UNITED STATES

NUCLEAR WASTE TECHNICAL REVIEW BOARD

FALL BOARD MEETING

September 27, 2006

Longstreet Inn and Casino
Stateline and Highway 373
Amargosa Valley, Nevada 89020

BOARD MEMBERS PRESENT

Dr. Mark Abkowitz
Dr. William Howard Arnold
Dr. Thure Cerling
Dr. David Duquette
Dr. B. John Garrick, Chair, NWTRB
Dr. George Hornberger
Dr. Andrew Kadak
Dr. Ronald Latanision
Dr. Ali Mosleh
Dr. Henry Petroski

SENIOR PROFESSIONAL STAFF

Dr. Carlos A.W. Di Bella
Dr. David Diodato
Dr. Daniel Fehringer
Dr. Dan Metlay
Dr. John Pye

NWTRB STAFF

Dr. William D. Barnard, Executive Director
Joyce Dory, Director of Administration
Karyn Severson, Director External Affairs
Linda Coultry, Program Support Specialist
Davonya Barnes, Staff Assistant

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P R O C E E D I N G S

9:00 p.m.

GARRICK: After the trumpet sounds, I should be saying it's time to place your bets. Maybe I should say that anyhow.

Well, good morning and welcome. My name is John Garrick. I'm Chairman of the Nuclear Waste Technical Review Board. And, on behalf of the Board, I'd like to say we're very pleased to be back in Amargosa Valley. It's been a little while. It's always a nice place for us to be, and we enjoy it.

And, before I introduce the Board members, I would like to recognize Jan Cameron, who is Chairman of the Town Advisory Board of Amargosa Valley, and ask her if she would say a few remarks.

CAMERON: Good morning.

I would like to welcome you here as well. We're delighted that you could come to Amargosa Valley. Since some of you may know, our town border, our township border, borders on Yucca Mountain. We are, in fact, the community that would be most affected by Yucca Mountain. Most of us are not particularly afraid of that. We are hoping that there will be some positive benefits from the activities out there.

We hope that you enjoy the day. We did order up some very good weather for you. It is not going to get terribly hot. But, lots of sunshine. And, I hope that you all will have a very successful meeting, that you will come back very soon and visit us here.

Thank you for coming.

GARRICK: Thank you, Jan.

As you know, our meetings begin with introductions of the Board, and I will begin with myself. I'm a consultant these days, primarily on the application of the risk sciences to a variety of industries, such as transportation, space, defense, and nuclear, chemical. My background and areas of interest are risk assessment and nuclear science and engineering.

And, as I introduce the Board members, I'd like them to raise their hand so that they can be identified by everybody in the room.

At the top of the order is Mark Abkowitz. Mark is Professor of Civil Engineering and Management Technology at Vanderbilt University, and Director of the Vanderbilt Center for Environmental Management Services.

Howard Arnold. Howard is a consultant to the nuclear industry, having previously served in a number of senior management positions, including vice-president of the Westinghouse Hanford Company, and president of Louisiana Energy Services.

Thure Cerling. Thure is a Distinguished Professor of Geology and Geophysics and a Distinguished Professor of Biology at the University of Utah. He is a geochemist, with particular expertise in applying geochemistry to a wide range of geological, climatological, and anthropological studies.

David Duquette. David is Department Head and Professor of Materials Engineering at Rensselaer Polytechnic Institute in Troy, New York. His areas of expertise include physical, chemical, and mechanical properties of metals and alloys, with special emphasis on environmental interactions.

George Hornberger. George is the Ernest H. Ern Professor of Environmental Sciences at the University of Virginia. His research interests include catchment hydrology, hydrochemistry, and transportation of colloids in geological media.

Andrew Kadak. Andy is Professor of Practice in the Nuclear Engineering Department of the Massachusetts Institute of Technology. His research interests include the development of advanced reactors, space nuclear power systems, and improved licensing standards for advanced reactors.

Ron Latanision. Ton is an Emeritus Professor at MIT and a Principal and Director of Mechanics and Materials with the engineering and scientific consulting firm, Exponent. His areas of expertise include materials processing and corrosion of metals and other materials in different aqueous environments.

Ali Mosleh. Ali is the Nicole J. Kim Professor of Engineering and Director of the Center for Risk and Reliability at the University of Maryland. His areas of expertise include risk and safety analysis, reliability analyses, and decision analyses for the nuclear, chemical and aerospace industries.

William Murphy. Bill is an Associate Professor in the Department of Geological and Environmental Sciences at California State University-Chico. His areas of expertise are geology, hydrogeology, and geochemistry.

Henry Petroski. Henry is the Aleksandar S. Vesic Professor of Civil Engineering and Professor of History at Duke University. His current research interests are in the areas of failure analysis and design theory.

Since our last meeting with you, the Board has restructured its panels and we would like to share with you what we have done. As most of you know, we previously had four panels covering, one, the natural system, two, the engineered system, three, the repository system performance and integration, and four, waste management system.

Our experience in conducting Board activities and our design to maximize the use of Board expertise has led us to a structure of three panels and eight technical discipline leads. The new panels reflect more of a systems perspective of the repository from the view of preclosure operations, postclosure operations and performance, and integration of the total waste management system.

The Panel on Preclosure Operations will focus on accessing the spent nuclear fuel or waste at the generator site, transporting and handling of the fuel or waste, and surface-facility design and operations, including repository emplacement operations. Board member Howard Arnold will chair this Panel. The Panel on Postclosure Repository Performance will cover technical and scientific issues, such as the nature of the radionuclide source term and the movement of radionuclides most significant to dose through the engineered and natural barriers. This Panel will be co-chaired by Board members George Hornberger and Ron Latanision. The Panel on System Integration will evaluate DOE integration efforts, including activities related to the integration of science and engineering, as well as the integration of preclosure and postclosure activities. Board Member Mark Abkowitz will chair this Panel.

For the technical disciplines and the lead Board members, we have organized ourselves as follows: for the Source Term, Bill Murphy; Corrosion, David Duquette; Natural System, Thure Cerling; Thermal Management, Andy Kadak; Transportation--he gets double duty--Mark Abkowitz; Surface

Facilities, Henry Petroski; Performance Assessment, Ali Mosleh; and Dose Assessment, I will be taking that one on.

As a matter of fact, we have a sheet in the back of the room that covers all of this. So, if you're interested in having that, you can get it from the table.

Now, at the beginning of each meeting, there are a few routine things that we do. One is for all of us to be clear about the distinction between member opinions and official Board positions. Board meetings, we want to be sure are kept as spontaneous as possible. We express ourselves quite freely, and we want to be able to continue to do that. So, when Board members speak extemporaneously, it is important to realize that we are speaking on our own behalf, not on behalf of the Board. When a Board position is articulated, we will do our best to identify it as such.

Now, let's turn to today's meeting, which is focused on the safety case for the Yucca Mountain repository. The need for the safety case arises because it may not be possible, in a conventional sense, to demonstrate precisely how a repository will perform tens to hundreds of thousands of years into the future. However, steps can be taken to increase confidence in the estimates of future repository performance. And, in fact, the Board has a long history of strongly endorsing DOE efforts to develop multiple lines of evidence that can support a safety case for the proposed repository, such as: performance assessment calculations; safety margins and defense-in-depth; insights from natural analogues; and performance confirmation.

To be credible and effective in supporting the safety case, development of each of the elements requires careful consideration and faithful execution. For example, the performance confirmation plan should identify in detail the elements of the performance assessment to be evaluated, how testing or monitoring of those elements would be accomplished, how information gained from the testing and monitoring would be evaluated, what actions would occur as a result of those evaluations, and how frequently such evaluations would occur.

Today, the Board looks forward to hearing DOE's approach to the safety case. There are five scheduled presentations from DOE on the agenda, beginning with a Program and Project Overview by Ward Sproat, the new Director of the Office of Civilian Radioactive Waste Management. We appreciate Ward's presence here, and welcome him to what we hope will be the first of many NWTRB meetings for him.

Following that, we will be getting a presentation by Lawrence Kokajko from the U.S. Nuclear Regulatory Commission. Lawrence is Director of the Technical Review Directorate of the Division of High Level Waste. He will be providing the NRC perspective on the safety case for Yucca

Mountain, after which, we will break for lunch.

Following lunch, Russ Dyer, Chief Scientist of OCRWM, will introduce the afternoon's presentations with an overview of the Yucca Mountain repository system postclosure safety case. Peter Swift of Sandia National Laboratories will give a presentation on Barrier Capability and the Assessment of Disposal System Performance. Pat Brady, also of Sandia, will discuss the role of analogues. Mark Peters, from Argonne National Laboratory, will present the Science and Technology Program and describe his role in the safety case. The idea here is to try to get everybody to relate their activities to the safety performance of the repository.

Then, Frank Hansen from Sandia will give a presentation on two other important elements of the safety case: performance confirmation and long-term science and monitoring. The DOE presentations will end with concluding remarks on the safety case by Peter Swift. All of these elements are important to the safety case, and we look forward to an engaging and substantive series of presentations.

Now, as usual, we have scheduled time for public comment as part of our meetings, and that's very important to the Board. You will notice that we have scheduled public comments pretty much at the end of the meeting, and we have been asked if we could allow some time just before lunch today for comments for those who will be unable to stay with us the full day. So, we will allow some time just prior to lunch for public comments. We are limited on how much time we have for that. So, if you can wait until the end of the day, that would be appreciated.

If you would like to comment, please enter your name on the sign-up sheet at the table near the entrance to the room. Of course, written comments of any extended remarks can be submitted and will be made part of the record. Some of you have asked about questioning during the course of the presentations. Our preference is for you to write down your questions, and submit them to Davonya Barnes or Linda Coultry over there by the door. They are seated in the back of the room most of the time. We will cover as many questions as we can.

Finally, I would like to ask all of you to turn off your cell phones and pagers, at least turn them to the silent mode.

Without further ado, I would like to introduce Ward Sproat. As I said earlier, Ward has recently been appointed as Director of OCRWM, and from all reports, has been enthusiastically engaged ever since. We look forward to hearing his assessment of the state of the program, and to learning what he plans for the future.

Ward, welcome.

SPROAT: Thank you. Good morning, everybody.

It's quite an honor to be here as the new Director of OCRWM, and to be the head and take on the challenge of trying to move the Yucca Mountain Project forward. And, what I would like to do this morning is to give you a little bit of background about myself, because I know a number of people on the Board, but I know there are another number of you who have no idea who I am or where I came from. So, I'm going to give you a little bit of my background.

So, I'm going to tell you a little bit about myself. I'm going to talk about the new schedule for Yucca Mountain, and how we derived it, and what it is, because we do have a schedule that we are going to adhere to. So, I'm going to talk about that. I'm going to talk about the four strategic objectives I've laid out for this program going forward, and what they are and why they are important. And, then, finally, I'm going to share with you my perspective on some key programmatic issues that this program is facing that I am personally going to be involved with, and heavily involved with, going forward.

I recognize that probably everybody in this room has more experience on this Project than I do. And, so, in a way, I feel like there's this fast moving train going on the track, and I'm running really fast to try and catch up and grab on and get on board. I hope that from the discussion this morning, you'll get a sense of how well I'm doing or not doing in trying to catch up with this program so far. But, I would encourage you to, you know, when I'm done, feel free to ask whatever kind of questions you want to ask, whether it's programmatic, technical, or whatever. And, I hope you'll get a sense of logging into the glean about this program so far, and the kind of level of involvement that I have as the new Director in the program.

Could I have the next slide? So, who is this guy who has taken over as director? And, I've got a background probably different than most of the previous directors. I've got a bachelor's in electrical engineering, and a master's of science and dynamics of organizations from the University of Pennsylvania. And, I'm a registered professional engineer.

And, from my perspective, this is the marks of demarcation point in this Project, from the science, which is still absolutely vital and will continue, as you'll hear later on today, to engineering. We're going to design this facility based on the insights we've gotten from the science, and we're going to move forward with the design and the licensing of Yucca Mountain. So, we are consciously making a shift in the focus of this program from science to engineering. I'll talk more about that later.

My professional background. I took an early retirement from Exelon in 2002. I was vice-president of

International Projects in Exelon Generation, and I spent all of 2002 in South Africa as the Chief Operating Officer of the Pebble Bed Modular Reactor International Joint Venture, of which Exelon was a shareholder. I was down there as a member of the Board of Directors of that venture for about three years. I was asked by the board to come down as COO for a year during 2002 to help the South African management team come up with and freeze a credible preliminary design, cost estimate, project plan, business case, so that that project could move forward.

I'm happy to say that we achieved the goals we went down there to achieve, and the South African government is moving forward with building a demonstration pebble bed in South Africa, at Capetown.

Now, prior to that, to give you another sense of my background and kind of experience that I'm bringing to the Project, I was Director of Engineering for the PECO Nuclear Fleet. So, I was the design authority for the fleet of plants, Peach Bottom, TMI, Oyster Creek, and, so, as the design authority, I got a lot of experience and background in nuclear, commercial nuclear plant operations, engineering, licensing, construction. And, some of those other jobs back that up.

I was Director of Maintenance, held the positions of Directors of Maintenance, Engineering and Projects at

Limerick, so I have a nuclear operations background and experience also. Next to the last job was Director of Quality Management at PECO, and this was a culture intervention across a 13,000 person company to change the culture, focused on process improvement and quality at PECO based on the lessons learned of the culture change we made at PECO Nuclear, at the (inaudible) corporate level.

So, as many of you are aware, this program has had quality issues in the past, and has a number of issues around quality culture throughout the organization. I'm bringing that experience with me into this job also to address the quality cultural issues that this Project has. I'll talk a little bit more about that in a minute.

And, then finally, at the beginning of my career, I was Electrical Project Engineer for Limerick Project. And, in that role, I had total responsibility for the electrical design and licensing of the Limerick Nuclear Plant. So, I learned a lot about licensing in NRC space there initially, so, I've been through a licensing process, written part of the license application, been heavily involved with NRC staff in the design of nuclear power plants, and I understand how it's done.

So, that's the background that I'm bringing with me and it's that experience base that I'm bringing to this Project as we move it forward.

Next slide? So, in my third or fourth week on the job, I had my first hearing in front of Congress and the House, and I announced the new schedule for Yucca Mountain. And, this is the schedule. We're going to certify the licensing support network, and I think most of the people in this room understand what the licensing support network is. We're going to certify that on or before December of 2007.

We have to issue a supplemental environmental impact statement on the Project. We're going to do that no later than May of 2008, and we will submit a docketable and high quality license application to the NRC no later than Monday, June 30, 2008. This Project does not have, and has not had a very good track record in delivering on its promises and its commitments up until now. I can assure you it will meet these dates. There is no question in my mind, we are changed and are changing the management processes throughout the Project. We've got new teams put in place, a new way of managing this, and we will meet these dates. This Project is going to go forward, and move into the light design phase and the licensing phase. We're going to meet that date.

Now, based on that I also announced at that hearing the best achievable schedule for opening Yucca Mountain. And, some folks criticized me on that, saying, you know, that's not realistic. I want to make it very clear I didn't say it's the most probable schedule, I said it's the best achievable schedule based on the issues that are under control of DOE and certain external issues that have to get addressed through legislation.

But, our construction schedule is to start Nevada rail line construction by October 2009, start repository construction in September 2011, assuming that we're able to maintain the mandated minimum licensing schedule with the NRC. Everybody, of course, has their own opinion as to whether or not that will happen or not. But, that's what that date is based on. We will submit the operating license application by March of 2013, and we would expect to receive, a license to receive and possess and start operations in the mountain by March of 2017. That's the schedule.

We're working to, we're putting together the Project baseline to that schedule. We're putting the Project cash flows together on that schedule. That's the schedule the entire team of 2,000 plus people are working to. And, we're going to stick to it. So, that's the new schedule that we've put together for the Project.

Can I have the next slide? Coming in, while I was waiting to get confirmed for seven months, so I had a lot of time to think about this, I recognized that this program, more so than probably--I recognized this program just has a number of issues that need to be addressed. And, so, I said it's very, very important to come in here with--figure out strategically what does this program and its management team need to focus on and make happen in the next two and a half or three years.

And, so, the first strategic objective, very clearly, is submit a high quality and docketable license application to the NRC no later than 30 June 2008, and we are committed to do that. The entire project is focused on it. We are changing the way, we're putting a whole different license application writing and review process in place than we ever had before, and we're taking a team based approach. It's not going to be a group of people over here writing it and tossing it over the fence to DOE to review it. It's going to be very much an integrated, collaborative approach to write this license application to meet that schedule, and have a high confidence in the management team and the licensing teams we're putting together to pull this off.

One of the things, just to give you an example of what we're going to do differently, we are going to have a licensing strategy team that's going to be involved with the front end of this process, where there are teams that are going to be assembled to write specific sections of the license application. They're going to come together, take their first cut at reviewing their section, some of it's been written before, what the gaps are, what needs to be enhanced.

They're going to come to the licensing strategy team, which I'm going to be on, and which there will be other senior nuclear people who have licensing experience also will be on that committee. And, they're going to present to us what the key licensing issues are, each of their sections of the license application, and we will make decisions from a strategic level as to what the licensing positions are going to be that we're going to take in that license application, and how we think we can defend them, and whether or not the approaches that have been, at least some people thought we were going to take, whether or not we want to maintain that position or we want to change them in the license application.

And, so, we're going to do that right up front, and then the license application, they're going to go up, figure out how to incorporate those strategies into the license application, and then they're going to come back one more time, and if they come back to say we can't do it that way, we think we need to do it this other way, we'll review that and give them an okay to take a different position.

But, the point is there's going to be senior management hands-on experienced people on the front end of this process, making decisions about the licensing positions, key licensing positions we're going to take in this license application going forward. That's going to be on the front end of the process, and not trying to be shoehorned in later on like it was before. That's subject number one.

The second objective, which you can read up here, is based on an issue that I think a number of people in this room and a number of people outside this room have voiced concerns about for a long time, and it's a recognition that the Department of Energy, at least as has been organized and focused around this project up until now, would have an extremely difficult time being a credible NRC licensee to want to license, to build, and run the Yucca Mountain facility under an NRC license.

In a lot of cases, it is missing some of the key competencies it needs, both managerial competencies and technical competencies, and it's missing a number of the key business processes that it needs in terms of business planning, in terms of performance management. And, quite frankly, it's got culture issues that are broader than just in DOE.

The issues that you're aware of that have surfaced over the last four or five years regarding quality issues in the labs, quality issues in the M&O contractor, are indicative of an immature quality focus culture. No doubt about it. And, so, the second objective is going to be probably the one that I'm going to be personally spending most of my time on over the next two and a half years, about setting this organization up for long-term success in terms of having the technical competencies and skills, but more importantly, the cultural competencies and skills to be a credible nuclear licensee, given the requirements of today and the cultural needs of today, in terms of the quality and the technical competencies that an NCR licensee needs to have to operate this repository.

Next one? The third one is something that I think most of the people in the room are also aware of, is that right now, the Department of Energy has a number of standard contracts with every nuclear power plant owner in the country to take their spent nuclear fuel. We are in default on a number of those contracts, and there is growing potential liability to the taxpayers of this country as a result of that.

This issue has been festering for a while. There have been some settlements, and as a matter of fact, earlier in my career with Exelon, I negotiated the first settlement between PECO Energy and the DOE on a settlement of the Peach Bottom spent fuel contracts. And that settlement has formed the framework of a settlement between Exelon and DOE, and has been kind of the basis for other settlements that either have been settled or are ongoing.

But, the issue here is that we can't keep going as we're going. There needs to be an integrated strategic approach to limiting taxpayer liability around the spent fuel contracts and taking an intelligent approach where both sides can benefit from this. And, so, that's something else we're going to be directly involved with, and there's a lot of different ways to go after this. I was asked in a couple different Congressional hearings, well, what are some of your specific ideas, and I said the reality is is there is not one size fits all here. There's a dead plant society, that the plants are shut down, they're torn down and the fuel is sitting on a pad.

There are, on the other side of the spectrum, you've got the Exelons and the Southerns and the Entergies that are in the nuclear business for the long-haul. And, then, you have another group of people in the middle. And, so, one fix is not going to address all of those. But, a set of creative approaches to those folks I think can generate some net win/wins, both limiting taxpayer liability, as well as making sure that the rate payers who have paid into the nuclear waste fund for this stay whole. So, that's going to be a whole area that I'm going to be involved with also.

And, then, finally, the fourth area is transportation. And, my opinion on this is that this is an area that has been woefully underfunded, and had inadequate attention paid to it over the last five or six years. I mean, we can come up with a great license application for

Yucca Mountain, come up with a great design, and we can get a license, but if we can't get the fuel there, we haven't gained anything.

So, this is an area where I firmly believe we're going to spend a lot of time, a lot of focus, and start to look at this in an integrated, national strategic process, where we maximize local involvement on the route planning, upfront, because it's going to take a while. We figure out how the emergency responder, the emergency plans need to be put in place along those routes, how we involve the counties, how we involve the states, how we involve the tribes in planning those routes, and to get that whole process going, because it's going to take a while. And, it's been done before, it's not--we're not reinventing the wheel here. It's a process that if it's done right needs a lot of care and feeding, and a lot of public involvement, and needs a lot of work to it, and I want to get that started now. And, so, we're going to devote a lot more resource, a lot more attention to transportation than we ever have before on this Project because I think it's that vital.

Next? So, my last slide, and this is around what I consider are the key programmatic issues with the program. The first one is around the organization and culture. And, I talked a little bit about this under my second strategic objective. Roles and responsibilities in this Project still are not clear to some people.

I know the Board expressed some concerns in your annual report, and from one of your previous meetings about the new organization that was put in place, and had concerns about it. I spent my first six weeks on the job doing one on one interviews, and small group skip level meetings in the OCRWM organization to understand, try to understand the organization as well as what the people in the organization thought about it. And, I'll tell you there's still lack of clarity among a number of people about their roles, responsibilities and how the various business processes in the organization are working or need to work.

So, this is an area that we're going to be focused on as a management team over the next three months to try and get this fixed, but not fixed just from a short-term standpoint, but looking at it from a standpoint of so given the role of OCRWM in the future, in running this repository, what does that organization need to look like, or the skill sets it needs to have, what are the competencies, technical competencies it needs to have, the managerial competencies it needs to have, and start to put in place a long-term human capital plan to build that capability.

The second area is about quality, and I talked about quality before, and focused on this. It's very clear to me that this is, you know, before we had the tagline of quality is Job One. For me, this is probably my Job One. It's about introducing and making sure that the people on this Project, beyond just the people who work directly for me, understand their role and responsibility about quality.

In my former role at Peco, where I was Director of Quality Management, and I learned about, you know, Demmings (phonetic) concepts and process improvement, and a lot of things around that, one of the things I learned is there is a key metric called the cost of quality. Some of you may be aware of it. And, it's a very good qualitative metric that allows you to calculate what the cost is of your organization to produce the requisite quality of product at the tail end of its business processes.

And, so, you do that by adding up what your training costs are to train your people to do things right, what your costs of inspections are for inspecting quality at the tail end of the processes, and what your cost of rework is in terms of, you know, poor product got out of the process at the tail end and needs to be reworked. If you add those together, you get your cost of quality in a very quantitative number.

I haven't done that, obviously, for this project yet, but if I was to guess, out of the budget for this Project for FY07, which isn't finalized yet, but it's probably going to be in the neighborhood of $480 to $490 million plus or minus somewhere. That's a lot of money. If I was to guess, I would bet almost a half of that is going to go to redoing things that have been done already once, and for various reasons, they need to be done again. That's a totally unacceptable metric, absolutely unacceptable.

And, so, this focus on quality, doing it right the first time, and getting that message through not just the DOE organization, but the BSC organization and the National Lab organizations, is something that I'm going to be personally involved with and committed to for the remaining two and a half years of my tenure in this job. And, it's absolutely vital to this program going forward, and it's really, really important. So, it's going to be an area that I will be spending a lot of time on.

One other thing about the organization and culture, it's clear to me that up until now, DOE has taken a position on this project that is what I call semi-hands off. They have taken an approach that says we hired an M&O contractor, a Management and Operations contractor, and we pay them to do this project and we stay out of their way and we manage the contract and not the contractor.

I'll tell you right now that is not my philosophy, and that's not how we're going to manage this project going forward. That is absolutely the wrong way to go for a nuclear project like this. It won't work, and it hasn't worked. I believe that's a fundamental cause of why we have some of the issues we have in the culture, and the quality issues that bubble up through USGS and other places over the years. It's because the senior management of DOE did not provide direct expectations and hold people accountable in the management teams of all those organizations to execute this Project the way it needs to be executed. That changes now with me on this Project.

My vision in terms of how DOE is going to be involved in this Project is going to be quite a bit different from how it's been in the past. I'm going to hold my management team accountable for knowing what's going on in the details, and managing this program to the schedule, to the baseline, and executing. And, I'm going to do that down through the management chains in all the major subcontractors also. So, it's a fundamental shift in our management philosophy for this program.

Second is around, again, on quality of the technical work products. This is an issue about okay, so given the quality issues, that they're not there for the past four or five years, what are the implications for the use of those work products in building a license application and its defense. Sandia, we had a meeting at Sandia last week for a day and a half.

I am very encouraged by the senior management team at Sandia and the way they're taking on this project and their role of lead lab. And, they fully understand that during the licensing defense phase of this, they will have to stand up and defend the technical work products upon which the license application is based, and they are preparing to do that by doing an extensive set of reviews and reworks of the AMRs, the scientific notebooks, and the other issues, the other technical work products that have to come together to support the license application.

So, we're going to go fix the problems that are embedded in those, before we submit that license application. Sandia has got the lead for that, and I have a very high confidence level they understand both the importance and what's needed to do that to do it the right way.

Third is the Sandia Lead Lab transition, just that management shift itself, is an area where we're going to spend a lot of time and continued focus. As I said, we had a very good set of meetings in Sandia last week. I have a very high confidence level in that management team that they have put together, that they can pull this off. But, I will be personally involved in overseeing how that transition is coming, because their leadership of the labs and the science program here is absolutely critical to success, both short-term and long-term.

The last one is an issue that I've come upon over probably the last four to six weeks that I think is really important. As I've talked to people, I think a lot of other people recognize this issue, and it's the transition from science to design. And, you know, there have been 20 plus years of very, very good science on this Project done by worldclass people and experts. And, you folks at the Board have been involved in reviewing that and involved in critiquing it, and will continue to do so.

And, I think as we all understand, the licensing construct for Yucca Mountain is not typical of nuclear power plants. It's not like you do your design, you get a license, and then you build it, and then you walk away and just operate it. This is an entirely different construct. This is about doing some base science, understanding the mountain and the systems well enough to design a repository that can operate well in that environment, and then a continuing program of science and measurement and learning over the next 50 years, 100 years, 150 years, whatever it might be, to confirm that what we know about the natural systems are in fact true.

And, if we find things that--we're learning new things all the time--we find that things are different than maybe we assumed, at this stage of the licensing process, we go back and we make adjustments in the design, or whatever we need to do.

So, we all understand this is a continuing learning process. But, the key thing is we're part of the program now, where we're putting a stake in the ground and saying we now know enough to design this repository and design it right, and that's where we are. So, taking the work that's been done by the scientific community and the science teams, and giving that input to the engineering teams and having them design and come up with a design bases for the surface facilities, the sub-surface facilities, the waste packages, the TADs that is based on what we know as of today from the science, that's exactly where we are in this project right now. And, that's got to happen well, and what I've seen so far tells me there's some gaps there.

It's not well understood and a well managed process. So, between working with the Sandia management team, I think they understand that challenge, working with my management team, I think they understand that challenge, we're going to do some things to force the surfacing--I should say force that integration to occur as we build this license application, so we have a very good, defendable, design base, set of design bases for those facilities that are linked back to the science that's been done in that program.

So, those are my really key issues, the programmatic issues that I'm focused on right now, and will be focused on for the next two and a half years as we go forward with putting that license application together. And, I'm really honored to be here, and I hope my enthusiasm for this Project comes through, and I'm really looking forward to working with the Board as we go forward.

With that, John, I'm open to questions.

GARRICK: Let me lead it off with one. We appreciate the enthusiasm and the focus that you seem to be committed to and giving the project. One of the problems that we frequently encounter is that when there's an issue or a project, a sub-project that is floundering or having problems, often the reason given is budgets. Transportation, for example, is one of those.

What is different in your regime than previous regimes with respect to your ability to get the budgets and control the budgets to get the job done?

SPROAT: I would say first of all that with a budget of $480 to $490 million a year, budget is not the issue. But, I mean, it's just not. It's a management issue about how that money is allocated to priorities and how that spending is controlled and how the line management is held accountable to spend it on stuff that makes sense.

So, for me, it's not an issue of there's not enough money. It's an issue of how the management team controls and allocates those funds to the priorities that it needs to be allocated to, and that's going to be fundamentally different with me here than probably what's been done in the past.

GARRICK: Mark, and then Ron, and then Henry?

ABKOWITZ: Abkowitz, Board.

Ward, I haven't had a chance to meet you personally, but I want to welcome you to the Project and look forward to working with you. I actually have three questions that are somewhat independent, and I'll try to be brief.

The first one has to do with your background as a Registered Professional Engineer, and as a backdrop, the Board is very familiar with what's going on in Finland and Sweden. We've been impressed by the fact that they recognize that engineering design changes radically when you start going through proof of concept, and you create sort of a test environment, and you learn an awful lot. Is there room in your program and in your schedule to go into a mode that doesn't jump directly from a design that's never been proven into construction?

SPROAT: I would say that I haven't specifically evaluated that or considered that as of late. Now, I would say that Part 63, as it's written right now, doesn't really allow that time and approach. Part 63, the way it's written, is a very front end loaded regulatory construct that basically requires you to take the science output, develop the design basis, and submit that, and then basically build it, where even the second stage of the licensing process, which is to get the operating license, is very narrowly focused in terms of did you build it the way you said you were going to build it, and do you have your staffing and your qualifications of your staff in place.

So, the regulatory construct for this project is really not set up to recognize or allow an approach like that. Now, having said that, what's very clear to me is that given the science and what we've learned about this Project and the various natural systems, there are various degrees of uncertainty around the various physical processes, everything from corrosion to infiltration to whatever, and each of these factors, for example, infiltration has, I forget what the Board's annual report said, but there's something like eleven or twelve different variables associated with that. Well, obviously, each of those variables has an uncertainty range around it.

Five years from now, ten years from now, we'll know that uncertainty range will be a little bit smaller. A hundred years from now, that uncertainty range will be even smaller. But, where we are today is where we are, so we need to put a stake in the ground and say here's our design based on what we know, and this is the way we're going to go forward. And, then, based on what we learn in the future, we may--that's where I would see those changes coming about in the future as we learn things about the science program.

But, in terms of a step-wise, incremental approach, design the repository, Part 63 is not set up to allow that.

ABKOWITZ: Thank you. My second question has to do with your comments with regard to transportation as a strategic initiative. And, I applaud your recognition that this has been kind of an ugly stepchild, if you will, for a while.

However, you also mentioned that it's a process that's going to take some time because of the need to interact with a variety of stakeholders.

I was wondering if you could clarify for me how that perspective relates to a DOE transportation external coordinating committee I attended last week, where your department showed a schedule that the national suite of routes would be designed by December of 2007.

SPROAT: In terms of--I don't know the process well enough, and as far as I'm concerned, the process for doing that is not finalized yet, because they haven't run it by me, and I get a vote. So, whatever we put out there in terms of what the plan is, what the schedule is, and the process for doing it, I can't address. I wasn't at the meeting. They haven't run it by me. So, I guess I'm not ready to tell you that I can defend that date yet.

ABKOWITZ: Okay. Well, it's a public meeting in which this was presented to about 70 different associations and tribes and states. So, it seems to me that that may be one of the culture issues you're still working on.

Finally, I understand from some of the discussion that you had on the Hill, you had identified that there would be an increase in activity in terms of independent review of what's going on with the Yucca Mountain project. And, I believe the issue was raised as to what role the Nuclear Waste Technical Review Board plays, since it was established to perform an independent review, and my understanding, and correct me if I'm wrong, your explanation was that the Board did not have the complete skill set to do that properly. So, in the spirit of quality and continuous improvement, I was wondering if you could identify for us where we need to beef up.

SPROAT: I guess I'm missing the context of that interaction, because I don't, and it's not registering with me where I would have said that regarding the Board. We are doing--I've commissioned three independent technical reviews on this project. One is on the draft license application, one is on the quality assurance program, and one is on the engineering processes. All right?

And, I don't think it's appropriate for the Board to do independent reviews of those. If the Board wants to, the Board is certainly welcome. But, from what I need from a management perspective, I'm looking for outside expertise, not involved with the project, to take a look at where those three areas of this project are and give me independent feedback around that.

So, for example, like on quality assurance, I'm looking for people who have been out there and understand what current standards are in commercial nuclear quality assurance programs, and measure what we're doing versus what the standards of today are. And, if the Board has that expertise, great. If that person wants to participate, they're certainly welcome. But, I wouldn't turn that responsibility over to the Board and ask you to do that. Because, quite frankly, I don't think that's your responsibility.

ABKOWITZ: Thank you.

GARRICK: Ron?

LATANISION: Ward, it was good to hear your comments, and I follow Mark's comment and welcome you to this deliberation.

I have two questions. One has to do with transportation systems, a bit of a corollary to Mark's. I think the Board has long felt that transportation does have the potential show-stopper characteristics. And, to paraphrase your language, if you can't get the waste to the repository, then the best engineering design isn't going to make a whole lot of difference.

But, I would like to get a little more clarification on what you mean by more attention to transportation. There is a plan which is being evolved that we've heard discussed over the last couple of years. Is it your sense the plan is not actionable, that it's not complete? What does more attention mean?

SPROAT: What it means is that me, the Director, is going to have more involvement in the overall strategic plan of how this is going to be rolled out. The issue of the national routes by the end of 2007, I guess they haven't reviewed that schedule with me, or explained to me how they're going to, or what's the process for developing those yet. So, I'm a very process oriented guy.

And, so, that might make sense in terms of they show me the process, and maybe the process is we need to put a proposed set of proposed routes out there by that date, and then there's an integral decision making process and collaborative process that takes place over the next two or three years to finalize those. So, I don't know if that's the case or not. If that's the case, that would make sense.

But, my point is is that there are issues around route selection, rail, road, the cask design qualification, the railroad cars that carry the casks. There's just a slew of issues. Is DOE going to own the casks and the cars or not, or are we going to subcontract that out? There are just a number of issues that a lot of people have different ideas, and maybe some people think they know what the answer is. All I'm saying is I want to take a very systematic, process oriented approach to putting together an integrated strategic plan that's very much in the public eye so people understand how we're going to go about doing this. And, I think that's different from what's happened so far.

LATANISION: Latanision, Board.

Second question, and this is kind of a cultural question. It's very clear that your position is subject to the transitions at the White House.

SPROAT: Yes.

LATANISION: But, even within the term of this President, we've seen at least three or four different people occupy your position, and one of the characteristics, at least from my perspective, that leads to effective development of engineering projects and other kinds of projects is sustained leadership.

SPROAT: Yes.

LATANISION: I'm concerned about that.

SPROAT: I am absolutely concerned about that. And, I recognize--I had this conversation with a few folks--it doesn't matter really what I do while I'm here in terms of putting together a high quality license application, a really good design, if after I leave, the whole thing just goes back to the way it was before. I recognize that fully. It's the strategy and the direction I've outlined in terms of DOE's role in this project going forward, in terms of its leadership and management approach, is fundamentally different than it's been before.

Now, how can I influence that set of issues after I leave? Well, obviously, I can't influence it directly, other than while I'm here for the next two and a half years, we're going to build a very, very good high quality credible federal management team. We're going to put in some state of the art management processes, business processes, and performance management processes, with a top notch quality federal, senior federal level management team that understands those processes, have bought into them, that basically will run the project long after I'm gone out of this position. That's how I'm going to address it. I have to.

LATANISION: Thank you.

GARRICK: Henry, and then Andy, and then Thure, and then Bill.

PETROSKI: Petroski, Board.

I would also like to welcome you, and I look forward to hearing more from you. Mark somewhat anticipated my questions and comments regarding science versus engineering, and I'm very pleased that you see it as an engineering project from here on out.

When we visited Finland and Sweden, we were struck, those of us who were on the delegation, that their time schedule is roughly the same as what you have put up, and yet for years, they have been engaged in developing canister designs, placing canisters in holes, casing them in bentonite, taking them out, dealing with all the practical problems that can be really showstoppers. Is it realistic for the U.S. to have a schedule like the Swedes and the Fins without having already started that? Because they've been doing this long before they applied for a license.

SPROAT: I think the answer is yes, it is. And, I'll tell you why. A couple different reasons. One is we'll always know more next year than we know now. Either we're going to move forward with this project or we're not. All right? I'm a very firm believer that this project--I'll tell you the level of frustration on Capitol Hill when I came to this position is palpable. It's like get this Project going or we're going to kill it. Nobody said that to me directly, but it's out there.

So, number one, it's time to move from continuous science to the engineering design phase and the licensing phase, number one.

Number two is the issues that you talked about about doing what I call practical, prototypical building and experimentation is very much, and should be very much of this program, as well as their program. But, it's not a series type of activity that can be done in parallel, because what it's going to--I mean, let's face it, we're talking about extremely long timelines for the length of these waste packages. And, so, another two or three years of prototype testing, or something like that, I don't think is going to tell us a lot more than what we know now.

I think what we do is we say here's what we know now, we put a stake in the ground, we go with what we believe is a defendable set of licensing positions, and licensing cases, we go through the licensing process to defend it, and we come up with the best designs for the waste packages and the repository that we can come up with now, and we modify it as we go forward. That's the only way we can do it.

PETROSKI: Well, I certainly understand that, and I wish you luck.

SPROAT: We will always know more tomorrow than we know today.

GARRICK: Andy?

KADAK: Andy Kadak, Board.

Welcome. I've got two quick questions. Your schedule is very ambitious, and there are a lot of things, though, that are outside of your direct control.

SPROAT: Yes.

KADAK: And, you pointed it out when you testified before Congress. And, I think the one key issue is this EPA final rule, because that will obviously set what you have to design too.

SPROAT: Right.

KADAK: Can you just comment on what you think that is going to be in terms of schedule, and how it might affect your program?

SPROAT: The latest information we have from EPA is they are intending to issue that final rule by the end of the year. I'm sure it will be litigated. I think that's reality. Now, in terms of what the final maximum exposure limits are, whether it stays at 350 or goes lower, I don't know. There are a couple other issues that EPA has gone back and forth on, and where they're going to come out on those, I'm not sure.

But, the approach we're taking in the license application is that in terms of that peak dose calculation and when it occurs, we are going to present the results in the license application over a span of a million years, show where the peak dose is, show what the uncertainties are around that peak dose, whatever the peak dose requirements that comes out of EPA, we'll be able to go to the chart and say that's where it is and how the system is anticipated to act at that point in time. That's the best way I know of trying to address it at this stage of the game.

But, the last piece is about schedule, and is that I don't need to have that EPA standard finalized in order to submit the license application, because the way we're going to write the application, and the approach we're going to take with it. We will need to have that finalized before the NRC can give us a license. That's clear.

KADAK: The second question is you mentioned that there were some science gaps that existed based on your review. Could you just highlight the ones that you think are really important?

SPROAT: Maybe I need to clarify. I'm saying not necessarily science gaps, but gaps between what the science program has determined, and what the engineering program is utilizing as design basis. And, there's a couple examples.

My favorite is volcanism. And, there's a requirement in Part 63 to analyze the consequences of disruptive events, which seismic is one class, and volcanism is another. And, the screening criteria says that if an event has a probability of greater than 1.0 times 10^8, it needs to be screened in and the consequences need to be evaluated.

Now, for people in the audience, just to give you an idea of how small that probability is, it's about the same probability of mass extinction of all life on the earth. So, it's a pretty low probable event. Most people would say it's not credible. But, we have a very deliberate process of expert elicitation around that that has come up with a number of what they think disruptive volcanic event probability at Yucca Mountain is, and it's about 1.7 times 10^8.

Now, a lot of us will argue that if we really think we can calculate that probability to nine significant figures, we're a heck of a lot better than we really are. I just don't buy it. But, if that's what the expert elicitation says, that it's 1.7 instead of 1.0 times 10^8, then that's the number. It's screened in. We have to evaluate the consequences, which we have done, and we're in the process of refining that as part of the science program.

The gap between there and engineering is so do you design for that, and do you put magma dams in your repository? My answer is no, you don't. You don't design for that. It's not part of your design basis. So, there's one example of that gap between the science program, the engineering, and then there are issues around some of the other areas, like science and disruptive events, and cement type materials, there's some other issues like that. So, we're trying to force the engineers to put down what the design basis events are, and what the design bases are for the repository and surface facilities, and to make sure we understand the linkage between that design basis and the science program output.

GARRICK: Thure?

CERLING: Cerling, Board. And, I also welcome you.

Between the Sandia Lab transition and the transition from a more science based to a more engineering based project, it seems like there's a lot of new people will be involved. And, so, I'm kind of wondering how you will assure that you'll maintain institutional memory along with getting the right people in the right place to do what you want to do.

SPROAT: Very good question. And, the issue about maintaining institutional memory is absolutely vital at this stage of the game. The first thing we're doing is as we form up these teams to write the license application, revise the sections we need to revise, we're making sure, very deliberative about identifying the key technical contributors to that, the people who really understand the science behind the AMRs and some of the other technical documents, and incorporating them actively into the teams.

And, then, what we're going to do is make sure we have in place the contractual requirements that we--for those who are either near retirement age, or are working for a subcontractor, we're going to make sure we have the contractual arrangements to have them in place and capture them through the licensing process so we don't lose them.

So, we're utilizing the license application team approach to identify who those key people are, make sure they're integrated into the license application teams, and then capture them contractually for the long haul.

GARRICK: Bill?

MURPHY: Bill Murphy, Board. And, welcome also, and I have one question.

Recognizing the necessity to transition to design and engineering and moving things in order to move the project forward, I wonder if you nevertheless recognize that there are still key scientific questions that are open or unanswered or perhaps scientific problems that are emerging, particularly in the context of the relatively recent focus, or change in focus, from a 10,000 year time period to a million year time period.

SPROAT: Well, my view is this. While we will certainly know more ten years from now than we know now about some of these issues, we'll probably also have more questions ten years from now than we know now. As we get smarter, it just raises another whole set of questions.

If you take an approach, and this is my engineering bent, at some point in time, you say I know enough to get this project started with a basic design. I also know enough to know where my key risk driving uncertainties are. And, from the work that's been done in the science and the TSPA, we have a pretty good idea of, you know, there are a number of uncertainties around a lot of physical processes at the mountain. There are only a certain subset of those that are key risk drivers, have really any significant potential impact on risk of the facility.

It's those insights about the risk significant uncertainties that are the key ones that I'm most concerned about. I want to make sure that, number one, we crank our understanding of those uncertainties into our design, and our design basis, number one. But, number two, we set up a long-term Performance Confirmation Program to focus on those.

Obviously, there are hundreds, literally hundreds of different issues out there in a science based program about the mountain that people would like to learn more about, whether it's infiltration, whether it's volcanism, whether it's seismicity, whether it's heat/thermal resistance through the rocks, I mean, there's a whole slew of those. But, only a subset of those are really the risk significant uncertainties. And, what I want to get this Project focused on are what are the risk significant uncertainties and what do we need to do in the long-term to reduce those uncertainty bands around those key risk significant uncertainties.

MURPHY: Can you identify some of those key risk driving uncertainties for us?

SPROAT: No. I've only been here for 13 weeks. Give me a break. No, I can't. There are a lot of people out in the audience who can, and save that question for Russ or some people on his team. I think they do a much better job than I could.

GARRICK: David?

DUQUETTE: Duquette, Board. Like everyone else, I want to welcome you to this Project.

And, I think it's to be applauded that a hands-on engineering manager has been put in place at this time without meaning to denigrate any of the former directors. It's just that I think it is time to move on with the engineering aspects of the Project.

I did have a specific question, and you may not have an answer for it. And, that is the concept of reprocessing has recently been reintroduced as a potential path forward for nuclear waste. I fully understand that you can't count on that for your license application, but I'd like to know how you feel about where that's going to go relative to future design of the repository, and so on and so forth.

SPROAT: Sure.

DUQUETTE: And, I'd also like to make one other comment, and that's I hope that whatever administration comes in recognizes that a program like this does need leadership independent of politics. But, I can't control the White

House either.

SPROAT: I understand. Let me ask--a very good question about G-nep and reprocessing, and it's a question that a lot of people have raised, and let me answer it in a couple different ways.

One is in terms of near-term impact on Yucca Mountain and the license application. The answer is zero impact. We are not going to be--the waste forms that will be generated from reprocessing are still, to some extent, undefined, and won't be defined for a while.

The time frames in which those waste forms will actually be generated and be ready for disposal at the mountain are out significantly in the future, certainly beyond, you know, the time I'm involved with the Project, or even while I'm still in my active career. And, so, from that standpoint, the approach we're taking on licensing here is that when those waste forms are defined sometime in the future, and we understand what those waste forms are, and the types of waste packages that are needed to dispose of them, we'll put in a license amendment at that point in time to qualify those waste packages and put them in Yucca Mountain at that point in time in the future.

But, in terms of today and what we know, we're going to design this application based on the high-level waste forms that are currently defined within the DOE complex, and commercial spent nuclear fuel unrecycled. That's what we're going to put in in the initial license application.

DUQUETTE: Thank you.

GARRICK: One more question. Howard? Well, maybe two more questions.

ARNOLD: I add my welcome, heartily, to this.

I just wanted to list a few engineering issues that relate to the interface between science and engineering, knowing that you already know about them. But, I was just wondering if there are any comments on things you've learned recently. One is the post-emplacement criticality issue, and the requirements, if you take it literally, that it places on putting difficult to design materials into current designs of the TADs and other containers.

A second one is the issue of, which comes from the corrosion studies, the requirements for the surface condition of the waste package, whether you can stand scratches, gouges, et cetera, or whether they're now a problem. And if they are a problem, what do you have as a surface spec, and what kinds of inspection can you do after you've handled that thing, and what repair procedures you have, and so on and so forth. All these, there's a bunch of issues there.

And, of course, the elephant in the room is the issue of thermal management. There's a host of issues there which go to the fundamentals of aging, what you can load into packages, even the choice of spacing of drifts. I've only touched the surface, but I know you're aware of these, and they are things that have to be followed.

SPROAT: Right. And, I'd love to get into the specifics of each one, but I'm really not the right person to do that. What I can tell you is is that each of those issues are a really good example of what I'd call that gap between the science and the engineering program, where an issue has been identified and a tentative solution has been developed that is either not implementable or just not practical. And, so, we're in the process right now as we go through putting the license application together, identifying those issues and coming up with specific strategies, licensing strategies that we're going to take, and licensing positions we're going to take in the application to address each of those.

And, I can talk to you off line about some of those. But, like, for example, the issue of surface finish on the waste packages. I mean, just not credible or practicable to have certain high quality, high gloss surface finishes on waste packages you're going to put in a tunnel underground. I mean, it's just not. That's not the answer to the issue.

So, all I'll say is that we're going to be working those issues very aggressively over the next six months to make sure we get a very good, defendable, credible solution to the issue, and present that in the license application.

ARNOLD: Thank you.

GARRICK: And, finally, George?

HORNBERGER: I certainly don't want to be the only one to not welcome you. So, welcome.

I just had a question that arose when you gave your example about volcanism, and other comments you made about having a risk based program. As scientists and engineers, we certainly understand that, and we understand very well how we would like to measure risk in basically one dimension. But, we also know that that's not how people make judgments, and I'm just curious whether there's any room in your concept for design for perhaps considering magma barrier, even though it's not on the one dimensional risk axis, but it might lead to greater public confidence.

SPROAT: Well, without getting into the specifics of it, obviously, the whole concept of Part 63 is a risk informed performance based design. It's not risk based design. So, the idea is to understand the risks of both the natural system, as well as the engineered systems, and to make informed performance decisions about what to design for, where your key risk areas and what to design for.

And, that's, as the licensee, that's our responsibility. And, once we take that position, it's also our responsibility to present that to the NRC, defend our position, hopefully defend it successfully, and make that the license design basis for the facility.

And, I'll tell you we're going to be making that the set of those decisions through all of the design issues on this repository over the next six to nine months. And, you know, I'll just give you that example. You might say well, you know, if you put magma dams in, it would give the public more confidence. Well, the first question is do you design for something that has the same probability as mass extinction of life on the earth? I think the answer is no. But, if you say the answer is yes and want to debate that in the NRC, you know, that's fine.

But, if you decide you're going to make that part of your design basis, the next question is okay, Mr. Licensee, so talk to me about your design for magma dams, how are you going to qualify it, how are you going to know they're going to do what they're supposed to do? All of a sudden you're down the road, not only have you conceded the point that it's a significant risk, which I'd argue that 1.7 time 10^8 is not, but now you've conceded that point, so now I've got to figure out how to design and qualify magma dams. I say that is a path to failure. So, that's my answer and that's the approach we're going to take in terms of coming up with what I think is a defendable, credible design basis for

Yucca Mountain.

GARRICK: All right. Ward, we really appreciate the candidness and forthrightness with which you--

SPROAT: Probably too candid, wasn't it.

GARRICK: It's welcomed, and we look forward to doing this many times in the future. Thank you. Thank you very much.

Our program calls for a break at this point, and we will do that.

(Whereupon, a brief recess was taken.)

GARRICK: I have been asked to make a stronger announcement on cell phones than I made. And, the announcement is that even if it's on vibratory mode, they're hearing it in the system here. And, so, the only solution seems to be to completely turn off all cell phones. We'd appreciate that a great deal, because it is interfering with the communication system. Thank you very much.

Lawrence Kokajko.

KOKAJKO: Good morning. My name is Lawrence Kokajko. I'm the Director Designee for the High Level Waste Repository Safety Division in the Office of Nuclear Materials Safety and Safeguards at the NRC. And, I say designee because Bill Reemer, a person who I happen to respect a great deal, is retiring, and Bill, where are you? I don't see. There he is. Is it still true you're retiring? That's too bad.

Bill Reemer is retiring after 29 years of federal service, I believe. He has been a great mentor to me. He's been an outstanding individual to work with, and I have to tell you he will be missed a lot, and he leaves some very large shoes for me to fill. And, I wish Bill Reemer well in his retirement.

I'd also like to introduce two people who will be joining the High Level Waste Program at the NRC. Jack Davis. Jack Davis is going to take over my position as the Technical Review Directorate, and be a Deputy Director in our program. And, Abby Mosini. Abby is back there. He's going to take Elmo Collins' spot. He is going to take over the Licensing and Inspection Directorate. Elmo Collins is going to be in charge of the entire inspection program in Nuclear Reactor Regulations.

Today, I'm going to talk a little bit on the perspectives of the safety approach, which is embodied in 10 CFR, Part 63, which is our regulation for the repository. And, I'm going to talk about the perspectives from both an operational and preclosure phase as well as the postclosure phase. And, first, let me say that I recognize that this is the first time I've been to the TRB before, and, however, I have spoken with Dr. Garrick and Dr. Hornberger before at ACNW, and I think I told you then I had the best job in the house, and I think you laughed at me, and you're right, that was wrong. This is the best job in the house.

Next slide. Thank you. I'm going to talk about a few things. I'm going to talk about roles and responsibilities, the safety approach, the objectives of the risk informed approach, as codified in Part 63, and, of course, our confidence in safety.

Next. If there's one thing I would like to leave you with, and make sure everyone understands, is that NRC and DOE have very different roles in the review of the repository. DOE is responsible for the design, construction and operation, and NRC is an independent agency, an independent regulator. We don't participate in site selection, and we don't participate in design. However, we do assure that DOE complies with Part 63 and any other portions of 10 CFR that are deemed applicable. Some of those other applicable regulations are 10 CFR, Part 20, which is radiation protections to workers; 21, non-conformance reports, notices to workers; and Part 19, 73, which is security. These are things that we will be monitoring across a spectrum of regulations, although the controlling one will be Part 63. And, of course, I hasten to mention 71, which is transportation.

The review scope will be determined by the application presented. This is not any different in any other application we have reviewed in context of our regulatory responsibilities. And, as many of you know, we have been engaged in many years of pre-licensing activities and many of you have been associated with the technical exchange we've held, not only on the key technical issues, but also some of the more engineering design approaches that DOE has suggested.

Next slide. Part 63 approach is a phased or multi-step approach, and this approach sets up very defined decision points. The construction authorization, the license to receive and possess, and the permanent closure phase. These steps or phases allow for decisions to be made incrementally at logical points in the development of the repository. The approach allows for continual learning between the steps that can be expected to enhance confidence in the safety as each subsequent decision is based upon new information. The requirement to have the capability throughout these steps allows for the possibility that if new information demonstrates that the repository will not be safe, then whatever waste has been emplaced can be retrieved. And, we do have a retrievability section in Part 63.

Next, please. More specifically, the Performance Confirmation Program is directed by our regulations as a program that continues to collect information to confirm the technical basis for the safety decision made at the construction authorization step. The performance confirmation continues to collect information until the time of permanent closure. And, I'm going to talk a little bit more about this.

Next, please. The safety approach in NRC's regulations contain three primary aspects: safety analyses that quantify the performance of the repository and are used to help identify barriers that are relied on to ensure safety; plans or procedures for safety; and, the continued oversight of safety. And, I will expand on these, but I hope you will see at the end that this is indicative of a comprehensive approach that's taken with the totality of information that we have available.

Next. Safety assessments are required for evaluating radiological exposures for the operational and postclosure phases. Quantification of safety with respect to dose limits provide an understanding of how structures, systems and components are important to safety during the operational phase and how barriers important to waste isolation contribute to safety during the postclosure period.

Importantly, the postclosure safety assessment is updated with new information from the Performance Confirmation Program I spoke of earlier, and at those decision points for the license to receive and possess, and the amendment for permanent closure. Of course, each of the safety assessments are subject to NRC review and approval.

Next. Beyond the safety assessment, we also know that there will be plans and procedures that will be put in place. This provides further assurance that any safety limits, license conditions are met. For example, during operations, procedures are required to ensure that personnel performing the operations are appropriately trained, tested, certified and requalified. If an event were to happen, we require that emergency plans are in place. And, this is in addition to anything that would be normally part of the program, such as quality assurance programs, engineering design and control procedures, and, of course, standard and off-normal operating procedures.

I'd like to digress for just a moment and suggest that DOE at a technical exchange meeting earlier this year did commit to a systematic approach to training, for example, which is state of the art process to qualify and certify trained personnel for nuclear facilities. The reactor community has been doing this for many years, and I think it was a--I'd like to commend DOE, commend, which I don't say that very often, DOE for committing in that management meeting and technical exchange to that process, because I think it is a worthwhile program to do, but also I think it puts the program in better shape for our review, because that will be a significant thing. And, I would encourage DOE to make further commitments at those technical exchanges and management meetings.

For the postclosure period, I previously talked of the Performance Confirmation Program, and the associated capability to retrieve as a means to enhance confidence prior to the decision to close the repository.

Next, please. Continued oversight of safety. Even after closure of the repository, the regulations prescribe plans for continued oversight and repository monitoring. Although this continued oversight of safety is expected to add to the assurance of safety after closure, the performance assessment of the postclosure period is not allowed to take account of any additional assurance provided by the continued oversight. This is a prudent approach due to the uncertainties of society to continue these oversight activities over periods of thousands of years.

NRC, of course, will review these plans for our review and approval. And, at that point, DOE would be the sole federal agency implementing the plan and doing the oversight from that point over.

Next, please. The objectives of risk informed approach. As promulgated in Part 63--and I want to stress that it's risk informed, not risk based--simply put, this approach is implemented in the regulation by specifying a quantitative measure for the overall performance of the repository, and in this case, it's the dose limit, and the

Department of Energy has the flexibility to design the facility however it deems appropriate.

The performance assessment used to analyze the performance provides the tool to risk inform the review, understanding the performance assessment includes understanding the effects of parameters, models, and assumptions on the meeting of the overall dose limit, including any uncertainties. All this information, including the independent performance assessment work that the NRC has done, will be used to assist in the review of DOE's proposed license application.

I'd also note that although we're talking performance assessment here, in the postclosure period primarily, there's also a preclosure assessment as well called the Preclosure Safety Assessment. And, it, too, is a risk informed tool that will help our understanding of the repository during what I call the preclosure or the engineering phase of the program.

Next, please. I'd like to point out that although the quantitative limits in Part 63 are based on overall performance, there is another important requirement, and that is the repository system must be composed of multiple barriers. And, this is a defense-in-depth concept successfully used within the NRC regulatory program, whether it's reactors or waste management. The repository is to include both the natural and engineered or man made barrier. Understanding the capabilities of these barriers is a very important aspect of understanding the safety analysis.

The regulations require the Department to identify the barriers of the repository system, describe each barrier's capability to limit water contacting waste or limit the release and transport of radionuclides. And, this information aids in the overall understanding of the repository system and is a fundamental aspect of risk-informing the review.

I would like to point out that the performance assessment includes the natural features of the geologic setting and the engineered design features, and the regulations also require the performance assessment to include those features, events, and processes that are detrimental to performance, if, of course, they have a significant effect on performance.

I know people think that there's not a lot of defense-in-depth in such a static thing as compared to, say, the power plants, but waste is buried deep underground in stable geologic formation at a significant depth. The repository is composed of multiple barriers. And, there is required monitoring. And, we believe this does provide that defense-in-depth necessary to meet the intent of the regulation.

Safety analyses are the foundations of the risk-informed approach. The regulations identify such independent lines of evidence that the Department should use to provide the confidence in the parameters, models, and assumptions used in the performance assessment. They could include comparisons with detailed process-level models, laboratory testing, field investigations, and natural analogues. And, I'm pleased to see that later presentations will cover some of these topics.

The performance confirmation program is also required to provide further confidence in the performance assessment. This program would provide information such as corrosion processes and rates for waste package material, and this information is expected to be investigated until the time of permanent closure, which is on the order of roughly 100 years or more of data and research to be collected to provide additional confidence in the safety analyses. The initial performance assessments will be updated with information collected over this extensive period.

The license application is required to have a detailed performance confirmation plan. And, obviously, this plan is expected to evolve further as the knowledge grows of the natural system, as well as the engineered systems. The plan needs to describe the types of experiments and tests to be conducted, both laboratory and in-situ. And, an important aspect of our review will be the types of experiments and tests to be conducted as those tests and experiments need to be linked to important attributes of the barriers, and include any related uncertainties. NRC review will examine how the repository design can accommodate the tests and experiments.

The performance confirmation program is a critical aspect of providing further confidence in our multi-step approach for regulating repository development. Information and knowledge will continue to grow and our understanding and confidence in the safety will increase as a result of this program. And, I dare say it will also be the same for the DOE program. And, again, we will be monitoring that this entire time.

And, I just want to summarize very quickly what I took in the previous other slides, which is NRC, as an independent regulator, has an approach to the repository safety that is iterative, has defined decision points, provides safety assessments and technical bases for our decision-making process, and is forward looking with respect to performance confirmation and continued oversight.

I appreciate the opportunity to be here today. I realize this is at a high level, but I do believe this is starting the dialogue that I think needs to take place on this important topic.

GARRICK: Let me start with a question. I guess I'm kind of curious as to where NRC stands with respect to its guidelines for reviewing the preclosure safety analysis. And, I say that because the standard, of course, is principally a postclosure requirement, and the reactor business, while it's not invoked literally, it's invoked for the most part, we have the safety goals, but I'm wondering how you're going to make safety decision with respect to the adequacy of the preclosure safety analysis.

KOKAJKO: That's a good question. First of all, in terms of Part 63, the preclosure safety assessment is required by the regulations, and there are performance objectives that they have to meet embodied in 10 CFR, Part 63, and we will monitor their program for that.

We also know that Part 20 requirements are not in abeyance because of this, particularly radiation protection standards for workers. And, I think 63, 111 and 112 provide the objectives that they're supposed to meet for both what I call Category 1 and Category 2 event sequences.

Again, the burden right now is on DOE to provide their engineering design and their PCSA outputs to tell us what their probabilities are, and if they exceed certain probabilities, what are the dose consequences of it.

We have been, as you may know, we have been engaged with DOE over a year, year and a half now, on all preclosure activities, and we are still in the early stages of trying to understand the design that DOE is promulgating, without trying to move into a more definitive statement regarding consequences, dose limits, as a result of preclosure engineering design activities.

GARRICK: As I understand it, the preclosure safety analysis requires probabilities of specific scenarios, but does not integrate the probabilities that we customarily think of as a risk assessment. Is that still the situation?

KOKAJKO: I would say yes. However, the next step is if you have that scenario that is likely to happen, you've got to do the consequence analysis, or DOE can design to preclude it. And, that's again the difference in our--this particular regulation, 63 being a risk informed, performance based approach, allows DOE a lot of flexibility to make those designs conform, and if they do their PCSA and find out that there is a flaw, they can go back and beef up the design, for example. This is not very different from the fuel cycle facilities in Part 70, and they called it there integrated safety assessment, ISA. And, all new facilities have to issue, for NRC review and approval, the ISA summary. So, this is more or less under the newer thinking in terms of regulation of these facilities.

GARRICK: Questions from the Board? Andy?

KADAK: Kadak, Board.

I've got a couple. On this preclosure, as I understand the surface facilities, they were to be more like the things that you've already licensed, such as perhaps spent fuel storage pools, surface dry cast storage facilities, hot cells, fuel handling facilities. Do you envision any major technical problems in doing that?

KOKAJKO: I don't. The biggest technical problem I have is that we have not seen a final design yet.

KADAK: Right.

KOKAJKO: And, I mean, I've said this in many public forums, the regulatory information conference, I've said it I think at one of the management meetings, we've said it in technical exchanges, and DOE I think is still evolving what they want. Now, at the last technical exchange, which was less than a month ago, I think, we had some discussions with DOE on their proposed approach, and their phase surface facilities, you know, the initial receipt and handling. They're proposing also wet fuel storage facility to handle a--or some repackaging that could take place there. Again, it's still at a high level, and this was a consequence of their CD-1 approach, or CD-1 decision point. And, we now are interested in those further attributes.

As a result of the systems looking more familiar with what NRC has typically seen, I think that we should be able to take advantage of our historical understanding of these facilities, and work through them, I don't want to say quickly, but as expeditiously as possible.

KADAK: The second question is relative to the flexibility that you have in terms of assessing long-term behavior in the repository. As you've heard, we recently have come back from a trip from Finland and Sweden, and had extensive discussions with their regulatory bodies about how they're approaching the licensing of their repositories, which have the same goals and objectives as we do. And, they have taken the approach that looks at several time periods, and I'll just highlight those for you.

In the first thousand years, there will be a detailed assessment, quite deterministic, but quite detailed. In the thousand to 200,000 year period, they have a less detailed, but still quantitative. In the post-100,000 years, it's quite a qualitative analysis, or defense, because there's a lot of uncertainties, and in many ways, you're only guessing at what the potential outcomes would be.

In the NRC's approach to licensing this repository, is an approach like that permitted in the current regulations, or are you stuck with the TSPA and prove with uncertainty bands to five orders of magnitude that you're okay?

KOKAJKO: I think, and I will defer to Bill if he has another view of this. But, I believe the Part 63 can accommodate different things. TSPA is a tool that is in 63 that we will monitor and use, and we, of course, are doing our own performance assessment with our own code to confirm the work that we're getting in the license application. If DOE were to prepare in their application some process by which you could do, you know, look at these time frames in this manner, we certainly would look at it. However, we are also driven by the standards that will be promulgated by EPA, and, of course, we will adopt in our own Part 63, and the quantitative limits, which I think is, what, 350 right now, they still have to meet. How they do that, I can't say, but we will review what has been submitted to us.

KADAK: Just one final follow up. Mr. Sproat gave a fairly compelling argument about magma dams. Would you have any reaction about that kind of an approach?

KOKAJKO: DOE needs to put it's best case forward, whatever it is.

GARRICK: Well, just picking up from that a little bit--

KOKAJKO: I'd like to, you know, by the way, I've met Ward Sproat in other meetings, and stuff, and I think he's a very energetic fellow and he said he was a process guy, you know, as a regulator, I'm not a process guy, I'm a product guy. Give me the product, and I can do something with it. I can look at it. I can accept it, reject it, deny it. You know, these are things that we do as a regulator, so we're interested in the products that DOE will produce.

GARRICK: Before I turn it over to Mark for his question, I just want to follow up because it's relevant to what Andy has just said.

Can you say anything about Ward Sproat's comments about the constraining features of Part 63 with respect to design flexibility and phasing of activities?

KOKAJKO: We have not had that conversation. I mean, Ward Sproat and I have not had that conversation. But, I am not sure that 63 is that constraining. But, Ward Sproat believes so, and that's his view. I don't believe it is, though.

GARRICK: Okay. Mark?

ABKOWITZ: Thank you. I have a couple of questions I wanted to get really more clarity on than anything else. The first one picks up on Dr. Garrick's question about preclosure. And, my follow-on question is I understand that these are separate efforts to evaluate the preclosure safety situation and postclosure. Are there any plans to also look at overarching issues to make sure that there's consistency between the two cases? Because it seems to me that one set of assumptions begets the other, and I want to make sure that there's something seamless about that.

KOKAJKO: Absolutely. At the last technical exchange, one of the things that we wanted to hear from DOE was some type of integration, the impact on the preclosure work, and as it impacted the postclosure work. And, DOE, in fact, after the lunch of that day, brought in someone to address for about a half hour to an hour, some of those integrated aspects, and we're going to focus more on integration of the two approaches as more the design becomes known, more of the assumptions become known, and, of course, our understanding of where they are in postclosure.

ABKOWITZ: Thank you. The other question I had, and I may be behind the learning curve on this, so if it's a naive question, bear with me. But, I've heard a lot of talk about the safety case, the safety case, the safety case. In fact, sort of the topic or focus of this Board meeting is the safety case. Is there any kind of prescription or checklist or something that is available that describes what a comprehensive safety case should include that can be used as a benchmark against which to see what you're look at?

KOKAJKO: Other than the performance objectives within Part 63, I do not know of a checklist per se. Each regulation has its own requirements. For example, Part 71 is very deterministic in what they expect for normal and abnormal conditions of transport, and what the transport package has to meet. 63 has much more of a, again, product oriented, here's the limits, you figure out the way to meet them type of thing. So, no, there's no checklist per se.

Other parts of the regulations do have it. Part 71 is one of the better examples. It says you've got to meet this, this, this, this, this. So, fir, you know, exclusion to water, those types of things.

ABKOWITZ: So, from the standpoint as a Board member trying to understand from the technical standpoint how a safety case is being presented, and its associated credibility, it's really geared to these performance objectives, whether in our mind they're being met or not?

KOKAJKO: Correct.

ABKOWITZ: Thank you.

GARRICK: Ali?

MOSLEH: Mosleh, Board.

I think it's maybe a variation of what Mark said. Your basis and philosophy for the regulation, when it extends to the repository, one element of it is, say, the quantitative assessment of safety as it's embodied in the TSPA. Another one you mentioned is the defense-in-depth. Are there any other elements that would constitute the risk informed philosophy with respect to the--

KOKAJKO: Other elements that--

MOSLEH: Any other pillars of--I think it's a safety case issue.

KOKAJKO: As I outlined here, the DOE has to present its safety, in its license application, its safety assessment.

And, of course, we review that and we'll issue our safety evaluation report. We also look at the totality of their program in terms of operating, plan, procedures, emergency planning, to give us some confidence that they're able to operate the facility properly, and the QA, of course, will be a component of that.

We do the performance confirmation program, as well as the rule does allow that if something doesn't look, you know, if it's a problem, and the safety is not going to be there, the retrievability is required.

I will also note that in Part 72, which is interim storage at the power plants, you have to be able to retrieve fuel there and get it back to the pool. And, that's always been a characteristic of these types of regulations, which is if things appear that don't look right, you have the ability, or you should have the ability to go back to where you were, where it was safe.

Defense-in-depth is a philosophy that has been promulgated within the agency for many years, and whether it's in reactors where you have multiple barriers, or whether you have defense-in-depth of multiple systems, we do something comparable in all the other parts of the regulations. And, in this case, emplaced waste is deep underground in stable geologic conditions. It is also a waste package that we will look at in terms of its corrosion potential, and, of course, the performance confirmation program and ultimately, you could retrieve it if you have to take it out of the ground.

GARRICK: Okay, thank you. Ron?

LATANISION: Lawrence, you mentioned, I think I have the language correct, but the testing in the preclosure period would be something you would not only allow and expect, but respond to, and, in particular, you used the example of corrosion testing. And, I just want to explore how the NRC would respond to the following situation.

Let's suppose that in 20 years after the LA and assuming it's positively disposed, let's suppose it were determined that C-22, which is today considered to be the outer barrier on the waste package, were inferior to a material that's being explored today, a spray deposited metastable alloy. How would the NRC respond to the proposal that the outer surface of the package ought to be changed from C-22 to some spray alloy, spray deposited alloy? Is that an acceptable evolutionary process from the NRC's point of view? I'm not predicting that, incidentally, for anyone who's listening. But, I'm just curious about how the NRC would respond.

KOKAJKO: I'm a little hesitant to respond, because I don't want to pre-judge what--I know that that spray alloy is in the OSTI Program, and also the Science and Technology

Program, and I know DOE is actively investigating that.

As an example of what I said earlier, if DOE comes upon a change that they need to make, they can prepare the analysis for that, and submit it for our review and approval. And, one thing that I would like to point out is that embedded within Part 63 is a change process, 63.44, and DOE is allowed to make certain changes once they receive approval from us to operate.

In this case, I think DOE would have to go back and look at the totality of the information that they have presented, what do they need to do to ensure safety, and given the magnitude of this change, they would have to seek our review and approval. But, we have a process in place to do that.

LATANISION: Thank you.

GARRICK: David?

DUQUETTE: Duquette, Board.

Could you go to Slide Number 4, please? I fully understand that Part 63 is supposed to give you well-defined, incremental decision points, but obviously there's going to be some subjective decision made in any kind of a safety case. It can't all come down to just decision points that have to be met. My question really has to do with procedure, and that is who--obviously, ultimately, the Commission itself will make the decision whether the license should go forward or not. But, who passes that decision on? Do you do that by consensus? Does a team report to you and then you make the decision whether it meets the safety case or not? How do you--what's the procedure for going through that to be sure that you've met, that the DOE has met all of the requirements for the safety case?

KOKAJKO: Generalized processes within the agency are once the application is submitted, it goes through review and approval. We would issue a safety evaluation report. In this case, a safety evaluation report would be vetted very high up in the organization before it would be signed out. If this were something a little more mundane, say a normal amendment to a power plant, typically, it's stopped at a level lower than mine. But, on something like this, particularly of a first of a kind and unique approval, this would be vetted all the way up.

In terms of who makes decisions internally and how it gets to that point, as Ward Sproat noted, in DOE where they have an integrated team approach, we do the same thing. We have our staff and contractors working together as a team, begin to fill in those pieces of the SER that we have to be able to stand behind and defend. The totality of that comes together and ultimately, it would come up to my level, or the person who will fill my role in the future, and that would start the process for the final say-so on the application.

DUQUETTE: Just a follow up. It goes out over your signature, basically, or--

KOKAJKO: It would not go out over my signature. It would probably be the Office Director of NMSS.

DUQUETTE: Thank you.

GARRICK: Thure?

CERLING: Cerling, Board.

In this slide and the last slide also, and we have seen throughout that there's a notion that you and DOE should allow for continual learning and progressive confidence, and iterative procedures, and so on. I'm wondering how you pass on the information that the NRC has to DOE, and how DOE transmits information to you. Can you just describe the sort of feedback between the two organizations so that you both are learning from each other in a useful way that provides for the safety case?

KOKAJKO: Can I ask a clarifying question of you? Do you mean in the current environment, this pre-licensing phase, or once the application is received?

CERLING: Now. So, before the license is received.

KOKAJKO: Okay, the Nuclear Waste Policy Act envisioned that DOE and NRC would communicate on the program so that we would understand where DOE was going. This envisioned, and as it has played out, we do, DOE has submitted material to us, whether it was an analysis model report, we would review and approve it. Through the KTI program, we addressed 293 agreements, and provided feedback on those. Some of those, we had no further questions. Some we identified further questions. Some were significant enough that we wanted to hear back from DOE on in terms of additional information.

We also assumed and have sent DOE letters outlining our expectations, particularly before certain technical exchanges that we thought were of significance to us. And, to say these are the things we want to hear about. These are the things we want to talk about. And, the technical exchanges themselves are a way to convey information and to understand the processes and products that DOE are following and developing.

In the post-licensing phase, we would have--similarly, we would have meetings. However, once the LA had been submitted, and we were now engaged in the review, we would begin to send out requests for additional information, formal requests for additional information, which defines the regulatory--the need as well as the regulatory basis for why we need the information. Does that address--

CERLING: Yes.

GARRICK: Bill?

MURPHY: Bill Murphy, Board.

Of course a very important part of the safety case is the performance assessment model, and that's used to judge compliance with those regulations, and I know that NRC--you mentioned that NRC is doing their own PA models, and I think that I've watched that and I think that that's an extremely useful practice, to have a separate set of PA models. And, you mentioned their confirmatory role from the perspective of the NRC. I wonder if you would comment on the extent to which the NRC's PA models are independent of DOE's models, and to the extent they are, whether or not the differences can be practically used to identify important technical problems.

KOKAJKO: In terms of identifying important technical problems, I leave that to the judgment of others to make that determination. But, I do believe that our model will help us provide additional confidence that whatever numbers are ultimately gained are right. In fact, some years ago, I think it was about 2003, maybe 2004, the State of Nevada requested through FOIA our current approved version of our TPA code, which is 4.1 JPD, and it's available. I mean, the executable piece. Now, the source term code in it is not, but the executable is, and I know the State of Nevada has it. And, I don't know if members of the Board have seen it or not, but that's possible to obtain because it's out there in the public domain, and you can make your own conclusions as to its effectiveness.

And, again, in terms of comparing differences, we have not seen the TSPA. We will be holding a technical exchange with DOE on TSPA, I think in early November, and I'm hoping it's a very fruitful exchange. It's going to be a multi-day presentation by DOE, and our questioning of it, and we'll be sending out a letter in the not too distant future, which will outline our expectations of what we expect that meeting to work toward. So, I would encourage members of the Board or Staff to attend that meeting.

MURPHY: Thank you.

GARRICK: Andy?

KADAK: Kadak, Board.

I'd like to find out--I mean, I was hoping a little more safety case stuff would come out, rather than a recitation of Part 63. But, from your understanding, how much work is NRC doing on actual fuel degradation in the waste package? Because we think that's fairly important, and, so far, we haven't seen a lot of that.

KOKAJKO: We have done some. I don't think there's a lot going on within my program right now on fuel dissolution and degradation. Spent Fuel Project Office has done some, as well as the Office of Nuclear Regulatory Research, but I would have to get back with you on the specifics of that.

KADAK: And, just to discuss this Part 63 rigidity or lack of rigidity, I think Mr. Sproat's claim or concern was that in Part 63 when you file this application, you have to make a determination forever about the acceptability of this repository. And, I looked at your slide there, it says allow for continual learning, progressive confidence, and I don't see that--based on showing me that this thing will work for a million years.

KOKAJKO: I believe our program does provide for continual learning up to the postclosure amendment. The postclosure amendment, which DOE would ask for to say we're ready to close this thing up, they've done the performance confirmation program this entire time, we will continue to monitor that, and once the postclosure amendment comes in and we approve it, I mean, the hole would be sealed up, again, this is sort of after I retire, but--

KADAK: It seems like everybody wants to retire.

KOKAJKO: The DOE would be the sole federal agency at that point to continue the monitoring of the repository.

KADAK: But, you understand the distinction I've made, or tried to make, and that is before you even start construction, you've got to have this thing completely defended for a million years, and this continual learning is just confirmation stuff. It's not really learning.

KOKAJKO: I think it is learning. The hearing says, at the construction authorization phase, this is good enough and safe enough for our understanding today to begin construction, but we continue to do performance confirmation in order to gain additional information.

If it were true that it's a done deal forever more, you know, we wouldn't have a retrievability clause.

KADAK: Right. Well, that's insurance.

KOKAJKO: The retrievability clause is meant to say hey, you could find a showstopper out there, and the retrievability clause says you've got to be able to figure out a way to pull it out.

KADAK: Thank you.

GARRICK: Okay, I think we're going to have to truncate the questioning, because we want to allow time for some public comment before the 11:30 break for lunch.

So, Lawrence, thank you very much. We appreciate your presentation and your time.

So, with that, I think we will turn the meeting to a public comment time, and I have two people that have been identified for making public comments, and one is Judy, and following Judy, will be Jeff Williams. Judy Treichel.

TREICHEL: I brought in a piece of paper with a quote on it that people are passing down the way, because I'm--oh, Judy Treichel, Nevada Nuclear Waste Task Force. I'm sort of the contact for people around the country to pay attention to this, normally not science kind of people, and there was an article published recently in several different places that included the paragraph that's on the handout page, and, it has raised all sorts of concern and whatever throughout the concerned public community. And, I guess I would like to ask the NRC representative and DOE representative if they agree with this statement, because it does seem to have a lot of people's questions. So, think about that. It's just a yes or no answer. It's not a big deal, but people are saying is this really true, and it would apply to the two of you, I would guess, more than anybody else.

But, people are paying attention, and they do care about this, and the question actually asks, "Do we know everything there is to know about Yucca Mountain at this time?" And, we had a lot of that asked over the last two days in a hearing regarding corrosion on the waste package, and we've been hearing about how it would fail or how it would not fail, but it seemed like over two days of talking about corrosion, that there were a lot of new questions that came up. So, people are concerned to know if the people in charge of the Project feel that they know everything there is to know. So, I just wanted to throw that out there and have you answer yes or no.

The other thing is that there is always talk about the deep underground repository, and I think it's interesting for you to note that when you walk outside of this building and you're standing out there, either in back or in front, the repository is a thousand feet over your head. So, that's something that people understand, but often gets lost in this because it's like you're putting it underground where it's halfway between here and hell, if you believe in that. So, these are all questions, and the kinds of things that people think about.

I don't have many questions or comments about what was said today because it appears we're in a transition between science and engineering, and a transition, significant changes in staff, and so forth. But, I just, because I've gotten so much mail and calls about this particular article, I just wanted to quickly ask the NRC and the DOE if in fact you agree with that statement. And, all it is is yes or no.

Thanks.

GARRICK: Thank you. Anybody want to comment on it?

SPROAT: Speaking for myself, Ward Sproat, I don't know all there is to know. That's for sure.

GARRICK: Okay, I guess our next public statement is from Jeff Williams.

WILLIAMS: I accidentally signed the wrong sign up form.

GARRICK: Be careful what you put under him.

All right. Well, we've got a couple minutes, if we want to ask any questions of either of two speakers from the Staff? Oh, yes, sure. Give your name and affiliation.

BASCONI: I'm Bill Basconi, and I'm a construction worker, electrician by trade. I've worked at the test site for a good many years, not currently, retired. But, I started out there in '64, with the handling of nuclear projects out there for well over 50 years. We're used to it.

I want you folks to know there's a good many Nevadans that take this as a national issue, not a State's rights issue. One of the things that we do feel you ought to emphasize is the fact that it is retrievable, and more emphasis should be on the monitoring, the temperature, the available means to retrieve it. That would be more acceptable to a good many people. We give the (inaudible) system a hell of a lot more credit than some.

We think in 300 years, there's going to be a lot of answers, but that might be a renewable energy resource. But, most of us are well aware of the fact that there's not (inaudible). There may not even be coal in 300 years. Nuclear is what's going to go, and this deal about assuring it for one million years is basically ludicrous. My God, one million years, I'd like to know how many glacial periods we have in one million years. We can relate to folks in Montreal, New York, Philadelphia, New Jersey and the rest of them come down here and help us figure it out in about 10,000 years.

GARRICK: Thank you. Steve?

FRISHMAN: That's a hard one to follow, but I'll change the subject.

Following up on Lawrence's discussion of Part 63--oh, Steve Frishman, State of Nevada--and the sort of undercurrent of discussion today about flexibility and the license application, and actually confirm construction and the stages that we know are Part 63, there's a point that didn't come out that I think is an important one, and that's that unlike plant licensing, Part 63 does not go through a preliminary safety analysis report, and then a final safety analysis report. And, I think this is intentional.

You have a case here where there's a decision that only can really effectively be made once. And, as I read Part 60, and again preserved in Part 63, the safety decision, an affirmative safety decision is made only at the level of construction authorization. That's when the disposal decision is made in that rule, and in the predecessor, unlike a preliminary safety analysis and then a final safety analysis.

So, when we talk about the flexibility and this question of when the decision really is made--we know when the decision is made under the one. If it's an affirmative safety decision, that's the one shot. Now, all these other stages where you have re-evaluation, learn as you go, amendments if they're reviewed and permitted, all of these can only be negative decisions based on the way the rule is written. They're only confirmatory of the original disposal decision if you do not come up with a negative decision.

And, the reason for this, as I said, is you only get one shot. If you don't know going in and are able to make a case based on--that is convinced based on what you know going in for a construction authorization under this rule, then you can't make an affirmative decision. And, I think it was intentional and I think it's really important, because you can't fix it. And, the alternative to money into a situation that yes is adverse to safety, but you really can't fix, the alternative is even worse than turning it down in the first place, because it means you've wasted an awful lot of time. You've created a situation, if it's so bad you have to consider whether and try to retrieve, with some success or not, then you have something that is essentially irreversible. And, you've lost lots and lots of money, lots and lots of time, and creates the possibility of irreversible harm to people and the environment.

So, I think it's important to remember that this rule was written specifically for repository, and the differences are not to be taken lightly. And, if you need flexibility on the way in on such critical things as the extent to which you can rely on your projections of the performance of a waste package because of problems with the site, then you're not ready to have a disposal decision made. Flexibility won't solve that problem. You're in a situation where you do need to know more.

And, yesterday and the day before indicated in that one crucial area it's pretty clear that people don't even understand and agree enough about the fundamentals, degradation of the waste package in the environment, which is not very well understood. And, this is a key failure mode for the repository, the waste package. Unfortunately, it shouldn't be, but it is in this case.

So, if you're talking flexibility, sure, it may be convenient, but it certainly is not, in the particular case we're talking about, it is not amenable to a safety case, because you've got to be able to make the case, and then if you want flexibility beyond making the case, well, we can see about it. But, the rule I think is very clear that you've got to have what you need to demonstrate a case, and after that, if you can make it better, fine. But, you've got to be able to demonstrate it on the front end.

GARRICK: Thank you. Andy?

KADAK: Just a comment.

GARRICK: You might make it short.

KADAK: Kadak, Board.

GARRICK: We have an 11:30 commitment.

KADAK: Just a comment. I think this is a conception permit stage, and is a loading permit stage, and then the final federal action is the closure stage. So, I think there's lots of opportunities, especially if the systems are retrievable, which I believe they can be made to be, to correct any mistakes that would be made, or to make any engineering modifications that are required.

So, I think it's not just a one stop, you know, final decision when you start construction. So, unless I'm wrong, that's kind of my understanding.

FRISHMAN: My only point is that that's not what the rule says.

GARRICK: Okay. I think what we're going to do now is recess until 12:30. Thank you.

(Whereupon, the lunch recess was taken.)

AFTERNOON SESSION

GARRICK: We understand that there's a long line downstairs of people trying to pay their bill and get up here, but I think in the interest of not denying people an opportunity to ask questions and get their message across, we're going to have to go forward. So, with that, we'll ask Russ Dyer to go ahead with his presentation. Russ?

DYER: Thank you, Dr. Garrick. Can you hear me okay in the back? Okay.

As a preface to this talk, let me say something. There's been an often stated assertion that DOE's safety case consists entirely of the numeric results of the Total System Performance Assessment. And, the purpose of this afternoon's session is to demonstrate that that assertion is wrong. And, we're going to talk about what a safety case is and what a safety assessment is.

Next slide, please. Let's go to not a United States Regulatory construct, but let's go to the International construct, and this is from the International Atomic Energy Agency, IAEA, who came out with a document this year, geologic disposal of radioactive waste, and in it, they give a definition of both a safety assessment and a safety case.

And, for those of you in the back of the room, let me read this. "Safety assessment is the process of systematically analyzing the hazards associated with the facility and the ability of the site and the design of the facility to provide for the safety functions and to meet technical requirements."

There's some elements of what I would call the safety case that aren't explicitly included in here, and that's things like treatment of uncertainty and demonstration of confidence in the results. But, if you look at the definition of the safety case, it substantiates the safety and contributes to confidence in the safety of the geological disposal facility. It's an essential input to all important decisions concerning the facility. It includes the output of safety assessments, together with additional information, including supporting evidence and reasoning on the robustness and reliability of the facility, its design, the design logic, and the quality of safety assessments and underlying assumptions.

There was an earlier question, is there a checklist for what goes into a safety case. Not exactly. In the IAEA document, there's four paragraphs that lay out the expectations for what need to be covered in a safety case. And, we'll talk about the similarity between expectations for a safety case, as laid out by the international community, and what the regulatory construct of the NRC calls for.

Next slide, please. In 10 CFR 63, and the Yucca

Mountain Review Plan, there is a mandate for an articulation of a case for safety, although it's not called anywhere a "safety case." Now, the State of Nevada petitioned, I think it was a couple years ago, for a rulemaking from the NRC to revise NRC's 10 CFR 63 to, in part, require an affirmative safety case for the repository. And, they cited the "International Peer Review of the Yucca Mountain Project, the TSPA for SR of March 2002" for this concept.

The NRC denied the petition because Part 63 already requires that NRC consider a broad range of information to support a licensing action, not just a judgment of whether or not numerical requirements are met. And, it's very clear in the Yucca Mountain Review Plan, which is based on Part 63, that compliance is more than just showing the models and the modeling results. There is a demand, a requirement for a comprehensive scientific basis in support of every important model, model assumption, and decision that's included in the safety analysis report.

Next slide, please. The Safety Analysis Report. And, as you're aware, really, we have two components to our Safety Analysis Report, a preclosure and a postclosure part. And, what we're going to be talking about this afternoon is focused exclusively on the postclosure part.

The SAR will comply with the requirements of Part 63, it must, and will need to demonstrate, first, a systematic analysis of the hazards associated with the facility, and a robust repository system composed of multiple barriers. It must demonstrate an integration of arguments and evidence that support the finding of likely safety. And, it must include a discussion and evaluation of the uncertainties in the analyses and why, in the face of those uncertainties, the applicant has sufficient confidence in the postclosure assessment to allow it to petition to move into the next phase of the repository program's life-cycle, facility construction.

So, here's where the confidence and uncertainty is treated that wasn't addressed in the definition of a safety assessment.

Next slide, please. To some degree, this slide reiterates points that Lawrence Kokajko of the NRC made in his earlier talk, and that is that there's a step-wise decision process defined by regulation, and there are elements of this step-wise process that lead to an evolving development of confidence.

The license application and its SAR will provide the basis, obviously, for NRC's issuance of authorization. However, during the construction phase, there will be a continuation of scientific and safety evaluation work, even after the receive and possess update to the Safety Analysis Report. There will, in the operations phase, this is when actual radiological risk will first occur, it's going to last several decades to perhaps a century or so, during which scientific work and safety evaluations will continue.

And, some of the things we're going to talk about in the follow-on talks are some of the plans for these long-term programs. It's hard to say exactly what we're going to be doing twenty years from now when we may have the benefit of new instrumentation, new conceptual models, but we can lay out a broad philosophical approach and some near-term plans of what to approach.

And, then, a final update to the SAR, this is for the permanent closure of the repository, will be required at the very end of this process, and, of course, there must be confidence on the part of both the applicant, the licensee, DOE, and the regulator, NRC, that there is sufficient confidence in the performance of the system at that time to actually close the repository.

Next slide, please. So, in the light of uncertainty, how do confidence arguments figure into this? Well, by submitting a license application and its included Safety Analysis Report, the DOE states that it has confidence in the system safety over the entire repository life-cycle.

Does it mean that we know everything? No. Does it mean that we know enough to have adequate confidence in the system safety? Yes.

Contributors to this confidence, and part of it is what exists now and part of it is what will occur over time, is a long-term testing program, monitoring, and the regulatory defined performance confirmation studies that will challenge as well as confirm the basis of the safety case.

And, let me just do a little aside here. The term performance confirmation, to some people, has a negative connotation. It sounds like a program that's designed just to confirm what you're asserting. And, this program cannot be that kind of a program. It's got to be a robust enough program to actually challenge the technical basis for the important things that figure into the safety assessment.

In our program, the current science and technology program and the performance confirmation program will demonstrate DOE's long-term plan to continually enhance system safety and efficiency, essentially part of a viable learning and safety culture that will evolve over time.

Next slide, please. We have used things like natural analogues for both building and evaluating portions of the safety assessment. You're going to hear about some of those this afternoon, but some of the ones you're probably familiar with, the climate and igneous events and processes, part of our safety assessment, rely on insights from analogue studies.

Analogue insights have helped us create the current colloid transport model, and there are also other analogue studies helping provide a level of confidence in other process-level models, such as the model for source-term behavior, and unsaturated-saturated zone flow and transport models.

Next slide, please. In the overall context of providing a case for the postclosure-system safety, we're going to have a number of presentations that follow me. First, Peter Swift of Sandia is going to talk about--to illustrate capabilities of barriers that might give insight and understanding regarding system functioning. The upper natural barrier, the engineered barrier, and the lower natural barrier. There's a multitude of ways you could break out the barriers, depending on whether you're lumpers or splitters. We have chosen the lumper approach, so we've got three fairly large and comprehensive barriers.

Next, we'll have Pat Brady of Sandia, who's going to illustrate uses made of analogues, natural analogues, anthropogenic analogues, industrial analogues, and self-analogues. And, then, finally, we've got two presenters here to talk about the Science and Technology Program. That's Mark Peters of Argonne, and, finally, Frank Hansen of Sandia is going to talk about long-term test and monitoring program and the regulatory required performance confirmation program.

Now, of the four presenters here, three are from

Sandia. There was a question earlier about the lead lab transition. So, let me just address that very quickly.

The transition of postclosure activities and responsibility, which includes everything from field work, bench test experiments, modelling, performance assessment, including responsibility for the preparation and defense of the postclosure part of the license application. The postclosure SAR, are the responsibility of Sandia as the lead laboratory effective 1 October.

We have been going through a lot of effort to get this transition in place to ensure that Sandia has in place all of the systems and processes they need to be successful here.

DOE conducted a readiness review of Sandia starting--it actually started earlier, but it completed in early September, and we're ready to attest that Sandia has successfully completed the readiness review.

We had about 150 transition issues that we worked with. There are a number that are going to slide past the 1 October date, but they are not relevant to performance of the work scope. They are things like inventorying equipment. Well, whenever individuals move from one office to another, sometime in mid to late October, we will inventory that equipment with where they are now, and what organization they're actually working with. So, there's about ten items like that.

As of yesterday, we were down to three transition items that need to be dealt with, consummated this week, and I have every confidence that we'll be able to do that between--by Friday.

With that, I'd like to close this off and ask if there are any questions of the Board?

GARRICK: Yeah, let me start by asking one question.

Russ, if you look at all of the safety-related activities that are going on, I count some five or six separate activities, if you talk about the TSPA, the Safety Analysis Report, the Margin Analysis, the Sensitivity Analysis, the analogue work, and so on, and, so, it seems as though there is a basis there for collectively, if it's done the right way, of developing something that would indeed be a safety case in the minds of most people, including the Board, who has been advocating for a long time the need for multiple lines of evidence. Is that story going to be told?

Because I think it seems to me at least it has the potential for being an outstanding story in terms of broadening the horizons for the public as to the kinds of things that have gone into evaluating the safety of the repository, much more than any single document, such as the TSPA. And, given that the TSPA cut-off time is coming up pretty rapidly, it's clear that a lot of this stuff isn't really going to get in the TSPA. How are you going to tell that story, and in what form? And, are you going to try to connect all these pieces together in some sort of a comprehensive accountability of the safety case for the repository?

DYER: I think we're going to have to tell the story in different ways for different audiences. The format and content guide for the license application doesn't have a section that is explicitly called the safety case. But, all of the things that constitute the argument for a safety case have to be in the LA. It probably would behoove us to put it all together in a cogent articulation somewhere in the LA, but not everybody is going to read through the seven or eight thousand pages of the LA. So, I see the probability of a separate document that would articulate the safety case that would be consistent with what's in the license application.

GARRICK: Yes, I remember a few years ago, you generated an engineering document about the repository that had pieces and parts of a lot of the activities that were going on, including the TSPA, and that document, I thought, was quite effective in giving simultaneously a pretty global view of what was going on, and at the same time, had enough depth to it to give some insights as to the level of the investigations. In other words, it just seems an opportunity that should be jumped on and taken full advantage of.

DYER: Agree.

GARRICK: Any questions for Russ from the Board? Yes, Andy?

KADAK: Kadak, Board.

I'm trying to find my notes from Finland and Sweden. But, let me just summarize by saying they are also trying to do a probabilistic model in the form of a total system performance assessment. But, they found that the models end up disguising a lot of key information. In other words, it's buried in the basic formulation of a very complicated code. And, what they're trying to do is take and extract from those very complicated models, more useful pieces of information that would give you a good idea of how this repository is really performing, which then could be perhaps an addendum to your TSPA.

But, clearly, it helps those who are trying to understand how this repository really works. And, this is beyond sort of the best estimate thing that we've been talking about for a couple of years. But, that would be something that I think would be very helpful, and the public support in both countries is quite strong, because they are trying to demystify all these horsetails and probabilistic treatments of uncertainties, to a point, well, here's how this repository really works.

So, I'm just seconding John's recommendation that you really do this, because, otherwise, it will be a very complicated, confusing document.

DYER: Agreed.

GARRICK: That's a short answer. Yes, Mark?

ABKOWITZ: Abkowitz, Board.

Russ, can you lay out what the plans are to put together the preclosure safety case, and also comment on how that will be intertwined with the postclosure safety case?

DYER: I have not dealt with the preclosure side at all. It's clear, though, from--that a safety case must be applicable for the entire repository, both the preclosure period and the postclosure period. So, we can't treat these in isolation. Your point is taken.

ABKOWITZ: Abkowitz, Board.

Does that preclosure safety case fall under your purview as well?

DYER: No.

ABKOWITZ: So, but the postclosure does?

DYER: The postclosure does.

ABKOWITZ: So, is there a management structure that will allow for that to occur in a highly integrated fashion?

DYER: I think that's one of the things that Ward is working on.

GARRICK: Any other questions? Bill?

MURPHY: Russ, as the Chief Scientist, I'm curious of your reaction or response or comment on what we heard this morning about a transition from science to design, and perhaps you're in a better position to answer the question about what are perhaps key risk driving uncertainties, scientific uncertainties that remain.

DYER: I think some of the places where we would benefit from more knowledge are in the area of the four coupled processes. I mean, this is really at the forefront of science. So, whenever you combine the thermal, the hydrologic, the chemical, and the mechanical, how those all interact in the, say in the emplacement drift environment, that's a healthy technical problem.

GARRICK: Okay, any comments from the staff? I cheated on you a little bit this morning by giving you very little opportunity, so I'll try to make up for that now.

(No response.)

GARRICK: All right, I think we'll move into the next presentation. Peter swift of Sandia Laboratories.

DYER: Before Peter gets here, there may be some confusion. Come on up, Peter. I'm the Chief Scientist for the Office of Civilian Radioactive Waste Management. Peter's title is Chief Scientist for the lead laboratory. We also look an awful lot alike. So, we've got the same title, different organizations.

GARRICK: I heard you once say that you were paid by DOE for your looks.

SWIFT: Well, I am Peter Swift, and if Russ hadn't made that clarification, I would have. Also, I don't actually have that title until next Monday morning. But, it's not on the viewgraph here.

As of October 1st when Sandia becomes the lead laboratory, yes, I will be the Chief Scientist for the lead laboratory. When I say lead laboratory, that is an inclusive term. That is the science team working on the postclosure aspect of this project. It will include, of course, scientists from other national laboratories, from the USGS, from contracting agencies. This is not simply Sandia. However, Sandia is the accountable management organization, and Mr. Sproat wants to know where his science program is going, he will call Sandia. So, my role then will be to try to steer and guide and direct the course of science done by the lead laboratory, including the other participants in the project. Sandia will have the management authority and responsibility for all those other participants.

So, on to barrier capability and the assessing of system performance. Going back to Russ's side where he showed the IAEA's definition of a safety assessment and a safety case, the safety assessment is basically the quantitative part. And, we're used to thinking of that as the Total System Performance Assessment. We've heard about that for years.

And, yes, we do need quantitative estimates. They are estimates, and they have uncertainty in them, and we need to acknowledge that. But, we do need estimates of the future performance of the system, and that's what I'm going to talk about. The next talks after that will look at the more qualitative aspects of the safety case.

And, one more point. The work I'm talking about presenting here today is the work of many, many people, most of whom, all of whom, actually, since the transition has not occurred, all of whom did this work on behalf of Bechtel SAIC, and some of it goes back to previous M&O contractors. I want to thank Bechtel SAIC for its work on postclosure science. I was part of that team also, and it's good work today. I'm happy to be here representing it.

First slide, please? So, just an overview here of what I'm going to talk about. The quantitative aspects of the safety case come in two categories here, barrier capability and system performance. The distinction between capability and performance is actually it's real. Capability is a potential capability of how things will work if they ever had to work in isolation, whereas, the system performance is how things all work together. So, if, for example, as long as the engineered system is intact and doing its job, the capability of the natural system to retard radionuclide movement is just a capability. It's not performing. It's sitting there waiting to perform. It's a potential capability.

And, I'm going to talk a little bit here about the process by which we build confidence in quantitative assessments. It's a methodology discussion of why do I, for example, have confidence that these models are something that we should all have confidence in. We have to evaluate--it's an iterative process. We evaluate both the component and system performance, and we acknowledge the uncertainty in it. That's important. We've done this for years. We are not claiming we know everything. We are claiming we understand our uncertainty well enough to inform decisions, and that's what a scientist's job is.

And, then, I'm going to give some representative examples of quantitative estimates, and these are just examples. Do not walk out of here saying this is the quantitative safety case. These are examples that I culled from previous analyses. The point is to illustrate the concept here, not to give the specific here's our last, best and final estimate.

Next slide, please? The iterative process, it's a fairly straightforward process of first characterize the system and its components. This is site characterization. It's been done for many, many years on this project.

Identify the important features, events, and processes. Indeed that one happens to be a regulatory requirement besides being good, common sense. But, this is where we identify what matter to the system.

Build models of the component. We characterize the uncertainty in those models and their inputs. We build a system model, we evaluate component system performance, identify uncertainties, and iterate. We go back through it. And, when I get to the very end of the talk, I'll show you we have been interacting for quite a long time.

Obviously, these steps go in parallel. It isn't a simple, you know, one year we do one, and then the next. Information is always coming in, The system is always evolving and has been evolving. But, the iterations we have in the past used each iteration to inform ourselves as to what matters and where more information is needed. I believe we are now at a point where we can inform a decision.

Next, please? Just a picture of the types of things that go into site characterization and design. And, there's nothing in any great detail that needs to be said here. But, it's a nice picture that shows the mountain, and the underground. And, this is the type information that we need in order to be able to do a quantitative safety assessment.

Next, please? The identification of the features, events, and processes relevant to Yucca Mountain. This is-- that features, events, and processes gets the acronym FEPs. It's not a very graceful acronym, but it is convenient. And, the FEP process is one which we follow. It's our demonstration to you, to the regulator of the completeness of the analysis.

You can't prove a comprehensive or a complete treatment of the future. It's not subject to rigorous mathematic proof or scientific proof. However, you can demonstrate that you have done the thorough and exhaustive job to the point of have you considered, and this is one of the few places that the word "all" would be appropriate, can we demonstrate we have considered all potentially relevant features, events, and processes. The only way you can do it is to make a long systematic list and to basically challenge people to find things that aren't on our list. And, if they weren't on it, if we didn't consider it, we should have.

And, how do you do this? Well, the international community has been doing it for decades. There are international lists of things that might matter for nuclear waste disposal. So, we adopted a list from the Nuclear Energy Agency. We reviewed our own literature. We went through iterative review processes, and currently, we have about 370 features, events, and processes that we evaluate for Yucca Mountain. Evaluate does not necessarily mean that they are included in the analysis. It means we have considered whether or not they matter and we have documented that consideration.

The total number, 370, it's not arbitrary, but it is a subjective number. Obviously, you can define features, events, and processes as narrowly as you want, or as broadly as you want. What's the level of detail you're interested in? The international list that we worked with had thousands of things on them, and they can be aggregated. That does not mean that we are overlooking things. It just means we're being more efficient at how we categorize things.

And, the process is open. If and when new FEPs are identified that truly were not already a subset of one of those 370, we will set out to evaluate them. And, if it turns out they do matter, then we would have to rethink where we were.

Next slide, please? Just a quick review of the process that we went through in this step process. I spent a little time here because I think this is part of the safety case. This is demonstrating the completeness. So, we adopt this comprehensive list from the NEA of irrelevant FEPs. This list is made from many different types of repository programs, including, for example, the Waste Isolation Pilot Plant in New Mexico, which was in salt. Features about the rate at which salt creeps in an underground environment are not relevant to Yucca Mountain. So, we take them off at that point.

We expanded the list with the Yucca Mountain specific ones, and then we screened them. We evaluate them as to whether they need to be included in our quantitative safety assessment or not, using criteria that are actually provided in Part 63, the NRC regulation. And, there are the two criteria that matter in Part 63.

That's the 10^8 per year probability criterion, which essentially is a regulatory definition of very unlikely, sufficiently unlikely it can be assumed not to occur. And, as Mr. Sproat pointed out, that's a very small number, very unlikely event.

And, if we can show that a feature, event, or process does not matter, has the consequence that is insignificant to overall performance, and, we can document that, and these screening argument, we call them, are documented in Project documents, then the retained features, events, and processes get put into the models, the quantitative models used for these estimates.

Next slide, please. The component models, here's a quick list of what they end up with. I show these here only for the nominal performance of the system. We obviously do consider those rare potentially disruptive events, such as volcanism, that have a probability just above that cutoff, but do have consequences, but we build a separate modelling framework for those disruptive events, because the processes we need to model are different.

So, each one of these components here is something that you can find a quantitative mathematical model with input parameters and uncertainties, capable of being solved. We can, and I can't tell you in detail, but somebody in the Project can tell you details about cladding performance, and waste form performance, because we have that component in there.

Next slide, please. Those are then linked together computationally into this thing called TSPA, Total System Performance Assessment. And, I'm not going to try and walk through this. I'm comforted to know that there are people who can explain what everything is in here. But, briefly, over here in these blue bubbles are models, computational models, for each of those processes shown in the previous slide, with the FORTRAN, most of them are in FORTRAN codes, and that sort of thing, and they pass information back and forth into a system model that eventually produces an estimate of system performance. We do this because, two reasons, it is good to know how the system performs, and we think it will perform what our estimates are, and, second, it is required. This overall dose measure here is one of the quantitative standards that the NRC provides, and the EPA provides. So, we will do this.

We will not claim that this is an easy to follow transparent modelling system. It isn't. But, it can be explained, and we will, in our licensing process, we will explain it in detail.

Next slide, please. So, why should we, or anyone, have confidence in these component and system models? We go through processes which I call them here use "confidence" and "corroboration" is the words. In quality assurance jargon, this would be model validation. But, there are multiple approaches we can use. We don't use them all with every model. They aren't all available, but we're available.

Direct observation. Obviously, you cannot corroborate a model of a million years with direct observation, this is what will happen a million years from now. That tool is rarely available to us. But, many of the components you can, you can run short-term tests and corroborate.

Analogue information. Independent evaluations where others, for example, the Electric Power Research Institute, EPRI, has done system level evaluations for years on this project. We have seen the NRC's own TPA results, they are their system level modelling results, several times. That's useful, very very useful. At the component level, there are many other independent models we can compare against, and we do.

Internal to our own model, auxiliary analyses and comparison of system and subsystem results. This basically if just a detailed analysis of our own model. Does it make sense? Can we take it apart and show you that our subsystem piece of a TSPA that models a particular process actually matches the process model that was run previously. And, yes, we do that.

Peer review. It's one of the gold standards of science. And, yes, we do engage in peer review. We want our work reviewed, and we want it reviewed hard.

The component models are evaluated individually and in the context of the system model. So, we don't just let those models stand on their own. You've got to see how they work together in the whole system.

Next slide, please. Acknowledging sources of uncertainty. It's essential to answer that question do we know everything? No. And, a scientist who tells you they do know everything is--well, it's not the scientist I would want to ask, because there are always going to be sources of uncertainty. Our job is to explain them and to show whether or not they matter, to inform the decision in the light of the uncertainty that remains.

Incomplete data. You can never get, for example, hydrologic data for every location in the mountain. You would have to take the mountain apart to do it, and then it wouldn't be a mountain.

Spatial variability and scaling issues. It should be pretty clear that you have data from a limited number of places. You have to make inferences about how they can be used to represent a large area, a large volume.

Measurement error. Rarely is this actually a large driver, and to keep track of it, it becomes of interest in tests that have--measure very small things with potentially large errors, things like corrosion tests where you're measuring very small mass changes, you want to be careful there with measurement error.

Lack of knowledge about the future state of the system. We don't know if these future events, let's take volcanism, will it happen or not? We can give you a good probability estimate from expert judgment. But, that still doesn't tell you will it happen on a given date or not, and we do acknowledge that kind of uncertainty.

Alternative conceptual models. For almost everything, other scientists, and including ourselves, can say yeah, there might be another way to do that. And, where different conceptual models, different representations of the world are equally consistent with the available information, i.e. you can't prove either one of them right or wrong, then we need to be able to evaluate both and show the effects that way.

We use Monte Carlo techniques to incorporate uncertainty in modelling. This is a modeler's term, but basically, we run the model repeatedly with different sets of input values, and get a distribution of model results. And, that distribution of model results depends on the uncertainty in the model inputs, and it is our display of uncertainty in the estimate of performance.

Next, please. Okay, quantitative estimates here. Everything I'm going to show here is for illustration purposes only. I said that already, but it's not intended for comparison to regulatory standards.

Next slide, please. We start off with barrier capability before I get to system performance. Barrier capability, what does a barrier at Yucca Mountain do? There are three main things a barrier might do, and these are actually spelled out in the regulation, Part 63, but here they are, not in regulatory words.

Barriers can keep water, keep the waste dry, limit the amount of water that reaches it. They can limit the release of radionuclides from the waste form, and they can limit the transport of radionuclides from the waste form to the human environment. So, our barriers have to do one of those three things, basically, and they do.

The barriers can be evaluated separately or as a part of the system. Separately, it's a potential capability, and the full system where we put the barriers together, complimentary and overlapping capabilities of multiple barriers. Not all barrier capabilities will be fully realized in the full system, because some of them are indeed overlapping, so if one barrier is working, the capability of the next one in line to do the same job may not be realized.

Next, please. All right, this and the next slide both show the radionuclide inventory at Yucca Mountain in radioactivity units, curies. This one tracks it out to 20,000 years. The next slide takes it out to a million years. I put them both in because the question is relevant, if you want to know what they're both doing, and I did not have an example that would give us enough resolution in the short time to put it all in a million year scale. So, I'm going to talk to this one, but be aware the next one is there.

And, the point I want to make here starts off with the observation that this black line, the total radioactivity, it's a lot, between 10^9 and 10^{10} curies at ten years. And, these are the curies that we're tracking. These don't include some of the very fast decaying stuff that is not actually included in the analysis because it's gone by the time the repository would be closed.

But, let's figure somewhere above 10^9 curie, a big number, what actually is driving that? And, these are radioactive decay curves through time. For the first few hundred years, it's cesium 137, strontium 90, that's americium 241, plutonium 238, plutonium 240, the green one is plutonium 239, americium 243. This blue line that's almost horizontal, that's technetium 99. So, our barriers, we're going to focus here on how much of the radioactivity, that total radioactivity, our barriers are going to contain.

Can I get the next slide? This is just for completeness to show you the full million year curve. It's the same. This is the technetium 99 curve here, plutonium 239, dropping off there at about 100,000 years, it starts to disappear pretty sharply. Neptunium, you've heard quite a lot about, as a somewhat troublesome contributor, it is down here. It is four orders of magnitude, five orders of magnitude below that initial inventory. It's a small contributor of the total radioactivity in the mountain.

And, just before the question comes up, these little steps here are because this plot was generated using 250 year time steps, those little right angle bends are not real there, that's an artifact of the scale of the figure.

Next slide, please. All right, keep those figures in mind, or come back to them when we get to the performance of the engineered barrier system. I'm going to start off here with the upper natural barrier. And, what does this barrier do? It keeps water, it limits the amount of water that might reach the waste form, and then the waste package.

The components of it, the surface, the land surface that is a fairly effective barrier preventing water from infiltrating in, most of the water that falls on a desert does not make it into the rock or the soil. Most of it either evaporates or is used by the plants very quickly.

And, then, there is the--what water does make it through percolates downward through this unsaturated zone, where much of it will then be diverted around the tunnel by the capillary barrier effect of the edge of the tunnel.

Next slide. I'll talk about that. All right, again, these are draft results that have come out of ongoing work that's derived from past analyses. The blue line here is precipitation. That's average, spatial average precipitation over Yucca Mountain, and, no, that's not measured at every location over Yucca Mountain. That's a reasonable estimate, taking into account changes in elevation and the real datapoints we have that were a measure of precipitation. And, this little step here, and there's a very small one there, those are the climate changes in our future climate model when 600 years from now, and 2000 years from now, we move into wetter climates in our model. --which is infiltration, that's how much of the water makes it below the near-surface soil zone.

By the time we get out into the wetter future climates, it's less than a tenth of what was falling on the mountain. It's even less than that in the present dry climates, we believe. And, these other curves down here, these are the seepage effects, and these are--I show here the fifth percentile and the ninety-fifty percentile, as well as a mean of seepage. The point in showing that is that unlike infiltration and precipitation, where it makes sense just to average them over the repository, seepage is strongly affected by the thermal history of the underground, so it makes sense to show you the range there, because the drier parts of the--the hotter parts of the repository will be quite a bit drier, and it does vary.

But, all right, what's the point of this little aside here? About a factor of 100 reduction in the amount of water that actually falls on the mountain, 1/100th of that, more or less, might make it into the drifts. And, I'll argue that's a pretty effective barrier for water movement.

Next slide, please. The engineered system. Again, here, it's the--the components would be the drip shield, the waste package, and the invert are the ones that are mainly of interest. Also, the waste form itself and the cladding.

Next slide, please. John, are you going to keep me honest on time here? I don't want to run long.

GARRICK: Yeah, I will. I'll keep you honest.

SWIFT: Okay. Now, the results shown here, and these are from interim draft work that is in progress, and I show these simply as an example of how we might show the effectiveness of the engineered barrier system. What we're showing here, the top curve is the total radioactivity in the repository off those earlier inventory plots I showed. And, what we see here is the amount of radioactivity accumulating through time, how much of it made it out of the bottom of the drift through time.

And, think in your head back to those inventory plots where I said cesium, strontium, americium, plutonium were basically 99.9 percent of the radioactivity, and they aren't even making it out of the drift. They're down here. What is making it out is--actually, cesium does, it's this one here, but cesium, the curve flattens off here because radioactive decay basically takes it out. Technetium makes it out. Strontium--when a curve goes flat here, it's a cumulative curve, that means basically no more is getting out. A curve that keeps on climbing is what's continuing to get out.

All right, so, as modelled here, and this is an as modelled, and I've got to acknowledge that, these are mean releases, calculated over a range of uncertainty, but they are shown for a modelling case in which the engineered barrier was largely effective. We did have, in this model, early initial failures of the waste packages, hypothetically due to manufacturing defects. We did have the drip shields intact in this analysis. The point of showing this is to show that the engineered barrier system has the potential, I'm not saying that it's doing it here, but it has the potential to retain the overwhelming majority of total radioactivity. That's eight orders of magnitude of radioactivity is not getting out. That's a tiny number that is, if we have intact drip shields and nothing but a small number of packages failing early due to potential hypothetical manufacturing defects.

Next slide, please. Just an example of a single plot. This one happens to be americium 241. Now, I'm just showing the americium decay curve, how much americium is left. And, it's just off the scale here, but basically, the two plots are converging. All that is going to get out is about, if there were originally 10^8 curies of americium 241, we've let out 10^{-8th} of it before the americium has decayed. And, that's pretty effective.

Next slide, please. The lower natural barrier. Here, we have groundwater flow through the unsaturated zone, and then flow and radionuclide transport out through the saturated zone through flowing groundwater, to a hypothetical water well, 18 kilometers south, just--that would be just north of the intersection up here at Lathrop Wells.

And, here, we're interested in contaminant transport processes, how effectively are radionuclides transported in moving groundwater.

Can I have the next slide, please? And, this is a little bit complicated, so I've got two or three slides in a row here on this one. This is what a hydrologist would call a break-through curve, but it's complicated because it has radioactive in-growth and decay factored into it. But, we've released a hypothetical unit source of inventory at a hypothetical time zero. This is not real, this is a hypothetical analysis. What if we released a unit source of radioactivity into the groundwater at the base of the drift directly below the waste packages, how much of it would get out through time. And, so, these numbers are normalized to one. One was the unit source we let out.

So, after 100 years--actually, letting out here means 18 kilometers away. We've actually, the very first models of technetium are just barely showing up there. But, we don't have half the technetium getting out until, what, 3000 years, or so? Most technetium is held in. These are mean break-through curves. Now, what's going on with this one? That's neptunium 237 where we've let out more than we put in. Well, that's real. Neptunium 237 is a decay product of americium 241, and it actually--it does form during that part of the transport process. So, the figure is a little bit hard to understand.

The other curves on here, plutonium curves, americium 241, showing basically it isn't going anywhere, but it's--the product of neptunium is.

Next slide, please. Now, the plutonium shown on the previous slide was a little bit misleading. It wasn't misleading, that was what we were calculating. And, again, these are means over a range of uncertainty. But, that was transporting almost entirely as colloidal plutonium. If plutonium were to remain fully in the dissolved state, less than 10 percent of it as on a mean is getting out at 10,000 years. So, that's the point of that one.

Next slide, please. This is to try to make sense of that neptunium one. Here's a neptunium transport profile, a series of break-through curves without radioactive decay. This shows just the chemistry and the physical transport of what happens to neptunium in groundwater. This shows the full suite of uncertainty here. There are, I think there are 200, I'm not sure how many curves, I should have counted--I should have asked somebody. I think there are 200 here.

Each one of those is a possible break-through of neptunium. What does it mean? It means that if this curve here, that will be the least favorable one, if that represents correctly the physical processes of a system, then half neptunium would indeed get out quite rapidly. If the slower one here, half neptunium would get out, that's 10,000 years. Half would be this line here. All the neptunium would be getting out by the time the curve got to the top.

So, take this 50 percent break-through line, the median break-through, when half of the contaminant has reached the hypothetical water well, and how long does it really take to get neptunium out? All right, we're out here at 6, 7, 8, 9,000 years, by and large, on this. This is a histogram drawn across this thing here at that level. So, the point here, the system, taking out that in-growth function, what does it actually do to neptunium? We believe that the most likely condition of the saturated zone and unsaturated zone is that neptunium will be retarded many thousands of years, perhaps many tens of thousands of years during transport. That is an effective natural barrier. Retarding--back up again two slides. Sorry.

We have completely retarded cesium, strontium, americium, most of the plutonium, and, yes, we are transporting technetium and neptunium through, but most of it is being retarded many thousands of years. And, that's an effective barrier.

Next slide? Now, system performance. These are what we've been showing for years as Total System Performance Assessment. This is a calculated estimate of the dose that a person living at the receptor point, which is here, might receive thousands of years from now. And, there are 300 curves plotted on here. Each one of these is a different result from Monte Carlo analysis that takes all those components of the system into effect. And, each one, taken together, they represent our treatment of uncertainty. Each one of them uses a different sampling of the uncertainty in the input models.

So, in that sense, to a mathematician, each curve here is an equally likely realization of the model. If the parameters of the system are such that they coincide with this little curve here, then that is our estimate of what it will look like. The mean shown here in red is the curve that the--to 10,000 years here, that the EPA has specified we should regulate on. And, obviously, the rule beyond 10,000 years is still in question.

Just a scale on this to put it in perspective. 15 millirem is about in there--sorry, it's there. And, 350 is up in there. What do we get from this, other than the quantitative compliance measure that the regulation asks for? We get a distribution of results that allow us to do a detailed uncertainty analysis to determine what of the uncertainty that separated all those curves out, what of it actually matters. We can go back into the model and say, all right, what was the groundwater flow velocity, what's the dissolution rates of the waste form, was it the solubility of neptunium, and the model allows us to back that information out and come back and inform ourselves as to where our uncertainties are important.

Next slide, please. I show this because in the interest of being complete with a safety case, we do acknowledge the possibility of rare disruptive events with large consequences. And, we've been doing this for years. Here, I show a slide, I think I showed this group four years ago, but this is the probability-weighted consequences of igneous disruption. And, I have in the past gone through the explanation of how we calculate the probability of weighted consequences, how they differ from the consequences associated with a single event. That's beyond the scope of this talk, but I show it for completeness to show that we want display, we do display the uncertainty associated with these rare events.

And, points to make here, just this blue curve is the eruptive, the dose familiar eruptive event, if an ash cloud were to fall here, that's the dose associated with that. This is the dose from a groundwater pathway, from a repository that has been damaged by magma entering it. This is all at a probability of 10^{-8} per year. And, this curve here, the black one, that is the nominal performance, what the system will be doing if the volcano doesn't happen.

The important point there is that when it comes to looking at very long terms, the curve we should be worried about, and concerned about, interested in, actually is a nominal one. By the time we see significant failures of the engineered barriers, and eventually there will be failures of those packages, the probability-weighted consequences of the volcano are not the total measure of interest. The question--really, the question of interest is how does the system evolve through time. You're just beginning to see the beginning of that there. On these analyses, we were starting to show waste package failures by general corrosion at about 70,000 years, and the curve starting to climb.

Next slide, please. All right, this is my next to the last slide, and I show this to make the iteration point. This is a composite of million year doses, I'm going to go ahead and show the million year curves, that we have shown going back eight years now to the viability assessment in 1998, and that was this red curve here. The black one was our first curve that we published for the site recommendation in 2001 and 2002, and the other two were also part of that site recommendation analysis.

The point of showing these is that, one, yes, we do do iterations and we learn from each one of these. The other point is that there's significant differences here in early time, depending primarily on whether or not we include the possibility of early failures due to these hypothetical weld defects, manufacturing defects. That's what creates the early curve in here. Uncertainty in this space in here is related to uncertainty in general corrosion rates in the waste packages.

But, we've got a fairly stable answer out here. I take some comfort in that. These are not the same model run over and over again. The models have changed. Our understanding has changed. And, yet, our answers are coming in there.

Next slide, please. So, I'll wrap it up here. Okay, the quantitative--concluding points--the quantitative estimates of barrier capability are part of the safety case. In fact, this quantitative safety assessment is required by regulations. So, we will continue to see quantitative model results.

Why do we have confidence in these? It has to come from our understanding of the components and their capabilities, our understanding of how they work together as a system. We have to clearly display our uncertainty, and we have to be able to show that we have followed a process that demonstrates completeness, and I should have added basically, the quality of the process. We have to be able to show that the work has been done to a sound process.

And, then, the last point, confidence in the overall safety case, which is basically the case that Russ described, and will be in the license application. It's multiple lines of evidence, and that's where the next talks come from. We'll go to Pat Brady on analogues, Frank Hansen on performance confirmation. These are the--just one piece of the parts of the multiple lines of evidence here.

I'll take questions. And, I apologize for going long.

GARRICK: Howard?

ARNOLD: Arnold, Board.

Would you go to Slide 18, please? You can draw from this slide perhaps a different conclusion than the one you were after, which is that nothing at all happens until some engineered barrier systems fail due to manufacturing defects. Actually, the assumptions that go into choosing the percentage that fail seem to me to be crucial in getting answers to this thing. And, you would draw a lesson that says I'd better--I had better have a good design, and (b), I'd better have a very good idea of how it fails, and why.

Once you assume failure, of course, the rest of it shows the capability of the other barriers. But, until you have that, if you had a properly manufactured engineering barrier system, nothing at all happens; right?

SWIFT: Yes.

ARNOLD: Except when you go to the million year case, then there's another rise, which are presumably due to nonmanufacturing defect failures of the engineered barrier system.

SWIFT: Correct.

ARNOLD: Whatever they may be. Now, I've been frustrated in not understanding either the short-term failures or the long-term failures, how they actually come about, because they're key to this thing.

SWIFT: Okay. The short-term failures considered here are--were developed by our waste package design engineers from a survey of relevant analogue information from the design community, engineering design community. What is the failure rate of other major comparable materials, boilers, for example? I did not develop that information myself. The conclusion was that with high quality assurance and quality control standards, you can get a very high success rate at building what you said you were going to build.

But, that's not my field. I agree, however, that these results will essentially scale up and down linearly with the number of packages they--

ARNOLD: They depend entirely on that assumption, yeah.

SWIFT: Yes.

GARRICK: Ron, and then Thure.

LATANISION: Let's look at this slide. The bottom bullet is an important statement, the barrier has overwhelming--has the potential to retain the overwhelming majority of the total radioactivity. If you look at this from the point of view of potential corrosion problems, we've been focusing on the question of what sort of penetration might occur under certain circumstances, whether it's general corrosion or localized corrosion, what sort of penetration would occur. And, then, the conversation becomes, well, will that have the effect of allowing release of radionuclides. Suppose we took the opposite point of view. Suppose we said what sort of breach would be required in the package to allow a substantive release of radionuclides, enough of a release to be of concern? And, then asked the question what sorts of rates of corrosion, whether it's uniform or localized or stress corrosion cracking, all of which I understand have some placement in the TSPA. I think that would be an interesting evaluation. Do you think that is something that could be incorporated into your plans, or--well, let me have your reaction to that.

SWIFT: Sure. Yes, it could be done. The modelling tools could do that. We are aiming here at a licensing case for the NRC, and they want us to give, as we heard earlier, give our best understanding of how the system will work, not an estimate of how it would work if it didn't work the way we thought it will work, which I think is what you asked for. And, I'm sympathetic. It's as simple as saying how many waste packages would it take to produce Dose X, how many waste package failures would it take to produce a certain dose? And, it could be done, but it is not actually part of our licensing basis.

LATANISION: I just add the--this is Latanision, Board.

Just add the comment, there is always a concern that you could capture in the words "so what." In other words, if corrosion occurs, does it really matter? And, I think it would be interesting to know what amount of corrosion would be required so that one would characterize it as mattering. And, you know, the way to get to that point would be to do the sort of reverse calculation. Instead of asking, you know, what might happen if the Rates X, Y, and Z, let's ask the reverse question. How much would the rate have to be in order for this to be significant?

So, I mean, I understand what you're saying. But, I think there's a dimension to the whole issue of the engineered barrier and potential corrosion phenomena that could be addressed very usefully if we looked at it from this point of--from the alternative point of view.

SWIFT: Thank you.

GARRICK: Thure?

CERLING: Cerling, Board.

Just continuing on this, you know, we've seen these sort of things a number of times, and I, you know, it's never illustrated. For instance, in this particular case where the levels of various radionuclides are rising with time, and at the end, they've plateaued, and how many waste packages in this illustrative example actually result in those curves? Is it, you know, one, or ten, or a thousand, or how many actually have failed?

SWIFT: Okay.

CERLING: The first part. And, then, I'll ask a second.

SWIFT: That one is pretty quick to answer. There are 11,000-some waste packages that were in this set of simulations, and the number of failed packages is--it's sampled probabilistically, but you can think of it in your head as one. It's a small number.

CERLING: One?

SWIFT: Yeah.

CERLING: And, then, second, how is the--what is the assumption on what happens to the waste packages, the case where essentially it disappears when it--

SWIFT: I suppose you could--and we've actually run this. This wasn't done that way. We've actually run this case with precisely one package failed, to simplify the problem, and then you could simply multiply those curves by 10 to the fourth, I suppose. And, you'd be there.

Some years ago, we did present to this Board a one-on analyses in which we added barrier sequentially one at a time, and I presented those, and I was a little uncomfortable with that exact presentation of here's how the site would work if the Department did not use waste packages. Because I'm very sure that won't happen, that that's not a plausible future state. And, I'm looking to try and analyze the plausible ones. But, the way to get at that would be to look at the effects of one package failing, which of course is scattered randomly around the repository, so some of them see seeps and some of them don't, and that sort of thing. But, then you could start with one and scale up from there, and, obviously, I don't imagine a situation in which all the waste packages fail immediately. That's just not a credible future.

GARRICK: Okay, I think David is next, and then Andy, and then Mark, and then George.

DUQUETTE: Duquette, Board.

I remember the one on, one off results that you presented to us, and it basically said you could fail all the containers, and it still would retain the waste fairly well. I actually had the same question here, and I think it was answered when you said this was just one container. I wasn't sure. This assumes, I think, if I remember correctly, one container failing completely, that is, the entire inventory, from one container being released instantaneously, if I remember that.

SWIFT: Essentially, yes.

DUQUETTE: Yes, but in any corrosion model, of course, that's not going to happen, unless it's uniform corrosion over the entire container, and then it has to get through the stainless steel inner container, and then through the clad as well. So, this assumption is both conservative and non-conservative in that it's only one container, but everything in that container is released at the same time, if I understand the model correctly; is that right?

SWIFT: Yes.

GARRICK: Andy?

KADAK: Kadak. Could you go to Slide 26, please? I just want to be sure I understand what you just said. At that million year time frame, is the assumption there that only one out of 11,000 containers fail?

SWIFT: No. No. The steep climb shown here, for example, or in here, that is when we have general corrosion creating failures of a large number of packages.

KADAK: Okay.

SWIFT: And, in most realizations here, most of these iterations, not realization, these were all means, each one of them is the mean of many hundreds of runs. But, in most of them, it isn't a safe bet to say all the packages failed right here. But, that's just when the bulk of them were failing.

KADAK: Okay. So, I guess that gets to the question of standard, at least for me. In the first 10,000 years, are you going to try to meet that was it 15 millirem per year dose to the public?

SWIFT: In the first 10,000 years?

KADAK: 10,000 years.

SWIFT: We're required to.

KADAK: Suppose you're 16 millirem per year, do you meet or do not meet the standard?

SWIFT: Say that again?

KADAK: Suppose it's 16.

SWIFT: Our model says we have 16 millirems a year and 900,999? I would--

KADAK: You know, NRC has this thing about numbers, and I'm just wondering whether that's--there's a range there or not.

SWIFT: That would be something that we would have to discuss with the NRC.

KADAK: This is something I think you should discuss now.

SWIFT: I'll point out that's still a rather small number in the world of radiation.

KADAK: Clearly, but I was really impressed with the Part 63 discussion from NRC this morning, which was pretty clear what the requirements were, and I'm just wondering if you thought about 16, or do you have to go back and sharpen pencils some more and massage the assumptions?

SWIFT: I don't have an answer to that.

KADAK: My other question is when you started looking at all these horsetails, and you tried to back out what are the significant contributors, can you give me a list of three to five key issues that you think you need more data on to better get a handle on those key contributors in terms of dose?

SWIFT: Yeah, I'll start by saying that I don't think I need more data. I'm comfortable with this display of uncertainty, but where would more data reduce uncertainty, and what would cause these curves to actually move? I think that's your question. The spikiness in them here is a function of having assumed that future climate changes occur at precisely known times. So, each one of those spikes is a future glacial event, which we had no uncertainty it will occur at year 780,000, or whatever. I think that is something that we perhaps could have had a more humble display of uncertainty on. That would have had the effect, however, of smoothing out those spikes, and in some ways, there's a value in showing them like that.

KADAK: You're going to get more data for--

SWIFT: No, we're not going to get more data on that. The point at which the curve starts to climb steeply here is basically a function of the general corrosion rate, and if the general corrosion were such that we were seeing large scale failures before 10,000 years, that will be something I would be concerned about. We don't see that.

The overall magnitude of the curves here, why is it settling in here, a key factor there would be the solubility of the phases in the waste form. And, I think, John, this is a point that you're coming to. Source term issues, degradation, although degradation rate of the waste form, a million years is a long time. If the waste form degrades and takes thousands of years, or even tens of thousands of years, that's still a relatively short window over a million years. But, if it is stablely sequestered in mineral phases, which we're assuming basically it's not here, then those curves are coming down. That's something that Pat Brady and Mark Peters will talk more about I think.

The amount of water actually reaching the waste, for example, if we were to see more or less seepage, infiltration, and then the dependent seepage, that would move those curves up and down, I think.

GARRICK: Isn't the convergence driven by the fact that eventually, it's an inventory issue, as much as anything?

SWIFT: I'm sorry. Excuse me?

GARRICK: Isn't the convergence, the eventual convergence due primarily to inventory?

SWIFT: Yes.

GARRICK: So, this suggests that the inventories on each of the TSPAs were the same?

SWIFT: By the time you are essentially releasing everything, you ought to be converging, is what you're saying?

GARRICK: Yes. But, that's the real driver for the stability.

SWIFT: Fair enough.

GARRICK: Yes. Okay, Mark?

ABKOWITZ: Abkowitz, Board.

While we were on this slide, I was just curious why we're not seeing any graphs from the last five years.

SWIFT: The--obviously, the work has been ongoing, and the--how do I best say this. There has been litigation over this, and we would prefer not to compromise the litigation right now by presenting those results. Do we have someone here from counsel?

ABKOWITZ: This information is discoverable, and that information is not?

SWIFT: Excuse me?

ABKOWITZ: Is it this information is discoverable, and that information is not?

SWIFT: This information is in the public record. This is all--you've seen all those curves before, or this Board has. We are preparing for a license application that will be litigated here, and it's just a somewhat sensitive time.

ABKOWITZ: Let me move on to Slide Number 6. My question has to do with the lower left-hand box. Under the EPA rulemaking, has any consideration been given to changing the screening criteria in that box to say FEP has at least one chance in 10,000 of occurring in a million years?

SWIFT: This comment was made during the public comment period on the EPA rule. I can't really comment. This is EPA's rule, not mine. However, it is my own belief that the reason--and, this goes back 15, 20 years, this phrase, one chance in 10,000 or 10,000 years--it's intended to be a sliding window of time, so that the 10,000 year period of interest could be between year 100,000 and year 110,000. But, the probability of occurrence during that 10,000 year interval is still one chance in 10,000.

If you take it all the way to one chance in 10,000 to a million years, you're dealing with probabilities that are--they are no longer in the realm of being credible. These would be events that have never happened in the history of the earth. And, it just seems improbable that we see intent of the regulation.

ABKOWITZ: So, then, 10,000 is somewhat of an artificial number? I could put in one? It would be a sliding scale?

SWIFT: If you could change it to 10^{-8} per year, which for events that have--follow poisson process, you can assume that's essentially the same. And, that might simplify the problem if it was simply defined as 10^{-8} per year.

ABKOWITZ: So, at the end of the day, though, I guess I'm having trouble intuiting this, it's basically saying, well, if something destructs, it's only going to happen, you know, less than once in every 10,000 years, then I can assume that from year 10,000 to year 1 million, it's no less likely to occur?

SWIFT: The--you have to make a probability decision based on how likely something is to happen in a time period. Probability is a function of time. You specify the time window. Here, they specify 10,000 years. Now, it is true that the longer you wait, the more likely it is that a rare event will have happened. However, does that make it something on which we should--this is the NRC and EPA's world, not mine. But should they make a rule that specifies we should regulate on something that is so rare that it may take--maybe not happen in millions of years, may never happen, may not happen again for millions of years, meteorite impacts would be an example, good one, the probability of a large meteorite impact is on the order of, say, 10^{-14} per year, something like that. You can get that number from looking at other planetary bodies, the moon, for example. Do we want to be regulating Yucca Mountain based on the recurrence of a giant meteorite shower on earth? We're missing something there.

ABKOWITZ: Well, it corresponds with one that we might be in the time of peak dose, wouldn't that change the answer to the question?

SWIFT: If a--if it occurred during the time of peak dose, would an event of that rarity change the answer?

ABKOWITZ: Yes.

SWIFT: Yes. Is that a meaningful thing to regulate on? I don't know. That would be the regulator's question.

ABKOWITZ: Thank you.

GARRICK: Okay. Moving right along. George?

HORNBERGER: Could we look at Slide 21, please? What's your average groundwater velocity for this slide?

SWIFT: I don't know.

HORNBERGER: You can guess. You can tell by looking at that. That's a break-through curve; right?

SWIFT: Yes. Well, at least some water is moving--enough to get that first arrival there.

HORNBERGER: Yeah, but I mean this is a single realization; right? This is not--

SWIFT: No, these are--skip forward two slides, please.

HORNBERGER: So, they're just the--

SWIFT: The means take you over a family of results like that.

HORNBERGER: Okay.

SWIFT: So, if you took the mean--

HORNBERGER: Yeah, if we go back--well, let's use the horsetail.

SWIFT: Go back forward two. Yeah, to a hydrologist, this is a more meaningful plot.

HORNBERGER: That's where I thought it was at, thought it was a single realization. That's why I went to that one.

SWIFT: Right.

HORNBERGER: So, what's the median groundwater velocity?

SWIFT: Here?

HORNBERGER: Yes.

SWIFT: The--

HORNBERGER: I know neptunium is retarded, so it's hard--

SWIFT: Right. So, take the unretarded species. Take the first arrival and assume that's essentially unretarded, a realization which we had sampled a very low retardation of neptunium. So, we're seeing median groundwater travel times there on the order of hundreds of years.

HORNBERGER: So, my question is then how important is it for you to have a good representation of this uncertainty? Is this an important thing? Suppose groundwater travel time were significantly more rapid than you're showing here, would that matter?

SWIFT: First, I want to correct what I just said there.

This would be a single realization in which the median groundwater travel time is a hundred years. It's not necessarily the full distribution of them. You'd have to apply, haven't got here for an unretarded species like technetium. But, would it matter? Yes, it--go back to the slide again.

All right, here, we have--this is a mean of technetium, the blue curve here, which is essentially--shows very little retardation in the groundwater. And, so, I can infer from that point there that the median of the--if I had the full horsetail of technetium plots up there, that median would be on the order of a couple thousand years.

HORNBERGER: Right.

SWIFT: And, that is actually a useful amount of retardation. I would rather not have technetium have to--technetium arriving sooner than that. So, yes, groundwater travel time does matter, groundwater transport time.

HORNBERGER: Okay, thank you.

GARRICK: All right, Ali?

MOSLEH: Mosleh, Board.

Actually, my question was on that slide also, Slide 23 that you just showed.

SWIFT: On the horsetail?

MOSLEH: Yes, the one on the right, and the frequency. It looks like you are not assuming that the transport time is a fixed value, that you have an--and underlying the--

SWIFT: Yes, we do.

MOSLEH: I mean, the median.

SWIFT: We do.

MOSLEH: And, you have a distribution of that median.

SWIFT: Yes.

MOSLEH: This is a distribution of that median.

SWIFT: This is a distribution of the median break-through time, the time which half the contaminant has reached the boundary.

MOSLEH: Right. So, is that not kind of basically in part an answer to what George was asking? Because there's no fixed median time. There's a value median time; right?

SWIFT: Right. And, this is dependent on uncertainty in the material properties of the flow system.

GARRICK: Ron, you had another question?

LATANISION: Yeah, if we could turn to Slide 17? I'm interested in the drip shield. The drip shield takes on particular prominence in the sense of the cool-down section of the thermal pulse when you might have seepage. It's also expected that it will prevent rock fall from hitting the waste package, and so on. I've always been very skeptical of whether it has the capability of really doing that in the long term, and, so, I'm just curious from your point of view whether you regard the drip shield from a science and engineering point of view as being something that is likely to remain, or whether you see the potential that it could be replaced by some other--by bentonite backfill, or some other approach to providing the same sorts of characteristics that you were looking for in a drip shield?

SWIFT: Our licensing case will have a drip shield in it. That's my first answer. And, that will use a licensable and appropriate design for the repository. At the moment, given our uncertainty in localized corrosion processes, it is serving a function. It's not--it's providing the margin in the analysis. It's not an essential part of the analysis, I don't believe. But, if we took it out, you would see more early failures. That curve where we talked about how many early failures there were, that would climb based on our current uncertainty and the possibility of localized corrosion, which is where we were the last two days.

So, that will be a fruitful place for ongoing work that might result in a more efficient, cost effective design for the repository. But, at the moment, it's a licensable design.

LATANISION: Okay, thank you.

GARRICK: Any other questions from the Board? Andy?

KADAK: In terms of dealing with these rare events like seismic, have you heard of an analysis technique called identifying--I mean, picking an event occurring at a certain time, given the repository has certain inventory at that time, then calculating the dose of that particular event, whether it be volcanism or a seismic event, and then taking what they call the mean of the peaks, is that what you use, or how do you calculate the consequent of a particular event like that?

SWIFT: It might be beyond the amount of time we have here, but basically, we do calculate--let's take the eruptive event, a volcano goes off, and there is a--the highest dose is in the first few years, and then radioactive decay and surface dispersion of the processes lower the dose that future generations might receive from a prior volcanic event. A person living at a time 1000 years from now, the obvious overwhelming most likely state they will be in is there was no prior volcano. But, there could have been, it's equally likely if there had been a volcano, and it could have been in any year prior.

So, in probability space, they would receive a probability weighted component from an event that could have happened one year before, ten years before, a thousand years before. Each of those possible consequences has to be assessed. So, let's imagine a human living a thousand years from now, we have to calculate the dose they might receive from a volcano that happened in year 100, and for year 900, and so on, and sum those up with the probability accounted for. Does that answer your question?

KADAK: I'll talk to you later.

SWIFT: Okay.

GARRICK: Okay, any other questions? Any questions from the staff? Yes, let's start from the far left, Carl?

DI BELLA: Carl Di Bella, Board Staff.

Could we go back to Slide 6 again? The FEP. And, of course, as you mentioned, we've just finished a day and a half workshop that was triggered by the Project intending to screen out localized corrosion caused by dust deliquescence based on that box, which we call the consequence box. Now, unlike the left-hand box, which is quantitative, the right-hand box is qualitative. It's got that word significantly in it.

Is there a quantitative measure of significantly that the Project is using, and is there one that NRC is using, and are the two the same? Can you answer that one?

SWIFT: I am not aware of one that the NRC is using. Within the Project, we have to do this on a case by case basis because the consequence of interest may be evaluated at some intermediate step. We can show, for example, that a particular process has no consequence on the next downstream component of the system. We don't have a quantitative cut-off there. We just have to make the case for the NRC, and for those others who want to review the FEP screening arguments. We have to make the case on a case by case basis. Does that answer?

DI BELLA: Not really.

GARRICK: John?

PYE: Yeah, Pye, Board Staff.

I'm interested in the relationship between design and performance, particularly the engineered barrier system. You finished a response to Dr. Latanision talking about cost effective design solutions. What is the service life of a drip shield? What is the service life of a waste package?

SWIFT: Let me make sure I understand the question here. From a design engineer's perspective, what should they perceive as the appropriate service life for an engineered component?

PYE: Correct.

SWIFT: This is--Mr. Sproat talked earlier about the need to make sure we are well connected between science and design, and this is an interesting point, because the scientists here would look at this and say our job is to understand when it fails, not how long it lives. It's a different--we turn the problem around.

Intuitively, I want the design engineer to tell me as much as they can about that package, and I don't see this having a service life. I see this having a life of--or it could be existence. And, my job would be to understand how it works. I don't impose design requirements. I don't-- postclosure science doesn't go to design people and say you need a 15,000 year waste package, or else. So, it's a place where there needs to be a little back and forth on it. You can infer from something I just said a few minutes ago that it would be good for demonstrating compliance at the 15 millirem standard if a salient fraction of the waste packages were still intact at 10,000 years.

PYE: You talked about back and forth? When should that process occur?

SWIFT: It is happening.

PYE: It is?

SWIFT: It is, yes.

GARRICK: All right, I think it's understandable why it's not a good idea for the chairman to go last. I have a lot of questions, but I think in the interest of responsibility we have to keep on time, we will take our recess now until 2:30, and we'll have to find another time to have some follow-up questions. Okay?

(Whereupon, a brief recess was taken.)

GARRICK: We're on our last stretch. It looks like quite a stretch, however, so we need to move on. We have three more presentations plus some concluding remarks plus an opportunity for any public comments that we might want to have.

So, with that, I think we'll go with the presentation on the role of analogues by Pat Brady from Sandia National Lab.

BRADY: Peter Swift started off his talk by showing a bunch of predictions with various horse tails and so on. What he leaves out is something that you all know, which is every time you do one of those realizations, you take thousands of individual data points as input, shove them into literally hundreds of submodels, which then run in parallel, some in series. And at the end of the whole operation, the calculation spits out a prediction of transport for a slew of radionuclides for hundreds of thousands of years.

Now, the complexity of the calculation and the effort involved is truly breathtaking, but let's be honest. We wouldn't be humans, much less scientists or engineers, if every once in awhile we didn't stand back and say, "Is it true?" Is the TSPA calculation really giving us a fair and accurate indication of what's going to occur at Yucca Mountain?

Now, in situations like this, the human brain almost automatically searches for analogues. It looks for industrial or geologic events that are somewhat similar to what we're considering today and tries to grapple with whether or not these are consistent with what we're predicting at Yucca Mountain. Now, we use several natural analogues; and for the next 15 minutes or so, I'm going to highlight the ones that we rely on most strongly.

If you'll go to the first slide, please. We have natural analogues. For example, the best one that I'll emphasize here is the Pena Blanca ore deposit. Specifically, there's a uranium ore body that sat in the unsaturated zone in a geologic situation similar to Yucca Mountain for roughly three million years. And the fact that uranium has been transported only minor distances gives us some general warm feelings that the same process might occur at Yucca Mountain.

We have unnatural analogues. For example, we can look at hazardous waste sites that contain some of the radionuclides that we're concerned about at Yucca Mountain, and we can look at the transport profiles of, for example, plutonium moving through a fine grain soil at a hazardous waste site. And we can get some ideas about what the mechanisms and absolute transport distances of plutonium are going to be like in the fine grain corroded mass of the waste package at Yucca Mountain.

I'm going to talk about some engineered analogues, too, in particular when we get to the case of technetium uptake. Now, the analogues that I emphasize are primarily going to be focused on the source term. That's partly a personal prejudice, I think, the geochemistry of the source term. It's probably the most critical to assuring the long-term isolation of the waste, so you'll have to bear with me.

In a general sense, we use natural analogues because (a) they're easy to communicate and break through a lot of the calculations. Secondly, and most importantly, we use natural analogues to identify the dominant mechanisms. As a scientist, if we calculate, for example, the dissolution rate and get it wrong by maybe a factor of 2, well, that's a crime, but it's a misdemeanor. If we misidentify the actual reaction mechanism, that's a felony. Natural analogues perform their strongest role when they allow us to identify the mechanisms which will prevail over long periods of time.

That being said, I have to emphasize that there is no perfect natural analogue. They are all not quite exactly what we need. Either they go for periods of time that are too short or distances that are too short or too long. We're always kind of comparing apples and oranges here. So there has to be a fair bit of effort that goes into matching to make certain you're getting useful information out of it.

Go to the next slide, please. Probably the most well-known natural analogue is the Pena Blanca site. The work that's been done over the years has primarily been done by the Center and by the NRC. In recent years DOE has worked at Pena Blanca. Pena Blanca is kind of a trophy site for Yucca Mountain for a bunch of reasons. First of all, it is a uranium ore deposit, UO_2. It's slightly oxidized. It's in welded silicic tuff. The UO2 is very similar in composition to the spent fuel that we'll expect to see at Yucca Mountain. There are very few impurities in the UO_2 at Pena Blanca, roughly 3 percent. The fuel that we'll be having at Yucca Mountain will have about 5 percent.

There are other--natural analogues, Oklo and other places. They are held back by the fact that they have impurities, which kind of obscures some of the mineral parageneses. This is an arid site. Most important, it is unsaturated and, therefore, chemically oxidizing like we expect to see at Yucca Mountain.

What happened at Pena Blanca--and, again, I'm drawing heavily here from the work that Bill Murphy and his colleagues at the Center have done; so if you correct me, I'll defer the question to Bill, most likely. At Pena Blanca the UO_2 formed about 43 million years ago. About seven million years ago there was a dissolution reprecipitation event where UO_2 was reprecipitated again. That was exposed through the course of basin and range faulting so that the ore body ended up above the water table, and it's sat there for the last three million years.

There are a couple of important points that come out of the Pena Blanca. First of all, there's the general good feeling of seeing this stranded ore body that's remained effectively inert for millions of years, suggesting the same thing may occur at Yucca Mountain. What we used Pena Blanca for in the Yucca Mountain Project is, we take the alteration sequence that is observed there and use it to set our solubility models.

At Pena Blanca there is a distinct sequence of UO_2, acquiring oxygen, turning it into sherpite. Sherpite then grades into uranium silicate phases, in particular sodyite, and then farthest out in the alteration halo, you end up with uranifane, calcium uranium silicate. So the sequence of fuel, oxidized hydroxylated uranium, silicated hydroxylated uranium, and calcium uranium silicates, that's what we've actually seen also when we've done our own tests, and particularly the Argonne drip tests show the same sequence.

Now, what we've done is we've taken that sequence, and we use those phases in the respective portions of the flow path to calculate the solubility of uranium. We use sherpite inside the waste package, and we use a uranifane further out in the far field.

Now, the Pena Blanca continues to be studied by DOE. We're hoping to get useful information about colloidal fluxes out of Pena Blanca. This is a question that we're sort of grappling with right now. Are there going to be fluxes coming off of the spent fuel? That is, are we going to get sherpite colloids coming off of the spent fuel? We hope to use natural analogues to tell us whether or not we will; and, if so, most importantly, how large are the colloidal fluxes.

Next slide, please. I would argue that although Pena Blanca is a good site for seeing what happens inside of the fuel rods, there is another facet of the waste packages that we'd like to deal with with natural analogues, and that is the incredible abundance of iron in the packages. On a molar basis, if you take a waste package and split up what is iron and what is uranium, you end up with mostly iron. There is seven times as much iron as uranium. Uranium is a trace component in the repository at Yucca Mountain. It is primarily a repository for iron, and that has very important controls over what happens to the chemical state of the radionuclides and how they're released.

There is a schematic over here where we show--and I should point out, this is work that was funded by the S&T Program, and I believe Mark Peters will talk about it later on as well. If, in effect, Yucca Mountain waste packages, once breached, are going to be large mixtures of rust with small amounts of uranium, we would expect something like the bottom case down here. In real life, when you coat something with iron or oxidized iron, you end up passivating the stuff underneath it. I mean, this is why steels work so well. You form a--iron oxide scan on the surface, and water can't get through nor can oxygen, and so the stuff underneath remains fresh. This happens when you oxidize a nail.

What we've been looking at is trying to see if this happens in a microscopic sense as well in a waste package where the corrosion products prevent the oxygen from even getting to the fuel. If this does indeed occur, it would have a profound effect on the solubilities of uranium and the other actinides. If you look over there, that vertical graph just shows the partial pressure of oxygen. The blue at the top, 0.2 partial pressure of .2 atmospheres, that's the air we breathe. If you drop it 40 orders of magnitude, you get down to the point where uranium dioxide won't dissolve. As you go lower and go down into 10^{-70} to 10^{-73}, these seem really extreme, 70 orders of magnitude, but that's actually the in situ redox state that you see at the interface of a nail or any corrosion of a low carbon steel.

Now, what we've done is tried to find a natural analogue, tried to find a Pena Blanca that had not just the uranium, but had all of the iron as well; and we were never successful, so we made our own natural analogue.

Next slide, please. Well, let's go back one. We made our own natural analogue. We made waste package mock-ups that are filled with steel and UO_2, and we put waters that are close in composition to J-13 to see, well, could you observe over the waste package what one sees on the macroscopic scale, can you actually get the self sealing, and does it actually lower the redox state? And what we find is--and I don't have a picture of the mock-ups here, but several of you all saw this at my last presentation--what we find is that in the space of about a month, corrosion of steel in the proportions we'll see at Yucca Mountain will drop the in situ redox state about 40 orders of magnitude and keep it there.

So what this says is that we end up right around the point where UO_2 quits dissolving because there's not enough oxygen, and what it says is, on a macroscopic sense, at least--waste packages are about this big--on a macroscopic sense over--so far it's been two years--over at least a couple years, we can get far more reducing conditions than we actually see at Pena Blanca and elsewhere. What this means for radionuclide solubilities is it drops the solubilities of neptunium by about 10 orders of magnitude and plutonium by 4 orders of magnitude.

All right, well, the question there is, are the results that you can get for one year or 18 months out of the S&T Program relevant to the million years that we have to consider at Yucca Mountain? And so, again, we go looking for natural analogues.

Go to the next slide, please. And the one we found is an old Roman fortress called Inchtuthil. You see up there that's Hadrian's Wall. That was going to be the full extent of the Roman Empire. At one point they wanted to conquer Scotland, and they went about 150 miles north of Hadrian's Wall and built a legionary fortress, and this happened in about 84 A.D. Well, they changed their minds three years later and decided that they'd just about had enough of Scotland and sent the legion to the Danube.

They took everything that was valuable with them, burnt everything that wasn't, and they were left with the question of what to do with roughly a million nails, 700 tons. They didn't want to leave them in the hands of the Scottish tribe, because they would have probably been beaten into spears and what not to throw at Roman soldiers who were heading south, and so they buried them.

Next slide, please. This is kind of a quick schematic of the buried nails at Inchtuthil. I think I said 700 tons, and it's 70 tons. It's basically a million nails. They dug down about two meters, buried the nails, and the volume of the nail cache would be three or four of these tables stuck together. They stopped well before they got to the water table, tossed all the nails in, buried it up, disguised the thing, and headed for Austria.

The whole cache was excavated in the 1960's. Oh, yeah, I should point out that the nails are--their composition was very close to the composition of the 8516, the low carbon steel that used to be in the design before

TADs, but I'll come back to that. What was found when these were excavated in the 1960's was an enormous pile of rust on the outer sides, but on the inside the bulk of the nails were pristine. If you'd used a regular dissolution rate law with a partial pressure of 20 percent, the air we breathe, the nails would have been gone in a hundred years, but they're pristine 2,000 years later. And the mechanism that controls this is thought to be that the formation of the iron oxyhydroxides seals the underlying nails and prevents the access of both oxygen and water.

So what it says is that over thousand-year time scales, there is the potential for what we see occurring on the passivation of individual iron objects. It looks like it can occur in a macroscopic sense.

So how do we use this natural analogue at Yucca Mountain? This goes into an alternative conceptual model and the solubility AMR. In the solubility AMR we calculate the dissolved concentrations as a function of pH for uranium, neptunium, and the rest of them, all at a partial pressure of 20 percent. The alternative conceptual model uses a much lower FO_2 indicated by here, and we end up with much lower values.

Now, one could calculate this occurring as well. And what you do is you just take the below carbon steel rotary action of iron plus--excuse me--zero valent iron plus oxygen, sending it to, well, any of the corrosion products. If it goes to magnetite, the calculation suggests that roughly half of the porosity of the waste package will be filled once all the low carbon steel is gone. If you go to the more oxidized M numbers, hematite and gertite, you end up filling the waste package, all the void space, before roughly a third of the iron has been corroded.

Now, corrosion products are more than just iron. Typically they contain a lot of occluded water. Occluded water means more porocity occlusion. The point here is that with low carbon steel and--I'll get to it in a moment--the stainless steel, there is a strong potential for the package to seal itself. Now, this has been changed somewhat in recent years. The TAD's design now calls for the substitution of stainless steel for low carbon steel. The low carbon steel is calculated to corrode away at about a hundred years under oxidizing conditions. The stainless steel, it'll take about a hundred times that much. Basically, the corrosion is expected to take about 10,000 years.

We would expect the corrosion products to be the same, though. Stainless is essentially about 70 percent iron, and the difference of the remainder is split between chrome and nickel. The chrome will probably be chrome-3. The surface chemical properties of chrome-3 are very similar to those of iron-3, so we would expect to see some of the same ability to absorb radionuclides. We're still playing catch-up on the TADs design, analyzing the corrosion products and trying to figure out what the final reaction paths are going to be, so this is kind of a sneak preview.

Next one. This is a an unnatural analogue, and this is again supported by Mark Peters' program, the S&T. What this shows is a micrograph of what happens when you take technetium and run it past low carbon steel with a head space that has an oxygen partial pressure equal to that in the room. That is, under oxidizing conditions, if you put oxidized technetium past low carbon steel, what you find is the technetium forms these little blobs--well, it gets occluded in these corrosion products. It's reduced technetium.

Recall from early on in Peter Swift's talk that the technetium pertechnetate, the large anion in the oxidized form, is the dose leader (phonetic) in the first 10,000 years. Technetium, when it is reduced down to $Tc0_2$ has a solubility that is very, very low. If you can reduce it to $Tc0_2$, it drops off Peter's curves. What we show here is that low carbon steel has the ability to actually reduce technetium.

Now, this wasn't a surprise to us, because, as I pointed out, there is an unnatural analogue here. This process was patented in the 1980's by Oak Ridge National Lab for treating technetium contaminated water. It's been known for quite a while that steel pulls technetium out, so there's another analogue evidence to suggest that there are sinks (phonetic) for some of these things that we hadn't considered before.

For all these natural analogues that I've been trying to point out where they go into the TSPA, where they go into an AMR, for this one I don't have an answer yet, because the data is kind of preliminary. We're still working on it, though. I should emphasize that if I were to write a reaction for this, it's reduced iron plus oxidized technetium going to oxidized--it's a surface complex of iron-3 and $Tc0_2$.

Next slide, please. There are several other natural analogues that we use. One that's gotten most of the press is the degradation of basaltic glasses. The glass that's going to be in the codisposal waste forms, compositionally it's not far removed from the basaltic glasses that you see here in the basin and range and elsewhere. We've measured field-based glass degradation rates, both putting them in jugs, but also just analyzing them in situ as well. Those things are used to anchor the base of the uncertainty band for the degradation rates for the borosilicate glasses. That's an input in the unpackaged chemistry calculation.

We use the natural analogue of Sierra Negro, a cinder cone that erupted in Nicaragua in 1995 to validate the ash plume model that allows us to estimate the thickness of ash flows in the igneous scenarios. For steel corrosion, as we grapple with the TADs design and we have to come up with more precise reaction targets for the stainless steel, we're going to expand our analysis of the corrosion of Josephinite and meteorites, iron materials that have some nickel in them. What we're going to do with that data is, essentially, we'll be analyzing those to identify what the corrosion products are so we can use those when we calculate sorption uptake inside of the package and then the EBS.

But, again, the trick there is to identify what are the reaction path endpoints. Do you go to gertite? Do you go to magnetite? Is it an iron-nickel spinel? That's work in progress.

One of the other areas where we rely strongly on natural analogues are in the selection of mineral suppressants and the reaction path calculations that are done for the unpackaged chemistry and the end drift precipitant salts model and the P&CE AMR.

When you use reaction path codes like--six, you can predict a lot of wonderful things, some of them which aren't really true. A lot of minerals that are never seen to form at the surface of the earth are predicted to form. We have to go through and individually suppress these minerals. We won't allow dolomite to grow when water lands on top of the waste package, and the calcium and the magnesium is concentrated. We don't allow dolomite to grow, because it's never observed to grow at 25 degrees. Garnets, although they are stable in sea water and should in theory grow, they're never seen to grow either, so we suppress those as well.

When we go through and develop a list of the suppressed minerals, basically we're stitching together a host of natural analogues. Every study where somebody went to a saline like that and said, "You know, the calcium and magnesium ratio's right, but we still didn't get these particular minerals."

All right. At this point I'm going to stop. I started off by pointing out that the TSPA is this vast edifice of equations. I would like to end by proposing an alternative view. I prefer to see the TSPA as a connected fabric of natural analogues. We use natural analogues to build the models, the submodels; we use natural analogues to validate the submodels. And so it's the connected fabric of the analogues that ultimately give us some confidence in the output of TSPA. Thank you.

GARRICK: Thank you, Pat. You actually ended with the question I wanted to start off with; that is, how is the analogue information transformed or mapped into, I'll say loosely, the safety case, but in particular things like the TSPA?

BRADY: That's a big question, John. I don't know if I could answer it all by myself, and Peter might have to hop in. There's not a quick answer to that one, John, because, you see, we use the natural analogue data kind of from the microscopic all the way to the macroscopic. It's implicit in the safety case, because we try to get the best mineral suppressions. We try to get the best corrosion--I mean, the best ones are not modeled predictions. They come from natural observation. I don't know if I'm answering your question, though.

GARRICK: Well, you started to at the end of your discussion, and I think that it strikes a lot of us on the Board that analogues are critically important here in demonstrating behavior over very long periods of time. At least my earth science friends tell me that. And, of course, what we're interested in is, how does this information really find its way into the bottom line results that we see? And to the extent that we understand that process, I think, would be beneficial.

SWIFT: This is Peter Swift.

To me, coming from the performance assessment perspective, I think I heard the question to be: How do we use those to derive or support the quantitative estimates that I showed you?

GARRICK: One of the things that really caught my attention was his comment about this being very useful, or something to that effect, with respect to the source term. That would be a very specific area that I'd be very interested in knowing how you use it.

SWIFT: That one I'm going to put back at Pat. Let me say something first here, Pat. Early on in my talk, I talked about the question of why you or I or any of us should have confidence in those quantitative models. And one of the strong bases for confidence would be if the model makes a reasonable interpretation of the natural analogue, also. Is it consistent with what we see in the natural world?

It is actually fairly rare that an analogue provides direct input, because, as Pat said, the analogues are slightly different. The only real analogue--true, exact analogue--is the mountain itself. So we use those analogues to inform the models and their parameter inputs, but basically the answer is that it's a validation tool. It's a confidence building tool. Does the model make sense? Is it consistent with what we see in the analogue world?

And now, Pat, do you want to take the question on the source term analogues and how we use them?

BRADY: Yeah. Trying to predict the transport of things like neptunium and plutonium and fine grain materials like soils or the corrosion product mantel, that's the forefront of science. If you just start off and take the off-the-shelf models,--, stick them in a retardation equation, you can't model what you see in bomb pulse profiles for plutonium. So there is an incredible burden on us to calibrate our models for the source term with natural analogues.

We're somewhat hampered, though. Plutonium--there is some data we can get from Oklo. A lot of it, though, we have to go and look at Hanford, we have to look at the bomb pulse stuff at Trinity and elsewhere. And how we've used that, we've used that to examine the possibility of irreversible uptake; that is, plutonium that goes onto a surface and then is occluded and becomes part of the crystal because of dissolution and reprecipitation. We're still working on those models.

Neptunium is much more difficult. We have looked incredibly hard to find neptunium plumes. I was in Spain last week, and my heart sang when somebody told me that at the Palomaris nuclear bomb accident, there was actually neptunium in the soil that had been measured. I'm still waiting for the data. We don't have a whole lot of data that can tell us what are the mechanism for neptunium uptake. In the absence of natural analogues, we have to go with surface complexation models, or we have to look at sequential extractions of the bomb pulse and the hazardous waste data.

By and large, the simple response to your question is: We try to use hazardous waste sites to give us some information to modify the original solubility calculations and the sorption calculations that we do in the source term.

GARRICK: Go ahead, David.

DUQUETTE: Duquette, Board.

I'm glad you didn't find iron nails at Pena Blanca. I do want to caution you--and Peter actually said it--that analogues are difficult. The Roman iron nails require a very long drying cycle as well as a wet cycle. If it were wet continuously--and I understand the repository will have a continuous supply of relative humidity--then the oxide that forms from the Fe_3 plus is not only a good electrolyte, it's very transparent to oxygen. We know that because if you take a piece of steel that's been continuously wet, that most of the corrosion product is, in fact, hematite, and only a small amount is the Fe_2 plus, which means that it's oxidized most of it, which means the oxygen gets down fairly deep into the oxide.

On the other hand, I like your models. I like the swelling and so on and so forth that you could get from that, but just have to be cautious on using analogues. And, again, Peter said that.

GARRICK: Andy?

KADAK: Kadak.

I'd like to understand the model, again, that you have for the waste package. Do you assume that water comes into the waste package and oxidizes all that iron, and the spent fuel is sort of in the middle of it, and it gets sucked up or at least squeezed out or--what is the visual thing that I can focus on here?

BRADY: To begin with, the fuel is distributed somewhat homogeneously amongst the iron. So you don't have--I'll get to your question kind of circuitously. The fuel is not in one corner and the iron is in the other. They're intimately mixed. What we do is, when the unpackaged chemistry calculation starts off, water comes in, you start dissolving the fuel. The low carbon steel, since it is calculated to last only a hundred years--and I'm talking about what we do right now--this is the high $F0_2$ case--within the very first few time steps, all of that iron is hematite or gertite or ferrihydrate, something like that. That is able to sorb radionuclides, which come off of the fuel.

Radionuclides come off the fuel according to the dissolution rate law for the spent fuel. So spent fuel dissolves--well, we figure in the first hundred years--well, we figure that the iron is going to be--iron shows up first, fills parts of the waste package, fuel starts to dissolve appreciably after that. The fuel components have to go through the iron oxyhydroxides to get out of the waste package.

Did I answer your question?

KADAK: Let me repeat what I thought I heard you say. Water comes into the waste package and begins to oxidize the iron, okay, which squeezes the spent fuel, which may, in fact, result in breaking the spent fuel cladding, which then allows water to get into it, assuming there's more, which then begins the dissolution of the spent fuel, which is then retarded by the iron, which is wrapped around this whole blob of stuff. Is that what was--

BRADY: No, I misspoke then. We made no explicit assumptions about a swelling pressure breaking through the clad and freeing up the--

KADAK: Would that happen, though, do you think?

BRADY: I don't know. That's out of my field.

KADAK: But the image is a solid block of rust wrapped around the spent fuel pellets.

BRADY: Yes.

KADAK: Held up as a waste package.

BRADY: Yes.

KADAK: And if it continues to get more water, at some point the waste package itself would fail, and you'll have this mass of rusted stuff that may or--does that then fall apart, or what are we doing next?

BRADY: You end up going down one of two paths. The way we treat it right now, you form the rust, you don't seal the package. The oxygen partial pressure is fixed at the ambient level of 20 percent. That's analogous to forming passivating surface layers on the iron at some point so that there's always access maintained for water and oxygen in and radionuclides out.

The alternative conceptual model that I was describing there was, the iron oxide is filling up and blocking all the pathways, not allowing water in, not allowing oxygen in. And the corrosion of the underlying iron would consume any of the oxygen that was trapped to begin with, and you'd be left with a lower in situ redox state and probably an unlikely path out.

So there were two models--

KADAK: What is in the current analysis? Which one of those two?

BRADY: The first one I described.

KADAK: The first one. Thank you.

GARRICK: Howard.

ARNOLD: Arnold, Board.

Well, just answered that one. The current analysis is that everything vaporizes and is released right away in one package. I mean, that's what I heard in the previous talk. But to ask you my question on this one, you're assuming that the outer envelope remains the same. In other words, the Alloy 22 package did not come apart; right?

BRADY: We don't actually make that assumption explicitly, because I don't think it matters--

ARNOLD: But your picture had a--well, it won't hold otherwise.

BRADY: I don't think it'll matter, because whether it stays intact or if it breaks, you either end up with a contained pile of rust or a big pile of rust sitting on the ground. The processes which might lead to appreciable retention is going to be the interaction of the radionuclides with the strongest--iron oxyhydroxides. It seems like you'll have that in either case. But I don't know what the hoop stresses--I think that's the right term for Alloy 22--what it takes to break something like that.

ARNOLD: Well, water got into it through a hole, and it isn't going to corrode anywhere else around its surface.

BRADY: I thought they covered all that on Wednesday or two days ago.

SWIFT: This is Peter Swift again.

I just wanted to clarify something that may not have been clear in what I said. In that analysis I showed earlier, the waste package indeed was assumed to fail in a single time step after the early failure. But we did continue on with the degradation of the waste form. All the waste was not available immediately. We went ahead and ran the waste form degradation and solubility models from there forward. So it was merely that water was able to reach the waste immediately.

ARNOLD: Reach the fuel itself.

SWIFT: Yes, that's right.

GARRICK: Ron.

LATANISION: If we could put up Figure 4, maybe that would help in the conversation. When iron oxidizes to produce iron oxide, there's a roughly three times increase in volume; and so depending on how much iron oxide you're producing, there must be some sort of internal pressure created. It may not be sufficient to cause the fuel elements to break. I don't know. That's an interesting point. But it could. It could, yeah, definitely could.

BRADY: There's a negative feedback at work, though, too. If you swell up the interseces of the package, you tend to block the subsequent access of water and oxygen. And so the question comes down to: Do you build enough pressure up first, or do you choke off the reactants first? In one case you crack the package; in the other you just seal it. And we don't know how to calculate that right now, but we're working on it.

LATANISION: Latanision, Board.

I agree in part. The iron oxides are not particularly impermeable to oxygen or to water, at least in comparison, for example, to the chromium oxides, which you mentioned also. So there are a lot of permutations here on all these variables that could be very important.

BRADY: I agree with you. Someone asked the question, I think, of Peter about what's the data you wish you had. And I'll say this with the caveat that I don't know a way to measure it accurately. But if I could wish for the diffusion coefficient of oxygen and water in a corroded waste package, that's the number I'd love to have.

And for what it's worth, the S&T project, that was one of the objectives was to--either you go in and you measure through some type of profiling through a concentration gradient what the diffusion coefficient is, or you just jump to the answer at the end and see what the in situ oxygen redox state is by measuring the iron to the iron-3 and the pH.

LATANISION: Latanision, Board.

Just one final sort of homely analogue here. I keep thinking when I look at this illustration of my windows when I was still at MIT that were frozen shut because of the corrosion of the steel frames and could not be opened. It's kind of a similar phenomenology here. That was because of deferred maintenance, though; it was a totally different--.

ARNOLD: Did oxygen diffuse into your office?

GARRICK: Thure.

CERLING: Yeah. I'm not sure if this is directed at Pat or Peter. But what I thought Peter said was that some of the results of this was actually included in the loss of the nuclides from the waste package during the previous modeling. Is that right?

SWIFT: The model that I showed earlier, which is the most recent stuff we've been running on the releases from a waste package, does include degradation of the spent fuel, which actually happens fairly rapidly, and it does include the effects of the iron corrosion products working both as a source of colloidal material for transport and also as a source of a sorbent that is stationary as well, so it affects release in several ways.

CERLING: Does it include anything in this model of sort of this self-sealing property so that part of the waste package would perhaps never see any more water.

SWIFT: No. For the results you actually saw of the waste package, the drip shield was intact in those, and there was water vapor available--behind. You'd have a water film on all the waste, and it was a diffusive--. We did not consider the possibility that corrosion, particularly for example, of the steel inner liner, the corrosion--might block water flow, no, we did not consider that.

GARRICK: Before you leave, Peter, some of these phenomena could be really important in terms of the waste package integrity. And you do have data; you do have some information. Has there been any consideration given to trying to incorporate some of these phenomena probabilistically where the probabilities would be based on whatever supporting evidence you could find?

SWIFT: That would be something that we would consider, and you alluded earlier to margin analyses, which we may do, where we look at information that we don't believe is ready now for use in a licensing case, but which we believe would be valuable information to demonstrate for our own benefit to ourselves there was additional margin to be had in the performance of the system.

MURPHY: Bill Murphy, Board.

Pat, first of all, I really like the term "trophy site" for Pena Blanca, and I think that Pena Blanca as well as many, many other geologic sites offers evidence that very strong redox potential gradients can be maintained due to self-sealing. At Pena Blanca specifically there is still uraninite at the site 100 meters above the water table in a nominally, completely oxidizing environment; but it's completely encased in silica that was deposited hydrothermally, and so it's sealed. And over a scale of millimeters or centimeters, there are oxygen potential gradients of--gradients existed at the Inchtuthil site as well where there was iron in the center and oxides on the outside.

But I'm concerned at Yucca Mountain about the mechanical integrity of an iron oxide seal in a seismic environment. And in that context, I'm led to question: Were the mechanical properties of the iron oxides at Inchtuthil investigated? Was it a solid thing that would stand up to hundreds of earthquakes?

BRADY: The student I have looking into that, Elizabeth Anderson at the University of Michigan, we even had her tickets bought, and, more importantly, we'd gotten--the trip thanks to Mark Peters, and it got cancelled at the very end. We were going to go back to actually examine it. So the short answer is: I don't know. The long answer is: We tried.

But back to your original question about the seismicity, yeah, if you take the bottom thing and dribble it like a basketball down the drift, and presumably you could smear out some of the iron oxide and expose some of the spent fuel, but I wonder--well, I don't know of a natural analogue that would give us a clear answer for that. I have difficulty believing that you do more than take an intact package and just spread it into a pile on the ground. I think because of the fact that you're going to have reduced iron all the way out to 10,000 years, so there's going to be dissolution reprecipitation going on. There still might be a potential to set up these redox--I mean, you could throw the question out and say, well, Pena Blanca is in the basin and range. There's seismicity there. Surely that had earthquakes that would have affected the silica ceiling.

MURPHY: Well, in that case, in fact, 99.99 percent is oxidized, and so it's only very rare remnants of reduced uranium that are left, and it's encased in this silica cement that's so hard you can't crack it with your rock hammer. So, I mean, that's not the same.

BRADY: But the case of an earthquake spreading it all out, yeah, that would be something we'd have to--I mean, before we put grade weight on it and the probabilistic assessment that Peter talks about, we'd have to have, hopefully, some independent evidence to say, well, it won't happen or it will and it's not so bad or it truly is.

GARRICK: Any other questions from the Board? Yes, David.

DUQUETTE: Duquette, Board.

I just want to share one minor story with you about natural analogues. In the steam generators in the nuclear industry, there was corrosion of the tube support plates in that particular system in a very low corrosive environment that resulted in denting of the tubes in the boiler. That was a case where iron oxide was being formed on steel at very low oxidizing conditions in that particular case, and it resulted in crushing the steam generator tubes.

And so, to me, that's also another natural analogue you might want to consider when you're thinking about using iron oxide as a protective film on anything.

GARRICK: Yes, Henry.

PETROSKI: Petroski, Board.

I'm a little confused about this cartoon here. Does it represent a physical experiment that is ongoing, or is it a thought experiment?

BRADY: It's both. The thought experiment was, that's an anatomically correct on a volumetric basis. Roughly the low carbon steel is the red, the blue is the stainless steel--this is the old pre-TADs design--and the yellow is the UO_2. Now, the main corrosion rates for the low carbon steel had it all turning into corrosion products in a hundred years. So that second picture of the cartoon was just taking that iron and splitting it amongst gertite, hematite, and at that point it's not really anatomically correct.

That experiment is ongoing right now at Sandia. We're doing it with just the iron. The graduate student I mentioned earlier, Elizabeth Anderson, is doing the experiments with the uranium dioxide at the University of Michigan. We still don't have results from that yet. So that was a cartoon, a model. We did the experiments to back it up.

PETROSKI: So you were extrapolating from the experiments to what you expect to see?

BRADY: In a perfect world, we would have gotten, instead of several hundred thousand dollars we would have gotten millions of dollars, we would have real mock-ups, but this was a start.

PETROSKI: So this industrial analogue, as I think you would classify this, is used differently from a natural analogue in that the natural analogue is a finished process that you use as validation. Here you're inferring something, and you're building a model to validate a model in a way.

BRADY: Yes. And I said it as we were making our own analogue, because nature didn't provide us the one we needed.

GARRICK: All right. Any questions from the staff?

Anybody else?

Very good, thanks a lot.

Our next presentation will be by Mark Peters of the Argonne National Laboratory, and he's going to talk about the Science and Technology Program.

PETERS: Thanks for having me back. It's an honor to be here. You made me really nervous, because you put an Argonne guy between a bunch of Sandians.

Let me explain why I'm here. Under the Office of the Chief Scientist in Russ's organization, you have the lead lab organization that's responsible for all post-closure science, at least as of Monday. And you have a separate entity, the Science and Technology Program, as you've known it over the past few years, and John Wengle is the DOE manager of that. He had another commitment, so I'm here effectively presenting on behalf of John.

So what I want to do today is, I first want to remind myself and you of trying to put this in the context of the safety case instead of just going through a bunch of highlights of the Science part of the Science and Technology Program. There's going to be some of that, but I'm sure you'll bring me back on point if I don't make the point. But I'm going to try to keep bringing myself back to where this might fit in. I don't have all the answers. I can't point to a document yet. You heard, I think, earlier today that that's under discussion. I know discussions with Ward, he looked at us and said, "We need to figure out how we take a lot of this very valuable information and incorporate it into our case." So that's something we're actively looking at and thinking about where that fits.

So I'll go to the first slide. This is directly from Russ's presentation. I don't need to read it. Helps me to remind everybody safety case is a lot of things. It's the TSPA; Peter talked about that. There's multiple lines of evidence like analogues. I think the Science portfolio, in particular, in the Science and Technology Program fits into a safety case argument. It probably fits in in the sense of telling us something about how we think, from a technical perspective, the system works.

In a lot of cases, this information--this came up in questions just after the past presentation how much of this is "in the TSPA right now." Actually, you'll find that probably very little is in the TSPA right now. But that said, I think it can add confidence in terms of the safety case.

Next slide. Again lifted directly from Russ's. I've already made the point that I want to make here, but I'm going to focus strictly on the Science and Technology Program. Frank's going to get up here next and talk about performance confirmation and long-term testing and monitoring.

Next. Just a reminder of the mission and drivers of the S&T Program. Again, I'm going to focus completely on the Science portfolio. Remember there's a technology portfolio that you've heard probably at least highlights of over past meetings; but today I want to talk about the three primary Science Program areas, that being materials performance, source term, and natural barriers. And, again, what I want to do is give you a general overview of what we're focusing on in each area in terms of technical areas and then use some highlights from the program to try to make some general points and then wrap up.

The way we're managing the program, I think, is important. Again, John Wengle under the Office of the Chief Scientist, is the manager on the DOE side; but we've broken it up into so-called thrust areas, and the Science thrusts are those three that you see at the bottom. And I think it's important to remind everybody in the audience who manages these areas on behalf of the Department.

Materials performance area, Joe Payer from Case Western, who I think most of you know. He was heavily involved in the meetings over the past couple days at the corrosion workshop. Source term is Rod Ewing at the University of Michigan and myself. And natural barriers is Bo Bevardsen (phonetic) at LBL, Yvonne Sang does a lot of work with Bo on that, and she's actually here in the audience as well.

Next slide, please. So first I want to make the point, one of the things that we've really tried to do--I don't want to dwell on this, but really what I'm trying to do here is, kind of in a cartoon-like manner, schematically lay out the kind of processes that we're thinking about from a technical perspective that occur in those three areas, meaning the natural barriers, particularly the near field around a drift--down here in the lower left--the material performance in terms of what's going on on the surface of the waste package, and then finally what's going on inside the source term.

A complex set of processes. Don't have to tell this audience that particular--that's self-evident to this audience. But what we're after here is, yes, we've got a case that we're ready to move forward to license application with. We're comfortable with that. That said, there are questions, yeah, we could study this forever and ever and ever and never answer all the questions. But we've set up a Science Program that we think addresses some of the key questions from a scientific perspective.

I also want to mention how we came to the portfolio. I would characterize it more as a bottoms-up as opposed to a tops-down. We didn't start with TSPA and ask ourselves risk-informed questions and drive down the program and then say this is the right portfolio. We did kind of a hybrid of that. We started at the bottom and asked ourselves: As scientists, what are some of the key uncertainties from a scientific perspective? And given the people that are leading the areas, I think you could probably appreciate that we have a broad understanding of the TSPA as well, and so I can't say that didn't inform our thinking, because it did.

So I think we've come up with a program that's trying to address some of those key uncertainties, and it will have a benefit to TSPA perhaps in future years.

So, first, the materials performance area. Really three major research areas that Joe has laid out. Looking again at corrosion processes on metal surfaces in environments where you don't expect--these aren't under water, right. You're dealing with metal surfaces that have deposits, perhaps dust, perhaps thin films of moisture, and deliquescence processes that might occur above boiling or could occur throughout the temperature range but may be very important above boiling. And then, finally, in the case when you get below boiling, you perhaps have seepage, and you have waters that contact the package at that point.

So a variety of geochemical environments that one could expect. Given certain environments, we might, in fact, initiate, say, localized corrosion, for example, in a crevice; and how does the corrosion damage evolve. Again, this was the subject of a lot of discussion over the last two days. And then, finally, tying all this together as how the environment evolves, what happens inside of a crevice, or how does the near field environment evolve, how does that fit back in with the evolution of corrosion damage. So not only initiation, but propagation, but also starting to think about if something starts, will it stop or will it stifle or will it slow down. So those are the kind of questions that we're asking materials performance.

Next slide. In the source term area, this is just a picture, a cross section of a fuel rod. Again, it isn't just a homogeneous bunch of $U0_2$. It's got cracks, it's got some of the products that have migrated to the gap, so its initial starting condition when it comes out of a reactor, we need to understand that first before we can really start to understand how they might be released if they get contacted by water. And on the right is just an example of some of the bubbles that form perhaps at grain boundaries, etc. from some of the products.

So in the source term area, we're thinking about it in four primary technical areas. First of all, how does spent nuclear fuel dissolve if it's contacted by, say, drips or it's covered with a thin film of water? Again, these aren't sitting in a pool of water. You're dealing with perhaps humid air oxidation at higher temperatures and then perhaps contact with perhaps water that could form thin films or maybe sporadic films on the spent fuel.

Let me jump to the third bullet. You're going to see some of the same slides that Pat showed. I'm not sure whether I stole them or he stole them, but they're the same slides. He went through that in some detail, but waste form-waste package interactions is code for the sorts of things that Pat talked about. What goes on if you breach a package, water contacts the insides, do you, in fact, set up scenarios where you maybe self-seal and lead to very low partial pressures of oxygen? What can that lead to in terms of radionuclide solubility particularly the actinides.

The second bullet--and that's something that we've talked about with this Board before, and I have a few slides on that to make a couple points. But this gets at, if you alter the UO_2, the spent fuel, and you form uranyl secondary phases, like shopeite was mentioned--there is a whole suite of them, I couldn't begin to list them all--what role do those secondary phases play in perhaps controlling the release of, say, actinites like neptunium? And that's something we're spending a lot of time thinking about in this portfolio.

And, finally, it's a complex set of processes, and so we're starting to put together conceptual models and also numerical models of how these unpackaged chemical and physical processes fit together so that we could start to try to put this into a coherent picture.

Next slide. Natural barriers. A schematic of a cross-section of the mountain. You're dealing with infiltration of water in the top, flow through the upper natural barrier, seepage into the drifts perhaps, then transport through the lower natural barrier out to the accessible environment and all the things that go into the flow and transport processes that are complex, uncertain. We think we've captured the uncertainty moving forward to the license application, but there are some key areas that are focused on in the natural barriers area.

Again, still looking at the seepage problem, the second bullet, the notion of a drift shadow where you might have areas below a drift perhaps by virtue of the presence of the seepage of the capillary barrier that leads to perhaps limited seepage in the drift. You may also form a shadow zone, as we call it, under the drift that may lead to perhaps diffusive transport out of the drift rather than invective transport leads to longer travel times through the UZ.

The nature of flow and transport in heterogeneous systems, I'll show a few examples of that.

And, finally, multi-scale/multi-physics coupled processes modeling. I'll show an example of that from the work by George Danko. That work that George did was funded at one time, at least by Nye County. John Walton talked about it at the workshop the last two days. That's now being carried on through the natural barriers program and S&T, so George is a PI for those programs.

Next slide. So some results to date, and what I tried to do here, at least in part, was start to think about, okay, what are some of the kinds of things that we could develop as we think about talking about system safety in a more qualitative manner, maybe I'll say, although there's quantitative behind it? What are some of the things that we might be able to say?

So I'm going to skip the first two bullets. Those are kind of general bullets that I've already touched on. The third bullet. We talked a lot at the workshop--I say "we" but I was in the audience--about the notion of stifling of localized corrosion. Currently in the total system performance assessment basis, there is not stifling of localized corrosion or general corrosion. If it starts, it continues until failure of breach and effectively failure of the package.

We're looking at mechanisms that might, in fact, lead to stifling of localized corrosion. We think we've got some promising results. As witness to the conversations of the past two days, there's also a lot of questions. And so we're continuing to look at those.

The fourth bullet. I'll talk a little bit more about this. Pat touched on the potential of incorporation or sorption of radionuclides into, say, alteration products like iron oxyhydroxides, perhaps surface complexation of technetium as $TC0_2$ if it's reduced by the iron in the package. Another thing we're looking at is perhaps neptunium sorption onto iron oxyhydroxides. We have some experimental evidence that that may occur. And we're also doing some molecular dynamics simulations to understand the sorption mechanisms as well. And I also touched on the potential incorporation of, say, actinides into secondary uranyl phases. I'll show some data on that.

And then the bullet to talk about the natural barriers, we're looking at perhaps the influence of matrix diffusion in UZ and SZ and how that might lead to potential retardation of radionuclide transport. And also we've got some experimental work going on to look at K_d's for some of the key radionuclides.

Next slide. First off, one of the things that we've done across the three areas--I'll use the word "jointly"--we're jointly funding an effort that's being led from Berkeley--Carl Stiefles (phonetic), the PI at Berkeley--to look at trying to put the processes--and obviously this is a work in progress, it's a complex set of processes--but try to put the near field processes both in the rock and in the drift and to start to put it together into coherent conceptual model.

And so this is just to point that out, that is an ongoing activity and we think important, and it could add a lot of value perhaps over the longer term.

Next slide. Some materials performance. I can skip over this, but it's a collage that Joe's put together showing the different sorts of things that we're focusing on in materials performance.

Next slide. Now I have a series of slides that the people at the workshop will hopefully not fall asleep, but they're things that you saw at the workshop, again talking about corrosion in thin layers of dust or particulate on the surface of the package. What's going on, how wet is the dust, what are the soluble salts, what's the evolution of the environment, what's the processes that are going on in the anode and the cathode, and those sorts of things. But these are very--I'll personally call them somewhat unique environments in the sense that they're thin layers of dust, perhaps not over the entire package; they go through wetting and drying cycles; and what happens under those thin particulate layers in terms of corrosion processes. Will it initiate localized corrosion; will it not; if it does, will it stifle--those kinds of questions.

Next. This talks about the stifling. This is something that Rob Kelly showed yesterday during his presentation. Again, looking at primarily stifling processes, if you initiate localized corrosion, will it stifle? And there are some processes that could go onto the cathode site in particular that might lead to some stifling of the localized corrosion. We're continuing to look at that very seriously.

Next slide. Model from folks at Case Western. Rob, I think, also showed this. The bottom line point here is they're doing some modeling--if you start with a crevice that starts as a precursor in a crevice former, anode here, virtual cathode out here, this is the evolution of the crevice corrosion as a function of time. And it gets to a point where you actually open the crevice to the outside and perhaps lose critical crevice chemistry that could also lead to stifling. Again, this got a lot of discussion. Is this a reasonable case that we might expect in a crevice on a waste package at Yucca Mountain? I think good question. We need to continue to do some focused work to try to get to that answer in the near term.

Next slide. Something you didn't see in the last couple days. There's also a program going on looking at the stability of passive films in these passive metals. This is an example from work from Tom Devine at UC Berkeley where he's using an in situ Raman setup where he can put the sample actually into an environmental chamber in situ and do Raman Spectroscopy and look at the evolution of the passive film in the environment. It's an interesting evolutionary technique that gives us important information about the stability of the passive film, which is vital to understanding the performance of a passive metal like Alloy 22.

Next slide. Source term. I'm not going to go through this. I put this up because when you think about the source term, some people say, "Oh, it's horrendously complex;

forget trying to understand that." I don't share that particular viewpoint. I don't think Rod does either. So what Rod and I have done is we've tried working with the PIs. We've tried to think about the processes and all the important processes that can go on in the source term, as we term it, and then try to put together a program that focuses on the areas of key uncertainties. So I don't have programs in every one of these circles. I have programs in the areas where we think we really have key uncertainties that could be important. And so that's primarily, again, evolution of alteration phases and how that may lead to uptake of radionuclides, and then also this whole notion that Pat talked extensively about about the evolution of the geochemical environment inside of a breached package, and then also how does spent fuel dissolve in thin films of water. Those are all important key uncertainties that we need to understand for the source term.

Next slide. I don't need to talk about this. This is the same slide, different title, that Pat showed. So we went through that, I think, in gory detail. I will say that Pat mentioned the work that's going on at Sandia where he, Kate Helene (phonetic), and Elizabeth Anderson are doing the work to look at the waste package mock-ups.

We're also doing--I'm going to show the same slide again, and he mentioned he showed the--go to the next slide.

He showed this slide as well. This is work that Ken Kripka (phonetic) at PNNL is doing as part of Pat's project, but it's a multi-lab effort. And, again, this is just showing the reduction of pertechnetate to $TC0_2$ and surface complexation on an iron oxyhydroxide. This could be very, very important observation in terms of retardation of technetium, which, as Pat mentioned, is a key contributor to dose in the first 10,000 years.

Another aspect that I don't have a slide on of this program is--I alluded to it a little bit in a comment earlier--is the notion of, when you do form these complex set of iron oxyhydroxides, do they play a part in sorption of neptunium. And that's something we're also looking at, both in experimental and modeling space. And I think the importance of understanding sorption of neptunium is probably self-evident, a key contributor to dose.

Next slide. This is just a slide to introduce the concept of the fate of neptunium in terms of alteration phases. This is from Ph.D. thesis work of Frannie Skemerski (phonetic) at University of Michigan; she's working with Rod and Uto Becker at Michigan. But she's doing a series of molecular dynamics simulations to understand the energetics of what happens if you put neptunium ion into uranium alteration phase. Important to understand these, because what we want to generate here is an understanding of the crystal chemistry of what neptunium does in a structure. Does it go into the structure? It doesn't go into everything, we don't think. And so if we can generate an understanding--and we think we can--we're within reach within a year, two years. If we can generate that understanding, we think we can put together a really solid basis for the importance of alteration phases in, say, neptunium uptake. And this is an important part of that.

Next slide. We have an experimental program associated with that. This is just one set of results for that. Let me talk generally, and then I'll talk about the specific. We've got several projects going on in this area, looking at the formation of uranyl alteration phases, the modeling energetics, but also a lot of experimental work from several institutions. This particular work is work that's been done by Peter Burns. This happens to be work that's in press. It's an article that's coming out in *Elements*, the magazine, in December, I believe.

But what Peter's done is he's done a lot of work growing these uranyl alteration phases and putting them in hydrothermal bombs with neptunium and seeing does the neptunium, in fact, get incorporated into the alteration phases. And one of the questions he always asks himself: Is it truly going into the structure--and that gets back to the energetics calculations that I showed in the previous slide--

or is it sorbed, goes along some kind of grain boundary in some way?

So what he's done and what's shown here is, he's grown these crystals, and these are about, for your all's benefit, on the order of 50 by 100 micron-type size crystals. And what he's done, the top plot shows a sodium-substituted metaschoepite grown in a hydrothermal bond, but he doesn't have any neptunium in it. And at the bottom he's got another sodium-substituted metaschoepite, but here he's grown it in the presence of neptunium. And you can actually see a line scam with the laser in this crystal where he's burned the crystal with a laser. It's laser ablation, ICPMS, laser ablation inductively coupled plasma mass spectrometry.

But effectively what he does, he blasts it with a laser, makes a cloud, sucks it into a mass spectrometer, and measures the neptunium concentration. And you can see when he starts the laser ablation here on the bottom, he does, in fact, pick up significant amounts of neptunium. It's not calibrated, so the fact that it's 500 counts on the side doesn't mean that he's got a calibrated scale and it equals 500 PPM in the crystal. We've got to figure out exactly how much of the neptunium in the bomb, and this is something Bill's brought up in previous meetings, how much of the neptunium in the bomb is, in fact, going into the crystal.

But we're starting to get real evidence that at least some of phases uptake neptunium. Now, again, all the phases probably don't, but we think we understand crystographically why that is.

Next slide. Natural barriers. You saw a smaller version of this--I'll just go to the next slide. A couple areas I want to point out. A lot of thinking about matrix diffusion that we've been doing is part of the natural barriers program. Looking at it from multiple fronts, there's work at Berkeley looking at field scale experiments and basically the effects of matrix diffusion on the scale of, say, a laboratory or field experiment. There's also experimental work going on. This particular slide is from the Livermore work where Max Shu (phonetic) and his coworkers at Livermore have been taking intact core and doing tracer testing along fractures in a fractured core and, through a variety of techniques, collecting the tracer at the bottom, doing tomography, and looking at the influence of matrix diffusion as you flow through a fracture, how much diffusion do you actually get into the matrix, and what would that do to retardation of a variety of--radionuclides.

Next slide. Also, Paul Rimos (phonetic) and his folks at Los Alamos, they're taking--this is actually both volcanics and alluvium, so I'm switching more to a saturated zone kind of problem here. This particular set of experiments is with alluvium, so it's been collected from a

Nye County well, and they're putting it in a flow through column and looking at sorption and desorption rates of key radionuclides. The plot here shows for uranium, for example--and this is a desorption curve, so they basically put the alluvium, run uranium-laden solution through it, and they do anywhere from one to 14 days, and they then take that same sample that's sorbed a certain amount of uranium, and they do a desorption experiment. And from that they back out the K_d, or basically the effective sorption of, say, uranium. And you can see the K_d's on the forward step are relatively low; but when you go through the desorption step, it's suggested that they're not completely reversible, so there is some irreversibility of the sorption, and you get fairly high K_d numbers. These are higher K_d numbers than we are currently assuming typically in the current TSPA. Could provide significant benefit. This would be a good candidate perhaps to look at in terms of margin analysis that Peter and John were talking about a minute ago--perhaps.

Next slide. I think this was shown or a version like this John showed the other day. This is, again, to remind the Board that George Danko's work on looking at multi-phase transport vapor and liquid water in a hot drift and how that happens actually along the drift. That's an important thing to understand, natural ventilation and convection processes. It could actually inhibit seepage into the drift, at least according to George's analyses; but it's also moving water vapor up and down the drift and perhaps has interesting consequences for water balance inside the drift. And so this is an important consideration. The TSPA currently has a CFD model for these kinds of processes, so this is a good comparison to that CFD simulation that's in the current TSPA.

Next slide. Drift shadow. Somebody has shown you in the past a couple of examples of how we're going after the drift shadow problem. This is a slide that I haven't shown you before, so that's why you see it, but you may recall that we're looking at drift shadow. We're using a variety of approaches to try to demonstrate whether we can, in fact, demonstrate the presence of a drift shadow. One approach is, we're in the tunnel with lithophysal cavities in the topapa (phonetic) and using uranium series disequilibria--this is USGS work primarily with Berkeley--to try to determine whether there is evidence of shadows under some of these cavities. And that's been, I would say, ambiguous to date.

We've also identified an analogue at Black Diamond Mine, a sandstone quarry not so far from Berkeley, where they actually have horizontal tunnels, one on top of each other, so it's an interesting question whether if you had drifts on top of each other, what that would do. But the bottom line is, they've drilled a series of holes, and they're about to start doing a series of tracer injections and geophysics to try to understand whether we would create a drift shadow under those tunnels. This is primarily a poor sandstone with some healed fractures in it.

And then this particular set of experiments is worked by Susan Altman (phonetic) at Sandia National Laboratories. This is done in the full visualization laboratory at Sandia. They've taken a stack effectively of bricks, and they flow water through the fractures, and they do real time tomography of this experimental setup to determine whether there is a presence of a drift shadow. I don't want to dwell on this, but when I studied this, this is also ambiguous.

So I would argue that drift shadow makes physical sense. If you think about seepage in an unsaturated rock, it makes physical sense. If we want to demonstrate it, we need to continue to strive for the experimental evidence.

Next slide. A couple points I want to make here with the summary. I think we're generating additional insight. I think we will continue to generate additional insight. I think it's focused on the right kinds of problems. Yeah, we are going from science to design, and that's an important step we need to take; but I still think there's some science that we can focus on some very important problems and get meaningful results.

The second bullet. This is a personal comment. This program's been really focused over the years on national laboratory investigators. I'm a national laboratory investigator. And this is not to denigrate the national laboratories, clearly. I work for one. But I think one thing that we've done here is we've brought in some university folks, and it's brought some diversity to the program. And I think that's incredibly valuable. All the programs--Joe's programs got an extensive university involvement, Rod and I's does as well. And it isn't just science for science's sake; we've been able to get them to focus on some important problems, and there are side benefits like people are getting Ph.D. theses out of these things, and I think that that, by itself, is also a benefit, especially if you get meaningful results.

And, finally, the last bullet. I think I'm going to anticipate probably what John or somebody is going to ask me, "Okay, this is all great. Where does it fit?" I can't point to the document where it's going to fit, but I know that we have a challenge to figure out how to take some of this interesting science information in the next short period of time and try to put it into a coherent package to put it in as part of the safety case, clearly. And that's the challenge that myself and Russ and others have in front of us.

So, with that, I'll stop.

GARRICK: Okay, thank you. I'm going to sneak a global question or two in. You're right, I was going to ask that question.

I think, Mark, you're aware of the great amount of interest this Board has in the Science and Technology Program and how we look to the Science and Technology Program as the most productive resource for addressing a lot of the questions we have. And so we have a continued interest in it, especially because we're constantly searching for fundamental understanding of phenomena and other technical questions.

But let me ask just two global questions. One is: Can you tell us what the current funding level of the Science and Technology Program is and, two, since you can't say exactly where the information goes, can you say something about the technology transfer mechanism between the Science and Technology Program and the Project--the mechanism?

PETERS: Yeah, I understand. Let me take them in the same order you asked them. The '06 budget for the whole S&T Program was on the order of 17 million, so that ends up breaking out, roughly speaking--do you want to know the breakout? Do you care?

GARRICK: Yeah.

PETERS: Okay. Technology was probably the highest by far. Russ is going to shake his head yes or no as I go through these numbers to make sure I've got them. Technology was probably on the order of 10, and then I would take the source term natural barriers and materials performance and roughly split them in three for purposes of this discussion, plus or minus. I think source term was probably higher--highest--than materials and natural barriers, but just for purposes of this.

Process of technology transfer. Good question. I'm not going to give you a direct satisfying answer, because we're working on the formal process. We need a formal process, clearly, and we don't yet have a formal process. People like me have been thinking about it for quite a long time, but it's never formulated into something concrete. So Russ has actually, I know, got currently an action that we need to work with him on to develop that formal process. That involves working with the lead laboratory, clearly, to understand how that will happen.

Now, saying that, what we have done in the past is try to integrate closely with the technical folks who are working on the technical basis for the license application. And so I hope you take some confidence in knowing that we have a series of integration meetings with our PIs, and we always have people from the program--the TSPA site for example--invited, and they come and they listen and they engage. But we need some kind of formal process for transferring it, and it's to be determined.

GARRICK: I was very pleased with your observation about reaching out to the universities, and now if you'd reach out to some of the industry resources, I think it would even be better.

Okay. Yes, David, first.

DUQUETTE: Duquette, Board.

I was going to ask the same question on the funding. That's about 3-1/2 percent roughly of the total budget for the Project that--.

PETERS: In '06.

DUQUETTE: Yeah. But the comment I had is a bit of a different spin on what John had to say, and that is, I've been on the Board long enough to remember when Margaret Chu introduced the concept of the S&T Program. And then we were promised as a Board that it would never be used to support LA.

PETERS: Right.

DUQUETTE: It was always going to be used to basically advance things that would be beyond LA and introduce new concepts, and things like the amorphous alloy program, I think, do that. On the other hand, part of your corrosion program was used to FEP out something for LA, and it seems like that's not what the S&T Program was intended to do. I don't what kind of response you have to that, but I, as a member of the Board and my personal opinion, think that the S&T Program ought to be not kept away from the Project obviously, but be used for more advanced concepts. And we were told that was going to happen.

PETERS: Yeah, I understand. Let me take your specific comment about--I'm assuming you're referring to the screening of dust deliquescence.

DUQUETTE: Yes, that's correct.

PETERS: Joe, correct me, but I was involved in those discussions. That wasn't a direct result of data that came out of the S&T Program that led to that decision to screen that out. There were people in the S&T Program like myself and Joe involved in the discussions, but I would--Joe is about to step up and either tell me I'm wrong or clarify it. I'll get back to your other concern, though, Dave, because I follow it.

PAYER: Mark is correct. That work and the presentations were not specifically done. The screening of the dust deliquescence was clearly--. Charles Bryan was the principal author, Ernie Hardin, and a cast of many produced that. But having said that, I think it's fair to say, Dave, that there's been a change in philosophy of the Science Program and what's its role ought to be. And I think under the current thinking we need to, in fact, be doing things that are good, solid science but do have a direct path to incorporation and building the confidence of the license case. That's just a reality of where we are. We hear Ward very clearly, and I don't think we have a problem with that. But it is a change in philosophy; it's a change in what you're going to do with the money.

PETERS: You stole my thunder. I was going to say the same thing. I was there, as I think you realize, when Margaret formulated it; and I understand the reasons why there was the perception that there needed to be a so-called firewall, I'll call it.

DUQUETTE: Duquette, Board again.

And, again, I'm not suggesting it was good or bad. It's just that what we were concerned about is what the money that should have been spent for Science and Technology to support the LA should have been done within the program itself, saving the S&T Program, per se, as a separate program that wouldn't necessarily support LA or ongoing programs. And so now it looks like they're being morphed together.

PETERS: They're not yet, so let's be careful. Let me take this in pieces. They're not. Under the Office of the Chief Scientist--I said this at the beginning--they're separate. They come together at Russ, but they're separate. The WEED (phonetic) lab has to integrate with me, but they don't control my budget. Clearly, we do priorities together, but they come together at Russ, so they're not organizationally together, and that was a conscious decision for exactly, I think, some of your concerns.

Point two was what Joe said. Yes, it has evolved in terms of the way we think about the way we fit into a safety case, and I think that's because Ward has a different perspective on it. And I'll speak for myself, but we all sat with him a couple weeks ago and listened to that, and it makes a lot of sense, because the Science portfolio--we were always struggling, okay, where's the boundary in those kinds of things? Maybe there isn't a boundary. Maybe you protect it by keeping it organizationally separate, to address your first concern, but maybe there shouldn't be a boundary.

DUQUETTE: I didn't mean that it was necessarily a concern. I'm just pointing out it's a difference in philosophy.

PETERS: It's definitely a difference in philosophy, and I think you see it because there's a new RW-1.

KADAK: Okay, we have Andy, George, Ron, and Mark. So, Andy.

KADAK: Kadak.

Yes, I'm with you on the let's make it more relevant to getting some answers. And the one question that I do have is, I think there's one element in the thermohydraulic modeling that desperately needs attention in terms of where the water goes. And we've heard a couple of presentations on--and I think it's Slide Number 24--that is very important in terms of answering that question. And if the old model that we saw about a year ago--correct me if I'm wrong, John--is still being used, that could be a major technical question in the licensing proceeding, because it may not be correct, especially when you consider some of these three-dimensional effects.

So could you just tell me whether or not what you're now showing is being reflected in the analysis of where the water goes?

PETERS: This particular analysis is not reflected in the TSPA. Peter, I'm looking at you, but this is George Danko's multi-flux effectively--coupled with a simplified CFD in the hole. There is the model that you're referring to--the one that you were referring to that you said makes the water do this. Could you expand on that a little? I'm not sure--

KADAK: There is no lateral movement of vapor along the drift, and most of the assumption was--and maybe it's changed--that the water goes up into the two-dimensional radial location above the waste packages, so you don't see any of this lateral movement. You certainly don't see the water condensing in the ends of the drift. And there is a certain assumption about this 81-meter separation, which, you know, if you don't have that right, there's a lot of issues that you're going to have to deal with when you come to licensing and the explanation about how this water really behaves.

PETERS: Let me try, Peter, and then you keep me honest. I won't get into with you whether or not the model is defensible or not. How about I don't get in a debate with you. I'm not the right person.

But if it's the multi-scale from a hydrologic model that you're referring to--

KADAK: Correct.

PETERS: --that's still the basis for the TSPA.

KADAK: That's still the old one.

PETERS: Correct. This is an alternative model for that, and we are actively thinking about how that compares. So, Andy, am I answering your question?

KADAK: Yes. My comment is following on what Dave was talking about. There needs to be, I think, some transfer really soon, because you may be operating on an incorrect model.

PETERS: Fair enough. Peter.

SWIFT: This is Peter Swift, Sandia.

The TSPA and its supporting models do not have a model like this one that actually couples the porous media flow in the rock with the open flow in the drift. However, we have looked at axial flow in the drift. We have a condensation convection model, which models only the flow in the open drift axially, and it uses boundary conditions from the multi-scale model.

So we actually do account for the effects of condensation in the cooler areas at the end of the drift and away from the hotter waste packages, for example, but we don't do it in the full coupled model as shown here.

PETERS: But, Andy, what I hear you saying is, this kind of conceptualization and model, the problem we need to be thinking about the linking back and forth to test the occult defensibility of our current basis.

KADAK: Yes.

PETERS: Fair. That's a good comment.

GARRICK: George.

HORNBERGER: Mark, Peter earlier indicated that the ground water travel time was important. A former member of this Board, Dick Parazek, for years suggested that having some information on fault permeability would really let us know a lot about flow concerns. And I know we've also had people suggest that having a closer look at using the Nye County wells to test DOE's mixing of various waters could really help build confidence in the Program, too.

And my question is: Is the Science and Technology Program looking at any of these issues to be addressed?

PETERS: Specifically on fault testing, when we looked at the first round of saturated zone proposals, we did an informal call. We went and talked to the scientists and said, "Where are your key uncertainties?" We blurred the boundary, but that's a separate issue. And one of them was permeability and isotropy, partly influence of faults, and we got some proposals in that area and ended up not funding them in the S&T Program. In my experience in the testing program over the years, it's been on the list but never made it to the level of being funded. It is in the PC plan, and I think Frank can speak to it, maybe if we would ask that question again, and Frank can tell you kind of where it's at, and I think Nye County fits into it, if I'm not mistaken.

GARRICK: All right. Let's go to Ron.

LATANISION: Latanision, Board.

Could we go to Number 9? I just want to add a perspective on the third bullet related to the issue of stifling. The comment that I'm going to make is similar to one I made during the day-and-a-half workshop that we had. But let me preface this by agreeing with you and with John that by adding the university folks that you've added to the S&T Program, I think there is great value. When you look at people like Joe Payer and Rob Kelly and Tom Devine, who you mentioned in terms of the Raman work he's doing, these are very good corrosion engineers. So I think that is of value.

But I do want to add a perspective here. You mention in your third bullet the issue of critical crevice chemistry. There's a tremendous database which shows that in localized corrosion phenomena, the chemistry inside a propagating crevice or pit or crack can become extremely aggressive. And so in addition to the language that you used when you described this stifling as perhaps stop or start or slow down, I think we have to incorporate into that series of potential events accelerating, too.

There's, as I said, a tremendous database indicating that localized corrosion does accelerate because of the evolution of not just a critical crevice chemistry, but an increasingly aggressive crevice chemistry. There is a more limited database in terms of stifling.

In one of the instances that we saw during the past day and a half, the work done by Ms. Xihua He from NRC, she created a single crevice by putting PTFE in contact with Alloy 22 in a condensed phase, in a beaker basically. So there's no question about having access to a supply of moisture. She used an environment that was half 5-molar sodium chloride and copper chloride added, 10^{-4} copper chloride added to it as an oxidant, and she showed a potential transient that is purported to show stifling. I don't know whether it does or not. I mean, it certainly shows a change in the current density and a change in the potential that one could interpret that way.

But what concerns me is that that's not at all a representative environment in terms of the repository--

PETERS: Right.

LATANISION: --either from the point of view of seepage or from the point of view of deliquescence. And, frankly, I think that's true of much of the other work that's being done in the S&T Program on the question of stifling. And I just want to encourage, first of all, a more global view of what potential phenomenology may occur. It's not just stifling. There is a potential that it could accelerate, which is perhaps more traditional.

PETERS: Fair enough.

LATANISION: But, on the other hand, I do want to encourage the use of representative environments. I'm not sure that introducing copper chloride into this chemistry is particularly useful. That's not an S&T project; that's an NRC project. But there have been similar chemical environments used in some of the S&T work, too.

So my plea would be to focus attention on environmental chemistries that are more representative of what might occur in the repository, either because of seepage or deliquescence.

PETERS: Let me accept your plea. I think Joe wants to saying something, but I want to agree with you, actually, because I sat through the workshop, as you know, I was there. And I was bothered by a lot of information coming forward, and I was asking myself the same question, is this like the environment, because we're drawing conclusions about performance of metals in environments that we're never going to see. And perhaps we were part of that, but I think everybody brought something to the table that wasn't terribly representative.

PAYER: Joe Payer, Case.

Ron, you made those comments, and I appreciated them yesterday and take them seriously today.

I think all of those tests we need to see what the relevance of the environment is and so forth. But, again, in a workshop where you've got a bunch of different topics, it's hard to get into much detail and that sort of thing. The whole stifling phenomena, you're correct, the initiation of crevice corrosion, the classic correct textbook of that, is the Fontana and Green diagram we show where the environment in a crevice becomes much more aggressive because of phenomena we know.

But that basically focuses on the initiation of crevice corrosion, and what's happening in the work that we're doing and other people are doing in this area is to take it beyond that initiation of crevice corrosion and follow the propagation of crevice corrosion as the surface changes, and you have to maintain that critical chemistry. In some cases, you do maintain it, and there's cases of failure analysis of all kinds of steels in sea water--stainless steels and that--where crevice corrosion has caused serious failures.

But in these corrosion-resistant alloys like the nickel-chrom-moly, there are other processes that, in fact, will cause the crevice to stifle and arrest. So it's a real phenomenon. It's a current state of research. We're not the only ones doing it. At the Electrochemical Society meeting this fall, there's going to be a special symposium on localized corrosion, and there's four or five paper, six or seven papers, where this will be discussed. So it is a current area of research.

Having said that, just to reiterate and to encapsulate what we've talked about the last day and a half, the Project--we believe--I believe--has justifiably screened out localized corrosion by deliquescent salts. The Project has not screened out crevice corrosion under drips and seepage conditions. And the picture we have there is that you can divide the world of environments up into five or six types of environments--carbonate waters, sulfate waters, chloride waters, calcium chloride waters--and in many of those categories--the carbonate waters--we believe there is evidence that show they are non-corrosive, they're benign waters. The sulfate waters are not corrosive.

The environments that can be corrosive are the mixed chloride and sulfate waters and nitrate and sulfate waters. And if you get the chloride ratios high enough, you can get into these kinds of concentrated chloride environments.

So that work is focusing on the subset of environments that we cannot eliminate from being possible in the Mountain and trying to understand how Alloy 22 behaves under those conditions. And the picture that's evolving from that is that some cases will probably drill their way through the waste package. In other cases we can see stifling and arrest, and now you're getting into a how many and how much and probabilities, and I don't know how to go there just yet.

LATANISION: Latanision, Board.

I guess I'm not quite as convinced that the case has been made to FEP out deliquescence-induced corrosion.

PAYER: And that's why I said, "in my opinion." I voiced that.

LATANISION: But let me just add that we've come a long way since the November 2004 meeting when this issue first came up and when the concept of a workshop evolved. But I think it is important to put in perspective the fact that if you look into the literature--and there's a vast literature--it may be that the literature should change. I'm not eliminating a priori the concept that stifling may occur under some circumstances, but when you look at chemistry in a propagating crevice or crack and you find that the pH may be units lower hydrogen ion activity orders-of-magnitude than the bulk environment and that actually is more aggressive than the bulk environment, then you know that the rates have got to accelerate. And that's a fairly well-established phenomenology.

PAYER: Agreed. And that's what starts it. Let me just tell you, we take--I take--your comments very seriously; because if you're looking at the work and say, "I still have some questions about it," then there's a whole bunch of other folks that would say the same thing. We take it seriously, we're looking at it, we believe it's a real phenomenon. And the question is: How can we say, does it apply all the time? No. Does it apply some of the time? Absolutely.

So the whole concept of stifling belongs someplace in our understanding of how stainless steels--.

LATANISION: Mr. Chairman, I just observed that this is the kind of conversation that academics ought to have about issues like this. This is sort of the workshop phenomenon--

PAYER: But it's also the kind of thing that engineers ought to be thinking about when they're designing waste packages for Yucca Mountain. So I think it's not all just a fundamental academic thing.

GARRICK: We're getting used to it.

I think Mark is next and then Howard and then Ali.

ABKOWITZ: Abkowitz, Board.

I'm going to ask, I think, a less technical set of questions if that's okay. I'd like to explore in a little more detail what I perceive to be S&T's search for its identity. And the first question I guess I have for you: Is there anything that you presented to us today that couldn't fall under the umbrella of the term "performance confirmation?"

PETERS: Strictly speaking--oh, that's a tough one. As I define performance confirmation?

ABKOWITZ: Sure.

PETERS: Yes. I think it could all fit as I define it. Now, as the NRC defines it or the regulation defines it, probably not.

ABKOWITZ: Well, I'm trying to grapple this whole concept. You have a performance confirmation requirement. My understanding is that it's to continue to do some experiential learning that will either validate what you propose is correct or prove our understanding subset we need to modify what's been proposed. I don't understand, in my simple mind, why this Science and Technology Program shouldn't either subsume the Performance Confirmation Program under it or vice versa.

PETERS: Let me modify my answer, Mark, if I can. In some cases--I'll use the word "beyond" the technical basis of the LA. For example, drift shadow is not in there.

ABKOWITZ: But Performance Confirmation is supposed to do that, is it not?

PETERS: No, it's strictly defined to confirm the basis for your PA analysis.

ABKOWITZ: But the Performance Confirmation activities go well beyond the period of time that the license application is being reviewed.

PETERS: No, I understand. There could come a day where, strictly speaking, it could transition into the PC Program. I'm getting bogged down in regulatory speak. Fundamentally--this is a personal opinion--I could see it being part of a Performance Confirmation Program the way I think about it, but the way regulation thinks about it--I'm not the NRC, they have their own interpretation--but I would say they would keep it separate. We're presenting it separate. We're not presenting this stuff as part of the PC Program in the LA as far as I know.

ABKOWITZ: Well, it just seems to me that in explaining what you all are doing and in making maximum use of what you're learning, that issue should be given serious consideration one way or the other. Now, let me pursue--

PETERS: Well, I obviously answered it wrong, because DOE is standing up.

NEWBURY: Claudia Newbury, Department of Energy.

I was going to suggest first that Frank Hansen is going to talk about the Performance Confirmation Program and remind you that it is in the regulation and very narrowly defined, and we want to keep it narrowly defined in terms of what we use as our Performance Confirmation Program. So while Mark is doing a lot of good work in Science and Technology, we will have to evaluate it and see if we want to make that as a commitment to the NRC.

Second is, the Performance Confirmation Program extends until the license to close a repository, so it is not just during the initial licensing phase, but through the whole life of the repository.

ABKOWITZ: I understand that, and I'm hoping that we will continue to learn as we move down that path, if we move down that path.

Two other very quick questions, if I could follow up, and I don't know whether this goes under Science or Technology or Performance Confirmation or whatever. I'd like to hear your thoughts on expanding the arena of the kinds of things that you're thinking about that can improve the safety and efficiency of the repository. One is: Has there been any discussion about including preclosure issues?

PETERS: Is that the end of your question?

ABKOWITZ: That's the end of my first question.

PETERS: Yes. There is work on seismic that has direct impact on the preclosure design surface facilities. It's an integrated program with the Project side, looking at the LA side, but also S&T's funding part of it. It's looking at updating the process for probabilistic seismic hazardous--particularly to take care of the tails on the really low probability earthquakes. It's particularly a problem in postclosure, but it will have some impact on surface facilities.

ABKOWITZ: Will it also look at TAD?

PETERS: In terms of impacts on the package?

ABKOWITZ: Well, in terms of the materials and its design.

PETERS: It's looking at package materials in the sense of structuring morphous metals, which one could envision applying to a TAD, just like you could the previous design. So I guess in that respect, yes, but right now that's probably about the extent of it.

ABKOWITZ: Okay. And then my final question, and this gets back to something that I brought up with Mr. Sproat this morning. It seems to me that, especially as this sort of evolution is going on with the Program, might we want to call this the Science, Engineering, and Technology Program and start to get into using this program as a mechanism for validating some of the engineering designs so that we do have some demonstration activities so that we don't go directly from design to production?

PETERS: I'm not sure this is the right place for that program, but you clearly need it. I probably don't want to comment on whether all of a sudden now it's SE&T Program. I'd like to stay an S&T Program and survive that.

GARRICK: Howard?

ARNOLD: Would you go to Slide 7, please? I hear very little discussion--I'd like to focus on the cladding there. One time when I asked about it, people waved their arms and said, "Well, in the aggressive water environment, it doesn't last long." If that's true, does that conclusion change if you look at the hypothetical situation on Number 17?

PETERS: Clad integrity--Zircaloy cladding--if you go to, say, low partial pressures of oxygen, what's the stability of the Zircaloy cladding? That's your fundamental question?

ARNOLD: Yeah.

PETERS: Let me go back to what the cladding does in the current model, Peter, and you can stand up and correct me. In the current model, there's actually a fair bit of performance of the cladding in the nominal scenario. Where you run into cladding failure is in the seismic shaking in the seismic scenario where you shake it and it's breached.

ARNOLD: All right. So you do have some clad integrity in your--

PETERS: Absolutely. Absolutely. In SR days it was a stand-alone barrier. Now we've gone to the three, so it's within the engineered barrier, but clad integrity is clearly providing some amount of performance.

ARNOLD: And it would be even better in--

PETERS: Pat, help me out. What would zircaloy do at low partial pressures of oxygen?

BRADY: Not speaking as a cladding expert, my guess is that a lower oxygen partial pressure wouldn't be a problem, and here's what I base it on. The 10^{-40} that we measure about halfway down there, that's the oxygen partial pressure you'd measure in a stagnant light. So this is not really a bad extreme of a condition. It might be the in situ partial pressure of oxygen you'd measure at the bottom of a pool. I suspect as you got down lower, there would be problems, because, again, the cladding forms the $ZROH_4$ acidation layer; and so at some point it would be problematic. I don't where it is, though.

PAYER: The equilibrium partial pressure for zirconium and oxygen is much, much lower by 10s of orders of magnitude than it is for iron and oxygen. So you're not going to reduce the zirconium oxide, which is what protects the zirconium. It's not going to dissolve under those conditions. You could crack it, you could break it, you could get hydrogen into it and--it, but you're not going to dissolve it.

PETERS: Right. But that's a real process. Understood. Okay. That's a process we have to at least consider in our analysis in terms of that.

GARRICK: Ali?

MOSLEH: My understanding is that evolution of the TSPA leads to the performance margin model or in parallel with that. The question is: Is it safe to correctly assume that there will be a tighter coupling between the projects under SNT and the performance margin modeling?

PETERS: This isn't something we've talked about in detail yet, but thinking about it myself, I could see the ability of them to use some of this information. But is it ready for "part of the basis in defending it?" But they could use this to inform some of those margin analyses. I think Peter said that earlier; right, Peter? So I think that's a candidate for that, but you guys haven't done detailed thinking about what margin analysis you're going to do yet and all that. That's going to go on over the next months.

So I think the answer is: It probably could be, but we haven't talked in detail about which pieces get back to the link.

GARRICK: Have we got anymore questions?

KADAK: What's the '07 budget request?

PETERS: Ward or Russ would have to tell you exact--for this program?

KADAK: Yes.

PETERS: That's not my bailiwick.

GARRICK: Anybody else?

DYER: This is Russ Dyer, DOE.

I believe the '07 request for the S&T was on the order of $23 or $25 million. You're shaking your head yes, but I'm sure we won't get it, because the entire budget is going to be less than the president's request. So until we see what the budget is, which is still hanging fire, well, we're all uncertain as to what's going to happen as of Monday.

GARRICK: Any questions from staff?

FITZPATRICK: Charlie Fitzpatrick, Egan and Associates for State of Nevada.

I don't want to elevate form over substance, but what Dr. Duquette said surely rung a bell of what Dr. Chu had explained. As a matter of fact, it was so separate from OCRWM that it even took on a different name. Is it still called OSTI, the Office of Science and Technology International, or is that out the window?

Real question. Substantive question. It certainly has a diverse group of people including graduate students and others doing some work. I was wondering if all the work that's being done--which is now there's a clamoring to have it transferrable to TSPA and LA--is all that being done in accordance with QARD, Rev. 17 or 18, whatever is the current--

PETERS: The S&T Program has its own QA program in accordance with the QARD. The majority of the National Laboratory work is done according to that QA program. In most cases--I'll speak for source term because I don't know--but in most cases the university work is not done according to that QA program. That said, we have had auditors go to the universities, and I've been told as the leader that, in the cases they've looked at, they have reasonable control. But the answer is: If it would be used, it would be non-Q, and it would have to be cooperative data.

DYER: This is Russ Dyer, DOE. Let me address the first question.

As you remember, we had a reorganization within the Office of Civilian Radioactive Waste Management effective in May. And the old OSTI organization, Office of Science Technology International, was split up and reassigned. The International part is now a part of the Director's office and responsibilities; Science and Technology came into my organization, which is a new organization. So the old organization got split up somewhat, but the entire Science and Technology Program came over as a whole under the Office of the Chief Scientist on the DOE side.

GARRICK: All right. We're right on schedule. Any other questions from the staff or anybody else?

Okay, Mark, thank you. Thank you very much.

I guess that brings us to the Frank Hansen presentation. Frank is from Sandia National Laboratories, and he's going to talk about "Performance Confirmation and Long-Term Science and Monitoring." Welcome, Frank.

HANSEN: Thanks, John.

I addressed the Board 17 years ago, I think, the very first board when Don Deere called us in and we talked about field testing. And since that day I've been in--well, actually, I've been in repository sciences since 1975, but I'm relatively new to this program. When we stand up the lead lab, I was asked to assume the responsibilities for Performance Confirmation, so I don't stand before you to be a resident expert on that topic, but I am an engineer, and I do understand what Mr. Sproat has put forward. And we at Sandia National Labs have stood up and said, "We're going to do that for you."

Now, today's talk has three points, and I will cover these three points; and then I think toward the end when we get to talking, we will return to S&T, long-term testing and monitoring strategy, and some of these things. But I want to make sure that I cover the three points that were asked of me in this presentation.

And the first is the regulatory requirements for performance confirmation and long-term testing and monitoring. We have a Performance Confirmation Program, we have ongoing activities, we have planning and those types of things that are objective evidence of a Performance Confirmation Program. We call it PC.

And then toward the end--I think this is where the real interest lies if I can read the tea leaves of the discussion on the S&T Program--and so we will talk about that toward the end.

Next one, please. There are, of course, many expectations for long-term testing and monitoring related to the safety case, and we will identify and speak to the regulations to some extent. But there are other components to the long-term testing and monitoring issues associated with the repository that aren't specified specifically by these requirements. We talked about that firewall between the compliance and the other things that are going on. So, in part, we have the compliance, we have what recently--and I do mean recently, because it was in the last couple of weeks when we started to formulate the strategy about where we need to go with the testing and monitoring strategy that we actually--with DOE, the customer--drew out some concepts for this evolution of the basis. And then we have the rest of the world. The rest of the world includes the university participants and S&T, the literature, research, and so on. So these are the three components.

Next, please. Part 63 tells you what to do. In 63.131 through 134 they delineate the requirements for the Performance Confirmation Program, and it's straightforward. They say there, "We want you to have a program and present a program with the license application that will verify, monitor, test, and confirm the assumptions that underlie the license application." That's pretty straightforward. There are some other criteria in 63 that allow for R&D in this particular case, and then there are other criteria in there that require you to update the PC Program.

Next, please. So, therefore, we have a PC Program that's based entirely on Part 63; and by definition then, it supports the long-term safety case. In addition, the Yucca Mountain Review Plan provides guidance for how the NRC will look at the program that we put forward. Now, this program was presented to the Board by Debbie Barr February 9, 2005, and I'm sure the Board probably appreciates it at least as well as I do. I'm a student of performance confirmation; I'm not a master of it. But the Board has seen all of the background material that went into the development of the PC Plan, the Performance Confirmation Plan, and, incidentally it's Rev. 5. It's been around for about--I believe the first draft was some seven years ago, and it has iterated. And I'll talk a little bit about this PC plan.

Next slide, please. Rev. 5 was developed using experts, and they used a multi-attribute decision analysis; and they identified a large number of specific testing activities. I was not part of that program, but some people in the room were part of the development of all of these activities. And they were consolidated and evaluated, and in the end they identified 20 specific activities in the PC Plan.

Now, these activities were crosswalked between 63 and the YMRP, and then they were reflected upon by performance assessment. I say "reflected upon," because it was non-quantitative; it was qualitative. And we, as a program, were going forward with the license application--I believe it was in the fall of '04--and the Performance Confirmation Program was reviewed with performance assessment and deemed whole qualitatively.

I wasn't working full-time on that, and I will explain a little bit about the recent history of Performance Confirmation, because it has not been institutionalized as an entity, and that's one of the things that I represent here is we're going to institutionalize that.

So then these activities in the Performance Confirmation Program, Rev. 5, reflect the key aspects of the postclosure safety case, and the next slide identifies these 20 activities. They're listed here, and I think probably in the presentation that you saw in February of '05, which was very recent after the compendium was put together and signed off, they went through what all of these things mean.

The next slide will put a different sort of a perspective on this. Mr. Sproat got up this morning and said, "We're going to submit a license application June 30, close of business, 2008." Now, I'm an engineer just like him--well, I'm a civil engineer, but a professional engineer like him--and so I have an engineering idea--and remember that we did this on WIPP, very similar. George Dials (phonetic) was the person that made the similar decision; he said, "We put a stake in the ground; we're going to submit an application to the EPA; and you guys figure out how to change the science into compliance." So here we almost use that same buzz term, science to compliance, science to engineering. And so with regard to the Performance Confirmation aspects, we are in that same situation.

So how do we get from here to there? And that's part of the reason, I believe, that Sandia National Labs and some of the WIPP people were engaged in helping us get from here to there. And we will get from here to there. And part of my talk will attempt to explain how I visualize that. Now, I don't have the roadmap exactly identified, but I know what needs to be done.

In the PC Plan there's a schedule. There's been a lot of science going on in the Program, good lord, 20 years or more. I was working in G-tunnel 17, 18 years ago. There's been a lot of science that has gone on, and there should be some science continuing; but right now the Performance Confirmation activities are limited. And they're limited for good compliance-related reasons; and that is, when you write that Performance Confirmation Plan, then you sign up to a regulatory requirement by review, and it has attended to it several important features.

We've been trying to stand up the lead lab. We have a PA Program. The creation of the documents in the Program have been called Technical Work Plans, TWPs. And I said we don't want to call Performance Confirmation test plans TWPs. We want them to be specifically identified as Performance Confirmation Test Plans so that people can point to them, that's a regulatory test plan, that is different, that's not SNT, that's not long-term testing and monitoring, that is a commitment. And that commitment has parts to it--and I will explain those parts--that make them specifically different and part of the strategy that I will use as we develop the Performance Confirmation Test Plans in the future--and that also explains why we only have a few being produced today--has to do with, when you sign up--and I think Mr. Sproat would say--these things look a lot like a tech-spec.

So if you sign up with the regulator that you're going to have--oh, I'll use something like rock mass modules 30 GPA--then when it goes outside of some range, then you are required to report that and assess what does that mean to the performance assessment. TWPs are more regular, what we're more used to, testing programs.

So when I came into the picture, the program was marching along in Performance Confirmation space. They had a program. John Arthur called the group together and said, "Do we have a program in performance confirmation?" The answer was yes. And the objective evidence, I used the analogy, well, what would we show the regulator if they showed up at the door and wanted to audit us to show them objective evidence of a Performance Confirmation Program. And we could point to products, the PC Plan Rev. 5, and then we undertook, at the behest of the DOE, the BSC folks undertook the creation of Performance Confirmation Plans.

That's where we are today, and we two weeks ago transitioned the Performance Confirmation Plans that were--one exists, by the way--and we transitioned two that are in process, and probably the most interesting one will be the fourth one, which, I believe, is the next in the pipeline. This is the long way of saying that these PC Plans will be developed sequentially, and some of them will require further long-term testing and monitoring such that we can write them correctly when the time comes to write them.

The one that is written is construction effects monitoring. Construction effects monitoring happened to benefit, because I know something about rock mechanics. I don't know very much about corrosion, but rock mechanics is one issue, and the deformation of the underground is something that is characterized for the PA, and they make calculations against it in terms of drift degradation, deformation, and so on.

And that was identified by the DOE as a deliverable; and it was written, reviewed, and submitted. And that's because we know quite a bit about that today. It's an ongoing activity, and that reminds me that another requirement that you can read in Part 63 is that many of the Performance Confirmation activities were started during site characterization and will continue to Performance Confirmation. So it's not always the same; in fact, we will acknowledge what was done previously, and we'll do what is required in Performance Confirmation when the time comes.

So that one was written. Precipitation monitoring is another one that has been ongoing for a long time, monitoring of the meteorological moisture snow, and so on, and other conditions. And that was created in the last year or so. The primary author was a USGS person, but it wasn't completed yet, but it transitioned to us, so it's in the pipeline. And I identified that within the senso stricto PC Program as a deliverable in the near future.

Another one that has been ongoing for a long time is seismic monitoring. There's a seismic array. It's mostly run by the cooperatives from the University of Nevada system, and that one's in the pipeline.

Next one, please. The expectation, of course, is that we advance the technical baseline, because we don't know everything today, and we expect that there will be a continuous assessment and involvement of the Science and Technology. In fact, we just had a presentation on the S&T Program. We acknowledge that, hopefully, as we march out, we will learn more. Certainly the technologies will advance such that in many cases we have to wait till the right time before we can sign up to some of those PC programs.

And also another aspect that I don't think too many folks have mentioned so far is that we have the S&T, of course, and we have a lot of folks that influence the program, but we haven't spent very much time reflecting on the international collaboration. And coming from the WIPP side of the house over the last 10 years or so, I was the international PI, and so I think that we have a lot to gain from them.

Next one, please. So here's where we are. Be reminded that I have not had a long tenure on this job, and so I'm telling you the story that I think is correct. We've had a little bit of discussion with the DOE and the basis of that discussion and discussion with Ward Sproat, that we think we see the path forward, and these are some of the components that are on that path. We already talked about the compliance requirements for a Performance Confirmation. We talked to some extent about the impact of the Science and Technology, other monitoring programs, engineering ES&H and so on, general literature, international programs, and so on.

So the long-term testing and monitoring strategy will comprise elements of this middle box here. So I'm going to talk about the elements of that middle box.

You can skip the next two slides--the next two slides are just a restatement of the criteria in Part 63--and go to the next one, the evolution of the technical basis. Here's the way I see the future of the Performance Confirmation planning. We have a commitment to send in the license application in June of '08; and if you back up from that date, then there are times when, I think, the phrase is, "You put your pencils down." The AMR is done, the information goes to the TSPA, then they run the calculations. So you have to back up from that date.

There will be a time, then, that the authors of the AMRs are freed up in some respects, because some of those same people will write that particular section of the SAR. Now, our section of the SAR is Section 4, and I'm not really worried about that. But the point of this is that we will have technical staff, the owners and the PIs from those AMRs, that will be available to help us define the PC Test Plans.

So some of the impetus and certainly the requirements within the PC Plan--see, the PC Plan is relatively generic, has to be. With the commitment that the details--the parameters, the ranges, expectations, and all that--the details of exactly how you implement that are driven down into the PC Test Plan, and my commitment is that we will have the right principal investigator write that information into the Plan.

In addition, there's a part of that PC Plan--and I heard it in spades yesterday when people stood up at the end of the day and say about the corrosion--a couple of different folks said, "And what difference does it make? What difference does it make to the TSPA?" This is a very important component, and it will be required of the author of PC Plan to put that information into the Plan.

And these are some of the other examples of the influence--reduce important uncertainty. Well, what does that mean? This is the Rev. 5 of the PC Plan. Certainly there will be Rev. 6 of the PC Plan. How are we going to get to Rev. 6? Rev. 6 will be issued after we march on out with TSPA, we perform the performance assessment margin analysis, because the PA right now is obligated to get their work done to get the Plan in. Soon we will draw on the PIs to help us understand the important uncertainties and incorporate that into the PC Plans. But this part that is embodied in these platitudes here is not the Performance Confirmation Plan. This is the way we get to the PC Plan; okay?

The next slide is basically what Mark Peters talked about, so we don't need to dwell on that.

Next one, please.

GARRICK: Frank, --the 50 percent rule, and you're into the discussion time now, so--

HANSEN: Okay. I'm just about done.

Next. And I just put this up because it's a colorful picture. It says we have been around the world, we have shared with the European Union, with ANDRA, with NAGRA, with the Canadian TSX, etc., etc. So we could draw on these people. The difficulty is that we don't have very much bench strength, and we can't really send people out that much, but we could do better.

Next. Okay. Ongoing and planned activities. I mentioned the Performance Confirmation test plans. They are being created now. They will exist at the time of the license application. There are continuing tests; I mentioned them. We will iterate with the TSPA folks and the principal investigators, and they will be obligated to provide us with the data, with the ranges, and trigger points, and all of that.

Next. Conclusion. The regulatory requirements from Part 63 are crystal clear. This part, long-term science and monitoring, is less regulatory-driven; and this is where we get to choose what we do.

And so I will end with this: The commitment that we have with the lead lab is, we will work with the DOE to identify and hopefully write the long-term testing and monitoring strategy that we need.

Thank you.

GARRICK: Thank you. I guess I'd like to make a comment about Slide 7. That's an impressive list of activities, and some of those activities are really potentially large-scope efforts. And yet we talk about this as being a prescriptive program. How much license did you take to generate this as the planned Performance Confirmation activities? Is this a direct fallout, in your opinion, from the Part 63 Performance Confirmation requirements?

HANSEN: Yes, it is. Part 63 is mapped. These 20 activities are mapped to the requirements for Performance Confirmation and the expectation of the YMRP. Now, having said that, let me say this: Part 63 says you will map, and we will map, but how you map and how you go about mapping can run many orders of magnitude and can expend a lot of effort. So it's up to us to define that program. With a few exceptions, like this one is fairly defined--some of these are well defined--but I also understand, John, that it's an enormous responsibility and a commitment. By comparison, the drift scale test ran eight years; this program will go on for decades, a hundred years or longer, until closure, some element.

So we hope to get smarter about these things. Now, I've been involved with experiments that run a long time; but if you take the drift scale test, it went on eight years, it cost something like--I've heard $53 million or something like that. That experiment, if it were undertaken in an active nuclear facility, would be much more expensive.

So I will say this: Our goal is to do the right size PC Program and not more. Like Einstein said, it needs to be as complicated as it needs to be, but no more complicated than that. So we know that there are big tickets attached to this, and we have to be smart about its deployment.

GARRICK: Okay. Andy?

KADAK: Kadak.

When we met with Ms. Barr--I think you said it was in February 2005--the program that she described was very, very high level. So our sense was that there really wasn't much of a program in place. Now, what you've described here, again, it also sounds like it's very high level; and it also appears that you're reluctant to get specific because of this tech-spec interpretation. But it seems to me what you need to focus in on is the critical attributes in each of these areas and identify what is it that you need to understand about the performance of the repository to be able to confirm that it's doing what it's supposed to do.

Now, who is working in that area?

HANSEN: We are.

KADAK: Who is "we?"

HANSEN: I should say, we will. It's a future tense, not a current tense. Now, we do that qualitatively, because we must.

KADAK: Excuse me. The TSPA in all these analyses have certain assumptions relative to flow rates, chemistry, all these other things. And it can't be qualitative.

HANSEN: That's right.

KADAK: So tell me what you're doing.

HANSEN: Okay. The plan is that the TSPA folks will help us with this quantitatively, not qualitatively. The reason that it's qualitative today is because if you ask the TSPA folks, "Tell us what's the very most important thing. Help us with this, prioritize this, tell us where we get the bang for the buck, what wiggles the needle." They can't really do that very well with the TSPA that they have today. And I can be corrected with the TSPA folks, but the goal for the more--and, again, I'm not steeped in the vernacular whether it's a realistic PA or the next generation PA or the performance margin model. But these tools that will be developed will be the tools to help us prioritize the PC activities.

KADAK: My sense, based on what we've heard at various Board meetings, is they do know the key parameters; so perhaps you should talk with Peter.

GARRICK: Russ wants to make the comment.

DYER: Russ Dyer, DOE.

There are a couple of things that play here. TSPA is one. A relatively new document in the higher--is the postclosure nuclear safety design basis, which kind of captures, for the postclosure side, those things that you're talking about. Now, getting the postclosure nuclear safety design basis synced up with the Performance Confirmation Program, all of that is coming to Sandia effective Monday. And it's going to be their job to make all of those interconnections between what we have in, I'll call it, a potential tech-spec list, which would be in the postclosure nuclear safety design basis. With our current understanding and TSPA and the programs that we need to challenge and test that over time, which is where the Performance Confirmation Program--.

GARRICK: All right. Any other questions from the Board?

From the staff? Mark, you're quiet at a time when you had raised some very much to-the-point questions on Performance Confirmation earlier. Have you got a reaction?

ABKOWITZ: Abkowitz, Board.

Yes, I'm still very confused. Thank you.

HANSEN: I'd like to respond to that. This is a true story. I have not had a lot of dwell time on this topic. And when I was given this responsibility, I too was confused, and I misidentified some of these things, because I couldn't sort out the boundary between--I understand the boundary between PC and long-term testing and monitoring now quite clearly. But there are other boundaries like with S&T that are still nebulous. And so one of the first things that I need to do with DOE, with some help, we will identify this long-term testing and monitoring strategy and clarify some of this and illuminate some of this area that right now is a little nebulous. So I, too, have struggled with that.

GARRICK: Okay. I think that's all we have in the way of questions.

Oh, do you have a question?

DIODATO: No, I'll pass.

GARRICK: No, don't pass. I didn't see your hand.

DIODATO: No. Mark asked my question.

GARRICK: Oh, I see. Well, anyway, Frank, thanks very much. We're glad to see you on board.

All right. We're now to the point of some concluding remarks, and Peter Swift is supposed to inspire us with that.

SWIFT: I'm Peter Swift here again.

When we were discussing the agenda earlier, the Department of Energy had suggested that it would be good to have a couple of minutes at the end to try to wrap things up, and I volunteered. But, Ward or Russ, if either of you would like to speak, please, we have five minutes here. However, I'll use the time. I hope I use it well.

The points here that Russ started off with discussing the international definition of safety case and safety assessment, basically the safety case is one of the answers to the question that Pat Brady posed earlier, which I would paraphrase as: Do we believe this? And we need confidence. You need confidence and we need confidence that we do actually know what we're talking about. We believe our models; we believe our scientific understanding.

The safety assessment is an integral part of the licensing case, which is a different issue. We need to make the issue to this group that we do have a safety case, we need to make it to the public, we need to make it to ourselves. And in doing so, that's a matter of building confidence in those quantitative models that I showed, confidence that our scientific understanding is appropriate--the analogue information is key there--confidence that we are doing the appropriate due diligent work to confirm and challenge our understanding. That's the Science and Technology Program, that's the Performance Confirmation Program. And that would be our safety case. You heard it in disjointed form there.

But the NRC will actually make the final safety case before a licensing hearing board, assuming we reach that point, and I hope we do. At that point the decision will be the hearing board's. We will have had to make our best licensing case at that point, and that's where most of the energy goes in the next year.

So the bulk of the work between now and June of '08 will go to putting our best case together to go into--our best case; i.e., our best understanding, not our most optimistic case, no; it's the best understanding we have--into a case for the NRC to evaluate and then take appropriately through the regulatory process.

And I will stop there.

GARRICK: Okay. Andy?

KADAK: Kadak, Board.

Is Yucca Mountain now accessible to people, or is it still a closed site because of some--

SWIFT: You mean, can the public visit the site? Oh, yes, that is certainly possible. I'll let Russ deal with that one. You do need to go through the DOE office.

KADAK: That wasn't the question. I thought there was some need to improve certain electrical wiring and things like that.

SWIFT: Oh, in the underground.

KADAK: Underground.

SWIFT: Russ, can you comment on how much the underground is available now?

DYER: Russ Dyer, DOE.

We have periodic maintenance going on. I know there is a large maintenance program looking at parts of ventilation, but that is periodic. I mean, it's on occasion as to what they're involved in and where. But we try to keep the underground open for visitors in the site as much as possible.

KADAK: So there's work going on now in the Mountain, like technical work?

DYER: Yes, there's some. It's mostly a monitoring program test that we put in place quite some time ago.

GARRICK: Any other comments?

SWIFT: I think for any of the speakers we should have questions or possibilities.

GARRICK: Okay. One of the things I guess I'd want to say as part of the concluding process is that I think there's a couple things going on here. One is, of course, the activities that are necessary to be in a position to file a license application on the schedule that Ward has presented. There's another aspect of this that I think is very important and is part of the motivation for some of the Board's questioning and inquiries, and that is: How do you build public confidence in this project?

I think one of the important reasons that we wanted to talk about the safety case was that there's a lot of activities going on with respect to this safety analysis of the repository that probably are not going to necessarily find their way into the compliance documentation. It just strikes us that that's kind of a missed opportunity, that you are doing a number of things that are very important for public understanding.

Ward made a couple of observations this morning that are in the category of reaching out to the public and getting them to appreciate the context of some of these requirements that we address in the nuclear business, these

10^{-6} and 10^{-7} and 10^{-8} requirements; and we speak about them so easily and so freely that there is a tendency for us to become of the opinion and of the state of mind that this is something that's really real. I thought the comment about the frequency of best science having to do with how often does the planet become extinct as far as life is concerned--and these are some of the kinds of numbers we are dealing with.

I've been involved in probably 50 different nuclear plant risk assessments around the world, and I am amazed at how these numbers tend to grow, sometimes without technical basis. And I think that we have to be very careful about the way we use them and the context in which we present them. And I think that a little bit of not only representation of the various things that are going on, that if the public knew maybe would build confidence, but also that this same kind of analysis and investigation address the issues of appreciating the risks that are being addressed here, because I don't think we do a very good job of that.

The reason I was so struck by Ward's comment about the 10^{-8} number was that I've been very heavily involved in recent months in analyzing the risk of certain threats to society, like terrorism, like hurricanes, like tornados, like asteroids. And the best information processed in the way in which we process probabilistic risk information does seem to suggest that the time between extinction events for just an asteroid event is something of the order of 50 million years with a bounding of between 20 million years and almost a billion years. All that indicates is that there's extreme uncertainty, but nevertheless it is a form of quantification that's very important.

So we are talking about events here that are comparable, in some cases, to those kind of extinction events. And I don't think that most of the public is very mindful of that context, and I see a great opportunity here to tell a story that at least is reflective of the work that's gone on in this business, and the attention that the industry has paid to trying to quantify its risk as being a part of that story, I think, would be a wonderful thing.

So I would hope that as we go down this path of trying to meet our licensing commitments, we would also realize that getting past the NRC is one thing; maybe getting past the public is another thing. We need to be sensitive to what has gone on here, and I think the Project deserves us to do justice to the work that's been done that will probably never find its way into the license application but is nevertheless important to this whole issue, in my opinion, of building public confidence.

So that's one of the reasons we're interested in having the meetings structured as we did today rather than as a TSPA meeting or a licensing meeting. We chose to try to come to grips with this concept of whatever it is that has any relationship to safety, and I think in that connection we want to thank the presenters and the hard work that was put into putting everything together for the presentation. As all of you know, the Board is constantly looking for some results, for some information, and we realize that some of these activities are still at the process and procedural state. The Performance Confirmation is kind of an example of that. But we will continue to have these kind of sessions to try to have as good an understanding as we can of what's really happening in the trenches and what kind of results are we getting and how these results are all tied together.

So that's part of our feelings with respect to concluding remarks.

SPROAT: I just wanted to finish the DOE talks by, first of all, thanking the Board for your involvement, your interest, bringing your professional expertise and experience to this project. Just so you know how much weight I put on your personal opinions and your involvement in this project, before I even got confirmed, I got a copy of your last annual report with the green cover. I read it, I highlighted all the issues, and on the inside cover I have a full page of handwritten 18 different issues that I took out of your annual report that I think are very valid issues that we need to address here between now and license application submittal.

I gave it to Russ, Russ is putting it into the business plan as we go forward so that we may not have definitive final answers on all those issues, but we're going to go after them, and we're going to address them as best we can between now and license application.

So I'm telling you that just to give you a sense that I don't see you as a necessary evil to the Program. I see you as a very helpful and essential part of evaluating what we're doing, how we're doing it, and giving us feedback that will add a lot of value to the work we're doing to try and give us a licensable design and a valid design for the Yucca Mountain system--as a system.

So I just want to thank you all again for your involvement and your professionalism and your help, because I view it as help. I really do. Thank you.

GARRICK: Thank you. Okay, I guess we've come to the public comment stage of our meeting. I have notification here that C. Fitzpatrick would like to make some comments.

FITZPATRICK: Charlie Fitzpatrick, Egan Associates for the State of Nevada.

I'll keep it pretty brief. You always recite the charter of the TRB at the beginning of every meeting; that's been the custom. The most pertinent part, "Conduct an independent review of the technical and scientific validity of DOE activities related to implementing the NWPA," and for today's meeting, "to review DOE's efforts to develop and articulate a safety case for a proposed geological repository."

I don't know if this is a question for Peter Swift or for the Board, maybe food for thought for both. Peter Swift's address was on barrier capability assessment of system performance. There were a lot of charts, for instance, the last subject of his bullet points, "representative quantitative examples of barrier performance." We saw horse tail charts of barrier performance; we saw horse tail charts of system performance incorporating various barriers.

One of the Board member's questions, "How come they have dates on them like 1998, 2000, 2001?" The answer was, "Well, obviously we've done a lot of work in that area since. Obviously the results are different. Obviously those charts are then, and this is something different now. But we're heading into a licensing proceeding, and so we can't let all of our information out of the bag."

I think that's a big problem for the Board to do its job. How are you supposed to conduct an independent review of the activities of the DOE? How are you, Dr. Garrick, supposed to see what's happening in the trenches when you come to a meeting quarterly, approximately, to review those activities and you get handed horse tail charts from five years ago that are admittedly changed since then?

So I urge the DOE to step back--okay, I'm not from Nevada today, I'm just a taxpayer. The DOE has burned 400 to 600 million per year since those horse tail charts were done five years ago, so that's a couple of billion dollars. As a taxpayer, I think I'm entitled to see the new horse tail charts.

And I think as we go forward to June 30, '08, you'll have several more meetings, ACNW will have several meetings, there's numerous technical exchanges scheduled, and a big question, I think, now hovering over each one of those is: How much of the current information is being laid out at these public meetings, and how much is going to be withheld for later utilization of the licensing proceeding?

GARRICK: Thank you. Anybody care to make a comment?

Are there any other comments that anybody would like to make at this point?

Well, okay, it's been a long day. I think it's been a productive one; and, as I say, we appreciate very much everybody's effort, and we look forward to meeting with you again. We are adjourned.

(Whereupon, at 5:20 p.m. the meeting was adjourned.)