U.S. DEPARTMENT OF ENERGY

NUCLEAR WASTE TECHNICAL REVIEW BOARD

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PERFORMANCE ASSESSMENT BRIEFING

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U.S. DEPARTMENT OF ENERGY
Forrestal Building, Room 6E-069
1000 Independence Avenue, S.W.
Washington, D.C. 20585

Wednesday, May 17, 1989
8:30 a.m.

NUCLEAR WASTE TECHNICAL REVIEW BOARD MEMBERS:

Dr. D. Warner North, Chairman
Dr. Dennis Price
Dr. Melvin Carter
Dr. Don U. Deere
Dr. Donald Lanqmuir
Dr. Ellis D. Verink
Dr. John Cantlon
Mr. William (Bill) Coons, Executive Director

NOT PRESENT:

Dr. Clarence Allen

DEPARTMENT OF ENERGY STAFF:

Mr. Tom Isaacs, Associate Director External
Relations and Policy
Mr. Ralph Stein, Associate Director Office
of Systems Integration & Regulations
Mr. Donald H. Alexander, Chief, Regulatory
Compliance Branch, Office of Civilian
Radioactive Waste Management

ATTENDEES:

Mr. Robert C. Murray, SAIC
Mr. Keith Kersch, SAIC
Mr. Mick Apted, PNL
Mr. Kenneth Krupka, PNL-BWO
Mr. Donald Lory, Weston
Mr. George Lear, NRC
Mr. T. H. Pigford, University of California
Mr. Carl Johnson, State of Nevada
Mr. Peter Spinglor, State of Nevada
Ms. Linda Lehman, State of Nevada

Mr. Maxwell Blanchard, DOE-YMP
Mr. Bill Barnard, NWTRB
Mr. Donald Coldwell, Golden
Mr. A. Scott Dam, Weston/DOE-HQ
Mr. Philip Berger, DOE-EH/Energetics
Mr. Donald Alexander, DOE-HQ
Mr. Paul Gnirk, RE/SPEC
Ms. Melissa Hamkins, ICF Technology
Mr. S.T. Hoxie, USGS
Mr. Cabe Van Luik, PNL
Mr. John Bartlett, TASC - EPRI Is>s.
Mr. David Michlewicz, Weston
Mr. Felton W. Bingham, SNL
Mr. Harold Ahagen, SKB/YMPD
Mr. Robert E. Jackson, Weston/DOE/ACP
Mr. C. Croley, DOE, TRW
Mr. Ched Bisadley, DOE/EH-25

ATTENDEES (Continued)

Mr. Gordon, Beeman, Buffollo - PNL/BWO
Mr. Ray Wallace, USGS HQ/DOE-HQ
Dr. Goeser, Westinghouse
Mr. C. Hanus, DOE/RW-40
Mr. John H. Austin, NRC
Mr. Bob Gainble, Weston/DOE-HQ
Mr. Stephan Broeoum, DOE/HQ
Mr. Lokesh Chaturvedi, EEO/NM
Mr. Norman Eisenberg, NRC
Ms. Ruth Weiner, CNWRA/WO
Mr. Siecee, DOE
Mr. Russ Drier, DOE/YMPO
Mr. Larry Rickartsen, Weston
Mr. Roy Brown, DSC
Mr. Marvin Gaske, SAA
Mr. Steve Baker, ICF Kaiser Engineers
Mr. William Sprecher, USDOE/OCRWM

AGENDA

May 16

Overview of Performance Assessment Program

10:00	Introduction and Welcome	DOE & NWTRB
10:30	Overview of Performance Assessment	Alexander
11:00	Flowdown of Regulatory Requirements to Performance Assessment Program	
11:30	Technical Integration of Performance Assessment Program	Gnirk
12:00	Lunch	

Current Status and Data Needs for Major Performance Assessment Areas

1:00	Performance of Natural Barriers	Hoxie
1:40	Engineered Barrier System Performance	Van Luik
2:20	Break	
2:30	Post-closure Total System Performance Assessment	Bingham

3:10	Pre-closure Safety Assessment	Michlewicz
3:40	Review of Tomorrow's Agenda & Discussion	Alexander
4:00	Discussion Period	

May 17

Investigative Approach in Support of Performance Assessment

8:30	Model Validation Strategy	Voss
9:00	Linkage from Performance Assessment to the Site Program	Blanchard
10:00	Break	

Recent Applications of Performance Assessments

10:10	Performance Assessment in Support of the Site Characterization Plan	Younker
10:40	Performance Assessment of Yucca Mountain in Support of the Comparative Site Analysis	Gnirk
11:20	Potential Impacts of Exploratory Shaft Facility on Waste Isolation	Bingham
12:00	Lunch	

Discussion of Waste Package Model Development

1:00	Models of Waste Package Behavior in a Repository Environment	Pigford
1:40	Calculational Model for Waste Package Releases	Apted
2:30	Summary	Alexander

VMT/AKF 8:32 a.m.

P R O C E E D I N G S

DR. NORTH: Good morning and welcome to the second day of the meeting of the Risk and Performance Analysis Panel of the Nuclear Waste Technical Review Board. Don would you like to go ahead?

MR. ALEXANDER: Thank you. Good morning, what I'd like to do is take a few seconds to introduce our first speaker by going over what we talked about yesterday for, in about one minute, and then talking about what we intend to cover today. Yesterday morning we talked about the Regulatory Requirements and their flow down into the Performance Assessments Program. We spent a little bit of time talking about uncertainties as part of that talk. In our second talk by Paul Gnirk, we talked about the integration of our Performance Assessment Program and then in the afternoon we talked about the major assessment areas that we have to respond to in the Performance Assessment Effort.

Today we're going to, if I might have the next slide Bob? Today we're going to look at some of the strategies that are used to drive our program. A model validation strategy that your hear about this morning, Dr. Charlie Voss will be talking about that and then the linkage from our Performance Assessments Program into the Site Program and Max Blanchard will be talking about that. So without further ado I'd like to ask Charlie to come up to the podium and deliver his talk.

MR. VOSS: Good morning, I have to admit that I'm a little bit nervous talking about a methodology. It was suggested that the Board was not really that much interested in methodologies and here I'm stuck with the title slide that says methodology on it. But I'm cautiously optimistic that based on some of the comments that were made yesterday that a lot of, parts of this methodology will address some of the concerns that were brought up.

What I'd like to do is, what I'm going to cover anyway this morning is why we need some sort of methodology for Validating Performance Assessments Models. I'm going to describe the components of the methodology, to make it a little bit more interesting I'm going to use an example to go through it and then I'm going to talk about how we plan to implement this methodology within the OCRWM Program.

Before I get into it, I just want to go a little bit back into some of the history involved. You know when most people think about validating models, you know they think about doing an experiment and then some how trying to predict with your models how the experiments going to behave, what the results are going to be. And as was mentioned yesterday in our case, in many cases its very difficult to do. For a number of reasons, we brought up how it takes a very long time for a lot of processes to occur and they occur over very large spacial scales.

In addition, the processes, the systems that we're interested in are extremely complex and the systems are very seldom homogenous. We're working in rock and so even if we, I mean it's unlikely that if we ran an experiment, a complex experiment, that we would be able to match it very well. Just due to the complexity of the system that we're modeling. Even if we did correctly predict how it was going to behave we would still be faced with a problem of having to defend that model. You can't think of them as black boxes you have to really be able to go in and explain what is contained in the model and the technical basis for it.

So with those things in mind, well let me back up one more, a little bit more. Recognizing all these things, Ralph Stein about two years ago at a meeting on Uncertainty and Sensitivity Analysis in Brown Water Flow and Radionuclide Transport, committed the DOE to developing a methodology for model validation. Once we came up with this methodology, Ralph told this large technical body that we planned to take this methodology and present it both nationally and internationally to the technical communities and allow them an opportunity to comment on it. And then based on their comments make some improvements perhaps or make some changes and then go forth with it.

Recognizing that because the Performance Assessments models play such a large role in the license application that we're, we have to be prepared to defend those Performance Assessment models and the way that we can best do that is through some sort of validation program. So with that in mind I'd like to go through, well one more thing. Two years ago then, Ralph, at Ralphs' request we formed within the Department in the program a Validation Oversight Group, and this group is made up of participants from all the national labs that are involved in the OCRWM Program, DOE Headquarters and some outside groups.

They are people who are involved both in Performance Assessment and in the experimental side. So it's one attempt of many to try and bring these two groups together. It also involves people from other parts, yeah parts of the program, particularly the Quality Assurance Program and you'll see that in a little bit. So, obviously the license record has to address the appropriateness of these models that we use and what the validation methodology attempts to do is provide some systematic approach for documenting these things.

It doesn't tell the person who's developing the model how to do it. All it is designed to do is to document how it was done and to somehow try to achieve models with a more uniform quality. Different people will do thinks in a different fashion if left to their own means and what we're trying to do is just give some guidance so that a large number of things that we feel are important are all done, are done by all the people involved in these modeling areas. I'll get back to this draft methodology at the end. Will you draw the next one please?

There are three major components to this methodology. The first one is I guess is probably the meat of it. It's the record of how the model was derived, all the premises, the assumptions upon which it's based, and the evidence to support these. It's largely just the documentation that goes along with it. Now those of you who have any kind of background with Quality Assurance, I mean this is Quality Assurance. Its just documenting what you've done and showing the traceability of it.

Another component and probably the one that most people think of when they talk about validation is the experimental phase. I'll show you a schematic in a minute that shows how these things inter-relate. And finally the third component is a Formal Technical Review. It's not meant to be a one time thing either. It occurs over the life of the model development and all these things are kind of an interactive process. Excuse me for a minute, did anybody see where the water went?

So here's this little schematic that just shows how their pulled together. Why don't we just go on, maybe you could put this slide on the other side and ah. I'm going to talk now about this first box. A lot of these components of this recording or documenting model development have been touched on yesterday and they'll be very familiar. Again, this is just an attempt to come up with this methodology so that things a done in a more uniform fashion. Something that's very important in model validation is that you keep in mind what the problem is that your trying to address with this model and answer with this model.

The validation is application dependent in other words, if you validate a model for a particular application for a particular problem, that doesn't mean that you can then take that model and apply it to other problems and you can assume that its valid for that, solving that problem. Because their are going to be obvious differences between what your really looking at in these different problems and so the first think in this methodology is to state very clearly what problem you're trying to address with your model.

This becomes very important when you're in the review stage or when people are questioning what you've done. They have to focus on the problem that you're addressing. Dwight spent quite a bit of time yesterday describing the conceptual model of the Yucca Mountain site, but there are other and that's, for all models you can kind of break it down into the geometry of the model, the boundary conditions, the processes that are important.

So, what we want to do is make it very clear to anyone what our conceptualization is of the system that we're modeling, and once we've done that we want to carefully document all the assumptions that are involved in these models. Dwight talked about the conceptual model of the Yucca Mountain site and the modeling that was done in the EEA and he listed the assumptions. Now you can, I think it's a good bet that when people want to question what you've done, the first thing they'll do is they'll go and look at what your assumptions were.

And, so we want to make sure that for each of these assumptions we state what our basis is for those assumptions. Now it can be a technical basis such as laboratory or field data. It can be something like a simplifying assumption, it could be a, part of the problem that you're given. The next step then, once you've stated your basis is to somehow try and prioritize the significance of each of these assumptions, and this is just to help you in your model validation effort. There are obviously going to be a lot of assumptions and if you're going to and defend all of them, it's obviously more important to address the critical ones, and not spend so much time on those that aren't all that important.

So we would use things like sensitivity analysis and some professional judgment to rank these things and then start addressing them. And then identify areas where you're not quite comfortable with the technical basis for your assumptions. The rest of these I will get into in more detail. I think what I'd like to do is, well okay, I'm sorry lets go on to the next one and I'll just, they are very short descriptions about the other two components.

The experimental design that your using to try and support these hypothesis and these assumptions that you've made are critical. We have a lot of test planned in the Site Characterization Program. They gather a lot of the types of data that we would probably need to address a lot of the assumptions in our models, but the design is critical. Just because we collecting data of the right type doesn't necessarily mean it's going to answer our question. It has to be, the experiments have to be carefully designed to resolve the questions that we're trying to address in these assumptions. We can go to the next one.

Ralph kind of committed me yesterday afternoon to talk a little bit about this. This third component is the Formal Technical Review. The objectives of this review group who are independent of the program, is to identify needed improvements in the model. They go to this record and they go through the whole process that was done to develop the model, and then they identify where they think improvements are needed. They confirm the parts where they think everything is okay and then they identify where additional work is needed.

DR. NORTH: Could you identify where the numbers of the Review Committee come from?

MR. VOSS: We haven't set this up yet, but --

DR. NORTH: Oh so this is future agenda, rather then existing practice?

MR. VOSS: Yes, although, we have an existing Quality Assurance Procedure for Peer Review. This will be based on that procedure and its very close. Because the DOE is responsible for everything in the license, they will be responsible for deciding who's on these review groups. But, well I've been in communication with people at IBM for example, talking with them about what they do in their reviews, and they recommended that it's good practice to get someone from outside the program.

So we have some guidelines about where these people will come from. But the idea is to break the model down into some sort of components and bring in people to address each of those components, but keep it small, not more than like five people. I'm sure you're familiar with the guidelines for these types of reviews, and we're following kind of industrial standards in that way.

MR. STEIN: Incidentally, I would hope that the Technical Review Board would have an opportunity or find time within their busy schedule to be one of the group of reviewers of the model validation process in the future. So, I think that if you want an answer at least one of the review bodies, I would hope would be the Technical Review Board.

MR. VOSS: Perhaps I should have stated up front that this methodology is in a, being prepared. A document concerning this methodology is in preparation and we're getting ready to send it out for review. Both internationally in the Intraval Program which I'll talk about at the very end. The National Academy has offered to review it for us and then of course within the program it will also be reviewed. Okay, so this group in addition to identifying where improvements are needed, I mean the other objective is to achieve this more uniform quality that I was talking about.

The interactive nature early on, they're going to be able to address gross defects and so there will be large improvements in the quality of the model. Later on you're just trying to maintain that quality level. Go to the next one please. Alright, I want to go through an example of what I've just showed you, very quickly. The example that I'm going to use has to do with the radionuclide release from the Engineered Barrier System. And what I'm going to do is focus on just one of the assumptions that, and it's really an assumption that deals with the mechanistic model of how the waste form will dissolve. And it deals with congruent and incongruent dissolution of the waste form.

By the way, this is an example that, the reason that we're using this in explaining this methodology to various organizations is, it's one that's of interest and one that we're doing some experiments in at PNL. So we actually have some ongoing work that helps tie this a little bit more into reality. The release of the radionuclides is a little, well okay. We're going to talk about why it's important. I mean there's a regulation that states that the radionuclide release rates have to be below some limit. 10 to the -5th, and very crudely that a problem we trying to address.

DR. NORTH: Could you be more specific about the time scales involved? Released when? Maybe remind --

MR. VOSS: I'm sorry from the Engineered Barrier System?

DR. NORTH: Right. are we talking about a 300 years our out at 3,000 years?

MR. VOSS: I think this is at the 1,000, well it's were ever we decide the life of the waste package is. I would think.

MR. ALEXANDER: So essentially it's post 1,000 year release rate we talking about?

DR. NORTH: Does it make a difference? Would different models be appropriate if we were looking at 300 years versus a 1,000 years?

MR. VOSS: I don't think so. I'll hasten to add this is not my area, I chose an example that happen to be convenient.

DR. NORTH: The point you made which I think is a very important one. It's the validation, its application dependent, but I think you really need to use that as your standard in test. Depending on what the application is, what your trying to predict in the model may dictate what assumptions are appropriate.

MR. VOSS: Yes.

DR. NORTH: And the age of spent fuel might be quite critical in determining which models are appropriate.

MR. ALEXANDER: It is, I presume you've read those sections in the Site Characterization Plan (SCP) that talk about waste package, and we have quite a bit of an explanation about the different inventories during the early period, and compare them to inventories in a later period. So, you're making a good point. There would be different assumptions and there, because of the differences in inventory.

DR. NORTH: Yeah, I want to hold you to your standard when you say validation is application dependent. You need then therefore to be precise about what the application is.

MR. VOSS: Thank you. Go on to the next one please. Our conceptual model of this system is that you have, we're talking about just spent fuel here. That you have this clodding and crud layers, the gap which contains around the fuel, between the fuel and the clodding. The Grain Boundaries and then the matrix itself, and we're only going to be dealing with some of the questions and the assumptions pertaining to the $U0_2$ matrix.

Here's just a pictorial representation of the system that we're looking at. Our conceptual model of it and here you have the clodding, there's a gap in here. Within that gap you have some, already have some radionuclides in the gab. We're not going to address that in this example, nor are we going to look at what's in the Grain Boundaries, but primarily we're interested in what's happening in the matrix. And I'll tell you the reason for that in the next slide. Oh I'm sorry, I haven't finished describing the system yet.

All of these things that we're looking at have a temperature dependence. They depend on the ground water chemistry. These are all things that you would have to described in this process. The question that, we're going through this model development and we're listing our assumptions. When it gets down to the UO_2 matrix one of the questions is do we have congruent or incongruent dissolution of the waste form?

In other words, do the radionuclides dissolve at the same rate that the $U0_2$ matrix does? Now, it turns out that this is a very important assumption. Whether or not you have congruent or incongruent dissolution? If you have incongruent dissolution, what that means is the radionuclides may be dissolving faster than the $U0_2$ matrix and according to some of the models that we've run, it appears that we may not be able to meet the requirements. 10 to the -5th release rates.

And, there is some experimental evidence, data pertaining to congruent or incongruent dissolution, but it's not at all conclusive. And so, there's two ways that you could go in your modeling. You could develop two models, one that assumes congruent dissolution and one that assumes incongruent dissolution. Or you can try to do some experiment to disprove one of these hypotheses. It's really a case of competing hypotheses on what's happening. Go on to the next one please.

The basis for the, whether or not you have congruent or incongruent dissolution is based on professional judgment, but we found professionals that believe both cases. And, then as I mentioned there is some data, but the interpretations are ambiguous, they are not conclusion.

MR. ALEXANDER: And then there are some of us that are of the school of though that you have processes going on at the same time.

DR. NORTH: I suspect you don't have any 300 year old spent fuel on which you can experiment.

MR. ALEXANDER: That is a problem. A small problem.

MR. VOSS: I kind of got ahead of myself in discussing that and quantifying the significance of these assumptions, but it does, as I mentioned there are some models that say if we do have incongruent dissolution that we would fail to meet these release rates. And so its a very important hypothesis to check, and so I'm going to talk briefly about an experiment that we're doing at PNL to try and address that. Skip over the next one please.

As I mentioned early the design of the experiment is critical, and what we want to do is test the hypothesis. Whether or not you have congruent or incongruent dissolution of the waste form. And so, there is a lot of detail here about how the experiment would be designed to focus just on that one question. And what we're trying to do is get rid of a lot of the things that would add uncertainty to the experiment. So you remove, you oxidize the fuel, you dissolve the exposed grain boundaries, and the idea is that all you want to be left with is the matrix. You can forget, I think we can skip of that.

One of the tougher questions in the validation process is, if you're going to do these experiments to support your model, how are you going to decide what criteria your going to use. Whether or not you've proven or disproven your hypothesis. And what I'm going to talk about for just a little bit is the way we've done it at PNL for this experiment. What we wanted to do was do a statistical test, a number of statistical test of the experimental data. One of the things that we had to know in order to do that is what kind of analytical error will we have in the experiment to estimate the standard deviation of the data.

The technicians involved estimated that there be plus or minus 10% analytical error. Go on to the next one please. What we're assuming is that the ratio of dissolved radionuclides and the UO_2 matrix would be equal to one in the case of congruent dissolution. Based on our estimate of the experimental error, the range of data would be approximately .8. This is probably a lot more detailed than any of you are interested in, but what I'm trying to get at is that there's all sorts of existing methods that you can use to come up with a well defined experiment, a well designed experiment.

I'm going to throw up two quick examples of statistical test that you can use. This one happens to do with confidence limits. The professional at PNL that we consulted with, said that he felt that if we, when we measured the ratios if we found a value of two he would feel confident that we were seeing congruent dissolution. In order to check his gut feel on what this ratio should be, we did a comparison of this confident limit value to his gut feel. And the way we did that, we had to estimate a mean which was, we used his and we estimated, we needed the standard deviation and the true ratio which would be one.

Anyway, when we stuck all these into this statistical test it turned out that this value of 2 is within the limits defined by the expected error in the experiment. So, all this tells us is that at least the gut feel of our professional fell within the range that seems to be appropriate for congruent dissolution. Given the experimental error. And the other method that we are going to use are with tolerance intravals.

And here once again, if you have an estimate of the standard deviation the error involved and, you can state a statistical test and in this case we said that with 95% confidence that 95% of the population of our data, the samples that we take will fall within a particular interval. And, so it just gives you a well documented way of showing the criteria that your going to use to judge the results of your experiment. Since I'm running out of time let me go ahead here. Go ahead to, I think what I'll do is I'll just end this discussion of my example because it doesn't seem to be going anywhere and talk about the implementation.

Paul Gnirk talked about the various working groups. Working Group Seven is the working group where we're planning on trying to implement this validation methodology. We'll do that in a number of different ways. One of the ways is to have people who have been involved in developing this methodology sit in on review of the study plans, for the experiments and the Site Characterization Program. Make sure that the activities meet the needs of the Performance Assessment people as far as validation goes.

We are at the same time developing a set of examples in each of the major areas. Like waste form, excuse me, hydrology. Examples of this methodology to help the people within the program understand exactly what it is we're trying to achieve and how we're planning on doing it. And finally we are participating in a number of activities. One of the international activities related to validation is the Intraval Program. The last, maybe you could put the slide up on the other side. I'm sorry the next one on the intraval test cases.

This is too small to read, but it's in your package. This is just to give you an idea of what this Intraval Program is trying to do. Its made up of about a dozen programs from different countries involved in high level waste storage, medium level, low level. And these are some of the experiments and some of the models that are being addressed in this program. The Intraval Group has agreed to review our model validation methodology and give us feedback. So this is one of the ways that we're trying to improve what we've come up with, up to date.

DR. CARTER: Is this where you take a given problem and run it through various models? Is that the basis of the Intraval?

MR. VOSS: Well, actually the charter for the group is to come up with a methodology for validating Performance Assessment models. These are perceived as these examples of experiments and then trying to model them are basically being used as tools. To try and demonstrate these different methodologies and how well they work and then just address some of the basic difficulties in using experimental data to support model validation. But, yes I mean a large, it depends on the text case but for each experiment there may be as many as five or six different modelers modeling that experiment.

DR. CARTER: What kind of time frame is this thing going to operate in?

MR. VOSS: The Intraval Program?

DR. CARTER: Yeah, in other words how quickly do you get results that are [inaudible], and so forth or is it a very slow thing like most of international programs?

MR. VOSS: It's faster than most, it's been in existence for about a year and a half, two years. Already a number of the cases have been fairly well, the experiments have been fairly well defined in that, the experiments are up and running. In some cases they've published data from those experiments and we have a meeting coming up in about three weeks, where people sit down and they discuss the results of their models in these experiments.

MR. ALEXANDER: Yeah, I might note that about a month ago we held a workshop here. We sponsored a workshop for Intraval and I had the good fortune of being able to take at least a day and sit in on some of the presentations and they were really terrific presentations. The quality of the information was coming back and the insights that they were gaining, and in terms of dealing with uncertainties in the various problem sets that they were working on, I think were very unlimiting. And I would highly recommend that this subcommittee participate or at least observe in some of the meetings that are upcoming. I think you'll get a lot out of it.

There was a presentation on the Losscusis (PH) Block Experiment, which was done in an unsaturated zone in TUFF which was very carefully controlled. I'm a firm believer in carefully controlled experiments, by the way rather than lying heavily on statistics. And ah, I found that they were getting some very good controlled results on Tracer Tests, Migration Test through that unsaturated zone, which will I think be very useful for benchmarking exercises. Our next speaker, thank you very much Charlie.

Our next speaker is Max Blanchard. Max is going to talk about the linkages between Performance Assessment and the Site Characterization Program. One of the things that we've asked Max to do, which puts a little bit of a slant on his presentation, is to go in or use Alternative Conceptual Models as an example of how those linkages take place. Max.

MR. BLANCHARD: In order to distill the linkage down to its simplest component between Performance Assessment and the Site Program, probably the easiest example is that given the regulations the Performance Assessment have identified information needs that are asked for the Site Program to provide information about it. And the information needs have come out in terms of parameters.

Well generally the parameters are things that aren't easily gotten by direct measurements. Such as flux. You heard Dwight Hoxie yesterday talk about flux, and there isn't a flux meter that we can go out to the site and measure the flux. We have to measure a lot of other things in the Site Program to get that parameter. So in the simplest form the linkage between Performance Assessment and Site Program is just that.

And you heard also yesterday Felton Bingham talk about his pyramid. Where the total system model has to be reasonable simple or you'd never have enough time to operate it and it would be too complicated for the computers available to operate it. And so it relies on a pyramid type building block where there are Conceptual Site Models that provide the foundation upon which these subsystems, the higher level system models and the total system model depend.

I want to talk more about the latter and the uncertainty that goes with that, that we've built into the SCP. The person that gives the next talk Jean Younker, who will be addressing Performance Assessment in support of the Site Characterization Plan will emphasis my talk in effect. The part of the talk that's the linkage between Performance Assessment and the Site Program.

In that talk you'll see examples of how we've tried to take the regulations, the performance and the design requirements and identify all of the parameters that we need at the various levels. And the confidence levels that we need. Jean is well suited to do that. She managed the development of Chapter Eight directly at the project level for several years. Now to scope my talk about the linkage and keep it with the theme that Don mentioned, looking at the uncertainty in Alternative Models or Alternative Hypothesis

Testing and picking up on Feltons' pyramid. You'd have to understand that the Alternative Conceptual Models that are in the disciplines within Geology, Hydrology, Tectonics, Volcanology are good firm building blocks on which to build the total systems.

I would like to talk about three things. A very brief overview, the simplest purpose of Site Characterization that one could expect. Second, a general generic approach that we built into the SCP for reducing uncertainty in the conceptualization of these models. Conceptual models within the disciplines and then explain some examples of hypothesis testing tables that we have in the Site Characterization Plan and illustrate what we've done.

In the simplest sense, the goal of the Site Characterization Program is simply to improve our current understanding of both the nature and the rates of the geologic process that act at Yucca Mountain. And, we're hoping that through Performance Assessment we could focus that on those processes that can have an adverse impact on containment and isolation. The rest of the things are of academic interest, but if they don't have an impact on that then we don't really need to study them very much.

Two fundamental things in the process of doing this and looking at these Conceptual Models is, our goal is to reduce uncertainty in the site parameters and our goal is to reduce uncertainty in the conceptualization of the physical system. And if we do that, we feel we've met our goal up here. Now to minimize the uncertainty in the site parameter values, we've had to use things like multiple approaches to obtain the parameters. I'd like to talk an example through with you.

Water Infiltration is something we need. You've heard Dwight Hoxie talk about that. You also heard Felton Bingham talk about that. We've not come up with one single measurement to measure water infiltration. We have taken multiple approaches. We'll be conducting field test and measuring natural infiltration at places out in the mountain, but also we're running controlled infiltration experiments. Where we're putting water on specific areas and measuring the influx and the evapo-transpiration. And then through the site, throughout its surface we're looking at the properties of the surficial materials.

So we have kind of a three pronged approach at obtained what we think are parameters that are needed for water infiltration. We have a redundancy there. Also in terms of making measures we know scale has a big impact and so we're making measurements throughout the site program at different scales. An example that Dwight Hoxie talked about was understanding fracture versus matrix flow.

Well in order to come up with a proper understanding of hydrologic properties in the unsaturated zone, we've got test, institute test from the exploratory shaft level in the Topopah Springs. Studying single fractures, suites of fractures and the entire fracture network, to better understand how water flows in Topopah Springs.

DR. DEERE: Excuse me Mike, I'll wait until you finish that slide. My question was this amplifies a little bit what you had in the previous slide. Could you go back for second to the previous slide? Cause I had a question about its completeness. In the rates of geologic processes operating and what I felt that we needed there, that we're also interested in geologic structures that exist there. Because if we introduce water by whatever methods, what is really interested is what's the permeability of the structures that can take it right to the water table?

MR. BLANCHARD: Yeah you're quite right. In a general sense natured rates of geologic processes was meant to involve all earth science processes, Geology, Hydrology, Geochemistry, Climate. And nature was meant to reconstruct the three diminsional picture as well as the magnitude of the change when you know the reaccurrence interval or after you've determined the reaccurrence interval. You're quite right.

Okay Bob I think we've talked enough about that one. Now also, the current plans that are contained in the SCP cover acquiring information about the, to allow us to build these alternate conceptual models in several ways. One is we have a surface base drilling program. Now that drilling program has some aspects to it. It has both the statistical and a feature aspect. The statistical aspect is that we have systematic drilling program derived from geo statistics and we have kind of a grid network of where we'd like to have our bore holes placed.

To the first proximation we'd like to have them 2,000 feet apart and we want to determine the Hydrologic properties and the Geochemical properties of that Yucca Mountain block in a three diminsional picture. Rock unit by rock unit, by rock unit. But, we also have features like the Ghost Dance Fault and other features that we want to drill holes in and to determine their properties to. It would be unfair to take the features program and extrapulate that information into the entire block because then we would not get representative information.

So we've got both going at the same time. Also we have monitoring from all of these holes. We want to monitor the under current especially for hydrologic properties and in every case reasonable we'll be retrieving core. For geologic holes we'll have a continuous core from the surface down to the bottom. For hydrologic cores we'll be coring intervals every ten meters or every twenty meters, so that we can get samples.

Going into the exploratory shaft we have an In SITU Test Program. It's reasonably comprehensive, it includes mapping for geologic purposes but also hydrologic purposes. I mentioned early about the fracture network. We have Waste Package Environment Test to try to determine the information you need to derive what you think is the corrosion waste of the waste package in the natural environment. And then we have a number of underground tests aimed at better understanding of hydrologic, geo-chemic and rock mechanic parameters that are called for in Performance Assessment.

But we also have other surface studies. We have a traditional Geologic Mapping Program. We have a Sizemic Monitoring Program, a Geo-physical Exploration Program. We have trenching of faults, looking for movement, determine the magnitude of the past movement as well as the reoccurrence interval along those faults. And then we have laboratory studies, bench scale test, the traditional geo-chemical test where you're determining the mineralogy in the geo-chemistry. But, bench scale test about water migration between fracture and matrix flow as well as detailed analysis of the core samples.

So this gives you a quick view of the current plans in the simplest form. Bob? Now we expect throughout the Site Characterization Program that some uncertainty will be inevitable, because as various speakers mentioned yesterday the geologic properties and the conditions vary in both time and space. That inherently measurements contain errors and finally the processes we're trying to measure are slow and difficult to measure. Some of them, like how water travels in the unsaturated zone are not well understood and in some respect we're developing a science of unsaturated zone of hydraulic.

The steps we've gone through to do, to look at these conceptual models and put them into the Procurement Assessment as part of the building block, is for leading to the first, in the process of doing this in writing the SCP and making this linkage between Performance Assessment and the actual site program. We've identified concepts and hypotheses and these rely largely upon the current information we have about the site and our understanding of the current conditions, but it's not restricted to those.

Also, once we've done that we begin specifying uncertainties in the current concepts and hypotheses and that's how we started building these pages. We've got a 100 pages of tables that we've labeled Alternate Conceptual Models. Again at this stage though, in the absence of a large data base it's largely the qualitative judgments. Then identify alternative concepts and hypotheses of course, you hope that you have some with lower uncertainty in the current hypothesis and that leads you to no alternatives, so it reduces your test program. But we don't have very many of those.

So we have rather broad and comprehensive test programs for this stage. And then to establish the need to reduce the uncertainty in current or in the alternative or in the alternative hypothesis by linking the performance requirements that the speakers yesterday were talking about. And determining the sensitivity to waste isolation that exist between either the current or the alternative hypothesis this brought forward.

This then is represented, these four steps in these ACM Tables. The next step is to collect information so we can begin discriminating among these competing hypothesis. Now in the process of doing that Warner asked a very intriguing question yesterday, and that was well I hope you not just deriving Performance Assessment simply from the regulations. I think we've tried not to, but I wouldn't want to suggest that we've come up with all the questions that need to be asked.

In each one of the disciplines in going through the Performance Assessment process and the Performance Allocation. We've asked ourselves within working groups many many questions and what I'd like to do is to share with you a few that have come out of the Performance Allocation Process.

In an attempt not to look at the regulation, but an attempt to look at what makes sense to reason mind. What's the probability that the Basaltic Magma will penetrate through depository in the next 10,000 years? What's the range of changes in the water table that can be induced, simply by taking Tectonic Events that are plausible over the next 10,000 years? How likely is Fault movement that could reach an individual waste package once it's in place. Whether it's during the pre-closure period, where we may have to retrieve it or after the depository closed during the 10,000 year time.

In terms of hydrology, some of the sample questions are what's the moisture flux through the Repository Horizon? A question which Dwight Hoxie asked yesterday. And is the saturated zone moisture movement predominantly a matrix or both in matrix and fracture flow, and when and under what conditions? What's the rate and direction of ground water movement from the Repository to accessible environment? I think Dwight went through all of these yesterday and more.

In geo-chemistry, what's the quantity in the distribution of the Sorptive

Minerals along with the potential flow paths of the radionuclides? And how will laboratory results on matrix diffusion and retardation be translated into field conditions? It's one thing to make measures in the column and look at the fusion and disbursion and come up with retardation. It's something else to have confidence that it will really work in the field.

In climate, broad reaching questions. How do we determine the bounds on future climate conditions if by looking at the past it's not the basis upon which we're going to make our future predictions? What will the impact of future climatic changes be on the unsaturated zone on the flow map in this [inaudible]? We've tried, this is a sample of questions that we've tried to ask as we built these alternative conceptual models and as we've gone through Performance Allocation. And ah, I think that when Jean gives her talk, she'll be glad to discuss these if you want to ask more questions. But any of us who've gone through Performance Allocation have participated in these kind of questions and answer sessions to develop hypothesis testing.

Now the strategy for conducting the site program is one of very simple logic, and I think you've seen it yesterday when Larry Rickertsen talked. You'll see it again in the next talk that comes after me, but it's one that's inherent I think in the scientific process that you would expect to see. Looking at the Regulatory Requirements and from our current site description and the conceptual models that we've derived from that site description. Lets try to focus a testing program to reduce uncertainty in the site models and in the site parameters that Performance and Design want information about.

Then conduct the investigation and analyze the results. Then ask yourself is there a need for significant change in the site description of the conceptual models? If you got things that you didn't expect, the answer is yes and you may go back to modify this or simply refocus testing. If the answer is no, then you can go on and say well how much confidence do we have that the model is adequate. The answer is no, then we expect to be going back to the, either expand the test or do alternative test, if we're not getting the answers that we thought the test would provide us.

If again the answer is no, then the question is can the strategy be changed? Should we run a different test program? Should we rely on something different to retard the radionuclides than what we thought we were going to rely on? Bob can you move that over just a little bit? There's a feedback link missing that will show up, if you -- there we go. If the strategy can't be changed, we don't know how to do that. Then we have to come back and decide well, what do we know about that sites suitability? Maybe it's not as suitable as we thought it was.

On the other hand, one would like to come through with yeses eventually, and get down here so that you can begin the process demonstrating compliance with the regulations and building your license application and preparing the SAR. Now, what site programs have alternative conceptual models or multiple working hypotheses? Well these are the seven that we've chosen to put ACM's or Alternative Conceptual Model Tables in.

We have, like I mentioned early approximate a 100 pages of tables. The tables are fairly involved and the numbers that I've got shown here are not meant to represent the number of alternative models. Their meant to represent a combination of models and multiple working hypothesis for sub-components of models. And to think about waste isolation and those things that are important to waste isolation from yesterdays talk. It's pretty obvious that there are some site programs that are more closely dependent upon assessing waste isolation capability of the site, then others.

For instance, geo-hydrology the path or the mechanism by which the radionuclide reaches the accessible environment is through water movement. And so it's not surprising to see most of our multiple testing hypotheses here in geo-hydrology. Also when you combine tectonics, both pre-closure and post-closure, it's not surprising to see that we have the second largest number of multiple, a working hypothesis there.

A pre-closure, we're focusing on waste handling buildings and whether or not an earthquake or rupture underneath the building could cause disruption in the process and damage cask or breach it open. As well as in placing the waste and retrieving the waste. In post-closure we'd like not to be closing that 7 centimeter air gap that Abe Van Luik talked about. It's important to keep that air gap open and we don't want to breach a waste package through faulting. So we need to know the magnitude and the rate or the reoccurrence interval.

Also climate, because climates closely linked to geo-hydrologic. We have a large number here in climate and finally geo-chemistry, because the mineral logical properties of the Tufaceous rocks in the Topopah Spring, and the Calico Hills contain minerals which sore breading employs retard the reading that Zeolites plays.

It's important to know where they are and how stable they are. Okay, so then this is the suite of site programs that have these alternate conceptual models and what I'd like to do now is to share with you an example of one or two of these models. On this other, on the left side this is a condensed version of one of these hypothesis testing tables. The one we've picked is pre-closure tectonics. Now on the right screen what I'd like to do is to simply talk you through some things that are in the columns labeled one, two, three, four, and five.

Before I start, what I'd like to do is just kind of peruse that table on the left side. To be sure it's simpler and more brief than what's in the actual SCP, but we're starting on the left side with a, what is the current representation in terms of local faulting and the geometry and the mechanisms of the faulting? And our current representation under column one is that we've not selected a preferred hypothesis. We think we need more information.

The reason we've not selected it is that the uncertainties -- we have limited data on the subsurface about the geometry of the faults, about their slip rate, their recurrence interval and their magnitude, and so we've not selected one. So, we can have the next slide on this side.

If you look at the alternative hypothesis we're working with, one is simply a plainer rotation fault model. Another one is that there is a detachment fault running underneath the site. And then all of the other large blocks above are riding on that detachment fault, so if the detachment moves then those small faults that are exposed at the surface are just, if you will, small things bouncing up and down on a larger detachment. Another one is that the local faults are part of a much larger system. The Walker-Lane System, it's to the west of Yucca Mountain, considerably to the west.

Another one is that local faults are Strike-Slip Fault, are related to a Strike-Slip Fault but it's concealed underneath the detachment fault. Another yet, is that local faults are normal and that they result from rifting along the Death Valley-Pancake Range and that's do to some very deep seated thermally driven process. And the team that put this together for pre-closure tectonics were trying to determine how they build confidence that they have the right design basis earthquake. So they need information about these and what we've set up in column five is studies which will help us differentiate between these. If we could go to the next one here in column four.

The significance of the alternative hypothesis, well the performance measures of Performance Assessment in the Design Program want a design basis earthquake. Was facilities important to safety. They want the ground motion, response spectra, we want to know the displacements. We likely to have a disruption underneath the waste handling building that's larger than what the foundation can handle. Are we likely to close that 7 cm air gap that Abe Van Luik talked between the waste package and the ground, in the emplacement goal.

Well we need confidence in that performance measure and we'd like it to be as high as possible. It's showing here medium to high. This is a general category we ranged them from low, to medium, to high. How sensitive is it? It's high. The local fault geometries could significantly impact the design basis earthquake and it could significantly effect the fault slip estimates. The need to reduce uncertainty, that's high too and so, Bob on the next one. We've identified a series of studies. These are the kinds of studies that the pre-closure tectonics specialist feel they need in order to come up with a high confidence. That they have a good understanding to come up with a design basis.

These, our studies or their activities under a study identified in the SCP and we'll be preparing a study plan for each one of these that will be going to the NRC. As you may have heard from the previous presentation, there is a 106 study plans which encompass some 320 activities and this is a list from which we have studies and activities. and these are the titles of the discrete studies that will be going on. Providing information that's feeding the Performance Assessment identify performance measure, if you will, that Felton talked about.

DR. PRICE: Could I ask how you're able to do this on the item on Human Interference? Is this as transferrable a topic area to layout like this?

MR. BLANCHARD: Well I think it's more difficult there because you have to project into the future what humans might do and what the likelihood is for demands for different types of natural resources. And I think that although people are willing to do that there's a great deal of difficulty in doing that. If we were doing that back in the thirties we would never have guessed that people would be using railroad cost and color televisions and things like that. So knowing how we're going to, or estimating how we're going to exploit our earths natural resources a 100 years from now or 10,000 years from now is a big job.

DR. PRICE: So really in the area of human interference it's kind of a concept that's a little bit inscrutable, you can't really -- there's only six concepts in the hypotheses compared to others. Which makes it sound a little more convenient --

MR. BLANCHARD: I think most of those have centered around things about the likelihood of people not recognizing a signs that are put up and there supposed to last a long time. And the likelihood of actually drilling into that because they may want to find something not recognizing the sign as a caution sign. Oh actually, it turns out that that's -- thanks for asking that question. That's example two in Jean Younkers' talk.

DR. PRICE: Okay.

MR. BLANCHARD: So if you don't mind, just ask that question one more time. Okay, now because I have sometime I think what I will do is just briefly go through this geo-chemistry one. It's the last one that I thought was worth bring up at this stage of the game from an introductory standpoint. Again, we have the same columns shown on the left hand side.

The question is, once the radionuclides get out of the waste package and start migrating, following the flow paths that's determine by the water, how stable are the minerals? If we now look at clays and zeolites and say gee we think those minerals will retard radionuclides. Are the conditions such that the minerals are met as stable and they 10,000 years from now or 5,000 years from now they won't be there. Or, if you pump heat and radiation into that rock do you change it so that those minerals aren't there? Or are they degraded into something different? And so our current representation is that the minerals that we know from our current investigative program builds us a three dimensional picture about the abundance of these zeolites and clays.

Their types of things that are hydrodrated minerals to be sure. We want to look at their stability, we also need to know how the secondary minerals along the flow paths alter. And is that altered in a predictable way. The uncertainty that one might pose is that the available thermodynamic data is not extensive enough and that the low temperature processes that go on in that environment are slow and they're difficult to quantify. So may you can't reach a degree of confidence that the minerals are stable and that's the alternative.

The local conditions are to complex and their not going to be known well enough, so you can't model.

DR. LANGMUIR: So you're also looking at that in several different, look at different aspects of the zonation. You have a disturbed zone as a total different part of the problem. Temperature wise and grading flux wise and then the natural barriers behind that. So you'd have to break it up into several different zones and treat each one separately.

MR. BLANCHARD: Yeah, in this particular table of this particular element, we were looking at far field. You're quite right we were not addressing near field because when the temperatures up around 200^c and things happen to these hydrated minerals that don't happen in the far field. And in fact, the test at Lawrence were in the past at showing that some of these feldspar and quartz strobe like minerals have broken down in that. Under their test conditions performing actual zeolites in the near field in a saturated condition. But for this particular hypothesis we were looking at the far field. You're quite right.

Moving into the middle column, what's the significance of the alternative hypotheses? Well it's directly related to radionuclides reaching the accessible environment because it determines or helps determine an overall retardation factor. We need high confidence and the sensitivity to waste isolation is high.

In order to reduce in column two over there you saw a medium. In order to reduce that from medium to low we're conducting this test or this study plan in column five. Stability of minerals in glasses and we have an investigation for a study which is devoted just to that. Okay, now if I can summarize.

DR. LANGMUIR: Max before you do that stuff, I'm sure I'm stepping ahead of things that'll come up this afternoon.

MR. BLANCHARD: Yes, that's fine.

DR. LANGMUIR: But, for a long time of course the other sites were looked at in terms of saturated zone interactions with the near and far field. And this whole business now is presumably one of unsaturated or possible saturated if there is a breach of some kind. And I suspect from what I've read in the past that most of the research has dealt with saturated reactions as a function of temperature as opposed to unsat. And I'm stepping again ahead of this afternoon I think, but I'm curious to what extent the program feels the saturated zone work applies to the unsat Yucca Mountain situation? And this applies to all the geo-chemical games we've been playing over the years coming to this question I think. What extent can you extrapolate them to the unsat situation we're going to be looking at?

MR. BLANCHARD: Well let me try to begin to answer that and I think Don may want to join in. One is, as you know thermal dynamic mineral stability studies have been going on for decades now. There are several textbooks out EQ 36 is a very effect modeling program. While empirically we won't be able to test everything in the laboratory that we'd like to, we're counting very much on EQ 36 modeling to be able to give us the kind of information that we need to predict the reactions that will go and the reactions that won't go.

So a large part of this I think is going to have to rely on something like EQ 36 that's science wide throughout, certainly throughout this country and other countries too. Relying on that as a geo-chemistry way to predict reactions.

DR. LANGMUIR: Just another fast question, two phase versus three phase problem. There's no gas phase in the saturated zone type problems we're looking at. Now we have one all the time, as a potential migratory route for radionuclides and reactants and fluxes of a different type mixed fluxes. Excuse me go ahead Don, I think you were going to try to answer part of that.

MR. ALEXANDER: Well, there are two things to keep in mind. Number one in this particular site, we don't take any credit for retardation as our primary, in our primary strategy. But, however, we have very extensive geo-chemic programs as a backup, and so our emphasis is not on it because we think we can make the case through the hydrologic games we're playing. I believe we can do that, but if not then we would invoke geo-chem as a backup. With respect to the type of geo-chemistry that you're look at in the unsaturated zone versus the saturated zone, the significant differences as you well know.

Number one, when you're dealing with the phases in the near field that matter namely the clays and the zeolites which happens typically, is that you drive off the bond of water and then as the water comes back in as temperature goes down it picks up some of that water and can revert back to its original form. The concern that was around years ago, was that people that were doing modeling would take credit for sorption on phases that were there under ambient conditions that would no longer exist or persist as the near field was effected by the thermal portibation (PH). But in this site I think it's a different problem all together.

Phase change that you're likely to see is one in which you, as I said, drive off some water and it's likely to revert back to its original state, cause the temperatures are not going to be that high in the rock.

DR. APTED: Don I should just add we going to talk a little bit on the specific examples in some of the differences in my talk this afternoon. If they put that question again this afternoon. Okay.

MR. BLANCHARD: Okay, does that suffice for a beginning for an answer? Okay, in summary then in closing my talk off, at this stage I believe the site program is reasonably comprehensive and it contains redundancy to provide the site parameters that are called for by Performance Assessment. At what we think are the needed confidence levels. The potential for alternative concepts and alternative hypothesis has been considered in developing the plans, its fundamental part of the building blocks that Felton talked about as he begins building a total system Performance Assessment.

As new site information is obtained from characterization studies we suspect the number of alternative concepts and hypothesis may initially increase. We're hoping that with additional analysis some of the concepts will be favored. Some of these alternatives will be ruled out. We're not assuming that we'll always go to one favored model. We may have to carry several on, right into the License Application. In cases where uncertainties remain large after Site Characterization, we'll have, simply have to go with bounding assumptions.

Site derived concepts and hypotheses provide a key interface between Performance Assessment in site program and are expected to provide confidence in the performance predictions. That's the direction that we anticipate that we'll be going in. If you have any other questions I'll be glad to answer any, if not I think we're probably ready to go on with the program.

DR. NORTH: Any questions? I think we have a break scheduled at this time. I was going to suggest given we're a bit ahead of schedule we plan on making it a 15 minute break and resume at 10:00 o'clock.

VOICE: I think that will be great.

-- Break: 9:45 a.m. - 10:10 a.m. --

MR. ALEXANDER: To stay on schedule I recommend that we take our seats and begin the next talk. We're into our next session. Session Four on Recent Applications and we felt that it was important for us to review the Performance Assessments that support the SCP as a part of this session. To review the Performance Assessments in the Comparative Site Analysis as an example of the use of Total System Analysis to date. And to reveal Performance Assessments conducted to evaluate the impacts of Site Characterization on long term performance.

Jean Younker, is going to among other things cover one of the request of the Board. Namely to provide a road map to Performance Assessment in the Site Characterization Plan and in addition point out the role of Performance Assessment in the Site Characterization Program. Jean.

DR. YOUNKER: Thanks Don. Okay, what we're going to talk about then in this presentation is, essentially try to give you a little bit of an idea of the way we interfaced from Performance Assessment to set up the Site Characterization Program that's in Chapter Eight of the SCP. We'll also try to build for you an understanding of the Site Program Linkage to the issue resolution strategies. And we've heard, I think you heard

Larry Rickertsen yesterday mention issues.

Give you a little bit of an idea of what that's all about. Then give you kind of a road map through the SCP as Don mentioned, as to where you can find the various pieces of the Performance Assessments Program in the SCP and how Performance Allocation, one application was used to guide the Site Testing Program. You've heard references to this as we've gone along, so I'll give you a couple of real light examples from the SCP. In terms of the way performance measures, Performance Allocations through establishing performance measures were used to better set up the Site Studies and Activities Program as described.

Okay, you heard from Larry Rickertsen' presentation yesterday that the site of the diagram that he used here, that you're going to find in the Site Characterization Plan is the part that's over here that's in orange on the diagram today. He described the general process of Performance Assessment and told you that you'd find more detail information in a couple of other documents. And so to get you oriented today, I'm going to talk about what you can find if you go to Site Characterization Plan or to Study Plans.

Okay, another diagram that Larry used, just to once again give you a feeling for where to look for what. If you look at the Site Characterization Plan what you will find and we'll show you kind of where to look. You'll find the Regulatory Requirements laid out, you'll also find Performance and Design Issues.

We'll give you a listing of those in just a minute in this presentation. You'll find this process that we've labeled Performance Allocation, I'll give you a little bit better understanding of what that is and you'll find our complete Program of Investigations and also the design issues that request specific site information. Not the complete Design Program by any means, but simply that part of the Design Program that rests upon site specific data.

You'll also find some strategies for how we're going to develop the complete set of site information, you'll find that information then being fed to the

Performance Assessment Program that is described in the Site Characterization Plan. You'll see our list of performance majors. Okay, this whole strategy that you've heard referred to in a number of different talks called the Issue Resolution Strategy has as a major component the area in yellow on this diagram, called Performance Allocation.

As you might guess Performance Allocation is, if you step back and say in the simplest term what do we mean by allocation? What we're simply saying, in order to figure out what kind of Site Program you need, you have to figure out what it is you're going to rely upon. And Performance Allocation is really just simply, what are the important features of the site and of the engineered system that you're going to rely upon for the fundamental performance. Meaning the repository performance requirements that are laid out in the regulations. So it's really not, in its simplest form it's not a very difficult concept at all.

When you try to apply it, it turns out to be very difficult for number of reasons that I'll tell you about. Okay, now this is the site trip that we promised you into were do you look in the SCP to find the various pieces of the Performance Assessment Program. And I think from the questions that you all have been asking in the last session, yesterday especially. Some of you have clearly been in the SCP and you know where the pieces are, but we'll give you just a very quick overview for those of you who maybe want to spend some more time. You don't want to really spend your time looking for the pieces.

If you talk about the overall issues, the issues hierarchy that the DOE has published. What that is, is simply a restatement in the form of questions of the Regulatory Requirements. So that for example, you heard some presentations yesterday that talked about Containment By The Waste Packages and people referred to Issue 1.4. Or, Rate of Release From The Engineered Barrier System and they refer to Issue 1.5. You can see the correlation to the Total CFR 60 the technical criteria for the repository for each of those issues.

And those of us who have been around doing this for a while tend to talk in those numbers, and so you know once and awhile you'll see Don or some of us slip into talking issues and issue numbers instead of talking about what the real requirement is. It's simply a shorthand kind of that we've adopted and same think for the pre-closure performance issues. You heard some from Dave Michlewicz yesterday. The dose to the public from routine operations, you would hear Dave talk about Issue 2.1, which is simply that part of 10 CFR 60.111 that sets up the requirements for routine operations, releases from routine operations.

So that's the basic idea of what this issues hierarchy is. And the reason it's called a hierarchy is because there are key issues that group these issues according to post-closure, pre-closure and then according to different typical areas. And so, it's basically a hierarch from the standpoint that there are key issues, issues, and you've also heard reference to something called information needs. And those information needs are the information needed at this time. Preliminary information to find needed, that is needed to resolve or satisfy anyone of these issues.

Okay, if you look at SCP Section 8.3 which is Planned Section of this total document. It's about half of the document, about 3,000 pages and this basically is broken down into the complete site program which is 8.3.1 and then from 8.3.2. through 8.3.5 you see the Repository Program, the Seals Program, the Waste Package Program, and the Performance Assessment Program, our topic here today. And bear in mind now that what you see there is in the Waste Package Seals and Repository, is only enough for us to lay out what the site requirements are. What the site data requirements are for Repository Design and Waste Package Design. It isn't meant to be the complete Design Program.

Okay, lets break down Section 8.3.5 for you then, which just goes one step further to make sure that should you want to find a specific Waste Package Requirement or specifically excuse me, Performance Assessment Requirement you would know were to look. For example, if you wanted to find pre-closure, you'd look at Sections 8.3.5.2 through 8.3.5.4. If you wanted to find the Engineered Barriers Waste Packaging and

Engineered Barrier System you can see that it's in 8.3.5.9 through 11. So this is just simply a little bit of a road map to help you get to the right place in this massive document should you want to see what our approach is for anyone of, meeting anyone of these requirements.

Okay, and one more way of looking at if for you, now making it as simply as possible for you to find the information in this document. If you look at each of the major areas that we told you about yesterday, Total System, Engineered Barriers, Natural Barriers, and Pre-closure. You will find then the correlation here laid out for your between the Issue number, which probably doesn't matter to much to you, but the SCP Section is listed tabulated over here for you. So this one probably is the most helpful one to you from the standpoint of being able to turn to the Table of Contents for Chapter Eight and find out exactly where the information is that you'd like to look at.

Okay, now what we're going to do is go into a little bit more detail on the steps that are in this yellow box. Part of the total issue resolutions strategy that's on the left hand screen and talk a little bit about where Performance Assessment really came in and helped us to get down to step #6 here, which is our testing strategy, the variables and parameters that we need to measure from the Site Program. So, what we'll do is kind of very generally walk through three, four, five, and six. Ending up here with then some examples of what our Site Program looks like.

Okay, step three then, in this overall Performance Allocation box that we're talking about, in order to really start through this process we had to first of all set up what our preliminary site description was. And in many cases I think this was done kind of in an abstract way, although you probably know that Chapters One through Five of the Site Characterization Plan are to represent the overall data base. What we know about the site right now and each one has a specific topical area. So in a sense at least, that's really, that preliminary site description is really Chapters One through Five.

We also had to lay out the range of conceptual models that are consistent with available data and I think those are described in Chapters One through Five as well. And as you heard from Max Blanchard in the previous talk, we then were very systematically, we pulled that information together in those hypotheses testing tables that he described for you. So that it's not only laid out in a descriptive way in Chapters One through Five, but then represented for you in a more logical probably and systematic way in those Alternative Conceptual Models Tables.

Alright, then the next step, once you've decided what your preliminary site description looks like is, you obviously need to know what your engineered system is going to look like. So you have in Chapter Six and Seven of the Site Characterization Plan, you have the conceptual design for the Waste Package and the Repository. Clearly, if you're going to develop any kind of an allocation scheme you need to know what the engineered part of the system looks like too. Okay, the next step which I mentioned earlier, is you need to then define the elements of both the natural and the engineered system that you're going to rely on. And that's really, that's probably the classic use of the term Allocation.

In this case if you think about the natural system, what kinds of elements are you defining while you're talking about unsaturated zone rock units for example. If you're talking about zeolites along the flow path as a backup barrier as Don mentioned, and perhaps the Waste Package when you come to the engineered system. Then we want to look at what process is related to those elements, do we have to characterize. What is it we have to understand in order to really be able to appropriately model, and incredibly predict the performance of those various barriers.

So that's the next step and then that step of course would be such things as you've heard about from Max and also from Dwight yesterday. The unsaturated zone flux and flow mechanisms would correspond to your, what you need to know about the unsaturated zone rock units or at least one piece of information you need to know. You obviously need to know stability of zeolites as Max mentioned in the previous talk and if you were talking about the engineered system as you heard about yesterday, you need to get out what kind of corrosion mechanisms and rates are really credible.

Okay, Bob. Okay, now moving to Step Four to the circle on the left hand screen. This is where I think probably the most time in a lot of fun was really, happened to a lot of us during the Performance Allocation Process because in this area of identifying the performance measures, setting goals, and setting confidence levels.

I think is where we had the most interaction and one of the key things I want to emphasis in this is that, the only way that you can go through this process is to have inter-disciplinary groups with engineers and geo-scientist types and earth scientist that are actually going to go out and collect the data. Altogether in the same room, hashing out, what is it you really need to know in terms of kind of conceptually and to, for a parameter in an equation.

Figuring out what is it you really can measure then from the standpoint of the actual site materials that will help you to figure out what value you're going to be able to use. And so it's a, there is a real, really good interaction occurs as you go through this process. So to establish performance measures and you heard Larry talk about performance measures yesterday.

Basically you're going to take anything, any previous work you have in Performance Assessment any kind of sensitivity studies and you heard some examples from the Environmental Assessment yesterday. Take any of that kind of information you have and figure out what parameters, what kind of measures you're going to use to describe the behavior of the natural and generic system. Now when you set that up obviously, you know you're basing it on as much judgment, as much background information as you have.

You're also going to go into the next step which is to set the goals. And the goals for those various parameters at various levels, the value or the limit for the measure of parameter that's derived from either the sensitivity studies or in many cases in the SCP you'll see that it's essentially professional judgment. If you don't have real sensitivity studies to refer to than you obviously take your best guess and hopefully a reasonably good guess. You use that then to guide and focus the site testing program as you heard from everybody. The purpose of doing this at this stage in the game, when I think some of you mentioned it's kind of early to be doing some of the things we have done and talked to you about.

The main purpose of that is to get the best chance that you can of getting the site testing program set up properly. And clearly, for these goals you want to remember that because it was a preliminary pass-through this whole process, that as we collect new site data and we get some sensitivity studies anyone of these goals could change. And I think Max kind of talked you through a little bit of how that might affect your program overall.

The current need of confidence is one of those things if you look carefully at everyone of the Performance Allocation Tables, you'll find that the way that the current and need of confidence is applied in many cases is a little bit different. And so you kind of have to look at the specific use of this concept, but it generally reflects an indication of how important it is to reduce uncertainty in the parameter of the measure that you're talking about. That's simply getting at the idea of how important is this particular parameter in the overall approach to calculating the compliance with the performance requirement that is driving this particular allocation.

Okay, the next step, Step Five which is over hear on the right hand side on the left screen. Clearly, once you figure out what measures you intend to use, you're not done, because most of those measures are not things that can really be measured in terms of site data. So what you have to do is start working down a hierarchy to figure out what you're really going to be able to measure. So you need to figure out what parameters you really will have to have to calculate a value for the measure.

You have to then pickup your site conceptual models, clearly any kind of parameter estimation, resting upon some kind of conceptual model. You get down to the level that you've heard about already and you'll hear some more this afternoon, about the lower level processor mechanistic models. And then there's other types of needs defined in the FCP as information needs that get into the whole application of Performance Assessment. So I'm not going to spend any time on these last two but you've heard about them in other presentations in this session.

I'm going to stay up here at the top then. Max talked about the conceptual models and the approach we used to them and the alternative conceptual models tables. I'm going to really stay with the parameter needs. Okay, as I said before we basically use what we know and we figure out what parameters are needed, and we try to work that to a level of detail that allows us to interface with the people who are going to make the actual measurements. So the people who are going to do the institute test and the exploratory shaft facility, people that are going to do the surface base testing.

We have to get that actual parameter value, get the parameter need down to a level that they can in fact provide something that is adequate for the Performance Assessment or Design use. And then we develop those goals and estimates of needed confidence as I said in the previous slide. Now, what's the testing strategy all about, which is box six. In this case when you look at the SCP and I'll show you a couple of examples of these tables. What you're really looking at is just a complete conciliation of all of the parameters that were specified as needed by the Performance and Design Issues Sections of the FCP.

So if you look at the Site Programs everyone of them has this table and I'll go into the table in just a second, but has the complete set of parameters that were requested. We also document the goals in this current and needed confidence and one very important step that's been mentioned by Felton Bingham and that's been mentioned by a couple of the speakers and I think Felton Bingham in his presentation immediately following or very soon will get into the total question of, you can't just plan the testing program without considering what constraints you have.

And one of the major constraints we have to be concerned about is what kind of impacts would we have on the site from the standpoint of future performance and also just ability to characterize the site. We don't want one test to in anyway interfere with the possibility of getting some important information from some other information down the street. So you really do have to make sure that you've carefully thought through what constraints you have. Especially when you're operating in the unsaturated zone where you really want to be very careful that you don't perturb the system to much. Then you go ahead once you've considered those constraints and develop your plans for lab and field study.

Now when you look at the FCP and all of these sections where you see these, we have multiple tables. Many, many pages of tables. We have the one set of tables that Max talked about called the Hypotheses Testing Tables that display the variety of alternative models that are being considered.

The other ones display the Performance Allocation Results and their set up such that in the Performance and Design Section generally you'll see something that starts with the element of the system that you're allocating performance to, walk through the steps that we've just talked about and gets down to a performance or design parameter that getting close to the level that the Sites Program can pick it up. And then take it as a Characterization parameter and drive it further down, in many cases you'll see several steps here getting down to something that's actually a measurable quantity.

And in each case, if we were able to do it. In some cases we weren't able to do it, but if we could, you'll see some current estimates of the value of that parameter and some estimates of the confidence needed, the current confidence and confidence needed in those parameters. All the way down as far as we could do it. Okay, now once you've done this whole process, you might ask the question where did that get you? What can you do? Well just in terms of looking at those tables in the Site Characterization Plan, there's a number of different ways that you might decide you wanted to prioritize the overall Site

Program.

There's some natural things that fall out of the tables and that would be such things as, if the needed confidence for the parameters to be determined by a study or an activity is very high? Okay, well that isn't the whole story though, because you probably then also want to look at, are you really characterizing a primary barrier. Meaning we told you we rely very heavily on the unsaturated zone and not so heavily on the saturated zone. So even if you had for some reason you had a high confidence needed in a particular parameter, but if it was for the saturated zone then you might still look at your overall allocation of resources and say well that's not as important a barrier so I'm not going to put as much time and money into it.

You then look also of course, at the difference between current and needed confidence. For example, if you have a current confidence that's low or medium and the table, the allocation processes come up with a needed confidence of high. Generally, speaking these are all interrelated so obviously, I'm breaking these up just to give you some examples of what you'll see when you look at the tables. But generally, if your current confidence, if you need a confidence that is high then probably you're also characterizing a primary barrier.

So you can see it's really not quite as simple as I'm making it but, also if there's a strong tie between the parameter provide by the study or activity and a particular performance requirement. A good example there is, I think the ground water travel time example. When you go into the Site Program the tie there is pretty close between needing to know the velocity distribution in the unsaturated zone and being able to calculate the ground water travel time. And so clearly, you know somewhere the tie is very, very easy to make. There're others where its' much, much more vague.

T2SA Okay, and then a strong tie between the study activity and the design requirements which of course is not the subject here in our discussion, but it's another one that was driving the Site Program.

DR. NORTH: Let me pose a question here, which maybe should be answered later on as apposed to at this point. And that's the question of timing on this prioritization. Do you do anything like a pert chart in terms of how all these activities are going to fit together in time?

DR. YOUNKER: Yes.

DR. NORTH: And do you have a system of priorities to identify where the critical paths are?

DR. YOUNKER: Um huh, yeah we certainly do. Do you want me to? We basically have for every Site Program, we have a detailed wall size network that takes every activity. Max mentioned there are 320 and of course below that level there's all the preparatory things you have to do to get ready to start any drilling activity or any exploratory shaft activity. We have that all diagramed out down to the smallest detail we can.

DR. NORTH: Do you have some management summaries for tracking it so you can see what's behind schedule and were the areas where you really want to emphasize getting that piece done because everything else is being held up?

DR. YOUNKER: Absolutely, and that's, there's a whole level --

DR. NORTH: Could we put that on our list for future investigation that we'd like to see that and understand how it works?

MR. ALEXANDER: Sure.

DR. YOUNGER: Okay.

MR. ALEXANDER: I think the answer is there's been a tremendous effort put into that and the logic networks as Jean points out could probably paper this room. So there is a very detail --

DR. NORTH: That's what concerns me. What concerns me is how do you boil it down to a couple of sheets of paper which tells you and Ralph what you ought to worry about.

MR. ALEXANDER: Yeah, yeah that's true.

DR. YOUNKER: It's a good question. Okay, I have a couple of examples now and I probably, go ahead.

MR. ALEXANDER: Maybe, maybe I should point out that if you look at the Site Characterization Plan, you look in 8.5 of the Site Characterization Plan, there are schedules there that are at an investigation level.

DR. NORTH: Yes.

MR. ALEXANDER: Okay, and if you --

DR. NORTH: That in part prompted my question, because viewing it essentially from a fresh start, the bulk of it is overwhelming. Trying to take into account all of those issues simultaneously. Across 20 divisions of 8.3.5, that's a tough order and I can't tell reading it how it all fits together.

MR. ALEXANDER: Yeah, and so there are a number of different cuts in the SCP there's the, there are different levels of cuts that are taken. Some cuts that are taken all the way down to the activity level in 8.3 and in 8.5 at the investigation level which is much higher. And then there's the Mission Plan Level Schedule which is at the very apex of the whole thing in 8.5. But, there are very comprehensive network diagrams that are used for critical path analysis as well.

DR. NORTH: What I'd like to get a sense of as we proceed is, how do you make the trade offs in terms of the timeliness versus the quality of the information that you're going to get. At some point you have to decide well this is probably good enough lets go ahead as opposed to we might be able to learn a little bit more if we keep doing this a little longer. And I very much like to see us get some insight into how you're doing that. So that when you go through this interpretive system, we have an idea of what your criteria are for managing the interpretation.

MR. STEIN: We have a great deal of concern in the program about when do we have enough. When is science being really exhausted, even though people might want to continue but as far as the program is concerned we believe we have enough information to support a licensed application. That has concerned us for a long period of time, as to how do we get a handle on when do we have enough information. We have been trying to address that and I think the question is right on target and I think that we do, we should have a follow on discussion on that particular point.

DR. NORTH: Lets identify if as an action item for the future because I think as we evolve, it is so easy to state the conclusion, oh we need to know more. And yet from my experience in doing analysis of doing decisions in the face of uncertainty, that's a real trap. There are many places where in fact you know enough to make the decision and you need an analysis that can show that, and give you a basis for cutting off the activity and going on, at least for this stage. And I'd like to see how you're doing it.

MR. ALEXANDER: I think that's an excellent question.

MR. STEIN: Yes, and I agree with your analysis. It's something that we should talk about and hopefully in the near future.

DR. YOUNKER: Okay, I have three examples of Performance Allocation Tables from the SCP, and I think I'm only going to go through one or maybe two depending on the time we have here. But, since lets do the first one Bob, which is the Ground Water Travel Time one. As you saw from the highest level obviously what you have to do, as I said before, is to start out look at the site and look at the natural system. What elements are you going to rely upon? And so, jump to the next one Bob and it just list them for you.

Obviously, the highest priority as you heard from several speakers is placed on the Calico Hills Unit in the unsaturated zone. More priority on other units in the unsaturated zone with the lowest on the saturated zone is a part or component of the total flow system. Go ahead. Okay, and then if you look at what kind of performance measure, as I said just a few minutes ago. This is one where the connection between the actual requirement and the site information is a little bit clearer, because you want to get at the

Ground Water Travel Time as the performance measure. And you set some goals then for the needed confidence, for having a 1,000 years or say lets look at our primary barrier at the Calico Hills.

But a 1,000 years at a high confidence and 10,000 years at a low confidence and this is just arrived at now in this case by some sensitivity studies that have been done, but I think Felton mentioned yesterday Ground Water Travel Time calculations that have been published as well as our overall approach to what we're going to base our confidence on for meeting the 1,000 year travel time requirement. Okay now if you were to follow these tables across now and get over to the level of a performance parameter that gets down to the kind of value that your going to be able to obtain from the Site Program. Now we're starting to get into some of the ones that Dwight talked about. Such as the estimate for flux.

You heard that that's probably our overall most important parameter in determining Ground Water Travel Time and understanding the hydrologic system. And so if we take that particular value of the flux now, and lets look over at the Site Program. Look at its response and see how, see what kinds of studies we have. Now we're walking, we're making the jump now from the Allocation Tables that you see in the Performance Sections, in this case it would be in 8.3.5.12, the Ground Water Travel Time Section. Over to the Geohydrology Program.

Okay, so now we're over in the Geohydrology Program and what you see in the Geohydrology Sections as I showed you on kind of a generic slid earlier. Is you'll get out some general things called Parameter Categories. Sometimes their called Characterization Parameters, sometimes their just called Activity Parameters because we have it listed out in a fair level of detail. In this particular case, you would see a long list of them and what we put on this view graph for you is just to pull an example, so it would kind of give you that guide through the massive tables that you see in the SCP.

So one of the particular Activity Parameters that we're obtaining from an

SCP activity that has this set of numbers is the Flux Through Fracture Matrix Network. Now if you go to the next page with me, you'll see that basically we track that into, these numbers are codes that help us to understand where the information is being picked up. It's in a study called Characterization of The Yucca Mountain Percolation in the Unsaturated Zone.

In this particular case we're in an exploratory shaft facility study. Now as Max mentioned in the previous talk, there will be a detailed study time prepared that describes that particular Characterization Activity and the activities within that study. There's one that's called an Intact Fracture Test in The Exploratory Shaft. There's one that's called Infiltration Test. And so in this Infiltration Test then, this is one way that we're going to get at estimates of the way whatever flux is present and lives through the Fracture Matrix Network.

That's just one example of the way the information is being compiled and put together. Through, starting from the performance requirement for Ground Water Travel Time, getting you down to the specific activity is going to be conducted in the Exploratory Shaft Facility. Okay, this one picks up on a question that came up on the previous presentation and although this is really an Allocation Table not a Hypotheses Testing Table. It does get at one of the linkages or another example from, starting with the Total System Performance Measure, which is a the EPPM. And I can't remember Felton did you talk about that yesterday or not? You talked about the performance measure for it.

One way of estimating the total releases, cumulative releases. You have a whole list of initiating events that you have to look at. If you look at the section that lays this out. In this case, we're look at initiating event that's exploratory drilling intercepting a waste package and bringing up waste with chloric or cuttings. We've set up this list of initiating events hopefully at this point to cover all of those that are considerable credible by team that has put this information together.

Based on those initiating events then you develop the set of parameters.

Performance parameters and some goals on those, and bear in mind once again, these goals are just something to help us guide the program. Not something that we have to meet. They are set up so that you figure out how much you really need to know about any given parameter. And in this case you'll notice that we're down in a, for this particular example having to do with the Readability. We have a current confidence of low and a medium needed confidence. And so this would give you an idea of how much emphasis kind of to place on this general area. Go on to the next one, it shows you the --.

Picking up on those goals now and taking it on across to the studies or activities in the Field Program. What kind of parameters do you actually have to get at to talk about something like, just as an example. How readable are your markers going to be. You required to have markers that will last. Well what kinds of parameters does the Site Program have to provide for you to get estimates on how well those markers will last. But clearly, you want to get at something like Rates of Erosion and Weathering.

You want to get at what kind of Igneous Activity is likely in the area of a 10,000 year period. And also sizemic activity at marker location. And if your look at the SCP, you'll see that there are activities laid out, in this case the example I gave, it's just a long term processes that could affect marker stability. And that particular study or activity is an example of one of those activities in the in the Site Characterization Plan, that rather than collecting a lot of primary data on its own.

It's really a dissimulation of information. It goes over to various Site Program and kind of policies them, and makes sure that they they're getting all the information that's needed to make this kind of an estimate of marker readability over this long time period. Doesn't really get at the question that was being asked, I think early. But this is an example of kind of the direction we've gone so far. And it's clearly recognized that we do need to go in kind of the direction of what kinds of potential human interference we may have to deal with. We really haven't emphasized that as much as just the data base that we need so far.

DR. PRICE: Yes, and I think in coming up with the possible human interferences and so forth it also comes back to something I said yesterday. That this can be approached in a systematic and somewhat rigorous way, rather than just simply what the team felt might be considered at the time that the team was thinking about.

DR. YOUNKER: Yeah, and I think right now the hope was to make sure that the Site Program would cover the data base that we're going to need in order for a better educated team if you will. A team with that systematic approach that doesn't sit down and layout the kind of thing that you're talking about. Okay. Yeah, go ahead Bob. Okay, one more real quick example since I'm not over my time yet. The link between the total system performance and the post-closure tectonics is a fairly interesting one it's coming through discussions here.

This is probably one of our best established links. We had a team of people that worked extremely well together on the Performance Assessment side and on the Tectonics side. The people that worked in those groups spent a lot of time hashing out exactly what kinds of performance parameters were going to do the job for the total system calculations and getting some parameter goals that people were comfortable with in these expert groups that we're working. For example, Volcanic Eruption Penetrates Repository causing Direct Release was one of the initiating events that we considered. What kind of parameter do you need for that? The annual probably of that eruption penetrating the repository, a tentative parameter goal is set and that one is to some extent established by the regulation. Bob.

DR. CANTLON: What about before you leave that. What about the question of whether or not a volcanic event penetrating this site would cause a release? The prior question.

DR. YOUNKER: Right.

DR. CANTLON: Is that pretty much it?

DR. YOUNKER: Yeah, there is another initiating event and I think that yeah it's broken out like that, but this one is assuming that it occurs. The of course you have to look at one of the other kinds of effects that you get from that.

DR. CANTLON: Correct, exactly.

DR. YOUNKER: From that intrusion. Okay, for the Site Program Response now you looked at the site parameters to be provided. Such things as location and timing of volcanic events in the area. What kind of structural controls do you have on where volcanic activity occurs? That's clearly an important one. If you can show that volcanic activity tends to occur out in the flats and not through the ridges like Yucca Mountain, then you have some kind of an idea that your less likely to have a true penetration of the repository by volcanic material.

Okay, and then the Presence of Magma Bodies in the vicinity of the site is another way to get at what's the past occurrence of intrusion of magmatic materials into the subsurface in that area? And there's a whole list of studies or activities that I've compiled here for you and this is just a part of the list. When you know that there is a total of 320 at the level that we're compiling here, you know that we're just trying to give you a little bit of a snap shot of parts of the Site Program.

Okay, then in summary we have these strategies laid out for meeting the Performance and Design Requirements and we develop them explicitly in the SCP and used them as a guide to set up the Site Program. And I think for some of the reasons that have come out here we convene that obviously you could set out to characterize the site in a lot of different ways for a lot of different purposes. And you could set up something that would essentially be a program that would give you a great deal of confidence in certain aspects of the site. But what you want to do is make sure you getting information about the right parts of it.

The right parts of it meaning, most parts that are most important to the way that the Repository will perform over the 10,000 year period that we care about. As part of implementing the strategies, Performance Allocations, this process that I've described real,

real generally. Was used to determine what kinds of measures, goals and confidence we need for each of the requirements as you drive it down to the parameter level.

We set up this hierarchy of parameters and that's your real link then to the site parameters, getting down the level of something you could actually measure that we would then feed back to the Performance Assessment Program which has been the subject you're hearing about today, you heard about yesterday and you'll hear some more about day. Thanks.

MR. ALEXANDER: Are there any questions for Jean? Okay, thank you Jean. The next speaker is Dr. Paul Gnirk and Pauls' going to be telling you a little bit about the Comparative Site Analysis that was conducted several years ago, that was used in part to decide which of the three sites would be eliminated and which would go forward. Paul.

DR. GNIRK: Thank you Don. This discussion or presentation deals with a comparative evaluation that took place in 1985-1986. A comparative evaluation of the sites that were being considered for nomination, for characterization as candidates for the first Repository. Now what I'm going to start with is some sort of a historical perspective with a couple of viewgraphs, because things have sort of changed from those times and then tell you what I'm really going to talk about, which is really the Performance Assessment aspects of that evaluation as they apply to Yucca Mountain.

The purpose as I said of the evaluation was to aid DOE in selecting three sites for characterization for development as the first Repository. The comparative evaluation used the Multi-attribute Utility Analysis Approach which was referred to in our report and our discussions as the decision aid methodology. That work, that application of the methodology was reviewed on three occasions by the Board of Radioactive Waste Management National Academy of Sciences in the late 1985 or late 1986 time frame.

As some of you may or may not know on the Technical Review Board. Dr. North was a consultant to that Board and Clarence Allen was a member of the Board and heard our presentations and made their reviews and comments. Next slide please.

DR. NORTH: I have asked that the report on this exercise be provided to the members of the Board. Which includes the National Academies' letter. Good.

DR. GNIRK: That report contains the letters from the Academy, will be provided. In late May 1986, Department of Energy selected three sites or rather the Secretary recommended three to the President, and those sites were approved for characterization and one of those sites was the Yucca Mountain Site. In December of 1987, Congress by Legislation decreed that the Yucca Mountain Site would be the only site to be characterized.

The talk that I will give today will focus as I said previously on the Post-closure Performance Assessment Aspects in that evaluation as they apply to the Yucca Mountain Site. And the talk will not focus on the Comparative Evaluation itself and the results of that Comparative Evaluation as history has sort of overtaken and passed us in that regard. Next one please.

In the application of the Multi-attribute Utility Analysis, there is process that must be followed. A process that's set up in this methodology in which you precede in a rigorous, well-established, precedented fashion to arrive at some answers you might say to rank order sites. In the diagram that I have here, you can think of it as two parts. On the right hand side, it says the application and the Multi-attribute Utility Analysis which is divided into one, two, three, four, five, six, seven steps. On the left hand side of the diagram I've added five steps rather that deal with the development of the technical information that must be used in the evaluation.

Step one is to established the objectives, which I'll talk a little bit about. Step two is to develop the influence diagrams, the performance measures against which you rate the site, or rank the site, or score the sites for particular scenarios or conditions. Step three, four, and five are parts of the analysis that require input from management. They involve value judgments, value judgments related to policy.

They involve establishing certain independence conditions or evaluating where the independence conditions exist among the objectives so you can develop a Multi-attribute function. And you have to develop the single attribute utility functions and the scaling factors, and that is a part of management. In the process that we followed the managers as such, were four senior managers at DOE. One of which were Ralph Stein, another of which was Tom Isaacs. This part I won't talk about. What I'm really interested in is in the white box here. This is laid out here, but I just mentioned this in passing.

The Methodology Lead Group consisted of three people principally. One from DOE, one Decision Analyst, and myself. Later in the process we added a second Decision Analyst, who concentrated mainly on the pre-closure aspects of the evaluation. The technical people, or the Technical Specialist, they were consisted of a group of 11 people. The aims of whom are attached to the back of your handout. These eleven people consisted of eight who were trained, early training in Geology. Two in Nuclear Engineering, Nuclear Physics, one in Geochemistry and they had many years of cumulated experience in the Waste Disposal Program.

That was a group of Technical Specialist that we used to handle the technical information development and sum the judgments that I'll discuss later on. Where probabilities were assessed and the sites were scored. Okay. The first thing you have to do is develop an objective hierarchy in this particular decision methodology process. Now I'm not going to say much about this, but this was the general objectives hierarch. I'll mention the following.

These are objectives of value in the sense that they deal with human values. In the sense of health, health and safety, impacts to the environment, socioeconomic impacts, and cost of money. As compared to, you might think of as objectives of accomplishments. Such as publishing the SCP on time in 1988 by the mid-December. Which is an objective of accomplishment rather than necessarily an objective of value. these value objectives are required in this type of analysis.

The post-closure on your left hand side of the diagram moves down to minimize adverse post-closure impact. To minimize adverse post-closure impacts on public health and safety. Moving to successfully lower objectives, terminates or ends in two principal sub-objectives which deal with minimizing health affects.

In the first 10,000 years and minimizing health affects in the period of 10,000 to 100,000 years. Now as it turns out as we developed the performance measures against which to rank these sites or rate the sites. We did not use health affects. We used a surrogate and the surrogate was releases to the accessible environment. If I had Feltons' slide from yesterday I would show you the, what we talked about when he talked about in releases going to the edge of this cylinder that surrounded the site. But that was our surrogate. We did not deal with health effects in the sense of doses, so forth to the accessible environment. Next please.

Now I'm going to move this viewgraph over to the other screen and I've created this viewgraph because as I said before and I emphasize again. The process is very important in the application of this particular decision aiding methodology. And the process is important in how we set up the scenarios, we screen them, we develop the performance measures, and we scored and so forth and come out to an answer. Please, I put that on the other side over there.

Now in approaching the first thing you, we had this group of technical people do or some of these people along their selves. Is to create what was known as an influence diagram. Maybe doesn't make much sense to you but the top of the diagram is what you're after. The number of health effects and you start, you put all the factors you can think of in some process, some sequence that contribute to that. And as you recall yesterday in Feltons' discussion, he talked about the water and the geochemistry and all these things that really lead to dissolution the waste form and the radionuclide travel and so forth.

Well when this process was done, with all of these factors you end up with a number of factors. Ground water travel time, retardation, ground water flux, volume of water contacting the waste, solubility limit, and waste package life time. These things influence two things. One being the radionuclide travel time, the other being the dissolution rate, and of course then they feed into releases from your Engineered Barrier System as the dissolution rate. Radionuclide travel time to transport to the natural barriers finally releases to the accessible environment.

When we went through this process we were looking for performance factors to develop a scale if you wish, against which to rate the sites against their performance measures. And the factors we picked were the radionuclide travel time and the dissolution rate. I'll show you how those were spooled together in such a fashion that we could use them. And that was the first process on the left hand side over there. Okay, if I might have the next slide.

On this process when we were working on this, I might say, that we had a second group which we called a Technical Review Group. Consisting of four people who had expertise in Performance Assessment. Three from the project, one from the WHIP Project that advised us on our deliberations in developing the scale for this performance measure for post-closure and the releases that we eventually derived from. Basically, the performance factors consist of two things. One is to measure the amount of radionuclides that are dissolved out into the ground water over a specific period of time based on the ground water chemistry and the amount of water that contacts the waste.

That is expressed as a ratio of the release limits from 40 CFR 191 RL_i being the release limits for the key radionuclides. "Q" being the amount of water that contacts the waste, "C" being the concentration of each key radionuclide based on solubility, or inventory, or whatever else. This was one factor, this was the water contacting the waste and liberating the waste. Next one please. This performance factor recalling the influence diagram once again, was simply a measure of the travel time of the key radionuclides from effectively the waste form to the accessible environment.

When I say radionuclide travel time, which is really the ground water travel time carrying the radionuclide, coupled with the retardation provided geo-chemically, mechanically, however it may occur, such that you're looking at the actual it takes for the nuclides to get from the package area to the accessible environment. These were our two performance factors. Now we roll those up, if I might have the next viewgraph. I'm sorry before we roll those up at one point, leave that on, no, no back, back, back, back.

This is a, what I want to illustrate here, this being the radionuclide travel time, the pro-cumulative probability on the vertical axis. If you look at accumulative distribution, and even from the calculations that were made for ground water travel time and you see things like this in nature, in other aspects of how things are stacked up in nature. What it says here anyway is, that if you have a ground water travel time of say the median being 50,000 years, I'm sorry. A 100,000 year median, then there will be some water that gets out in about 10,000 years. Some that gets out in 100,000, about half of it will get about.

The water will make it out in a 100,00 years from the waste package area to the accessible environment. So, if there is waste dissolved out in the first 10,000 years, and you have some paths in which water can flow and it takes less than 10,000 years to get out. Then some portion of the waste that's dissolve out, will get out to the accessible environment. Very simple mind, just think of it in your mind using this type diagram. We roll this all up then into a couple of things to help our people when they scored the sites. And simply this is a table, waste form dissolution one side here, key radionuclide travel time here, and then the score 0-10 if you wish related to the cumulative releases.

Now what this says here for these combinations of circumstances and this is, each of these represents only one possible combination. There can be many combinations that give you the same answer, but for example, if you have extremely low ground water flow coming across the waste form the chemistry is such is hard to dissolve out the waste. We estimate the amount of release that you would get from the waste form in the first 10,000 years is about 10^{-4}, which will be what 100 of a percent, something like that, of that order. I'm sorry that's the releases. But the release that you get from the waste form less than 1%.

Then the travel time taking that into consideration. If it's a long travel time, good retardation capability, have long radionuclide travel time, then you can make an estimate of what the releases are to the accessible environment. This is one of the tables that we used or gave to the people who were exploring the sites and I'll explain in a minute. Next slide please. Then this is all rolled up into a diagram like this cause you have to give certain aids in this process that you go through to the people that do the scoring.

For example, on the vertical axis is a release fraction of the radionuclides dissolved into the ground water at the mole or core of the release limits. Starts at a 100 times the release limits, 10, 1/10 and so on. From the horizontal axis is the median travel time of key radionuclides. If you have a travel time of ground water of 20,000 years, you have a retardation of a particular radionuclide or on the average of the radionuclides of 100. That gives you a travel time of the order of median travel time of about 200,000 years.

If, for example, the conditions and the geochemistry in the water are such you dissolve out about a 10th of an EPA release limit in 10,000 years then the actual release that you estimate to the accessible environment is approximately 10 to the, that's an error there. It should be 10^{-3}, this is 10^{-2} in 100,000 years. This type of chart, but you could make these estimates on which to determine what the releases where for specific conditions. Okay, next. Now we're moving across that diagram. The next thing we did was to work, to look, have this group of specialist look at all the scenarios that could be looked at in this case.

For all the five sites. Not only the expected conditions but those disrupted sort of things and this is the process that they went through, and the screening process of selecting the scenarios, identifying them and then screening the out on the basis of two considerations. One being that the impact or the releases were negligible. The second being that the probability of the occurrence was less than one change in 10,000 in 10,000 years. According to the EPA standard. This is the process it went through. Next please.

These were, I'm going to. These two viewgraphs, this one and the next one show the types of phenomenon or types of scenarios that were considered. This is the expected conditions. Everything that we could fit unto the expected conditions for each of the sites. The types of things that were considered. The second scenario at the bottom is known as Unexpected Features. That scenario came out as a consequence of the process as you might say. If we have time I'll explain how. Next viewgraph.

These are the disruptive processes and events that we considered. Now for all five sites, the Geological type things, Tectonic Activity, human interference. A large set of human interference type considerations, including drilling ground water withdrawal injection, military activities, mining, underground storage, and all of this sort of things. And then premature failure of waste package, incomplete sealing of the shafts of Repositories. Now remember, the group is doing this for five different sites, not just for the Yucca Mountain site, but I'm only really gearing in here for the Yucca Mountain site. Next viewgraph please.

This was the set of scenarios that were screened to arrive for the Yucca Mountain Site. As we're moving in that process once again. I might mention that when this work was done and the scenarios were screened out, then the technical specialist met with representatives from each of the projects. To evaluate their selection or to look at how good their selection was. It was done totally in a vacuum without regard to what was being done at the projects themself.

We came up with four scenarios. Expected conditions, unexpected features, and an Extrusive Magmatic Event occurring during the first 500 years and after the first 500 years. This number three and four were simply a magma that comes through the

Repository area about 4 meters in width plug of magma that entrains portions of the waste and moves it to the surface. It could entrain it in such a fashion that it encapsulates it or whatever, but it goes through the Repository. All the rest of these were sorted our on the basis of not being credible or not significant in 10,000 years. In terms of releases or probability.

I might mention that for 100,000, for the time period 9, 10,000 years to 100,000 years, we only considered those scenarios that were initiated in the first 10,000 years. If a scenario was initiated in the first 10,000 years it was considered in the period 10,000 to 100,000 and that had to do in part with how the interpretation of 40 CFR 191 in decisions by the Department. Okay, this column has the probabilities and I'll say a little bit more about those and the expected consequences here TBD means to be determined which is part of this process. Next viewgraph please.

Okay, just to show you what the solubilities factors are, because we had to make some calculations in this process as to the amount of waste that would be dissolved out from the site at Yucca Mountain for various conditions. And these were the solubilities, these were taken from the Environmental Assessments and during the times periods these calculations were made as to what the fractional release would be from the waste forms for periods of a 1,000, 1,000 to 10,000, 10,000 to a 100,000 years. Okay, next viewgraph.

MR. ALEXANDER: Is it very small or is that the narrowing of the slide there? Is it very small?

DR. GNIRK: No very small less than one.

MR. ALEXANDER: Cause you have moderate to small. Okay.

DR. GNIRK: I think that's right. Okay, now I want to say, okay, let me just see what we have. Let me just back up for a second.

I want to say something about the probability in the assessments. Now we went through a very stringent process with the people who are the Technical Specialist in this scoring activity, in this Probability Assessment Activity. Effectively locked these people up in a motel for almost a week and we went through this process of identifying the expected conditions for each of the sites. Identify the scenarios, the disruptive scenarios for each of the sites. Describing out what these where and went through a probability "N" coding exercise, in which people were asked to make judgments as to the probabilities of these things happening.

High probabilities, low probabilities, and their best judgment. And you'll see that on successive slides where it says high, low, best judgment. Subsequently, we had these people group score the sites against our performance measures to rate these sites, and we scored in the scale of 0 to 10. I've converted everything here to releases. I'm not going into the actual scores themselves as such. Okay, to do the scoring now of the sites, you have to make these calculations. You have to determine the calculations of the amount of waste that could be potentially dissolved in the waste form. You have to make calculations of what the median radionuclide travel time would be and that of course is based on the ground water travel time estimates of the retardation.

This information along with the site characteristics, everything else was given to these people to make judgments as to what the releases were relative to those scales I showed before. This value of 44,000 cubic meters of water for a 1,000 metric tons of heavy metal of waste is based on the upper limit that was used, expected infiltration at the Yucca Mountain Site. It's the same value that's used in some of the extreme calculations that were put in the EA, that were in the EA by the project itself as I'll point out in a minute.

The releases from the Engineered Barrier System could be a fraction of a percent ranging up to almost 10 times the EPA release limits. Depending of course on what the volume of water that was in contact and how much was dissolved. The ground water travel time could be very long for the radionuclide travel time the order of millions a year based on the retardation. But you give all this information to these people, cause of discussions that follow that will facilitate by the lead group and they were asked to score the sites. Next viewgraph.

Now in effect you're looking at how the scores came out, but I don't have scores under the right hand side here. This has been converted into releases because we're interested in this case in releases, not in the scoring activity itself. What we're talking about in this portion right in here where these people made these judgments as to what the releases where. Considered judgments based on the information they have. We have the expected conditions, unexpected features, being a typo in your handouts, and the two magmatic events. The probabilities of the expected conditions for the site ranged from about 80% to almost one. Super confidence.

The releases in all cases for the expected case are very, very low. Even in the situation where they judgment on releases was pessimistic if you wish. The releases are still considered to be low. And how we got people to make judgments on what the releases were, parking the probabilities now on the releases, we asked them to give their best judgment and then a high judgment so to speak. If they felt the conditions were so favorable that there was one chance in 20 that the site would be better within what they expected. And to give a low estimate in the inverse of that. If they felt that it was one change in 20 the site would be less favorable, the conditions would be less favorable for releases.

DR. CANTLON: The releases you considered here were only the soluble not the volatile?

DR. GNIRK: That's right. Yes, okay. So you can, under the unexpected features condition you could get releases of the order of the EPA limit. I mean that were projected of approximately one EPA limit in 10,000 years and about 10 EPA limits in 100,000 years. Okay, so these are types of numbers we came up with. Next viewgraph please. Okay, this is sort of a summary of everything. Of all the, what we arrived at, and I've divided it into two parts.

The lower part is what you'll find in Environmental Assessment for Yucca Mountain. It's right along the lines which Felton Bingham alluded to yesterday in the calculations that were made. The upper part is how we rolled everything, how everything could be rolled up, how I rolled it up for the purposes of this talk in terms of releases. At the very top is the expected conditions, high best judgment, low. These are the fractional release rates from the Engineered Barrier System. These are the releases of the accessible environment for the expected conditions very, very low, very small.

Even at a 100,000 years approximately 35% of one EPA Release Limit. Under the worst most pessimistic conditions. What I've done in the center part here is to weight the releases by the probabilities for all the scenarios. So that the numbers that you see over on the right hand side are the releases from the given scenario, weighted by the probability of that scenario, summed over all the scenarios. And once again the releases are small. Even in the worst case in 10,000 years, of the order of 2/10 of an EPA Limit and 100,000 years about 35% of one EPA Limit.

The lower part as I said was what came from the Environmental Assessment for Yucca Mountain and the cases considered. The reference case which was the expected conditions at the site, very low fractional release rates from the waste, very low releases to the accessible environment. On the order of 10^{-7}, 10^{-3} based on calculations that were made by the Yucca Mountain Project people. And then below is the performance limits case, 10^{-5} for actual release rates from the waste is, relates to a performance objective. In Part 60 the instructions were to take an order of magnitude on either side of that release, that fractional release and calculate the releases to the accessible environment.

These conditions as such, considered not realistic at the site. Highly, highly unlikely, can't be, not credible. Once again the releases were very small. The comparative evaluation approach considering the scenarios and everything effectively bounded these numbers. Last slide please.

So what can we conclude here? All of this. Number one, the Department has gone through an orderly, documented process in which you select scenarios, determine if those scenarios are credible or significant by particular rules in a process involving groups of people. Of experts and specialist and have documented this in such a way that it's to the public. Based on those scenarios estimates of the releases to the accessible environment we made on the basis of the site characteristics, known site characteristics considering the uncertainties in those characteristics.

The results of this process of this evaluation showed number one, the releases are very small in 10,000 years. Well within the EPA Limits, the judgment that when you roll all this up. We found that the scenario of unexpected features was found to have the highest probability of occurrence among the set of scenarios considered disruptive.

Now, Warner North asked me back in March of 1986, did this really mean we were uncertain? And probably had a lot to do with uncertainty within knowing the characteristics of the site itself. But it's my opinion that this scenario of unexpected features is a scenario whose' probability will be considerably reduced during Site Characterization. Because in essence what you're doing is characterizing the site to determine as much as you can about the features and decrease the probability of unexpected features. This is what you do in Geotecnical Engineering.

I fully expect that the ends you have a residual probability that there will be unexpected features at the site because that's the way nature is. But it will be significantly decreased. Finally, as I said before, the releases bounded, that came out of the study bounded those recorded in the Environmental Assessment by the calculational techniques. I think I'm there, I'm three minutes over Donald. Thank you all very much.

MR. ALEXANDER: Thank you. I had forgotten about those comments from several years ago. I find them most interesting to be reminded of them. Ah, could you comment on the validation of this exercise and the academy review and else where?

Especially against the presentation we heard on model validation.

DR. GNIRK: How we validated this process? Well as far as the performance measures in the scale that I'm talking about, because I think you once again and maybe Kiley and some other people asked us to document things like that. And with my Associate, Larry Rickertsen. We found three separate cases in which we could compare our scales to make some notion as to if they made sense or not. One of which had to do with the calculations made by the site, by the projects for the site.

One case had to do with those conditions that were used by the Environmental Protection Agency in arriving at the releases that went into 40 CFR 191. And the third Larry, was a case from Carusa Sand Stone down in Texas with some, something that was calculated in that chart. But we put three of those cases in there to try to validate, to make sense of what we were doing.

DR. NORTH: The other point that I wanted to draw from you was the academies review on this whole exercise.

DR. GNIRK: The academies review on this whole exercise, well the bottom line it made us all feel very good at the end of the day. The compliments were very good.

DR. NORTH: I'll remind you of a comment that wasn't so good, which was that we suggested that the inputs from this furthest analysis might have been drawn from a wider circle of Technical Experts than that of DOE and its contractors.

DR. GNIRK: Yes, Warner that comment was made on, in two of the three meetings. That comment and other comments that were made were considered, were taken back by the Methodology League Group, and Tom Isaacs, who was the lead member at the meetings. Each of those meetings. They were considered by the managers and determined that because of time and schedule constraints, and certain sensitivities of what we were doing in all this, that the need was to keep it within the department, with the specialist.

But I also remind you if I might, in response to a question from Kiley and some other people at that time in which they asked. How would the answer, do you think the answer would have changed if we would have had a second or third group of experts? And I said in my opinion since it involved that process from A to zero, from A to Z that I felt we could take another group of ten people, a mix of Geologist and Geochemist and so forth, with the same experience. Put them in the room and taking the people who facilitated this, and the people who assisted us to do this type of scoring and the probability estimates. That the net results would not be significantly different from what we arrived at.

DR. NORTH: I think that would be a very interesting experiment to carry out.

DR. GNIRK: It would have been. History has changed.

MR. ALEXANDER: Don.

DR. LANGMUIR: Yes, there was a question asked Paul during your presentation, had they considered gas migration and your answer was no. And in that connection, what do you think that's going to do to this whole thing when you deal with radionuclide gases, radon, C14, C02? And related to that were any of the validation sites that you selected, ones in the unsaturated zone?

DR. GNIRK: No, none where in the, the answer to the last question is no, because what we were validating was the performance measures scale. In response to Warner question. Secondly, on the release of gases, I'm assuming you were talking about paragraph 14, it could trip you up. That was not considered as a scenario in this case, but however we approach, whatever the methodology we develop to approach the licensing and the EIS Evaluation. That I'm certain will be considered as a scenario, the Carbon 14 release.

There will be an estimate made as to what the consequences are and I assume there will be an estimate made as to what the probability is and however we roll all these things up. For one or the other Don. It will be considered, it's being considered now.

Thank you.

DR. NORTH: Thank you, thank you very much. One of the things that we've emphasized over the last day and a half, have been the ties from Performance Assessment to the Site Characterization Program. One of the of course important aspects of our work in Performance Assessment is to help in the guiding of design work that goes on. And the talk that Felton Bingham is about to give will talk, he will talk about some of the ties to the Design of the Exploratory Shaft for considerations of Shaft Impact. Felton.

DR. BINGHAM: Alright, lets take a look at the scope of the presentation and I'll explain what I'm about here. Recently there has been a set of calculations done to answer some concerns raised by the NRC Staff, about the Exploratory Shaft Facility at the site. To try to go through that whole set of analyses would be a morning, or a day, or maybe even a whole week.

So what I've elected to do instead of trying to present the whole set of analyses, is to pick a couple of examples. The heart of this talk is going to be running through those two examples, explaining what we did. When I do that, I'm going to do something I think maybe more important than just showing you what the details of those examples was. I hope to get across to you some of our ideas, our feelings about the way calculations should be done. Some of our underlying philosophies about the use of codes for example.

At the very end I'm going to try to tell you what the conclusion of the complete study was, just to wrap everything up. But I do not expect that you will be convinced by these two examples that those conclusions are the correct ones to draw. Alright, to put things in perspective let me talk a little about, well first the ESF itself.

There hasn't been a lot of mention made of it in the talks up to now. I'm kind of surprised that I haven't already seen a bunch of slides about it. For our purposes, lets consider it as something like this. An early part of Site Characterization is going to involve sinking a couple of exploratory shafts. Down through a pository depth, and then the installation at the Repository depths of a number of areas where experiments can be performed in situ (PH).

That's the, that collection of shafts and experimental rooms and drifts is known generally as the Exploratory Shaft Facility, I'll probably not come out with that string of syllables again, I'll just say the ESF from now on. That facility was described in the consultation draft of the Site Characterization Plan. And after it came out the NRC Staff expressed some worries about it.

I had intended to let you know that the things I'm talking about were done in a recent time period, but I find that it gets harder and harder now days to remember what year it is. This is suppose to say 1988, that's the time that the NRC Staff asked for these, for some more look at the set. Particularly the thing that we were worried about was this. That ESF will eventually become part of the repository itself. Now how can you be sure when you build it that you haven't somehow compromised the site, so that the repository itself is no longer suitable. The site won't work.

It's true that no waste is ever going to be implaced in the part of the workings that we're calling the ESF. But the question still remains, since it is going to be part of the repository, how can you be sure that it's okay? The DOE in response to this began a bunch of analyses about how the ESF could affect Waste Isolation in the long term. And the approach that the DOE used to answer this questions was to look at the changes that are going to be induced in the site by building the ESF and by the test that will be conducted in it.

Then to evaluate this question of how the ESF is going to affect Waste Isolation. The DOE looked at those analyses, analyses based on those changes, to see what the affect on Waste Isolation would be. That may seem like an obvious thing to do. I'm not sure whether you will regard it as obvious or not, but it may not be obvious if you think that another way of doing it, would have been to construct the full CCDF.

Like the kind a lot of speakers talked about yesterday, without the ESF in place. Then to do it again with the ESF in place and see what the different is. That would be the full perfect way of deciding what the effect of the ESF on Waste Isolation is. But I hope that after all the talks you've heard, you would agree with us that that would be very impractical to do. CCDFs' aren't the kind of thing that you want to do now.

I mention this not only because to say one more time, that CCDFs' are hard to do, but also to erase any vestiges that there might exist in your consciousness. That somehow total Performance Assessment is done by a giant computer code. That has in it a picture of the repository and the site. So that you could bunch a button and get a CCDF and then go in with a light pen or a mouse and draw the exploratory shafts over 5 meters to the right and punch the button and get the different CCDF again. That of course is not the way that a total system is going to be assessed at all.

That it consist of putting together a lot of different pieces and then making judgments about them all. Is there any doubt now that you believe, that I believe that the CCDF would be impractical. These are a few words about how that complete set of analyses was done. The idea is to begin with some data on the locations of the shafts and the test rooms and how they are to be constructed. Then to try to look at the fluids and materials that are going to be introduced in them, to try to compile a data base of what we expect is going to happen in that ESF.

Then it was possible to try to do some of those analyses to look at the effects on the Hydrologic conditions at the site, the Geochemical conditions, and the mechanical conditions of the rock. What changes will be wrought in those areas by the ESF itself? Those effects look not only, those analyses look not only at what the effects would be, but it wasn't very persistent or not. Clearly things that are transient, that will be gone shortly after the repository is closed wouldn't be expected to affect long term Waste Isolation. But it's important to try to find the affects that will persist on into the isolation period. Up to 10,000 years after closing.

These data are all and the analyses are summarized in a section of the Site

Characterization Plan. A full understanding of those analyses requires going back beyond these summaries that are here and look at the reports themselves. That's, and there are lots of those reports. There dozens of these analyses and that's why I say I don't stand a chance of covering them all today. And to predict only two examples and the two I've picked are from the Hydrologic analyses.

Now this will be example one. Let me say before I begin these that in contrast to the kind of personal expertise that Professor Pigford is going to bring to his talk after lunch. There are gaps in my understanding of some of these analyses, I didn't do them myself and it would be very easy for you to ascertain that I didn't do them. It's embarrassing for me to admit that now, but I think the embarrassments a little less taxing then the mortification I'd feel if you asked a series of probing questions and then discovered that I didn't know about it.

So, I won't hesitate to say I don't know when the time comes that I don't. To build the exploratory shafts the methods that are to be used, it's conventional drill and blast. But in the drilling and for dust control, water is going to be introduced to the shaft. Nearly all of the water will be taken back up again with the muck as the broken up rock is removed from the shaft. But the question remains, what will that water do? Will it change the characteristics of the site enough, perhaps to invalidate the site itself as a good place for a repository.

Well this is the approach that we use to try to find out about that. We started off with an analytical solution and this is the first of the philosophies that I want to point out to you. I think that as a group, we in the total system Performance Assessment business trust analytical solutions more than we just giant computer codes. I think its our prejudice that we like to begin with analytical solutions whenever we can. And it's a second point of philosophy that we like to try to do things that are sort of bounding analytical calculations to start out with.

The danger in that always is that people will then assume that those bounding assumptions you made, which sometimes can even be kind of silly, of what you expect a site to be. But we think that running that danger is probably worth the advantage you get from scoping out a problem first, by looking at what its bounding affects might be. I want to say a little about the results of that analytical solution. So Bob if you'd move the clear slide over to where the green slide is, and put the next slide on tope of this machine.

This is a picture of some results of that simple analytical solution, which were basically just geometry. Supposed you take all that water that you think is left in the shaft and people who are familiar with this kind of operation told us that about 10% of it would probably be left behind after the muck was removed. Suppose you just assume that it all ran out into the sides. How much would the saturation in the rock change? Well this graph may not be exactly what you think it is. It says, suppose that the water ran out only so far, to some radius and that the rock were uniformly saturated throughout that entire radius. How much would the saturation change?

Well this says for example that if, all the water were contained within about meters of the shaft center line. Well we'd get a number that looks something like this. That if it were uniformly saturated that kind of distance, the saturation would change by 2% or so. But if it were initially 85%, it would be about 87% in that region. If the water does manage to get all the way out to 10 or 15 meters, the change in saturation, assuming again that the rock is uniformly saturated out to that distance, would be less than 1%. And this kind of thing looks a little convincing.

It's hard to believe that a 1%, a change of 1% in saturation over a limited area will really affect Waste Isolation. And in particular for the testers who may have to do experiments that look at saturations very carefully. It's hard to believe that those experiments are really going to be capable in even detecting changes that are down here below 1%. This is the kind of calculation that gives us the feeling of what we might expect if we did a more complicated one.

The conditions, the assumptions made in this, tend to over estimate the saturations. We think these are about as big as the saturations could be.

DR. LANGMUIR: Felton, has anybody measured the conditions rates of the TUFFs'? It's such an easy thing to do.

DR. BINGHAM: Yeah, there are some experiments that measure those imposition rates.

DR> LANGMUIR: How do they compare to this?

DR. BINGHAM: But, they are not strictly comparable to these, because these depend on a number of other things. Like the depth, the particular rock in which these calculations were done. Generally, speaking the imposition rates seem reasonable, but I'd hesitate to quote them as validation of this model we're using. And this model of course is a bounding model. It tries to over estimate. We think that a change of even as much as 5%, very close to the shaft itself would be very unlikely. But to look at that in more detail, we'll run over to the second bullet that's on the far slide over there.

Lets get out one of the big computer codes now, because it can help us do some other things. Time dependent movement through the rock for example. This all has to assume a steady state, has to assume some unrealistic things about saturation. The NORIA Computer Code as this points, is a big finite element code. It can handle water and vapor and air and energy transport in the porous median, but it uses the complex kind of description of hydrologic properties that we have, that Dwight eluded to brief. And I've got a slide, Bob, if you'll put that on the close machine.

This is the, this is oneway of expressing hydraulic conductivity of our kind of rocks as a function of the negative pressure head. The point is, this is a very steep curve over a small change, relatively small change in pressure head. The hydraulic conductivity may change by several orders of magnitude. That makes the equations that are to be solved very non-linear. Impossible to do analytically. That's the, the NORIA Code uses curves like this, which are thought to be among our best descriptions of the hydrologic properties of the site. To get a better edge than the simple analytical solution can give us.

To use the computer code, the third bullet there expressing one of the boundary conditions. It was assumed that around the shaft the rock is going to be broken up. It's permeability will be increased in a region called the Modified Permeability Zone, the MPZ. And the assumption there was that the permeability would increase to 80 times the original permeability existing around the shaft. I have a slide that shows something about the, some results of the analytical model that let us think this. This is also useful cause it has a little picture that I probably should have showed to start out with.

If the shaft looks like this, and its radius happens to be 2.2 meters. This is the region out here around the shaft where the water would move and where the Modified Permeability Zone would exist. The analytic solution began by looking at the stresses that can be expected to be exerting in the rock. By using field data to extrapolate and this gets a little swirly, between calculated stress and changes in permeability that actually occurs as a result of those. But after that kind of calculations, what is done, we got a curve that look like this.

It shows, you get out from the shaft by distances like these, the permeability changes by numbers that are at most on the order of 10 or 50 or something like that. And quickly a few meters away drop down to be very small. The assumption made here was that in the Modified Permeability Zone the large number that's up here, 80 was the thing to be assumed. Since this calculation is a very uncertain one, this is another of our philosophies. That when we do have a lot of uncertainty in calculations we'll tend to go with the conservative values. Since 80 was the biggest number that this kind of analysis suggested, we decided to use that for the whole Modified Permeability.

DR. DEERE: Question, but isn't it true that you're dealing here with sort of a uniform case in the effect of the existing rock and the existing fractures not being loosened by a blast? In other words we can have one fracture that can move a three, four, five millimeters and suddenly its permeability doesn't increase by 80. It increases by 1,000, 2,000 or something like that. So, as we get away from the shaft, then of course we get back into what you are showing there. But I would think that figure of 80 is highly suspect when it's dealing with opening up of fractures.

DR. BINGHAM: The fractures that already exist?

DR. DEERE: Existing, yes.

DR. BINGHAM: I think the idea here was to try to look at a sort of a bulk feature of the rock contained. Those things that you were talking about would probably happen in very close. Like a meter.

DR. DEERE: They will, but that is what will carry the water. I can't be concerned about what happens at one meters, two meters, five meters, because they'll have the kind of changes that you're showing. I think these are realistic, but the changes closer in can be very much more irregular, but also very much greater.

DR. BINGHAM: They certainly may be, but I think that the. Let me remind you though of course that, the use of the Modified Permeability Zone in this calculation is a reservoir to hold the water. So that it then can move out at farther distances, because the distances we're concerned with the distances away, if waste is going to be implaced away from the Exploratory Shaft Facility, is considerable. It's tens of meters away. So that little changes that are occurring in the first meter are considered in this calculation to be ways to let the water get in fast. To be held immediately in this Modified Permeability Zone so that then it can seep out over time.

MR. ALEXANDER: So Felton, isn't this a bulk value that's averaged over the total rock mass in that interval. Because opposed to a local change that could be a 1,000 fold, or a 100 fold Don. I think you're talking about something that's averaged over a the total volume within that interval.

DR. DEERE: Yes, but the experience that we have in not only talks about other low permeability rocks that you don't see the water necessarily seeping very slowly in a wet surface. You see water running out a crack. In other words the water thats coming into the floor and coming into the think is coming through one discrete opening fracture.

DR. BINGHAM: I have some more to say about fractures and we may get back to that. Remind me if I don't answer what you're saying. Alright, lets look at the next slide. This is a result now from the NORIA Code. For rocks at the Repository Horizon, this is again radial distance from the center of the shaft. This is saturation. The initial saturation in this rock is shown by this line. Almost 86%. The Modified Permeability Zone, we'll assume be here ar like five meters. After one year the saturation profile predicted by the computer code looks like this. After two years the water has moved out a little farther and it continually moves out farther.

After a 1,000 years the saturation has changed, you see by a fraction of a percent and is still of course somewhat higher than the aim is, but it's still a very small change in the saturation. The computer code resulted in and agree with those bounding calculations made analytically. The assumption here is that the water moves out in fractures and then is absorbed and bond by the matrix. And that's what leads to this, to the curves that look this way. Okay.

This summarizes the results of those calculations, mostly on the basis of that picture I just showed you. The water moves pretty slowly, it takes it a long time to get out very far. The saturation increases when you get farther than five meters away, for small always less than three percent. And at 10 years the water had moved at most able 10 meters in the shafts [inaudible]. But even there the saturation change is very small.

Now this has to do with the matrix. What happened to the fracture question is what's addressed by the next slide or two. To estimate how far the water would penetrate in a fracture is another matter. So here we again went back to an analytical model, that just tries to go from the fundamental equations for how a capillary opening will pull water. Two analyses, one assuming that the matrix is impermeable so the water stays in the fracture and can't go anywhere. And one assuming that it's permeable, so that the water does get in by it. And, in this calculation we tried to use data that are sort of representative of what we think the hydrologic properties in the rock at that depth are.

The next picture shows a little bit about what the calculation looks like. Here's a surface you put water on the top, it will begin to soak into the matrix but some of it will run immediately down the fracture. As it goes down the fracture it gets invived into the matrix. I tried to get a couple of equations out of that paper to show you. To prove to you that we were being technical. Unfortunately all the equations in it are in dimensionalist units. The kind of thing that I figures it would take half an hour just to explain what the units were.

So I will refer you to the original report. If you'd like to see those, the equations that were used in this and just go on to showing you what its results were. This is kind of a result that you can dig out of the dimensionalist units. That the penetration distance in a fracture depends on a square root of this ratio. Matrix to fracture permeability, but the, our Repository Horizon the results look like this.

As you let water the water infiltrate for 30 minutes and that seems to be kind of a reasonable time for about how long it's going to be sitting out there. If the fracture aperture is at 25 micro-meters wide, then the penetration distance is less than a meter. If they are this much wider the penetration is still less then 10 meters and the data that we have on the fracture apertures in this unit, so they are generally much less than a 100 micro-meters. So, this would be kind of an upper bound for how far we think the water would go in the fracture.

There are some other studies that give similar results. The previous slide mentioned the Mortineis (PH) is the source of this and there are a couple of others like Varsson Quickless who get, that get similar results. If you look at their papers. Now let me warn you about the thing that led me astray, in looking at first in them. They do assume a higher head of water pushing through the fractures than what we assumed here, which it was essentially zero head because there really isn't any stack of water setting in the shaft pushing out into the fractures.

This is a picture of some of the results that come from it with that impermeable matrix and what we think a realistic matrix with a Topopah Spring. The time and seconds that the water is sitting on the surface, this is how far the penetration of the fractures will go. For this one you will notice that out at the 30 minute kind of time range, we're out at something like five, five meters, six or something like that. Well this is the schematic to try to sum up what we had. If it's just matrix flow, the kind of things we got with the NORIA Code and the Analytical Solution.

The places where the saturation changes tend to be very significant more than just a couple of percent are in very close, they are on the order of centimeters. The fracture flow for little apertures runs out to be about a meter at a 100 micro-meters, it runs out to be still less than 10 meters. But the waste itself is going to be more than 30 meters away by design. So we sight this as evidence that the water introduced into the shaft is not likely to reach the waste and is therefore, not likely to affect Waste Isolation. And I guess that's what shows up on the next.

The changes are transient, the stay only about 10 meters away, so the water won't reach the waste. Still there were recommendations to the people who were drilling the Exploratory Shafts, don't use anymore water than you have to. Don't put anymore head on it than you have to. Use as small a volumes in any particular place as you can get by with it and then go ahead and tag the water you use. So, that if in the experiments some water shows up that's not expected, it will be possible to identify it as having come from the exploratory shaft.

Alright, the second example. There was a question of, if you have a shaft and the area around it floods, won't the water from the flood run down the shaft and fill up the repository and destroy the Waste Isolation Characteristics of the place? Well we had a couple of examples about this and I'm particular please to report this because since we decided on what would go into this talk, we've heard the NRC Staff preliminary comments on the Site Characterization Plan. And I think the phrase, and I hope this is an exact quote from the staff member who made the presentation on the Flooding Analysis were that it is satisfactory and acceptable.

Alright, we looking at liquid phase movement through the shafts. We want to assume a probable maximum flood. I'm going to ask you Bob to do the same thing with this slide now. Put it over on the far machine and let us see the next one. The first thing, to put this in perspective I want to point out that these shaft collars are really way above the elevation of the probable maximum flood plus debris. This is a cross section through the ground. The shaft is said to be in a wash, Coyote Wash. That's this surface here. Water does run in Coyote Wash.

Up here along the side is where the collar for Exploratory Shaft Number One is going to be. This shows how some of the existing hill will be taken away. A pad will be built, but the probable maximum flood, including the debris that raises it higher is down here somewhere. So on the surface of it this makes things look as though the flood waters themselves are not likely to enter the Exploratory Shaft itself. But that doesn't satisfy everything of course. How about the possibility that water could get from here or that something else happens during a large thunderstorm or a rain storm, to make water get into that shaft.

Well several analyses have been reported. I'm going to present just two of them. One that's a kind of a bounding case and this is also intended to illustrate this prejudice of ours. Lets start off with something that looks Bounding and then what we think is more realistic case. This is intended to show you a little more that the water isn't likely to get there. There are a number of washes around Yucca Mountain. One of the most prominent ones that every visitor see is called Forty Mile Wash. It drains 312 square miles and the peak flood discharge is about 540,000 cubic feet per second.

Coyote Canyon where our exploratory shafts are is much smaller. It drains only a couple of tenths of a square mile, the peak flood discharge is this much. On the basis on the kind of cross sections and roughness factors that appeared in that previous slide. The mountain water it would take flowing through Coyote Canyon to reach that first exploratory shaft collar would be this number, which is something like 45 times as big as the probable maximum flood. To get to the other collar it requires even more. Further evidence that the flood waters aren't likely to get to the collar.

Well, here is how we tried to do the bounding case. Lets assume that there is an intense rain fall in Coyote Wash produces a problem maximum flood. That all of the rainfall is going to infiltrate to ground surface and for purposes of analysis there were two things assumed. One that is uniform over the whole area and another is that it is just concentrated. All the water runs down into the drainage courses and infiltrates there. Now Bob I'm going to ask you to do the switch with the pictures again, because the next couple of dots that are there I want to illustrate with a picture.

The assumption here is that none of the waters retained in the formation, but that if you break up either the whole area around the Exploratory Shaft or the Drainage Courses into a series of discrete elements. The water that moves from that element into the Exploratory Shaft is determined simply by the angles subtended by the shaft at that element. This is a uniform dispersion of the water. This is an assumption that the fractures are so close together and so randomly oriented that there will be a path from any surface element to the shaft determine by that angle. That's what the last three dots there is suppose to be about.

Well the results of that kind of analysis, which are describe in detail of course, since the reports are that the total amount of water in either one of those cases. That you get in the Exploratory Shaft is about 1,200 cubic meters and that's a volume that could be contained within the ESF without moving the out into the rest of the Repository.

This much water pures down the shaft and enters the ESF it still doesn't reach the waste and that's the second bullet. But at a time we did this bounding case, it's only common sense to try to think but now there are a lot of unrealistic assumptions made in this that are outlined in the report itself. What would a more realistic answer give us?

And the people who did it thought about it for awhile and said, suppose you, certainly run-off is going to be a factor, not all the water is going in the flood. Some of it's clearly going to be retained within the formation.

Just considering things like that, you'd guess that it's likely to be one to two orders of magnitude less than that number. Actually going into the shaft. So that's what the realistic analysis think. This is another probable maximum flood event. Two kinds of problem maximum floods, one that results from a general storm and one that comes from a thunderstorm. The idea being that a general storm last longer at a lower rate. A thunderstorm puts more water in a short length of time right on the site. The assumption is that all the surfaces, all the fractures in the other surface are open and ready to accept water.

That's not exactly a realistic assumption, but it seems to be a conservative one. And if you can swap the slides again Bob, I want to have a picture to go with the next couple of dots. This is an area view looking down at the site. Here are these two Exploratory Shafts, here is the base of Coyote Canyon, this is Coyote Wash running this way. A tributary that comes in this way, and these lines show the heights, if we had all the contour lines on here. These lines would show the heights for which the probable maximum floods will make water stand there. And again, as you can see the water doesn't get close to the path. But here the rain fall water is assumed concentrate in here, and also of course the fall on the pads.

Some of the water, it doesn't go into the canyon will infiltrate the areas around the pads. Now it's certainly not true that the assumption made in that bounding analysis is right. That all the fractures just somehow manage to divert the water into the Exploratory Shaft. Most of them are not going to divert water toward the shafts at all. They will divert it somewhere else. So a calculation was made as part of this, again described in detail in the report. To compute zones of influence, for several, several cases depending on the degree of enthusiasm and conservatism. To decide over what area will water that falls on the pad get to the shaft.

The next slide is the going to explain the results of that. The total predicted flow then from either event. The general storm or the thunderstorm is less than 50 cubic meters going into the shafts. It turns out that the drainage channel under these more realistic assumptions doesn't contribute any water to the shafts at all. Because of this assumption that's made here. It wasn't made in the Bounding analysis. As the water moves to a fracture the matrix of course is imbibing as it goes along. As you get all the way from the channel in the Exploratory Shaft it seems very unlikely on the basis of the calculation that are presented here.

T3SA This volume can easily be contained, 50 cubic meters isn't very much at all. So again the conclusion is that the water won't reach the Waste Emplacement Area. And I sight this as an example of the use of Bounding calculations and then more realistic ones to build probably a more convincing case. Then you could have had with either one of alone. The whole study all the analyses that are reported in the FCP reach this conclusion. That the presence of the ESF is not going to compromise the ability of the site to perform as a Repository System. And the reasons that are summed up in this EPA are these.

The first is that the changes to hydrologic properties calculated in these analyses show that they are limited in extent. They don't occur over very big areas, they are localized, just as the changes, the significant changes in saturation in the matrix are confined to a region very close to the shaft. The changes to water flux through the site are small and they also are limited in extent and the penetrations that are made.

Like the shafts themselves don't create preferential pathways for releases to occur. And some subconclusion that are made that lead to that are that, these localized effects generally occur a good distance away from the implaced waste. The ESF itself, I haven't mentioned, is designed so that it will drain away from the waste in case any water were to reach it. And furthermore the penetrations are to be sealed that pouring water into them is not a likely way to fill up the ESF with water.

Now I don't make any pretense to that I've convinced you that these conclusion are true. I presented you only two examples of a lot of other analyses and I presented these in a kind of a skip over fashion. Though Pulte described them a fairly thick and difficult to get into. As I say, I sight these in summary as an example of the way we think things should be done. And as I listen to the discussion this morning, I thought of one more point to endorse. Dr. North raised the point that the use of models is application dependent and I want to heartily endorse that.

One of our objectives in making the Quality Assurance Procedures for example, for validating models has been to take that into account. That no model will be validated so that it's useful for any use that an Analyst might wish to put it to. The particular model that we used here, the NORIA Code that I mentioned in the first one, is a very generally applicable code. But, we have put into our own Quality Assurance Procedures the notion that any Analyst who uses it must include in his documentation, the reasons why that code is at least in his opinion and in the opinion of the reviewers who pass on his work, an appropriate code to use for his calculation.

I couldn't resist bring that up having heard it this morning.

DR. NORTH: Good.

MR. ALEXANDER: Are there any questions for Felton?

DR. DEERE: Is the topography a down stream of Coyote Wash precipitous enough that there might be a land slide induced by prolonged rain fall? Like you'd get with the PMF or the PMP. This is something that happens very often and with a very heavy rain storms in dry areas and in many countries. And the temporary dam that has formed by the land slide will raise the water level as high as the dam happens to be, until the dam fails. And creates another flood down stream and that may be from one or two days to several months or never. But until we visit the site I don't know if there is any topography that is sufficiently precipitous with respect to the elevation of the shaft, for this to be even plausible.

DR. BINGHAM: Yeah, it's certainly possible for Dams to form down stream, but I think that the argument that is not likely to pure water directly into the shaft, depends on the comparison of those elevations that I showed in that cross section. It would be a very high dam.

DR. DEERE: What are we talking about 50 feet or a 100 feet or a?

DR. BINGHAM: There were sizes like that to occur in a wash with that shape. It was piling up a lot of dirt and I think we probably need, you'll feel better when you've seen it I think.

DR. DEERE: Yes, I hesitated to ask this now, until I'd seen the site but I wanted to make sure I didn't forget the thought.

DR. BINGHAM: And it's certainly not one that the Analyst neglected either.

DR. NORTH: We're almost right on schedule.

MR. ALEXANDER: Yeah, Felton really let me down but it turned out that it was my question and then a couple of questions at the end that slowed him down. So actually he did a great job, and I appreciate it, thank you. What I'd like to do is recommend that maybe we get back together at maybe five after the hour. Just allow one hour for lunch, so that we can try to stay on schedule. If that's okay with everyone?

I'd like to give Tom Pigford the benefit of his full 50 minutes and I think you'll really appreciate that. For people that are interested in corrosion, the sciences, Metological Sciences, and Geochemistry, this is going to be a really exiting session. I hope to see you back after lunch.

DR. DEERE: I'd like to make an announcement if I may.

MR. ALEXANDER: Sure Don.

DR. DEERE: Cause perhaps some will not be back this afternoon. I would like to announce that the next full meeting of the Board is the one scheduled in Los Vegas from June 26th - 28th. And the state of Nevada has been invited to present on the first day their Technical and Scientific Assessment of the Yucca Mountain Repository Site. And the second day we are planning on being brief by DOE and their related groups on the Yucca Mountain Geology, Hydrology, and Geochemistry in greater detail than we have had to date. About what is know and what is not known about these areas.

On the third day there will be a field trip to Yucca Mountain Area which is very important to the members of the Board who are very interested now in seeing it physically. And we will have a chance to observe the geological outprops, perhaps some of the trenches that have that had been made. The general topography, the presence of susceptibility to land slides due to prolonged rain fall. Rock core samples representing the various strata that are present etc. We looking forward very much to that meet.

The next meeting of the panel group has been set tentatively for July 24th and 25th, and this will be either in Washington, or Albuquerque. This will be the first meeting of the Panel on Containers and Transportation and the agenda items will be developed next Thursday after the DOE presentation of their MRS thoughts. And these items will develop by Panel Chairman Dennis Price, who will be up here next week together with Executive Director Bill Koons and myself. And we will be discussing these items with Tom Isaacs and his colleagues, including their Transportation and Container Specialist.

-- Lunch: 12:08 p.m. - 1:08 p.m. --

MR. ALEXANDER: Okay, before we get started on the next presentation. I'd like to let everyone know that there were two copies of Tom Pigfords' presentation that were passed out. Be sure to get the copy that's stapled in the upper right had corner. Okay, that's the latest version. Some of the formulas were missing in the original text. In this, just to remind you, in this final session, you'll be hearing a lot about Waste Package Modeling, Development both at a third level as we characterized it early in the meeting and at a Subsystem or System Model Level. And try to keep in mind that we're using this as an example of how we're developing modeling capability at a subsystem or system level, for use in addressing the Regulatory Requirements.

It's really not suppose to be an in-depth treatment of Waste Package Modeling per say, though you'll get a lot of that through these talks. But it's suppose to represent the kind of coordination and collaboration that is taking place in our modeling community. And I think that you'll find that Dr. Apted, and Dr. Pigford represent that kind of collaboration very well. So without further ado, Tom Pigford is going to talk to you about his work. Tom.

DR. PIGFORD: Thank you. The first thing is to clarify what my work is or maybe what's not. In spite of a lot of things that have been incorrectly said so far. I'm not going to speak to you about Container Corrosion or Container Failure. It's a very important subject but that is something that should be discussed at some future meeting. I will indeed attempt to talk about some of the implications of Container Failure, how and when.

I'd like, I'm delighted and surprised to hear about Felton Binghams' trust in me, but I don't have it myself. And so I'll tell you we don't know really enough about any of these things and my purpose is to confront you with some of our ideas and learn from your reactions. Our theme at Berkeley has been on Analytical Solutions and I didn't realize that that was accepted as much as it's being accepted by Felton and I'm glad to hear that.

We've been at Berkeley, in, working in this field for DOE and various offices now for 12 years. We got into it in studying Far Field Transport and are still working on that, but my focus today is on the Near Field Transport issues on the Waste Package. Now I'm not going to talk you, tell you only about what we do at Berkeley, but attempt to summarize what I know of the various approaches by the many groups in this country on how to develop the modeling of the Waste Package Performance in Terms of Release Rate. And perhaps because we are in a University atmosphere we found it easy I think to work with all of the DOE groups. Some of them, I find are very cooperative, some of them maybe your surprised to hear this, but we have learned a lot from the work at Savannah River, Catholic University, Besado (PH), Brookhaven Laboratory which has supported DOE, Livermoore Laboratory, Pacific Northwest Laboratory and we've learned a lot from the Canadians and squeeze the British, the Swiss, the French and more recently the Japanese.

Now they talk about some of that too, because all of these provide some inputs to our knowledge and also inputs to assessing the validity of what we come up with. There are three general models for the Waste Package Releases in Yucca Mountain. One is the Dry Scenario. And the Dry Scenario is what I believe the project expects to be the most likely case. Namely that the hot waste dries out the rock and it takes thousands of years for it to recover back to ambient conditions and even then it's not expected that moisture will penetrate through even the officially failed containers.

Why because the failure is expected to be localized cracks and not general corrosion. So you don't expect to see the metal disappearing, there will be small penetrations. Gases can escape and on the dry scenario the gas issue seems to be the important one. However, preceding along the lines of being more conservative and developing models in that direction. There are two general categories one called the Wet-Drip Scenario and its not intended to be for jarrative (PH) at all.

This is the one that the Livermoore Laboratory has fostered and appears in the EA and is discussed also in the SCP and the Wet-Continuous Scenario which is an adaptation of some of the best transfer models at Berkeley and other places that first appeared in the report of the Waste Isolation System Panel of the National Academies. We actually did that work for that Panel beginning in 1981 and it is concentrated at Berkeley and other places. Now the next slide, the ones with the yellowing.

The goods news is that I'm not going to show all the slides. Messrs you'll have to find where I am and if you want the page number I'll be happy to tell it to you. Alright, the other slides were put there for several purposes. One to help answer questions if they come up, also to stimulate your imagination and curiosity to ask questions and clearly whatever other purposes you might imagine. Here is the schematic of the Wet-Drip Scenario, which is the one that Livermoore Laboratory has fostered.

Here they imagine a waste container and it's important to note that in this case it's in a vertical bore hole in the TUFF. And there is a air gap between the container and the rock. Bottom and top, all around, and that air gap is very important. It breaks the pathway for diffusion from any material in water that may be on or near the container to the rock itself. Now, if this container doesn't fail. It's not an issue in terms of release rate, but imagine if the containers have survived their failure criterion for about a 1,000 years and they have failed.

I'm going to come back later on I hope you'll raise the questions what constitutes failure? But at least I'm going to assume as the Livermoore does that the failure is by localized penetration. Stress corrosion cracking or the cracking techniques. And water which may drip or it may not drip onto the container from the rock above, and this can happen only after the thermal period. Where the Repository rock has cooled down, down to the neighborhood of around 94 or 97 degrees centigrade, water can drip down.

It's assumed that it penetrates into the container and starts filling it up. And in this model they multiple White Hoxes, Dorsey Flow Rate, .5 millimeters a year times a cross sectional area and get the, and they get now Mick, excuse me. As useful as those are I think it may be a little disruptive because I'm not going to use it.

So lets just stick to the yellow ones right now. And so they calculate that about liter per year can drip onto a package and if the package is failed in a way that that water can penetrate and there is a big uncertainty right there. It can fill up and there is about one cubic meter of void space in the package as now designed and so that means that it will take around a 1,000 years for it to fill up. And then it can either drain out through another penetration at the top, or maybe it doesn't fill up and drains out at the bottom. It's also important that drip out to the rock below and not form a continues pathway.

Now how to calculate the release rate. Conservatively, they've assumed that water gets in and gets out, and they've assumed that the fuel rides which are clad in Zercaloid, which is a very powerful containment, have no Zercaloid around them. The Zercaloid is assumed to be missing and so this water contacts the fuel rods directly. And it's assumed that the low solubility species, Uranium and the Actonides mainly come to saturation and that water dripping in, and the release rate model is a very beautiful and simple one.

It's a one line statement that the release rate is the volumetric flow rate of water, one liter per year. Times the solubility of each one of those species. That's for the low solubility species. The next slide shows the result. Now I'm a little embarrassed because this is one of the slides I didn't draw and if I were careful I'd recognize that such a simple model can never produce so many inflections in it. And that's just drawing draftsman error.

However, it's exactly what I got from Livermoore, so it's not my draftsman, it's their draftsman. But what is it? This is a plot of the curious per year of the Plutonium Isotopes that you see coming out in this drip versus time. And this is assuming that the a, it gets down to the dry disc, up to the moisture that you can have dripping the temperature, in a little over two thousand years. Now why does the Plutonium 240 go down and the Plutonium 239 go up? It's because the Plutonium 240 half life is life is shorter, 6 to 600 years. The Plutonium 239 half life is longer than 2,400 years.

The two together plus Plutonium 242 combined to make up the elemental solubility which in this case is assumed to be 3 x 10 to the -10th molar. And so as the Plutonium 240 decays away, Plutonium 239 can come to a higher concentration with a solubility limit and that's why its release rate goes up. It's that simple. And it's also a very lice (PH), because its a very low release rate. How low is it? Curious per year is one measurement, but if you convert that to grams per year and divide by the inventory. This turns out to be a fractional release rate of around 10 to the -11th per year.

Is that the most conservative release rate? As a matter of fact no and I'll tell you later on. Why not? However, many of the radionuclides are not solubility limited. For example tec nitiam in this environment is not. The next slide shows what happens there. Here then we imply another release rate model. No longer can we get this by multiplying the volume floor rate, drip rate of water by the solubility because, well there is a solubility rate for tec nitiam but I'm afraid its a little high for this purpose. Instead we go to another model.

Experimentally, Livermoore concludes that there is a constant Alteration Rate of the Uranium in spent fuel going from U02 property, to the alternation product U307. And it's a solid, solid alternation caused by oxidation from water and dissolved oxygen. The laboratory data suggest that species are released congruently with that alteration rate. That's not congruent with the net release of Uranium into the solution. Congruent with the solid alteration rate. And they use a value of 10 to the -3 per year. I'm going to tell you later that I think that's perhaps very, very conservative and I'll tell you why.

I think it's possible that experiments may come up, if done, extended for a longer period of time to a much lower volume. But they assume 10 to the -3 per year and that happens to be the fractional release rate of tec nitiam into the water. Now, what happens then as the water fills up the container, because you're exposing slowly a little more fuel, unclad fuel to this dissolution of tec nitiam, as the water fills up. When the work first water hits the top of the container and it's not plug flow, it's well mixed. THen you've got the maximum release rate of tec nitiam. And fractiously that's a little of 6 x 2 to the -4 per year.

And that's why I think it's very important to explore the possibility of a lower alternation rate than this one, which has to be done experimentally, but guided by theory. By that time actually all the uranium has been alternated if this is the right rate. And so what we're seeing then is the drop in the tec nitiam release rate do to dilution of more drip water into the filled container and overflow for the top. I guess we all next all the time. That's their model for the soluble species coming out to matrix.

There is a third group of radionuclides that was mentioned this morning by Charlie Voss. Namely those that were already released from the U02 matrix during reactor operation, and I'm afraid some of them will continue to be released after that. Mainly those in what we call the gap. And the grain boundaries, the pores, the gas Plutonium in the field rods declared you ought to interface. Now I'm not going to show you the results from the Livermoore model on that, because I don't have any, and I think their just beginning to flush out that model.

In my notes I'll give you what I think is a concept of the model, but it requires a quantity de sigh (PH) DT, which we haven't decided yet how to evaluate. So all of that is just a hopeful mathematical statement. I'll have to then return to that issue and I'll show you as the alternative model that I'm going to go to right now. The alternative model is more conservative and less realistic. We imagined here that we have a waste container and it's badly failed.

In fact I'm going to assume that it's so badly failed that it offers many, many openings or diffusion of liquid. Contaminated liquid from inside the Waste Package out. And there has to be a continuous diffusion pathway from there into the rock. How did that occur? If this Repository were to get saturated then it would be a continuous diffusion pathway of water. Or leaving it unsaturated, if that 2 centimeter air gap were to fill up with expoligated (PH) spoiled material, what drop off or if the rock mass itself in jointed sections were to move in onto the waste container? You do have opportunity for diffusion pathways.

I can not defend the assumption that the container isn't there, but this is the same category as our previous assumption to zercaloy clay is not there. We're going a little further. And it's worth going further to see what this might result in. The next slide shows that. Now this is the beginning of the Chemical Engineering Type Mass Transfer

Theory that we introduced into the Report of the Waste Isolation System Panel, that was published in 1983. And we introduced it in 1981 because it took us two years to write the report, because we were greatly concerned at that time that we found no really convincing model of the source term in the Repository.

Now here we imagine a simple Waste Sodded, say a cylinder, looking at it in In View and in the simplest case surrounded by Porous Rock. Now some of the rock may be fractured, I'll show you later how we deal with fractures in the rock. If they are there you may have an intervening layer of specially prepared clay. Back field I call that, I think that's the wrong word in this project. They call it packing. It's not presently in the design, but the Project has asked that we do some calculations on it. The possible benefit of packing either inside the package or outside, in case they find they need that help. But approaching the waste is ground water moving at a Pore Velocity U, and it moves in well defined stream lines around it.

In fact for the first time in my professional career have I found a case where I can use the quotations of potential flow for a real system. And that's because we are dealing with the low flow limit of an obvious Flux equation. And I was delighted because now we can claim that cure results are accurate. We know those flow stream lines we can write the diffusive conductive transport equation for every point in space, at any rate along the normal to the surface there will be a concentration profile.

Going from some surface concentration to on out. And if we know that profile, we can then calculate from the gradience there in knowing the diffusion coefficient in the liquid, in the rock. We can calculate precisely the mass transfer rate from the surface into the ground water in the surrounding porus median. Now getting that concentration profile is the tricky part. Let me talk about the boundary conditions. There are three, and herein comes the three models.

One solubility limited species, again like the aclanyde geraniums, or in the case of Bolosilicate Glass, the silicate matrix itself. And there as a bounding case we said its already at saturation at the waste surface. Notice I didn't say solubility because I know Mick Apted is going to object, because in emorophous material doesn't have a solubility. And that will save us a little time, so I call it saturation and they do exhibit saturation in experiments.

And so as a bounding case, ignoring colloids which I want you to challenge me on, as a bounding case without colloids present, that's the maximum concentration you can have. And we can calculate quit exactly from mathematics, the mass transfer rate is a function of time. Integrating over all the surface. And those equations were solved by our group and some simple results have appeared in the Waste Isolation System at part.

Now many people claim, but the real concentration of the surface won't be quite at saturation. So we did that problem and we used the reaction rate boundary condition instead. And there we used experimental data and we found much to our surprise. That for the experimental data on both Bolosilicate loss and U02 fuel that the matrix itself dissolves, reacts rapidly enough, chemically with the ground water that it brings that surface concentration to within a fraction of a percent for saturation. And that tells us that in fact, it's not only bounding but it's almost reality, that the surface boundary condition for the low solubility species is, can be taken as the saturation concentration itself.

It takes only a matter of a few weeks a month in a Repository environment to come to that. It also means that the real release rate is not controlled by the chemical reaction rate of a solid. It's not controlled by the extent of cracking and so forth, which affects the reaction rate. It's controlled instead by the rate of molecular diffusion and confection in the porous median outside. I hope some of you will question why do I say molecular diffusion? And I say this in general even for Repositories with higher ground water flow and you should question that because we know eventually a hydrodynamic dispersion will come into play. And that will give me an opportunity of answering a question that I think I know the answer to.

DR. LANGMUIR: Tom are you ever going to give us time to ask these questions?

DR. PIGFORD: Of course not John, but if you want to please go ahead.

DR. LANGMUIR: Well you asked us to ask you why there aren't any colloids or why we can ignore colloids in this calculation for example?

DR. PIGFORD: Alright, the answer is, colloids are very important and up to this date I'll have to say that our analyses are subject to that criticisms. There is a great opportunity for colloids to form. I will talk later about the possibility of a red ox prod a few centimeters away and for uranium that can change your solubility almost discontinuously by 10 to the 4, from highly soluble to low soluble. Giving you a great opportunity for colloids from the super saturated solution. This is a subject that every countries project is vulnerable to it and no answer.

Now many answers are reasonable. Colloids filter out very readily in the porous median, and we know that. However, since it's the subject of my groups ongoing research for this year, which I believe was the first serious effort to actually model coloid transferred. I don't think that's the end of the story, because when they are filtered out their going to be sitting out there as sources for soluble radionuclide either by their dissolution or by deception if their sudocoloids.

The bottom line is keep asking the question and I hope next year we can tell you more about it. In fact they do obey how mass transfer analysis, there are measured diffusion coefficients on colloids and their measured values are about a 100 to 1,000 times lower than phosaloids. And that is another way saying we expect them not to move very much, but it has not been carried far enough to give a, what I think is a convincing answer.

DR. NORTH: Lets make sure this is on the list for bounding calculations. It sounds like it would be very useful for us to dig deeper onto the coloid issue.

MR. ALEXANDER: This subject has been around for the 10 years that I've been in the Waste Program and Don and I and many others in the Geochem Community have been talking about it. It's a very difficult subject. The other important --

DR. LANGMUIR: The other point is that colloids have a thermal stability and as temperature goes up, which it will be high near the package, their less stable. The temperature functions of stability are headed in the way of removing them. Up "T" (PH)

DR. PIGFORD: The real problem is that colloids have been studied a lot in other systems. Chemical Engineering Literature, but they've studied only colloids themselves. In the time scales of our job here the doubters of colloids, which what happened when they dissolve after being trapped are extremely important. Or would they dissolve after being trapped. And so we need to come up with a theory that has the coupling of coloid and solid transport all in with it, and that's what is new.

Okay, the third boundary condition is not any constant concentration of the boundary when instead it impulsed release sudden dissolution, all of that material readily cycle material season iodent and so forth, that's in the fuel planning gap. And although that will dissolve readily when water gets into the canister it will not diffuse out immediately. And again, the diffusive corrective analysis will give us an answer to that and it's an interesting answer.

Alright, now the mathematical solution to this is beautiful. Some people call it complex and it's in many forms. A simple form is an Esintotec (PH) Solution given right here an this has many purposes. First to turn off must of you because it's an equation, and secondly to point out that this is the real tool of sensitivity study. To have a functional form of each one of your parameters. Now this is an expression of the steady state fractional dissolution rate of a long life species as a function of the parameters and saturation concentration in the numerator. The square root of the diffusion coefficient and that must be measured, but for bounding calculations we can give you an upper limit, which is 10 to the -5 square centimeters per second. Within a few factors of two or three, which is a well known value for liquid continuum and we expect it to be reduced one to two orders of magnitude by torch velocity of the porous median. And that needs to be a measure.

The porosity, the approach velocity of the ground water, core velocity and these dimensional quantities and the concentration in the waste solid. The higher the concentration of the solid the lower the fractional dissolution rate, because that's the normalization. Now it's a wonderful equation. This is very important, it applies only when this dimensionless product the peck lay number is greater than four. And that's the limit. You must not apply it below that limit. We know that limit by the general solution, which I don't have time to write down or space, but that is a very important limit.

The next slide shows the result of our complete analysis. Here is the fractual dissolution rate and the parameters didn't get on this figure so, and there over there. So we calculated this using the value in the SCP for the solubility of uranium, which I'm sure Don Langmuir is going to object to. It's 50 grams per cubic meter, that's a solubility of around 10 to the -4 molar and it's perhaps applicable if you have air saturated water. And so, and I'll tell you later I think it's a high number, but that's what we, used that from the SCP.

The dimensions of the waste form are given there. We assume 32 square centimeters per year, which includes a torch velocity factor of 10. 10% velocity for our TUFF, maybe it should be a little higher but that's not very important. Now on this slide, this line right here to the right is that equation I showed you. Slope of one high and the limit of validity happens to be right here at a ground water velocity, core velocity of around a 100 centimeters per year. And so you should immediately challenge me. Why am I showing this for the TUFF Repository? Only to show you, you need to have this to avoid making mistakes.

This same equation that I had, has been derived by others and it's a very proper Chemical Engineering Approach using Boundary Layer Approximations. We make more approximations. Using the Boundary Layer Approximations it only gives you a steady state solution. It does not give you the limit of validity. It was first derived independently with accurate within a factor of two by Neretnics (PH) in Sweden, and it was valid for their Repository because that Approach Velocity is one meter per year. And he uses that in their calculations. It was also derived by Kariasks De Lossundoss (PH) for the TUFF project and incorrectly applied, but it's not a criticism he doesn't make as many mistakes as I do. It only helps lead to our understanding and incorrect applied to your 1 millimeter per year.

And so there is the incorrect extrapolation you don't know it's incorrect unless you either do two things. Read our reports or do the mathematics, with you learn the validity, or else use a little physical intuition and save that. If you continue to zero velocity, it predicts zero release rate. That's impossible, there is still molecular diffusion. Just like for using the Goodis Billator (PH) equation for heat transfer down to zero velocity, it predicts zero heat transfer, but heat conduction still goes on.

The proper solution and this was the hard part. Chemical Engineers have been trying to do this for years, is to get this part of the curve right here. And we were surprised, to my surprise successful in doing it. Actually, the zero velocity case is a very easy one thats classical diffusion and that's the one that gives the right answer for the TUFF project. And so here we are zero velocity intercept that here. For such low velocities the time to steady state is enormous. I have a chart on it in the handout.

It depends upon the retardation factor, the larger the retardation factor the greater the time for steady state. Retardation factors say of a 1,000 as might be typical for some of the radionuclides. It takes thousands of years to reach steady state, so you must not use the unsteady state solution. Because we must be prepared to calculation fractional release rates at all times. Even with this very conservative model, no container, no cladding. The fractual release rates are rather low and if we readjust our solubility to what I think we should be using, we'll be around three orders a magnitude lower.

Now this is one merit of an ultra-conservative model. Can anybody think of something worse? I'm sure you can, and I can too. Like a rebel running through the

Repository and that just puts you up on this portion of the curve here.

DR. LANGMUIR: Tom would you tell us why you think this idea is that much lower than the solubility of U02 on hydraulic conditions?

DR. PIGFORD: Yes, a later chart shows you the Livermoores' present belief on the solubility and I think it has been approached this way. They use the geochemical code EQ 36 and calculate what happens if you put some U02 unclad in contact with a certain volume of clad ground water, G13 ground water. That may not be the right ground water and put it in a hypothetical closed system and let it react. React for a much longer time than you could do in laboratory experiments.

Well it starts off with water saturated and oxygen from air, and like you're looking for that. I think the oxygen is consumed and it goes from oxidizing to reducing conditions. And so they conclude that the proper solubility for uranium in their system is around 2 to the -6 molecular. And I'll give you some other numbers Don for the other hectomides.

DR. LANGMUIR: But why is it a close system Tom if you've got contact with atmospheric gases in the unsaturated zone --

DR. PIGFORD: Boy if I had wanted a straight man I would sure hire you. Well in their model Don, it's almost a close system because ground water comes in only very, very slowly and the container is still there. Now I will show you later that I have a little trouble with this because once the container has failed I think air will come in also as the container cools. And I have a quantitative analysis of that which is my last slide. A so, it is not a close system in terms of oxygen sources and I think that needs to be fractured into the calculations. And to my knowledge it has not yet been done.

On the other hand, according to my calculations there is a limit on how rapidly air comes in. And I can, I think give you an accurate answer on that. And that's still rather slow and so that may limit the rate at which uranium can alter, which will affect the tectiam release rate. So you see we're uncovering these beautiful linkages not only between laboratories. Livermoore and Berkely and PNL and so forth, but between technologies. The properties of the Waste Canister Failure to the Geochemistry and the Modeling of Release Waste. And of course as you see its the Chemical Engineers who pull it altogether.

DR. VERINK: Does you model also take into account that there is group radiolosis affects on the model.

DR. PIGFORD: Not yet, and that will be on the next to the last slide. That's something yet to be done and that's very important because that's an issue not resolved. If we take the most conservative approach on radiolosis, similar to the one taken by Nuretnics (PH) in the KBS 3 Analysis which you're familiar with Dr. Verink. That will then cause the uranium locally to go to an even higher oxidation state and could even conceivable give us a solubility greater than that number. In the years where you wait region. So there are a lot of "ifs" about that but I don't consider the radiolosis a closed issue. And that's on our list of work to be done. Don does that, I know you probably would like to go into that issue further. It's going to come up again, if you haven't had the opportunity to --

DR. LANGMUIR: Okay, that's enough.

DR. PIGFORD: Back to this slide, also notice that with this design in our design point which is down at low velocity. The release rate is independent of Ground Water Velocity. Independent of Ground Water Velocity, you do not need to ground Ground Water Velocity the release rate. This is a contrast to the Witkas were its proportional to Ground Water Velocity. And so it as well you can choose you model and take your trust, and that's exactly right.

If this is the model you chose, which is a more conservative model then it is independent of Ground Water Velocity. How much more conservative on this slide, I have put also the Wet-drip Case, which I call Bulk Re Solubility (PH) Limited. The numbers of the product of the drip rate times the concentration. That's this equation right here, you can't see it but it's on your handout. Divided by the inventory and it's this line of slope unity here. And you see it comes down here and at a design point of a half a millimeter per year.

It is the, a little over three orders of magnitude less than the continuous case. Therefore, with these continuous case parameters are right and I'm going to come back to that. It is a more conservative case about a factor of a thousand. Yet the project should argue it. That case is unnecessarily conservative because I have, really have the dry annulus. When it boils down to rock mechanics issue, what's the possibility of that annulus filling up or being closed locally. And we need the Rock Mechanics people in on this.

In fact if this analysis is right, if only a 10% of the waste surface comes into contact with the surrounded rock and makes good contact with diffusion pathways, you see you have 10% of a factor of a 1,000 which means you've brought it up two levels of magnitude. It's that sensitive. So this is a scenario that must be considered. I'm in no position to argue which one of these you should take, because it is partly a matter of probabilities which we have gone into and I must say also a matter of policy. Whether we should keep them both going.

For a release rate itself, you do not need to know flow rates. You can even take solubility limited case for all the water forms for the Repository and it will be below this reduced rate here. Physically that's possible because the Repository is a three dimensional body that can receive water by diffusion from all directions. However, if you want the source term for far field transport then the solubility limited release rate of all the water would be at upper limit. Leaving out colloids.

Now here is what we calculated to be more specific of Borosilicate Glass. These saturation concentrations were developed by a Carol Bruton at Livermoore Laboratory using the EQ 36 Code except for the seizon (PH) concentration which Dick Apted and his colleages have deduced from their measurements at PNL. The Borosilicate

Glass which I understand to be the result of the Polosite (PH) formation. This is using our model, again the lowest of all limits. I think the parameters are listed here. We tried to use them for Borosilicate Glass in the TUFF Repository and we calculate this is the saturation concentration of morophous silicate using Verdehayes (PH) data. And we calculate that for the glass the matrix will be released at a fractual release rate of 10 to the -7 per year.

However, it can still alter at a rate greater than that and so it would not necessarily limit this value of release itself, net dissolution would not necessarily limit the release of other species. Uranium on its own intrinsic solubility as a hydrated oxide we calculate then would be released 10 to the -9 per year. And what does that mean. Two orders in magnitude below that with a matrix, so the matrix at least tries to release it more rapidly. Uranium can not go into a solution that fact, it can not transport by diffusion conductions. It forms a percipitive at the surface.

And I first got this whole idea by listening to the presentation in 1980 by McVay showing us the beautiful results at PNL by Rye and Strickard. Where they actually saw this same thing happening through glass and solutions and found that more Plutonium and Neptunium came to the solubility limits of a stable hydrated oxides. And that helped us a lot for our extension of this theory. Likewise, Neptunium comes up into the monocyte per year, it will be controlled by its own precipitive solubility. The same for Plutonium, the same, not so for amorition although it probably will be controlled by its own precipitate, because the restructure rate will be more rapidly than that for the silicon.

DR. LANGMUIR: Tom, what temperatures are assumed for this? You're right on the spent fuel.

DR. PIGFORD: These are 80, 90 degrees centigrade.

DR. LANGMUIR: I'm sorry, I wasn't in --

DR. PIGFORD: This is not spent fuel, this is more recipitive gas. And notice that with the results from PNL on Polysate even seizon (PH) is solubility limited. This evidently is not true in spent fuel as you may expect. Mick and Apted can give an outset on that.

DR. LANGMUIR: What solubility, what would seizon (PH) be limited by?

DR. APTED: It may not be. I mean it may be a, because in the glass these are aluminum silicate, or aluminum silicate glasses so there is a high activity of aluminum which is simply not present when you're talking about spent fuel. So the only source is the ground water and it's not abundant so we may not be looking at aluminum silicates this seizing but some other, I mean the oxides and the hailites (PH) are all very soluble to that component.

DR. PIGFORD: No I want to point out, before I leave this part where the simple theory is before you. That that theory is not only simple, it's putting our next way out. There are no adjustable parameters. Everyone of the parameters could be measured and should be measured specifically for the Repository. And I have claimed in some talks, if the Repository, if things don't beehive that way it's something wrong with the experiment, not our theory. Of course that's a little arrogant.

We recommend that with material like this and these are the kind of theories of course, you hope for for making long-term extrapolations. You can validate the theory itself. The theory should be challenged and tested with experiment. That's different than visioning the parameters. You measure conducted experiment to challenge the theory and one such experiment is being conducted by my friends at PNL and they got amazingly close. I couldn't believe it, but it was up in the high flow range and I hope that they will be able to carry those experiments forward to a more challenging area. This is a very important part of validation.

The next, oh, Abolition. Now I wanted to show you the solubility or saturation concentrate which is so crucial and how well do we know it. That is the real problem. I was interested in how things had changed over the years. Here's what was published in the EA, and for Uranium that was the value for 10 to the -4 moles per liter. It raised by an order of magnitude in the SCP which was conservative for water and equilibrium with air. And then as a result to the analyses that Livermoore has done, that I described to you, going down to 6 x 2 to the -5 per year.

Now I give you ranges of uncertainty on the others, I didn't give you the range here because I was running out of time to prepare this and so I didn't get the numbers on Uranium. I'll supply them to you later on.

DR. LANGMUIR: Which of these are measurements and which are strictly calculations in terms of thermodynamics? Tom.

DR. PIGFORD: Don, I have with me the measurements but I don't have a slide on it. These are calculations, all of these are calculations. The measurements fall within the range. Now these happen to be at 25 centigrade. We have measurements and calculations at 25 and at either 85 and 90. And I have some data with me, I'll be glad to give you which is a thing from Livermoore. These were published only recently in the last of April by Carol Bruton at Livermoore. A very excellent compilation.

And if it hadn't been for Don Alexanders' coordination work which really has helped a lot in the TIG. I wouldn't have gotten those and had a chance to present them to you. So all of this is helping us do our work very, very much. But we need to know what those are and you may not be able to measure these and any real time in a laboratory experiment. Because it takes a long time for these changes to occur.

DR. LANGMUIR: It's quite fair to measure them at 100 degrees and thermomamically bring the information down. That's --

DR. PIGFORD: Don if you say so, I think -- incidentally they found on most of these Don, that the solubility at 85 to 90 is less than 925. And I use to understand that for Uranium in the in the Canadian environment because of the hemotype ecomagma, but I haven't learned a lot, enough about their calculation to know whats doing it on Plutonium.

DR. LANGMUIR: I'd like to see that.

DR. PIGFORD: You should ask Mick about that. And he has a degree in

Geochemistry. The next slide, I put this up to show you the result of our model and I'm not going to bore you with equations on the readily soluble species. This is the fractual release rate. We've assumed one percent of the total Cesium and Iodine is in the gap. Actually it may be greater than theirs like they do us. Some data are showing two or three percent, I think it's possible it may turn out to be less.

Assuming it all dissolves instaneously when water gets into the package and the collecting of the presence of the Zircolite Cladding, we then do a trangent diffusion calculation out into the rock. Assuming rock is in mediate contact with this Waste Package continuously fusion pathways and there the results for Iodine, Cesium monford in five and that applies at anytime after failure because of their long half lifes. 17,000 billion years and one billion year.

Also for Seizon (PH) 137 an extremely conservation value. Assuming the container fails immediately after replacement. Which I hope is the very low probability event. But notice the fractual release rates initially are very high and they deplete also rapidly because of simply your depleting your source. I should point out when we do these calculations for the TUFF Repository we are assuming a diffusion coefficient usually water reduced by a factor of one order of magnitude for torch velocity. That needs to be measured.

A critical measurement, it's high time we got some data, it's quite possible that there are not enough continuous diffusion pathways in this matrix. Especially at low saturation that you are even up to that. It's possible this diffusion coefficient could be many of orders of magnitude lower. And that's worth looking for. We're unable to handle that problem theoretically.

DR. LANGMUIR: That may suggest some rates that were a lot faster because of the saltation surface affect in moisture that might or might not apply.

DR. PIGFORD: Yes, alright, that's on my list of additional questions for you to ask which you've run across perhaps. You would have asked it anyway Don. And yes this bothers us enormously. If you have surface affect diffusion the affective diffusion coefficient can be several orders of magnitude greater than that for the pure liquid. And so it's worth looking for. Nuretnics (PH) hasn't measured it, he's measured it, he's seen it for seizon (PH) and some of their bentonite (PH) clays. And it's so important that they then isolate it and I cannot remember the details on this. The particular clay that was getting that, and the clays they are now selected do not show surface diffusion.

This is extremely important if you using either fusive conductive models. So there is a lot of danger. Surface diffusion can make things worse, a lot of benefit, polls pores can make things a lot better.

MR. ALEXANDER: You know, Tom, Clay Radkey at U.C. Berkeley worked on the same problem years ago, and you ought to spend some time with him. Talk to him about his results on surface diffusion clay.

DR. PIGFORD: Yes, we have compared notes there. I think Clay agrees that there are clays that he sees, he does not see surface diffusion on for these species. The on he's tried, but he hasn't tried all of them. Also in this chart is a contribution from the Waste Forum. This happens to be a calculation for extremely reducing conditions. Which shows you the sweet of U02, factors of 10 to the 5/6 depending on the solubility.

The next slide shows you first on mathematical virtuosity. We not only solve these diffusive conducted equations or single species, we solved them for the whole radionuclide chain. And we can give the results per chain of any length. It only increases the order of the difference of equations and my colleague who's a wiz in mathematics is able to format these in a way that they are generally applicable. There is one chain that isn't poor. And that's the chain known as U-234 half life 247,000 years. -- 30,000 years I think. The radium 226, 1,660 years. And so that chain U-234 is there from the beginning the doubters keep building up. They peak out at 200,000 years.

Okay, here is a calculation of the release rate from the single problem as a function of time. Since the initial failure, it doesn't make any difference. Whatever failed at 1,000 years or whatever, and this is calculated normalize to the 1,000 year inventory as required by NRC. And if you're interest I can explain the strange wiggles in the curve, but notice after a 1,000 years that fractual release rates of radium and thorium keep climbing and the worst case occurs in this case upper dot million years.

Fortunately, there is still all the smaller fractional release rates in this model. Uranium is solubility controlling, forms a precipitant and we assume, and I believe that the doubters mainly will be developed in that precipitant and be released, dissolved congruently with the U-307 precipitant. However, that assumption of congruency needs experimental justification. And nobody is anywhere near that experiment yet.

I can also give you some scenarios that will increase this structural release rate a great deal depending upon the parameters I use. It's an important issue, it may not be overwhelming. The next slide shows you conceptually what we do if you have a case where there is water in the fractures. And from what I've learned from my friends at Sandia and Livermoore and elsewhere in this project, that could occur only if we reach saturation conditions. If you reach those conditions then we have pathways or dissolve species to diffuse into the fracture as well as into the watt matrix.

Now this is the problem analyzed by Nuretnics (PH) in the first place, that he used in a KBS field analysis. Using that Don Langmuir approximation. He neglected diffusion from the solid into the matrix and assumed it was all going into the fracture. He is a very clever guy by site calculations he could prove that that was the main pathway for his configuration. We have developed, and he had only a steady state analysis.

We have developed the general time dependent release rates from the Waste Package through a possible packing material into the fracture, into the matrix, into the fracture and the results some of them are shown schematically in the next slide which I'm not going to show to you. So that tool is available. We can also show you in some conditions even with a fracture there it really behaves from a waste rate point of view just like porous rock. And I believe that will be the case for TUFF, because of the porosity of this matrix. Which is unusually high for rocks.

The next slide then gets us into a subject that I'm not suppose to talk about. My subject is the Waste Package In Near Field Analysis. I'm going to skip quickly over the questions that I have posed in my handout. What about temperature affects? We have the solution for that. What about chemical reaction affects? We have the solution for that. What kind of Repository do you need to have so that the chemical reaction rate of Bolosilicate Glass is controlling? We have the solution for that, the answer is a Repository in which the flow rate is about several hundred meters a year and I hope that's not in a Repository we have to deal with.

I did that and most of our analysis are side analysis to answer questions that are coming up. What about the effect of dispersion? We know that dispersion will occur, well it won't occur unless you have finite flow rates. So it's not a good question for TUFF, but it can finally occur. And I can tell you if you take our analyses out to a large enough distance I can show you we must make a transition from molecular diffusion to dispersion.

Fortunately that distance is far enough removed from the interface, it will not affect our calculations for release rate. Some people have incorrectly applied our equations to a farther field transport and then I think they have made a mistake. Now the best issue is Gaseous Releases, $C0_2$. I'm justified I'll hope in showing you my far field calculations because I'm going to have to make assumptions on the source term and I hope to show you that your all convict performance objectives can affect what you need to know about this Source Term. The two are very much independent. They should not be analyzed independent.

So we took the SCP Source Term of 200 Curies per C_{14}. They are around 70,000 Curies total in the Repository. 2/3 in the U02, 1/3 in the Zircoloid from MP reactions on nitrogen. And then the SCP justifies that only a small fraction of the containers will be fail around less than 20% and only a small fraction of that. Carbon 14 imbedded in the Zircoloid U02 will be available for release. Probably by crud formed during operation of the reactor on the surfaces. That gives us 200 Curies for the total Repository.

We have developed a transport model which requires that we know the flow of gas, air. We take from a analysis by a colleague at Berkeley, who calculates the temperature aided flow rate of air. Which is around .04 medius per year on the average to the surface. You see it doesn't take you too long to get to the surface. We calculate the retardation of C02 by the C02 and the gas dissolving into water in the pores of the matrix at the interface fractures pores.

Defusing in the water through the pores it may not come to equilibrium, it's wrong to assume equilibrium and we invoke the C02 by carbonate equilibrium to get the use of the data or the sturben marking, for the equilibrium data. Neglecting the possible foundation of calcite which can invalidate our analyses which will make them look a little better. And we then are able to calculate the effective retardation of the C02.

With those tools and we calculated a retardation coefficient assuming PH7 which we don't know well enough, calculate the gas concentration at the surface in micro Curies per, in your handout it's micro Curies per CC. I'm using the wrong slide here evidently. It's not micro Curies meters per year. Micro Curies per CC is a functional distance to the surface, which is 350 meters up. And these are various times after the release and we assume the impulse release. Which maybe is the worse case. Neglecting all barriers to release. And you see we are finding surface concentrations in the neighborhood of around ten to the centix -6 micro Curies per CC.

Now I take that each one of these curves for different times, the peak value, that's the worst case and it occurs over a long time. I'm going to calculate a lifetime disk commitment. And then I recalculate that for various durations of the release not an impulse, but a continuous release of various times to see how sensitive it is. The next slide shows you. And here we see the Peak Gas Concentration, the worst case.

Assuming that your performance criteria has a function of the Band

Duration, the release time. Running from zero, well it's a log scale I can't go from zero. But from almost zero, my impulse release up to a 1,000 years. And for the expected Ground Water, I mean expected Air Velocity superficial Dorsey Velocity. The peak concentration is in fact independent of the release rate. And this is something we discovered in the analyses we did for the Waste Isolation System Study back in the 1980's. I can explain that if your interested. Even if you're not interested.

The Molecular deficivity of gas is so high and we can count on that. We don't even need to know hydronamic dispersion, it's comparable to or even slightly greater frequently. And so we can calculate I think quite comfortably the magnitude of the dispersion effects on a band of C02 going through. The effective dispersion is to round off the corners of the Band. If the band is short lived like an impulse release the dispersion immediately lowers the aptitude.

If it's a long live release with low aptitude dispersion only works on the edges and never eats into the center. That's why the peak release is very insensitive to the release rate. That tells me if this is our performance criteria, we don't need to work very hard on getting the C02 Source Term for that purpose. However, since there is another criteria in the NRC Release Rate Criteria, you need to work on it for that.

For that purpose then I need then to marry several different studies. I'm going to adopt the picture that Waste Packages Fail only in localize penetrations. Localize Penetrations and secondly in the SCP is a guidance value on what constitute failure of a container. Now unfortunately, I left my notebook with all my knowledge in Los Vegas last week and so the number I remember may be off, but you can look it up anyway. It's in the SCP someplace and it says that, if container fails, if at anytime you hypothetically were to measure the Leak Rate from it with a good helium leak detector and got a certain value, which is expressed numerically equal to the value in the ASME Pressure Code for testing Pressure Bussells. And I'm not going to quote the number I remember because I remember the number but not the units and it won't do you any good.

However, what really happens, we take a container, I want to use the other first Mick, thank you. And we, I take this value of the temperature versus time from the SCP for the Repository. Here is the Peak Thrill temperature, the peak container surface and I'll take an average of the two as a rough measure of the average internal temperature. And the peak temperature rises initially for about 30 or so years and then monotonically decays after that for cooling. And it's still cooling off after a 1,500 years.

Okay, that cooling affects greatly what happens to a container when it officially fails. The next slide shows that. Now I took the criterion in the SCP and said what is the size of hole if it were only one whole that would give me that liquid. I expect there to be many many holes, but this is the single equivalent hole size. And to my amazement it comes out to be a single hole 5 microns in diameter.

I hope I've made a mistake, but so far I think it's probably right because my student did the calculation instead of me. And if so, here then is a series of curves of the amount of gas inside the container as a function of time. Now I did the worst case calculation here for a container that fails immediately. I won't have time to show it to you for contains that failed at 300 a 1,000 years. This is the most dramatic case. So if the container only has three micron holes, its officially unfailed but it continues to leak gas out, but not very much for a thousand years.

If the container is 5 microns, it leaks gas out until finally the pressure gets to be atmospheric and then as the container fails, as the temperature falls further air leaks in. And from here up you can calculate the number of Moles Air Leaking Unit. That's the container that just failed. If they failed I'm going to have to find out how big they failed, how badly and we have a colleague who's just begun working on this Roger Stayley. I wish we had him at Berkeley but he's in Minnesota and he is undertaking to provide us some estimate of the aperture versus time for container failure.

I'm at a lost to do this but I'll take his results. Right now, I'm going to assume that some of them have at least 10 microns and I'll bet you my bottom dollar they'll be some a lot bigger than that. If the container failure mechanism of griddle fracture that I understand is working. If it's a 10 micron hole and only one then you see it relaxes its pressure very quickly and then as the waste cools it brings air in. Then I can tell you how much air comes in as a function of time.

And a thousand years around five moles come in, from this calculation. That's the worse case, if it fails later, not many come in because it's down to cooling curve. What happens if 5 moles of air come in? I'm worried about it oxidizing the Uranium, to go to higher solubility, I think than the value a little more calculates from the close system.

DR. LANGMUIR: But the amount of oxygen involved is so small the quantity of Uranium that should oxide would be small.

DR. PIGFORD: By this time I'm going to finish my talk. [Inaudible] and so there about three to four thousand bags of Uranium there and so only 5 moles can only oxidize a tine fraction. In fact it's not enough oxygen to give you 10 to the -3 per year that I showed you earlier. And so this is another example why I think that number from the Bath Tub Model is a little pessimistic and why I think we may be able to extend our modeling to eve help on that.

With this we're marrying the Berkeley Continuous Pathway Bottles with a Wet Drip Case. Then the next thing to do once these concentrations are there, not all the C02 gets out immediately. It has to diffuse out. First it has to diffuse out against the inflow of air, although I tell you that's not very much. I can't count on that. So it's really molecular diffusion through these holes and I can calculate that. And I don't have any results yet because I only got the other results last week. But we'll be telling you about that later on and I think that will give us a far more realistic and defendable Source Term on the C02 Source Term than you've heard about so far.

Even though it doesn't make any different to the peak concentration unless it is so week that it extends us to band release times of the tens and hundreds of thousands of years. Wait for the next installer. Now because I have to catch an airplane and you have to hear from Mick Apted, the wind up is there are a lot of things yet to be done. We need to do more on what the effects of solubilities are. I think Johns' questions in our discussion show just were to go.

I think that's part of what I call refining the present tools to anyone of the models. We need to measure the diffusion coefficients. The most important thing in validation is to challenge and see if the theories are correct. It wasn't until I gave a talk in Sweden two years ago, with a wonderful theory that finally somebody there questioned me and I found I had been making a terrible error. We need more of this and that's the most important point of validation I think. And it takes people all over though not necessarily into programming.

I've given you many specifics on what needs to be done. I forgot to be Colloids down there and I hope you will remind me about that next time. We have given you then two release rate models. The Bath Tub Wet Drip and the Wet Continuous. They may converge depending upon regiments of diffusion coefficients. We don't know that needs to be done. I think we should go in more experiments to challenge the models them selves. And Mick can describe I think for you the very beautiful experiment that was done by PNL. And finally we moving the direction because we made need more factors of safety, lower release rates than either of these models predict.

I hate to make things complicated but if we need to be more realistic to get lower release rates the pay off is to look into partly failed containers and that's where we are now. Don I'm happy to answer questions to the extent you think there is time.

MR. ALEXANDER: It's really up to Warner with respect to time --

DR. NORTH: Well we're running a bit late but I don't want to cut off any discussion.

SIMULTANEOUS VOICES:

DR. NORTH: Okay, so I think in view of that we probably ought to go to the next presentation, unless --

DR. CONTLON: I've just one bottom line question. Since the Dry Case is, the expected case at Yucca remains dry and you're dealing then with the volatile. What's your feeling at this point? Are we in pretty good shape?

DR. PIGFORD: Well in my opinion, Rick, I don't think we have a good Source Term on the volatile. I can show it's not important so much for the Peak Concentration but for the other criteria, we don't yet have a good Source Term. That's evolving laboratory experiments on rapidly release Carbon 14, we're just beginning on that. And then that needs to be married to the diffusion models. I am very optimistic on the diffusion models. To me I don't understand the laboratory data very well.

We're seeing quick releases on Carbon 14 even in the absence of oxygen, Iogon (PH) that still comes out as Carbon 14 C02. It may be surface trapped oxygen I don't know and these are short term experiments. But, in terms of is the Dry Case vulnerable, I would have a little trouble defending that water doesn't get in. You see I've showed you that there is an in leakage of air. If there is an in leakage of air, the logical question can't there be an in leakage of water? And also even for the unfailed containers you can have in leakage, because those are the ones that didn't fail, they just didn't meet our test.

Now indeed you may say, well we'll test more carefully and that would be a valid design approach.

DR. LANGMUIR: There's a little input to the air leakage business which is relevant I would think here. And that's the C14 dating that has already been done, of C02 Gas in the unsat zone of depth. It's thousands of years old. And unless you, of course if human intrusion equating the Repository as a potential other way to get oxygen in there, but apart from that you've got a very dominant ate of movement which you can date from the C14 of the C02 as a Source Term in your buildative oxygen from the atmosphere to the system. I would think some nice mass balancing, just simple formulative stuff would be appropriate here. And the quantities of Carbon 14 that have been created by an given

Waste Package. The quantity of oxygen can get in given the times that your dealing with and how much can you make, and given the volume of rock it's got to get out through. What are the concentrations going to be? I think those are fairly simple.

DR. PIGFORD: Well Don, where does the oxygen come from for that case?

DR. LANGMUIR: Replenishment very slowly at the rate in which C14 dating tells you C02 has come in, with air. The C14 dating tells you the C02 has come in from airs, 10,000 5,000. I forget the exact dates but they're thousands of years. That's giving you the rate of oxygen access to the system in normal air.

DR. PIGFORD: How about putting that down as something you recommend we do?

DR. LANGMUIR: That sounds good to me.

DR. PIGFORD: And we'll use you as the source. I also want to point out on Colloids, just two weeks ago I learned that at Loss Almos, not in this courtroom. They have found, they do have Plutonium Colloids in one of their environmental areas and they know where it is at the beginning. They now have it 50 and 100 meters away. We also have a lot of travel time from Tredium measurements and so we even have some field data on Plutonium in Amorition Colloids. Thank you very much.

DR. NORTH: I'd like to note a point for a future meeting. And we've just heard a lot of very fascinating material, we haven't had the opportunity to go through in details, but I would like to see an effort to summarize this into the total system performance. To see what kind of differences the insights from this research can give us.

MR. ALEXANDER: Well as a matter of fact what we'd like to do is present some of that right now.

DR. NORTH: Great.

MR. ALEXANDER: As I pointed out earlier, Tom Pigford is representing hundreds of folks in our program that are doing this kind of modeling, model development or trying to develop a physical, an understanding of physical mechanisms and processes that are going to take place in a Repository. Mick Apted is representing those folks who take all those physical mechanisms and pull them into system level models that are used to compare the results against Regulatory Requirements and so you're going to here a little bit of that right now. Mick.

DR. APTED: Thank you. I'm going to get on the phone with my agent about booking me in right after Tom Pigford is a (laughter). I think Bob Hope could follow that presentation. Lets move on. The scope of my presentation today will be to discuss the structure of one particular Subsystem Model that has been developed for the Department of Energy for Waste Package Engineered Barrier System Submodel and that's called the AREST Code. And I'll show a little bit of typical results, some of the benchmarking that we've accomplished to date and just very quickly just hit on what are some of our near and longer term future activities. So lets move right on.

Several people yesterday presented this slide. I think Larry Rickertsen was talking about Performance Measures, well he presented this overall organization. And this gets to what Don was just saying Tom, in the area of Particular Release Models has been, in their group at Berkeley having been developing the Physical Models, the Mass Transfer Models as have other groups within the program at Livermoore and also at PNL in our group. But what I'm going to be focusing on is sort of taking not just Mass Transfer Models but also models that describe the Near Field Waste Package Environment.

Basically, combining that to give us an idea, alright Toms' models less say rely on solubilities. How can we calculate realistic solubilities. It's enough to say that's important parameter, the next step is okay how do we get to evaluate what is a realistic solubility. And from this calculational model, this subsystem model we're going to go on and show a little bit of some of the calculated

results. What does the rest stand for? It's Analytic Repository Source Term Code, the title actually owes its origin to Don Alexander. We've been working with Don since about

1985, 86' in getting this original program going.

Basically the, what we're doing with such a code is trying to integrate process submodels as I said, in the area of Near Field Environment, Containment and Release. Bringing all these together to give a picture of the space on Temporal Evolution by Performance of the Near Field Engineered Barrier System. We going to a, by integrating this process, as I say calculating performance and as it was noted yesterday in Abe Va Luik' talk. One of the important outputs that we want to look for is not just deterministic analysis as see like from Tom, where we have an exact analytic expression. But looking, doing simulations of a number of Waste Packages that may have different Near Field Environment hence leading to different containment time, hence even perhaps even different release behavior. Next slide.

Our approach in terms of linking these Surforate (PH) Models of Near Field Environment Containment and Release is not, is to separate it out. We've not in a sense complete fully coupled approach. What we've done is to try to divide the problem into solvable small bits and put those together. First and primary is to obtain the input data that's necessary including information on the design. Perhaps Repository Logistics, such information about Heat Loading, Area Heat Loading and its distribution within the Repository. Information from Site Characterization.

As more information and revisions come to this data of course we've got to go back and to some new calculations. So calculations I show you now are a snap shot as of today and next time we meet there will be perhaps different emphasis and different results. A key aspect as I mentioned on the Near Field Environment Assessment is that we use detail Thermo Mechanical Hydrologic Codes. We call these support codes to support our analysis. Now for example in the area of Geochemistry we use the EQ 3 Q 6 Model. Now this is a tremendously large code. Much larger the the AREST Code is itself.

It would not make practical sense to use this as a subroutine that we would sit there and call up and have it do calculations for a 1,000 or 10,000 different simulated

Waste Packages. So instead what we do and similar for very detail codes like ANSYS that we use for Thermal Mechanical Analysis, TUFF Code for Thermal Hydrologic Analysis. We use these outside of the AREST Code proper. We do a detail set of analysis of the evolution over time of the Thermal Mechanical Chemical Hydrologic Chemical Characteristics of the Near Field. And then we tabulate or create algorithms that simplify and I'm going to show you some examples of how we take what is really a very complex and large active field within the program and distill it down to a usable form when we're interested in probabalistic assessment of the subsystem.

The third approach is in the area of Containment and Release. Is that we develop a Modular System. There are a number of materials for example, container materials that are being considered. A given container material may have any several different failure mechanisms or modes. As data gets to be developed in that area we need be able to make a swoop out of our information on a stainless steel and put in something on a hastalloy or copper alloy corrosion model.

Likewise as Tom has just sort of exhaustively reviewed and even in the area of Release there are a number of different models that can be called for. What we've created is called modular that allows us not to, to select among those. And finally all this being said and take up to this point what we're doing is calculating the performance of individual Waste Packages, is we integrate the behavior of individual Waste Packages over a larger array of input data from the site and design variables and Site Characteristics variables that we have to give a probabalistic expression of performance. Thanks a lot.

Okay, in picture words the same thing I've just shown. Stage One, Design Variables and Environmental Variables. Stage Two, The Support Codes here in these imputed arrays. These are also shown here in what I call these modules here which are not models but may as I say represent tabulated arrays, algorithms, some simplification. The we have our Waste Package Containment Model for an individual package, Waste Package Release Model. You're going to explode what's actually in here in a little more detail.

And finally our Engineered System Model, by that, this is the part that traps the interactions of monicarlo (PH) sampling of our data arrays. And of course in addition to having a calculating performance of the Engineered Barrier System, this information is vital to fit into the Far Field Transport as a Source Term to that analysis. Thanks a lot. Lets move that one all the way over and just leave it on the other side. Thanks.

Okay, what are the techniques and I'm going to show some limited examples and I'm contained by time here. A little bit on the, mention the Modular Structure, a little bit on how we've gone from Detail Process Models which simplify these down to algorithms and tabulations. During our development of the AREST Code what we've come across, maybe not surprising if you think about it is temperature as a very prime, as a prime parameter. Driving many of the other processes, you cannot do realistic Geochemical Analysis for example without taking into account the temperature affect. The same way with the mechanical analysis in the Near Field and the Hydraulic also aspect.

I'm going to show a little bit about some of the support work we've done in evaluating Coupling Process like for particular example, I'm going to show this Thermal Chemical Coupling and that's an example of how we simplify the geometry. Okay, in the area of Thermal Modeling I mentioned how its a prime driver for what we're doing. We looked, this is for a particular for spent fuel, which has in some was a most complex analysis because it's a, it has a depending on the logistics of a receipt and born up averages the fuel is not even fabricated let alone been used in Repositories. There can be quite a broad distribution of heat generations of the fuel.

We have a two stage analysis for deriving Thermal Models. One is to use an access code which is to develop inability to predict average Repository temperature and the history over time. As a basis of the waste package design from a Waste Two Code which is a logistics code which tracks the various scenario, the various test cases of projections of how fuel will be generated in the U.S. in the future. We can get distributions of the Waste Form Heat Generation Rate and because this is distributed what we're going to find out is that the temperatures in our packages may also be distributed.

Now we can, this can be circumvented by actually engineering around the question and actually making a homogenous heat deposition rate in terms of loading the fuel into the Repository or what we've looked at is the other extreme. Which is that fuel may show actually a great range of heat generation rates as implaced, leading to different time temperature behavior. So that's sort of a, I won't say conservation it would be the other opposite extreme. Lets go on here.

Now this is the type of Finite-Element Mesh out of an ANSYS Code that we'd used to calculate Repository Temperatures as a function of both space and time. Go on. So again this is not something that's in a AREST per say. This is not a subroutine that calls up and we do our Thermal Analysis. This is something we do outside of AREST, summarize the results from such test. Now this is a bit of a rabbit out of a hat. This cumulative frequency here was built up from information for a base case of key generation range of spent fuel as received at a Repository. And there is a relationship which allows us to from Heat Generation to Initial Temperatures of the fuel center line temperatures of the fuel. Which in turn allows us to calculate, here is the reference case for a reference Waste Package.

What we're showing here is that because there is maybe a distribution, not that there will be but what is the effect if there is a distribution of heat loading. Well then there is a resulting distribution and temperature time profiles for different packages. From differences in temperature time profiles, these can translate into differences in containment time. Container processes many of them are very temperature sensitive. They may also change into different temperatures at the time of the release and hence the solubility terms that we're going to use may also be different because of different temperatures at the the time of failure.

I don't show it, but from this sort of relationship we actually develop an algorithm which allows us to calculate this time temperature line from initial heat generation rates. But I don't have time to go into that full. Excuse me.

DR. NORTH: Have you done some sensitivity analysis on that? Does that seem reasonable for the variety of different containers fuel ages that you've considered?

DR. APTED: We haven't. As I say we more or less just looked at the extreme bounding case which is a, not looking at any sort of blending of the fuel with the widest possible distribution. We have looked at several different scenarios, several years ago and MRS non-MRS but not sensitivity perhaps as you mean.

DR. NORTH: Well some of the extreme bounding cases may be sufficient but everything tends to fit on the same pattern, but looking at MRS versus non-MRS in the extremes of ages of the fuel might give you a good start on that.

DR. APTED: That's, yeah that's very true. Now there are other, I know the Yucca Mountain Project is looking into this same question from a different slant actually in terms of trying to establish a uniform heat deposition rate so that they can have a more uniform thermal profile cross the entire Repository. So there are other considerations that may drive such decisions and we've not in that sort of policy area where sort of the what if, try to zero to the parameter.

I think we missed the lead into this but if you go to the Geochemical Model. Okay, basically we started with some sort of initial ground water composition. Not just J-13 we're looking of course at the range of ground water compositions as they may exist or can be recorded at the site. Thermodynamic Data Base --

DR. LANGMUIR: You've also mean Botonic (PH). It's always being called ground water but it's largely Botonus (PH) water, is not ground water.

DR. NORTH: Well this is a habit we've gotten into, but there is a very big different.

DR. APTED: Okay, good point. We can then run such information as initial conditions through EQ3 and all. To develope ground water compositions as a function of temperatures. Assuming the equilibrium conditions now. That was a previous constraint, we're now getting to the point where we getting some reaction past kinetic capability into these models where we can look at, away from the equilibrium assumption. But again that would be a very long presentation also in itself. So from this Geochemical Model let me show you how we, basically what we do. And the next slide is basically tabulate, no the one you showed before that, tabulate.

This is some old data we've done. This is basically what we tabulate is ground water composition. This happens to be in contact with a clay in five degree intervals, we do a cut off from species that are of lower concentration. This type of information we feed back eventually into our solubility models.

DR. LANGMUIR: Mick this is simply rather than being a representative of what you expect in the Repository. This is a reduced ground water which is --

DR. APTED: Absolutely, good point. That's what I say it was actually a, it was the one I happened to grab.

DR. LANGMUIR: It was a convenient example.

DR. APTED: That's right. This is the illustrative on the case. Okay, lets go to the next slide. I matched in one of the other examples to evaluate the importance of Thermo Chemical Coupling or as some of the future work and ongoing work is looking at other coupling. Lets go on in the SCP. Next slide. One of the things that was pointed out is that the boiling phenomenon may be to precipitation of new minerals as the water evaporates to dryness, locally at this boiling front.

Here's the boiling front 97 degrees it greatly expanded here. Where our concern now and Don really brought up the question. The difference between the former work done on saturated systems and this Betos (PH) type water is that now we're doing the two phase chemistry. That there is not only the, actually three phase because there is the solid, the water, and there's an air. And in the past we've been dealing just with [inaudible] type reactions. And furthermore because we have an air system we have the potential for a very open system type of behavior.

This is almost, this is getting up to the state-of-the-art in Geochemical Modeling. I know that there is groups both at Lawrence Livermoore and at PNL. We're going to do reprogram and our Sea Contractors are also looking very seriously at this type of information and this type of modeling because the fell its very, very important. The quantity and quality of the ground water are important factors in determining performance. This type of boiling finding can greatly affect the quality, meaning the composition of the ground water. Next slide.

As I said the SCP noted that as water would evaporate to dryness you may precipitate minerals. Well there is another region actually much closer when the water initially boils and you drive off the preliminary volatiles in solution. Particularly the C02 that you can lead to dramatic changes in the pH. This represents less than a one percent on a by volume of water that has been boiled off. This is worked done by Randy Arthur at PNL. This is Moles Per liter concentrations of carbonate in solution. This is a nominal value for J-13 water and this is a decade on either side.

Starting with different initial pHs', showing the pH shift that may result because of a very limited amount of water boilings.

DR. VERINK: Say again what you say these are most of these are Carbonate is it?

DR. APTED: Carbonate. Concentrations of Carbonate Moles Per Liter, I'm sorry that that, I left that off. Now again Randy Arthur has several papers on this that deal more comfortable if you're interested in further details on what is, is actively being model here. But we want to show that there may be some important affects not at tremendously degrees of boiling but even in the initial. But what we find when we model it with EQ 36 is that initially the calcite precipitates and then calcite redissolves. Silicate precipitates and the later it sometimes it redissolves.

It's a very complex behavior going on. And that type of other aspect gets into this precipitation dissolution, gets into coupling thermal chemical and perhaps hydrologic properties. And we're getting very messy at that point but this is some of our preliminary work. The next slide shows some work the Solid Minded say, well don't say boiled on it. Are calculations using a Kinetic Reaction Path Model within EQ 36 to calculate the composition of water evolving in contact with Tonepah (PH) Springs TUFF. What we've done is shown taking now water that's under gone 10% boiling and showed how that water now chemically reacts with the again, the Tonepah (PH) Springs TUFF using the same reaction path calculation. And there can be significant differences here depending on the initial ground water that's used.

DR. CANTLON: Ten percent boilings means you lost 10% of the water?

DR. APTED: Ten percent of the water volume plus I want to say also that the C02 particularly has been lost. I mean that's the primary effect that we're looking at here. So this again is work thats just emerging from our program. We feel it's very important if we're going to do acceptable subsystem performance. Is, it's not enough to go just use equilibrium assumption. We have to move beyond that and look at some of this coupling and as I mention groups within DOE and the NRC support staff at Southwest Research Institute are looking at this and we need more work on it obviously. Next slide.

Very quickly simplified Waste Package, Tom has already mentioned that, many of the types and models that we derive at, he's derived at. Analytical solutions involve simplification into spherical or cylindracal (PH) geometries from the infinite or semi-infinite stream flow geometries from more classical geometries here. This is path or packed [inaudible] equivalent including like an air gap. This is a general configuration and many of the analyses that we use actually had simplified geometry. Next.

Waste Package Containment Models as I say the modular nature based on the material, and its speculatory in words of making uniform corrosion, pitting or stress corrosion or some other type of model identified here. I'm going to identify it later that getting the models is perhaps one of the greatest challenges facing us at the moment. From this, from having these types of models in using the environmental data we, the model calculates time container failure for the container and or cladding. Next slide.

DR. LANGMUIR: Isn't that likely to be just a statistical function that you're looking at something like pitting corrosion? You have one thing fail out of ten or one out of twenty in a given time frame?

DR. APTED: That's right and the question then becomes also is it important to characterize, especially for something pitting the aperture, the geometry of that and how many pits and so on. Waste Package Release, I've sliced the Release Model Universe in a slightly different way, but all of Toms' models that he's talked about fall into one of these three categories. From the Solubility Limited Release, Boundry Condition, Reactionry Permitted Boundry Condtion which we're finding more and more is just not applicable and we've go to start getting away from collecting this kind of data. And Inventory Limited Release.

We're not really solubility limited a small initial pulse goes into the solution.

DR. LANGMUIR: These's a little permeation which we talked about in the end of Toms' talk and that was if the release rates related to the amount of 02 that can get into the system from outside the package that limits release.

DR. APTED: That may be the most viable case where it's not the actual fluid reaction rate of the, in an open system but it may be rate limited by mass transfer. Basically, and like the Swedes' were very successful for example with our compra (PH) corrosion model for just that reason. They use a mass transfer rather than a reaction rate type limited. Again that's not reaction rate now it's mass transfer.

DR. LANGMUIR: It's not inventory either. It's none of those things listed as such.

DR. APTED: No, well what we can do is employ some sort of solubility limit at the surface in terms of the concentration of whatever the product is --

DR. LANGMUIR: But that's not limiting --

DR. APTED: We're run with diffusion the other way. We've done it and its basically this case in reverse. But from this we calculate fracture release rate as Tom shown and of course it's easy enough to calculate a cumulative release rate by just integrating that type of information. I think we're going to jump now into typical results. Those are not typical their very hand selected, but they show a range --

MR. ALEXANDER: You're gonna talk about congruent versus semicongruent?

DR. APTED: Yeah, that's one of, I think the very first one. This is actually U02 is unstable and U02 is stable. This is one of the cases that Tom mentioned the congruency where, we use an individual radionuclide solubilities many of these solids can show very much higher release rates.

If on the other hand there's congruency argument, now this is the case where U02 is stable rather than some U307 phase you can actually have, you'll have a much lower release rate. And the reason is that these release rates now are are constrained by the solubility of the matrix and in a product of the mass fraction. And of course many of these are very small mass fractions of the spent fuel. And so you're multiplying solubility U02 which is low in this case times another sweep fraction. It's much less than one. So you get very low release rates. These are comprobable to a, not surprising to the rates that Tom was showing in many of his examples for congruency. Next slide.

The one thing we have look like, although we haven't actual data to defend the distribution of container failure is what is the effect of that? Tom shows and this is on a different scale, sort of a long log scale. The release gap material from a Waste Package, this is one Waste Package failing at a 1,000 years point failure. Ice spike release and then of course this gradual fall off. If on the other hand there is some sort of distribution of failures of packages and this is where we're getting into the probablelistic aspects the overall system performance rather than one Waste Package.

The performance of the system now, the average system is different because essentially we're taking the same sort of heat release and now there's [inaudible] failing all around, primarily distributed around a 1,000 years. Now Ms. Andre' [inaudible] is saying well how do you defend that distribution, and I don't. What we're trying to do is show the effects. Show the sensitivity and if there's a sensitivity then perhaps it's worth trying to establish the credentials of distributor container failure if that can be shown to be important.

There was much mention that KBS-3 and 1983 the Swedish design was successful only, well not only, but chiefly they had a problem with the Iodine 129 even with a million years of containment. If they all failed at a million years, Iodine 29 in the gap was released as a spike. And so what they did was they assumed the uniform distribution of container failures. Again, it sounds ad hoc, I'm just saying that there are people out there Tom Pigford, the Swedes', other international groups. The Canadians who are looking at this effect, trying to document what is this effect of distributed container failures. Next slide.

We've gone into putting into the effect of what it might be, happen if Uranium precipitates, someone mentioned this radiolis affect. What happens if things are oxidizing highly soluble at the waste form surface and then there is a redox (PH) front maybe 170 centimeters or one centimeter away from the waste form in a more soluble uranium solid forms? And this is some of our results showing what is the effect on release of precipitation at these various fronts.

So again trying to show what is a sensitivity of release to the affected precipitation. We've also taken some of Don, Toms' endorsements and enhancements, looked at the effect of no decay chain or effective decay chain and as he was showing some of the effects here get to be more important at beyond from 10,000 years and beyond. That the grow in from uranium 234 series of thoriam (PH) and uranium becomes, can become significant.

Benchmarking very quickly. The a, a few years ago we went and engaged in a benchmark comparison of the AREST in the SYVAC-VAULT Code. SYVAC is the total systems model developed by AECL. Vault is their submodel for Waste Package. The reasons for engaging this is a, to help establish the credibility of both our codes for predictable Performance of Assessment. Identify a deficiencies and were did we find a lot in both codes at that time. From that identify future improvements and which we could borrow from one another. And to form a better understanding of both approaches because they are different. Next slide.

There actually a much larger set of assumptions and aspects of the models to relate to you in this comparison. Just some of the things that we need to identify before undergoing any sort of benchmarking is to understand the differences in the model, because if you understand that a head of time you can: (a) prior predict where some of the problems are going to be and where some of the different results are expected.

Anyway so its pherical versus plainer geometry. We use an exact analytics solution as Tom said versus approximate. A number of semi-infinite Close Rock Thickness versus a Finite Rock Host Thickness, and understanding these we were able to anticipate differences in our results. Lets go on to the next step.

This is for the gapped release of the AREST versus the SYVAC Model. I don't want to say to much about that. Lets go onto the matrix model. Here we see three regions really were the codes can be compared at early time up to 7,000 years. Out to about 10,00, excuse me a 100,000 years and then beyond that. The reason we understand why SYVAC falls off here because the have a Finite Host Rock Thickness we don't. They predict a higher release because their using an arbitrary mass transfer coefficient so that they can match break through times to the AREST Code. Anyways there's a very similar jost of studies that we've done on initial comparison of our code with the SYVAC-VAULT Model.

DR. LANGMUIR: Which do you think most applies to the Yucca

Mountain?

DR. APTED: Well at this state, in these models unfortunately none of these, because there well, to the extent these represents the Wet Continuous Pathway Case. In diffusion so to the extent that that model would be relevant to whatever probability in the number of packages, then that would be fine. You've got to realize the Canadians have very little interest in a Dry Case or even the Drip Case. Because it's just not useful for them. So what we've done is gone after the type of benchmarking that we can do that makes sense. We are limited in that sense. The Far Field Modeling people have the same problem in a sense.

DR. LANGMUIR: Are there any other codes that can deal with unsat conditions that you can benchmark then?

DR. APTED: Not at the Near Field Codes in a Waste Package Codes. We've looked at the Key Chain Grow In. You see very similar trends in, you know relative trends in our models are consistent which is encouraging. Next slide. Now we looked at also precipitation, host rock boundry, the ingredient actually gets a little bit better and if we look at precipitation on the next slide. If close to the Host Rock surface results are wonderful, in wonderful agreement. As Tom has said probably to good an agreement. Anyways this will give you a flavor of some of the work we've already done to date.

Now currently we're undergoing defecation of benchmark problems within the program that the Yucca Mountain Project, the Berkeley Group, the PNL Group and other groups will participate in to compare approaches.

MR. ALEXANDER: Wouldn't that include the PANDORA Code as a one of the toys of the 80s' --

DR. APTED: Yes, yes we would. I hope it would. Now we've, I haven't shown now we've, we have as their [inaudible] similar a flow saturation model as the PANDORA Model contains and do some of the same sort of corrections and shared solubility limits and so on. So, it's basically one liner code, it's algebra, algebraic equation. So we like to get their involvement in that area. A lets go on to, we on our future activities.

Okay, we're particular seeking this is not a real special work, with modifications to containment models, alternate container materials are being considered and were discussed in the SCP. Planning failure is also discussed in the SCP in models for describing that are under investigation. Enhancements to the release models, Tom didn't show you'll his ideas on further development of release models but basically what we hope to do is take his developmental work and implement it.

Basically we in the business, the mass program of implementing. Many of these other models particularly lets say the mass transfer models into a subsystem code. So take it beyond characterizing just one waste package into a system. Future evaluation of coupled processes, our group and Thurston Frost at LBL doing thermo hydrologic modeling with TUFF. Looking at global changes in saturation fronts, that are degrees of saturation due to boiling. Thermo mechanical work, Charlie Voss at PNL and others, but I work closely with Charlie. We're looking at thermo mechanical effects particular around this emplacement hole that Tom stress was very important in terms of trying to decide which of these models in release are going to be appropriate.

Someone mentioned radiolosis, there are radiolosis codes that exist. My one believe is that the radiation in radiolosis effects have to be brought into Geochemical modeling because basically that how they enter the picture. What effects did they have on pH and EH locally. Formation of other complexes. Scale effects we're finding there is a difference between modeling the thermo field of one Waste Package versus one panel versus modeling a whole Repository system.

Benchmark comparisons as I mentioned were needed next week to go over and finalize a host of test problems. To begin that benchmark comparison and I've run out of time on Sensitivity Analysis but that also we're going to try to identify key parameters.

Some we can get by direct inspection of these equations. I think Tom mentioned that and I think that's very key. Other parts will have to be modeled as the interaction of several processes together. Thank you.

Mr. ALEXANDER: Questions. Any questions for Mick. Well Warner that concludes our Technical Presentations for this session and I turn the meeting back over to you and Tom Isaacs.

DR. NORTH: Well we'd like to thank you very much for two days of indepth discussion. I think your performance has overall been most impressive in terms of the quality of the material you've given to us. The care and thought which you took the instructions we gave you and implemented them and I think did an outstanding job of giving us the kind of presentation that we wanted to hear. I think we covered a tremendous amount of material in this period of time and I think clearly achieve the objective that I wanted to see us attain of getting our panel up the learning curve very quickly so that we had a good overview of what you were doing where you were and where you were going.

So my congratulations to all involved and what I think was really a very good job.

MR. STEIN: Warner from the Technical people that made the presentation today and yesterday I'd like to thank you for those comments but obviously the [inaudible] had quite a few very indepth and I think were very pertinent comments that we recognized that we have to take to heart as we continue our program. I think that your comments are going to be a great help yours, and I mean the entire board of course. Your comments are going to be a great help to us and that's the sort of think that I hope that we can continue to do as we move forward in the program and benefit from your experience and capability. Thank you again for the time that you gave us and we do appreciate.

DR. NORTH: I'd like to close with a parting observation. In terms of a sense of priorities on our interaction. I conclude at the end of this two day period that perhaps the highest priority out to be on the problems I was discussing a couple of hours ago on the management.

The setting of priorities the issue of how much is enough so that we resist the temptation to go further into the interesting science or the response to critical comments. Then the program really should do and how do we make those trade offs between wanting to go a little further pursue the science pursue some very interesting questions or get a little bit more supporting information. Versus the need to get on with this project in a timely fashion. And you have an exhaustive amount of material.

I mean my headaches thinking about what I've done to prepare this meeting, for this meeting and what we've covered in the last two days. Trying to think about how do you synthesize it into one management plan so that you could explain to top management be that the Secretary or interested parties in Congress or interested parties in the public. In five minutes or an hour just what are the critical issues in terms of implementing the Repository and making decisions on is the Repository acceptable.

And so I'd like to set as our collective agenda in risk and performance analysis getting that apex of the pyramid view of the management of this with respect to time and with respect to quality in terms of doing the job that needs to be done. Do I have any further comments from any of you --

DR. CANTLON: I'd endorse that I think that is very, very important.

MR. ALEXANDER: Of course I hope that you felt that we endorse that as well because next year we're embarking on heavy duty sensitivity effort and I really appreciate the endorsement frankly.

DR. NORTH: Well, we certainly want to come out with a ringing endorsement on that point and I view it as a really awesomely difficult job to manage something that is this complex and has I'll say so much visibility. The number of people you have in this effort and the number of disciplines involved I find quite awe inspiring. And to the extent that we can help you in sharpening up some of the questions I feel that's a major goal of our whole activity.

MR. ISAACS: Let me just make a few comments [inaudible] if I can. First I want to thank you for the compliment you paid us on the preparation and I'd like to take the oppor, presentation excuse me and I'd like to take the opportunity as I did in Los Vegas If you don't mind to thank the staff that worked so hard in making sure that this thing came together as effectively as it did. And obviously I sense that it was extremely effective and appreciate the comment and would like to make sure that those who had to leave early, made presentations and those who supported them are made well aware of the comments that you made in closing. And I will see to it that they get copies of that and I appreciate that.

Your points are well taken. Some of the thoughts I had were very similar to yours on the presentations. It does point out the tremendous management challenge that we have as well as technical challenge in this program. And it's very important for us to balance as I tried to indicate for those of you who were there in Los Vegas. The balance that we need to draw between doing absolutely everything that is necessary and doing a bit more because you don't always know what's going to be necessary and therefore you have to air to someone on the side conservatism while keeping your eye on the ball. And the ball in this case is not a research and development program. The goal line in this case is to determine if the site is suitable and if its suitable to go forward based on the wall.

We would recommend very much I think that we work together to try and find the right mechanisms for getting involved in these programs. One of the things as you know I've focused on very heavily on these first few meetings is lets be crystal clear on what the objective is when we get together. So we don't waste our time and we don't come here in five minutes and do a presentation and you say excuse me but that's not what I was interested in hearing about.

So it's very important that we continue that and these kinds of discussions say to me we need to find a mechanisms to do things efficiently and to hit the target each time so that we make the best use of this time because it is tremendously resource intensive on our side. I'm sure you recognize that we've got to take the people who are actually doing the work and say wait a minute we need to do this. And that's hopeful, I continue to preach that this is a virtue for the program but not with out cost and we have to make sure that it's good for both sides to do that.

I think we'd like your help in that regard. We need to examine that. The one point that I mentioned to Don that I think we also need to explore be, is to recognize where the Board can help us look forward. Here's a classical example of where we are at. We've done an awful lot of work but in some cases, we're just tieing the track shoes on we're not down the track. And we need the, we can use some help in this regard so that seven years from today or what have you we are prepared for a license application if the site is good.

That's a very good example, but we need to make sure that what we hear back from the board we can distinguish between why don't you think about doing this and wait a minute you're doing this wrong and you really need to fix it. And those kind of distinctions would be very important as we fan out with these panels and staff and consultants and subject matter getting into depth. So that we can sift through it and understand where to apply our resources and you can help us make sure we don't fritter our resources on thoughts that you have that we really think we have covered but maybe we misunderstand one another. In these kinds of discussions and therefore we go off.

So I just want to say that from my perspective and I think my Departments perspective I continue to be more enthused with each of these meetings. That doesn't mean that there's less work. There's more work but I think it's going to pay off in the long run. We certainly very much appreciate that opportunity. We continue to need to work with all of you and with your Chairman very closely to make sure, and obviously with your Executive Director to make sure that logistically and substantively we make good progress here. I'm optimistic that we off to the right foot. Thank you.

DR. NORTH: Are there any further comments. Then I believe we stand adjourned. Thank you very much.

Adjourned: 3:13 p.m.