UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD

JOINT PANEL MEETING

RISK & PERFORMANCE ASSESSMENT PANEL
and
STRUCTURAL GEOLOGY & GEOENGINEERING PANEL

Hyatt Regency - Denver
Anaconda Tower - Room 210A-B
1750 Welton Street
Denver, Colorado

March 19, 1990

BOARD MEMBERS PRESENT

Don U. Deere, Co-Chairman
D. Warner North, Co-Chairman
Clarence Allen, Co-Chairman
Donald Langmuir
Ellis D. Verink
Dennis L. Price
John E. Cantlon - not present

William W. Coons, Executive Director

I N D E X

SPEAKERS: PAGE NO.

P R O C E E D I N G S

DR. NORTH: Good morning. I'm Warner North. I'm chairman of the Risk and Performance Panel and co-chairman of this meeting.

Before we proceed I would like to introduce Dr. Donald Deere, the chair of the Nuclear Waste Technical Review Board, who has some announcements.

DR. DEERE: Good morning, ladies and gentlemen. I'm very happy to have a chance to meet again. The purpose of my announcement is simply to say that we've had a slight reorganization in the panel restructuring. We went through a year with the panels that you all know about, and it was decided in Tucson that we would divide the Transportation and Containers Panel into two panels, so one will be the panel on transportation and the other one will be the panel on engineered barriers. Dr. Price will be the chairman of the Transportation Panel and Dr. Verink will be the chairman of the panel on engineered barriers. In addition, a new panel was created by the board on quality assurance, and this panel will be chaired by Dr. Cantlon.

DR. NORTH: As many of you are aware, this two-day session was scheduled several months ago as a Risk and Performance Analysis Panel meeting as a follow-on to the last meeting of this panel on May 16th and 17th, 1989. In early February of this year, the Nuclear Waste Technical Review

Board staff prepared an outline for this meeting, incorporating technical issues that I felt were essential if we were to truly get at the question of performance analysis of key elements of the repository conceptual design.

Shortly after sending this outline to DOE headquarters, we received a request to take part in a conference telephone call as DOE headquarters felt a significant clarification was needed with regard to the agenda. What had started as a risk and performance analysis had evolved into a project applications oriented meeting. Given the close relationship among design performance allocation and performance assessment. This evolution is not surprising.

At the beginning of the conference call--which, by the way, could be submitted to the Guinness Book of Records as the largest ever conference call--I was asked by DOE headquarters a to what I hoped to cover at the meeting. I responded by reading to them their own draft text, which speculated on the contents of our not-yet-released first report to Congress. Parenthetically, this report will be released on Thursday of this week.

The DOE draft memo stated: "The report may contain the following thoughts: A comprehensive analysis should be made of the entire waste disposal system. The analysis should consider an increased emphasis on the performance of the waste package in meeting waste isolation requirements. The implications of cooling the spent fuel for an extended period should also be analyzed."

While I cannot comment in more detail until Thursday, I will commend DOE for the accuracy of their speculation. Perhaps some from DOE headquarters are not yet convinced that these design issues are proper subjects for a risk and performance analysis meeting. I have heard it said that a proper risk and performance analysis meeting should be directed to issues of process, such as reviewing implementation or strategy plans, and I will note in passing that our panel will review DOE's implementation and strategy plans later this year. These items are not on our present agenda for a lack of available time in this two-day meeting.

It is my belief that risk and performance analysis techniques are tools that have meaning only in the context of their application. To convene a meeting to discuss risk and performance analysis, aside from their application, is to set this discipline apart. I believe such separation is not productive to the goals of early characterization of Yucca Mountain; that is, identification of any disqualifying features at the earliest point in time. I also believe that risk and performance analysis should have an important role in the planning process in guiding the selection of the design and of testing activities.

After obtaining agreement with DOE on the contents of this meeting, the Nuclear Waste Technical Review Board staff suggested that because of the interrelationship of thermal loading to the repository and exploratory facility conceptual designs, we were deep into the turf of our structural geology and geoengineering panel. It was, therefore, felt that this meeting should be jointly chaired by the Risk and Performance Analysis and Structural Geology and Geoengineering Panels; hence, our co-chairman is Dr. Clarence Allen.

You will recall from the May, 1989 panel meeting that the objectives of performance assessment are to: one, guide design and testing activities; two, assess sensitivities and uncertainties in the performance assessment; three, evaluate environmental impacts for the environmental impact statement; and four, evaluate system and subsystem performance to demonstrate compliance with the technical criteria of 10 CFR 60 and other applicable regulations for the license application.

If you will examine our agenda for this two-day meeting, you will notice that each section contains reference to performance assessment. In the early stage of conceptual design, performance assessment activities should be providing guidance to the design and testing activities as stated in Item 1 above.

I've had the opportunity to review a draft of the presentations to be made over these next two days and, in general, there appears to be much new information which I'm pleased to see. There are also some areas where I believe we need some more information and I believe the panels will be making our requests for such information at a future date.

For those presentations which contain materials that were presented in the Risk and Performance Analysis Panel in May of 1989, the Livermore meeting January 18th and 19th, 1990, or here in Denver on January 31st, February 1st, 1990, I hope the speakers will provide us a succinct review and not a lengthy discourse.

One final comment. If you will note in our agenda, the only times listed are the beginning, adjournment, and the breaks. We are seeking an open forum of discussion and do not wish to interrupt lines of inquiry by speakers or others with arbitrary time constraints. We have a full two-day agenda. We may well complete all topics in one day, or find that a good part of the first day will spill over into the second day. To the extent that time permits, we will accept questions from the audience as I think it is useful that we all have an opportunity to clarify our understanding of the basis for some of these major repository design decisions. So please wait to be recognized by the co-chair or--rather than by the speakers. In other words, Dr. Allen and I are going to manage the audience participation.

Clearly, questions from the board members and the consultants have priority and Dr. Allen and I, as co-chairs, will be the judge of how much audience participation time permits, and we ask that your questions be brief and to the point. Since we are making a record of this meeting, we would also ask members of the audience to identify themselves and their affiliation prior to asking a question.

So that concludes my opening remarks and I would now like to ask Dr. Allen to make his.

DR. ALLEN: Thank you, Warner. I'm Clarence Allen, Chairmian of the Structural Geology and Geoengineering Panel and co-chairman of this meeting, as Dr. North explained.

Like the DOE, I had assumed that Warner would be discussing risk and performance analysis procedures and processes and I, too, was a bit surprised when the staff sent me the agenda for this meeting several weeks ago. In retrospect, however, I believe the agenda looks very promising. Actually, my script says, "I believe the agenda is right on," but my script writers seem to be more dramatic than I am.

In particular, I believe that the technical community should examine carefully and in depth the thermal pulse of high level waste prior to disposal in a geological repository. A number of papers have been written over the last several years criticizing the U.S. position of specifying an areal loading of the waste packages in the repository that results in maximum rock temperatures of about 235 degrees Centigrade, particularly so when the rest of the world is looking at areal loadings that allow rock temperatures to be no more than 100 degrees Centigrade.

Although there may be technical pros and cons on this issue which we will be hearing over these next two days, I believe it is important to recognize the major differences in building a repository in unsaturated geology as opposed to saturated geology. I would like to second Warner's comments on our desire to have these two days as an open and free exchange of information, and I strongly believe--I agree with my script writer--that we will make progress in this program only by increasing our mutual level of understanding of the issues as the basis for key decisions.

Thank you.

DR. NORTH: Okay. At this point we'll invite Dr. Max Blanchard to make the introduction for the Department of Energy.

MR. BLANCHARD: I'm Max Blanchard for Carl Gertz and the Yucca Mountain Project Manager, and Leif Barrett, the Manager of the Office of Siting and Facilities. I'd like to say that I'm quite pleased to be here to represent them and the design team who will be talking with you today. We're pleased to be invited and have the opportunity for this discussion.

The design team effort, waste package and repository design and the analysis that have been done by that team worked for Leo Little, who's back there. Leo, please raise your hand. He's my equivalent at the project office. He's the engineering development and design division chief, and the work is done under the branch that Mike Cloninger heads up for waste package and repository design. You're all familiar with Mike from the January panel meeting.

I only have a few view graphs to cover in my introduction before we get into the agenda. First, as this momentous telephone call occurred, we evolved into five general discussion topics and what I'd like to do is to very briefly explain the orientation of our presentation for the next day and a half or so.

First, we'll begin by deriving the performance and the design requirements from 10 CFR 60 that we used in our design plans and in the SCP, and of course, these are the requirements for the repository, the waste package, and the site information that's needed for the design of the repository and the waste package, as well as the performance assessments that will go with that for post-closure.

The second aspect is the development of the conceptual repository design from this information that was derived from the regulations and will include the expected waste inventory because that's a necessary component of any preliminary conceptual repository design.

Third, we'll cover the development of the conceptual waste package design and, of course, in order to do that we'll also include the characteristics, anticipated characteristics of the spent fuel.

Fourth, development of the program to characterize the site, which is reflected now in the SCP. It's information that's needed for further design activities in repository and waste package, and in order to make post-closure performance assessment calculations on waste isolation.

The last item doesn't fit necessarily with repository and design requirements, but it was a request made by Dr. North at a previous meeting, which was to better understand the linkage. As you know, we have a system we call paratrack, and it links the regulations and the requirements down to the actual parameter level within the site test program, and we have a person to talk about that.

The presentations will emphasize the effects of heat from the emplaced waste. These effects occur to the site itself. They also cause constraints for the repository design effort and they cause constraints for the waste package design effort. The three together have to be fully compatible to have an effective design and to understand heat effects, and so we're going to try today to show you how we've linked those together for a preliminary conceptual design.

Considering the heat effects and hydrologic conditions, the design goals have been established for a myriad of things and I'd just like to highlight four of those things which are at a very high level. One, maintaining elevated temperature to achieve a dry near-field waste package environment. That, we believe, is our design goal. Limiting the maximum near-field temperatures to moderate effects on the site's geochemical, hydrological and mechanical characteristics in the near-field; very small effects in the far-field. Establishing controls on fluids and materials that will be used during construction, during site-characterization construction and operations, and fourth, the repository layout itself, especially for things like areal power density and the drifts and the canister spacings.

That is as succinctly as I could put it, the picture that we want to give you during the next day and a half or so. With that as an introduction, what I'd like to do is to go straight to Steve Brocoum, who will be talking about the programmatic basis for the design requirements.

Steve, are you ready?

DR. BROCOUM: Sure. Okay, good morning. My name is Steve Brocoum. I will be talking about the programmatic basis for the design requirements. I'll talk briefly about just three topics: the federal statutes, regulations and DOE orders very briefly; the waste inventory, the utility contracts and the waste-acceptance schedules; and other external and programmatic and miscellaneous considerations that we have to undertake.

First, the statutory basis. The Nuclear Waste Policy Act of 1982 governs the development of the requirements by defining responsibilities among the various groups. DOE, as the lead agency, has the siting, the construction, the operations and the closure responsibility for operating the repository. EPA is responsible for developing the standards in 40 CFR 191. NRC has responsibility as a regulatory agency for the requirements and criteria for evaluating the adequacy with regard to--as to the criteria for licensing. That includes 10 CFR 60, various regulatory guides, generic technical positions, and so on, and although the state doesn't have any requirements, they have a general oversight responsibility through consultation and cooperation, or a broader participation under the benefits agreement as described in the Nuclear Waste Policy Act's amendment.

It also, the Nuclear Waste Policy Act also specified the development process for the siting and the licensing, and that process included site screening, preparation of EA's in 1986, nomination and recommendation of sites for a characterization and, in fact, nomination of sites for characterization included a site characterization plan and also required a conceptual design specific to the site and a description of the waste package specific to the site and much of what we'll be talking about today comes out of the preparation of those parts of the SCP and associated documents for the SCP. And finally, the recommendation of a site to the present for repository.

The Nuclear Waste Policy Act was amended in 1987 to designate Yucca Mountain as the only site to be characterized, with the possible exception of a negotiator finding a volunteer state.

In addition, it established constraints on the repository siting and operations. For example, DOE was required to come up with the DOE guidelines, 10 CFR 960, which has tenacle and institutional considerations, and it established capacity limits of 70,000 metric tons until the second repository was in operation, and it linked the repository to other systems elements, particularly a Nuclear Waste Policy Act amendment which linked the construction of the MRS to the construction authorization of the repository.

So the primary design--primary sources of design requirements are the Nuclear Waste Policy Act and 10 CFR 60. Additionally, other additional requirements are offered by NEPA and other environmental statutes and implementing regulations. The Mine Safety and Health Administration, Occupational Safety and Health Administration regulations, there are hundreds of these. Many of these are covered in DOE orders. The Resource Recovery and--I'll get the right name here--and Conservation Recovery Act and other implementing EPA regulations. The effect, to the extent that DOE produces toxic wastes at the site, these are implemented; and finally, DOE orders.

Last Friday, DOE issued their waste management systems requirement document, Volume 4, which covers the repository, and that document lists all the DOE orders which apply to the mine geologic disposal system, and there's on the order of about a hundred DOE orders that are applicable.

Now I'm going to just briefly talk about the inventory projections. This will be covered in great detail later on today or tomorrow by Eric Ryder. If we assume no new reactor orders and we assume a current life cycle of reactors without extending their lifetimes, approximately 87,000 metric tons of heavy metal will be discharged through the year 2037, when the last reactor under current assumed lifetimes goes off line. That can be shown graphically by this chart here, so things level off as you approach 2037. So that's our current projections.

With regard to high level waste, there are approximately 300 canisters in borosilicate glass at West Valley of civilian high-level waste, and of defense high-level waste, there are approximately 18,000 canisters spread around three DOE facilities, for a total--well, total, 18,000.

Now, a few words on the utility contracts as specified in 10 CFR, Part 961. Acceptance of spent fuel and commercial high-level waste to begin after commencement of facility operations--I like to say on or about January of 1998. Now, in order for DOE to meet this date, several things have to happen.

First of all, the current linkages as specified in the NWPAA, which constrains the start of the construction of the MRS to receipt of construction authorization from the NRC and a repository would have to be modified, because currently we're putting our license application in in the year 2001, allowing roughly a three-year license review, we're talking about 2004 or thereabouts on our current schedule.

Secondly, we need to have a--the Secretary has said to Congressman Johnson--a volunteer site which would be negotiated by the negotiator. So we need these things. We need to have a modification of linkages. We need to have a negotiator, and then we need to have a volunteer site on the order within two years from today for DOE to meet that date. And that--I'm paraphrasing what the Admiral said to the Congressional committee two or three weeks ago.

The contract specifies that oldest fuel or high-level waste will have the highest priority for acceptance; however, the utilities need not ship the oldest fuel first.

That is subject to DOE approval. Utilities may among themselves trade rights to ship fuel, and the minimum cooling time for the standard fuel is five years. Again, other fuel may be accepted, subject to DOE approval.

Some more constraints on acceptance. I already talked about the MRS and the linkages, and so it depends on how these linkages finally end up what the waste acceptance schedule can be. The presence of an MRS in the system gives you a lot more flexibility and lot more ability to control the thermal load of the repository. These linkages may be able to be changed per negotiated agreement with a state by the negotiator for an MRS site. Any agreement the negotiator negotiates has to go back to Congress for their approval.

The capacity of the first repository is limited to 70,000 metric tons. We already know we'll have at least 87,000 metric tons of spent fuel. The Nuclear Waste Policy Amendments Act required DOE to report to Congress between the years 2007 and 2010 on the decision or the need for a second repository. Also, there would be a possibility of expanding the capacity of the first repository, so there's various options to be considered that at this point are unclear.

Well, this bullet says about the report to Congress. Finally, of course, we have to have an interface, obviously, between the transportation and the cask system and the repository facility.

I want to say a few words on greater-than-Class-C waste which must be disposed in a geologic repository currently, but not necessarily in the Yucca Mountain repository unless otherwise approved by NRC. To date, greater-than-Class-C waste has not been considered in the current conceptual designs. Estimates on the amount of greater-than-Class-C waste range from 2,000 cubic meters on the low end to over 17,000 cubic meters on the high end. If you had 17,000 cubic meters and you've had to put it in packages similar to the waste packages we're using today, that would be about 52,000 waste packages. In the Yucca Mountain site, we are currently planning to install 30-40,000 packages. The point to be made here is that to consider Class C waste in the Yucca Mountain site may have a major impact on the design, and obviously the thermal load in the repository.

The NRC has asked, or will ask tomorrow at our meetings--a meeting or meetings, tomorrow we're having a meeting to plan the next six months of meetings with the NRC, and they will ask for a meeting on greater-than-Class-C waste so they can get a better understanding on DOE's estimates on the volumes, get a better understanding of how DOE is planning to proceed in disposing of Class C waste, and to get a better understanding on the impact of greater-than-Class-C on the repository.

Other design considerations, based on NRC regulations, are the waste package must provide substantially complete containment for 300 to 1,000 years following closure. There is uncertainty as to how substantially complete containment will be defined or interpreted. The staffs, both on the DOE and the NRC have had numerous meetings. This is an issue we have not closed on. The waste package and the engineered barrier system must be designed to meet performance objectives assuming anticipated processes and events. Uncertainty exists regarding how anticipated and unanticipated events will be defined or interpreted. Again, the NRC and DOE have had several meetings on this issue and we have been unable, to date, to close on this.

Additional questions or considerations for design include--and this is not necessarily all-inclusive--will spent fuel be consolidated prior to packaging? If it is, what happens to the assemblies? What is our need for greater than 70,000 metric tons? How far should we age the fuel prior to disposal? Most other countries age it for a longer period of time, or are planning to, than the United States is. What will be the linkage between the MRS and the repository?

There will, of course, as site characterization goes on, be a continual feedback into the design of the repository. And are there any other implications in the interface between the ESF and the repository since the ESF is in the repository block and will eventually be incorporated into the repository.

DR. NORTH: I think I might interrupt to comment--and I'd encourage other members of the board and our consultants, if you have comments or questions, we can interrupt and that's the idea of having a free-flowing discussion, as I said in my earlier comments.

These look like excellent questions on your last slide. I think one of the questions that we would like to pose to you is, how are you doing? What's the status report in terms of the extent to which you have answers or working answers to these questions, and we'd like to see that come out in the next two days as much as possible. To the extent that it's not there yet, they definitely are items for future meetings.

DR. BROCOUM: Many of these things I'm talking about will be covered; some of them will not. For example, I don't think greater-than-Class-C is going to be covered but that in itself is a whole topic on its own.

Things such as anticipated and unanticipated, I don't believe are being covered at this meeting, and I guess substantially complete containment probably is under the waste packages; is that correct? No? Okay.

I just wanted to pose some of the--I was just trying to present a high overview of the kind of issues facing us. Some of them we're addressing at this meeting; some of them we can address at future meetings, okay?

DR. DOMENICO: Will the repository accept less-than-Class-C waste?

DR. BROCOUM: It's not even clear if the repository will accept greater-than-Class-C, you know. I don't know. No, my answer presently is no. I can't give you a definitive answer on that, but it's not even clear we're getting greater-than-Class-C type waste at the present time.

MR. DOMENICO: What's left? It's either lesser or greater. You've got to get something.

DR. BROCOUM: I'm not trying to dance, but I'm trying to --you saw the huge number or the potentially huge number of canisters from greater-than-Class-C. One of the points I didn't make is, the earlier estimates on small volumes--this is kind of an important point--one of the earlier--the early estimates on small volumes worked through the year 2020. At the original base repository, we'll be accepting waste from 1998 through about 2020. The current dates are it'll be accepting waste from 2010 to 2033. Well, between the years 2020 and 2033, it's estimated that the greater-than-Class-C waste will double, so plotting the question on the volumes or the amounts is related to the schedules.

Early on, DOE had decided that there would be no characterization testing with live waste. Informally, the NRC has suggested that we may want to be testing waste packages. If DOE should want to consider live waste in its testing program, we would have to get concurrence from the NRC. The size of the ESF, the area and the drift size and the extent of drifting should be constrained so as not to appear that a repository construction has started. There are several reasons for this.

The first is that in order to build a repository means you've got to have construction authorization from the NRC. The second is, when we were characterizing these sites, including Yucca Mountain, we didn't want to appear to the state as we were constructing a repository. So there is a, in a sense, a conflict between the desire to get more information and have more drifting and to get representative data on the one hand, and on the other hand, not to be building too many facilities so it appears you're building a repository.

Originally, of course, when we had three sites we were going to characterize, the plan was to get comparable data and that's what led to the fundamental decision to have shafts at all three sites, even though perhaps at Yucca Mountain it might have been more reasonable to have a ramp.

DR. DEERE: But Steve, isn't this really part of the problem, that we are still living with some of the design ideas and study ideas where we were looking at three sites?

DR. BROCOUM: That's something to reflect, that's right. That's why I'm--

DR. DEERE: And they keep coming up as restraints, when really, they no longer should be considered as restraints.

DR. BROCOUM: No. I said these were past--that's correct. This comparison of the three sites is no longer a restraint. I was just trying to give you some background as to how we got here. That's correct.

DR. DEERE: Yeah. But it is a problem that's lingering.

DR. BROCOUM: It is a problem, that's correct.

For example, I'll just give you a small example. We were concurring on WMSR Volume IV last week and I was reviewing it, and it still referred to shafts as opposed to a means of access or some other worry, so, you know, even at the very last moment we had to pull that word "shaft" out so as to not influence the ESF alternative study. But you're right, there are a lot of history with the program.

The ESF, it was decided in the original mission plan, would be incorporated into the repository if the Yucca Mountain site was found to be suitable. That has led to the NRC giving us very close scrutiny on the design and the construction of the ESF since it would become part of the repository. In a sense, they've almost treated us like a licensee, particularly with items, such things as the impact on, potential impact on waste isolation and the ability to characterize a site. In other words, it's given the hooks, it's given the NRC hooks into our program that--greater than had the ESF been outside the repository area.

So these are just some of the issues I wanted to bring up.

MR. BLANCHARD: Steve, could I help you out on an observation?

DR. BROCOUM: Yes.

MR. BLANCHARD: With respect to things that have been carried over from the program that existed when we were comparing three sites--focusing in on the question you asked about how much of that is still a constraint--I think that we need to bear in mind that 10 CFR 60 does have a provision in it which admonishes the department not to begin building a repository under the guise of conducting exploration, and so a fair number of constraints, it's probably fair to say, are in there from a design standpoint or from a site characterization standpoint because the department did not want to give a telegraphic sign that we were making it this way just to ensure it was compatible with repository design. And this is an open area, fruitful for future discussions between DOE and NRC. We're not quite sure what criteria they would use to determine whether or not we were building a repository, so to speak, before its time.

DR. BROCOUM: It's also a good time to be discussing things since, you know, the Admiral has stated we are not undergoing any more design at this point in time, certainly not on the repository. What we're basically talking about today are historical, how we got to where we are but we, of course, we have taken up design as we've moved forward and, for example, we are applying to reinstitute the ESF design next March, perhaps sooner, so any major--any historical things that don't apply anymore, it's a good time to discuss these and resolve them.

The other major effort going on is, you know, we're creating our document hierarchy of requirements and we have to be very careful about that we don't build into our requirements past constraints that are no longer applicable.

The last slide just summarizes that, the design requirements can evolve through time. They will obviously change as site characterizations yield data. The site characterizations will feed into the design and those may change, probably will change depending on legislation, depending on as regulations are modified or clarified as we better understand waste inventories, utility contracts, greater-than-Class-C, shipping schedules, and as other programmatic decisions are made.

Thank you.

DR. PRICE: Could I ask about the no new orders assumption, planning assumption, why that is used, what the validity of that is, in your opinion, and have you used any other assumption, alternative assumption to that?

DR. BROCOUM: I don't know the answer if any other assumptions were used. I think Eric Ryder, who I don't see here, will be presenting that. I think--personally, I think the assumption of the RCRA lifetime probably is an incorrect assumption because I think many plants will extend your lifetimes. In terms of new orders, it's hard to say. I think it would be intelligent first to use our assumptions and--for new reactors coming on line in the next, you know, 20 or 30 years, so I was just trying to give kind of a general view of where we are today.

DR. PRICE: But you have no curves to show us of other assumptions as to--

DR. BROCOUM: I need to ask Eric that question. Do we have others?

MR. RYDER: There are other scenarios that are used.

DR. NORTH: Could you identify yourself for the record, too?

MR. RYDER: Sure. I'm Eric Ryder.

The only one that's maintained within the Oak Ridge database is the no new orders case, however, and it assumes that there will be no new reactors built, that anything that's not currently under construction will not be built, but it does not make any assumptions in terms of extending the lifetime. The lifetime will remain essentially the same. From Oak Ridge we can get--and I have looked at them--additional scenarios in terms of how the waste will be discharged. I think there's about five or six, but in terms of the actual database that's available to all the participants, only one is maintained.

DR. PRICE: But could this board see those other scenarios?

MR. RYDER: I don't have them but, yeah, I can give you a reference who at Oak Ridge--

DR. PRICE: I think it would be interesting for us to see those.

MR. RYDER: Okay.

DR. NORTH: Let's make that a request.

MR. RYDER: Okay. I can give you actually a contact number.

DR. NORTH: And to the extent that there's anything that's been done on the life extension issue, we'd like to see that.

MR. RYDER: Okay.

DR. NORTH: It would seem like an excellent exercise to go through, to do some sensitivity cases on life extension.

MR. RYDER: Okay.

DR. HUNTER: Tom Hunter, also of Sandia Labs.

If you look over the last decade, there have been different scenarios based on reactor development in the U.S. assuming growth over the next 40 years or so. The question of how you decide which one becomes the basis for design is a policy question, and it's largely tied up in what Steve brought up in the question of going beyond 70,000 metric tons. The capacity of this repository is limited to 70,000 metric tons by law. The policy question always historically had been, if there is growth of nuclear power and there is more waste discharged, that becomes a second repository question, and--but there have been historically over the last decade numerous projections and EIA, Energy Information Agency, had maintained several different curves of growth of nuclear power in their historical documents.

DR. NORTH: I'd like to put one additional question up to Steve before you leave, and that's to give us a little bit more information regarding the equivalency of, in metric tons, between the spent fuel and the defense waste. You were talking about the Class C wastes, and I notice in the defense waste we have 11 of the 18,000 canisters in waste form to be determined, and I'm not sure what that means in terms of the relation of volume to weight.

DR. BROCOUM: It isn't even clear of all these defense wastes that they are all going to the Yucca Mountain repository.

DR. NORTH: Could you give us some sense of what difference this means in terms of the requirements that might be placed on the repository?

DR. HUNTER: Tom Hunter. I have a slide which is going to address that in my discussion of the basis design for the repository. We can discuss it now if you'd like; either way.

DR. NORTH: Let's wait and we'll cover it later. We just want to make sure that these things are on the list so that we've made our interests known to make sure they're covered as we go along, either in this session or at a later session.

Are there any other questions?

DR. PARRY: Jack Parry from the NWTRB staff. You might also want to provide information on the separated strontium and cesium capsules, how they might be handled, what their effect might be in terms of repository capacity.

DR. NORTH: Is this a Class C issue, or is this something separate?

DR. HUNTER: I'm Tom Hunter. I'll try to clarify the question. I believe you're referring to the strontium and cesium capsules extracted from defense waste production; are you not?

DR. PARRY: That's right.

DR. HUNTER: Okay. I'll try to comment on that.

DR. NORTH: Okay. Before we go on, I'm also going to give this as an opportunity for questions from the audience if we have any of those at this time. We're a few minutes before our break, so time permits a few questions at this stage.

Do we have any questions from the audience?

(No audible response.)

DR. NORTH: It appears not.

MR. BLANCHARD: If not, then we'll go on to the second talk. This one is given by Mike Voegele on deriving the site specific performance and design requirements from 10 CFR 60 where you'll see greater detail in those parts of the regulations that are constraints and provide guides.

Mike?

DR. VOEGELE: Good morning.

I'm going to speak a bit about how we derived the site specific performance and design requirements that were used in the development of the site characterization plan and partially in the development of the repository and waste package conceptual designs from 10 CFR Part 60.

The topics that were on the original agenda that we developed this talk from are listed here. Basically, the suggestion that we gave the board as to why these were relevant discussion topics is simply that these five elements are basically the backbone of the technical criteria in 10 CFR Part 60, so we structured the discussion around the technical criteria of 10 CFR Part 60. We're going to spend a little bit of time prior to discussing the actual technical criteria explaining to you some of the things that we did in the development of our site specific requirements, so that when we get to the actual discussion of the technical criteria of Part 60 we'll have a framework in which to deal with it.

We structured the discussion basically to discuss two items preceding preceding the discussion of the Part 60 technical criteria. Basically, we need to talk just for a moment about the stages in the licensing process, where we are today and where we're going, and something about the process that we used for translating the requirements that we found in Part 60 into the data that we needed for site characterization and, as you'll see, the process that we used for doing this resulted in the development of what we have called for the purposes of this presentation performance-based design requirements.

After we talk about the technical criteria and how we interpreted them in a site-specific manner, we'll give you an overall summary and then an example of some of the specific criteria that we used in the design documents; specifically, we'll focus on several examples from the exploratory shaft design requirements documents.

10 CFR 60 describes basically four parts, four stages of the licensing process. I'd like to emphasize that we are in the site characterization stage now. It will be followed by a construction stage, a period of operations, and then permanent closure of the repository. Basically, this is a map into the license application and the various amendments that are needed through permanent closure.

But to show you basically the meeting of the site characterization phase in terms of the design process that we're going to be talking about, we're just in the process of beginning, or moving toward the beginning of surface based testing. We've prepared conceptual designs, as requited by the Nuclear Waste Policy Act, to support the development of the site characterization plan. The important topic here is, however, that the advanced conceptual design has not yet begun on the repository and there is--to be followed by a specific license application design, to be followed by a final procurement and construction design. So we're back in the conceptual design stages, and the design work that has been done to date has not been done primarily with the focus on license application. It's been done primarily with the focus on supporting the site characterization program.

I mentioned that I would like next to talk about the process that we used for translating these requirements that are in Part 60 into the data needed for site characterization. In the SCP, we adopted a formal process for deriving the site characterization needs. We called it a performance allocation process, and the emphasis is that it was to derive the site data needs that we needed from Part 60, and that was the focus of our site characterization plan.

As I've mentioned before--and as I will mention again and Tom Blejwas will mention--the performance allocation process that we used to derive the site data needs also resulted in the definition of design requirements. These are basically site specific interpretations of what you need to do in the designs to help your site meet the performance objectives of Part 60, and as I've also mentioned, while we were preparing the site characterization plan to develop the testing strategies that we were going to go in the field with, conceptual repository and waste package designs were developed and they were based on more comprehensive requirements documents than simply the requirements that we dealt with in the site characterization plan to develop the testing strategies.

Just to put the preceding topics in focus, many of you are familiar with the site characterization plan. I'd like to re-emphasize that contained within the site characterization plan is a summary overview of the repository conceptual design that we used and the waste package conceptual design. It's a different level of detail here. There are separate repository conceptual design reports existent. The total at the time of the SCP waste package conceptual design was contained within the SCP. Those conceptual designs, together with the information that we knew about the site formed the basis for our development of the plan test program for site characterization.

I'm going to come back to this slide in moment. I've had a change of heart this morning, and I would have preferred that I had left this slide two spots onward in the view graph package, but I'd like to talk about it just a moment right now. In fact, this is one of Tom Blejwas's slides and he's going to focus extensively on the development of design requirements. I borrowed it to try to emphasize once again that when we were developing the site characterization plan, we went through a performance allocation process where we took the performance objectives and the design requirements, design criteria that are found in 10 CFR Part 60, and developed the data that we needed for a site characterization plan.

The emphasis of this view graph is, in fact, that of the total subset of design requirements that were used in developing from--flowing from the regulations down into the requirements documents that served as the basis for the repository conceptual design and will serve as the basis for the forthcoming repository and waste package designs, there's an overlap. Many of the requirements that come out in this design requirements development process do not come directly through functional requirements applied to the regulations as they exist. They come from the strategies that we have developed to combine the performance requirements and the design requirements in our site specific application. So this little bit right here is an important bit. It does not exist in the regulations. It's something that we developed site specifically to deal with the performance and design issues.

DR. NORTH: You know, I think the existence of that overlap is the rationale for why having this meeting with this agenda makes sense. Our working hypothesis is that that overlap is very important.

DR. VOEGELE: I hope you will conclude as a result of our presentations, that we believe that overlap is very important.

DR. ALLEN: It's bigger than the picture would imply.

DR. NORTH: I refrain from commenting on that.

DR. DOMENICO: How much of this was driven by the issues hierarchy? Is that still in effect?

DR. VOEGELE: Okay. I'm going to--yes. Let me talk to that next, please.

The famous issues hierarchy. I'd like to just draw your attention to a document that was issued in either late '82 or early '83, I don't remember which. It was a--it's called a draft site characterization analysis. It was issued by the NRC upon their review of what was at that time a site characterization report prepared for the Hanford site, the BWIP site, and this diagram is taken from that. I've taken the liberty of simplifying it a little bit. I guess my Xerox copy of that document has gotten so blurred that it doesn't reproduce anymore, so in preparing it for this presentation we simplified it a bit. The thrust of it is the same, though.

The idea behind issue development comes from an NRC suggestion that DOE do its program planning and identify the performance objectives and design criteria in a manner somewhat like this. The idea was to take DOE criteria, NRC criteria and EPA criteria. At that time, you'll see that Part 60 and 40 CFR 191 were not linked the same way that they are now, but the idea is the same. The focus was to roll those criteria into a set of site specific criteria, look at those site specific criteria in a preliminary performance assessment based upon your existing conceptual designs, and identify specific issues and information needed from the site characterization program. This is the origin of the term "issues" that we use throughout the SCP, and you can see basically that the next step onward in this diagram was to develop test plans for analyses, detailed test procedures, and integrate the site characterization activities.

The preparation of our SCP basically drew the line at this point and we proposed that we would try to capture this information in the SCP and leave more of these details to study plans and specific implementing procedures. Just to emphasize once more, this is where the ideas of issues came from in the development of our SCP.

DR. NORTH: You have an interesting diagram coming up a little later on in which you show essentially feedback loops where you make that comparison again and again, and it strikes me that's also a useful thing to do here; to consider that this comparison of performance assessment versus the site specific criteria, and resulting from that, both the identification in the issues and the specific plans is something you want to iterate on a lot, and we'd be very interested in learning more about, one, your past history of making such iterations from what you've learned; and two, your plans to do so in the future.

I continue to have a grave concern, based on what I've learned at the May, 1989 meeting and subsequent reading, conversations, et cetera, that not much has happened in performance assessment in terms of applications as opposed to theory since 1986, and given my interest in seeing the iterative process go forward, that's a concern.

DR. VOEGELE: I'd be happy to try to answer that question now or try to answer it during the process of the talk, or turn it over to Steve or Max, because it is a programmatic question.

DR. NORTH: However you would like to, collectively.

DR. VOEGELE: Let me first ask Steve or Max if they have any comments on that.

Okay. I guess to be very candid, there has not been a significant program activity to iterate the performance assessment calculations and the basis for the site characterization plan since we first developed the SCP in 1986. In our defense, however, I would like to point out that the preparation of the SCP, particularly the final, the statutory version as opposed to the consultation draft, did have a very intensive iteration on the performance assessment aspects of the program, but it was focused on the testing impacts to the site as opposed to focused on going back and redeveloping an issues hierarchy-type approach to the problem.

With respect to where the DOE is going in the future on this, I think we've been very receptive to all the comments we've heard from many sources where we've heard the proposal that we should be going back and looking at this. We are just currently developing a plan for how we're going to manage our site characterization activities and one of the central themes of that plan is to revisit this on a relatively frequent basis to make sure that we do, in fact, have the correct tests planned for site characterization.

Max?

MR. BLANCHARD: We have a set within our performance assessment program, a goal this year called performance assessment calculational exercises, and I can't remember whether at the last meeting Russ Dyer talked about that or not, but we have seven working groups and it includes teams of people from both headquarters and the headquarters contractors, as well as the project office contractors working together to attempt to internally appraise our ability to do the necessary performance assessment calculations. In the early looks at sensitivity analysis--and I believe Russ Dyer handed out a multi-page list of references which discussed the preliminary sensitivity analysis we've done at the last meeting.

The perception on those is that the state of maturation of the performance assessment calculational techniques is not at a mode where it can really give us some quantitative estimates beyond what we've already done in the SCP and the EA with respect to waste isolation and containment right now, and that first they need more data, but they also--and that is data from the site characteristics and processes, but they also need a better confidence on the calculational methods and some verification of validation of codes, and that the goal for this year was to appraise our internal health with respect to our ability to do that, and that's why we set up these performance assessment calculational exercises.

Steve, would you care to add more?

DR. BROCOUM: I just want to make one comment. Your comment, Dr. North, about the use of those things to help us guide our--is a criticism we have been getting for the last several years. I remember when we were completing the SCP, which I was heavily involved in the final SCP, that was a constant criticism, but it's always been very hard to get--the criticism is always there but to get helpful information that helps you define your program in specific ways has not been there. We haven't gotten there. Maybe we'll get there this year, but up until now we certainly haven't gotten there. It's usually--essentially because we get no such criticisms from performance assessment types. So we said, "All right. Help us. Tell us. Give us some specifics. What do you need?" And we've never been able to close that gap, okay, and that's been an issue for several years at least that I'm aware of.

DR. DOMENICO: Well, based on that box, preliminary performance assessment based on conceptual design, which led you to the identification of specific issues, has that been done and has it been--is there a document on it; preliminary performance assessment based on conceptual design?

DR. VOEGELE: I would say basically that it's primarily been done by supporting calculations that are referenced in the SCP. There has not been a formal total systems performance assessment that led to the full identification of these issues.

DR. NORTH: I, frankly, go myself to the 1986 exercise that was presented to the National Academy, the multi-attribute utility exercise in which there was an attempt to go all the way to bottom lines on the five sites that were candidates for selection as the final three, and at the May meeting I had asked that we get essentially a status report of what had changed since those calculations, which are documented in the report of that time, and I guess my general summary of what I heard was not a whole lot had changed.

Now, there have been some very important things that have happened since. For example, we now have a seven-year delay in the program and we're no longer looking at 2003, we're looking at 2010, and that has certainly implications on the aging of the fuel issue, which is the focus of our discussion at this point, and maybe those implications aren't large and, hopefully, during the course of the current two-day meeting we're going to learn a lot about what the implications are, but there are other issues of the same kind, basically, that things have changed somewhat and the question is, what implications does that have in performance assessment?

I also might add at this point that I've seen the Sandia documentation on the performance assessment for WIPP and it starts off by saying, "This is admittedly incomplete," but on the other hand, there is a lot of information laid out there that shows you what the problems are and I'd say rather dramatically identifies what are the specific issues and the kinds of considerations, often at a policy level as opposed to specific data, that need to be clarified as the licensing for that facility proceeds.

And something I noted in May, I am concerned that leaving some of these rather difficult issues until later may be a problem. It may be useful to get on with identifying some of the hard ones, especially where we have interpretations of the regulation, so that there will be time to have the appropriate discussion, resolution and consensus building as opposed to finding out, for example, what do we mean by human intrusion is a crucial issue and we don't wind up dealing with that until we're just about to try to license the facility. It's much easier, it seems to me, if you can get some of these things identified well in advance and have the time to work them through with a rather large group of individuals and agencies that are concerned. So I would hope very much that these efforts can be directed at identifying these areas as quickly as possible, and then getting on with the work that needs to be done.

Clearly, some of that is happening. I think the interest of the board here is seeing what else can be done to go even further and faster.

DR. VOEGELE: Steve or Max, do you want to respond or...

(No audible response.)

DR. VOEGELE: Okay. This is a diagram that basically summarizes the process that was used to develop the testing strategies that were placed in the SCP. There are several points I want to identify on this diagram that are important; that basically, through this process of developing the issues, we focused on the regulatory requirements, primarily the regulatory requirements in Part 60 to define those issues.

For each of those issues, which involves the performance objectives that are found in the technical criteria and the design criteria that are found in technical criteria in 10 CFR 60, we did develop a site specific licensing strategy that led to the development of the testing strategy, but more importantly, it defined a basis upon which we were trying to resolve the performance and design related questions associated with the regulation, and it's this activity that led to our understanding of the design and performance interrelationships which subsequently found their way into other requirements documents.

I'm going to just briefly show you a couple of examples or a more descriptive text, or a picture, actually, of these particular three steps, and the primary purpose of doing that is to provide a linkage that we can use to talk to --

DR. PRICE: Before you leave that--

DR. VOEGELE: Certainly.

DR. PRICE: --is there an assumption here that all of the issues that are of importance are somehow covered in the regulations?

DR. VOEGELE: That's a very difficult question. I think there's a tacit assumption that to get a site characterization program started, you have to assume that the regulation is comprehensive. I do believe that the SCP acknowledges the possibility of other issues related to the regulatory process being discovered at a later point in time.

DR. PRICE: Is this discovery basically serendipity, or do you have a planned approach to identify issues?

DR. VOEGELE: Basically, I think, you're raising a question which we just discussed and I'll try to answer it again. This particular version of the diagram does not clearly show that it is the intention of DOE to continually look at the results coming out of the site characterization program and factor back into this, first of all, the definition of the issues themselves and, more importantly, the strategies that we've used or we've proposed to be the basis for resolving those issues. It also feeds back into identifying different measures that we should be using to assess the site's performance, as well as different information that we would need, and that would have a concomitant effect on the testing strategy. So there is inherent in this process feedbacks throughout this. I think the focus of the site characterization plan was more on getting the testing strategies laid out for people to look at and not so much on showing what all this different feedback is, where there were subsequent publications presented by the DOE that emphasized this feedback nature coming from the lower part of this diagram.

DR. PRICE: Yeah. I wasn't just trying to refer to the iterative process that we were just discussing, but actually in the definition of issues, a concern that really what the program is all about is satisfying regulatory requirements rather than identifying relevant issues.

DR. VOEGELE: I think I better appreciate your question and I think the way to answer that would simply be that for the purposes of the exercise that we were talking about here, the focus was on the information needed to satisfy the existing regulations. This is not a programmatic document, per se.

DR. BROCOUM: Mike, maybe we should take some other track on this. You know, we're also getting all our requirements documents in place and isn't it the intent of all these requirements documents to cover all the requirements in the system necessary to build a repository? And so, inputting our requirements documents, including the WMSR's and all the flow-down documents from that, presumably once those are all in place we will be comprehensive and cover all requirements and/or issues as you're defining them.

DR. PRICE: Yes. Because what this really shows is that your main thrust--it looks to me like that your main thrust is regulatory compliance rather than issue identification.

DR. VOEGELE: For the purposes that this diagram was developed and implemented, the main thrust was regulatory requirements and the information that could flow from it.

Now, whether it seemed like I was going to get there or not, Steve, that's exactly where I was going. There's a completely different process involved in the DOE to develop the full set of requirements and it has more programmatic overtones, and the real programmatic-type issues find their way to requirements documents as opposed to following this process. This process was not laid out to govern the development or the maturation of a set of requirements documents. That's a different process. This one was laid out to get the site testing strategies laid out for the site characterization plan.

DR. BROCOUM: What we're currently doing now is trying to mesh this process with the process of a document hierarchy, which are being developed both at headquarters and at the project office, and that's been a very, shall I say, difficult task, but I think we're getting there.

DR. NORTH: Tom, did you have something you wanted to add?

DR. HUNTER: Yeah, Tom Hunter. I just wanted to comment on it may be helpful to comment on what the issues really are. I usually think of them as a set of organizing principles, broad categories of types of questions which need to be answered. They are not specific technical issues. An example would be the development of, you know, which scenarios are the critical scenarios for performance assessment is a subset of how do you satisfy the isolation issue, the EPA isolation issue. And if you think of them as organizing principles, I think what we've found is we can capture all the current regulations into these organizing principles, but many others can be added to those within the same set of issues. So you don't necessarily have to add issues, but you just elaborate and put technical content and detail onto them as you learn more.

DR. DOMENICO: Maybe I'm getting a little bit ahead of your story, but some of us are interested in some technical issues such as thermochemical effects, thermomechanical effects, those sorts of details that might affect the rock, as opposed to these which, I think you admit, are dealing more or less with strategy for obtaining a license. Will we hear today about some of the--

DR. VOEGELE: Okay. I did not mean to downplay the importance of the issues because the exact questions that you're raising as issues are, in fact, the result of this process that we applied. For each of these issues that we developed, these organizing principles as Tom called them, we did go through and develop a logical strategy to look at how one would resolve that question.

When you're looking at the performance objectives of 10 CFR 60, which we're going to discuss in a few minutes, they're very broadly based and 10 CFR 60 tells you you have to consider a lot of things in determining that you've shown compliance with these performance objectives. It is the strategy that we laid out for how we would show compliance with these performance objectives that led to the identification of the importance of things like thermal mechanical effects on the site's ability to meet the performance objectives, and so for each of these issues which correlate to the regulations of 10 CFR Part 60, you will find descriptions of parts of the repository system and processes that it is subjected to that are important to meeting that regulatory question. From that, we derive measures of how well that we can demonstrate that that system element or that piece of the repository system would meet its component of helping the site to meet the performance objectives.

We did set tentative goals and estimates of the confidence of these performance measures and they were developed primarily as a basis for determining what types of site testing we would have to do to get the information to answer these questions. Those performance and design measures in turn--you'll see I've tried to correlate that to the next step in the box--were translated into particular parameters that one would use. These typically are things that encompass a large part of the system's performance and it may need information being fed in from a lot of disciplines, like thermal mechanical effects on the rock into a design calculation, and they result in the definition of particular parameters that have to be obtained so that you can do these calculations up here to assess the performance of the site. And again, we assigned tentative goals and estimates of confidence in them in order to develop the particular characterization programs, things that we had to go out in the field and actually measure.

Now, that's the three boxes that we had on this diagram that correlate to--the first table correlates to the licensing strategy and the identification of performance measures. The second table really is the basis for identifying the information that we need to go out in a site characterization program, and the third table is really the basis for developing a testing strategy, the particular tests that we're going to use and the parameters that we're going to measure in the field. And they do, as you'll see in the forthcoming slides, get right to the heart of the matter, and that is, what is the interaction between the design of the repository and the waste package and its eventual performance that we need to assess to meet the performance objectives of 10 CFR 60.

MR. BLANCHARD: Mike, if I can help, the question addressed by Dr. Price and Dr. Domenico, it may be that we're not communicating all that close with respect to the definition of issues. When Mike had that previous view graph up which had defined the issues, he's using a very specific definition for issues, like Tom had mentioned. It's part of our organizing principles. The first set has only four issues for the whole program, and then the hierarchy spreads out like a triangle, getting larger and larger as you ask a series of questions in different disciplines of science and engineering.

We have a document out, OGR-B/10, which was the organizing principle for hundreds of issues which start high, get low and get expanded and expanded down. I'm not sure that I understood your question with respect to whether it was focused on that, or whether, in the way you asked the question, the issue could be considered a debateable topic about a process which would be addressed along the lines in our program the way we're conducting a test and getting the same parameter or the same value, like hydraulic conductivity, ten different ways so that we have confidence that the way in which we get it, we can have a belief or a confidence in, say, the mean and the standard deviation that we'll use in subsequent calculations.

DR. DOMENICO: Maybe we meant technical concerns as opposed to how you've used issues.

DR. VOEGELE: Okay. I've just put this view graph back up for a moment. The entire focus of the remainder of my talk is basically on what is in these tables, and I think you'll find the focus of Jean Younker's talk, which is probably coming tomorrow afternoon, is more on the focus of this part of the process.

There's a tendency to want to give an example and, unfortunately, you want to pick an easy example, and this one is almost too easy because the regulation requires a specific numerical value for groundwater travel time, but in approaching the question of groundwater travel time--which is an issue in our issues hierarchy--we basically have to look at the different pieces of the repository, and for this case it's primarily stratigraphy, and we have different components for that stratigraphy and I believe we've shown this view graph to this group that shows that within the different elements of the stratigraphy, we take different amounts of credit for how much we expect that particular piece of the stratigraphy to retard the movement of water, and basically, that results in the definition of parameters such as actual groundwater movement which you don't measure directly. You would want to calculate that based upon flux and other parameters, and eventually work your way down to actually deciding that to make the calculation up here you would need to know things like saturation and hydraulic conductivity. And so there's a logical process from the issue all the way down into the specific testing that you need to do out in the field. Unfortunately, as I said, that's the easiest one of the bunch, and I doubt that that's the one that you're the most interested in for today's discussion, so what we've tried to do in the next part of the presentation is to take specific technical criteria from 10 CFR PART 60 and try to show you what the site specific interpretation of it was.

Now, the focus of the examples that I'm going to give in this part of the presentation is on the design aspects that help you meet the performance objectives, so we're basically going back into those tables that I showed you previously for the performance measures and the system functions and processes, and working our way through into the first part of those tables, which is what is important at the site, interacting between the design and the performance objectives that you need to understand in order to demonstrate that you will be able to meet the performance objectives.

There are basically six parts--I like to think of it as six parts--to the technical criteria in 10 CFR 60. They're found in sub-parts (e) and (f) and we're going to talk about four of them primarily today; four of them today because of the focus of the discussion. The first part we're going to talk about is the performance objectives, and then we'll talk about the design criteria for the geologic repository operations area and the design criteria for the waste package and its components, and really focus on how these particular design criteria are important in demonstrating compliance with the performance objectives, and then we'll briefly mention the performance confirmation requirements.

Basically, there are two major components to the performance objectives in 10 CFR Part 60; those that apply through permanent closure of the repository, and those that apply after permanent closure of the repository. The items through permanent closure tend to be relatively straightforward design issues related to radiological health and safety. The retrieval question is a bit more difficult, but it's a problem that is to be solved in the pre-closure time frame, the time that the repository is open.

When you turn to the performance objectives that are applicable after permanent closure, there are two categories. There's an overall system performance requirement which is basically the EPA standard in 40 CFR 191. There are additional performance objectives set on what are called particular barriers, performance of particular barriers in 10 CFR 60. There's a performance objective set on waste package containment, a performance objective set on waste package release rate, and a performance objective set on the pre-waste emplacement groundwater travel time.

It's probably worth noting that there is, in fact--there are words in 10 CFR 60 that suggest that the Commission is willing to negotiate with the DOE on the performance of the particular barriers. If we could propose equivalent performance objectives on the particular barriers that met the

NRC's satisfaction, they would replace these particular barrier performance objectives with those. That's how I interpret that part of the regulation. I didn't get a scream from Seth Coplan, so I guess it--

DR. DEERE: I want to say that's a very important part of the regulation.

DR. VOEGELE: It is. It's a very important part of the regulation.

There's really only one more thing that I wanted to say about the performance objectives before turning to the design criteria, and that has to do with the question of anticipated processes and events and unanticipated processes and events, and permit me to address the bottom half of the view graph first.

10 CFR 60 describes the application to meet the performance for the particular barrier performance objectives as the engineered barrier system shall e designed assuming anticipated processes and events. Now, given that we will eventually reach conclusions with the NRC as to what the difference between an anticipated process and event and an unanticipated process and event, this could make the design of the waste package and the repository somewhat easier than the design of the total system performance, because you only have to assume anticipated processes and events.

To meet the overall system performance objective, which is the release standard in 40 CFR 191, one is directed to develop a system such as that system releases to the accessible environment conform to standards with respect to both anticipated processes and events and unanticipated processes and events. There's a bit of uncertainty in our minds as to how to apply this because the system itself is composed of the natural barrier and the engineered barrier system, so there's a little bit of cloudiness associated with just exactly how to work this piece of the regulation together with this piece of the regulation.

You could read the regulation as saying that since this is true, therefore, the only part of this piece that one needs to address with unanticipated events is the natural barrier system, not the engineered barrier system. One could also read this to say, however, because of the way the design criteria are written in 10 CFR 60, they're specifically written to say you will design your engineered barrier system in a way that assists the site in meeting its performance objective. You could conclude that this means that you have to design the engineered barrier system to unanticipated processes and events. And so this is a problem that we need to work with the NRC.

DR. NORTH: Yeah, I think this is a problem we are very concerned with, that to the degree that it's cloudy, if one can work toward early clarification of this, it may be extremely useful because this is a very major issue that drives a lot of the details of your licensing strategy, the determination of the design selection and the testing requirements. This is really basic.

DR. VOEGELE: With that in mind, I'd like to turn to the specific design criteria for the geologic repository operations. Incidentally, you'll find that probably half my view graphs aren't in your package and if there are those of you in the audience who believe that that's for your benefit that we have this outline structure built into my presentation, good for you. I think it's for me.

DR. PRICE: I hate to interrupt, but I'd like to ask a question here. If, for example, the engineered barrier system were a strong engineered barrier system, that would, it would seem to me, would interact with the grace period of 50 years for retrievableness. Do you get into these kinds of discussions and make these kinds of tradeoffs and, if so, how does it manifest itself?

DR. VOEGELE: I'm not sure I fully understood your question. If the question was have we considered the aspects of retrievability, such as handling that package twice in the development of the waste package, the answer is definitely yes.

DR. HUNTER: I assume the question is one of the coupled nature of the objectives and how, when you establish requirements to meet one objective, you're also either accomplishing another one or conflicting with another one.

DR. PRICE: Yes, that's correct, and maybe in the process of--that's correct as to what my question was. But maybe in the process of looking at some of these things and interpreting 300 to 1,000 years to not be a limit where it self-destructs at a thousand years but goes on beyond, and maybe we'll have a relatively stronger engineered barrier system than might have been originally anticipated, how does that then couple back and interact with the 50-year grace period and considerations and feedback that might go back to changing those criteria, and so forth?

DR. HUNTER: I think the best way to address the question is look at how you really establish what those things turn out to be; that is, how do you actually design them and how do you set up the whole system so it does meet the requirements.

There are really two things that are used here. One is the establishment of design requirements, and each of those objectives are, in fact, captured in an issue and each of those objectives give rise to a set of design requirements. Those requirements, you go through a process of allocating those requirements to all the pieces in the system. When you do that you try to optimize and tradeoff in the design process, the so-called system engineering process of functional allocation.

The other way that that is addressed is when you do the process of this performance allocation which basically says, a priori, what credit am I going to take? And your example is a very good one. If, in fact, you've decided you want a very long-enduring, tough waste package that would last a thousand years or so, and it turns out to be a very thick metallic container, it probably well meets the requirement for retrievability, where you only have to undergo 50 years. That will come out when you do this allocation of requirements across the elements when you design them.

So basically what we do, then, is get from those objectives to a set of design requirements and allocate those to each piece of the system, and then design them.

DR. PRICE: Yeah, but the direction of the question then ultimately goes to the retrieval requirement and providing any kind of feedback into the requirement side so that the 50 years may be changed now to 100 years or 300 years of retrievableness, just for sake of discussion.

DR. VOEGELE: After listening to you the second time, I thought that's where your question was going. I can't, within this particular process that we're talking about, point to something that would be so heavily involved in a modification to a regulatory basis. The 50-year retrievability period, there are NRC staff in the office who can speak to the basis for that far better than I could, involved a lot of deliberation. Basically, I'm assuming that it was put in there for at least two main reasons. One of them was that we wanted to watch it for some reasonable period of time to ensure that in case we had done something wrong, we'd have a longer basis through performance confirmation to basically decide that we had to get those waste packages out of there.

There's the ultimate question--and I don't know how heavily this influenced the regulation--of wanting to keep that facility open for some length of time in case we should want to get that waste out of there for some other reason, like the national policy changes and we wanted to go towards reprocessing. Now, Seth is shaking his head no, so I guess that wasn't a major factor in the definition of the 50-year period.

DR. PRICE: But whatever, in coming up with the 50-year period, does that then become indelible forever and ever, and even though you may learn things, there is no feedback or interchange--I'm sure I'm putting it in a very unreasonable light in order to draw up what I'm trying to get to, that there are no changes possible because somewhere in the past someone decided 50 years was the period that it ought to be for the reasons that existed at that time, where we've got a very dynamic process going on here that may require adjustments.

DR. VOEGELE: I don't believe the NRC would support the position that that number couldn't be changed if we had additional information that would suggest it should be a different number, and I think they would be receptive to talking to DOE or the board or anybody if they came up with evidence that would suggest that the number should be different, but I'd like to get back to what I felt was the original thrust of your question, which was how does that potential for change factor itself back into the design requirements, and I don't believe I have an answer for that question at this point in time. I think we've pretty much assumed that the requirements are a good set of requirements and they are the set that we have to meet. I expect that if information came up in the future that would suggest there was something fundamentally wrong with the requirements, we would--both the NRC and the DOE would be doing a lot of scrambling to try to make sure that their programs could address that concern.

DR. HUNTER: I could elaborate on your question with another example of the kind of competition between the requirements or the regulations. In a salt repository, which was in our history, there was a concern for retrievability at 50 years and the natural creep closure of the materials which contributed extensively to the isolation capability, meaning that if you design the repository so that it stays open for 50 years, you don't allow it to close quickly and seal up the waste materials. And so there was a natural competition between those two.

I can't think of a good example of competition between the regulations and this project which is like that, but I think that goes to the nature of your question. Because then how do you make those tradeoffs and adjust the basic requirements. As Mike said, we don't plan on modifying things like the 50-year retrievability based on our design to date, our analyses to date. I think he also said that those performance objectives were negotiable, the sub-element objectives, and it's in that negotiability, I guess, where those tradeoffs get ultimately established.

DR. VOEGELE: Tom, I guess the best example I could give of the tradeoff that we have in our repository is we have a design objective to maintain stability of those excavations for 50 years, and if it turned out that--first of all, those of you who've been underground know that we can do our best, we can try for 50 years. We may succeed in having 100 years. We may have 20 years, and I think we've built contingencies into the process to try to address that, but for us to change the design bases at a late point in time to say maintain stable excavations for 100 years as opposed to 50 years is something that I believe we could try to factor into the design process. I think it becomes more difficult to predict --it's difficult to predict excavation stability for two or three years, it's more difficult for 50 years, and it's much more difficult for 100 years, but I think we would try either to reach a consensus that we had done the best job that we could on design. We might over-design it, we might over-reinforce it, or we might turn to an alternate strategy, and that strategy might be going back in and recovering that, letting the--backfilling, for instance, as opposed to not backfilling, and then going back in and re-mining those out if we had to have 100 years. It could be a totally different strategy, but I think it's one that could be accommodated by the design if somebody changed the basic performance objective.

DR. BROCOUM: Also another question, I think, underlying all this is how late in time can you make a major change in an objective without really perturbing, you know, your ongoing design. I mean, there's probably a period of time you have. You could change it now and not have as much perturbation as if you change it ten years from now, and at some point where you identify it, you know, once you go beyond a certain point in time, then it becomes much more difficult to change.

DR. VOEGELE: I'd like to perhaps not take exception to Steve's point, but to address it from a slightly different perspective. And that is, we do have an advanced conceptual design plan, a license application design--and this is the design that we're going to go to the NRC with as a design that helps us and we can design criteria in the performance objectives, but coming out of the license application, we recognize the potential for a final design. Each of these designs will be predicated upon a requirements basis, okay? If the requirements documents change, there's a built-in mechanism here. If the requirements upon which the requirements documents are based change, there's a built-in mechanism through the design process to address that and you'll notice that there's a license hearing. The licensing hearing actually is completed before, or will be contemporaneous with, I guess--the idea behind the final procurement and construction design is to address concerns that are raised in the licensing hearing that this particular license application may not have met suitably.

So I'd just emphasize the point I was trying to make, there are requirements bases for these designs. So we'll be revisiting requirements throughout this project as the basis for the design.

MR. BLANCHARD: Dr. Price, I think suffice it to say that the current program that we have for conceptual designs of the waste package and the repository in characterizing the site are predicated upon trying to make the regulations work. We're trying to implement them to the extent that we can. I don't think we've found anything right now at the conceptual stage that would suggest that the regulations can't be applied successfully. And in fact, when we developed OGR-B/10, the issues hierarchy that you questioned earlier, we asked hundreds of questions for which we thought we had to have answers to reach a conclusion, would the repository be safe. Those questions weren't derived from the regulations. They were derived from the scientists and engineers in our program who weren't reading the regulations, but who were looking at what is it that's necessary to reach a safe condition for the emplaced waste.

And so while the regulations in 10 CFR 60 strongly drive our current structure, I think we also have had our technical teams examine the myriad of questions which we think are first, second and third order questions that we need to have answers to. But, of course, there are always alternatives, and as we begin to learn more about the site and the processes that work at the site, then I think we get into design tradeoffs that Tom and Mike were discussing, and when we get into those tradeoffs, then we have to decide, how well does this aspect of the regulation apply and to what extent can we implement it, and is there a possibility for another alternative. But that, I believe, is downstream as we acquire more information.

DR. VOEGELE: I might mention that if you'd like to take your break pretty much on schedule, we're about to go into the hardest part of my presentation. It could be quite lengthy, depending on the questions, so if you want to stop now and reconvene?

DR. NORTH: Why don't we take your suggestion and we'll have a break of about twenty minutes, so that we'd reassemble, then, about ten minutes after ten.

(Whereupon, a brief recess was taken.)

DR. NORTH: Before we resume with Mike Voegele, we are going to hear from Carl Gertz with some information on several questions that were raised before the break on Class C wastes and on the EIA projections for nuclear fuel.

MR. GERTZ: Thanks, Warner. For those of you who don't me, I'm Carl Gertz, and a couple questions came up this morning that I thought we ought to clarify just a little bit for you all.

First of all, we talked about Class C waste. I think we all have to recognize that low-level waste, which Class C is, is a responsibility of the states as of 1980, and the states were to handle all low-level wastes, A, B, C and greater-than-C. The Department of Energy was to handle high-level waste with the '82 Waste Policy Act.

Well, the states went on trying to take care of that issue and they said, "Gee, we have a problem with this greater-than-Class-C," and there became a new law, the Amendments Law, Low-Level Waste Amendments Law that said greater-than-Class-C now becomes a federal responsibility, but not necessarily OCRWM responsibility. Somebody in the federal system, as opposed to the states, has to take care of greater-than-Class-C, and it's not been designated as to who in the DOE system will take care of greater-than-Class-C.

And then NRC said, with some low-level waste laws, greater-than-Class-C must be handled equivalent to putting it in a geologic repository, or something equivalent and DOE, you tell us what you're going to do. So that's a separate issue all by itself, is greater-than-Class-C. The implication is, why not put it in Yucca Mountain? But, boy, you can't draw that implication just yet because our Waste Policy Act says you only take air spent fuel and high-level waste, which is reprocessed fuel, and that's all we're kind of looking at. But there always is the alternative that accomplishes federal responsibility. The states are still responsible for A, B and C and they're still trying to get out of C like they got out of greater-than-C. But I hope that clarifies it a little bit for you all.

The second thing you talked about the projections. At one time, the Energy Information Agency, we were carrying three projections; a high, a mid and a low. The low was no new orders, the mid was completing the 16 or so plants that are partially constructed or on the boards in significant design, and the high was starting new reactor orders in 1990. Programmatically, the Department made a decision, or the

Administration made a decision that for nuclear power, we'll go with a no new orders case as to the contribution of energy to the--nuclear-generated energy to the overall energy mix, and that's just a programmatic decision. We have archives of all the other alternatives. It just depends what assumptions you put in and then that'll generate how much waste new plants would order, and we'll provide those to you as part of the activity.

DR. NORTH: I think the issue of increased fuel burn-up is also an important related issue that I gather you will be covering later on?

MR. GERTZ: Yeah, sure. The longer it's in the reactor, the less spent fuel assemblies you might have and a lot of that becomes part of the second repository, and I want to point out that Congress, I think, made a wise decision and said, because volumes are so uncertain and we won't know until the year 2000 or beyond, why don't you come to us sometime around the year 2007 and see if we need a second repository or what other alternatives there would be; expansion of a first repository or whatever. But right now, it appears there's at least 70,000 metric tons out there by the time we get ready to move with the first repository, wherever that may be, and the law says, design a repository for 70,000 tons right now.

Thirdly, just to allude to what Jack talked about, the cesium and strontium capsules, and we'll get to you more on that, that's considered a by-product and not a waste yet and we're not hoping to see it just yet. Eventually we might see it, but it'll have to be in some kind of glass form or acceptable form, not as it is right now. That's part of this greater-than-Class-C. Eventually the repository may become the resting place for lots of things, but it's not in our cards or in our charter right now today.

And the other thing I wanted to add on is what Max said, is we're continuing to look at the regulation all the time. If the regulations don't make sense, it's incumbent upon us to work with the NRC and NRC to work with us, and they have rule-making scheduled for lots of the ambiguous regulations, and that's just a continuing iterative process throughout the life of the program, and boards such as yourself and the National Academy of Science can add to that process by pointing out opportunities for clarification or for what makes more sense at the time. As you're well aware, these were promulgated years ago.

Thank you for the time, but I just wanted to clarify those issues.

DR. NORTH: Thank you, Carl.

Okay, Mike?

DR. BROCOUM: I just want to make one comment, Carl. There's a letter of February 16th from the NRC to DOE about management of greater-than-Class-C waste, wherein I think the

NRC is assuming that OCRWM is going to take care of it, so I was really kind of talking from this letter in a sense in my comments.

DR. GERTZ: The NRC's assuming that, I'm not sure of the Department's position just yet, though.

DR. VOEGELE: Okay. Where we left off, we were just about to go into the second part of the technical criteria presentation, which was the design criteria for the geologic repository operations area. There's a second level of outline built into this one to help us all keep track of where I'm going, and I'll show you that in a moment.

The design criteria in 10 CFR 60 are found in Paragraphs 131 through 135, and they are described within Part 60 as being the minimum criteria for the design of the geologic repository operations area. The list is not presented as being exclusive. In particular, it is noted that DOE is obligated to provide whatever design features are needed to achieve the performance objectives.

The way we dealt with the design criteria in the SCP was to treat the design criteria as though they addressed features of the design that are incorporated to help us meet the performance objectives, and we used the performance allocation process to specify how the--particularly how the design criteria helped us to meet the performance objectives.

There are four parts to the design criteria in 10

CFR 60. There is a set on general design criteria for the geologic repository operations area. There's a set called additional design criteria for surface facilities in the geologic repository operations area. There's a third set called additional design criteria for the underground facility--and this is the piece of the design criteria, the additional design criteria for the underground facility is the piece that has the primary post-closure focus, and it'll be the primary focus of my presentation as well. There's a fourth set of design criteria and they deal with the designs of seals for shafts and boreholes. So we'll start with the general design criteria for the geologic repository operations area.

Part 60, in this first of the four sets of design criteria, focuses on radiological protection, and structures, systems and components important to safety. There is very little that's site-specific with respect to compliance with this part of regulation. They're relatively straightforward design criteria for handling radioactive materials, protecting the worker, health and safety, and identifying those components, structures or systems of this total overall system that are important to meeting that radiological protection. This is analogous to most other radiologic materials handling facilities, particularly nuclear plants.

When we get to the second part of the additional design criteria, these are the criteria that are focused on the surface facilities in the geologic repository operations area. They focus on radiation protection, radiation control and monitoring, waste treatment and decommissioning. This is wastes that are generated within this process. The site-specific work that's needed to address this particular part of the regulation deals with developing a monitoring baseline that has some specific components due to shielding effectiveness. But again, this part of the regulation which deals with the pre-closure aspect is relatively straightforward.

Now, we get to the additional design criteria for the underground facility, and as I mentioned, this is the part that really has the post-closure focus. It tells you that the repository, the underground facility must be designed to contribute to containment and isolation, must be designed to retain flexibility to accommodate whatever site-specific conditions one might encounter. It should be designed to reduce the potential for deleterious rock movement and limit the potential to create preferential pathways for radionuclide movement. Basically, this we interpret as being the part that's dealing with fracturing of the rock mass, creating an easier pathway. The regulation tells you that the engineered barrier system should be designed to assist the geologic setting in meeting the performance objective. And here again is part of our problem that I showed you with between anticipated and unanticipated processes and events applying to the natural barrier system or the total system, or the engineered barrier system. It also tells you that the predicted thermal-mechanical response of the system should allow compliance with the performance objectives. I'm going to try to give you some examples correlating to these bullets for the site-specific interpretation.

What we have tried to do is develop a layout for the repository in a way that contributes to containment and isolation. Specifically, we have developed a plan, which although we've discussed this with Dr. North at a previous meeting, we have not fleshed out all the details of exactly how we're going to do this, the plan for the development of the repository is to identify particular areas that are not within the licensing specifications and isolate those from the rest of the repository and skip them, should any of these areas exist.

We also intend to have a design that will allow us to adjust thermal loads for local conditions. If we find we have a higher degree of saturation or a lower degree of saturation, or for some reason, some differences in conductivity, we would adjust the thermal loads to accommodate that. And we've also tried to develop into our requirements the need to limit the amount of water that actually contacts the container.

With regard to the layout specifically, we've approached that problem as a problem of drainage, and we're dealing with a slipping repository. The question of water usage is addressed in the next bullet, but we wanted--we have set requirements on our repository that we would limit water usage and potential chemical changes, and basically what we want to do is control the type, quantity, and the location of the materials that we use in the repository such that we wouldn't be putting materials that might complex with radionuclides and promote a faster radionuclide travel time. We wouldn't be using, as we pointed out in the second bullet, any more water than we need to for dust control and equipment operations.

I'd like to emphasize that this particular bullet, the one on limiting water required, is one that we've taken what we believe to be the most conservative position one can take at this point in time. We're only going to use the amount of water that you need down underground necessary for health and safety, for dust control and for equipment operations. Should our performance assessment calculations and the bases for our impact assessments mature sufficiently through the different design phases, it may turn out that we can demonstrate to our peers and boards such as this that, in fact, there is not a need to control water this much in a repository operation, but our current planning basis, because we are unable to demonstrate that we don't need to control water, is to control the water as much as we possibly can.

DR. DEERE: This drainage that you mentioned to limit the amount of water to contact the container, this is during the emplacement stage?

DR. VOEGELE: Yes. And, in fact, the repository will be --currently is planned on being developed with a slope, sloping within a sloping horizon. The degree to which that repository drainage would be effective after closure has not been assessed. It's basically one that we believe if we do develop sloping drifts, that there is a potential to move water away from the waste packages, should we encounter it.

DR. DEERE: And this will be handled and pumped out for the 50-year period, or whatever it is?

DR. VOEGELE: Right. I think it would be our hope that we could demonstrate some effectiveness to that, because we will have created--if there is water, the drifts and their ultimate collapse still would be an easier flow-way than the surrounding rock, and so it's intuitively clear that there's a potential there for the water to still move then in the post-closure time frame.

MR. CORDING: But it is planned to pump the water out, is that right, during that 50-year period?

DR. VOEGELE: Yes. Tom just pointed out--I was going to

--I have two points to make here. The first one is it's not clear that the ventilation itself wouldn't be sufficient to move whatever water we would expect to find within the repository. The second one is, in the post-closure, those of you who are more familiar with the program may remember that part of our sealing strategy is, in fact, to allow free drainage at the base in the shaft so that we would get that water out of there if it did, rather than letting it accumulate there. There's a tradeoff between how fast that water would drain off if, in fact, it did run down the repository drift, and whether or not you would even have any water there to pump it out, but the plans for a repository operation are to pump the water out.

Another aspect is to limit the excavation-induced permeability changes, and we would try to do that through controlled blasting, control of the subsidence which would be related primarily to our excavation ratio, and basically a backfilling program to prevent further collapse of the rock mass. The idea here is to not--to limit the creation of pathways which would preferentially move radioactive material out of the repository. Finally--

MR. CORDING: Could I just ask one question on that?

DR. VOEGELE: Certainly.

MR. CORDING: The blast control, you're talking about excavation and, of course, there is also the potential for excavation with boring machines, which means that there is no blasting.

DR. VOEGELE: Certainly.

MR. CORDING: So that blast control, a more general statement might be to include the excavation by boring machines. Is that--would that be the intent?

DR. VOEGELE: That's completely consistent. What I'm doing here is emphasizing the work which has been done to date in the site characterization plan, and our planning basis at that time was controlled blasting. I certainly recognize the suggestion of the board and the development of the requirements documents for the future repository designs would certainly address the question of blast control as a question of whether or not you should use mechanical excavation or unconventional methods.

DR. DEERE: Our method controls it rather positively.

DR. VOEGELE: Okay, exactly. Finally, we have thermal and mechanical response and we have specified that we would like to limit temperature changes in selected barriers. We would like to limit the thermal loading to the point where there is no continuous joint slip, again creating fractures, and we would like to keep the borehole walls--and these are the waste canister emplacement borehole walls--above the boiling temperature of water for at least 300 years.

This is a fundamental element in our strategy and we're going to be talking about it in the repository design part of this discussion, as well as the waste package design part of this discussion, and it's basically, I believe, what we're here to talk with you about. We have developed a design that we deliberately try to keep the rock hot to keep the water away so it can't contact the waste packages.

DR. DEERE: You looked at alternatives and you made a selection at that point in time, and that's the one you're going with.

DR. VOEGELE: Exactly. That's the one--that's our design basis in the conceptual design that supports the site characterization plan. Again, anything that we've identified as a performance measure, going back to the diagram where we had the three tables here, was a planning basis for the site characterization plan, and you'll find that it's consistent with the conceptual designs that existed at the time the site characterization plan was issued. Any issue resolution strategy that we've developed these specific performance measures from is subject to change, depending on exactly the kinds of meetings that we're having here and the results of evaluations that come out of these kinds of meetings.

If, for instance--well, this, as I said, the borehole walls above boiling temperature is really the focus of this meeting. You'll find that Tom Hunter and Tom Blejwas's presentation will address the effects of different waste aging on how effectively we can do this, because this particular requirement, you'll see in Tom Blejwas's presentation, conflicts with most of our other thermally-derived performance objective design criteria. So basically, to us it was a tradeoff. We had to recognize that we wanted to limit, for instance, the thermal effects to the geochemical barriers, which would have driven you in the direction of lower temperatures, but trying to keep the borehole walls above the boiling temperature of water to maintain the waste package integrity was balanced with these other requirements, and I think you'll find that theme running through the presentations over the remainder of today and tomorrow.

DR. NORTH: Yes. We're very interested in exploring those last several points and we'll be interested in finding out more about what alternatives were considered. I mean, not just, this is a requirement that comes out of the blue, but as you consider what you can accomplish with the engineered barriers versus what you're going to accomplish with the geology, what's the origin of the borehole walls above boiling temperature for at least 300 years? What other ways might the design have been developed with alternate requirements, and why did you wind up selecting this one?

DR. VOEGELE: I respect that, so--

DR. DOMENICO: One major point, I think, is the temperatures above boiling for 300 years would seem to be inevitable based on the loading, and the other question is, what's 300 years compared to the 10,000-year time frame?

DR. VOEGELE: I think I'll ask Eric Ryder to answer the first part of your question and I'll answer the second part of your question.

MR. RYDER: Can we wait until we discuss that? I'll be covering that.

DR. VOEGELE: Okay. I'll answer the second part of your question, what 300 years is in comparison to the 10,000-year period is the waste package containment requirement in the performance in the particular barriers. It's a requirement to maintain a waste package lifetime of from 300 to 1,000 years. This was built in and perhaps Lynn Ballou or somebody else from Livermore would like to help me out on this one. Basically, it was built in as being a mechanism to provide more assurance that those waste packages would last for 300 years.

DR. DEERE: Yeah, but not the fact that you had to keep it above the boiling temperature, that was your design alternative.

DR. VOEGELE: Our design alternative was to keep the water away from the packages for 300 years.

DR. DEERE: Yes, so you could have--

DR. VOEGELE: So we would have more assurance that those packages would last 300 years.

(Inaudible question.)

DR. NORTH: Could I get you in the habit of identifying yourself at the microphone so we've got it on the record?

DR. VOEGELE: That was Dinesh Gupta from the NRC, and he asked me to elaborate on the second point on the thermal and mechanical response, which was no continuous joint slip.

Basically, the idea behind that particular component of performance was to--was derived from the idea that we did not want to create continuous pathways for groundwater movement or radionuclide migration, and the concept is quite simply that if you don't allow continuous slip along a joint surface, where it may occur inevitably at discrete points around the repository, if you don't allow it to form a continuous slip you will not have increased the host rock's capability for transmitting water or radionuclides.

Does that answer your question?

MR. GUPTA: How would that translate into a design requirement? How would you--would you have wired joints?

DR. VOEGELE: No, no. No, I'm sorry. Okay, I understand. This really translates into a design requirement in terms of the thermal loading, because the extent of the orientation and configuration of both the repository and the structure that exists within the host rock, coupled with the thermal loading that you've placed in the host rock will give you some rock mass displacement. What we were trying to do was trade off the repository layouts, the excavation ratios, the thermal loading to preclude development of continuous joint slip. So this is not a criteria to avoid areas where there are fractures or joints. It's a criteria to look at the design, the thermal loading, the existing structure and find a way that minimizes damage to the rock mass.

I've slipped into the last part of the design criteria, which is the design of seals for shafts and boreholes. Part 60 requires that seals should be designed so that shafts and boreholes do not become pathways that compromise performance. It further requires that materials and placement methods should be selected to reduce pathways for groundwater or radionuclide movement.

Basically, within the current program strategy which is laid out in the SCP in the conceptual designs, we're trying to encourage drainage as opposed to preventing water from getting at the repository facility. And also, should we encounter areas within the rock where there is a water-bearing feature, we propose to create a bulkhead or a dam of some type to get that water away from the repository and out to a shaft where it can drain as quickly as it possibly can. So rather than trying to seal this fractured rock mass so that no water can get into the rock mass, get into the repository, our strategy is basically to get the water out of there if it does get in.

DR. DEERE: For 10,000 years?

DR. VOEGELE: For 10,000 years.

DR. DOMENICO: How can we be reasonably assured that these methods will last for the order of 10,000 years? For example, can you have some precipitates that may form that'll block a channel?

DR. VOEGELE: Exactly. That's exactly the NRC concern about our sealing strategy, and which we are assessing at this point in time. They're very concerned about precipitates clogging the shafts that we've tried to allow the drainage to occur through and preventing that drainage. The fact that you have a sloping repository helps you again if the drainage is at the lower part. The shafts would be at the lower part of the repository and the shaft would be the more likely pathway of water movement into the repository horizon. You're still at the lower levels of the repository, so a lot of water has to build up before it can get up to the elevation where it's starting to contact the waste packages. Other than that, we have not gone much beyond that other than to note that it is a specific concern.

DR. NORTH: Those issues would be--seem to be particularly important issues in the risk and performance analysis area, and to the extent that some of that work's been done, I haven't seen it. I'd be very curious.

DR. VOEGELE: Tom?

DR. HUNTER: There is quite a lot of material presented in the SCP about the sealing program. In the context of performance, I think it's important to keep in mind that much of the--in the unsaturated zone, particularly Yucca Mountain, almost all of the sealing characteristics are extremely backup barriers because if the unsaturated zone behaves as we expect it to behave, or even with some reasonable modification to that, the role of the seals is extremely small. So these are fairly redundant systems when we talk about sealings, but the question of where to put seals and how to make them so they're long-term stable is addressed and discussed in our sealing program and at future opportunities we can blend that in to, say, a performance assessment discussion.

DR. VOEGELE: I'd like to ask Dr. North if you've seen the reference report by Fernandez, I believe, Hinkebein, that supported Chapter 8.4 of the SCP. Have you seen that? It showed the calculations of the amount of water that could move down a shaft.

DR. NORTH: I have seen some material of that kind. I can't verify that it is that reference.

DR. VOEGELE: Okay. There is a report and if--

DR. NORTH: But I haven't seen it in the context of just this issue; namely, the formation of precipitates and the question of how much the sloping drifts and the shafts may allow you to be sure that you've solved that problem. It seems to me that for a number of the types of scenarios being considered, that these issues are relatively crucial and at a future time, if not in these two days, we'd like to learn more about it.

DR. HUNTER: Tom Hunter again. In those discussions, it even discusses things like the concrete line and the removal of same to be sure that you can provide for drainage in the base of the shaft, so that's all discussed in that report Mike mentioned.

DR. DEERE: But again, this is manned for 10,000 years, the pumping stations?

DR. VOEGELE: No. It's all passive. The pumping would be during the operational period and, in fact, part of the concern that was expressed by the NRC that was just echoed by Dr. North was simply that we have not yet demonstrated that that could last for 10,000 years and perfected it.

DR. NORTH: I mean, I think the one you want to work is assume a pluvial climate, and now for 10,000 years you have an amount of water far more than today's situation draining through the repository and you have a certain degree of mineralization which may not be steady state condition because we're starting this new epic. There are things that can dissolve, get into that water, and they just might happen to precipitate out as you get down around the repository.

How can we be assured that the system will work for

10,000 years and not plug up? So to the extent that you've worked that problem, I think we'd be very interested in seeing what you found.

DR. VOEGELE: We have not worked that problem much beyond the supporting calculations in the SCP. Tom, you probably want to comment during your presentation or now; it's your choice.

DR. HUNTER: I wasn't going to comment during my presentation. We will discuss that when we talk a little bit about the performance assessment basis for the requirements. Tom Blejwas will discuss that. Some of the scenarios that were considered, in fact, echo similar things to what Dr. North said.

For instance, the assumption of having a surface impoundment of water independent any changes in the climate so that surface--essentially a lake over the shaft, and ask if that occurs, where would that water go, how fast would it go down before it might dissipate?

DR. NORTH: If the lake is the worst case as opposed to climate change, maybe that satisfies my interest.

DR. VOEGELE: Well, all I can say is we assumed that ponded water over that--in fact, we did many of these calculations in support of the exploratory shaft impact assessment. We concluded that ponded water was the worst case you could have. There was like an infinite source of water sitting above you, not just increased recharge.

MR. BLANCHARD: Dr. North, did you want us to send you a copy of that publication?

DR. NORTH: Yes, and I also flag it as an issue on which we may want to have presentations in the future. As I react to what you said about a pond in the shaft, I would also be concerned about the situation where you have, perhaps, less water but over a much larger area. You're considering how can you drain the whole repository and is that going to plug up with precipitates over a 10,000-year period. It may be a different question.

You know, to the extent that you and the NRC have already had extensive discussions on these issues and I'm not aware of them and other board members are not, perhaps you can provide us with that information. To the extent that the NRC has a concern that they've expressed in that area and it really hasn't been worked through, I think what I'm saying is we're concerned about that, too.

DR. VOEGELE: I think your latter conclusion is the more correct. Our discussions with the NRC have not gone much beyond the stage of literally what we've had here. They identify problems within the strategy and want to know how we're going to approach those problems.

The third part of the technical criteria that I'd like to talk about are the design criteria for the waste package and its components. Again, we tried to summarize briefly a rather important part of the regulations, but basically the design criteria say that you need to design the packages so that the properties of the waste package in its environment do not compromise the waste package function or repository performance. And we interpret waste package function or repository performance in this case to be substantially complete containment and the release rate controls.

The design criteria also specify that the waste form shall be solid, which is very important, and placed in sealed containers. And the packages are not to contain explosive or reactive materials or free liquids.

The way that that's been factored through into the site-specific interpretation deals with container environment interactions in a partially saturated media, and I think you'll find the presentations from Livermore tomorrow to really address what this means. The design criteria that we've adopted also specify that we would like to limit the peak temperatures of the waste package components themselves. We want to limit the quantity of water that could contact the waste package, and control the quality of the water that could contact the waste package, and we've also utilized a container to borehole air gap, again to try to keep the pathways for water to contact these waste package containers to the minimum that we can.

Finally, I just want to touch on the performance confirmation requirements part of the technical criteria, not because they were an overriding influence on the development of our strategies for the characterization plan, but because they have a very significant role in the ultimate closure of the repository.

We're directed in Part 60 to implement a performance confirmation program that will provide data that indicates that the actual subsurface conditions are, in fact, within the limits assumed in the licensing review. When we're going to go in with our license application, we're going to tell the NRC what we believe we have at the Yucca Mountain site. That will actually set conditions upon, there'll be conditions on the license that basically says if what you have out there is different from this, we need to talk about it, and the performance confirmation program is basically the basis for telling you whether or not the conditions that you found out there were what you told the NRC you were going to find when you submitted your license application.

Also, the performance confirmation program is intended to provide indication that the natural and engineered systems are functioning as intended and anticipated. This is a very important part of the performance confirmation program, because basically this is going to be the part that says the design that we have developed and built actually does what we said it would do, and drainage actually occurs in the way we said it would do, and seals will actually function the way we said that they might do it. This is the basis, I believe, for making the ultimate determination that we have reasonably demonstrated, or reasonably assured the Commission, in fact, that we can close this repository safely and protect the environment.

We're also asked to confirm the geotechnical and design parameters that were assumed or--

DR. NORTH: Before we get away from that, it seems to me the other case also has to be considered. Supposing the data comes in the other way, and rather than confirmation you get some surprises. To what extent can those be anticipated and can you have flexibility, both within your design and within your performance allocation so that you can adjust to those surprises and at what point do they become real show-stoppers in the sense that you can't make the adjustment? Finding out, you know, where we are in that spectrum seems to me of critical importance.

DR. VOEGELE: I believe that the performance confirmation program, as well as the actual construction program, will be heavily focused upon making sure that the site that we place the repository, the waste in is, in fact, as we have said it would perform.

The other aspect of your question is far more difficult, and that would be that, say, you had emplaced most of your waste and begun to get 35 or 40 or 50-year performance confirmation measurements out of the waste package monitoring program and you discovered it was all wrong, okay? You know, the easy way out of that is to basically say, well, that's why we provided for retrievability, so that we could take the waste out. On a more pragmatic basis, I can't at this time define the limit at which you would have to say, you know, half the waste in and you find something is wrong and you have to abandon the--

DR. NORTH: Well, let me give you an example relating to the previous point I was raising about the drainage and the precipitation. Suppose you've got the waste in there and you find through some measurements that there is much more mineralization in the water than you had anticipated, and you find that you're going to have to have a drain that's five times the size in order to be assured that it's not going to plug up in the period. Is there a way to put in that additional drainage, perhaps by enlarging some shafts or putting in some other shafts, or otherwise re-engineering to deal with that problem? It seems to me if you thought about that in advance and you have a contingency plan thought out and all ready to go, you're much better able to assure that essentially we're not going to get into the problem of being two-thirds of the way through the repository operation period and all of a sudden find we've got to take everything out and go somewhere else.

DR. VOEGELE: Tom Blejwas would like to address that.

DR. BLEJWAS: Tom Blejwas from Sandia.

As part of my presentation later this afternoon, I'm going to talk briefly about our contingency plans and if that's adequate it may answer your question; if not, you might want to ask me the question again at that time.

DR. NORTH: You'll find that contingency plans are one of my favorite subjects. I'd like to see lots of them.

DR. BLEJWAS: I've been warned, but I'm not sure I could be adequately prepared.

MR. BLANCHARD: Dr. North, I'd like to call your attention to the fact that at this stage of the site program we're carrying on a very large number, literally hundreds of alternative conceptual models for conditions or processes that act at the site in terms of geology, hydrology and geochemistry, and our program in site characterization is geared towards trying to eliminate those for which we can get substantiating information to eliminate, but we expect to carry those alternative processes all the way through the program and I believe a number of people fully expect that we won't be able to come up with one conceptual model or one model for the way hydrology works at the site, or only one model for the way volcanic hazards work at the site, and as a consequence of that, I believe the design structure for design requirements and modifying designs is aware of alternative models that they need to address. So I don't think it's an oversight. I think that it's encompassed in the program, but at the performance confirmation phase. There's not much we can say about it now until we really have gotten more information from the site so that we can elucidate better which are the driving models and which are not for processes acting at the site that the designers have to address.

DR. NORTH: Well, it seems to me it's extremely useful to carry through many hypotheses and consider proposed designs and testing requirements against that mixture of potential ways nature could be down there so that you don't get into the position of having your data come back and indicate that, indeed, there is a surprise, you're not within the limits assumed in the base case SCP; rather, you've got something else. And if, in fact, you've already thought through that it might be way out here instead of in the middle there, then you're prepared to deal with that problem.

DR. VOEGELE: You've focused on a very important aspect of this bullet. The limits assumed in the licensing review are the responsibility of DOE and if we do a good job of understanding the interactions between the natural barriers and the design, we will make those limits as broad as they possibly can be made to minimize the types of impacts that you're talking about.

DR. NORTH: Well, I think in assuring us that you have, indeed, taken such broad limits, you know, way out to very unlikely cases, then we and everybody else who's watching can feel much more assured that, in fact, we're not going to find problems down there that call into question whether the whole design can work.

DR. VOEGELE: I believe the whole question of reasonable assurance that we have to demonstrate through this licensing process focuses on that. If we were to set these limits very narrowly, I doubt that we could convince the NRC that we considered just exactly the types of things that you're talking about, and I doubt that we could then provide them with what they need, which is the reasonable assurance that we're going to protect safety, or protect the health and environment, provide safety.

DR. DEERE: Well, I think the board's concern also goes back not only to this post-closure, but in the exploration phases to make sure that it is sufficient to know that we have a realistic geologic model before we are so far along into it and we discover something late. We have given emphasis to the importance of faults and I will not back down at all on this emphasis, and I would like to give an example which is about 15 days old which no one in this room has heard of, but I was so impressed by this particular instance.

It's an island in the South Pacific with extremely large landslides, and in the process of carrying out some exploration, an exploratory drift was driven into the rock adjacent to the landslide because trying to drive through the landslide would be very bad, and to try to get around behind it and see what the water conditions might be. Upon going about 200 meters, a fault was hit, and they stopped the thing. Unfortunately, it was about a week before the International Board of Consultants arrived for a routine study of the results to date, so we had a chance to go in and see at the end of the tunnel a footwall, or the footwall on the underside of the footwall of about an 80 degree or 70 degree dipping fault, and putting our hand on that fault, and it was the driest fault you had ever seen and the gallery coming into the fault was very dry.

And when they drilled a hole through the fault, the first thing that came out was yellow toothpaste, and then that was followed by the largest surge of water you ever saw in your life through a six-inch borehole, and they were able to stop it, and the measured pressure was 120 meters, 400-foot water head on the other side of a dry fault. Fortunately, some piezometers had been placed in the area and it wasn't completely unknown that they were going to get in some high water pressures, but what was impressive is how very much this fault, which was parallel to the river valley but back in--that's why they had the landslide, the fault was holding up the water levels--but how this fault acted like a dam, a perfect dam, but along that fault 100 meters away was a piezometer that in two weeks lost half of its head, showing you the great permeability parallel to the fault, and that's the thing that's going to really govern the movement of groundwater.

And unless we know where those are, all the calculations and models and things we do are not going to have any similarity with reality.

DR. VOEGELE: I certainly agree.

DR. DEERE: And you cannot discover these faults, and all of them and their relationships with borings, and that is exactly why we continue the recommendation of exploratory galleries across the site, even though they may give you some problems with sealing, et cetera, et cetera. You have to accept that.

DR. HUNTER: I wanted to make a point, if I could, that relates to that last discussion. If you recall Mike's schedule that he showed earlier, the actual commitment to construction will be done after site characterization is completed, and if you look on that chart it's really--the final design and procurement and construction, no construction starts until that time, you know, 2004 basically, and it's between now and 2004 that a large body of information will go into that design.

The other point is that when we talk about initial construction, only a very small portion of the underground is excavated with the initial capitalization of the construction. The rest of the excavation is done over the 20 or 30 year operating lifetime of the facility. It is the understanding that all during that time you make changes to that actual design. When you learn things as you do the final construction, you'll make changes in how that configuration is and allow for these contingencies.

DR. NORTH: Good point. But then, understanding the limits of what you can change and how well you can do in anticipating the contingencies becomes quite critical in understanding, you know, what we may wind up with.

DR. HUNTER: Which I think is one additional point that should be mentioned. You made the point essentially about draining, Dr. North, that you concluded more draining was necessary.

DR. NORTH: Might be.

DR. HUNTER: And that's a very important point because what that means is all during the time of final design and final construction and operation, you'll need to have this ability to make these evaluations, resident and able to decide what really is important perturbation and what's not an important perturbation. So this role of performance assessment and deciding whether you've got a serious problem, the ultimate serious problem being that you'd have to retrieve the waste, has to be maintained all during that time frame and you have to be able to call on and to make those judgments for a long period of time.

DR. NORTH: That seems to me an extremely important point and part of it is that some judgments may not need to be made in their final form all through the period of operations right up to closure. In fact, it may even be that there are provisions for going more than 50 years if that turns out to be the best way to proceed. So what I'm pleading for is let's try to do all the anticipating and contingency planning that is reasonably possible.

DR. VOEGELE: I believe I probably over-interpreted--that's unfair. I had a different flavor from your question when you originally asked it, because there are things that we can do in a repository design, and as Tom said, the performance confirmation program will be providing us continual feedback so we can modify the design. Once you've committed to a waste package container material, emplace that at a hole at a given spacing, it's a lot harder to change the design. I mean, you have to physically pull waste packages out, you know, in the absolute worst case, say you discover that the particular stainless steel or whatever material you used isn't quite what you want to use, you're talking about taking packages back out and repackaging them, and that's a different category. And I think I just want to reemphasize that it's incumbent upon the DOE to do the best job they can before they go into license application so that those things that I would call--I'm going to call irrecoverable only in the sense that they're a major impact as opposed to modification of the design--are limited to the absolute best that we can do.

Basically, I want to match a little schedule for the performance confirmation to the activities. The scientific investigations of site characterization proceed up through license application submittal. At that point in time, one is developing baselines and monitoring changes in the baselines. This is the origin of the concept of--or the relationship between the performance assessment program and the site characterization program. You really need to start these performance confirmation activities during the site characterization program so you have as long in the baseline as you could possibly develop.

During the license application review, we expect that we will continue some of that monitoring that began during site characterization, and once one begins construction we actually move into a phase of confirming the engineered barrier system performance and the seal performance, but we still continue the baseline monitoring out through closure.

Okay. I wanted to provide a little diagram that sort of wraps up a lot of the interrelationships that we've been talking about, and I'll do that in three steps because when I put it up all at once, people tend to gasp. We basically have a design program focused on two major aspects of design. There is the post-closure aspect of design and the pre-closure aspect of design. We basically have a post-closure design program which addresses the performance concepts I was talking about on the preceding view graphs. It interacts with the pre-closure design. This is the actual AE designing a repository kind of activity. This is a program that heavily interfaces with post-closure performance assessments and the relationship between the design that you're building for the engineered barrier system and the natural barrier system.

What I'd like to show you in the next view graph is the way the design criteria themselves interface with those two major parts of the design program. Basically, within the post-closure design we have seal characteristics talking to these performance-related design criteria, and the waste package post-closure characteristics also talking to it. In the pre-closure time frame we're concerned more with the waste package production technologies, the waste package characteristics for handling, et cetera, the repository design criteria for radiological safety, and the non-radiological health and safety aspects being handled as a relatively normal design process, but again, interfacing with this focus on the post-closure design-related performance aspects of the repository.

Finally, I'd like to show you what that diagram looks like in all its glory when you add the performance assessment aspects into it as well, and you can see we've talked about the performance of particular barriers over here, the waste package containment and the engineered barrier system release rates, and they're factored into the waste package characteristics. They also talk to a total system performance assessment capability which is driving the post-closure aspects of the design configuration.

Likewise, there were pre-closure performance objectives that we identified on retrievability and radiological safety that are interacting over here on the repository design criteria. Overall, the total set of criteria comes from both of these things. The emphasis of my talk was basically on how we are trying to develop the relationships between the design criteria in the post-closure time frame and these total system performance and waste package containment, engineered barrier system release rates concepts.

It's a very complex diagram when you look at it on the surface, but I think it gets right to the heart of the matter here. We recognize that this repository design over here is extremely heavily influenced by the performance objectives on the repository and factoring those through in the design.

DR. NORTH: I think one of the most important messages of this slide is that the arrows go both ways between design and performance assessment.

DR. VOEGELE: I think you will find that we deliberately tried to emphasize that in the SCP, and I know that when you get to these arrows, you're at a tremendous level of detail in the SCP, but we continually talk about the iterations between the performance assessment calculations and our strategies for the designs to meet those performance assessment considerations in the SCP. This is Issue 1.11, for those of you who are SCP fans, and to me, it's one of the most important things we have in the SCP because this is the one that tells us how we're going to design that repository and the engineered barriers, which are 1.10, or the waste package, which is Issue 1.10, to meet these total system performance objectives.

DR. PRICE: Could you elaborate a little bit on how RCRA fits into things? Dr. Brocoum referred to it earlier. Is this going to be a permitted facility of some sort?

DR. VOEGELE: I believe the decision as to whether or not this will be a permitted facility hinges upon some forthcoming guidance from the EPA. I would prefer to turn this over to Scott Dam or one of the real licensing types who's in the room, because I'm going to stumble and fall real soon.

Scott's gone. Would you be willing to address the question on RCRA, Scott? Basically, what I know about the RCRA issue is that at the current time, high level waste is not--that's the wrong way to say it--high-level waste is on the verge of being classified as a hazardous waste, depending on a test which is about to be promulgated in the RCRA standards. If that happens, the high-level waste becomes hazardous waste if we can't pass this exclusion criterion, and at that point in time, we would have to be a permitted RCRA facility.

DR. PRICE: So you're going to be a treatment storage disposal facility under RCRA?

DR. VOEGELE: If the amendment goes the way it looks like it's going. There's a--what I know about the standard is that you're going to have to grind up the waste and run some sort of a test on it, and if we can't pass that exclusion test, we become a hazardous material handling facility and would have to be permitted.

I gratefully turn the floor over to Scott Dam.

MR. DAM: This is Scott Dam from Weston, supporting DOE headquarters.

There's two things one might mention which is the testing that's going to go on--I believe Oak Ridge is doing that or going to be doing that--to determine is both the spent fuel waste form and the glassified waste form a hazardous waste per the RCRA requirements. That test will go on. The preliminary information is that it's not and will pass and, therefore, will not be considered a hazardous waste. That's preliminary.

In addition, I believe there's some legislative action in Congress right now to perhaps exempt this program and the WIPP program from the RCRA requirements completely.

DR. VOEGELE: Thank you. There are probably a half a dozen people sitting in the audience right now who are saying to themselves, "Is he or isn't he?", so he is.

This diagram has been around for a long time and it's known in the vernacular as the PIG diagram, and so when you want to refer to this diagram all you have to say is the PIG diagram, and anybody in the project will know what you're talking about. Now they say, "Why is it the PIG diagram?"

DR. NORTH: Yes. Enlighten us.

DR. VOEGELE: I guess you could call us missionaries when we developed this diagram. This is a bit of a departure from the way people were treating the regulations up until a few years ago and we worked very hard to try to blend in the flavor of the importance of the performance objectives and the design criteria relationships, and every time I present that diagram, unfailingly, somebody would put this view graph up on the screen, so that's why this is the PIG diagram.

DR. NORTH: You haven't encountered a singing pig before?

DR. VOEGELE: Okay. I'd like to wrap this up with a couple of specific examples of the types of--what these criteria look like by the time they get into requirements documents and I'm going to do it with some examples from the Exploratory Shaft Facility.

You know that we are currently planning on developing an Exploratory Shaft Facility which can eventually be part of the area, be within the area eventually occupied by the repository and we need, therefore, to apply the same kinds of performance-based design criteria to the Exploratory Shaft Facility that we will eventually apply to the repository.

DR. DEERE: Before you take that off, just because I'd like to keep it up, where is the Ghost Dance fault?

DR. VOEGELE: Ghost Dance fault is sort of on this side, right in through here.

DR. DEERE: But there's flexibility in the program in layout?

DR. VOEGELE: Oh, we're--I won't touch that one. Yes.

Okay, now the next--there's no way to put the next six view graphs in your package in a way that makes this an easy presentation, but I have a little matrix table that I'm going to go through and then I'm going to go back and you'll see that I've put a couple of highlights on these matrix tables and those are the ones where I'm going to try to show you some of the performance-related design criteria that we have in the ESF design.

This is a list of the criteria that we believed at the time the SCP was written, or shortly thereafter, were applicable to the design of the Exploratory Shaft Facility. We have since been told by the NRC staff that there are some that we did not consider and we will be addressing those in Title II design. Okay, so the first ones I'm going to show you have to do with boreholes and shafts and pillars. The next ones I'm going to show you have to do with the question of control of water and gas, and in particular--I'm sorry I moved a little bit fast on this.

DR. ALLEN: What are these physical elements up there?

DR. VOEGELE: Yeah. Let me explain that to you. The requirements document that governed the preparation of the Exploratory Shaft was broken down by physical system components, and so basically what we did was we looked at an individual requirement and then we said just exactly as I showed you on those tables, we said, "What physical system elements are relevant to the resolution of that issue?" And for instance, the example we have here--I'll pick an easy one --well, retrieval of waste or control of water and gas along the bottom here. We basically identified requirements on the Exploratory Shaft Design in the areas of the site, facilities on the surface, the utilities supporting that, the first shaft, the second shaft, the underground excavation, the underground utilities and the underground testing program. so you'll find in our requirements documents under each of these physical system parts of the Exploratory Shaft specific requirements that were developed to ensure that we meet that part of 10 CFR 60, which was the control of water or gas. So it's an organizing principle. It's a table of contents for the requirements document, and it's just basically laid out by nine physical pieces of the Exploratory Shaft, broken down because you do the same--you do similar things. It's an aggregation of similar sorts of things, basically. The shaft things that you do are different from the things you do on the site, so we've aggregated them that way.

Does that answer your question?

DR. ALLEN: Yes, sir.

DR. VOEGELE: Okay. The other--the third one I'm going to show you has to do with 60.133(i), which is the thermal-mechanical modes and I'll show you a couple of them relating to the shaft and the underground excavation. Now, I apologize, the next--excuse me--there's one more of the matrix and I have not highlighted anything on that. The next three view graphs are in the incorrect order in your presentations.

I'd like to talk about the first one on that matrix, which was the 60.15(d), which we've interpreted as a requirement.

We've stated that to the extent practical, exploratory boreholes and shafts in the geologic repository operations area shall be located where shafts are planned for underground facility construction and operation or where large unexcavated pillars are planned. Now, there's--basically, these criteria simply reflect those words. The reason these are considered to be performance-based criteria is the specific reason that they were included in Paragraph 15 of 10 CFR 60, was because these things represent potential pathways for radionuclide migration, and so what you want to do is keep them as far away from the waste packages as you possibly can, and that means put them in shafts or pillars. And so what we've done, basically, is said that we're going to put them wherever you've got a--we're going to put the shafts, to the extent that we can, where the shafts are planned for the repository facility, the idea being there we would not use two--we would not include two extra shafts in the repository design simply to support testing.

And also, we intend to drill the exploratory boreholes so that they do not intersect any underground openings, and you'll find in the gory details of this that we actually have developed a standoff criterion, supported by some calculations as to how far away from the drifts we need to be.

DR. DEERE: In another discussion, as you recall, a year ago, we had quite a little discussion about what is meant by "to the extent practical".

DR. VOEGELE: Right.

DR. DEERE: We'll still leave that as open.

DR. VOEGELE: Well, certainly. I think I'll go with your assumption.

Under 60.133(d), we have a requirement to design the underground facility to provide control for water or gas intrusion, and basically one of the things that we developed under here was a corollary and we said the amount of the water that we're going to use in the construction and operations is going to be limited so as to limit the effects on the containment and isolation capability of the site. Now, granted, the literal interpretation of this is natural water. We were looking for a place to categorize the water that we are going to introduce into the site because it was important to us, and so we categorized it under that one. There isn't a place in the requirements where you can obviously see that the NRC has said, "Minimize the amount of water that you want to use on construction."

Now, finally the last three examples that I wanted to show you had to do with thermal effects, and this is a pretty faithful reproduction of 133(i). The underground facility shall be designed so that the performance objectives will be met taking into account the predicted thermal and thermomechanical response of the host rock, surround strata and groundwater system.

Here's three of many. I should mention to you that the document, the performance related design criteria that were developed as a part of this exercise is a document that's an inch and a quarter thick. Basically, I've just picked very few of them just to give you an idea of the sorts of things that we're talking about, but we addressed the shaft liner design, said that it needs to withstand pressures exerted along its length and around its perimeter under the anticipated conditions, including reaction to thermally induced stresses resulting from the thermal loads that we've placed in the repository.

Now, basically, this is one where you have to trade this off against the ultimate decision whether or not you're even going to take that shaft liner out of the repository, but given that that's an option where you may not decide to take it out, it's prudent to design it at this point in time so that you can leave it in. I think that's an example of the kind of thing Dr. North was talking about.

Okay. We designed the ESF so that the thermal and thermomechanical effects on ESF operations and testing do not produce intact rock failure or gross rock mass failure along potential pathways. Now, this is basically a recapitulation of the idea of not creating fractures through the concept of blasting control or what could eventually be mechanical mining, as well as the idea of limited slip along joints, limiting that so you don't have continuous joint slip.

Finally, we want to design the Exploratory Shaft Facility so that the effects of the operations and testing on the groundwater system do not significantly increase the saturation of the host rock in the waste emplacement area. Basically, the concern there is that if one were to create a saturated zone within the repository boundaries, one could have an area where you might have a more rapid radionuclide transport time in the subsequent repository operation. So basically we're planning and have done some assessments of the actual effects of the tests. There are a couple of heater tests going on in the repository right now in the waste package area as well as the--I'm sorry. There are heater-type tests planned for the Exploratory Shaft Facility that will basically need to be assessed and have been assessed at this point in time to determine what kinds of effects they have on the overall rock mass properties such that it would preclude or inhibit or limit our ability to comply with the performance objectives.

So these, to me, and I believe to the DOE, are, in fact, performance-based design criteria that we're putting into the system.

DR. DOMENICO: The second one, the ESF shall be designed such that the thermal and thermomechanical effects of the ESF operation do not produce failure. That's an easy question. How would you apply these same ideas to the host rock holding the canisters? On the shaft, it's easy.

DR. VOEGELE: I do not have the answer for that question because the answer to that question is the repository design. I need to point out and emphasize something I did not emphasize, and that is these ESF design criteria came from our repository design criteria. These are the same criteria that we've built in the requirements documents saying you have to design a repository to do this. I don't have the answer as to what that'll ultimately look like because, as I said, the designs we have at this point in time really only support the characterization program and our focus has really been on impacts.

DR. BLEJWAS: A large part of the discussion that will follow Mike's talk will deal--later this afternoon, rather--will deal with what some of the impacts are, the thermomechanical impacts are on the repository. So that will be discussed later.

DR. VOEGELE: I'd like to conclude just simply by saying that the reason we went through this discussion this morning was really to set the basis for the kinds of talks that Tom is going to be giving and the Livermore people are going to be giving. It is perhaps maybe more detailed than some of you who have been subjected to this kind of presentation in the past were expecting, but I think you'll find that we use the same flavor throughout all of our presentations, the same kinds of things that I was talking about in these view graphs will show up again in Tom Blejwas's and Tom Hunter's, Lynn Ballou's view graphs, so you'll see the same theme running through this and hopefully we can show you how these performance-derived design criteria are actually being treated in the designs--have been treated in the designs that exist today and how they could be treated in the future designs.

Thank you.

DR. PRICE: Is it possible if RCRA were to be relevant and applied, that NRC could approve a license and it be blocked on a permitting basis?

MR. BLANCHARD: In this program, I'd venture to say anything's possible.

DR. VOEGELE: I think the answer to that is a very real yes. I think that the relationship between RCRA and the 10 CFR 60 has not been thought out because there never was an intention, I believe, when 60 was developed that RCRA would apply, and we've all seen what happens when conflicting regulations tend to get on top of each other. You know, it gets harder, it doesn't get resolved. So I think the answer to your question is yes.

DR. PRICE: Well, I mention it because it might be something that this board wants to consider and take a position on.

DR. VOEGELE: There's not a person in this room who's not shaking his head yes.

DR. BROCOUM: Also I'd like to make one--you're kind of emphasizing it and I'd like to present it a different way. You're emphasizing the difference between licensability, which is what 10 CFR 60 emphasizes, and suitability of a site, which is a lot broader than licensability and takes a lot of other things into account. So they're two different issues. We basically have to get over the suitability hurdle before we get to the licensability hurdle in terms of getting through the final EIS, for example.

DR. PRICE: But you'd have to bring in some kind of sequence of processing, for example, to obtain the permit before you get the license the way things are.

DR. BROCOUM: That's correct. Right. That's why I said suitability comes first, in a sense.

MR. BLANCHARD: Dr. North, we are at a point where we had anticipated that we'd be here a little bit later. We're a bit ahead of our schedule. The question is, do you want to take advantage of this thirty minutes to begin the presentations on the repository? It's broken into three sections; the design requirements, the baseline design, and then the design approach. I could ask Tom Blejwas, to what extent do you think for the next 30 to 45 minutes you could cover the next level of design requirements?

DR. BLEJWAS: I would estimate that my design requirements talk, with even minimal questions, will go at least an hour and probably with a lot of questions could go an hour and fifteen minutes or an hour and a half.

MR. BLANCHARD: Do you see a natural break? For instance, you could--

DR. BLEJWAS: There's not a natural break that I planned on and I'm not sure whether one exists, but I could certainly break.

DR. NORTH: Why don't we try to accelerate lunch, starting immediately and resuming at 12:45, then.

MR. BLANCHARD: That would be fine.

DR. NORTH: And hopefully, we'll get ahead of the crowd and we'll be all set and ready to go for this material this afternoon.

MR. BLANCHARD: 12:45 for a reconvene time?

DR. NORTH: 12:45.

(Whereupon, a lunch recess was taken.)

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

DR. NORTH: Everybody take their seats and we'll begin the afternoon session.

MR. BLANCHARD: What I'd like to do is introduce the first speaker for the repository design requirements part of this afternoon. And, that will be Tom Blejwas, who will talk about another level of detail from a design requirements standpoint. Tom.

DR. BLEJWAS: I understand there was some concern about people being able to hear in the back of the room. Are there any problems with hearing now? Thank you. As mentioned, I'm going to talk a little bit more directly about the repository design requirements.

I wanted to first start out by reminding you that our requirements come from a multitude of places and we have a variety of requirement documents on our program.

We have the Regulations and the Mission Plan shown in the upper set of documents and during the time when the site characterization plan was being written and the conceptual design report was being written, we had a generic systems requirement was on the next level. And then below that we have system function requirements and below that we have subsystem functions.

The names of some of these documents are evolving and changing, but generally this is still the organization of our documents. Most of what I'm going to talk about in terms of actual requirements would be something that would be contained in this level of document. You know of a subsystem requirements where we talk about performance goals and site conditions and so on. And a little bit of what I'm going to talk about will deal with our system organization at this next level up.

I think it's real important that design requirements are something that are going to evolve with time and they are going to evolve in change as we get technically more technical and we understand our site better. So what I tried to represent on this view graph, is that we start with our various regulations and high level requirements. And some of those are stated so explicitly, that we can actually just say they are indeed design requirements. Those are the easy ones to get into our requirements.

Some of them though, require some interpretation, and at least at an initial level, we'll perform some professional judgment to interpret those regulations and we come up with requirements, design requirements. As we get smarter in various areas, we look at doing simple analyses and we come up with more complicated decision making processes to develop other design requirements. The requirements themselves may be very simple, but the method by which we come up with those requirements may get more and more complex. As we get to our license application design, we would expect that some of the design requirements would have been obtained through a relatively complex set of analyses and decision-making process. So, most of what I'm going to say today, deals with the existing design requirements that are generally based on professional judgment using available site data and assumptions.

Some of them have been determined using simple analyses. Virtually all of them were developed through the performance allocation process that Mike Voegele talked about earlier and I'll talk about a little bit more. In general when we are dealing with the thermal problems that you've addressed many of your questions to, they show up in our design requirements generally as constraints on our temperatures and on our layout. And, I'll talk specifically about several of those.

I tried to captured the design and performance assessment logic that we followed and we would continue to follow in some variation of this into the future. We start out with the regulatory requirements and we've had some discussion about that this morning, and we also discussed the fact that we developed an issue resolution strategy. We also have to develop some functional requirements. We know that there are some things a repository is going to have to do, and we developed some functional requirements based on those things and they are not necessarily represented in detail in the regulations.

From that, we look at establishing our design basis. And, the design basis consists of two parts. It consists of design requirements that will be the focus of most of what I'm going to say, but there is also a reference information base that we have. We have to have a base of information for our design process and for determining our design requirements, and I'll talk about that some more later on. From this, then we have the information we need and we develop our design. I've shown then a process where we developed the design and we evaluate the design against the design requirements. This is the kind of operation that would be done by the design organization that's looking specifically at the design requirements. They might not understand all of the regulations from which these requirements flow, but at least in this step they are going to be evaluating the design against the specific requirements that we've developed.

After we see whether or not that design can meet all of the design requirements that we've developed, then we look to see are the design issues likely to be resolved. If we have satisfied all our design requirements, then there is a strong probability, that yes, all of the design issues are likely to be resolved. If we have problems with our design and we are not able to meet all the requirements or there are some unforeseen problems that we were unable to build into our requirements, then the answer may be no. And then we go back and we look at can we change the performance allocation? Can we modify our assumptions in some way so that we can still meet the requirements. If so we go back and we go through and cycle through and this is part of the cycling process that we talked about this morning but wasn't shown explicitly on some other view graphs.

We still have potential for more cycles. If the design issues are likely to be resolved, then we would say yes, this is probably a good design for this design phase and we would use that design in any performance assessment calculations that are being done at the time.

However, if it's not the final phase of design, then another phase would be required, and we'd go back and we'll look at the regulations again and look at our issue resolution strategies again and so on and come through it. Because, in each design phase you are going to have to look at your requirements as well as the design itself. If the answer is no, this is the final phase you are going to look at whether or not all the issues that are influenced by the design process have been resolved. And again, if the answer is yes, we are ready to proceed down further and we prepare our license application. If the answer is no, then we go back and look at our performance allocation process. If in the performance allocation process we find there is nothing we can do to change things and make them better, then it's probably not feasible to proceed.

I want to talk a little bit more about the two parts of the flow chart that deal right here, the issue resolution strategies and the functional requirements in establishing the design basis. So, I'm trying to represent here, pretty specifically the process we went through with the conceptual design report and the site characterization plan. At the time of the site characterization plan, we had some performance assessments that had been done. We had available site data and with those two together, we looked at developing an issue resolution strategy. And in this strategy, what we tried to do is say, okay, we have to meet a particular requirement. For example, the ground water travel time being greater than a thousand years. We look at what systems are we going to rely on to meet that. What systems, both natural systems and engineered systems.

Where they are natural systems, they feed into data needs. That means we need to go out and find out more about that particular system at the site. Where they are engineered systems, that interacts with the design process. And that's how we develop some of our functional requirements. So the four sets of functional requirements I've shown here are some of the ones that Mike Voegele discussed earlier. We established requirements for the layout, for the water usage, for the permeability changes and for thermal loading. That's an Issue 111 that Mike mentioned this morning.

From these functional requirements and additional knowledge about the site, and our issue resolution strategy, we'll go ahead one step further and we'll establish some goals. And these goals are specifically for the design. We have other goals over here for the data needs, what do we expect to find out at the site, but these are what are we going to try to design into our facility. And I've shown this dotted line here to indicate that for the thermal loading what we are going to end up with, our goals, are some temperature constraints.

Now, what I'm going to do in my talk--let me put that back on for just a second, is I'm going to concentrate, at least for the initial part on some of the things in this part that feed into the functional requirements and the design requirements. In my second talk I'll talk more about the specific requirements that we came up with. But, for now, I'd like to give you the background information on our performance assessment and our available site data. So part of what's going to feed this process is the information we know about the site. The site characteristics. And obviously talking about the site characteristics everything we've done for the last ten plus years could be several presentations in itself.

So, I am not going to go into a lot of detail. I just want to give you a flavor for the things that are obviously going to feed our design process and show you some sources of information where you can look for other pieces of information about the site.

So I'm going to just talk very briefly about topography, the faults that we are considering in our design process, about the stratigraphy, and this one will be particularly important. I'll spend a little bit more time here because a lot of our requirements are for specific units and they relate back to the stratigraphy. So, you have to have an understanding of the stratigraphy.

Then I'll talk about the actual properties that would characterize, for example the units within this stratigraphy, and that are all contained in our reference information base that I'll describe very briefly. But in addition to just the information that's in the base, some of it is subtle in that it changes with temperature and I'll try to give you a little bit better feel about what we know about how the properties change with temperature. And finally, I'd like to end up with a couple of examples of how changes in our interpretation of these properties, in particular the stratigraphy can have a very large impact on our design and is already in fact in some of our design concepts for the future.

Fortunately, the photograph is very dark but I think most of you have been out to the site, so I don't have to go into excruciating detail about the site. You can see from this photograph though that we have a relatively complex topography and that's going to affect several of our issues. And indeed we have an interactive graphic system in which we can portray both the stratigraphy and the surface topography and helps us evaluate various issues. The dotted line around is intended to be the boundary of the underground repository, superimposed upon the surface and here we see the locations of exploratory shaft of one and two that were in the Title I design and are presently being considered as part of the alternative configurations.

The site for the surface facilities isn't shown on this figure, so let me just briefly put this figure up that is a top view. Over in this area is the repository boundary and over here is the location of the surface facility. This is Midway Valley and I'll talk a little bit more about the features in some of the next view graphs. Again I'm not going to talk about any of these in a lot of detail. I think that some of them you are already planning on getting more detail in the future. But, the faults that I've represented on this figure, in some way or other are likely to affect our design. We obviously are concerned about Ghost Dance Fault since it runs through the proposed repository boundaries.

We have the potential for imbricate fault structures to the east of the repository boundaries. To the west we are bounded by the Solitario Canyon Fault, and we have some other faults, drill hole wash faults that are relatively un-characterized, Bow Ridge Fault and Wash Fault. Also shown on here are some of the drill holes where we have gotten a lot of our information, USW G-1, USW G-1, G-4 and G-3, and I'll talk about some of those a little bit more in the next few minutes.

Okay, this is a cross section to give you a perspective of the stratigraphy that we think exists at Yucca Mountain. I've chosen one that passes through the two exploratory shaft facilities to give you a feel for a sizing relative to that facility. Unfortunately this is south basin view. Most of the time when we look at stratigraphy, we are used to looking at a north basin view, but I like the view graph a lot because it very clearly shows up that this is the volume of rock we are interested in placing waste in. This is the Topopah Spring Unit that we call in our mechanical thermal stratigraphy TSw2. Underlying that is the vitrophyre, which we characterize as TSw3 in our mechanical thermal stratigraphy. Underlying those two we have both zeolitized and vitric Calico Hills. The vitric being on top and the zeolitized being underneath it. And then we also have the various overburdens.

I will spend some time discussing some of the boundaries between the repository units in the upper and lower and particular contacts with the vitrophyre underneath and the contact with the TSw1 above. The TSw1 is the Topopah Spring welded lithophysae rich. And what we are talking about there is that there are a large number of relatively large lithophysae voids in this rock and that's the primary reason we do not wish to place waste in it as a first choice. So, the contact to that is important in terms of figuring out the location of the repository.

DR. DEERE: Where is the trace of the Ghost Dance Fault on that?

DR. BLEJWAS: It would be off over here. It wouldn't show up on this figure.

DR. DEERE: It would be pretty close to it, wouldn't it?

DR. BLEJWAS: It would be running about like this (indicating), over here. So my cross section was coming across right close to G-4, but didn't go out quite far enough to get to the Ghost Dance Fault.

DR. DEERE: I just wanted to emphasize that.

DR. BLEJWAS: And you are welcome to emphasize that again later.

DR. DEERE: I will.

DR. BLEJWAS: I was afraid of that.

I'm going to talk about some examples of properties from our reference information base. The listing up here just happens to be the type of properties that we have in our thermal mechanical properties. We show the stratigraphy in our information base. We have various thermal properties of the rock units, the heat capacity, thermal conductivity, coefficient of thermal expansion, mechanical properties of the intact rock and mechanical property of the joints. This is just an example of the type of information.

I brought a copy of the entire referenced information base if any of you are interested in any particular properties. This is a controlled document. When we referenced it, we have to reference the version that we use so that we are sure we are being consistent in our design process and everyone is using the same set of information during the design process.

Now, just as an example, I've chosen to talk a little bit more about thermal conductivity just to give you a feel for the information that's here. It's intended that you would look at your handout and not try to read the screen on this one, particularly the people in the back of the room unless you have 20/10 vision.

What I put up here is the first page out of the reference information base on rock thermal conductivity. And you can see on your handout, that it talks about the process that we go through to get thermal conductivity and the basis for it. On the next page it shows that we talk about the quality assurance information relative to the reference information base for this particular property, and we also provide the reader with additional sources, so that he doesn't just have to use the data values blindly. He can go back and look at the sources to see where they came from.

DR. DOMENICO: Could we go back to the previous slide?

DR. BLEJWAS: Certainly.

DR. DOMENICO: Indicating there is two phase material -- you have water and you have solids. It's a two phase material that you are treating that as, so that's a composite?

DR. BLEJWAS: Right. Let me get to that with the next view graph.

DR. HUNTER: There's water, air and solids.

DR. DOMENICO: Water, air and solids.

DR. BLEJWAS: Exactly. So that for example, in this particular view graph, what we are looking at is the thermal conductivity of essentially the solid material. It's the zero porosity thermal conductivity.

DR. DOMENICO: So that would be of the individual mineral grains?

DR. BLEJWAS: Right. And then we combine that with the values for in situ saturation and we come up with both--in situ saturation values and dry values so that the person that's using the information can use these values if they are appropriate or use these values or we've even given them the equations if he wanted to try to calculate a value for a different saturation level.

Now the particular values in that last page were developed from some actual tests on samples and I've just put this up to give you a feel for the numbers of samples we are talking about for the properties at this point in time. What I've got is thermal conductivity as these larger squares shown for three different drill holes and I believe they are the three that I showed on the previous view graph, USW G-1, G-2, and G-4 and these squares are plotted against this upper scale and it gives you a feel for about how many values we have. We don't have a lot of information on thermal conductivity. We have a lot more information, the dashed line on what porosity looks like. So that's the reason that at least during scoping phases what we are trying to do is develop relationships between thermal conductivity and other parameters as a function of porosity.

Now that is the information we have put in our RIB and some of the basis for that information. We also learned some things about the properties that are important to us and indeed will be represented only briefly in the RIB and that is how do these things vary with temperature. And that gets at the heart of the issue we are going to be discussing more this afternoon, the design of the repository for thermal effects.

So, we have different temperature ranges where we have different things going on and we have characterized our rock at least for thermal mechanical properties with respect to these different temperatures. So as we get 95 degrees, we are going to have a decrease in the thermal conductivity. Why? Because we are going to have boiling and removal of the pore water. Similarly we are going to have a large increase in the volumetric heat capacity. We are going to have an increase during the boiling and then it will decrease after the boiling is done. We will have a slight increase in intact rock strength. And these are things we've learned by doing tests on these different rocks.

Then from 95 to 230 degrees we are going to have some other things occur. We are going to have some dehydration of the hydrous minerals, mainly the zeolites and we are also going to have some dehydration of the glass. And that's going to cause probably a decrease in thermal conductivity. A contraction of the zeolitized units and the welded vitric, and then a slight decrease in Young's Modulus and a slight increase in Young's Modulus, where they welded.

Finally, when we get to very high temperatures, the type of temperatures that would only be experienced close to the waste packages, we are going to have some silica based transformations and again these would only occur in our welded devitrified units, and we are going to some large increase in the coefficient of thermal expansion, a small increase in volumetric heat capacity and a small decrease in Young's Modulus.

DR. DOMENICO: By large increase in the coefficient of thermal expansion means you've entered the inelastic regime, is that correct? It's not now elastic expansion, it's now fractures, microfractures.

DR. BLEJWAS: I'm not sure I know that that's true.

DR. DOMENICO: Is it based on experiments?

DR. BLEJWAS: Yes, it's based on experiments and I'm not sure whether that's--

DR. DOMENICO: That is what you would logically expect is the differential thermal expansion of individual grains and large increase would suggest that you've entered the inelastic regime, which means microfractures.

DR. BLEJWAS: It would suggest that, but I don't know that for a fact. Yes, I agree with your logic.

Also, we'd have a general increase above 25 degrees of the heat capacity. The heat capacity is not really a constant as we would like to think of it with temperature.

Now, I've talked about some of the laboratory testing and what we know about the properties. I'm just going to mention briefly that we've also conducted some field experiments and I'm putting up here a photograph of our heated rock experiment in G-tunnel. It was conducted in a welded tuff and we learned some things about the larger scale behavior of the rock mass as we heat it.

This particular experiment was conducted to fairly high temperatures, but not to very high stresses. And when we conducted another heated rock experiment in the exploratory shaft facility, we plan on going to much higher stresses as well as high temperatures.

The experiments though that probably provided the most important information with respect to some of my discussions later are G-tunnel heater experiments. And these were conducted several years ago and we conducted these both in welded tuff and non-welded tuff. In the welded tuff, we conducted the experiments up to placement hole temperatures on the order of 300 degrees celsius. And we didn't experience any spalling around the openings. However, we have to recognize that the G-tunnel welded tuff is not identical to the tuff we would expect to find underground at Yucca Mountain. However, it does give us some feeling that we are not running into large problems with the basic properties of welded tuff at high temperatures.

We did conduct one test in non-welded tuff and in that one we had placement hole temperatures up to 180 degrees celsius and again we had no spalling. So, we took it to the temperature range where you would expect to start getting drying out of some of the zeolites. However, I should point out that neither one of these tests were conducted for a long period of time. They were at high temperatures for on the order of like 20 to 30 days. Not long enough to necessarily see all the effects that we need to investigate further.

DR. DOMENICO: Did they produce water?

DR. BLEJWAS: There is some conflicting evidence that there was some water in some of the holes. But, it's inferred from the experiments rather than measured directly or seen directly. One of the thermocouples in the bottom of one hole acted as if it had been in contact with some liquid water.

We did take it upon ourselves to try to predict the temperatures around these heater experiments using the laboratory data from the thermal properties, and then what we knew about our heat source. And indeed we were able to get fairly good predictions of the temperature fields around these heater experiments.

MR. BLANCHARD: Tom, before you go forward, I would like to try to answer the question asked by Dr. Domenico about the previous view graph which was referring to silica phase transformation. That's really the alpha-beta transformation for cristobalite. It wasn't the inelastic expansion and breakdown of the characteristics of the rock.

DR. DOMENICO: Well, at those temperatures you have to expect, at least all experiments I've ever looked at, the differential thermal expansion of the individual grains does result in something called microfracture. And if you are doing this on the basis of experiment, you are actually looking at volume changes, the large volume changes are frequently associated with the inelastic phenomena as opposed to--you are outside the elastic range at the lower temperatures. This is at least my experience in terms of stuff that I have seen, and theoretical calculations as compared to actual laboratory measurements. It's almost inevitable.

DR. BLEJWAS: We don't see though a large change in the mechanical properties in the rock at those temperatures necessarily. So, I'm not sure how much microfracturing we get. I think it's something we need to look at more.

DR. CORDING: You are speaking of the welded tuff now, not the non-welded?

DR. BLEJWAS: No, I was talking about--let me put the view graph up. We are talking about here where the silica phase transferred to welded tuff.

DR. CORDING: Right.

DR. BLEJWAS: Yes. And we don't see any significant changes in the mechanical properties. That's the point I was making. We only see a small decrease in Young's Modulus. I would have expected if we would have had a lot of microcracking we would see a larger decrease in Young's Modulus, and only a small change again in the strength. So, I think what we are seeing is something that's really due, as

Max pointed out, directly to the silica phase transformation.

DR. DOMENICO: You've actually heated that long enough to undergo a true phase transformation? Long enough?

DR. BLEJWAS: Yes, we think we have, yes. We recognize that we probably need to heat it longer to be sure that we are seeing the phase transformation.

DR. LANGMUIR: The alpha-beta transition is instantaneous and reversible. It doesn't require time Pat.

DR. DOMENICO: It doesn't require time?

DR. LANGMUIR: It's a second order transformation.

DR. HUNTER: I just want to add one comment to this whole discussion of reference information. This reference information base as Tom pointed out is extremely important for the designer to have a place to go to to do his design calculations. But, it does not represent all of the data. There's lots of data, as Tom pointed out in references and there is also within the project an organized data base which contains the actual data that were collected.

So, there is a judgment that goes between taking all the data, for instance, all the values for thermal conductivity and asking which one should the designer use to do his calculations. And as Tom mentioned the judgment that goes into the design, that's one facet of it. We don't expect the designer to go back and look at all information that was ever taken and come up with his own values. We expect to provide him that based on the analyses that were performed.

DR. BLEJWAS: Yes, and actually part of my reason for pointing out that we have this additional information that is partially represented in the RIB is because a lot of this feeds into the design requirements, but will not necessarily feed as much into the design basis that we would use in the actual design of the facility.

You will establish your requirements because you know a lot of things about the rock. If you know something bad will happen at a certain temperature, you are going to impose that as a constraint. And we learn things from these tests that give us confidence that we need a constraint or we don't need a constraint with respect to temperature.

Now, I'm going to give you a couple of examples of the kinds of things we've gone through using some of this information, types of information. And, one of the things we've done is look at the useable area for the nuclear waste disposal in Yucca Mountain. There are several different factors that entered into what we think is useable area. And we've shown a couple of them on this view graph.

The very dark area in the middle is the proposed repository boundary, but we also have some additional useable area in yellow. And the way we came up with that is we looked at the stratigraphy and what we know about the rock at the various stratigraphic units. And this particular line right here constrains us because of the contact with the TSw1 unit which has a high lithophysae content. Over here the small dotted line shows the constraint because of the overburden and finally the dashed line over here shows a constraint due to the vitrophyre intersection. That is the boundary between the TSw2 unit where we would emplace the waste and the vitrophyre that occurs underneath it, the TSw3.

DR. DEERE: Could you discuss for a moment that 200 meter overburden cut off and the real purpose of it? I know it's a loaded question.

DR. BLEJWAS: Why don't you go ahead.

DR. HUNTER: No, it's a very significant question with respect to our discussions this morning about regulations and how they apply to specific design.

You will find in our Part 60 statements about potentially adverse conditions and favorable conditions which talk about desired overburden. This particular requirement comes directly from a DOE requirement from the 10 CFR 960 siting guidelines, which essentially states that you want an overburden of at least 200 meters. And, it in fact has become a driver for how you would locate this repository right.

DR. DEERE: Was that for comparing sites?

DR. HUNTER: It was to evaluate the suitability of sites.

DR. DEERE: Okay. So, this is once more--we have a carry over--they are looking at several sites versus one site.

DR. HUNTER: It's a carry over of the siting guidelines into the design requirements for a particular site.

DR. DEER: It would have to be subject to applicability at the site.

DR. HUNTER: And there is--I wish I had thought of this this morning. This is one of those conflicts that one could lead to. In the unsaturated zone, one of the desirable features is the distance from the water table. In fact, the bigger that distance is the more likely you are to have a long ground water travel time and potential for radionuclide retardation. That one is one that we have used and have maintained in our current design which is in conflict with having a maximizing distance to the water table. But, it's still a formal requirement in the requirement system.

DR. DEERE: It is one that could be questioned.

MR. BLANCHARD: Tom, could I elucidate that a little bit more? It's a potentially adverse condition in 10 CFR 60. But in 10 CFR 960, it turns out to be a dis-qualifier. It reads something like this, "The site shall be disqualified if the site conditions do not allow all portions of the underground facility to be situation at least 200 meters below the directly overlying ground surface." And so that drove screening of all the sites when we went from nine to five to three. How that gets translated into site specific requirements is not all that clear at this point because, as you know, 960 was a general guideline for screening and it didn't have specific criteria in there for any one individual site, but nevertheless, it did have disqualifying factors. And, the extent to which those are translated into site specific requirements, I don't think we are in a position yet to be able to explain that because we don't know how we are going to apply that.

But, the NRC didn't intend to be a disqualifying factor, only to be a potentially adverse condition from a siting standpoint in 10 CFR 60.122. And as Tom mentioned, one could conceivably believe that in order to enhance waste isolation, the overall goal for repository in the unsaturated zone would be to maximize the distance between the water table and the bottom of the repository. And so that's certainly a performance goal so there is some sort of an inherent conflict existing there between the screening criteria, the adverse conditions in 60.122, the disqualifying conditions in 960 and/or overall performance requirements.

DR. DEERE: You know, I think these things become more apparent to us because we are seeing them for the first time in this past year. While they are ones that you have grown up with and they have been applied and carried through. So I think it's legitimate for us to ask the question. And is it logical that some of these carry on through, or should there be a re-examination of some restraints, which may be absolutely restraining in the wrong direction.

DR. BROCOUM: I just want to make one correction for the record. In the NCR 10 CFR 60, it is a favorable condition if it is cited more than 300 meters beneath the surface. It's not a potentially adverse condition or disqualifying condition.

MR. HUNTER: There is one point with respect to the way the disqualifier is stated, which implies that you have to have an environment where you couldn't site it. In other words you could only site it in a place where it was closer to the surface than 200 meters. One could argue that you could show at the Yucca Mountain site that you have your options of doing it anywhere you want. So, you aren't forced to have it above 200 meters. It's just a way in how you interpret this disqualifying condition.

DR. BLEJWAS: Okay, well I'm glad you asked that question, because actually I'm going to talk a little bit about moving the repository up and down in the next few view graphs.

DR. DEERE: I tell you, we didn't know that.

DR. BLEJWAS: But, the information I'm going to talk about is based on boreholes and I wanted to show these first so you could get a feel of where we were getting our information from. It's based on information from G-2, G-1, G-4 and G-3. And it's perhaps worth pointing out that these are in a generally north-south direction in terms of their location, so we don't have a lot of lateral information that I'm going to show you. It's mostly in the north-south direction.

Now, remember earlier when I was talking about the stratigraphy, I was mentioning that the TSw2 is the Topopah Spring Unit in which we would plan to emplace the waste. The TSw1 is the unit above it that contains a lot of lithophysae voids. And what I've shown here in this solid line is the contact between those two that was in our reference information for the conceptual design.

The problem was that the information was interpreted by several different people and they weren't all consistent in their interpretation of what consists of a lithophysae void. And some took just the actual void space and others considered the void space plus the phase altered material around the void and they turn out to be quite different. And because of that we got an inconsistency in the interpretation of the information. We went back over the last year and a half and looked at that data again and said now there is a problem here. We should be interpreting this data consistently and when we did that we came up with a contact being shown with the dash line across here. So that when if we look at the percent lithophysae content that's plotted on the vertical axis, now this contact tends to show a fairly sharp change above and below this dashed line. Whereas the solid line particularly in a drill hole like G-1, there wasn't really a sharp change here. This pick seems to be fairly arbitrary. So, we think we improved our pick. Obviously, we need more information to be sure of that pick.

Now, what affect does that have on design?

DR. DOMENICO: Could you return to the slide with the pending bore holes? The one just before that?

DR. BLEJWAS: The planned and pending?

DR. DOMENICO: Yeah. I don't know how to ask this, but where is all the faults that may give rise to some displacement there? Are there any in that line from USW G-2 down to USW G-3? Does that cut the Ghost Dance? And are there other potential faults where some displacement may be detected once those other bore holes are put in?

DR. BLEJWAS: Yes, basically--I'm not sure what you want.

DR. DEERE: We met with the Board last time and they said we ought to have a convention on all our drawings.

DR. BLEJWAS: I'll apologize for this figure.

DR. DOMENICO: So, you missed the Ghost Dance basically--any offset on the Ghost Dance is not reflected, is that not--

DR. BLEJWAS: Well, that's not--the one line would come across here because here is G-4, and we have information further north that would have crossed the Ghost Dance Fault and then again when we go down to the south, we would cross it again. And indeed the Ghost Dance Fault is represented in our graphic system to show the offset and we incorporate that and we use the information.

Okay, what I have tried to show on this view graph is this is a drawing from our graphing system showing cutaway. This area here being the repository, all the rock being cut away above it. It's located in the TSw2 unit and down here is contact between this unit and the vitrophyre underneath. What I want to concentrate on though is the contact between the TSw2 and the TSw1 above it where we have the large amount of lithophysae voids.

You'll notice that in the information we were using for the conceptual design that that contact tends to come down and very much prescribes the maximum height we could have or the maximum elevation we could have for this north part of the repository. When we go back and change the contact, it allows us to have some other concepts for the repository. Instead of having a repository that is shown by this dotted line that consists of a fan-like structure, it allows, at least one option would be to have a completely plainer repository and now the elevation has changed. We can move up this northern part of the repository and still stay in the units the way we had intended to stay in them, still consistent with the constraints that we had set up and try to be in the Topopah Spring unit TSw2 enough so that our mining would be done with confidence.

Now, that allows us to raise it in this direction. As I pointed out we really need more information east-west so that we are sure we are tilting it properly in the east-west direction and this gives us much more flexibility in our design.

DR. DEERE: Is there any downhole geophysical survey that shows up in density or the lithophysae zones on in the sonic velocity? In other words, rather than having a pick from the core, can you just run something up and down, which we often have to do and we can get a better pick than we can from trying to examine the core.

DR. BLEJWAS: I'm not familiar with any geophysical logs that have given us information on that. But I suspect that there could be. I'm just not familiar with any in our existing data base. If anyone from the DOE is familiar with any--it's something that certainly we should look at a little bit more if it hasn't been already. I'm just not knowledgeable on it.

MR. BALK: My name is Jerry Balk and I worked for the DOE and we can't run a sonic dry hole density log. I'm not certain--

DR. DEERE: Well, we have run a lot of sonic in dry holes, but you have to have--you can't do a normal sonic in a dry hole.

DR. BLEJWAS: Okay, the last thing I would like to talk about in terms of background information on the information we know is to talk a little bit about boundaries and interfaces between things at the site because I think it's important that you have an understanding for what those boundaries and interfaces are. But, before I get into that I wanted to make sure that you understand that we have organized our approached based on an systems engineering approach. So, we have looked at the hierarchy of functions and components in the repository. And, I'm not going to talk about this in detail, but just to make sure that you understand that that's the basis by which we have come up with a lot of our interfaces.

For example, on the next view graph, I've shown the different parts of the Yucca Mountain mined geological disposal system and this is based on our system engineering approach. This is a generic repository. Where I really was aiming at though is the parts of the system to isolate waste and what the different boundaries between them are. So that for example, within the Topopah Spring unit, I have figuratively shown the Engineered Barrier System which consists of the waste packages in the underground facility. And then, there is going to be some boundary between that in the disturbed zone which is shown by the crosshatch. And then that disturbed zone will be another boundary between that and the natural barriers that we will use to ensure meeting the requirements down to the water table.

DR. DOMENICO: By disturbed, do you mean something within the thermal pulse?

DR. BLEJWAS: Yes, and I'll have some discussion about exactly what we mean by the disturbed zone. It's actually a regulatory term and we need to come to grips with what it means technically?

DR. DOMENICO: Can I infer that there will be no heating below or outside of that--

DR. BLEJWAS: No, you can't infer that there would be no heating, but as I'll discuss a little bit more later, you can infer that the amount of heating probably doesn't cause a significant change in the permeability or the porosity in this rock. That would be the intent of the NRC interpretation of disturbed zone.

DR. DOMENICO: Do you have estimates on temperatures through there some place?

DR. BLEJWAS: Yes, and I'll be presenting that too.

DR. HUNTER: A point, this system structure and these words that you just see on this chart are in fact the words that are used in the performance allocation, that's in the SCP. So, the question what units are you actually counting on to achieve performance objectives, we'll use that same nomenclature, and that's why we called that the system structure.

DR. BLEJWAS: So, I've chosen what I have considered to be few key physical boundaries to talk about. And then the interfaces I've shown here are the interfaces that come out of our system's requirements. So the physical boundaries I'm going to mention briefly--the boundary of the Engineered Barrier System I will discuss the disturbed zone as I mentioned and then the inaccessible environment.

The interfaces that are represented in our system's description include the waste package repository interface--we have an interface between the surface and the underground, although it's not explicitly spelled out in our system's description, it is inferred that we have an ESF repository interface.

We also have some external interfaces that I'm not going to talk about. These are primarily things like interfaces with the transportation system. Other parts of the geological system for the repository approach. And we also have some repository site interfaces. The way they are represented in our system's documents is information that's required and I've already discussed that so I won't be discussing these last two at all anymore.

Okay, the Engineered Barrier System, what I want to point out is what it does include and what it doesn't include because this is dictated by the regulations. The Engineered Barrier System includes the waste package and including associated components, it includes the underground openings in general, with the exclusions that I'll mention in a little while. And it includes the back fill materials.

But according to regulations, it specifically excludes shafts, boreholes and seals. And there is an NRC position that it also excludes the post rock. So when we talk about the Engineered Barrier System, you might want to keep in mind that that does not include per se, shafts, boreholes and seals, but of course we are going to include those in our assessment of the system. It's just that when we say Engineered Barrier System, this is what it includes.

Now the disturbed zone has caused a lot of study, a lot of consideration of what is appropriate for the disturbed zone given the regulations. There is an NRC draft position that the disturbed zone is defined by the zone of significant changes in intrinsic permeability and affected porosity caused by construction of the facility, whereby thermal effects of the emplaced waste. And that's represented in our 1986 draft position.

In an earlier draft position, they define significant as being about a factor of two change in affected porosity which would generally correspond to about an order of magnitude change in intrinsic permeability.

And finally, in the 1986 position, they gave some minimum guidelines such that for our particular site, we believed that the minimum according to this interpretation would be 50 meters. So the boundary would be a minimum of 50 meters away from the emplaced waste.

Now we've taken an approach that's a little be different than directly applying the NRC position. And this is the position that's outlined in our site characterization plan. What we think is really important with respect to the disturbed zone--the disturbed zone is used primarily in the ground water travel time issue. And when we measure ground water travel time, we have to measure it from the edge of the disturbed zone to the accessible environment. So, it's important in terms of calculating ground water travel time. So, we think that defining it we should first identify the paths of ground water travel and the modes of flow. In other words, we are going to try to relate it back to water movement in the repository.

We are going to obtain predictions of changes in the matrix porosity and permeabilities and this assumes matrix flow. It assumes we are correct in our assumption that we'll have predominantly matrix flow. Then we are going to evaluate the extent and duration of these changes in this due to the repository. Then we will conduct analyses and we will compare the ground water travel time with and without a repository to evaluate whether the property changes are significant. And if we change the properties, but it doesn't change the ground water travel time, significantly, then it's not really important to the regulation. And finally, we would evaluate and consider any other repository induced changes as necessary.

The last boundary that I'm going to talk about is the accessible environment--

DR. DOMENICO: One more fact on the disturbed zone.

DR. BLEJWAS: Yes, sir.

DR. DOMENICO: Porosity and permeability, those are fine considerations, but how about the affect of heat on the zeolites?

DR. BLEJWAS: That would be part of what we would consider. We would look at, if we changed the zeolites and altered the ground water movement through the zeolites--

DR. DOMENICO: I was more concerned about their absorptive capacity than the movement.

DR. BLEJWAS: Oh, okay. That would not affect necessarily the disturbed zone, at least for the regulation, but it of course may have a major impact on what we would calculate in terms of the system performance, the total system performance, and we will consider that.

DR. HUNTER: The context of the disturbed zone is primarily a ground water travel time question.

DR. BLEJWAS: Pre-emplacement.

DR. HUNTER: Pre-emplacement for ground water travel time. So there, they try not to account for anything with respect to radionuclide transport. Just ground water.

DR. DOMENICO: But a real consideration outside of what the regulatory says, you must consider as the affect of heat on the zeolites.

DR. HUNTER: You bet. And, as Mike mentioned earlier this morning, we have a compound problem. We have to address each of three performance objectives independently. And then we have to do a total system which includes them all. In the total system you would consider that, but in the one on just ground water travel time, you would not.

DR. BLEJWAS: Right. And I'll talk about that a little bit more.

DR. DOMENICO: But since we are talking about thermal effects, it's legitimate to ask what those temperatures might be.

DR. BLEJWAS: Right. And indeed in my second talk I'll show you some temperature profiles, some isotherms down in those areas.

DR. CORDING: One question, on the matrix flow, to what extent do you think the fracture flow will control in the welded tuffs as opposed to the matrix flow?

DR. BLEJWAS: Well, our position is that right now we think that we are going to have predominantly matrix flow. And if we don't have matrix flow, we are only likely to have a few weeps and seeps where we have a small amount of fracture flow occurring, but not continuously from the surface down to the water table. Now, that's based on the evidence that we have at this point in time.

DR. CORDING: I'm referring to the welded tuff in the disturbed zone. I am not talking about the flow through the entire system, which is obviously very different, because you have some real barrier confining type layers. I was thinking in the repository level, you are basically in welded tuff and you are talking about the disturbed zone in the welded tuff, are you equating the effect to matrix flow, I was wondering where does the fractured flow come in there?

MR. BLANCHARD: Tom, let me help.

DR. BLEJWAS: Sure.

MR. BLANCHARD: With respect to your question, I believe the calculation methods we are using for ground water travel time links both matrix and fracture flow together. And the question then is what are the conditions and what is the flux that would cause one to be predominant over another. And if the properties of a rock unit such as the Calico Hill or the way they are as we expect then, then matrix flow in the rock unit in Calico Hills, the water flow is largely expected to be in matrix flow.

But in another rock unit like the Topopah Spring which is welded, and if the flux is very high, the flow may well be mostly in fracture flow and we expect the ground water travel calculations to reflect that as the characteristics of the flux and the inherent properties, or characteristics of each one of the rock units.

DR. BLEJWAS: I think it's important that we remember for ground water travel time, what we are looking at are anticipated things. So, when I talk about the flow predominantly in the matrix, I'm talking about the conditions that exist at Yucca Mountain right now, may be predominantly in the matrix. We have to consider other unanticipated conditions and I'll talk about those later. But, for ground water travel time we are talking about anticipated.

DR. CORDING: I don't disagree with what you are saying. What you are saying, Max, fits very well with my understanding of what we are talking about, but we are talking about a disturbed zone that is principally in the welded tuff, and it's impact is not on the Calico Hills, it's on that welded tuff. And if we are referring to that disturbed zone as only being related to matrix flow, that seems to me to be--not fit what I understand of some of the welded tuff units.

MR. BLANCHARD: No, I think that was a misstatement. Those--

DR. CORDING: I mean, that's what I'm getting from it and was getting from this approach, I think, that we are describing.

MR. BLANCHARD: Tom, can you speak for--

DR. HUNTER: I think in December when you had the discussion on ground water travel time modeling and the site hydrology, there was discussion about how close the parameters in the Topopah Springs were with the assumptions about flux. And, I don't remember the numbers exactly, but if the flux values are very low, like .1 or so across Yucca Mountain, those are essentially below the saturated hydraulic conductivity even in the Topopah Springs. And, those are the basis of these assumptions.

If the fluxes were for some reason higher, I don't remember the number, but it seems like it takes a few tenths or so to exceed that in the Topopah Springs. Maybe four-tenths is kind of the limit. If that is the case then the fracture flow would dominate.

But, in this case the assumption was made that those fluxes were as we expected them to be which is those low numbers.

DR. CORDING: So you really are assuming then that we are talking about matrix flow in the Topopah Springs in the vicinity of the cavern?

DR. BLEJWAS: In the description of what our plans are for determining our boundaries of the disturbed zone, yes. But that's not limiting us in other calculations that we are doing in terms of what conditions might exist at Yucca

Mountain. This is just our planned approach to the disturbed zone calculations.

DR. DOMENICO: I think the key is the word assumptions. Infiltration has not yet been measured at all. It's been estimated.

DR. BLEJWAS: That's correct.

DR. DOMENICO: And there's been two measurements of hydraulic conductivity and two measurements of porosity in the Calico, one of which is 50 percent, I think on the affected porosity. I don't think anybody knows anything about the Calico.

And, then to re-emphasize a point that Dr. Deere keeps bringing up, we seem to be hindered by things in the program that relate back to when they were trying to compare three sites. And ground water travel time is one of those damn things. It doesn't mean a thing when you are looking at one site. So there is an awful lot of emphasis on it, but I think issues like that should be--there should be some attempt to clear up this. It was very fine when you are looking at three sites, which one has the longest ground water travel time. But we are down to one then ground water travel time doesn't mean anything. As a matter of fact most hydrologists don't know what the hell it is.

DR. BLEJWAS: I don't what to touch it either.

DR. HUNTER: You might be interested to see what the NRC would say about that.

DR. BLEJWAS: I did want to mention one other thing and that is that we have excavated it in Ranier Mesa in G-tunnel in welded tuff. And I understand that you may be going underground some time in April to look at that facility. There are only a few places in there where we have any ground water motion that you can actually see. Those are very isolated places and that's why I said that I would expect that in the Topopah Spring unit, we are probably only going to have some weeps and seeps, because we have some evidence of that in Ranier Mesa, which has a much wetter environment on its surface. So, that's a little bit more information.

DR. DEERE: Tom, also we are going to visit the N-tunnel at the same time and we are going to show you no water seeping from the softer tuff and a lot of water coming from a small fault in that tuff. It's running out the floor and out the portal. And every bit of it comes from small faults. So, there are a lot of things to be learned on this trip. What was the estimate of that flow rate?

DR. CORDING: I think we said on the order of ten or less. It was somewhere in that one to ten somewhere.

DR. DEERE: It's not flowing very much, but you are not able to drink the amount that comes out.

DR. BLEJWAS: Okay, the last boundary that I wanted to talk about is the boundary with the accessible environment just so we understand what the DOE's present interpretation is of what the accessible environment would be. The crosshatch area shows the controlled area. The clear area is outside the disturbed zone so that this is the boundary of the--I mean not disturbed zone, but the accessible environment. So when we talk about calculations to the accessible environment, this is the boundary that we are talking about either on the surface or underground.

Okay, now one of the interfaces that I mentioned that is shown in our system's description is the interface from the waste package and the repository, that interface. And there are a lot of different physical considerations for the interface. We have the dimensions of the waste package, the waste to the waste package, because they will affect in the repository the transportation systems, the emplacement facilities and so on and the surface facilities in particular. But, the one I've tried to represent here is that we are also concerned about the interface between the waste package and the repository from a performance perspective. What are we going to do in terms of calculating performance for the total system? What's that interface look like?

So that what I've shown here is the boundary of the Engineered Barrier System with a waste package within it, and then what we need to know in order to do our total system calculations, is what is the radioactive release from this

Engineered Barrier System? However, we will not only have releases. At the same time we will have some type of disturbed system. It will be a locally disturbed flow system, disturbed primarily because of the excavations and the thermal loading on the repository. What we would like to do in the future is to develop a good interface between the people that are calculating this release from the Engineered Barrier System, and the repository people that are doing the performance assessment calculations, because, then they can provide not just what the release looks like, but what also the disturbed local environment looks like since they have to consider that during their calculations of the Engineered Barrier System releasants.

I'm not going to say much about the interface between the surface and the underground, except to point out to you that at Yucca Mountain, that interface will occur along ramps as well as shafts, and that will be the primary physical interface. We have experience in our exploratory shaft facility design of being sure that we have the right organizational interface for the surface and the underground. That's also very important.

We mentioned earlier, Mike Voegele did, that it's the DOE's position that the exploratory shaft facility will indeed be incorporated to some degree for the repository. So, what I've shown on this view graph is in blue an outline of the entire repository underground, and then I've enlarged one small corner of it showing in blue the drifts in the repository in red--the drifts that are in the Title I exploratory shafts that we designed. And as you can see, for example, this long drift would be enlarged and would become a part of the repository as would this drift. It would be part of the tuff ramp.

Now, I'm going to go back to this view graph that I showed earlier and I mentioned--

DR. DEERE: I know I've been bugging you a lot, but can you back up just one?

DR. BLEJWAS: Sure.

DR. DEERE: And you do show the Ghost Dance Fault there. I just wanted to acknowledge that.

DR. BLEJWAS: Yes.

DR. CORDING: Only one intersection.

DR. BLEJWAS: The intent of this particular drift was to intersect the Ghost Dance Fault underground. That was the reason that drift was where it is. The reason that this drift is where it is, is that we were hopeful of intersecting the imbricate fault structure that would exist underground there. This drift was being driven so that we would intercept any drill hole wash faults that existed in this region.

DR. DEERE: Right. And as you may recall, one of the criticisms of the place that you crossed the Ghost Dance Fault is since it's a hinged fault, you may have only a few meters displacement while we may have up to 20, 30, 40 or 50 farther to the south.

DR. BLEJWAS: Right. That's something that needs to be considered in alternatives.

DR. DEERE: Right. And, I think you are.

DR. BLEJWAS: Yes. I'll say yes, even though I'm not involved in it.

Okay, I had this view graph on earlier, looking at how we had done performance allocation for design goals, and I've concentrated looking at available site information. We talked a little bit--Mike talked about our issue resolution strategy. We haven't talked much about performance assessments and how they may feed our design requirements. And, I'm going to spend a little bit of time on that.

Just as a very quick refresher, the design requirements that come out of 10 CRF 60, that are related to performance occur in what I categorize as three sets. We have pre-closure performance objectives that are primarily radiation projection that references 10 CFR 20. And we have requirements on retrievability. We have four post-closure objections in 112 and 113. And then we have a series of general and additional design criteria including 134 which is ceiling requirements.

I'm going to talk not about all of these, but I'm going to emphasize the post-closure, because it's the most difficult to build into the design.

So in the next circular view graph, what I've tried to represent is the full set of potential anticipated and unanticipated processes and events going all the way around this. With this little pie shaped piece being on the anticipated processes and events.

We have, you remember, our post-closure performance objectives. We have three of them that deal with individual systems. We have one that deals with the containment of the waste package, so I've shown that as just an arrow of what is getting out of the waste package. We have another requirement objective in terms of the Engineered Barrier System release and the release rate. And I've shown that again. It's just an individual arrow across that boundary.

Then we have the ground water travel time requirement that goes from the disturbed zone--the boundary of the disturbed zone to the accessible environment. So, each of these are requirements on individual systems. But, they must be--the design must incorporate these for anticipated processes and events according to the regulations.

However, when we look at the total system performance objective, we find that the total system performance has to look at the releases from the waste to the accessible environment. In addition to looking at it for anticipated processes it has to look at it for all unanticipated processes that are significant also. So, for that reason, most of what I'm going to talk about in the next part dealing with performance assessment, is going to deal with just the total system performance because it's the one that tends to drive our design requirements.

I know you have been briefed in the past on performance assessment and the next few view graphs are just a very quick summary of some of the information you got earlier. We know that for the total system requirement we are dealing with an EPA standard that requires that we integrate, that releases over a 10,000 year period and then compare the releases for individual radionuclides with an EPA limit. And there is also a normalized sum of those releases of which are compared with a release limit.

And the way we approach this is that we develop scenarios for all--for the potential approaches to releases. And generally they fall into classes. And I'll talk a little more about these different classes of scenarios in a few minutes.

For each one of these classes, we have different scenarios. For each of those that we think are important that need to be analyzed further, we have defining parameters. We define a set of parameters for those individual scenarios. Then in the calculations we perform, we look at calculations of the fluid limit, the fluid flow rather. We look at the calculations of the releases from the Engineered Barrier System, and finally we look at the transport of those radionuclides through the fluid system. We put all of that together to get a cumulative release at the accessible environment.

So, for example, for a particular radionuclide, in this case Iodine-129, this shows the concentration of the radionuclide on the vertical axis as a function of time and as a function of distance from the water table. And these are the kinds of calculations we'll need to do for perhaps a variety of scenarios.

When we put these together, we put them together into something that you've been told is a complimentary cumulative distribution function, which basically looks at multiples of the EPA release limits on the horizontal axis and then looks at the probability of getting those releases on the vertical axis.

And I've drawn in this jagged line a hypothetical CCDF and then the solid line here is the EPA requirement. Clearly, we would have a problem in this area. We would be violating the EPA release limit and it would require that we go back and do something different or disqualify the site.

DR. LANGMUIR: Just a question for you. On the Iodine, how are you assuming it's moving through the system in this case? Strictly with the water with no continuation? Just radioactive decay is the only effect?

DR. BLEJWAS: Yes. And then the sorption into the--

DR. LANGMUIR: You are assuming sorption?

DR. BLEJWAS: Yes, I believe so.

DR. HUNTER: I think this calculation was a conservative calculation with no sorption, I believe. But the flux was fairly low, .1 and it had both fracture and matrix, matrix dominating.

DR. LANGMUIR: In fact what you are doing is leaning entirely on the flow of the water itself as defining the transport of the radionuclide.

DR. HUNTER: With those particular conditions, the ground water travel times are ten's of thousand's of years themselves just to the saturated zone, not even out to the accessible environment. So you get the same result whether you have it or not.

In fact, if you look at the performance allocation tables in the SCP, it talks about such questions of are you relying on retardation or is it a backup barrier. And are you relying on the saturated zone or is it a backup barrier. And as you go through the scenario different assumptions are made about different ones.

MR. REITER: I wonder if I could ask a question?

DR. BLEJWAS: Yes.

MR. REITER: My name is Leon Rider. I'm with the TRB staff. How do you deal with uncertainty in a particular scenario?

DR. BLEJWAS: Okay, I'm going to talk a little bit about that later on. If I haven't addressed your question adequately, why don't you pose it again in a few minutes.

In fact on my next view graph, that's what I begin with. We are saying that we can't right now put together a CCDF that we would have great confidence in because we can't put together all the resources and just instantaneously come up with an evaluation of all significant scenarios. However, you don't really need to look at the entire CCDF to get a feel for how important a particular scenario might be to the your total system performance. With each scenario, we would look at the probability of that scenario occurring. We would also look at what would be the potential release given that particular scenario. The two of those together are going to have some impact on performance. It may be a very significant impact, it may be a very small impact. Where scenarios are very likely to have a very significant impact, those would be the ones that we would consider further in our design requirements.

For the cut that we are presently doing on looking at scenarios and of entries and this is unpublished work that we have ongoing right now, we are looking at all sufficiently credible natural processes and events, and for sufficiently credible we have limited it to just those events that have a probability of greater than 10^{-4} of it occurring in 10,000 years.

And then we are in addition looking at, as I pointed out earlier, can it have an impact on the CCDF. I mean, is the release likely to be large enough so that it would have an impact? And we are also including human activities in these as well as the natural processes.

DR. DOMENICO: How do you put this in this context, like, you are going to drive a lot of water off with heating, both above the repository unit and below the repository unit. It's going to go up, it's going to cool down, it will condense and possibly of coming down and flooding the repository and fracture flow takes off.

DR. BLEJWAS: Right.

DR. DOMENICO: How does that fit into that, because I think that's a realistic scenario.

DR. BLEJWAS: That's a realistic scenario and it was exactly the kind of thing we are in the process of considering. We are developing event trees that look at those kind of conditional things. If we get certain things occurring above a certain level, we would expect that probably we'll have some other process occurring.

DR. DOMENICO: You would classify that as a possible anticipated event?

DR. BLEJWAS: A possible anticipated event. That's correct.

DR. HUNTER: If I could interject another example, at the risk of mentioning the faults again, Don, one event which is possible could be a large amount of flow through one of the faults from some change in surface climatic conditions. If that in fact is something that results in a large consequence, it may or may not, it could influence, for example, the stand off that you have to have in your repository design from that fault when you lay out your underground. I think that's a tangible manifestation of the way Tom would express it here in terms of resulting in design changes.

DR. BLEJWAS: As a matter of fact, you are a great straight man, because I have that type of event on one of my next few view graphs.

DR. HUNTER: Sorry, Tom.

DR. BLEJWAS: No, that's a good lead-in.

These are the basic events that we are presently considering. I don't want to imply that necessarily these are all basic events that will need to be considered before the license application, but these are the ones that we are presently considering. The nominal flow, human intrusion, basaltic vulcanism, climate changes, tectonics, gaseous releases, other human activities such as irrigation, and then closure of the repository. That is, for example, a sealed barrier where the closures don't work as anticipated.

What we do with each one of these basic events, and I've said basic event or condition, because the nominal flow would be a basic condition, we construct event trees where we look at what events or processes can occur given this basic event. And we try to consider all that we can think of. And, here is one case where you are going to have to rely on experts to give you all of their opinions as to what things may occur. Then depending on your--what we know about those events, we are going to look at the probabilities for each one of these occurring. Then given a bad event or process occurs, you look at what other events or processes will follow. So, I've shown a path down through here where now we have probabilities for each one of these and so on so that eventually we get to a single scenario and we have some concept in terms of what the probability of that scenario is. If we look at the events and processes carefully, we can also make some estimate in at least initially a qualitative sense as to whether releases are likely to be significant or not with that scenario. And hence, knowing those two things, we can make some estimate of the contribution to the CCDF.

Again if the contribution is large, we may have to do something about it in our design. If it is very small, we are not going to do a lot about it.

DR. NORTH: Question, how are we coming in terms of updating the scenario collection from those documents dated around 1986 or prior?

DR. BLEJWAS: Okay, that's exactly what we are working on right now.

DR. NORTH: So, do you have something you can share with us, or will you shortly?

DR. BLEJWAS: Well if it weren't in draft form right at the moment, I would have shared it with you, but it hasn't been distributed within the project. So, I wasn't--I didn't bring one with me. But, we have examples of what I've drawn up here that would fill up about half of the wall here looking at these different processes and events.

DR. NORTH: I think it would be very instructive to see these soon at the level of are we a long way from 10^{-4} as the cut off or are we pretty close, or are we clearly over the line as for example the items you have on the last page?

MR. HUNTER: It was our understanding, that would be the subject of explicit discussion when we are having a meeting on performance assessment itself. And I assume that's forthcoming.

DR. NORTH: Yes, I said in my introductory remarks it's forthcoming and depending on when this exercise is going to be at a state where it could be shown to us, we would certainly like to include it.

DR. BLEJWAS: Well it is at a state now where it is soon to be distributed, or a large part of it is soon to be distributed within the project to get comments from other technical experts. And then there will have to be a period where we work together with those technical experts to get something that we would feel confident showing to you and others. So, I think we are at least several months away from showing this to you, but we are making progress and that is one of the focuses of our present work.

DR. NORTH: Well it would seem like in terms of the plans for the strategy and implementation of performance assessment, this would be a key building block.

DR. BLEJWAS: I agree.

DR. NORTH: So, I think we would very much like to schedule our next panel meeting to be able to address this.

DR. DEERE: What could be a realistic date, July, August, September? Some time frame like that?

DR. BLEJWAS: Somewhere like that, but I would have to talk to the people that are working on that right now to feel confident in giving you a date. I'd rather put you off until I've had a chance to talk with them and feel confident that we can prepare something that we think is good.

DR. NORTH: Perhaps at the meeting coming up in early April, we could have a discussion regarding the timing with those of you who will be there.

DR. BLEJWAS: Yes, we can be prepared to discuss the timing at that time.

DR. HUNTER: And I think the DOE would have to address how much internal review and diagnosis would they like to have before there is a discussion with the Board as well.

DR. BLEJWAS: Right.

MR. BLANCHARD: There are two things similar in this vein going on at the same time. One is event tree analysis for scenarios that relate to the prior position of surface base testing program as well as another set which is for repository design and total systems performance. Both of those are ongoing. Both of those will need the same kind of multi-disciplined internal critique and team building to make sure that they make sense before we meld them together. We will look forward to--

DR. NORTH: I'm sure you would like to go over them for some consistency among the exercises as well.

MR. BLANCHARD: Yes.

DR. BLEJWAS: The last view graph is a hypothetical scenario to give you a feel for the kinds of things that may result from the process that Dr. North is asking us to hurry up on. And I'm trying to relate this back to the repository design.

What I've done here is to say is if we have some surface flooding, then we will have to evaluate the potential for some flow along preferential pathways. For example, as you mentioned earlier Tom, along, perhaps a fault. Given that we have flow along the preferential pathway, we may end up with some partial flooding of the underground opening. Given that, we may end up with some flooding of emplaced boreholes and that may in turn have some impacts on releases. If th significant. Or, it may be that they are and we have to do something different in our design process. So, what I've suggested over here is that we can look at the probabilities from each step to the next and decide where is the best place to put our money?

For example, we may decide that we know enough about the preferential pathways that there is some way of reducing the potential for flow along the preferential pathways. Hence, we would change the probability from this step to this. It may turn out that we can change our drainage requirements simply, so that we do not get partial flooding of the underground our we minimize it. It may be that instead of that we decide to change the package orientation, so that even though we get partial flooding, it doesn't cause a flooding of the around the waste packages. These are the kinds of things we'll be able to consider when we have those scenarios constructed and we can build that into our design requirements in the future.

DR. NORTH: I'd certainly like to encourage you on that.

This is just exactly the kind of calculation that I was alluding to earlier. And, I would like to encourage you to proceed rapidly, do it with back of the envelope calculations and try to get a sense of what are the more important as opposed to less important pieces as you go through a great many of these, rather than try to get very precise calculations which would require a lot of time and resources.

DR. BLEJWAS: I agree. And I believe that's the direction we are presently heading.

DR. NORTH: The implications for design and testing activities would seem to be very considerable and it would be nice to go a little further than the 1986 data base and the insights that are already in the SCP.

DR. HUNTER: I just want to comment that I think the Board has seen an explicit example of this in your discussions on vulcanism with Bruce Crow, where basically the argument presented by John Trapp was that you have high consequences and high probabilities of Yucca Mountain and then you went through the discussions about how each of those probabilities might be different. How the consequences and the probabilities might be different. And you've seen exactly the same argument for one scenario.

DR. NORTH: Yeah, and that would seem like a good one to focus near term because a lot of information is available and we can see this hypothetical scenario perhaps worked out with some numbers that are reasonably credible.

DR. HUNTER: And that particular case, I believe the discussion was that the consequences are--most people don't disagree on the consequences. They could be fairly large, but the probabilities are a lot of discussion about the probabilities.

DR. NORTH: Yeah, this whole issue of where do the probabilities come from and how much is enough for the quality assurance process is a very important one. I think that's something that we commented on in our earlier panel report is that we would like to see in detail how it is you propose to go through this with a real panel of experts where some disagreement among them is to be assumed. That process I've watched in various other contexts. A number of organizations have been through these exercises and I think it's very well to have your planning in place as to how you are going to do it and how you are going to assure those people that watch you that it's been done well.

DR. BLEJWAS: If there are no further questions concerning the presentation I just completed, I'd like to introduce Tom Hunter from Sandia--

DR. NORTH: Let me look across the audience and see if we have any questions back there that anybody wants as well as the front of the table. Yes.

DR. MAGUIRE: My name is Robin Maguire. Referring to this diagram here, it doesn't have a number on it, Hypothetical Complimentary Cumulative Distribution Function--

DR. NORTH: Could you give us your organization also?

DR. MAGUIRE: I'm with RISK Engineering, Inc.

I'm referring to the line that you referred to as EPA requirement. Is that referenced in some document or is that a hypothetical requirement or what is the basis for that?

DR. BLEJWAS: Yes, that's in the EPA regulations, 40 CFR 191.

MR. REITER: Could you go back to the slide, Leon Reiter, TRB Staff, could you go back to the slide that shows the example of the hydrology?

DR. BLEJWAS: The hypothetical scenario, sure. Don't forget it's hypothetical.

DR. REITER: I understand that. And if I understand you have hypothetical scenarios and hypothetical decisions and those decisions are based on the size of those XX, YY and ZZ.

DR. BLEJWAS: Right.

MR. REITER: I guess the question I was getting at, although you show two significant figures here, the error bars can be quite substantial over that, and how are you proposing to deal with that? Is this supposed to represent a mean? Is this supposed to represent a central tendency among this distribution?

DR. BLEJWAS: I believe initially I believe it would represent the mean of the judgments of the people that are involved in it. I am not sure where we would go from there.

DR. NORTH: That's just exactly the point of my previous questions. Those things need to be worked out in advance.

MR. REITER: We have learned in the reactor side in looking at these things is that if you are comparing one scenario against another in using expert judgment or using some other way of doing it, you have to be extremely careful in making sure that you approach this in a consistent manner. Because, what can happen is that detail of the distribution--the way you deal with the uncertainty, may determine how the results come out. So I think you'd be very careful before you draw those conclusions that you are looking at apples and apples, not apples and oranges.

DR. BLEJWAS: I agree. I answered that question a little bit too quickly. I didn't want to give the impression that in all cases we are going to base our decisions on the means for the probability. When I showed earlier that we looked at scenario classes, that by the time we get the licensing we hope to have is, for each one of these parameters we will have defining parameters. Those parameters will cover a distribution of parameter properties. So, in addition to coming up with the probability of scenario X versus scenario Y, we also have to worry about what given that particular scenario, what are the probabilities for the distribution associated with that particular scenario, so we are planning on doing that.

DR. DEERE: Yes, if I could interrupt a minute, Clarence.

DR. ALLEN: This morning, we probably should have introduced Leon Reiter. Let me just point out that Leon Reiter has just joined the staff of the Nuclear Waste Technical Review Board for exactly one week, I guess he's been on board. He comes to us from the Nuclear Regulatory Commission. Many of us in this room have interacted with them for a number of years in licensing of nuclear reactors. Welcome aboard, Leon. He will be serving, particularly my panel among others. His background is in geology and geophysics.

DR. BLEJWAS: Okay, if no further questions, then what I would like to do is proceed to the next part of our presentation which is the Baseline Design, conceptual design and that will be presented by Tom Hunter from Sandia.

DR. HUNTER: Good afternoon, members of the panel, ladies and gentlemen. What you are hearing today is a substitute for the people who would normally describe the design of the repository. Most of those people are working in fact on the repository alternative study and they agreed that I should come and give this talk on their behalf.

You've heard from Mike Voegele about the basic regulatory frame work in which design requirements are developed. And you've heard from Tom some specifics which have to be added in terms of looking at our side and the way we intend to analyze our site, and some of the system components which we envision at the Yucca Mountain site to be more specific about those. What I'm going to do now is basically present the design of the repository that came out of the initial look of those requirements, so that that can serve as a background for the subsequent talk by Tom for some specific impacts that deal with thermal effects. And then tomorrow, we'll do a similar thing with the waste package and you'll have a discussion essentially in this same chronology where we talk about the background, define the baseline case and then talk about some specific requirements.

So, let me begin by giving you a reference. In January of 1988, a report was issued which was a site characterization plan conceptual design. That was a fairly lengthy document about a little over the half the size of the SCP. It was issued with the consultative draft of the SCP. It has not be revised and it is a document that described at that point in time essentially the '86/'87 time frame what the repository design would look like. That document as Mike mentioned this morning is summarized in Chapter 6 of the SCP. I would encourage you to read either, but Chapter 6 is shorter and this has a lot of drawings and a lot of background discussion that goes with it.

Much has changed since that time. We are trying to adopt a formal process of design control however, where we have a reference design, and until you go through another design phase, you really don't change the reference design. You do a lot of design studies, but you go through a formal action to change the reference design. So what I'll describe for you today is in fact a reference design, which is several years old now, but is expressed both in this document and in the SCP.

You've seen this picture before today, mine has more smudges. What I'll try to describe today is both the surface and the underground facility of this conceptual design. When we talk about this topic, we really try to say, well, what's unique about Yucca Mountain and why does it look like this?

Well, probably one of the most unique things besides being the unsaturated zone is just the topographic features at the site. And it's Yucca Mountain that has, because of elevation differences of this fairly flat land to the east and the mountain itself, allowed the development of the surface facility out here and an underground facility here within the central block, which we've already talked about this morning.

That allows from a designer's standpoint, the use of the ramps and that allowed some specific advantages in terms of construction time and construction cost, which we felt were always favorable characteristics of the Yucca Mountain site.

I'm not going to relay to you the entire design basis, nor am I going to relay to you the complete design. I'll try to just hit a few snapshots of both the surface and the underground to let you know some of the basic features.

One of the things we are trying to do today is talk about the fact that the waste that comes to a repository has certain characteristics which we have some control over but not a lot. The spent fuel and defense high level waste that comes to a repository is by and large determined by its history in the reactors and its history in the defense program's recycling. What I've tried to do is summarize a few characteristic parameters, which I'll try to talk about a little bit to give you a feel for what the impact of these parameters are on the repository design.

First of all, Mike mentioned that the Nuclear Waste Policy Act of 1982, specified a limit that the repository can have. That limit is expressed in terms of metric tons equivalent, or more formally metric tons of initial heavy metal. MTU's is fine for most purposes. And basically, that capacity of 70,000 metric tons is broken down into really two different waste types. Those two waste types encompass then both defense and civilian reactor programs. The view graph should have a little space here and this number should line up with defense high level waste and this should line up with West Valley high level waste.

Basically, there's 62,000 metric tons of uranium, which in rough numbers is about 70 reactor life times or 80 reactor life times, something like that. Rule of thumb is it's between 900 and 1,000 metric tons per reactor life time. So as Mike mentioned--I guess Steve mentioned earlier, you can't but the whole nuclear fuel cycle, as we envisioned, now into these numbers. And, we are not really taking 70,000 metric tons, we are taking 62,000 metric tons in the current design. That consists primarily of pressurized water reactor and boiling water reactor, different numbers because essentially the number of reactors which exist of that type.

The defense high level waste is another matter. The metric ton equivalency of defense high level waste is some which I have never really understood, and I don't think anyone is ever really going to tell you how that number is arrived, but I can come fairly close to it. We anticipate that the equivalency in metric tons is about 7,000. The argument I think, goes something like this. We've always known that the Savannah River project for example produces a few hundred watts of thermal energy. It just depends on the time and a lot of different factors, but it's fairly cold. So, one container produces about 200 watts. At one time, the thought was it was about 500 watts. The point is it's just a few hundred. As it gets longer in time, the waste is decaying and the number keeps changing as they do mixes at Savannah River.

But if you assume this number is 500 watts, then you've got a nice round number, and if you assume that a metric ton is almost always a kilowatt, as another number, you basically end up with the fact that each canister represents about a half a metric ton. And so, from the figures Steve showed you this morning, you end up with about 15,000 canisters of defense waste program for the first repository, and if you divide them by half, you get about that. That's about as close as I can come to answering your questions for why that's the equivalency.

Now, maybe you people know more about that equivalency than I, but that's the way I've always in my mind interpreted it. So, because the process is very complex, you don't load those reactors like you load civilian reactors and the cycle is different and a lot of different factors that go with that.

So, as a rule of thumb, though the defense high level waste is fairly cold, a few hundred watts per container. Each container is assumed to be equivalent of about a half of metric ton and we anticipate about 15,000 canisters of defense high level waste. That defense high level waste is in fact, if it's Savannah River product, essentially a two foot diameter by ten foot long cylinder, it's all converted to metric to make it sound very scientific when you read about it in the discussions, when in fact it's a two foot cylinder, three-eight's inch wall, stainless steel, about ten feet long. And so we know something about that and you know the status of that.

Now, this is more than Savannah River will have so there's allowance here for other defense waste product of facilities either at Hanford or at Idaho. But, these are the basic numbers. A lot of fuel assemblies in these 62,000 metric tons and about 25,000 containers. Notice the difference. There is 62,000 metric tons here, 25,000 containers, in rough numbers and only 7,000 tons here, about ten percent, almost the same number of containers. So, the point is on a metric ton basis the defense programs are taking up very little of the repository. To the guy that's operating the facility, it's almost an equal number coming in the door to be dealt with.

There is a little West Valley product which should be 640 metric ton equivalent, about 300 containers in the design basis and they also have a fairly low thermal power, a few hundred watts. I think the way this is basically arrived at is just reversing it and saying that in that case each metric ton produces about--each container produces about enough thermal energy to be equivalent to two metric tons.

So, this basically then is the design basis, which means the design of the repository is given these numbers. This flows all the way down starting first with the 70,000 metric ton requirement by law, to the requirements document by DOE headquarters, a generic requirements document and ends up to the designer to lay out the facility. Well, you can drive some other numbers for this that describe our facility. You can ask the question, how many casks arrive at the facility in the life time of the facility. Well, if you make the assumption that the waste would come 70 percent by truck and 30 percent by rail, you get numbers like this. I don't remember all the details, but the assumptions here are that the truck cask holds about a ton and rail cask always holds about seven times as much so about seven tons.

This is one assumption about the repository. The repository is actually designed so that it will accept either large amount by truck and a small amount by rail or a large amount by rail and a small amount by truck. The design basis actually goes up to about 80 percent by rail. If you read the discussion about the MRS, if there were a MRS, they talk about dedicated trains from the MRS to the repository. In that case, the amount by rail would go up because almost all the waste would arrive by rail.

Another point that just kind of goes with it is, the assumption is that the east coast fuel from reactors in the east, would come through an MRS if there were an MRS. The west coast fuel from reactors in the west, might come directly to the repository. So, there would always be some that might come to the repository and not go through an MRS. But the MRS question is not decided in terms of a design basis. So, the design I'm going to represent to you today allows for the fact that there were would be no MRS. If there were an MRS, you might change that.

The repository is also not designed to start up at full capacity at day one. It starts up at a fairly low rate. For the first few years, the repository would accept 400 tons per year of PWR. That's about two--for a PWR each ton is equivalent to about two assemblies, so that's about 800 assemblies if it were PWR, or twice this number here for PWR's. So, a fairly small amount of fuel comes in. You ramp up after the first three years to a higher rate, double and then double again, and then essentially you get the equilibrium rate which is 3,000 tons per year. 3,000 tons per year, you can just ratio these numbers to get how many assemblies that is, but basically for a 250 day year, I believe that amounts to about eight canister per day that would have to be processed. And that essentially is a throughput of the facility.

At the same time, you would put the defense high level waste or the West Valley waste in a rate of 400 tons per year until you've exhausted this number, 7,360 plus 640. So the real throughput water per repository is 3,000 metric tons of spent fuel and 400 tons of high level waste or defense high level waste. That basically determines the size of the facility, the way it operates and how much and what the throughput has to be.

You've seen various pictures of this nature this morning. I'll just try to point out a couple of the features. We've pointed out that the surface facilities over here to the east Exile Hill are on the current design as six openings. The six openings are two ramps, the tuff ramp up here further to the northwest, the waste ramp which has to come somewhere near the surface facility and then the four shafts. A functional shaft here and the men and materials shaft, I believe that's construction air intake. And then the exploratory shafts which really are two, not necessarily because of the repository constraints but because of exploratory shaft constraints. Two exploratory shafts here and then the emplacement exhaust shaft over here.

I won't describe in any detail the ventilation system, but there are two separate ventilation systems, the construction operates off the men and materials shaft and the ramp and the emplacement of the waste, the radio active area--the area where you are handling radio active materials, which is controlled by the intake here and the exhaust over here. You can see it laid out here around the Yucca Mountain site features.

I'll quickly go through the surface facility, but I want to make a couple of points about that. This is that surface facility area over to the east of Exile Hill. And, it really isn't a very sophisticated facility. It has a few buildings which I think are important to point out. All this over here doesn't count because that's where our children or grandchildren will be meeting in the future. That's where all the access, the visitor control, all the administrative operations will be going on. The geological repository operations area at the surface consists of two waste handling buildings. And the reason there are two is just because there was an intent to have a smaller scaled operation to get waste operations evaluated and in place at the first repository which said let's build a small one and see if it works because we can do that more quickly.

I'll show you a view graph which you do not have on construction times, but basically, the real time involved in building a repository are Yucca Mountain site, is building this building, a waste handling building. And that makes the construction time what it's--it's not the underground, it's the surface. And that building is complex and it needs a lot of check-out, reviews, quality control features, because it's a fairly complex radioactive handling operations, because it will essentially be handling this 3,000 metric tons per year.

So, that building is complex and time consuming. This building is simpler and not so time consuming. The basic difference is this is a full scale and provides for consolidation of the spent fuel and this one does not provide for consolidation of spent fuel. In our reference design I believe the situation is, that once this in operation this building would be used for the defense high level waste processing and handling which means you would bring it in and put it in a container and send it underground. So, I've pointed those two buildings out.

There is a performance confirmation building. That building is in the design. As the design evolves, it's not clear where that will be, but it was intended to be a facility where you could go in and bring out radio active packages from the underground, examine them and do diagnosis to decide how your waste package performance was going during the lifetime of the repository. It's a special facility just for that.

You notice the rail access, the parking area for trucks and I think that's about all I'll point out on that one.

DR. PRICE: What is the waste treatment?

DR. HUNTER: The waste treatment building is the building where if you generate onsite waste from the washing operations of the trucks and the casks and the canisters, would actually go into a waste treatment building for processing. There would be no treatment of the waste itself as that comes in--Safe consolidation which I'll talk about in a minute.

The bigger waste handling building is the more complex of the two. And, it contains some fairly standard features, but I'll point out just a couple of them. The reference design has eight receiving bays. They can take either truck or rail. So, depending on this mix of truck or rail, you have to decide how many of these you really need. So, in the final design if there is an MRS for example, and you get only rail it's a matter of a different facility than you have today. In this stage of the design, eight receiving bays, truck or rail. Another area where the casks are prepared and the casks actually go down underground and come into these consolidation facilities and then get transferred out into access to the underground. And, I'll show you a cross-section of this, but basically just an unloading area and a transferring and a consolidation hot cell.

Schematically, if you look at a cross section of that building, and look at the first part, not counting the consolidation cell, you would find that a truck or rail car comes in, the cask is put on a transfer car--is uprighted and put on a transfer car, rolled through a barrier, into the unloading hot cell. There the spent fuel assemblies are taken out, and if they are not going to be consolidated or if they are defense waste for example, they will go directly into a container to be welded and sent to the buffer to go underground. If there is spent fuel to be consolidated, then, they go across and go into the transfer car which takes you into the consolidation hot cell.

An extremely important feature of both the schedule and the design, is the fact that this consolidation does occur at the repository. Our analyses is that we have done and published, in fact indicate that the consolidation at the repository is not essential for the repository and we'll talk about that when Lyn Ballou and people will talk about the waste package design, they will talk about what the container looks like and how many spent fuel assemblies there are in each container. In our view there was not a significant gain to be made from consolidation at the repository. Nevertheless, we have provided for it, but it does not come at a small price. It comes at a fairly significant cost and scheduled penalty, as well as the question of having to deal with pre-closure radiological safety.

The first rule in radiation protection is if you don't need to do something, don't do it. And, you will be in this consolidation operation, dealing with a large amount of material and essentially handling a large amount of spent fuel assemblies. If the MRS were in the systems, this very likely would not be a part of the repository design. We do not have a final or sophisticated design for consolidation, but as schematically shown here basically tells you just take the spent fuel assemblies as a bundle like a bundle of pencils and turn them over into a trough and they all roll down to the bottom, and you pick them up again after you've chopped the ends off and put them into a container with tighter spacing between the fuel rods. That's the so-called horizontal and consolidation concept. Then you simply put it into a transfer cask and off to the weld station and then they are ready to go into the ground.

That's basically all there is to surface operations. And we have talked, I think, with the Board before that if these operations occur the way they are outlined here where there is consolidation and bare stem fuel assemblies, we deal with questions like pre-closure radiological safety, like seismic analyses of the building. If you were worried about seismic at the surface facility, these consolidation hot cells are the area where the spent fuel is most vulnerable. It's opened there, it's taken out of any container, if it's going to be consolidated, the ends are chopped off, perhaps, and that's the real concern. These hot cells are the ones we are primarily concerned about for seismic in concerns about the surface facility. If you don't consolidate, it's a lesser concern.

DR. DEERE: What size are these?

DR. HUNTER: The spent fuel assemblies?

DR. DEERE: No, no. The hot cell area?

DR. HUNTER: Good question. I'm going to ask Leslie

Jardine to remind me of a few numbers.

MR. JARDINE: The walls are five and a half feet deep thick and about 30 foot height. I can't remember the surface area.

DR. DEERE: Sort of like a cube?

MR. JARDINE: Put the footprint back up, then tend to be long and skinny. We have very short, squat structures with five to five and a half foot walls thicknesses.

DR. HUNTER: I believe this is in the order of 50 feet or so and this is in the order of a couple of hundred feet. And the walls are very thick because of shielding and they are fairly low, hence they become very high frequency things for earthquake--seismic events. Inherently a tough, high frequency structure. You can't build them flimsy because you need the radiation protection. And they are basically just big hot cells with overlying bridge cranes overhead--

DR. ALLEN: It doesn't have a lot of umbilicals going to it.

DR. HUNTER: Oh, yes. Oh, yeah.

DR. ALLEN: Yes it does or it doesn't?

DR. HUNTER: It does. You have to do all those operations I just mentioned remotely--with remote operations, if that's what you mean by umbilical.

Now of course there are all kind of questions that go with this. The repository is going to operate in 2010, say, and one would ask the question of remote handling technology robotics and things like that two decades from now and ask what it's really going to be.

That's one of the real difficult questions in repository design is when do you fix the design and what technology do you use? Let me show you a slide which you don't have, which I can get copies of, and the dates across top indicate this is the old schedule. So ignore the top, but it's right in terms of years, so basically put zero about here for all practical purposes it is. That originally meant to be 1998 here, which is now the 2010.

Okay, I said the facility is built in two stages. The first phase is about a four year construction operation. The second phase, which really includes this building, this more complex building, takes about seven and a half years. After you've started initial construction, you would have built the surface facility, you would have built all those buildings, you would have built only a small part of the underground. I believe it's one emplacement panel is the underground construction. That's easily done in the seven and a half year period because it's the surface that's driving the construction schedule.

You will not have to build, as I said this morning, the entire underground, just a small piece of it. And then here's a small scale operation occurring early. If you put in this 62,000 metric tons or a total of 70,000 metric tons, it takes about 22 years to put it in. So, about 22 years to put it in and then there's a caretaker period. The caretaker period is one that occurs while you are waiting out your 50 year retrieval period. You cannot close the facility at that time, you have to wait 50 years before you can make a decision whether to close the facility or not. So, you are essentially--at the end of 25 years, and I think the sum total of this is almost 60 years. At the end of 60 years, you have to make a decision. If you do not have retrieval and do not need to retrieve the waste, then it takes you four to ten years to do the decommission since you've have buttoned it up and sealed all the drifts and take care of the surface facilities and walked away.

If though you have to retrieve, then your rule of thumb is it take about the same amount of time to take it out as it did to put it in, in rough numbers. So, you have this other period here where you actually have to take out the waste that was put in and then you have to button it up and go through he same sealing operations but this time you are sealing up an operation with no waste in it. Or, maybe defense waste and no spent fuel.

The point I would make is this is a long time. And if you take this century and overlay it there, you have the Wright brothers are back here somewhere and transistors are right in here somewhere, computers are out here somewhere. A lot happens in that period of time. And all during this time here, like the constructions, 22 years in itself is a long time. So, things will be learned and operations may change during that time. We are not going to try today to predict for you all those things which might happen.

DR. NORTH: I mention in passing, performance assessment might change over that time, too.

DR. HUNTER: It might. I started to comment this morning, I think it's going to be really important for our universities to make sure that there are people available three generations from now who can do same.

You've seen this slide before and Tom explained it. I use it merely as a transition from the surface to the underground, because once we went through these analogies which I think Tom explained rather nicely, we have identified a usable area and Eric will talk more about this usable area and where it came from and what the uncertainty and availability can be. And just for pragmatic, practical reasons, chose a smaller area which had enough room. I think this is 1490 acres. It must not be 90 because this ends in 90 and I never remember things twice, but about 1400 some acres which would be used for the underground.

Now the reference design that you have which is in the SCP and which is in our SCP-CDR, has two modes of waste emplacement. And we've made some progress on deciding which is the foremost of those two and I'll talk about that when I'm done. But, you'll find described in there, the underground design for horizontal emplacement. And the area Tom showed earlier where the exploratory shaft and the initial mining is up in here, repositories are always about three square miles, so this is about three square miles of underground development. And if you look at any one of these areas in here, what you find in the horizontal case is that there are a small number of drifts and essentially that the waste is put into boreholes horizontally into the wall, drill along and in the case of the CDR a long borehole into the wall and emplace the waste packages into that horizontal hole. And so you see that what you have are access drifts and emplacement drifts, the yellow here being an emplacement drift and then these holes are long boreholes that do not connect in the middle, but in the reference on the CDR they are quite long and quite a quite a large number of containers and we'll take a look at this in a minute. But, that's the basic idea.

The reason for going to horizontal emplacement and this was something that occurred about 1980 or so, was the incentive to reduce the amount of excavation, so you wouldn't have to mine as many drifts. You essentially would do a drilling operation and load the waste packages in one at a time.

That turns out to be a significant savings in terms of cost because you don't mine as much and your operations are nearly as much. I say significant, about ten percent. I did not mention, by the way, if you are trying to get rough numbers on cost this facility is estimated to cost like a million five--a billion five, we would buy it today if we could get it for a million five. A billion five--one and half billion dollars for construction and then about another five billion for life cycle operation. So, the total life cycle cost is on the order of six to seven billion dollars. And that's what is in the Fee Adequacy Report.

Something which I may have mentioned, if I can get the number right, if you take 70,000 metric tons of waste and ask what the revenue that was generated perhaps with the Nuclear Waste Fund, I believe the number is about 18 billion dollars. In other words, the waste fund generates enough revenue to build the repository as well as develop it. And if you look at the total life cycle cost, total life cycle estimated cost for the Fee Adequacy Report, you'll see those numbers reflected.

DR. ALLEN: Does that include transportation?

DR. HUNTER: Well, the six billion does not. The number I quoted for total life cycle cost does not include transportation. It's construction operation of the repository.

DR. ALLEN: And all the costs going on right now?

DR. HUNTER: No, it doesn't include any of those. It's from the date--the six and a half billion? No, it does not include that. It includes from the time you start formal design with a formal design contractor and what we call life and application design. It includes that design, final procurement and construction design, and it includes construction operating costs. It includes--none of the work here today comes out of that six and a half billion. Someone would have to quote me on the Fee Adequacy Report number, but the two repositories are in excess of 30 billion dollars. That includes everything. Transportation, MRS, the whole business.

The only thing I would note on here is in this particular design the drifts primarily these emplacement drifts here are low ceilings and wide backs--wide ribs. The reason for that is the waste canister would come in horizontally and when you are ready to put it into a hole, you would turn it 90 degrees and put it in like so (indicating), so you need room to turn it. And the facility casks are on the order of 20 feet long or so, so you need that room to make that turn. At this point right here, you have to come in and turn 90 degrees and stick it in the hole. So, they look like that.

The other design is for vertical emplacement and there you see the drifts again. This is the same layout. The emplacement panels in that case would have a large number of drifts and each one of those drifts would have boreholes in the floor with a single waste package in them. And the drifts in that case become high backs and narrow ribs. That's because in that case, the waste canister--the facility case would come in horizontally and be raised 90 degrees to vertical and then dropped down to the hole. So, the drift configuration changes depending on whether you are horizontal or vertical.

If you look at a more detailed cross section, if you go back and look at this drift here (indicating), on horizontal emplacement and look into the rib on one face you would see a series of boreholes like this. This is the reference design. And what you see is boreholes into the rib of alternating defense high level waste and spent fuel. The layout is consistent here in thermal power density. I think locally about 69 kilowatts per acre and globally about 57 kilowatts per acre, and Eric will talk more about that. So, that's the layout.

Each one of these that's in the design of the SCP-CDR has fourteen spent fuel containers, one after the other. So, for that you can get your aspect ratio in the layout and all of those things.

Now, we have done some work on this and concluded two things. One is that we think the likely case to choose is vertical. And there's some reasons for that and there's some performance reasons for that. There's some retrieval reasons for that. Question is can you get all these containers back out? This whole would be lined by the way, would be lined with a steel liner. Can you retrieve them easily and readily? Can you drill the holes straight and all those questions. But the two reasons that we really chose was one respect to performance and a couple of simple arguments you can make. If you have faults or these predominantly vertical structures which might have motion over time, you cross a lot of them with a horizontal hold. You can cross more of them than you would in this case.

And then if you get a 50 cent performance analysis, maybe a 65 cent performance analysis, in one case you've got a waste package like this the cross sectional area is equal to the diameter times the length, and the other case is a vertical flow. In the other case you've got a package which is like this and the cross sectional area looking down is Pi r^2 or Pi rd^2 over 4. So you basically have a different cross sectional area intercepting a vertical flow, and questions like that have led the program to deciding that the preferred case is the vertical case and all experimental program now is lined up around the vertical emplacement option.

We also concluded that if you did horizontal emplacement that it is unlikely that you would do as many as 14 containers because these questions that I mentioned about potentially crossing a lot of structure and being able to retrieve so many of them. They are about 15 or 16 feet long each, so they take up quite a bit of space. So we really think if you did horizontal design you would limit the number to about three. There are still some real operational advantages of doing three and you are up off the floor. We talked about earlier this morning if you are worried about this drainage then having them in the rib might be an advantage.

I should comment on that point. That's not exactly my perspective on the Yucca Mountain site, wading around in miner's book sloshing through the water. It reminds me of the WIPP cartoon we had in the paper where they were talking about a brine in flow and the caption was surf is up. People were wandering in with their surfboards. When in fact if you go into the facility you can't see any water. The drainage arguments in my mind are a argument that would occur--there will be places where there might be wet rock and drifts, but the drainage probably would not force us into the horizontal configuration. But, yet, with site characterization information, we may conclude that is an advantage. So, right now, we have--if we had it horizontally we would have no more than three containers, and the reference case is vertical.

The vertical emplacement panel--this is looking at--if you take this vertical emplacement mode and go down and look at one of these emplacement drifts here or two or them say, looking down at the top you see this view, and basically what you see is a configuration like that. Here are these tall narrow rooms again, emplacement rooms, the waste package for which the design will be described tomorrow in some detail with a shield plug on top, about 15 feet long placed in a hole about eight meters deep.

What you see in the reference design is a layout which is consistent with I believe about 69 kilowatts per acre assuming there are about three kilowatts per canister, spent fuel canister. The black ones I believe are spent fuel and--let me get the code here. The blacks one are spent fuel and the open circles are defense high level waste, or vice versa, it doesn't make any difference. But the thermal power density that this configuration has in it, is basically 69 kilowatts per acre and three kilowatts per container.

Now, the defense high level waste is what we call commingled. It's put halfway in between each one. If you recall those figures earlier about the power levels, it's a couple of hundred watts per canister, it doesn't contribute much. It may have some of the same concerns about maintaining high temperatures which I will talk about tomorrow when we talk about waste packages. It's just commingled and put in the same environment as the spent fuel. We've had designs and alternatives where that was off by itself; a separate dedicated area for defense high level waste. In the reference design we chose to make the commingled design and there's an example of the area where we have taken an alternative and end up with a set which has the commingled option.

The extraction ratio here is about 12 to 13 percent, which basically means if you take a cross section through here that you cut away about 12 percent of the material holding up the over burden. And the borehole spacing is about seven and a half feet. We do have a stand off both in the vertical and the horizontal case where the stand off is used to control the temperatures in this drift and Tom will talk more about this in the future. The horizontal provides this for you by just shoving it further away. The vertical provides it by having some drift here in which you don't put any waste packages. The reason for that is to maintain this drift temperature low so that you can go back in and retrieve because the thermal source start here and eventually over time the rock becomes hotter and hotter as you go out towards the access drift and you want to be able to walk without having your feet get too hot, and you want the air so you can work in it. So, there is a stand off which is assuming that.

And so that's the basic configuration. Our plan now is to talk more about how we arrive at that configuration, some of the requirements which led to that configuration, and then look at some variations on that depending on what we understand about the waste inventory and waste receipt. So that's a general introduction.

DR. NORTH: This is probably a good place for a break. We are right about a 3:00. So, let's plan on 20 minutes.

MR. GETZ: Warner, can I make a statement first? I'm sorry.

DR. NORTH: By all means, Carl.

MR. GETZ: Excuse me. We've talked a lot about 70,000 metric tons and design requirements and what not. I want to put it in perspective of the way the law reads now so you know why we've designed to 70,000. But as written right now, the Waste Policy Act says, "The Commission decision approving the first application shall prohibit the emplacement in the first repository of a quantity of spent fuel continuing in excess of 70,000 metric tons of heavy metal or solidified high level waste until such time as a second repository is in operation." It doesn't say only 70. It says it will prohibit for 70,000 until a second repository is in operation. And then after that law in '82, the '87 law says it's 2007 before you determine whether there's a second repository. So, we are limited by the approval of operational constraint on 70,000 right now and that's what we have designed our 70,000 to. So, I want to put that in perspective as to why that's a design requirement.

The second thing I want to allude to is although Tom talked about consolidation at the repository, our current position in life cycle costing is that we wouldn't construct facilities at a repository to do consolidation. If it's going to be done it would be done somewhere else, i.e., an MRS. If we were to do it at a repository designed facilities today, we probably wouldn't have consolidation cells in today. But, I wanted to add those two things.

DR. DEERE: Even without an MRS?

MR. GETZ: Even without an MRS we'd have to re-think that overall decision right now. But, as Tom points out it's no benefit to us in repository by consolidation, and therefore without an MRS, an MRS would add to the benefit of reducing transportation containers so there may not be any benefit to the system overall, but I can't allude that right now.

DR. HUNTER: Another key decision would be the decision of whether to have a one or two phase facility which goes part and parcel with that and whether you would need that.

DR. NORTH: Okay. Bill.

MR. BARNARD: Bill Barnard, I'm a Board associate. There is a 70,000 metric ton legislated limit. What if that limit were changed? What's the overall capacity of the 1400 acres?

DR. HUNTER: We are going to talk about that specifically. Eric is going to talk about that this afternoon specifically, because, what he's going to show you is some analogy we did looking at the likelihood of having the building put 70,000 metric tons in as well as what other area is available and how much could be put into the basic area. So if we could defer that--if we don't address it, just ask us, but we intend to address just that question.

DR. NORTH: Twenty minutes.

(Whereupon, a recess was taken off record.)

DR. BLEJWAS: Okay, well we are at this point in our presentation after the break. We are now going to talk a little bit more about our design approach, the DOE design approach. And I'm going to talk about the influence of thermally induced effects on the repository design. and I'll spend some time with that. But, most of my talk is actually designed to lead into the presentation that will follow by Eric Ryder where he will talk and show you some of the real trade offs that we've done in the repository design area for thermal loading.

So again, the subject I will be talking about is the influence of thermally induced effects on repository design. And the way I have organized my talk is that I will first talk about what kind of rock temperatures we expect to see for different thermal loadings and what those changes are like and then what kinds of thermal stresses we anticipate they will cause. I'll talk very briefly about what kind of hydrologic changes we would expect due to this thermal loading and what kind of geochemical changes we would expect. And, I'll also talk about design goals. But, my design goal discussion will actually be intermixed into each one of these three. So, after I've talked about an influence or effect, then I'll talk about the design goals we've developed in our performance allocation process.

I'll show the view graph again that Mike Voegele used this morning showing the overlap of our performance allocation process with design requirements development and I agree with someone's observation that the overlap looks pretty small there. Actually, it's quite significant. And that indeed is the basis for most of the performance based design requirements that we've developed. And those design requirements show up in both our site characterization plan as goals and where appropriate, they show up as requirements in our requirement documents.

I've tried to show on this view graph, some of the potential effects of heating the repository. We have heat input which is going to result in some temperature changes. That heat input is going to cause changes in chemical interactions and fluid flow and in our mechanical system in terms of stress and strain. Also, some of these are then going to in turn tie to radionuclide transport. Part of my reason for showing a lot of interactive movement here is that each one of these interactions is relatively complex. And I hope you understand that we could probably spend at least a half a day just talking about heat and then chemical interactions or heat and fluid flow. And, I'm not prepared to do that. I'm going to talk about these relatively briefly, and I'm not enough of an expert to necessarily deal with all the details for all of the heat inputs. If you have questions it may lead to future discussions and future meetings.

DR. NORTH: Yes, I think the issue is what are the implications when we get into the performance assessment of the design in terms of potential problems that we ought to be foreseeing with regard to the acceptability of the repository. So, if our calculations indicate that there is a potential problem of interest, let's go into it, but let's avoid of getting into a long discourse on the interesting science involved.

DR. BLEJWAS: All right. Well, we will not get into that long discourse I don't believe with my presentation, but you may find that you want more detail in some areas because it is relatively brief.

In the rock temperatures that we get, most of those are design analyses using conduction models and part of the reason we think conduction models are relatively good is because our G-tunnel experiments and comparisons with those, and also, as I will show you a little later, we have done some analyses with models with vapor transport and indeed we don't see a big change in temperature field due to the vapor transport.

And one of the things I want to point out is that I'm going to talk about the trade-offs that we have of high temperature constraints and low temperature constraints that was alluded to in one of the earlier presentations that most of what we are trying to do in the repository leads us to low temperature constraints, with the exception of the waste package where if we can keep the waste packages hot for a long period of time, we potentially can keep them dry for a long period of time. And these are somewhat conflicting requirements.

I'll also mention in the area of the thermal stresses and the temperature fields that we do analyses at three different scales, a container scale, a drift scale, and a far-field. I'll talk briefly about and show you some examples of far-field analyses and drift analyses. For container analyses we will wait for tomorrow. The waste package people will talk more about the containers.

And in my thermal-mechanical analyses I'm going to briefly give you some results using linear-elastic analyses and also some using what we call continuum joint analyses. We are also in the process of doing analyses that could be characterized as discontinuum joints, but we have--we don't have any results to show you there.

Okay, this is an isotherm plot for a waste emplacement of 80 kilowatts per acre. So, here I've departed a little bit now from the conceptual design approach. I'm talking about 80 kilowatts per acre because that's one of the things we've studied since we did our conceptual design. We've looked at different loadings of the repository thermally. And what I've plotted here, the repository is in the center of this area right here and we see the different temperatures that we would get around the repository. This is a two dimensional analysis. This is at 100 years. And some of the peaks occur at 100 years. Others occur at later times.

I didn't think that was very helpful because I didn't show any of the formation on there. I chose to show a critical formation this one rather than getting too complex. What we have here is the 115 degree centigrade isotherm is the inner one and then the 95 degree centigrade isotherm is the outer one, and then you can see the relative relations of those to the top of the Calico Hills formation.

DR. DOMENICO: Is this above ambient?

DR. BLEJWAS: No, this is the absolute temperature.

DR. DOMENICO: The absolute temperature.

DR. BLEJWAS: Right.

DR. DOMENICO: What's ambient down there? Ambient must be--

DR. BLEJWAS: I've got it on one of my next figures. You can see what ambient would be. Right at the repository level it's about 25, it will go up as we go deeper. So part of my reason for picking these two temperatures is obviously some temperature like 95 is going to be the boiling point of this elevation, so that shows you the volume of rock that would potentially be above boiling and then the 115 degrees is one of the temperatures we have chosen for some of the constraints I'm going to show you later.

Now, the isotherms we are looking at are nice in terms of getting a feel for what's going, but sometimes it helps to look at cross sections to get a better idea of where the peaks occur. So, what I've shown on this figure is this cross section running through the center of the repository in this two dimensional analysis, and we see that I've plotted here the temperature profile at 100 years and the temperature profile at 1,000 years. The peaks near the repository are very similar, but you can see that 1,000 years, the temperature is spread out considerably, so that at 1,000 years now, we can see that the Calico Hills formation is reaching a higher temperature that it is reaching at 100 years.

DR. HUNTER: The ambients on there is the first curve.

DR. BLEJWAS: The first curve right here is the ambient so that the repository levels were at something like 25 degrees centigrade.

Now these analyses were done as a precursor to doing thermal-mechanical analyses to look at what the stresses would be. And what I plotted here are the horizontal stresses and these are isobars. You can see that right around repository we are going to reach pressures on the order of like about 20 mega pascals. The negative here is compressant. So we have all compressant stresses in this region. However, those stresses drop off very quickly and on the surface we have now reduced the in situ stress to something that approached zero.

DR. DOMENICO: These are mean principle stresses? Total stresses that are--

DR. BLEJWAS: These are just horizontal stresses.

DR. DOMENICO: Just horizontal stresses. Effective or total?

DR. BLEJWAS: Total. Again, this is the same stress distribution though just showing the stresses along this intersection. And we have the horizontal stresses peaking at 100 years at something like 26 mega pascals. The stresses go down at later times, the peak goes down, but we do get more of a spread of the stresses.

Now to put this into perspective, the vast majority of the test we've done on the Topopah Spring welded tuff, have given us strengths on the order of 100 mega pascals or more. So, from these figures, we are not very close at all to the matrix strength. Actually, what now would really become important is what affect might these stresses have on the joints and potential for joint slip?

For that we primarily are going to want to look at near-field calculations. And what I've shown here is the temperature field at 25 years after emplacement for vertical emplacement. Again, a two dimensional analysis. One thing that's interesting is that even after just 25 years, the 100 degree centigrade isotherm has spread out pretty far above and below the drift in the waste package.

DR. DEERE: Just to give a practical vent to some of these temperature centigrade, at about 45 degree centigrade miners go on strike.

DR. BLEJWAS: Right.

DR. DEERE: And at about 55 degree centigrade, when you touch it you take your hand away real fast.

DR. BLEJWAS: Right.

DR. DEERE: So, that gives you some idea that it's pretty hot down there isn't it?

DR. BLEJWAS: It's pretty hot down there but these are drifts where the emplacement has been completed and they are closed off. They are not being ventilated.

DR. DEERE: Oh, they are not.

DR. BLEJWAS: Now, we do have a plan that if we need to go into retrieve that we would blast cool the drifts that indeed the miners could go in and access the waste.

DR. DEERE: Is that very effective?

DR. BLEJWAS: The studies that we've done suggest that it is effective, and that would could blast cool, yes. I don't have any of those results but I know they have done that for us at the mine ventilation.

DR. DOMENICO: You've decoupled the fluid flow out of here. This is now just conduction model?

DR. BLEJWAS: Just the conduction model, yes. Now, there is a lot of convection here because the drift is closed.

DR. HUNTER: Just as a side point, it turns out that one of the principal means of heat transfer in the room is actually radiation. It turns out to be a very effective way of getting heat from one side to the other.

DR. BLEJWAS: Okay, I'm not going to spend much time with the rest of these except to show you that after 50 years, the 100 degree isotherm has fallen off the bottom of this figure and it's pretty far up in the top. The maximum temperatures though are not as high as they were on the previous view graph. So, the near-field temperatures are now starting to go down. The ones closest to the waste package, but we are starting to spread the temperatures out more. And then the third one showing at 100 years, this is as far as we took this benchmark problem. We see that now the 100 degree isotherm is completely off the figure and indeed again the temperature is near the waste package and dropping even more.

Now the first figure I'm going to show you was not done in conjunction with these temperature analyses, but it's the one I had that I thought gave us the best physical representation of what is going on with stresses around the openings. And what's shown in this figure are the principal stresses now around the openings. Each one of these little cross hatches is a representation of the two principal stresses in this 2-D analysis. And you can see at the time of excavation, we have some stress concentration around the opening but you can also see the effect of the predominant vertical stress in situ stress. But none of those stresses are very large. They are on the order of like eight to ten mega pascals.

As we go up in time, we see two effects. We see that the total magnitude of the principal stresses is going up, but we also see a significant change in the direction. So, by the time we get to 100 years for an unventilated drift, we see stresses that are much larger and they are much larger in the horizontal direction. So, we've gone to a condition where now we are pushing in on the sides.

We expect that at Yucca Mountain our joint sets are going to be predominantly vertical. If we are accurate in that it may be that instead of actually causing a lot of joint slip, we may just be tightening everything up, but I don't believe it's that simple.

Now, I'll show you some, very quickly, some analyses that were done during the same exercise that I showed the temperature fields.

DR. CORDING: When you are saying tightening them up, you are thinking right in the immediate vicinity of the opening, or certainly away from the opening?

DR. BLEJWAS: In the immediate vicinity of the opening. What I'm thinking of is that one of the things we have to be concerned with is the stability of rock to fall into the opening. And right around the top of the opening, what we've done is we've created compressive stresses that if indeed the joints are vertical, these stresses are going to tend to keep the rock there instead of letting it fall into the drift.

DR. DEERE: What was the magnitude of that build up? Was that still 25 or more?

DR. BLEJWAS: It's on the order of about 30 mega pascals. And some of the figures I have for more detailed analysis will show that a little bit more clearly. This one is at 100 years, but this one is again another just horizontal stress. And we can see that the maximum magnitudes are on the order of 25 to 30 per horizontal stresses.

But now I mentioned the joints and the fact that we've done some analyses with a continuum joint model. This one had two joint sets. It was orthogonal joint sets, a vertical joint set and a horizontal joint set, where the horizontal joint set was spaced much further apart than the joint set for the vertical.

And it's interesting that the calculation of stresses for this different model have a very different pattern. But, also it's interesting that the magnitudes are not a real lot different. Here we do see though some larger stresses here in the floor in the order of 40 mega pascals, where previously the magnitudes were more on the order of 30.

But difficulty here is though that we are using a continuum joint model which is not going to represent real well the field right around the opening. It's best for looking at what's going on further away from the opening.

DR. CORDING: What do you assume in that joint? Do you assume certain strength properties for it?

DR. BLEJWAS: Yes, you assume certain joint properties, the joint strength, the joint shear stress and some assumptions about the friction of the joint when it actually moves.

DR. CORDING: But you assume now that the entire medium has that characteristics at any orientation--

DR. BLEJWAS: Well, no, the joints are oriented so that you have a joint set that's vertical in this case and a joint set that's horizontal. So your model is an orthogonal model. But again the joint properties are spread out. You can't say there's a joint here and there is a joint there. Those things are spread through the mode.

DR. HUNTER: Tom you might mention what a benchmark problem is.

DR. BLEJWAS: Okay. Dr. Hunter suggested that I mention what a benchmark problem is. What we do with benchmark problems is to try to validate our codes or verify our codes. We do different analyses with different models and compare them to give us confidence that indeed the models are predicting things that are real and mathematically. It's not a validation, it's a verification process.

Okay, what perhaps is most important with some of these joint models though, is the prediction of joint slip. And so in this figure I've shown the joint slip from the orthogonal joint model near the drift. You can see that we get some joint slip real close, on the order of about a half a millimeter of joint slip. Now again, predicting things real close like this is somewhat misleading because the joints themselves are discontinuities and you are going to have individual joint slips as opposed to things being smeared out locally. But, it does give you a feel for the fact that we are not talking about very large magnitudes of slip. We are talking about relatively small amounts of slip and most of it is occurring very near the drift openings in our analyses.

So based on that, during our performance allocation process, based on what we knew about the thermal response, the thermal stresses, both experimentally as well as analytically, we came up with some design goals and these are what I've called thermal stress design goals because they relate to temperatures to try to limit the stresses due to--or constraints on temperature to limit the stresses around the openings. And so what appears in our site characterization plan is that we will limit the temperatures near boreholes. And one of the limits we chose is that the temperature one meter from the borehole would be less than 200 degrees C. Now, I think you'll remember that when I showed earlier the process of coming up with design requirements, it's an iterative thing. Initially, you are going to base your requirements on engineering judgment. And there's engineering judgment in each one of these design goals that I'm going to show you. However, I did want to point out that we have our experience from G-tunnel. It gives us confidence that if we put this constraint in place we are not likely to get a lot of bad things happening around the boreholes. That will be confirmed later with continuing experiments or other experiments at Yucca Mountain in our exploratory shaft facility.

Also, the main reason for this as I mentioned is near-field rock mass integrity and I've already mentioned the G-tunnel and heater experiments.

The next constraints we've put on is to limit the temperature of the container in the borehole wall. And what we got from the waste package people and they'll talk about this more tomorrow is that they would like the center line of the container to be limited to 350 degrees C. We did some simple analyses to determine that if we can strain the center line to 350 degrees, that will result in an approximate constraint of 275 degrees at the borehole wall. So that's the reason we chose 275 degrees at the borehole wall. This allows the people that are doing the analyses of the rock to not have to worry about the details of the waste packages. So these constraints are intended to be consistent.

And the reason on the container is cladding integrity and as I mentioned that will be discussed further tomorrow.

DR. DOMENICO: The whole driving force here is the effect of temperature on boreholes?

DR. BLEJWAS: No, the whole driving force on this particular one is cladding integrity.

DR. DOMENICO: Cladding integrity.

DR. BLEJWAS: Yes.

DR. DOMENICO: But, I mean you are concerned with the stresses on the boreholes and that's where you come up with the 200 degrees, is that not true?

DR. BLEJWAS: That's where I came up with the 200 degrees, that's correct.

DR. DOMENICO: It's effect in the far-field to the near-field did not enter into your considerations at all?

DR. BLEJWAS: No, because once we get past that the temperatures are going to drop off and those problems are going to be smaller. We already know that from our experience and the analyses suggest the same thing.

DR. DOMENICO: Well I did see some slides on the Calico Hills being heated up pretty considerably.

DR. BLEJWAS: Right, but the Calico Hills doesn't have any openings in it. Or at this time the plan is that it wouldn't have any openings in it. And these constraints are driven at what will happen around openings.

DR. DOMENICO: It's got zeolites.

DR. BLEJWAS: Right. And the constraint on that arises for other reasons. And I'll get to that.

Okay, we've also got what I've called strain design goals, thermal strain. Or you might say displacement design goals. And, one of those is to limit the surface temperature rise and uplift. And there's two of these. Let me talk about the second one first.

That is that the surface uplift would be a half of centimeter per year or less. And the reason for this constraint is so that we wouldn't drastically change the integrity of the surface and create preferential pathways to the surface. It's engineering judgment that if we limit it to this much we are not likely to have preferential pathways established.

The other one is the temperature on the surface being less than six degrees C, delta less than six degrees C on the surface and the reason for that is so that we don't completely change the environment of Yucca Mountain.

There's also another constraint that Mike Voegele mentioned in his talk and that is that we have no intact rock failure or continuous joint slip. I need to qualify this though. We are talking about no intact rock failure in the Calico Hills unit and other units other than the TSw2, the rock that we would emplace the waste in. Because, we can withstand some intact rock failure around our boreholes and there's likely to be some small amounts of it in local areas that are particularly weak. And, that's not going to hurt us.

However, we can't accept that we are going to have intact rock failure large distances from the waste emplacement. Also, we are not going to have--

DR. CORDING: Is that away from--are you saying that no intact rock failure in the mass or at penetrations in those other formations?

DR. BLEJWAS: No away from the rock mass--away from the waste. In all the locations away from the waste.

DR. CORDING: But in a penetration of some sort?

DR. BLEJWAS: No, just in general.

DR. CORDING: In the intact material.

DR. BLEJWAS: All the intact material. So our calculations for stresses will need to show and they have shown in our preliminary analyses that the stresses are low enough in anything but the TSw2, that we are not going to cause intact rock failure. And if I showed you--go back to the view graph that shows the stresses in the far-field, you'll see that except right near the waste, the stresses are low. And this aimed at that.

Continuous joint slip is continuous joint slip from the emplacement area to the surface or from the emplacement area to the water table. So we are not talking about having a short distance where we would have slip. We have recognized that that is going to occur. But, we don't want to have large amounts of slip for long distances and this is the constraint that we've put on our design.

Now evaluating that constraint is very difficult and we are going to have to get smarter to be sure that we can evaluate that one accurately.

DR. DEERE: Perhaps as a matter of interest, you are aware of the study that was made in England where they were mining a coal seam and it was an open cut excavation, and they were pursuing this coal seam and progressively got taken back to high wall. And they found that there was always a shear zone at a given level. And first they thought it was a natural shear zone. But they believe that probably it was forming as the stress was being relieved, because there were in situ horizontal stresses and as they relieved it it was relieving itself along a weak seam. But only to a certain depth. So, they designed an experiment, put a shaft in and a tunnel and went into the seam and then it was unsheared. And then they started mining for it and when they got within maybe 50 feet or 75 feet, I don't recall exactly, it sheared. So that's exactly what you are saying here, that you are getting movement close to the opening that goes back some distance and then you have enough strength on the elements that it probably stops.

DR. BLEJWAS: Right, that's actually--the system you described or the phenomenon you described is part of the reason we have planned for our exploratory shaft facility to have mine-by experiment, where we first mine two drifts fairly far apart and then put instruments in this unmined area in between them and then mine that third drift, so that we can see what the total excavation effects are and we are not just guessing at what they are by monitoring a drift as we drive it.

Of course we have the additional complexity though that with the addition of the heat. And that's part of the reason we also have as Jean Younker will talk about tomorrow, we have some very large scale heater tests planned.

DR. DEERE: Yes, I was alluding to the case where you had high in situ horizontal stresses which you would only have here with the heat. In the case in England, they had high in situ horizontal stresses induced by something else other than the heat. So, you may not see in your experiment anything happening at all because you are not relieving very much.

DR. BLEJWAS: Right. But then we will have a system that we now have monitored all the way beginning with excavation. Now we can put heat in and we continue to look at that same value of rock and see what happens while adding the heat. That's what our plan is.

Okay, I'm going to talk very briefly about thermal influences on the hydrologic system. And I've divided these into two things that I've called mechanistic and things that are basically just changes in properties. And the mechanistic ones--let me talk from this instead for awhile. Part of what we think may happen around the waste emplacement volume is that we maybe driving moisture away from the waste packages and we may develop what we call a heat pipe effect that will be discussed tomorrow by the people from Livermore. But, what we have is a circulation of vapor and then water movement though either the matrix or the fractures back inward. And one of the things that may occur with this is some zone some distance away from the waste that's at least nearly saturated, and so this is one of the ways we are going to perturb our system.

But the system itself is already relatively complex. And I want to make sure that you understand that we think it's complex and we don't necessarily think we know all the details of what is going to go on at Yucca Mountain. We may have a few locations with some perched water and we may have some fracture flow, some weeps and seeps. However, we think that most of the flow is going to occur in the matrix. This so-called heat pipe effect is going to affect potentially both of those. It can effect the matrix flow and it can also perhaps change the characteristics of any fracture flow that might occur.

We also will change the properties. The heat will change the flow parameters. Another factor that may be important is that the heat may change the codings on the fractures and in-fillings and that could change the characteristics of any potential fracture flow and we recognize that we need to look at those also.

Also it could change the gas movement. The gas movement at Yucca Mountain may be relatively rapid. We may have a lot of in flow and out flow of air at Yucca Mountain right now, but however, when we put the heat in, indeed the gas movement is going to increase in terms of velocity because of the buoyancy effect.

Now, we have done some non-isothermal hydrologic scoping calculations. We've done both near-field and far-field. I mentioned earlier that we were relying a lot in our design on models that only have conduction in them. And part of the reason we feel we can rely on those is because of some of these scoping calculations, so I'm going to talk about these scoping calculations in the near-field, just very briefly. In fact, all I'm going to show you are some results.

These analyses were done with the TOUGH code and the solid line is the a line of what the temperature at a distance of about I think it's one-third of a meter from a waste package with D, with just a conduction model. The circles indicate calculated temperature if we have fractures, but if the movement in the fractures is predominantly vapor movement. The little squares indicate what the temperatures would be if we had a lot of movement in the fractures of moisture in liquid form. We don't think that we are going to have a lot of movement in the fractures in liquid form. We expect that most of it will be in vapor form. And you can see here that it will make a difference in the temperatures, but it's not a large temperature difference. We are talking about on the order of ten to fifteen degrees celsius difference if we included the vapor movement. And the Livermore people will present some more analyses of these types tomorrow.

So based on our understanding of the hydrologic system and again relying on the performance allocation process where we brought performance and design people together, we decided that it seemed to be prudent to limit the extent of saturated conditions. So that we decided that we will emplace waste where the local saturation is less than 90 percent. In that way we are not close to a fully saturated condition and we are less likely to have fracture flow. Also, as Mike mentioned earlier, we would control the use of fluids during construction and operation again reducing the potential for fractured flow.

Then, the next one is the constraint that goes contrary to most of the others in terms of leading you to lower temperatures. This is trying to limit the corrosiveness of the container environment. And the constraint that appears in the site characterization plan, is that the majority of the borehole walls will be above boiling for greater than 300 years. So that we have greater confidence that we are going to have a dry environment. It reduces the potential for liquid water contacting the containers. Also, we will design for drainage and convection away from the containers.

And I'll leave it to the people talking about the waste package tomorrow to talk more about why that particular constraint is important to their strategy.

We had an incorrect view graph in your package, so we have handwritten up the one that we think was supposed to be here. And what we are talking about are the influences on the geochemistry. What we believe is that for minor temperature changes, that is increases to below boiling, we may have some minor reversible dehydration with some minor volume decreases. However, we are relatively confident that the sorptive of the rock is not significantly affected by these relatively small temperature changes.

The real concerns of the geochemistry may come when we look at significant changes above boiling. Here we would expect that we are going to have some dehydration of smectite, zeolite and glass, with water and volume loss. Also, we would expect that we may have possible reaction of zeolites to other phases. And this effect depends on the volume of the zeolites that are affected.

DR. CORDING: Is that slide you are referring to the welded tuff?

DR. BLEJWAS: No, the zeolites, I'm specifically referring to the non-welded tuff. The Calico Hills zeolitized unit.

DR. CORDING: You do see a significant difference in behavior with heating between the non-welded and welded tuffs?

DR. BLEJWAS: Oh, yes, very definitely. They are different in terms of chemistry significantly. I have some back up view graphs I could--if you have any specific questions, I could show you some differences.

Okay, now here, what I've shown is a plot that's very similar to the one I've shown you. It was done with a different analysis so you might see some differences as to the actual repository horizon, but the trends are the same. What we've got here are the temperatures as a function of depth along a line passing through the repository, and we've got temperature lines for 100 years and a 1000 years. And one of the lines shows what the temperatures would be for the waste emplacement density of 57 kilowatts per acre that was used in the conceptual design. The other shows the temperatures for an APD of 80 kilowatts per acres. So that we can see when we go from this dashed line here at 1000 years, we increase the APD--we go to fairly significantly higher temperatures. Perhaps the most important temperatures are those in addition to right at the repository horizon are those in the Calico Hills unit because there is where we have some zeolitized units. And we can see that if we have the waste emplacement at 57 kilowatts per acre, we are going to have temperatures that are below boiling in all likelihood throughout the entire Calico Hills. If we go up to a waste emplacement of 80 kilowatts per acre we are talking about a total temperature on the order of 115 degrees C. in some of the units in the top part of the Calico Hills unit.

DR. HUNTER: Tom is 1000 years the peak?

DR. BLEJWAS: Yes, a thousand years if very close to the peak. I didn't show you other temperatures because 1000 years is very close to the peak that we would get.

This schematic cross-section shows the various minerals and secondary minerals are shown in the different units. So here we have the repository horizon. Within the Topopah Spring member we have some mordenite and quartz. Within the--well this is all the Topopah Spring member. Here we have the vitrophyre where we have a higher amount of smectite and then below, now here we get into the zeolites, and this line here is the zeolitic tuffs. So here we get into some mordenite and clinoptilolite.

So based on the opinion of the geochemist, primarily at Las Alamos, we came up with some temperature limits in the units below the emplacement unit TSw2. And it was their view that we should limit the temperature int he TSw3, that is the vitric Topopah Spring unit, and the zeolitized and vetric Calico Hills units to less than 115 degrees C. This would reduce the potential for mineral alteration and dehydration.

Also, indirectly it's related to changes to porosity and permeability that are intended to limit the extent of the disturbed zone. I should point out though that part of the reason for selecting 115 was because we recognized that we could do some testing up to 115 degrees rather easily and get a better handle on how important these changes are because it may be that 115 degrees C is not a tight enough constraint.

I think though I've shown you that if it's not we can lower the constraint to something less than boiling and still be able to design the repository to meet the other requirements.

DR. VERINK: You said you haven't done that test?

DR. BLEJWAS: No, we haven't done those tests, that's correct. But, they are part of the site characterization plan.

Okay, and here I've summarized all of the design goals for thermal loading and what possible effect they may have on the design.

The first one was a temperature of less than 200 degrees one meter from the borehole and this was intended to maintain the structural integrity in the near-field. This would lead to varying the package loading, the borehole and drift spacing and perhaps a stand off. And as a result it would limit the areal power density.

The two dealing with the temperatures for the cladding are a temperature of less than 275 at the borehole wall and also at the centerline of the container. They would result in the same kind of trade off. We would have to vary package loading, borehole and drift spacing and also we might vary the internals of the individual waste packages. Again, leading to a limit of APD.

Next to the surface temperature and uplift and the intact rock failure or continuous joint slip, remember these are limiting in the far-field, not the near-field. They would tend to limit APD not necessarily the details of how you did the emplacement.

The local saturation would really only limit your usable area. It may be that when you do your excavations you are going to find that you have some volume of rock that's greater than 90 percent. This would lead you to skipping those areas. So, it's going to limit the usable area.

Finally, or next to final, we get to the borehole walls above boiling for greater than 300 years. This is going to raise the package loading and potentially raise the areal power density.

And finally, the last one that I've talked about, the temperature is less that 115 degrees in these three units, would again limit APD.

So, you can see in looking at all of these, all of them lead to lower temperatures being good to meet the requirements, except for the one where we are talking about the borehole walls above boiling for greater than 300 years. It goes contrary and there we have a trade off.

And that completes my presentation. I'd be glad to answer any other questions you might have.

MR. BLANCHARD: Tom, you went through one view graph kind of fast, and because there was a lot of focus on that, would you mind going back to view graph number 26, which was the schematic--yes, that one right there. Perhaps we could take just a minute more to explain that.

The vertical fractures shown in the midline represent the codings of the materials that are thought to represent in-fillings in fractures which have the potential for retarding radionuclides. Mordenite, heulandite, smectite and other things. Those occur throughout the section and they are shown here diagrammatically above the Calico Hills, in the Calico Hills and beneath the Calico Hills as materials which have the potential for retarding radionuclides when they travel through fracture flow.

Of course, the radionuclide potential is largest distributed not through the fractures, but through the Calico Hills rock unit as that area that's stippled in the Calico Hills rock unit where you can hardly read it, but it says zeolitic tuff. And so, obviously those radionuclide retarding minerals in the repository arise in part of the Topopah Spring which would get hot are in the fractures and the bulk of the distribution of radionuclide retarding minerals beneath the repository are in the Calico Hills and there they occur within the rock unit as well as in the vertical fractures.

DR. BLEJWAS: It's perhaps also worth pointing out that if we decide we need tighter temperature constraints on some of the rock units it would probably be the zeolitic tuff that we would be most concerned about. Notice that it's the furthest away of the tuffs from the repository. Also, we can in addition to just limiting temperatures, we may also be able to look at changing the horizon for the repository as we understand the stratigraphy better. So there are a lot of trade offs that we can potentially do to disturb this volume of rock in some minimal way.

DR. DOMENICO: Tom, can we look at your third or fourth slide showing all those coupling effects?

You know you are looking there at one of the most complex couplings you could ever hope to encounter in the earth sciences. It's possible to understand conceptually, maybe. It's very difficult to understand all things quantitatively. And a lot of the stuff you wrote off in terms of not being important, but in many cases you decoupled some of things, such as conduction only and the fluid flow and where the chemical interaction, just how much water is going to be driven off. I don't know how much of that I buy, but I'm only consultant to this Board, but I'm going to recommend that that sort of thing make up one of our future panel meetings, because I think this is critical and I think that we have to talk to the people who have done these--all these are based on model studies went into the models and how they are doing it because I think this is a very crucial part of this whole scheme here.

It has nothing to do with geo-technical design of the repository. It has to do with basically the post-closure period. And like I say I'm not going to buy most of what you say when they are back of the envelope calculations and based on decoupling. I understand this is not really your bag, but I would think that these are the kinds of things that we have to look at very carefully.

DR. BLEJWAS: I agree. I think we need to look at them very carefully. Actually, when I put it up what I should of said is this is the kind of thing we are looking at for being smart enough at licensing to be able to explain in some fair level of detail.

It may also be though that when we put constraints on our temperatures we are minimizing some of the coupling.

DR. DOMENICO: But I don't consider 250 degrees at borehole a constraint for some reason. I don't consider temperatures in excess of boiling constraints. I consider those excessive right now. Unless I learn more about this.

DR. HUNTER: I just want to make a comment about the whole concept of coupling though. It is a very complicated chart and does represent virtually all the physical processes which might happen. And you are right there are various models that look at all of those. But, it is crucial in terms of development and overall understanding of what is important and what is not important to decide which things are not coupled. If you make the assumption that everything is coupled you never can get started. You have to do some uncoupling to start breaking the problem into solvable things.

I think you are right. Having a significant discussion on each one of those things would be very important, but I'd hate to discount the process of decoupling, because it's crucial--

DR. DOMENICO: I think you can decouple. I have a hard time understanding why a free convection doesn't transport more energy than you say it does. You say it's not important. Vapor transfer has been know to transport energy around and use a conduction only model. You haven't accounted for it and I'm curious as to the criteria by which you can say, yes, we can forget it.

DR. BLEJWAS: I'm sorry if I said that it's not important. It would probably be very important. For doing the type of scoping efforts that we have been doing at this point to see whether our repository concepts are good, I don't think it is important. I think that we can come up with relatively accurate predictions of temperature without including that. We are going to have to get more accurate though in the future and we are going to have to include those effects. That's the intent as we go into the future is to include more and more of that into our analyses.

DR. DOMENICO: Well I view this as the temperature problem, right there. What you've got right there is the thermal problem with the repositories.

DR. NORTH: We come at this from the point of view of what is it going to take in performance assessment to be successful in the license application. And, from what little I know of the complexity in this, it strikes me that we are getting further and further away from where we have good data based on experience. Maybe one can get that data with a large scale test and be able to validate the models. I think the importance of the Calico Hills layer in the performance allocation is such that you would really like to know a lot about that. And, we might want to ask when is that information going to be available? What flexibilities are there going to be in the design and performance allocation process to accommodate any surprises. I would certainly like to second Dr. Domenico's suggestion that at a future time we may want to return to this both from the point of view of the hydro-geology and from the point of view of the performance and risk analysis.

I think what we are looking at just to put in a final thought here for this section. We have this requirement regarding the borehole walls above boiling for 300 years which is taking us in the direction of higher temperatures and everything else tends to point in the other direction. Then we are going to be looking basically at what does that requirement buy us in terms of assuring the engineered barrier versus what are we losing in our ability to assure that geological system and the total system performance by having the temperatures as high as we are proposing.

DR. DOMENICO: I'm reminded too at WIPP for example based on linear elastic theory, the rate of closure was estimated. The actual rate of closure exceeds that estimate by I don't know how much, simply because it is not deforming elastically. It's deforming delastically. And I believe that everything built into here is elastic theory. I've been down in the tunnels. I could see them cracking.

DR. HUNTER: But the divisions were not based on linear elastic theory. They were based on--

DR. DOMENICO: By your calculations?

DR. HUNTER: No, the WIPP calculations. The WIPP calculations were both primary and secondary.

DR. DOMENICO: Well they are not working. The models are not working very well, let's put it that way.

DR. BLEJWAS: They were not, that's correct. However, our initial comparison with experimental work in terms of the mechanical and thermal response--the thermal-mechanical response, I should say, suggest that we do understand the thermal-mechanical response at least in the short term fairly well. We do have fairly large scale experiments from G-tunnel that would suggest that indeed it's behaving as you would expect.

DR. CORDING: One of the things on that thermal mechanical aspect is the movement around the joints as they are heated, and I would think that particularly in an orthogonal joint system and a relatively orthogonal excavation or at least it's in the same orientation and high horizontal stresses, that is a condition that would lead to very, very little in the way of slip. If you've assumed joints of other orientations which aren't as common, it would be obviously more important. But I think the one thing that I would think would be one of the most prominent effects from high horizontal stresses would be more of a buckling phenomenon in the roof and floor. And that would be occurring along your bedding planes and bedding separations.

DR. BLEJWAS: We don't see strong evidence. You have this trouble distinguishing any bedding within the Topopah Spring unit.

DR. CORDING: I understand. But even with more subtle features like that, sometimes you can--even if they are not as pronounced you can get them in some locations. I'm not saying that that's a show stopper at all, it's something one might have to deal with.

DR. BLEJWAS: Well, that's consistent with our thinking. One of the near term experiments that we were hoping of conducting in G-tunnel was a prototype experiment of a thermal stress test where we heated a large volume of rock in the roof to look exactly at that to see if we got some buckling coming in. We are still looking at the possibility of conducting that some place else.

DR. CORDING: One of the things in looking at high horizontal stresses or high stress fields we often try to minimize the very large wide openings that are in those roofs that are in the same direction of the high stresses. And that's principally the reason, although it doesn't give you the high stress concentration, it gives you the worst stability problem very often.

DR. HUNTER: If I could make a comments, really two kind of interrelated subjects. As you go through these temperature calculations, one point I think we didn't emphasize was as you change from one field to the other, you can't expect the temperature to always be correlated. Necessarily when you do the far-field calculation and mae these homogeneous source assumptions, which kind of smear everything out. And when you make the room scale you are making yet another set of assumptions, and when you hear tomorrow about waste package temperatures, you are talking about very close temperatures around the waste packaging. And you can't always make a comparison between those two until you get far enough away.

The second point I'd like to comment on is Dr. North's comment about the coupling of nature to performance assessment. And there is even another coupling which is important here and that is as we learn more about the site, and if the fluxes are in fact very low and the travel time from the Calico Hills is in fact very long, let's say it is forty to fifty thousand years. Then the concern you have in the top of the Calico Hills about these couplings becomes very small. If in fact though the Calico Hills travel times are on the order of a few thousand years or on the order of 10,000 years, then you are more concerned about the effects all through the Calico Hills. So the problem is not coupled just in the physics, it's coupled in terms of what you are taking credit for and what you allocate in terms of performance. So, both of those couplings have to be addressed and it's not a simple straight forward.

DR. NORTH: That gets back to my initial comments of the design considerations, the performance allocation considerations and the performance assessment calculations are all coupled. And it would be nice to look at this as a Gestalt and see all those couplings as opposed to see theory on one side and data on the other side and they haven't gone together. Now, we may be able to put them together relatively securely only with a lot of work after many years have passed. But trying to see how they might line up against each other at the level of back of the envelope calculations, seems very, very important as we go through these considerations.

DR. HUNTER: I usually term the problem as one of successive bounds. You establish a set of bounds in one regime in one set of phenomena and you look at another regime in another set of phenomena and ask are those bounds consistent of what is going on here. And if you leave one can you conclude something about the other? To couple all the interactions mathematically and with some kind of modeling predictive technique, you sometimes lose that whole physical intuition by what's really important and what trade offs you have to make.

MR. BLANCHARD: Tom, some of your early view graphs where you were predicting temperatures, predicting horizontal stresses and then doing thermal analysis of benchmark problems, didn't sight Sandia publications where other view graphs did. Could you share with us the state of readiness with respect to--

DR. BLEJWAS: Those are published reports. The benchmark problem is--oh, no, it's in your shop for review.

MR. BLANCHARD: So that's about to be approved, the benchmark.

DR. BLEJWAS: Yes. I hope it's about to be approved.

MR. BLANCHARD: What about the predicted temperatures and the predicted stresses?

DR. BLEJWAS: That's the same--the same situation.

MR. BLANCHARD: Okay, so they are yet to be published but it's awaiting final approval.

DR. NORTH: Those will be Sandia?

DR. BLEJWAS: Yes, those will be Sandia reports.

DR. NORTH: Do you think we can get through Mr. Ryder's presentation this afternoon?

MR. RYDER: What time do you want to quit?

DR. NORTH: How long do you think it's going to take you?

MR. RYDER: An hour or an hour or so.

DR. NORTH: You think it will take an hour?

MR. RYDER: That's what it's been running.

DR. NORTH: Okay, do we have a potential revolt if we start on something that may take us to 5:30? I'm looking at the agenda in terms of tomorrow, and looking relatively full. Well I think we've got three alternatives. We can either wrap up a little early and put this into tomorrow. We've had a fairly long day already. We can go halfway through it up to about 5:00, or we can grit our teeth and go all the way through it perhaps with a bit of inhibition on the questions and discussions that we might want to have.

MR. BLANCHARD: We have a lot of give--what do you think Max?

MR. BLANCHARD: We are amendable to either suggestions.

DR. NORTH: Is there a natural break point in it?

MR. BLANCHARD: I think the natural break point is really here because tomorrow it goes into waste packages so if you want the whole picture on the repository design approach, you need to include Eric Ryder's discussion.

DR. DEERE: I think we need it tomorrow. We want to be alert for this. I mean more alert than now. Okay, Tom?

DR. HUNTER: I just wanted to make a comment that I forgot to make when I was talking about the design requirements. And that is going to be important and Eric is going to address it so you will have it in your minds for tomorrow. We do have requirements for a wide range of both ages and burn-ups in the design requirements and I forgot to mention those. But we actually in the design requirements that are given both to the conceptual design and the future designs will be addressing burn-ups as high as 60,00 mega watt days per ton, and ages as early as five years. And they are passed down all the way through this requirements hierarchy as specific design requirements. I forgot to mention that and I just wanted to make sure you are aware of that.

DR. NORTH: I think our feeling is that we would just as soon see this as a package tomorrow. We will assume the risk of perhaps compressing things a little bit in the latter part of tomorrow. So, I think 8:00. Now, before we adjourn for today, does anybody have any questions, discussions that perhaps they might want to get out that we haven't taken time for? Ed?

DR. CORDING: You may want to discuss it tomorrow, but I just was wondering, you described some temperature limits.

How low can you go on the temperatures with your present designs? How low could you drop the temperatures and handle the waste?

MR. BLANCHARD: That's answered, at least in part on design studies that Eric has done and that's part of his presentation.

DR. HUNTER: Well the one design goal that you saw there, there is only one that limits the lower temperature and that's the one Tom showed there about staying above a certain temperature for a certain time.

DR. NORTH: Have you looked at relaxing it? Supposing you ignore the consideration of keeping the container above--

DR. CORDING: Sure, not talking about the container 300 degree container situation, but getting it--assuming that's not a criteria how low could you go?

MR. RYDER: There is no lower. There is just that one goal that constrains it to keeping it hotter longer.

DR. CORDING: I don't mean in terms of regulatory requirements, but in terms of practicality, what you can take in terms of waste?

DR. HUNTER: That's what he'll show you. He'll show you the curves of inventory and what is available.

DR. CORDING: No hint? No hint to think about tonight?

MR. RYDER: Up to a point there is a diminishing area requirement with aging. There is however geometric constraints that you run into after a time so there is a point where you will just be geometrically by the extraction ratio and borehole spacing minimum in terms of putting your canisters in. So, I will talk about that tomorrow. I don't think I brought a curve that shows that actual trend, but it is in fact true if you relax that one constraint of hotter longer.

DR. CORDING: Does that also--will you also get into what's the age of the waste being supplied to you. Will you talk about those alternatives?

MR. RYDER: Yes. In fact I'll show some curves showing the average age and the initial ending age and all its implication.

DR. DOMENICO: Is there a minimum loading kilowatt per acre where a repository would cease to be "worthwhile or commercial"?

MR. RYDER: Not that I know of.

DR. DOMENICO: Coupled with the fact that you have a volume constraint here at Yucca. In other words, are you looking at loading of 89 now as 57. Can you still do something at 57? Can you do something at 40?

MR. RYDER: There is no minimum. There are maximums however.

DR. HUNTER; It's just a time question. It depends on how long you are willing to wait.

DR. DOMENICO: Yes, you would have to factor in--I'm talking about going forward with the assumptions you made where you got the high temperatures using those very same assumptions. Is there some lower limit that no longer becomes economical? No?

MR. RYDER: No, but there is that one goal, just taking hypothetically if you could relax that goal, then there would be no lower limit.

DR. DOMENICO: Keeping in mind you'd have to find room for 70,000?

MR. RYDER: Right. yes. You'd run into the geometric constraint.

DR. DOMENICO: You would run into problems.

MR. RYDER: No, actually there would be plenty of area to lower--the colder the waste the tighter you can get it up to a certain point. But we have that one goal of keeping it hotter longer and that constrains us from that.

DR. DOMENICO: I know that goal is obviously being questioned here.

DR. HUNTER: But if you pick a time that you would like to get the repository built in, the only practical constraint then becomes when you run out of area at Yucca Mountain. But if you let that time be open, if it's a thousand years, then--

DR. NORTH: Anything else? Don, you have some comments you wanted to make?

DR. DEERE: Yes, another reason we would like to terminate now or in the next few minutes is we need to meet as a Board and the two panels need to get together now. So, if we can meet in room 401 over at the hotel, let's say at ten minutes to 5:00. That would be all the staff and the panel members and consultants. It will give us a chance to review a little bit some of the things you've said today and also to take care of other matters.

DR. NORTH: We will resume in the morning at 8:00 a.m.

(Whereupon the meeting was concluded to reconvene March 20, 1990, at 8:00 a.m.)