.

BULLEN: Yes.

DEVLIN: All right. Put it in writing.

The other thing I have to talk about is my favorite one, and about three and a half years ago, again at the Nuclear Waste Technical Review Board at a public comment, I asked Mr. Luger about microbic corrosion and collateral movement of water, and he said that wasn't important. So that's when I went back to school again. And to me that is the most important topic of everything. You have microbes that are just amazing in the basalt 4500 feet down in the rock eating the rock. You have SRS eating the steel weld. You have it everywhere. And every day they come up, just like DNA, with more microbic corrosion. And I think this is terribly important subject because you can't take CLR or Pledge and take a rag and wipe it off the rods. If the water that they're in is full of microbes, which was in one of the reports that I gave you, the other thing--and I gave you some more today about how the microbes love nickel, one of your casings, chromium, and all that good stuff. So I have been following this through for some years now and having a grand time with it. And so please remember my bugs that are very productive and very dangerous and very new and everything else. Because if the water coming through canisterization or whatever it is, or flowing from Paiute Mesa or wherever it is flowing, has the microbes in it, we're all in big trouble, because they love to eat anything.

And with that, that concludes my report, and I'm sure everybody's hungry, right? Can we all eat anything?

BULLEN: Bullen, Board. Just a quick response to Ms. Devlin here. The Expert Elicitation for waste package degradation or waste degradation has written a little on it. Has Sally gotten a copy of that report to address the issues of MIC? Because there were some recommendations made in that Expert Elicitation that she may be interested in. Could she get a copy of that report? I mean, I have one and I'd give it to her, but I guess it would be better if it came from DOE.

HARRINGTON: Harrington, DOE. We can get you a copy of that report, Sally.

DEVLIN: Is that the stuff from Livermore?

BULLEN: This was actually the waste package materials Expert Elicitation that Kevin ran, and so there is a report that Geomatrix wrote, I think, about the Expert Elicitation thereof. So that would be very helpful to you in answering your questions about MIC. Microbial induced corrosion, MIC, I'm sorry.

DEVLIN: MIC.

BULLEN: Yes.

DEVLIN: That's my latest thing.

BULLEN: But the DOE has a report that would be probably very useful to you.

DEVLIN: Well, you know the one that they're doing up at Yucca Mountain on the rock to me is very disturbing, because remember John Cantlon listened to hours and hours of testimony on the hydrology and he said, "Would you do it?" and they said that Livermore--

BULLEN: You should be at a microphone, Sally. We really want to capture all this, Sally, so please--

DEVLIN: Anyway, when John Cantlon was chairman and we watched 40 minutes of hydrology, the fractures, the fissures, the whole business, and then he asked the gentleman that did the brilliant report, "Where did you do your homework, or your science, or whatever you call it?" and he said, "At Livermore Lab." And he said that's not acceptable. And of course my little bugs out in the rock that they're doing is not being done in situ, and I think that's terribly important. Is it valid? These are questions that I have for you. And especially on my bugs, you know, I love my bugs.

MCGOWAN: Madam Chairman, were there any responses to my questions? They were serious questions.

And incidentally, that's M-I-C-K-E-Y C-O-H-E-N. Mickey Mouse, you're a runt. Thank you very much.

Were there any answers? That's the reason I came back to the microphone. There were three or four succinct questions.

NELSON: There were three or four succinct questions--

BULLEN: His first question was, where is the water coming from?

NELSON: --relating to--

MCGOWAN: Yes.

BULLEN: And he was very--

NELSON: Where was the water from?

BULLEN: Well, I am concerned about the water that's in the relative humidity near the waste package.

MCGOWAN: Where does that come from?

BULLEN: So basically it's in the air, in the drift, it's basically imbibed in ventilation and water as it goes by.

MCGOWAN: Does the unsaturated zone have anything at all to do with that?

BULLEN: Right, so there's water in the unsaturated zone. That's my main concern when I mentioned the issue of radiolysis, which you talked about.

MCGOWAN: Okay, fine, that partial answer is acceptable under the circumstances. Somebody from DOE, I believe it is, what is the meaning precisely of the--oh, NRC, of the term "reasonable assurance," and according to who, or whom? Reasonable assurance, what does that mean? Does that mean almost pregnant or what? What does it mean? Because that's what you're going to bases your criteria on, is that correct?

NELSON: That's right.

MCGOWAN: Either you or the USEPA standards lowering agency. Now, these are serious questions.

NELSON: Now, your other question that related to the groundwater flow and whether it was coming from outside, there have been some reports that are available that monitor --or that report on where the groundwater flow is coming from outside of the mountain.

MCGOWAN: Not underground water, the water prior to the arrival of the groundwater, that's what acts on the repository, unless the groundwater is on the "up" elevator. I don't think it is. According to Szymanski it is, and maybe he's right, so maybe Ubanski (phonetic) is right, or Archembulla (phonetic) is right. None of those three are on your agenda. Neither is integrity, come to think of it.

When I ask you about which way you point the problem of ship, anybody here from the Navy? Quick, which way do you point it in a high wind? You point it so that the ship is broadside to the sea or prow out to the sea?

NELSON: Mr. McGowan?

MCGOWAN: The question is, why do you have the canisters arranged so that they're maximally exposed to the oncoming flow of water? Don't bother to explain. The point I'm trying to get here is I wouldn't even begin to critique your uncertainty assessment, because that's what it is. Thank you.

NELSON: Okay, we have one final speaker who's been very patient.

TREICHEL: Oh, don't ever accuse me of being patient.

NELSON: Thank you very much, Judy.

TREICHEL: Judy Treichel, Nevada Nuclear Waste Task Force. I have to leave, the earthquake has caused my answering machine to have a stroke. But you should be aware that the public is going to play a larger and larger part in this whole process, and they must be taken seriously, and they are going to take seriously an earthquake. And I know that DOE's automatic response is that it's not as dangerous underneath the ground as it would be on the surface, so the repository is just going to be fine. But when you're talking about a surface facility with some of these designs that would be doing blending, that's a big deal, and that could have serious effects, especially from an earthquake like this.

They're also going to wonder by the tuff at Yucca

Mountain is considered to be the greatest thing in the world for a repository and yet you would import either limestone or marble or something from some other place. That seems not to make sense.

But a lot of this stuff is going to have to be sold, it's going to have to make sense, or they just aren't going to let it happen. And it's going to be messy and nasty, and that's just the way it is. And that's what people say when they crater my answering machine when they call on stuff like this.

So thank you.

NELSON: Thank you very much, Judy, for your patience.

Okay, we've heard from all of the public comment people who signed up. Are there any additional comments?

(No response.)

NELSON: Hearing none, I adjourn this meeting of the Repository Panel, and we will reassemble with the rest of our Board members at 1:00 tomorrow in this room to convene the Board meeting. Thank you.

(Whereupon, the meeting was adjourned.)

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