UNITED STATES

NUCLEAR WASTE TECHNICAL REVIEW BOARD

SPRING 2012 BOARD MEETING

Wednesday

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Sheraton Albuquerque Airport Hotel
Chaco Room
2910 Yale Boulevard, SE
Albuquerque, NM 87106

NWTRB BOARD MEMBERS PRESENT

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Dr. Rod Ewing
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Dr. Ronald M. Latanision
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I N D E X

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P R O C E E D I N G S

8:00 a.m.

GARRICK: Good morning, and welcome to this public meeting of the United States Nuclear Waste Technical Review Board. My name is John Garrick. We have chart files on all the Board members at the desk in the back of the room.

It's been more than, I guess, ten years since we've had a public meeting here, although many of us have been here several times on fact-finding and technical meetings. We always very much enjoy our trip here. We also like to be able to walk from the airport to our hotel, it's a real advantage. This is an especially appropriate location for today's meeting because a fair portion of the work that the Department of Energy is doing is on the topic we're focusing on, geological disposal, and it's being conducted here at the Sandia National Laboratories.

As most of you know, the Board is an independent federal agency that was established in the 1987 Nuclear Waste Policy Amendment Act, and its purpose was to conduct unbiased and ongoing technical and scientific peer review of all the activities undertaken by the Secretary of Energy related to the implementation of the Waste Policy Act. These activities include the disposition of commercial spent nuclear fuel and the management and disposal of DOE-owned spent nuclear fuel, as well as high-level radioactive waste. I will refer to all these wastes as just “high-activity” wastes.

The Board evaluates all technical aspects of the waste management system, including packaging, handling, storage and transportation, as well as the design and operation of waste storage or disposal facilities. Integration of these program elements is a very high priority for the Board, and we spend a lot of time looking at how all the things fit together and how one part of the waste management system might affect the other.

Since the Secretary of Energy terminated work on the Yucca Mountain repository project about two years ago, DOE has initiated new research and development programs on fuel cycle option and on R&D designed to increase understanding of issues related to the disposal of high-activity waste in a range of potential geologic disposal environments, and the Board has continued its technical review of DOE’s work, and we will be talking today about the R&D associated with generic repository media and site criteria.

In addition to the technical review of DOE activities, an important part of the Board’s mandate is advising Congress and the Secretary of Energy and reporting our findings, conclusions and recommendations, on waste management issues. To help in doing this, the Board frequently prepares reports on specific technical topics.

For example, in December 2010, the Board released a report discussing the possible effects of storing spent nuclear fuel in dry casks for extended periods and some of the technical issues associated with subsequent handling and transportation of this spent fuel. And in June 2011, the Board reported on a systems analysis tool that we developed, called NUWASTE, which we use to evaluate the effects on the management of high-activity waste at various fuel cycle options being considered by DOE.

Something I’m especially enthusiastic about is the Board’s focus on learning lessons from the U.S. repository program and from waste management efforts in other countries. In fact, a portion of our meeting today will be devoted to hearing from the U.S. Nuclear Regulatory Commission on what we can learn from the NRC technical evaluations of the Yucca Mountain license application. We issued a report this summer that focuses primarily on the U.S. experiences with geologic disposal of high-activity waste in terms of the technical advancements the Board believes we have made. I think you can pick up some of these reports on the table in the back of the room.

Many of you are aware that the Board has published two reports on the experience of countries around the world in managing their high-activity nuclear waste, both of which are available on the NWTRB website. The report, titled, “Survey of National Programs for Managing High-Level Radioactive Waste and Spent Nuclear Fuel,” that report provides a 2009 snapshot view of nuclear waste programs in some 13 different countries. The report titled, “Experience Gained from Programs to Manage High-Level Radioactive Waste and Spent Nuclear Fuel in the United States and Other Countries,” was issued last year and provides a more detailed description of the nuclear waste programs in those 13 countries, including their histories and inferences that can be drawn from their efforts to identify candidate repository sites and processes of site selection, characterization and approval.

I also want to note that because the Board evaluates all the technical activities undertaken by the DOE related to implementing the Waste Act, we have reviewed activities of DOE’s Office of Environmental Management related to storing DOE-owned waste and preparing it for eventual disposal in a permanent repository. In so doing, over the past three years we’ve visited the four primary federal sites at which DOE-owned waste is being stored and/or processed and we will soon issue a report on that subject. All Board reports are available on the Board’s website, and, as I mentioned, some printed copies are available here today.

Now, as you can see from the agenda, which also is available to you here, we have a very busy day. As I mentioned earlier, the primary focus of our meeting is current work being undertaken by the Department of Energy related to geologic disposal of high-activity nuclear waste and, in particular, the technical suitability and site selection criteria for a deep geologic repository as today's deep geologic repository. Today's discussion follow DOE presentations at the Board's meeting in February last year in Las Vegas, Nevada, on the desirable geologic attributes, disposal concepts and technical factors, relevant to the potential siting of a repository in three different rock types; namely, granite, shale and salt. Today's presentations will add to the understanding of DOE's work in these important areas.

We are also looking forward to special presentations from representatives of the Blue Ribbon Commission on America's Nuclear Future and the NRC that are very timely and deal with extremely important issues and technical topics. I will talk about these in a little more in a minute.

The first DOE presentation will be made by Dr. William Boyle, who is Director of the DOE Office of the Used-Fuel Disposition Research and Development. Bill will update us on the activities of the Office of the Used-Fuel Disposition and describe ongoing and planned work, focused on fiscal year 2012, including the scope of the work being undertaken, funding levels, and where the work is being done. Bill will also represent DOE on a panel, analyzing repository site selection criteria and constraints. He will open the panel session with a presentation based on DOE’s experience in this area.

We are pleased to have with us today two representatives from the U.S. Geological Survey, and one of them, Kenneth Skipper, will join Bill Boyle on the first panel. Ken, who had a strong history with the Yucca Mountain project, will present the USGS perspective on site selection criteria and constraints related to deep geologic repositories.

I also mentioned earlier that in June of last year, the Board released a report that discussed a number of technical advancements and lessons learned from the Yucca Mountain program, as well as other repository programs. After lunch we will continue to explore that theme in a way that is a departure from the Board’s usual practice. We have invited two senior staff from the NRC, Larry Kokajko and Timothy McCartin, to discuss what was learned during the NRC’s review of the Yucca Mountain license application, that will be very useful the next time a license application for a radioactive waste repository is submitted for review by the NRC.

Following the NRC presentation, Peter Swift, from

Sandia National Laboratories, will discuss the status of performance assessment models developed for a potential repository constructed in three different rock types. He also will explain how these models can be used to help prioritize DOE research and development needs and be applied to site screening, selection and characterization.

Dr. Carlos Jové Colon, of Sandia National Laboratories, will then discuss ongoing DOE R&D activities related to the development of engineered barrier systems concepts, processes and models, for the same rock types that will be discussed in the performance assessment models.

We will wrap up the scheduled presentations of the day with a panel discussion on deep borehole disposal. Bill Arnold, also of Sandia National Laboratories, will discuss relevant technical issues related to the concept, including siting criteria; and Steven Ingebritsen, of the USGS, will tell us about the hydrology of deep boreholes as applied to nuclear waste disposal.

At the end of today’s meeting, members of the public will have time to comment. This is something we always find very useful to the Board. If you would like to ask a question or make a comment, please put your name on the signup sheet at the desk at the back of the room, and there should be somebody there to assist you. If you prefer, remarks and other material can be submitted in writing, and will be made part of the Board transcript. These statements also will be posted on our website, along with the transcripts and presentations from the meeting.

Now, a comment I always have to make about how the Board operates. The Board members freely express their views and opinions, and these comments do not necessarily represent agreed Board positions, and we're not always as alert as we need to be in making a distinction between what is a Board position and what is not, but we will try our best. The agenda indicates when we will have question-and-answer periods during the day. Generally, this time is entirely taken up by Board members; time permitting, staff will be able to ask questions, and if time also beyond that is available, members of the public can make comments. It is very important for those of you who have questions or comments to speak into the microphones and tell us your names and the organizations that you represent. And, of course, we ask you to put your cell phones on the silent mode for the meeting.

Now, with these preliminary remarks out of the way, I'm very pleased to introduce our first guest speaker, Dr. Albert Carnesale. Dr. Carnesale and I have a couple of things in common. We both have advanced degrees in nuclear science and engineering, and we're both heavily involved at UCLA. Of course, Dr. Carnesale is involved at slightly different levels than I am; he is Chancellor Emeritus and Professor at the University of California-Los Angeles. He holds a Ph.D. in Nuclear Engineering, and his research and teaching focus on public policy issue, they have scientific and technical dimensions. Dr. Carnesale was appointed to the Blue Ribbon Commission on America's Nuclear Future by Secretary of Energy Chu in January 2010, and the BRC was created at the President's direction to make recommendations on a path forward for managing the back end of the nuclear fuel cycle. Dr. Carnesale will give us an overview of the BRC's final report, and recommendations to the Secretary of Energy released just over a month ago.

Now we are extremely pleased that you're here and we very much look forward to your remarks.

CARNESALE: Thank you, it's a delight to be here. I appreciate the invitation, and, as you said, I will--and speaking for the Board, I can say the same thing about the Commission--I will do my best to present what is the consensus of the Commission. When I'm expressing my own views, I will make that abundantly clear, I hope.

So, let me see if we can get started here. Well, first, the origins and purpose of the Commission. It's already been mentioned, but there are a few key words I'd like to point out. First of all, as was indicated, this effort originated with the President, writing a memorandum to the Secretary of Energy, saying, “I want you to appoint a commission.” This was January 29th, 2010. “I want an interim report in 18 months, and a final report in two months.” And it’s important to recognize what the charge was; conduct a comprehensive review of policies for managing the back-end of the nuclear fuel cycle and recommend a new strategy. This was a commission to come up with a strategy. It was not to come up with a new technology, not to explore all of the plausible technologies--strategy.

Also, not a siting commission. We have no findings regarding Yucca Mountain or any other site. We didn’t look at particular sites, either as potential alternatives or substitutes, and rendered no opinion on the withdrawal of the license application, all right? We were supposed to be looking forward. And we also made no recommendations on the role of nuclear energy in the future energy mix of the United States. That was not part of our charge. Our charge was, “What are we going to do about the back end of the nuclear fuel cycle,” and that’s basically it.

And that’s reflected in the Commission membership. Our co-chairs were Lee Hamilton and Brent Scowcroft. Lee Hamilton’s distinguished career as a member of Congress from Indiana, Chair of the Foreign Relations for many years. Brent Scowcroft, National Security Advisor to the first President Bush, and distinguished in the defense community.

Notice that neither of them is a radiochemist, or a geologist, right, or a nuclear engineer. Again, these are people who have reputations for being able to solve, or show a path to solve, some complex problem that involves policy and politics, as well as elements of technology. All of the members are volunteers, which is the polite way of saying we don’t get paid for doing this. It included former elected officials, as well as former appointed officials, from both parties, members from academia, non-government organizations, industry, labor, and what we had in common was a shared commitment to craft a strategy that we believe would work. We had a great staff as well, headed by John Kotek.

So that’s half the members; here’s the other half. There were 15 of us in total. Included some techies, as well, experts in the technology, but, fundamentally, it’s a strategy commission.

So, nuclear waste, what’s the problem? Here’s the short form, and, again, this reflects from our perspective in trying to form a strategy. We, the U.S., have been trying to figure out what to do with this stuff since the 1960’s. Under current law we were supposed to start putting spent fuel into Yucca Mountain in 1998. You may have noticed that that has not happened. All this time utilities, or, indeed, their rate payers, have been putting money into a fund to pay for the government taking this spent fuel off their hands, but it's just not going anyplace because we have no place to put it, is the basic problem.

So Congress and the administration have to act to do something about this, to get us beyond the current impasse, to recognize that the old strategy just isn't working and was unlikely to work. We have an ethical, a legal and a financial responsibility to dispose of this fuel safely, at a reasonable cost, and in a reasonable time frame. No matter what your views are on nuclear energy, or the like, these are points on which most Americans agree, that we have to do that.

When it comes to strategies, we have not come up with a silver bullet. As a matter of fact, you will find that almost all of our recommendations reflect what you might call old ideas, that people who work in this field are familiar with. But we also have a strategy right now that also consists of old ideas that haven't worked, so we've put together a strategy that consists largely of old ideas that we believe will work.

Why do we think it might work now? What's changed? First of all, the liabilities of continuing down the current path have become all the more evident. It's been more costly, more time-consuming, and more divisive and controversial that anyone would have expected at the time that the Nuclear Waste Act was amended, and yet, at the same time in the United States, mainly WIPP, and abroad, there's been some progress in some areas. There are methods that do seem to work or have promise.

Now, this is a rather faded chart of the nuclear fuel cycle. The only reason I put it up here is not to explain the nuclear fuel cycle to this audience, but rather to make an important point. We used two terms here. Where it says “interim storage,” and “final disposition,” we refer to that as “storage” and “disposal.” So storage meant putting it somewhere for some period of time, it's under some sort of human intervention, and it can be retrieved. That's storage. Disposal is its final resting place, is the idea. Perhaps under some emergency somebody might try to move some of it, but it's not intended for that. It's to be the final resting place.

Now, you all again know about spent fuel. I put this up here only to remind everybody that right now we have about 65,000 metric tons of spent fuel, about 75 percent is stored in pools, 25 percent in dry casks. That's of the commercial spent fuel. It's a lot of stuff. Yucca Mountain would have been limited by law to 70,000 metric tons of spent fuel, so we are just about there already. So no matter what your thoughts about Yucca Mountain are, at a minimum, we need another place, unless the law were to be changed to allow more material to go in.

This just shows where the commercial reactors are, which is also a pretty good surrogate for where the spent fuel is, since most of it is at the reactor sites. You know it’s preponderantly in the east. It’s interesting if you do a--if you draw a line sort of separating east and west rather arbitrarily, about 80 percent of it is in the east. If you look at DOE spent nuclear fuel, which would just mean their inventory, that’s scattered around a bit more. Most of the inventory resulted from plutonium production, but there’s also been R&D activities and foreign and domestic research reactors where there was some highly enriched fuel, the Naval Propulsion Program, et cetera.

And the high-level waste is located at Hanford, Idaho, Savannah River and West Valley. What is interesting, again, just in terms of the quantity, if you sort of draw a line down the middle of the United States, about 80 percent of the high-level waste is in the west; 80 percent of the spent fuel is in the east.

The high-level waste--this is just really a picture of the form that’s in West Valley, has been converted to this form, and the idea is that it will go in storage facilities until somebody figures out something else.

Commission activities. I won’t spend a lot of time on this, but rather just to illustrate, I have two slides of this; 2010, 2011. The full commission, or members of its committees--we initially formed three committees, reactor and fuel cycle technology subcommittees--one on transportation and storage, and one on disposal. Then, very close to the end, there was a committee on the comingling question of the defense and civilian waste, when this issue came up at the very end, but that one we actually punted. We said, “Boy, this is too complicated to do in the time we have available,” and said DOE should get about figuring that one out.

But you can see that we visited not only places here in the United States like Hanford and Maine Yankee, but also Sweden and Finland and France and the U.K. and Russia, just to get an idea of what others are doing, especially where there seems to be some progress being made there.

Now I’ll try to review, we had eight recommendations, eight elements of our strategy. So let me do an overview of this. This is really the main thrust of the report. The report, I should say, by the way, is available easily--as a matter of fact, the easiest website to go to where you can also find the subcommittees’ reports, is brc.gov, Blue Ribbon Commission, brc.gov, and everything is there.

So, the first recommendation is that the U.S. should adopt a new approach to siting and developing nuclear waste management facilities. And this has been the most consistent and intractable challenge of the entire spectrum of activities involved in managing nuclear waste. Of course, the first requirement, it's got to be safe and environmentally sound and the like, but beyond this threshold we have to find sites where affected units of government, whether it's states, tribes, communities, are willing to support, or at least willing to accept the facility, top down efforts, such as the one that resulted on Yucca Mountain, haven't worked in the United States. They also haven't worked elsewhere. Nowhere has it been successful, with the possible exception of the Soviet Union in a different time, but I think that's a different story.

So we believe you need a system that's basically consent based, and it has to be explicitly adapted and staged, and, most importantly, consent based. Now, a good--what would be a good measure of consent would be if, in the end game, the essential parties would be willing to come to some sort of a binding agreement. It can have clauses in it, it can have stuff in it that protects a bit, but some sort of a binding agreement on the basis of which you could continue. In this kind of approach, we believe, you could have the public trust and confidence needed.

Some of you, I presume, that members of the Board may be aware, others may not be, just last week a letter was written by the Governor of South Dakota to Secretary Chu, asking for the support for a research program going on at the

South Dakota School of Mines and Technology on shale, broadly. But one aspect was to be what about the suitability of shale in South Dakota for storing radioactive waste? And he said he supports this fully, but he put in the usual caveats. The fact that it turns out to be promising does not guarantee that South Dakota would say, “Okay, put it here.” That they would have to go through some process themselves. But it’s not as if nobody is willing to step forward to even think about it.

Now, these photos, I don’t know how visible they are. The one on the top right was taken in Sweden, after Sweden announced where its repository site would go, and the smiling fellow in the middle is the mayor of the town in which it is to go. And the lower picture is Spain, right after the site for their consolidated storage facility was announced, and he’s the smiling fellow on the cell phone.

Recommendation number 2 is a new organization dedicated solely--solely--to implementing the Waste Management Program, and empowered with the authority and resources to succeed. The Department of Energy and its predecessors have been managing this problem for more than 50 years. In that time there have been some successes; WIPP, some cleanup programs, but the overall record in this domain has not inspired widespread confidence, to put it very mildly, or trust in the Waste Management Program. For this, and other reasons, we believe we need a fresh start. A new entity, a new organization, a single purpose, to implement this Waste Management Program is needed for stability and the focus and trust essential to get the Waste Program back on track.

Now, we don’t feel strongly about what form that organization should take, but it’s got to be--have a degree of independence, it’s got to have access to the funds required, and it has to have the attributes to carry out its mission. We thought that one suitable such sort of organization would be a chartered federal corporation, but that’s not the only way you could think of it, that’s the one we put forward.

The third recommendation, and it is the first three that we consider to be the most important; first, a new consent-based process; second, a new organization; third, how are you going to pay for all this? And this new organization has to have access to the funds that the nuclear utility rate payers have been paying into the Federal Treasury for the purpose of nuclear waste management.

Now, these curves, it’s not important to look at all of them, but the upper curve is the cumulative amount in the Nuclear Waste Fund over the years. It’s now, if you can go out just a little bit further, at about $19 billion. That doesn’t count interest, that’s the cumulative amount that’s been paid in. The lowest curve is how much has been appropriate for nuclear waste. That's about--what is it, eight?--$7 billion. So the different is about $12 billion. If you include the interest, the Nuclear Waste Fund is now at about $27 billion. And this was all done under a polluter-pays idea, that this money was to go for the storage--for the disposal of commercial spent fuel. So that's the 1 mil per kilowatt hour fee, which, by the way, many have observed that it's never been, quote, "corrected," close quote, for inflation. Actually, it can be. The Secretary of Energy has that authority to correct it for inflation anytime he would like, but it probably would not have been a wise political move since people putting money into the fund, it's accumulating, and the waste ain't going nowhere, it's a little hard to say, "We have to charge you more right now for us to do nothing with your spent fuel."

But the way the fee is managed, because of acts that have taken place by Congress and the Executive Branch passed, mostly Gramm-Rudman-Hollings back a while ago, means, actually, the fund is not available for waste management purposes. Or, put it this way, the receipts from the fund, for those of you who know how the federal government works, go into the mandatory side. The expenditures come out of the discretionary side. So these appropriations are made, competing with every other requirement of the federal government. It’s not the way it was intended, that there’s this special pot of money. The special pot of money just sits in the federal coffers and helps reduce the size of the apparent deficit.

In contrast, by the way, defense waste is paid for directly by appropriations and the money comes out of the Treasury. So it doesn’t work as intended, and this has to be remedied. I’ll say a little bit more, specifically, about ways we recommend doing that.

Now, the fourth recommendation is prompt efforts to develop one or more geological disposal sites. As I indicated before, no matter what, we need a geological disposal site, no matter what you think might happen to Yucca Mountain. And it’s an essential component of any waste management system. Scores of expert panels have looked at this in the U.S., and elsewhere. They call come up with the same answer, and every country that’s proceeding with a waste management program has come to the same conclusion, that geological disposal has to be part of it.

Now, an important point comes up here is what about recycling? As many of you know, it has been a sort of a mantra, especially among those of us trained an nuclear engineers, that neatness counts, and the idea of having this “stuff” that comes out of the reactor that has plutonium in it, and some slightly enriched uranium in it, would be thrown away is just painful, right, because neatness counts. So how come this hasn’t been done? Well, people come with all--they blame it on Jimmy Carter. There are all kinds of reasons, but the fact is uranium’s too cheap. That’s the problem. It is not economical. So, indeed, just for this audience we had the French and British--excuse me, not the French and British--we had the French and the Japanese. Visits were made there, but also they came to the U.S. to testify in open session, very nicely, at one of our meetings in Washington, and they were pressed, “If you had to decide today, and you did not already have the capital investment for reprocessing and the commitment to it would you do it today?” And both of them, after fifteen minutes of back-and-forthing said, “Probably not. Probably not.”

But even--so we concluded, and we had people that came into this very hot to trot on reprocessing, and others thinking it was the worst thing in the world, but we concluded, and everybody agreed, it is clearly premature to commit now to a policy of closing the fuel cycle. It’s probably also premature to say, “Never, never, never,” but that should not be a commitment to be made at this time. And, by the way, if we have reprocessing, we’ll still need permanent disposal for those wastes, not to mention for the large amounts of spent fuel, the older spent fuel in particular, that you probably wouldn’t want to try and reprocess.

Let me--could I--yeah, well, I guess I--yeah. That's where it should have been, number 5.

In addition to the geological disposal, prompt efforts to develop one or more consolidated storage facilities. Storage, remember, some people call it "interim storage," we call it storage, largely because people are thinking, "What's the term for how long it might have been stored?" When you start talking about decades, or perhaps a century, "interim" doesn't sound so good to the people that live in the area. It makes sense if what you're thinking is that, ultimately, it's going to have to be disposed of, so from a technician's point of view, that's the right term, looking at the fuel cycle, but when you're trying to site it, "interim," to them, a hundred years is not what they generally have in mind.

So we need safe and secure storage. It's another critical element of an integrated and flexible system. Experience. We have experience with this, others have experience with this, either at or away the sites where it's generated, and that can be implemented safely and cost effectively. It would allow the federal government to begin some orderly transfer of spent fuel away from reactor sites, especially decommissioned reactors, where there's stranded spent fuel, and you require--you can't use the land for anything else and it requires all the security as if you still had a reactor operating. As a matter of fact, we recommend that the stranded fuel should be first in line to go to interim storage, which is not the current practice.

The sixth recommendation, prompt efforts to prepare for the eventual large-scale transport of spent fuel and high-level waste to consolidated storage and disposal sites. And the reason for this recommendation is why does this have to be prompt? We found that the current system, transportation system, has a phenomenally good safety record for the transportation of spent fuel. But it’s one of the things that people worry about most, and the WIPP experience demonstrated that. The current set of guidelines seem pretty good in regulations, but they have to modified, for example, if for no other reason other than we’re getting burn-up rates in the spent fuel that are much higher than what the current regulations would permit you to ship.

Also, if we’re going to step up the volume of transportation, there will be new public concerns just about the new, the higher amount of shipping and, as your financial advisor would tell you, past performance is not a guarantee of future success, so we’ve got to be vigilant about this.

We also believe it’s important that the states, the localities, the tribes that might be engaged, be given the resources necessary so they can discharge their roles and responsibilities in coming to agreement on these things. But WIPP has shown it's possible. It helps to have your state senator be chair of the Appropriations Committee--at the time, Pete Domenici--that may not always be the case, but Pete Domenici was a member of our commission.

Seventh. We support continued U.S. innovation in nuclear energy technology and workplace development, and that's because we believe that advances in nuclear energy technology have the potential to deliver an array of benefits across a wide spectrum of plausible future energy policies, and we believe those benefits justify continuing support for R&D in fuel cycle technologies in advanced reactors, and the like.

In the near term, of course, the focus is on improving the safety and performance of light water reactors and spent-fuel and high-level waste storage. But, in the longer term, there exists some possibility of game changers, things that would really alter the problem in a positive way, and you won't know unless you look. We support what the NRC has been doing in its risk-informed performance-based approach to regulations, but also the efforts, the ongoing review, about reclassification of waste.

And to put it strongly, we need the necessary labor force at all levels. And another important point is we have a number of capabilities and infrastructure that are simply dissipating, and to turn that around, in addition to trying to build some new capabilities.

And the final recommendation is we recommend that there be active U.S. leadership in international efforts to address safety, waste management, non-proliferation, security concerns; more and more countries expressing interest in pursuing nuclear programs. U.S. leadership is essential if we want to meet what we hope to achieve in safety and non-proliferation and security and counter-terrorism objectives. We may have to help some countries, particularly countries with smaller nuclear programs, because if they have materials that can easily be stolen, or they have facilities that could easily have accidents, that's bad for us. That's bad for us and we may have to help them.

But if we don't get our own house in order, on the back end of the fuel cycle, the chance for us of being leaders in an international effort when we can't do it ourselves is going to be extraordinarily difficult. It may well be appropriate for us to look carefully, at least, at international facilities for spent-fuel storage, and possibly for disposal, particularly for smaller nuclear programs.

So, proposed--some of these things require legislative changes. I won't go into these into detail, but to fully implement our recommendations, some changes have to be made in the law. You have to establish a few facility siting process. There is none. As amended, Yucca Mountain is it. They are not siting another one. So it has to be amended to allow for some sort of consent-based process to be used in selecting and evaluating sites, and licensing, consolidated storage and disposal facilities, in the future. You have to authorize consolidated interim storage facilities. Right now the government has provision to construct one consolidated storage facility; however, nothing is to start in that effort until Yucca Mountain is licensed for construction. So that has to be modified as well.

You have to broaden the support to jurisdictions affected by transportation. That’s what I was telling you about before, making available the kinds of things that were made available in WIPP to get communities to agree to this, that there’d be some sort of compensation for them, that they’d have money to really examine this carefully and be confident that it would be safe.

Establish a new waste management organization; that will require legislation. Ensuring the access to dedicated funding; that also requires legislation. And promoting international engagement to support safe and secure waste management; if you want to do some, for example, spent-fuel take-backs and the like, that would probably require some legislation.

Let’s see--I think I jumped ahead of one here.

Yeah, let me go back one. That’s okay, there it is.

Key features of the new approach. I think I mentioned consent-based. It has to be transparent. Phased--in other words, you don’t decide everything at once. Adaptive, so that the process itself may need to change some in the future. Standards and science-based, and governed, ultimately, by partnerships arrangements. Also we did point out, and made it clear, that it’s not just the federal government that has some responsibility here. The states and the local communities, and, to some extent, the tribes, have some responsibility also in dealing with this problem in ways that serves the national interest. It isn’t just the federal government that’s got the responsibilities.

Empowering a new waste management organization. To succeed, I mentioned there are several options for the organizational form. Scope of the mission I have spoken about. Resources and the authority to do it, and governance. If it’s for a fed corp, they would--for example, a Board of Directors, we would recommend nominated by the president, maybe 11 members, including the CEO of the fed corp, that would be confirmed by the Senate. There would also be an advisory board with a much broader spectrum of expertise and perspectives that would be advisory to the Board of Directors.

Almost every other country that has proceeded with its waste management program has gone to something like a fed corp, something like an independent agency. And again, if you look at what we described as the mission of this new organization, it does not include reprocessing, all right? That’s a decision to be made later, and how that might be--the decision, for now, the decision is not to do it now, is what we recommend. If that should be changed in the future, then it should be thought about how best to deal with it then.

The funding problem requires two steps. One can be done by the Executive Branch. That deals with the payments itself. Doesn’t require legislative change. Right now it’s about $750 million a year. What we recommend is what--be divided into two parts, in essence. The part that is collected would correspond precisely to the amount that is being spent that year. The remainder would go in trust. So it’s not just continues to go into the Federal Treasury forever. A third party trust, so you could get to it, when you need it.

The second part says, “And what about that $27 billion,” or whatever it will be. At some point it needs to be transferred to this organization as well, otherwise, think of what it’s like when you do finally pull it out and it shows up as a big hole in the budget. But doing the budget, you’re not doing the budget any favors by keeping the money there because those are real liabilities that eventually have to be paid. The liabilities are already in the billions of dollars.

Let's see--yeah. Okay.

We got fixing the funding problem. Exciting new facilities getting started. There's nothing especially new here, but the legislative changes described it. We also believe there's an important role for EPA and NRC, and they should continue doing what they're doing. Those responsibilities should not be transferred to this new agency. You want an independent regulatory agency doing the kind of work that they're doing.

Getting the consent. This has been the biggest challenge. All of the parties have to feel that their rights have been respected and their interests have been protected. There's no easy solution. There's no one size fits all. But, based on the experience of other countries, and the experience with WIPP, we believe it can be achieved through adaptive consent-phased process.

Support for participation is essential, and that's going to--can take several forms. Here in Albuquerque, it's worth observing the wonderful Bypass Highway around Santa Fe. That's a condition for WIPP. But, as I say, good to have your senators chair the Appropriations Committee. But things, some things like that, will be essential.

And, of course, the WIPP example, I don't have to tell you about it, especially here, but it's really been working quite well. Another part of the deal, of course, was no high-level waste. But that could be modified. As a matter of fact, some of the folks in the community at WIPP are already starting to push for the idea of becoming a repository.

Now, further days, not only irresponsible, will be costly. Right now, the fuel that's being stored at the utilities, that should have been taken by the government, the process is the sue the government for the costs. And the case gets settled because it's clear the government's going to lose. What did it cost so far? Two billion dollars have been paid for that. It's estimated that--let's assume we don't have a place to put it or we get an interim storage facility in 2020. By then it'll have been about $20 billion. So there are strong reasons for getting this done.

Other countries, the status--well, you can read about that, but Finland selected a repository site; Sweden selected a repository site; France, they've had an agency volunteer for underground site characterization programs; Canada, implementing an adaptive consent-based process; and Spain, as I pointed out before, has a consolidated storage facility. So these things are possible.

And one cannot give a talk on this kind of subject without mentioning Fukushima. We recommended, some of the others have recommended as well, that the National Academy of Sciences take a good look at what are the lessons. It’s worth observing that the dry-cask storage and the away-from-reactor fuel storage at Fukushima performed quite well. The storage at the reactors, where the storage fuels were elevated, was not such a good idea. As somebody put it, “Here are the lessons from Fukushima. Spent fuel down, diesel generators up.” So, we can do better but we have no reason to believe that current reactor storage in the U.S. are not adequately safe, but we do have to be open to these lessons.

And, finally, the overall record of the U.S. nuclear waste program has been one of broken promises and unmet commitments. And yet, for the reasons I said before, the commission finds some confidence to believe that can be turned around. We know what we have to do, we know we have to do it, and we even know how to do it. There aren’t very many problems that one can address that have those three parameters going with it.

The experience in the United States has shown there are suitable sites, the knowledge and experience we need are in hand. The necessary funds have been and are being collected, but the core problem remains what it’s always been, finding the site. This is not an easy problem. Other countries have had trouble, too, and they’re not all the way there yet. But significant progress has been made. And, also, having seen the accident in Japan, Americans might be more sympathetic that we need to do something about this spent fuel and get it someplace.

So, against that backdrop, we believe the conditions for the progress are arguably more promising than they’ve been in some time, but we’ll only know if we start. And so we urge the administration and Congress to do so and without further delay.

So, let me stop there and try and answer any questions you might have.

GARRICK: Okay, we’ll ask some questions. Henry?

PETROSKI: Thank you for your presentation. Given your extensive experience in both the technical and policy arenas, could you make some general comments about the interrelationship between policy and technology? What is the intersection of policy and technology, and how does each inform the other?

CARNESALE: Well, I mean, that’s a very broad question, and, of course, the only answer is, “It all depends,” because it depends upon the problem. Some problems have high political content, others don’t. This has high political content, which means it automatically has high policy content. But, by and large, it’s an iterate of the process.

You rely upon science and technology, in large measure, to identify what are the options in that domain, and what are the relative advantages and disadvantages of each of them, and how far apart are they? Is there a big different between Option A and Option B? Or does Option A just win out by a hair but would be almost impossible to implement? Then it is, also.

So, by and large, you start with the science and technology, when it’s that kind of problem, but with them recognizing that you need more than, “Here’s a solution,” because it may not be implementable. One of my favorite sayings to classes was, “An optimum policy that cannot be implemented ain’t optimum.” Right? So you need some iterate of process there to do so. It also is important, I have found, and this is a role that a number of us play, I think a role that I have played in many of these issues, is as a translator. You need some people who can speak both languages.

So, on our panel, for example, we had Dick Meserve, former Chairman of the NRC. Dick has a Ph.D. in Physics from Stanford and a Harvard law degree. He can do technology, he can do policy. Ernie Moniz, who served on the Department of Energy but heads MIT’s energy program. So you have some of us who can speak both language when it’s necessary. But then it’s rather--it gets rather specific and it involves tradeoffs. If the technology says, “Look, I’m sorry. That thing that’s easy to do politically--“ For example, doing Yucca Mountain was easy to do politically. Turns out there are a lot more members of Congress who are not from Nevada than there are who are from Nevada. So, politically, that was clearly a lot easier except for the politicians in Nevada. So you just need somewhat of an iterative process.

GARRICK: Okay. Bill Murphy?

MURPHY: This is Bill Murphy of the Board, and I enjoyed your presentation and I very much appreciate the work of the BRC. I have--in 1928, the Nuclear Waste Policy Act set out the strategy to look at a variety of sites--

CARNESALE: Right.

MURPHY: --and they picked a dozen or so and narrowed it down to five, and then narrowed it down to three, and then that process was terminated or derailed--

CARNESALE: Correct.

MURPHY: --by the selection of Yucca Mountain to be the only site--

CARNESALE: Right.

MURPHY: --to be characterized before any of them had been characterized--

CARNESALE: Right.

MURPHY: --to a substantial extent. And I’m curious, in your development of a new strategy that addresses both consensus and technical issues, was this issue of characterizing and evaluating multiple sites addressed by the BRC--

CARNESALE: Yes.

MURPHY: --in your mind?

CARNESALE: Yes. The answer is yes, and we though there should be two parts, or two ways, to get this started. One is calling for, based on what we know now, calling for communities and states that might have an interest in this. Now, you know, if it’s, you know, sitting on the Atlantic Ocean of the United States, well, “Thank you very much. Perhaps a storage site but not a disposal site.” But one is to solicit interest.

The other is to go out and try and recruit. And, but, multiple sites, yes. Definitely. Characterize multiple sites, and that would be part of the consent-based process as you’re going, because you may find out people are not going to be willing--South Dakota example’s a good example. Before anything starts, to say, “By the way, if you find that our shale is a good place to put it, we are ready to sign right now.” They want to know, “Well, what did you find out? How good is it?” What are the politics of doing that? But the answer, the simple answer to your question, is, yes, multiple sites.

MURPHY: Thank you.

GARRICK: Ron?

LATANISION: Latanision, Board. On your slide, I think it was number 7, that showed the fuel cycle--

CARNESALE: Yeah.

LATANISION: --your comment was that storage implied retrievability.

CARNESALE: Yeah.

LATANISION: But final disposition, I'm not sure what the implication is. Is retrievability, from a policy perspective, is retrievability a part of BRC's vision of final disposition or not?

CARNESALE: No.

LATANISION: It's not.

CARNESALE: The answer is no. In other words, that was the distinction that we made that were some sites, in the engineering of those sites and the like, that are well suited to disposal that are not so easy to make well suited to retrievability--

LATANISION: Yeah.

CARNESALE: --and we don't like that tradeoff.

LATANISION: Well--

CARNESALE: Safety first. You want to store it longer because you're not sure? Store it longer.

LATANISION: Yeah.

CARNESALE: Don't try and dig it out of a salt dome after the dome has collapsed.

LATANISION: It seems to me there are two very important consequences of that decision--

CARNESALE: Yes.

LATANISION: --or that thought. One is that there is a school of thought that suggests that this generation's waste may be another generation's--

CARNESALE: Right.

LATANISION: --resources.

CARNESALE: Yeah.

LATANISION: And, secondly, it would seem implicitly that that position would rule out deep boreholes as a consideration, would it not?

CARNESALE: Would rule out--

LATANISION: Deep boreholes.

CARNESALE: --deep boreholes for what?

LATANISION: As a retrieve--huh?

SPEAKER: It would rule them in.

SPEAKER: Rule them in.

CARNESALE: Yeah, well, I don't understand. Why would it rule them out?

LATANISION: Oh. Oh, you're saying retrievability is not a--

GARRICK: Yeah.

LATANISION: Is not a--

GARRICK: Right. Right, right.

LATANISION: Scratch that--

CARNESALE: It’s storage--

LATANISION: Okay.

CARNESALE: --or disposal.

LATANISION: Okay.

CARNESALE: And, by the way, there is--to take your argument about what about future generations--

LATANISION: Yeah.

CARNESALE: --some of this stuff is likely to be stored for a long time. Now if you’re worried about generations, you know, three centuries from now, or two centuries from now--and by the way, more of it’s going to be produced--

LATANISION: Yeah.

CARNESALE: --you know, that--you’ve got to be rather humble about making technological predictions like that. “Gee, the problem is we’re going to run out of uranium--sea water by then.” You know, maybe it’s not implausible. So we do believe we have an obligation to future generations, and the most important obligation of future generations is get some of that stuff down there where it will be safely disposed of.

GARRICK: One question I’d like to hear you comment on--the Blue Ribbon Commission, of course, was primarily a policy commission--

CARNESALE: Uh-huh.

GARRICK: --but you heard a lot of traffic of technical issues in the course of the many deliberations you went through. Do you have, as a nuclear engineer, do you have an opinion on the basis of what you heard, of what the top two or three technical problems are with respect to nuclear waste management?

CARNESALE: Well, as you can see from the report, we found the dominant problems to be political and policy--

GARRICK: Yes, I know that.

CARNESALE: --not--and said so. We, as you know, even in the end, short words, “We know how to do it.” You know, the problem is where? So we didn’t--now, if you say, “Well, there’s some hot button issues,” probably the hottest button issue is reprocessing, and that’s because this has been a hot button issue in the nuclear enterprise for a long time. Whereas, I say, first of all, the neatness counts part, so you get energy, that seems like a nice thing.

Secondly, people forget. President Carter didn’t say there will be no reprocessing in the United States, he said the federal government won’t pay for it. Nobody came forward and said, “Oh, okay, I was on the GESMO Hearing Board, and so I remember it very well.” So we waited to see, you know, was there any interest might this go forward, in which case we’d have to go forward with the hearings to see.

That was their generic environmental statement on mixed oxide fuel.

Nobody was interested because it just wasn’t--it wasn’t economic then. It is less economic now because we found a lot more uranium. Then we hadn’t looked so much, didn’t know as much. It turns out uranium’s in a lot of places. I used to say, “It’s hard for me to believe that uranium is found only in former British Colonies,” and it turns out it’s not. It’s found in lots of places. It’s found in lots of places, and it just--it doesn’t cost that much, number one; and, number two, the fuel is not a big part of the cost of producing nuclear energy. It’s a very small part. It’s the capital cost that’s--I think the fuel and the O and M is something like 15 percent of the cost.

But if you’re going to building an $80 billion facility, turns out that’s very expensive. It would be off the chart expensive if it weren’t for federal loan guarantees. That’s what you’d have to pay for the money. You’re talking about building one full-scale, say, 1,100 megawatt electric power plants requires what the average revenue stream for large utilities is per year. That’s a lot of money. That’s a lot. So, it’s the capital cost, and that’s why people are looking, well, what about small modular reactors? Matter of fact, the Secretary of Energy, or the Secretary of Energy’s Review Board, has just formed a committee just in six months to give some further recommendations on the program for small modular reactors of DOE, and we have our first meeting on Friday.

GARRICK: What’s your reaction, in terms of priorities, between finding a host region, or a host community, versus finding a site, or number 3, an iterative process, between the two? What should we do first?

CARNESALE: What should we do first? Well, you need to do--I think first you try and work with communities. People have asked, “Shouldn’t we--wouldn’t it be more efficient to go out and do some site investigations right before we talk to the communities so they don’t get--“ One of our big problems is people don’t trust you. How’s about you have a bunch of people out there digging holes in the ground with a big sign on the truck that says, “We are from the, you know, Waste Management Program,” and you haven’t talked to them about it? So we actually believe that the talking to communities first is probably the right way to go.

Now, some of those it may not take a lot of talk, but, for example, as I say, South Dakota just happened last week, so they’re--I mean, there’s a quid pro quo, where he says, right, “Fund my university’s research program and it will have a part that’s exploring is this shale good for high-level waste or spent fuel, and that’s okay with me, I support it.” You know, if you would have asked three months ago, what’s the chance of a governor coming forward like that, but I think part of it is looking at the recommendations, knowing that it will--that he’s not going to get it shoved down his throat if it turns out that shale looks pretty good.

GARRICK: Okay. Andy?

KADAK: Thank you. Kadak, Board. I was very taken by your comment about--let me get--see if I get it right, “An optimum policy that cannot be implemented is not optimum,” is that correct?

CARNESALE: No, it was “ain’t optimum.”

KADAK: Ain’t optimum.

CARNESALE: That was not in the report. That’s--

KADAK: Okay.

CARNESALE: That’s me.

KADAK: It’s a personal comment.

CARNESALE: Yeah.

KADAK: The question I have is, you remember David Leroy spent a lot of time trying to find volunteer sites, and you’ve talked to him, I’m sure. And what is the difference between then and now, where we think this might actually work?

CARNESALE: Well, I think there are several things that are different, some of which I mentioned, but one of which is can we have a system where they don’t have to give an absolute “yes” before you even start looking at the site, before they know the whole story. So we would provide some resources for them that they could do their due diligence, so to speak.

Secondly, we recognize that it may take substantial resources to get consent. And some of it isn’t necessarily payment, it can be there will be facilities there that will provide X jobs. We will, with regard to the transportation, if you know where are the storage canisters made for WIPP, where are they manufactured? Carlsbad, New Mexico. So, there are a number of things that were done to make this attractive. Now they had to be making--some made someplace, but you have to give at least the government the flexibility. It doesn’t have to be the lowest bidder. You know, you can try and work something out, recognizing that this is still an inexpensive payment to provide the jobs there. It might cost you a little more. It might have been cheaper to produce them in South Korea, but that wouldn’t have helped with your biggest challenge, namely finding a site.

KADAK: Okay--

GARRICK: Follow-up?

KADAK: How long, you know, given that we have to have some legislation to implement--

CARNESALE: Yeah.

KADA: --a large portion of this, how likely do you think this will happen in the next year?

CARNESALE: Well, in the next year--Lee Hamilton was asked that question and said, “I’m hopeful.” Long experience--but, the fact is, first the Department of Energy has formed a group under Peter Lyons, the Assistant Secretary for Nuclear Energy, given only about six months to recommend to the Secretary, “Okay, here’s what we think about the report in terms of what should be implemented.” So I don’t think anything much is going to happen before that because the Department of Energy isn’t going to be the champion.”

I can say that our recommendations already have received some very strong signs of support in the Senate. In the House there’s still a very large group saying, “Yucca Mountain. Yucca Mountain. The president screwed it all up. We should go into Yucca Mountain.” That will probably ease some after the election, I guess, either because the current president is re-elected or because he’s not, and then it will become less of something to hold over his head as it’s all his problem.

So that’s the part, the hopeful part, you know, because right now if you just look at the tea leaves--if you only look at the tea leaves of today, boy, it certainly doesn’t look good in the House, but you don’t have to be a hotshot political analyst to get, “Well, yeah, but, wait a minute, I understand that.” So we got two things; you need the election, but you also need the Department of Energy to come forward and say what it wants to do.

GARRICK: Final question. George.

HORNBERGER: Now, you recommend--the recommendation, of course, is to have a new entity--

CARNESALE: Yeah.

HORNBERGER: --focused on waste management, and I could see that, certainly the first five recommendations went right to it, but the last three, I just wonder if this is a gray area. Transportation.

CARNESALE: Yeah.

HORNBERGER: Research on nuclear technology. International issues related to non-proliferation. How do you see those things interfaced with the new entity?

CARNESALE: No, this would be an implementation of the waste management program, period. That’s it. These other things are--essentially, we don’t expect a non-proliferation policy to go to this agency that will remain the White House, the State Department, the Department--you can’t have an independent agency making policy decisions about things other than their scope. Now, their scope to us sounds very big, and it is, and in terms of this problem it’s very expansive. In terms of the policy issues facing the United States that have the word “nuclear” in there someplace, that’s a lot.

HORNBERGER: But transportation is pretty integral.

CARNESALE: Well, yeah, but transport--no, but transportation, we would expect them to be responsible for transportation. Yes. Because that's an integral part of the waste management program, whereas non-proliferation policy is not. We would expect them to take non-proliferation into consideration, just as our commission--if you look at our charter, which is in front of the report, the President, in his letter, not just in our charter, said, "I want you guys to take into account," and on the list, I think number 1 or 2 was non-proliferation implications, of what you do.

GARRICK: Okay, well, thank you. Thank you very, very much.

CARNESALE: You're welcome.

GARRICK: Okay, Bill, go ahead.

BOYLE: Okay. Thank you for this opportunity. I'm William Boyle with DOE's Office of Used Nuclear Fuel Research and Development. I'm going to present an update on the activities of that group. I'm going to focus on some things that have happened since the last time we met, approximately two months ago, in January. Since then the Blue Ribbon Commission Report has come out. We've taken more steps to flesh out exactly what we're going to do with the extra funds we received in the fiscal year '12 appropriation, which came out shortly before Christmas; and, also, since the last time we met, the president's fiscal year 2013 budget has come out.

And here are some statements by the Secretary on the BRC, Blue Ribbon Commission's recommendations: "The DOE recognizes that the report represents a critical step toward finding a sustainable approach to disposing used nuclear fuel and nuclear waste." The DOE acknowledges that, "the specifics of a new strategy for managing our nation's used nuclear fuel will need to be addressed in partnership with Congress." That flanges up to the presentation by Chancellor Carnesale on how much legislative action might be needed. And, "The Department will work in parallel to begin implementing the new strategy by taking sensible steps towards the implementation of the near-term recommendations."

Okay, in the BRC report there was an assessment of the current DOE nuclear energy used-fuel disposition program, particular in Section 7.8, related to the near-term steps. And the BRC report confirmed, "the importance for DOE to keep the UFD program moving forward through non-site-specific activities, including research and development on geological media, and work to design improved engineer barriers." And the BRC report recommends, "the continuation of activities currently being conducted in the used nuclear fuel disposition campaign, including identify alternatives to some of the problems," as in the discussion between the--I think it was Professor Petroski and Chancellor Carnesale--"the intersection of policy and technical work," and Chancellor

Carnesale mentioned that the technical people need to identify the alternatives and the pluses and the minuses.

The report recommended, “Research and development on transportation, storage and disposal options for spent nuclear fuel from existing and future fuel cycle.” And a further recommendation, “Other non-site-specific generic activities, such as support for and coordination with states and regional state government groups on transportation planning.”

Now, as to the question of will there ever be another organization, will it continue to be DOE if there is another organization, what form will it have? Well, there is some good news here; that the work that’s being done today, the results of the analyses, the results of the tests, don’t care, right? They are what they are. They can serve as inputs to whichever organization is responsible for whichever parts of the problem. So I view that as good news, and that’s what this slide is supposed to represent, that the work that’s being done today by the used-fuel disposition campaign will be available to whichever group gets responsibility for whatever in the future.

So, the next few slides will deal with the fiscal year 2012 activities, and storage and disposal and transportation. For those who can recognize the difference between the black and the blue, we did, in the fiscal year

2012 appropriation, get more in the appropriation than had been requested in the president's budget a year ago February, and as someone who has the chart that Chancellor Carnesale showed, that wasn't the tradition for the Office of Civilian Radioactive Waste Management, that this is a change, and so the black items tend to be those that we had planned all along, ever since a year ago February, as part of the President's budget, but the blue items are the items that we're now adding because of the additional appropriations we got in the December appropriation bill.

So, what we're doing today is we are laying groundwork for evaluating consolidated storage, and building on the previous DOE and industry work on licensing efforts. But this first blue item, it does flange up to the suggestion of the BRC report that we interact with the potential host communities and--

GARRICK: Bill, let me ask a question right here because it's so timely, it seems to me. And I thought the example, the North Dakota example, was a classic case in point, and that is the issue--is the issue really communication, or is the issue, "What is the deal?" And who's working on the deal?

BOYLE: Yeah. Probably in the end, my personal opinion, I'm not speaking for the Department, it probably will get down to, well, what's the deal, right? But I believe--

GARRICK: And why aren't we--why aren't we creating that? Why aren't we--

BOYLE: Well, I'll get to that, and--

GARRICK: Yeah.

BOYLE: --and I believe Chancellor Carnesale actually mentioned it, in part. The Congress did request a report from the Department in six months after the BRC report on what the Department intends to do about the recommendation. So people are working on that, and I do plan on--I have some more words to say about that later.

So, the next--the second large bullet is we are doing research and development to understand the potential degradation mechanisms in long-term dry cask storage, since we're storing it for much longer than people had originally anticipated.

Okay, next slide, slide 6, it's--you can see that there's more blue on this slide than the prior slide, but in fiscal year '12 we had planned all along to gather data, to continue the support of licensing of transportation casks, required to transport the used fuel, but because of the increase in appropriation, we are revisiting the recommendations of the 2006 National Academy of Sciences report on transportation. For those of you who have read the report, the review was done at a time when Yucca Mountain seemed relatively imminent that transportation was going to occur, so I think the review in 2006 took place under those circumstances, but we’re going back and looking at the recommendations and seeing how many of them still apply, and what steps the Department might take.

The Office of Civilian Radioactive Waste Management used to have interactions under Section 180(c) of the Nuclear Waste Policy Act for interacting with local and tribal safety officials, and we are looking at restarting that. And we are also doing a technical study, this last bullet, on if the task ever came to remove the spent fuel from what I’ll refer to as “the orphan plants,” those that are no longer generating power--if the task came, let’s take their spent fuel first, we’re looking at the various technical aspects of that.

Next slide. In disposal, we are continuing. We had always planned on conducting our research and development on generic geological media, and that continues to go forward. Because of the increase in appropriation, where the three blue sub-bullets at the bottom, we’re putting aside some extra money, looking at the behavior of salt in response to the heat-producing radioactive waste, to put aside some funds for further investigation the deep borehole disposal concept and furthering work with international partners in granite and clay.

BOYLE: Other strategic near-term activities. We had always planned on initiating work on standardized cask systems to enable storage transportation and disposal without repackaging. These are the sorts of studies that Jeff Williams described at the January meeting. And there was also explicit money in the appropriation for working on developments of models of potential partnerships to manage the waste.

So that was fiscal year 2012. Since our last meeting, the President's fiscal year 2013 budget has come out, and the quotes, first two quotes, are from the President's budget. And when the commission is mentioned here, it's the Blue Ribbon Commission not the Nuclear Regulatory Commission. "The Blue Ribbon Commission's near-term research and development-related priorities, aligned with how the funding is allocated within the used nuclear fuel disposition program in FY 2012." And the second quote is, if you will, the fiscal 2013 congressional budget requests builds on those efforts, that, "It's in the view of the Department that we're all ready for the near-term actions recommended by the Blue Ribbon Commission that don't require legislation." We, in good faith, are taking them into account and it's already affected the work we're doing.

And then last month, this gets at what Chancellor Carnesale mentioned, and I'll give more than just this quote, but this February 15th, the Secretary of Energy was at the

Volvo plant in Georgia for the kickoff activity there, if you will, and the Secretary said today, “I am announcing an internal working group to assess the Blue Ribbon Commission recommendations and develop a strategy that builds on its excellent work.” And more detail on that internal group, it’s an internal working group, chaired by Assistant Secretary Pete Lyons, that will also include representatives from the Office of Environmental Management, DOE’s general counsel, Congressional and Intergovernmental Affairs, and the National Nuclear Security Administration.

Dr. Lyons has asked Phillip Niedzielski-Eichner, a respected official who has worked on nuclear issues for many years to lead the effort. He will report to Dr. Lyons. The working group will draw resources and expertise from the across the Department, as needed, and, as I had mentioned earlier, it was one of the congressional bills, requested a report within six months of the Blue Ribbon Commission reports, so approximately July.

And here’s a budget--here’s bullets related to the fiscal year 2013 budget. These are cut-and-pasted from the President’s official submittal. This is what’s being proposed for the used-fuel disposition campaign at the highest level in fiscal year 2013, which is to continue the systems analyses, along the lines of what Jeff Williams talked about at the last meeting; continue R&D on extended storage, that's a challenge today; complete plans for a test facility to support the technical basis for extended storage; expand interactions with potential stakeholders on transportation; look at the National Academy of Sciences' report on safe transport and see what actions we might need to implement there; and continue our generic work on geologic disposal. So, those were the slides I had.

GARRICK: Okay, Rod.

EWING: Ewing, the Board. Bill, several times you talked about taking advantage of international experience, but you didn't give any details, so what are the mechanisms or strategies that you'll pursue in order to take advantage of this experience and knowledge?

BOYLE: Yeah, it's--we, I believe this came up at the January meeting. We've been accepted as a member of the Mont Terri work in Switzerland, which has--it's in Switzerland, but many nations participate. But I think that's an example of the type of thing we want to do, is when the costs are shared by multiple countries, it becomes easier on all the countries, so we're participating in Mont Terri, we're just getting started. We reinitiated our membership in Decovalex, which is, again, a very large multinational effort to look at the heat-related effects of repositories, so as a general--our first approach is, generally, to look around and see is there an existing framework that exists that we can join and benefit from those activities? And then once we've joined these frameworks, whether it's Decovalex or Mont Terri, then, by participation in those efforts, we necessarily have to fund work ourselves at national labs, typically, you know, to be a contributor to the effort, so--

EWING: Right, so these are projects that are ongoing, and there's a long history in Europe of these cooperative efforts, and there's also a history of DOE participation fluctuating quite a lot over--

BOYLE: Yes.

EWING: --over time. But above that, wouldn't it be wise to really look at these international programs, do peer reviews, ask the question, "What were the major issues for clay, for salt--"

BOYLE: Oh, yeah. Yeah.

EWING: --and so on, and that would come from your side.

BOYLE: Yeah, yeah, and we do do that, and it's--

EWING: And who's doing that?

BOYLE: Well, it's the used-fuel disposition campaign. Last March we produced our, for disposal, our research and development road map--

EWING: All right.

BOYLE: --where the--Mark Nutt (phonetic), who's in the audience today from Argon National Lab, he was the lead author. He presented to the Board on this report--

EWING: Right.

BOYLE: --in Salt Lake City in September.

EWING: Right.

BOYLE: Inherently, as part of that effort, they looked at, well, okay, we’re not the first people to look at argillite; you know, the French have, the Belgians have. We’re not the first people to look at granite; the Swedes and the Finns have. What’s their experience? What did they find to be important, and they inherently used that, the looking at those other programs to come up with, well, what do we think are the major items? Like if you were to go and look at that report, the disturbed rock zone, you know, how it behaves--

EWING: Right.

BOYLE: --was an important issue for us, and I’m pretty sure if you go ask the French and the Swedes and the Finns, that they might say the same thing. So I think, inherently, we do do that review as part of our day-to-day effort.

EWING: Okay, thank you.

GARRICK: Andy, did you have a question?

KADAK: Yes. Yes. Just a follow-up to that question. Is that report publicly available?

BOYLE: I don’t know if it is or it isn’t. Mark Nutt’s nodding his head. And then I was going to say, even if it weren’t yet, I’m not aware of any reason why it would not be, so--

KADAK: Okay. I think as a Board we should follow up and see what the lessons learned are, to make sure that we capture them. But my question really gets to the transportation sector, and that is, as you, I'm sure, are well aware, the private fuel storage group did a lot of testing on rail cars and working with the railroads very closely, in terms of designing rail cars that are suitable for shipping spent fuel. Can you describe what interactions you've had with PFS to capture some of their experience?

BOYLE: I have probably not that much right now under used fuel. I'd have to turn to Ned Larson, who used to be involved with our transportation group, and ask him what, if any, interactions they had with PFS, and I'm assuming there were, with PFS back when that project was more active than it is now.

KADAK: I'm looking at this now.

BOYLE: Yeah.

KADAK: You're saying you're going to be doing this stuff--

BOYLE: Yeah.

KADAK: --which sounds like you might be repeating what they've already done.

BOYLE: Yeah, well, people will look into that. And let me speak to some of these efforts that are a result of the increase in appropriation. Some of the activities are already underway, and others aren't underway yet. We're still in the process of, you know, getting the procurement paperwork in place and getting the people on board. I don't know the exact status of this one.

KADAK: One final quicky. Can you find or describe this test validation complex?

BOYLE: Yeah. Essentially, if you will, it's what facility, facilities, new or modified existing facilities, should the Department have in terms of getting at these technical issues related to the longer storage of spent nuclear fuel, and including the longer storage of higher burned up spent nuclear fuel. It's a--should we have the ability to test full storage casks in a hot cell or something or other, and so it's an effort to look at that to try and determine what do we need to know, what's the best way to figure, you know, to measure that, to, you know, get at the technical issue, and what facilities might we need.

KADAK: Thank you.

EWING: Could I follow up on that? Again, going back to international experience, have you looked at facilities in France and other countries that do this type of thing to see what they can do--

BOYLE: Yes. Inherently in this, all the efforts related to storage, we, the DOE, participate in this international effort, the ESCP, and the Nuclear Regulatory Staff are here today, they participate; the Electric Power Research Institute, they participate; the Japanese. I do believe the one thing that does come up is the topic that Chancellor Carnesale brought up. Although these other facilities are certainly available to the United States, it might, for other reasons, the United States choose to develop the capability in the United States for the purposes of having the abilities themselves, or fostering continuation of expertise and that sort of thing, so that, I'm sure, that would eventually get considered in our path forward.

GARRICK: Okay, Howard.

ARNOLD: Arnold, Board. I want to pick up on the standardized containers. We have a checkered history of several false starts in that regard. What do you foresee actually happening there?

BOYLE: Well, and as I recall, this came up two months ago when Jeff Williams presented the Department's rationale for wanting to do analyses of the standardized devices to facilitate a look at the entire system, and then multiple members from--I think, John Kessler from EPRI spoke, and Adam Levin spoke from Utility, and they said--I'll paraphrase now--sure, they loved standardized canisters, as long as they're the ones they use today, and the bigger the better.

And so what we're doing is we're doing technical analyses to look at. We’ll have available the pluses and minuses for policy makers, if they so want to choose to engage on this topic, and perhaps--because it is--the contracts are available. The Department went to the other parties in the contracts and said, “Look, we would like something different done,” and then a negotiation would occur. And prior to doing those negotiations, I’m sure the Department would want the pluses and minuses from these sorts of analyses.

ARNOLD: Just a follow-up statement. It appears to me that when this, perhaps, fed corp, gets set up, this will be a major item on their technical to-do list, and, hopefully, it won’t be too late because what happens, of course, as years go by and fuel gets put into containers of various sorts and repackaging it gets harder and harder as the time passes.

BOYLE: Yeah, that is true, we have what we have today, and every day that goes by we have more of it, and so--and, therefore, it makes the solutions different the longer you wait then. So I would guess then that whatever the organization that gets responsibility for the waste, particularly if they want a lot of flexibility, they would actually prefer smaller standardized canisters, but--

GARRICK: Bill, did you have a question?

MURPHY: This is Bill Murphy of the Board. Thank you for your presentation. You spoke in a number of contexts about the importance in your program of research and development on alternative geologic environments, and I wonder, having worked on Yucca Mountain for over 25 years, I can think of lots of hard technological problems that persist for Yucca Mountain, in addition to the hundreds of contentions that were levied against the license application. I wonder to what extent that your R&D program on alternative geologic sites is addressing some of those technical problems.

BOYLE: Well, to the extent that they were restricted to that site, nothing, right, which we know enough about Yucca Mountain, much more so than other generic sites, if you will, but for a concern that was raised about the Yucca Mountain license application that, inherently, really isn't restricted to Yucca Mountain, like the claim that the total system performance assessment is a "black box," right? You know, it would probably get that claim for a total system performance assessment at any site. So we can do efforts there, and we are working on--and Peter Swift will talk about total system performance assessment--but I'll point out it's not just the Yucca Mountain license application we can look at now, and questions about it, the Swedish license application.

The SKB has been kind enough that they hired an international review group to come in, and all of the questions and responses are all posted in English, eventually. You can find them at an SKB website. So we can gain insights into what questions are raised about a repository in granite. You know, they sought a license application somebody submitted, so there are ways to get at some of the questions. And, inherently, I would say my experience at Yucca Mountain, and also my experience at looking at some of the questions posed to SKB on their license application, it’s usually useful to, when looking at the question, amongst the things you should ask yourself is in what difference would it make, right, you know? Some questions are probably more important than other.

GARRICK: Ali?

MOSLEH: Yeah, Mosleh, Board, and thanks again for your presentation. Following up on this line of question about the generic studies, how do you bound generic studies, because you can make them open-ended, and a lot of questions, as we have seen in the case of Yucca Mountain, could continue for years--

BOYLE: Right.

MOSLEH: --but you have to have a sense of, you know, when is enough to be able to do comparative assessment of different alternatives or enough foundation so that we have base to start with when we are looking for site, how do you bound?

BOYLE: Yeah, well, that’s a good question, and so, part, I believe we’re lucky in that we were sent back to square one with essentially all the other geologies because it does give us an opportunity to try and develop the models simultaneously with the same sort of rigor and degree of development so that we don’t have an unlevel playing field of comparing a repository in geology a versus a repository in geology b. And but there is an issue here that’s tough to get at. As long as it remains generic, it would--you always have to have a ground truth.

You always have to look at it, okay, what properties do people measure and report for geologies of this type? Like, for example, we can look at what have the Swedes used in their total system performance assessment? What do the French use? There has to be some basis in reality to the numbers because otherwise you could just put in whatever numbers you like and get whatever answers you like, and so that is always inherently a bit of a challenge with respect to the generic studies that tend to go away when you get into more detailed site-specific studies.

GARRICK: Bill, can you give us a little better resolution on the appropriations, or the funding? Does the $60 million that you site in your presentation include the funds that you didn’t expect to get?

BOYLE: Yeah, okay. Now this is always complicated.

It’s when the Congress appropriates, it appropriates in what I’ll term “gross dollars.” Within the Office of Nuclear Energy, apparently there’s been a virus--well, no, I shouldn’t put it that way. There’s various taxes within the Office of Nuclear Energy, so when you see the appropriated numbers, those are never the numbers that end up being spent at national labs or private industry.

We have--when I actually saw the complete listing of the various taxes and the percentages associated with them, it reminded me of my property tax bill at home, you know, such a percentage for the library district, such a percentage for the schools, and on and on and on. But to make this long story short, within the Office of Nuclear Energy, those taxes, the largest of which is probably for the Nuclear Energy University Program, total out to about 30 percent, plus or minus, you know? It all depends. So the $60 million really isn’t 60 by the time, you know, the money goes off to these other places. So, with that, we’re somewhere in the neighborhood of $30-plus million. And I could give further detail. We’re starting, historically--

GARRICK: I was mainly interested in what you received for the Blue work in your proposal--or, in your presentation.

BOYLE: Yeah, I do have some more detail on that, and some of it’s not completely in place yet, as I already mentioned, like--and this just represents this fiscal year with no bearing on what we might get in future fiscal years. For the studies to resolve the stranded fuel, that’s $400,000. Design concepts for consolidated storage, $2.8 million. Communication packages and community involvement, $500,000. Standardized cask systems, $5 million. Document previous siting efforts in America and abroad, $500,000. So that--

GARRICK: Thank you. Yes, Andy.

KADAK: Is this available?

BOYLE: Anything is--

KADAK: No, no, I’m just trying to figure out how do I find this information because that’s a level of detail that I have not seen--

BOYLE: Yeah, yeah, and--

KADAK: --seen before.

BOYLE: --we’ll--it’s probably best that I have Jeff Williams transmit the appropriate documents to Nigel, and then--

KADAK: Okay. The question I have is really the result of an exchange that Monica Regalbuto and I had at the last meeting, and that was--and it relates to your comment, and Howard’s comment, about the fact that we’re continuing to add spent fuel into dry cask storage. Every year it gets more and more, loading hotter assemblies, higher burn-ups, and the exchange basically dealt with the question of, instead of trying to remake--

BOYLE: Yes.

KADAK: --waste package, why don't we--

BOYLE: Yes.

KADAK: --look for a repository--

BOYLE: Oh yeah.

KADAK: --that is capable of dealing with the waste package?

BOYLE: Yeah, yeah.

KADAK: Is there anything going on--

BOYLE: Yes.

KADAK: --in that area?

BOYLE: And it's buried in one of these other titles--

KADAK: Thank you.

BOYLE: --not yet--yes. Essentially, for those who were not at the January meeting, there's a lot of spent fuel today that's in dual-purpose canisters that would be a challenge to dispose of any time soon and anything other than what was referred to as an open repository.

KADAK: Geological--

BOYLE: Yeah. So the question that Dr. Kadak posed is are we doing any work to look at, technically, what can we do to dispose of the existing DPC's today? And the answer is, yes, we are.

SPEAKER: Good.

BOYLE: I don’t even know that we have that, you know, the money in place yet, you know, and that sort of thing, but we--I can get that to you. We certainly have a statement of work for it.

GARRICK: We’re right on schedule, and if there’s one more burning question, we’ll take it, but, otherwise, we’re on schedule for our first morning break, and we’ll reconvene at, I think it’s 10:05, and we’ll hear from Bill again. So, let’s have our break.

(Whereupon, the meeting was adjourned for a brief recess.)

GARRICK: Okay, I think we have a quorum, so go ahead.

BOYLE: Thank you for this opportunity. William Boyle again, DOE’s Office of Nuclear Fuel, Research and Development, and I am going to give a presentation on siting criteria for geologic repositories in the United States. And if you’ve looked at the slides, I would characterize them as a very abbreviated history, up to a certain point, told mainly through the reports that existed, very commonly using quotes from the reports.

And I would like to acknowledge two individuals who produced much more detailed and much more history than I am presenting in these slides, one of whom is here today, Dr. Michael Voegel, and the other is Dr. Thomas Cotton. There really is a long history of siting criteria in the U.S., and

I'll go through some of it.

Another point, I made my notes a while ago on what to say, but, ultimately, what I want to get at in this talk is something that Chairman Garrick mentioned in his initial remarks when he was mentioning the Nuclear Regulatory Commission presentations in the afternoon. Have we learned anything in the previous efforts dealing with siting criteria? And I'll give my own personal view of that.

So the first report I start with, although arguably certain wastes were being handled in certain ways before this time, you know, up at Hanford and that sort of thing, but with respect to high-level waste, I view a good place to start is the 1957 National Academy of Sciences report. And for each of these reports I discuss in my presentation, I usually give their titles at the bottom of the slide, and most of them are findable through the internet, and I recommend them to people, in particular, this 1957 National Academy report.

The first quote is, "Radioactive waste can be disposed of safely in a variety of ways and at a large number of sites in the United States." So, 55 years ago that was a view. I think we just heard Chancellor Carnesale mention that the challenges are more political and not technical.

Another quote is, "The most promising method of disposal of high-level waste seems to be in salt deposits."

They were largely considering liquid reprocessing wastes, but you'll see in a later quote that that wasn't all that they considered.

The third quote seemingly might be at odds with the first one. "It will not be possible to dispose safely of large quantities of high-level waste in many large sections of the country." The first and third statements are not in conflict because we have an immensely large country, so even though large parts of it might not be suitable for the disposal of waste, that still leaves, nevertheless, other large areas that are, too.

This fourth quote, the answer was in response to a question that the authors of the report said that they had received before, and the question posed was, "Would it be possible to dispose of the high-level waste within 25 miles of Tarrytown, New York?" Now, being a native of California, I didn't immediately know where Tarrytown was so I went to Goggle Maps and it turns out it's what I would call a suburb of New York City. It's, coincidentally, also the location of "Sleepy Hollow" from the Washington Irving story, and about a hundred years ago it was also the residence of John D. Rockefeller and Jay Gould. And even today I would characterize it, based on the statistics in Wikipedia, as "above average income."

Now this statement that it could not be disposed of anywhere near that site, the report does not expand on it, it’s based upon my quick review, and it’s possible that it’s non-technical reasons why this answer is being given. It’s possible that, as represented in the 1982 Nuclear Waste Policy Act, this report in ’57 realized you might want to take population density into account in siting, which the NWPA explicitly does. Or, it might be political reality that there’s no way that you’re ever going to get it in a neighborhood like that. I don’t know, but it’s possible.

Another quote--the report really dealt with a whole lot of issues, one of which was, and I’ll put it in my words, “You tend to remove transportation as an issue if you co-locate your processing facilities and your disposal facilities.” But, with respect to the Savanna River Plant, which already existed at the time, they said, without saying why--I think they might have said geologically why. I believe that the groundwater path, I think, ends up in the Atlantic Ocean. So it was, essentially, just a time delay and it would all end up in the Atlantic, and I think they didn’t care for that. But they said, “Ultimate disposal at Savannah River appeared gloomy.”

They considered things other than geology, hydrology and the earth sciences, with this next bullet. They said, “You know, if you change the waste form from liquid to a solid, you have other options.” And the last bullet deals not only with transportation but with economics, cost. And so as far back as 1957, this report, I think, did a very good job of identifying both the earth sciences issues, if you will, for the problem that they had at that time. Other non-technical considerations, including, potentially, politics, cost and other--so the criteria that one should take into account I think people have done very well at identifying for a long time, and I think you'll see that in Ken Skipper's talk, as well, which I looked at when I got here this morning.

So, but, now one thing, these authors of this NAS report, they were not charged with actually finding a site, nor, to the best of my knowledge, were they charged with coming up with a process of how to process these criterias that would lead to the selection of a site.

So, going forward in the history, eventually one of the predecessors to the Department of Energy, the Atomic Energy Commission, the AEC, they selected a salt mine near Lyons, Kansas, as a repository, and they were wanting to go ahead with it as a repository for high-level waste, but it turns out there were many technical concerns, and in the early 1970's, the Atomic Energy Commission abandoned the project.

Now, I will not claim to have done an exhaustive search of any records or history to try and find, well, how did the AEC decide upon Lyons? What process did they use? What did they consider? Who did they talk to? What trade-offs did they make? It’s not immediately findable easily via the internet, so I would offer it up as, in my eyes, this represents a case where I think Chancellor Carnesale, in one of his responses earlier, referred to the technicians. This was a technician’s answer, “Oh, you want a disposal? We like salt for various reasons. We found one in Kansas, let’s go ahead.” Perhaps to the detriment of a process, or as--the word that the BRC report uses, is an “approach” of how to deal with this information, and the public, and in what ways.

So, the next slide, and it’s good that you’ll see, in my next slides, that it’s good that you asked the United States Geological Survey, USGS, to be here as well, because by both practice and law they have had a long role in looking at siting for nuclear waste repositories.

In 1972 the Atomic Energy Commission asked the Geological Survey to look at media other than salt, and as had mentioned earlier, by the way, the report that this comes from is at--well, it’s at the bottom of the page, and the USGS does a very good job of making most, if not all of these reports, available online, and you can find them.

But the five modes of disposal that were to be considered were very deep drill holes, a geometric array of shallow to moderate-depth drill holes, shallow mine chambers, cavities with manmade engineered barriers, and explosion cavities. And the report cited 30 previous reports on geological disposal and concluded that knowing what the water is doing is of paramount importance, which is probably true for all repositories. And I’m told that this is actually the report that first publicly recommended consideration of the unsaturated zone in the Great Basin of the Western U.S. But, again, as with the other studies up to this point, the USGS was--they weren’t tasked with finding a site, nor were they tasked with coming up with a process to interact with the public, or a process to consider these sometime conflicting inputs.

The next slide had to do--I see my reference is gone, but it had to do with work done by another predecessor of the Department of Energy, the Energy Research and Development Administration, ERDA, and the National Waste Terminal Storage Program. And here they did specifically begin a search for possible repository sites. They considered three geologic medias, salt, argillite--or, clay shale, if you wish--and crystalline rocks. And now they added something that’s inherently not related to the earth sciences but, nevertheless, a relevant factor. They decided to examine federal sites that were previously contaminated from weapons-related activity. They identified potential areas in 36 states, and concerns from the 36 states caused reconsideration of the scope of the search, and so no sites were picked from this process; and, again, as far as I can tell, they did not have a process for interacting with the public, or publicly stating how they were going to handle the different inputs.

Another report by the Geological Survey came out in ’78 by Bredehoeft, England, Stewart, et al. I believe--I think John Bredehoeft has presented to the Board before, and I’m pretty certain Ike Winograd, one of the other authors, has as well. In 1978 the Geological Survey was confident that acceptable geologic repositories can be constructed, much like the 1957 NAS report. The inability to predict with numerical models can be offset, in part, by adoption of a multiple barrier defense and depth philosophy. The USGS brought up there were many questions concerning the behavior of rock salt that must be resolved, and in particular, its high solubility. And because of that, in part, they recommended system examination of media other than salt should continue because that had already been started.

KADAK: Excuse me, I’m just wondering, where is this going to take us?

BOYLE: I’ll get there.

KADAK: And just that last bullet, where you said, “Any other site but salt should be considered.” How does that affect your thinking today?

BOYLE: Well, I'll get there, but I'm glad you stopped me for a second. And again, this group also was not--they did not produce a site, nor a process for how should we consider multiple sites, how should we process the information and interact with the public. I'll get there. I just want to show in part what a rich history this is and how many groups have been involved in it, but I'll get to the point.

In 1978 there was another National Academy of Sciences report on geological criteria for repositories for high-level radioactive waste, and came up with a listing, explicitly, of geo-economic factors, geometrical and dimensional factors, geologic stability factors, hydrological, geo-chemical, all listed. They even introduced the concept of exclusionary criteria--if the following is present, or not present, it's a no-go.

So, again, they readily came up with the technical criteria, but this group, again, they weren't charged with finding a site and, therefore, did not; nor did they come up with a process for how to interact with the public and consider multiple sites, and sometimes conflicting information.

Another report in the ongoing continuing history was--it's a U.S. Geological Survey reference listed at the bottom but it was funded in part by the Department of Energy as well. It was a multi-agency effort, if you will. The 1980 earth-science technical plan working group deal with criterion factors. For the 48 contiguous states they divided them up into provinces, regions, areas and sites, getting smaller and smaller, and much like the 1978 NAS report on the previous slide, they were able to come up with these technical factors that might affect the siting of a repository for the rock. There were nine factors; groundwater, tectonic, resources--but in their general considerations they said, “It will be difficult to develop a universally acceptable set of criteria.” You know, applicable to all sites under all conditions, you know, and that was their view at the time, and there are probably people who still believe that today, but they also, other than setting this framework that would have allowed people, if they had proceeded down this path, to choose provinces, regions, areas, sites. There was no site selection that resulted from this, nor was it explicitly explained how the interactions would take with the public.

That same year there was the Environmental Impact Statement, EIS, that looked at alternatives. This is the very large report that looked at sub-seabed disposal, shoot it into outer space, but, in the end, recommended mined geologic disposal, and specifically had considered salt deposits, both bedded salt and dome salts, granite, shale and basalt. But because it was an EIS, it was aimed at finding a site, nor did it explicitly generate a process for interacting with the public or how the different factors should be weighed against--what weight should they get against each other?

Same year there was yet another Geological Survey report, and it continued with the concerns of the USGS with salt, pointing out that it’s worldwide, it is a resource under many circumstances, but also it’s a geo-mechanical stability, and did point out that crystalline rocks as repository sites had certain favorable attributes, including that they’re widespread in the United States. They tend to be stable geologically, and other than the fractures, which we’ll hear talked about this afternoon, they tend to have low permeability.

And, finally, we get to 1982 and the Nuclear Waste Policy Act, and I think this gets at the heart of the question, what had people learned by this point? That if you go back and you look at the Lyons, Kansas example, and other efforts, they were largely technically focused, and I’ve said on many of these slides, they did not explicitly address what processes would be used for weighing the different information and how to interact with the public. And so by the time you get around to the NWPA, the Nuclear Waste Policy

Act, it is very process oriented. Even for the President of the United States and the Secretary of Energy, a lot of the Act actually, you know, there are the technical considerations, but now it is process focus.

And Section 112 of the Act required that guidelines be issued and there be--the DOE consult with the affected governors, an explicit requirement; that the Secretary nominate at least five sites as suitable for characterization for the first repository; the Secretary would have to ultimately recommend three sites and the President would review the recommendation. So the NWPA really now, I think, people are starting to learn the lesson, this isn’t only a technical problem, that there is a very much more fundamental process issue here--how do you deal with a country as a whole, and certainly the affected states and local areas?

And as some examples of part of the process are some quotes, where I could fit it in, from the NWPA, the Nuclear Waste Policy Act, but it explicitly required that the DOE consult with the Council on Environmental Quality, CEQ; the Environmental Protection Agency, EPA; the Geological Survey, and interested governors. It even gave a role of concurrence on those guidelines to the Nuclear Regulatory Commission. And the Act specified that the guidelines should specify detailed geologic considerations, shall specify factors that qualify or disqualify a site, include various technical factors, but also, when you get to the last part, proximity to population, also back to, you know, its relationship to the Atomic Energy defense activities, the Act take into consideration the proximity to the waste, factoring in transportation, shall specify population factors that will disqualify any site, consider the cost and impact of transporting, consider various geologic medias, and use guidelines; have a formal process for recommending the sites.

So in all this, you know, the NWPA required this, and it resulted in 10 CFR Part 960, which are the guidelines DOE was going to use for this identification of sites and recommendation and selection of sites, and I would submit that 960.4 and 960.5 are in the long tradition of identifying the technical things that matter, but 960.3 was it represents the now realization, you know, that the process is every bit as important as the inputs to the process, that the technical and policy people consider.

So here, by the time of the issuance in 1984 of 10 CFR 960, there was both the process and criteria that could be used to identify, nominate, recommend and characterize sites. And it was implemented. And that's pretty much where the history of my history today stops. And a brief subtotal of the lesson learned is it was always with the technical people early on not only could identify the technical considerations for a repository, but also things not related to the rocks and the water, cost, population density, political concerns. And I believe what was finally learned after a couple decades was, okay, as long as you have that information, what are you going to do with it? How are you going to interact with the affected parties? How will you weigh one factor versus another? So that’s one point learned.

Now, subsequent to all that, there is other things that happened, and that’s what I want to bring up on this slide, that the Nuclear Waste Policy Act led to an EPA regulation, which is 40 CFR 191, right, and which led to an NRC rule, 10 CFR 60, which led to a DOE rule, 10 CFR 960. They were all--I link them together. Then, as the years went by, the Congress asked the EPA to interact with the National Academy of Sciences and come up with a Yucca Mountain specific rule that led to three more rules, all specific to Yucca Mountain, and they’re the ones listed at the top of the slide, 40 CFR 197 for EPA, 10 CFR 63 for the NRC, and 10 CFR 963 for the Department of Energy.

But, when you go back to the original three rules, the ones that came out of the 1982 Nuclear Waste Policy Act, as the first bullet says, and I’m using 960 as the example, those rules are fundamentally subsystem oriented with go or no-go criteria for the technical subsystems. Famously, at Yucca Mountain, if the groundwater travel time was X, the site was in or out. And there were various other subsystem criteria. But when the Congress asked EPA to engage the NAS in the '90s, the National Academy recommended a system-oriented risk-based approach that produced three regulations that are in the title, and so, again, using 10(c) of the DOE regulations as the example, even though 10 CFR 960 and 10 CFR 963 consider the same geologic information, hydrologic information, all the same information, the two rules permit the use of the information in different ways. 10 CFR 960 views that information as, fundamentally, at the subsystem level, as go/no-go criteria; whereas, 963 views that same information as an input to a system-wide evaluation that, in the end, will lead you to a go or no-go decision.

And back to the Blue Ribbon Commission, it's on page 53, at the bottom of the left-hand column, starting with the sentence that starts with, "First the BRC has recommended that the EPA and NRC come up with the rules that would be applicable to repositories other than Yucca Mountain," and so this is something that EPA and NRC will probably look at if they go forward and accept that recommendation from the BRC should--will any future rules be more in the spirit of 10 CFR 63, which is a system-based approach, or will it be a return to the go/no-go subsystem-based criteria, as represented in 10 CFR 60, if you will, or 960. And we'll see how that plays out. If the Department of Energy is still involved, we, of course, will follow whatever the regulations are of the EPA and NRC.

So all this talk has tried to focus in on using the 1957 National Academy of Sciences report as the starting point, more than site characteristics were considered. For example, the waste form, cost and societal concerns, like if there's anybody here from Tarrytown, you're not getting it. And, also, ever since multiple geologic media have been considered.

And then I finish up with the quote that I had in the previous presentation, from the Secretary that I expounded on, and the other one that's what to do with the BRC's recommendations, explicitly on, you know, siting and that sort of thing? The DOE is looking at--there should be a report in the summer timeframe. We will see--I will point out on page 53, in that same left-hand column of the BRC recommendations, after saying that first NRC and EPA should look at regulations, the BRC recommended that the siting be actually with the Waste Management Organization, which begs the question, well, who is--they didn't, you know, they didn't explicitly say, you know, the replacement, the DOE. They didn't say the DOE--I mean, after all, it might end up DOE still has the responsibility, but it's whoever has that responsibility ought to be the ones to implement the siting criteria.

So, those are my prepared remarks.

GARRICK: All right. Okay, I'm going to give Rod first choice here.

EWING: Thank you. So, Bill, you started the story in 1957. So it's over 50 years have passed, and as I reflect on the science during these past 50 years, the science of hydrology, I think, is a little better than it was in 1957. I can certainly say geochemistry, reactive transport modeling, computational capabilities, I mean, the world is very different now. So as your group, this working group, considers the recommendations of the Blue Ribbon Commission and thinks about criteria and strategies, will the state of the science and engineering play any role in shaping your thoughts, and how will you introduce the new world to these old ideas?

BOYLE: Yeah, I don't know how the group will consider it but one way of looking at it are the very strong statements, even in the 1957 NAS report, or one of the subsequent GS reports, is even with the state of science at that time, which, generally speaking, we know more today than we did yesterday, and I'll even use as an example, numerical modeling has just--it's far beyond what people could do in 1957. They were confident then that, you know, it could be safely--you know, that's the word, the adverb, used in the 1957 report, it could be safely disposed of. So, from my personal point of view, the increases in knowledge, the advancements of science, will permit people today to do things with, perhaps in certain areas, less uncertainty, or, one would like to believe, less cost, but I think if one were even to factor out inflation and look at the estimates for what it costs to dispose, they tend to get larger with time. They really haven't gotten smaller.

GARRICK: Andy?

KADAK: Yes, Bill, thank you. I was trying to capture what it is that you're trying to send as a message. The message sounds like we've already done a lot of the fundamental site generic characterizations by all these studies done by prestigious organizations. Yes, maybe the science may be more developed but that wasn't ever the problem. The problem is getting political, or local and state support, for moving forward.

BOYLE: Yeah, I think that's--

KADAK: Is that what I got?

BOYLE: I think that's a fair--

KADAK: Okay.

BOYLE: That's one of the fair messages to take out.

KADAK: All right, so how are you going to take advantage of all the history of these various Academy studies that exclude certain sites, without having to spend all this money again to do the same thing?

BOYLE: Well, this, again, is my personal point--

KADAK: Tarrytown included.

BOYLE: Yeah. It’s a--I think--I’ll use Tarrytown as an example. It’s--one need not necessarily--how else can I say this? Not all total system performance assessments need to be cut from the same cloth, that some can probably be done simpler and more easily than others, and for a site like Tarrytown, if you will, that’s in New York City, you would probably--it might be faster and easier to set up an analysis that focused in on that you had so many people living close by, and it might not take very long to even, at a systems-based approach, rule it out, fundamentally, using the subsystem factor of population density. You really wouldn’t want to put it here.

KADAK: Right. Do you agree with the quote that says it will be difficult to develop a universally acceptable set of criteria?

BOYLE: I’m glad there’s a transcript. I characterize that as somewhat as they said that--

KADAK: Okay.

BOYLE: --and I think that there are probably people that agree with them, and I think there are people today who disagree with them. It’s--

KADAK: What is DOE’s view?

BOYLE: I don’t think DOE has one yet. Well, I’ll wait for the July report and see if DOE weighs in.

KADAK: Okay. I had one other question, but it’s okay, I’ll go back. Thank you.

GARRICK: Okay, Bill?

MURPHY: This is Bill Murphy of the Board. Thank you, Bill, for your presentation. These are things I’ve been thinking about a lot lately and I--much of what you said reflects my own thinking, which I’m going to elaborate on a little bit and try to get your reaction on it. You seemed to emphasize that over this period of half a century or more the big change has been the increasing recognition of the social or policy aspects of doing the problem, and that’s been my impression as well, but the technical criteria are pretty obvious and have been very well established for a long time now, and despite--or, even in the context of our advancing technical and scientific sophistication, the basic criteria really haven’t changed much over many, many generations, or many decades. And I’m trying to identify those things that have potentially changed.

One thing that occurs to me is that we’ve come to learn how difficult it is in fact to do a legitimate site characterization. It takes a lot of work and it takes a lot of time, and to under-emphasize the significance of site characterization and the effort it takes is something that we’ve learned when, over this period of time, when people estimated it would take a few years. That's not a realistic perspective, I think. There are a lot of technical problems that arise as one does site characterizations.

And another lesson we've learned, it seems to me, is that there are some times, or maybe always, difficulties in implementing technical regulations that were devised independent of a site, and independent of site characterization data, and a lot of stress is associated with making--and we saw this, certainly, in the case of Yucca Mountain--making rules that weren't necessarily useful or practical, being difficult to implement in the case of the recognition of the site characteristics. So perhaps you have something to--

BOYLE: Yeah, I--yes. It's my own view that, as you--you know, you said it in your own words, the technical issues have been readily identifiable, and it's more the process issues, or the--and I think this flanges up to the Blue Ribbon Commission recommendation on a consent-based approach, right? You know, they didn't, at first--of the eight top recommendations, none of the eight are go out and identify the technical site criteria. And I think even Chancellor Carnesale said here at the end, in his remarks, that it's the interactions, the policy, the political, and less the--we know how to do it, as he said it, so that's one thing.

And another point you brought up is I think if we were to do a history of the projected cost of either site characterization or a repository and factor out inflation, I believe we would see that it was more expensive than people thought. And I think that's true even outside the United States. I believe in some of the other countries, the organizations responsible for paying are usually chafing a bit at what it's costing them, in terms of getting repository sites characterized and/or repositories, open, so--

GARRICK: Yes, Andy.

KADAK: Bill, thank you. I found my other question. The discussion between 960 and 963 as criteria for design of a repository clearly, and I think the Blue Ribbon Commission also addressed what is the standard for disposal for which we should design the facility? It's a big difference between trying to reach for a million-year standard versus a ten-thousand-year standard, or some other number. And they recommended a relook at this, as best I could read the report, and I'm wondering what role will DOE play in moving that relook forward?

BOYLE: Yeah. Well, you know, the times for the regulations, they inherently come to DOE from EPA and NRC regulations, and the DOE's participation in that process is essentially the same as anybody else's. The EPA and NRC publish those rules through a public comment process, and the

DOE does participate, and has, for the existing rules, participated in that process. And I'm glad you characterized it the way you did, as ten thousand, a million, or some other number, because I like to point out to people that the NAS report, specific to Yucca Mountain, actually says the regulation ought to be for the period of geologic stability, which, for Yucca Mountain, is in the vicinity of a million years; but, arguably, other sites, it's some other number, potentially larger than a million years, and that's something that would be addressed, I'm sure, in any rule making going forward by the EPA or NRC, and the public and DOE would have a chance to participate in that process.

KADAK: Just a quick follow-up. So, as a result of the Yucca Mountain experience, where you found it difficult to, let's just say, for the sake of argument, credibly defend, technically, a million-year performance standard, would you, the DOE, be willing to provide that kind of input to NRC and/or EPA about the realism of such a standard?

BOYLE: Well, I won't, today, try and guess what DOE will say about some, as yet, unwritten rule, but for the rules that applied to Yucca Mountain, we had challenges but we faced them. DOE, and I'm sure other groups had challenges as well, we faced them. The rules worked, the process worked, there was nothing inherently unworkable in them, even if some parts were harder than perhaps some other countries have, or even the people at Woodpad with the ten-thousand-year standard. There wasn't anything unworkable in the rules or process. Having said that, my DOE comment, you know, for a different way to handle the timeframes? Sure. People did make those comments at the time. Historically, before DOE had the million-year calculation in the license application we did have a million-year calculation in the environmental impact statement. So there are examples of different ways to handle it. And what that turns out to be in the future, we'll have to wait and see.

GARRICK: I may not be remembering the right phrase here, the right reference, but I thought the million years was in reference to geologic stability and that that--

BOYLE: Yes.

GARRICK: --the specific reference was made to calculate it out to peak dose.

BOYLE: I forget those exact words, it was a--

GARRICK: Yeah, so that's different.

BOYLE: Yeah.

GARRICK: That's a little different--

BOYLE: Yeah.

GARRICK: Yeah.

EWING: Of course, if I could add to that, one of the ironies is it means that for a lousy repository the peak dose comes early--

GARRICK: Right.

EWING: --because you have the maximum release barrier.

GARRICK: Right, uh-huh.

BOYLE: That’s an advantage, yeah.

EWING: Well--

GARRICK: But that isn’t the question. The question is, if you’re talking just about the geologic containment capability, when you’re talking about a repository you’re talking about the total system.

EWING: Right.

GARRICK: And the better you design the engineered barrier system, the long out in time the peak dose--you push the peak dose out.

EWING: Right.

BOYLE: Right, so I took--one way to take Professor Ewing’s comment is if an applicant knew they had to continue to look further and further out in the future the better and better they made the system, there might be an applicant somewhere who goes, “Oh, to heck with it.”

EWING: Yeah.

BOYLE: “I’m going to deliberately make some waste packages a little less good and I’m going to sort of bring that peak forward so I don’t have to--always keeping it under the public, health and safety standards.”

EWING: Right. So I want to be clear. I don’t want to ascribe motives to anyone.

BOYLE: Neither do I.

EWING: It's a illogical connection.

BOYLE: Right, but I'm glad that this discussion is taking place now because working to an assumption that the NRC and EPA will accept the recommendation of the BRC and come up with new regulations for repositories, these are the sorts of things that should be up for discussion. This inherently fundamental difference, if you will, historically, between the first three regulations and the subsystem-based approach, the more recent regulations with the system-based approach, should we go to peak dose, should we go for a fixed-time period? What should the fixed-time period be? That's all ripe for discussion.

GARRICK: Okay, any more discussions for Bill? All right, thank you. I guess we're now ready for Kenneth Skipper.

SKIPPER: I'd like to thank the Board today for allowing us this opportunity, on behalf of the G.S., to address the Board. My comments today are going to focus on implementation of an early screening process, as well as scientific updates to be considered in that process.

It's been several years since the USGS has addressed this Board, so I want to spend a few minutes reacquainting the Board with the USGS and provide a short background on information on changes that have taken place. I want to present a retrospective of the first repository siting process, I then want to discuss implementation of an early screening process, utilizing disqualifying conditions and potentially adverse conditions, and discuss development of criteria for that. I want to give some examples of geo-policy considerations. I want to give some observations on who are the consenters, and then I want to provide a scientific information update of earth and natural science and geographic information update since the culmination of the first repository siting process before offering my conclusionary remarks and taking the Board's questions.

The USGS is one of nine agencies that comprise the Department of the Interior. The director of the USGS, Dr. Marcia McNutt, reports directly to Interior Secretary Salazar and services the chief scientists of the Department of the Interior. I want to update you on several recent developments, as far as personnel. Bill Alley, who has addressed this Board in the past, was the chief of Office of Groundwater, retired the first part of this year, and Bill Cunningham is acting chief of that office now. Jim Devine, who is the long-time face of science at the USGS in Washington, he was the senior science advisor, also retired the first of the year, and both Bill Alley and Jim Devine are pursuing their technical interests at the USGS in their retirement.

The USGS serves the nation by providing reliable, and I really want to emphasize, impartial and objective science information to the nation. I want to briefly address the USGS's Yucca Mountain project branch closeout, and I want to call your attention to the third bullet, which is just preservation of scientific information. The USGS puts significant resources and efforts into preservation of Yucca Mountain's scientific information within the agency. To this end, since the branch was closed, and to today we continue to work on preservation of that information, including completing several in-process reports at the time of the branch closure, and these were in the areas of seismicity, geochemistry, precipitation erosion, and Volume II of the Geological Society of American Memoir, which summarizes the hydrology and geochemistry of the Yucca Mountain area is in final review and we anticipate that that will be published by GSA in the fall. And I might note that that's a compendium document to Volume I of the GSA memoir, which summarized the geology and climatology of Yucca Mountain that was published in 2007.

Additionally, the USGS is in the process of requesting DOE permission to utilize some non-expended funds for a post-mortem, lessons learned, to report on the institutional knowledge that we had from our Yucca Mountain experience, as well as we believe that it’s important in preserving the scientific information to complete a USGS publication and bibliography and update it from ’92 to the present, and there are literally hundreds of documents through this period that would be included as part of that bibliography.

Now I want to talk about a retrospective review of the first repository siting process, and the BRC, with regard to this, talked about that future siting efforts should be informed by past experience. Bill talked about the 1957 National Academy report that came out of the 1955 proceedings, and I’d just like to add to that that it was both a historical time period for the waste program in that it was really the birth of the thought of geologic disposal of radioactive waste, and it was also precedent setting from the standpoint that, both nationally and internationally, that concept was adopted, the geologic disposal concept, was adopted and has survived the test of time through the world countries, as well as the international science societies.

Again, Bill spent a little part of his presentation discussing about the numerous reports that were completed. I would just add to that that these numerous scientific reports were completed by leading authorities of their times as the G.S., at the national labs, academic institutions, the Atomic Energy Commission and its contractors, and state geological surveys. Bill talked about the diversity of these reports, and in the handout package that you have today, we've included some example covers to give you an idea of some of the reports that were prepared.

To give you some walkaway points from this retrospective look, and the first of these is that there were significant scientific information and thought went into their first repository siting process, that out of this resulted extensive scientific information, and we believe that a comprehensive and very broad review to today's scientific state of understanding needs to take place and that a process to validate or invalidate the findings and conclusions of those reports, that that effort should take place, and that should be one of the starting points we look at a new repository siting process.

With regard to that new siting process, the Blue Ribbon Commission in their final report stated that they found it favorable to encourage expressed interest from a large variety of communities that have potentially suitable sites, and that, with regard to the development of a set of initial siting criteria, that these criteria will ensure that time is not wasted investigating sites that are clearly unsuitable or inappropriate.

Consistent with the BRC statements, as well as the implementing regulations for guidelines within 10 CFR 960, USGS believes that a early screening process that utilizes disqualifying conditions and adverse conditions in developing the supporting criteria for that, it is essential for early identification of regions and areas for further consideration in the siting process, and to be able to focus the attempt to find a consent entity.

So now I'm going to show some examples of what we believe are disqualifying conditions, and we've heard some of those earlier this morning already. Bill spoke about those in his talk, briefly, and I've shown these with a red traffic light, and, again, they're what we would consider kind of intuitive disqualifying conditions.

And the first of these is population, the proximity of siting repository to a large population. I think that, intuitively, that tells us that it's not necessarily a good idea. This is a 2010 census map provided by the U.S. Census Bureau, and it shows population across the U.S.

The next disqualifying condition example would be areas of potential active volcanoes, and this map depicts those areas, all of which occur in the Western United States.

KADAK: What's the radius around that that's excluded?

SKIPPER: I actually will get to that.

KADAK: Okay.

SKIPPER: That's one of the things I'm going to point out is the criteria needs to be developed for that.

KADAK: Okay.

SKIPPER: Seismic hazard. This map depicts seismic hazard in relationship to ground motion, and you can see on the scale that the white areas are low ground motions, increasing to areas that is higher ground motions. So, again, we see disqualifying conditions where there would be--where seismic hazard would be too great.

KADAK: What color is disqualifying?

SKIPPER: Again, I’m going to get to the criteria part of things.

KADAK: Be patient.

SKIPPER: I might note on that, however, that, in the first repository siting that was conducted, that they used the Uniform Building Code map, and what they utilized was that areas of seismic risk 3 and higher were excluded.

KADAK: Three and higher. So you’re really talking the white areas that’s left, if I understand that chart.

SKIPPER: Again, I think that that’s part of the criteria that really the scientific community needs to develop and come to agreement with.

KADAK: Okay.

SKIPPER: We also believe that the disqualifying condition is along coastal areas. This map illustrates an 80-meter sea level rise, which we see as a bounding condition that would represent melting of all polar ice caps, and, again, we see that as an absolute bounding condition. As you can see from this map, that large areas of the Atlantic coast seaboard would be inundated from today. The entire State of Florida, large areas in the Gulf of Mexico, and the Mississippi River Delta, the Central Valley of California area, as well as areas in Washington State.

The next disqualifying event that we see would be single events, sea level rise, related either to storm surge-seiche, or from induced tsunamis from either landslides, volcanic activity or seismic activity. And we'd have to do some additional analysis. We largely believe that most of these would be contained within the 80-meter sea level climactic rise. That is a bounding condition but we need to do additional regional and area work to make sure that that was the case.

I also want to talk about examples of potentially adverse conditions in coming back to the Board question there with regard to criteria. That, we believe, absolutely needs to be developed, and, for example, on the volcanic slide, at some point and some distance away from the center of that volcanic activity you would transition from a disqualifying condition to an adverse condition, and we would be need scientific and technical consensus of what specifically that criteria is.

The next one I'm going to talk about our past, present and future energy in mineral resource areas. These are depicted in yellow as potentially adverse conditions. And this map is an area of historical oil and gas development and production, and there are many of these areas that, due to the nature of the activities that took place, as far as deep vertical boreholes and hydraulic fracturing that took place in these areas, that these areas' abilities to isolate waste would be compromised. But there are other areas and regions within these that perhaps that the isolation capabilities of those areas have not been compromised, and, again, that criteria would need to be developed.

This map depicts coal resources by geologic case, and under--in many of these area there are subsurface workings, and you would also have these for certain minerals as well, and those disqualifying conditions would likely be very similar to that of the historical oil and gas drilling, where the regions and areas have been disrupted and their ability to isolate waste is compromised. There are other areas, however, such as--and I'll use strip mining of coal as an example--where those operations have taken place, that those may be near surface activities and perhaps should still be considered in deciding process.

Geothermal is another one that would have disqualifying conditions, we believe, as well as adverse conditions. And principal aquifers would be another area.

Principal aquifers, recharge areas to those aquifers, and major river basins that--those features that supply water to major populations, or, in the case of aquifers and surface water, to provide agricultural needs, that some of those areas would be disqualifying conditions, where other areas, where surface and groundwater are removed and not utilized for agriculture and water supply purposes, that those may be adverse conditions.

In summary, we see the identification and formulation of a criteria that utilize disqualifying and potentially adverse conditions should be used early in the screening process, and that in this early screening process that a GIS-based map, or a series of maps, would be the product resulting out of those efforts, and they would enable the regions and areas to be either disqualified and removed from further siting or that they were areas for additional evaluation and consideration as a potential host site. This would potentially identify suitable regions and areas and would narrow the initial search prior to efforts looking for consenting jurisdictions, and I think that that is key from what we discussed this morning with regard to how to make the technical and the scientific information map up with the societal challenges that this program has.

And we also believe that this then satisfies both what currently is the 960 implementing guidelines as well as the BRC objectives, ensuring that time and resources are not wasted investigating sites that are totally inappropriate.

Some of the geo-policy issues were discussed this morning. We believe that additional dialogue needs to take place on these, and that, really, the state of the science and technology needs to be developed in consensus with the scientific community.

I’m going to discuss the unsaturated zone on the next slide. On this slide it’s illustrated the general depth of the groundwater across the nation. As you can see on the scale, the white areas are greater than or equal to 100 meters of depth to groundwater, while the pink areas are greater than 100 meters. So a decision to site a repository in the eastern U.S. would almost certainly be in areas that would be in the saturated zone. These pink areas are in mountainous areas, but the bulk of the land mass in the east in the saturated zone, and if a decision were made to site a repository in the unsaturated zone, in all likelihood that would be in the western United States.

USGS scientists would welcome a summit to discuss these geo-policy considerations, as well as to begin the discussions on criteria development for an early screening process. We believe that the timing of that should take place sooner rather than later so that that information is available to scientifically and technologically informed policy and decision makers.

I next want to discuss who are the consenters, and the Blue Ribbon Commission in their report said that ultimately has to be answered by a host jurisdiction, using whatever means and timing it sees fit, and that there is a willingness of affected units of government, the host states, tribes and local communities, to enter into legally binding agreements with the facility operator where these agreements enable states, tribes and communities, to have confidence that they can protect the interests of their citizens.

I'd like to offer a slightly different observation of that, and it is that traditional government entities that were sited may potentially be too limited and that perhaps a broader community of stakeholders and consenters is needed to include current and future multi-resource users, and, for example, that could include downstream-based and principal aquifer water resource users as an example of that. And, again, that would be somewhat region and area specific to where a potential host site would be.

I next want to discuss scientific information updates since the first repository siting process, and, really, some current issues that are going on next that should inform the next repository siting process. First of these is that there's been significant update to geologic information. Technological advances has allowed great enhancement in being able to share available information, historic information, such as on mining and mineral resources, and there's an abundance of information that will help inform this next repository siting process. Additionally, the USGS is involved with many of the state geological surveys currently to refine state geological maps, and in some areas, really, mapping for the first time some of the states, and that information will be available shortly to help inform, as I said, this new repository siting process.

There's significant new energy exploration and development domestically, recent technological advances, particularly in directional drilling and within the hydraulic fracturing operations and monitoring those operations that are being utilized now to recover resources previously not economically recoverable, and it's widespread across the country the use of these technologies.

Most of you are probably familiar, due to the media coverage, of the activities that are taking place in the Marcellus shale in, principally, New York and Pennsylvania, as well as the Bakken area, but this map illustrates additional potential shale and gas development areas that is either currently underway in early stages or, in very near future, are going to be boom areas, depending on the energy economics.

This map is one of the energy assessments that the

USGS does as a futuristic looking approach that looks at resources into the future and could be used for repository siting from the standpoint of identifying what areas have potential for domestic energy development, and there's a whole suite of these, four different resources, that the USGS produces.

There's considerable uncertainty on what will be relied on, as far as traditional energy sources. I've cited as an example of there, coal, and there's many of these that have been subject to economic and policy sorts of pressures, but it really creates, as we look at resources in the future and repository siting, it's going to take some effort to look at what the nation's future energy mix is down the road and where these resources occur.

Another area of significant development is mining metals and industrial minerals, really, to supply both domestic needs, but a world economy, and there's many of the industrial minerals that are really categorized right now in shortage categories. Things like sand right now, due to the new energy demands in hydrofracting, sand resources are absolutely maxed and strained, and there are some of the energy companies that are importing sand from abroad.

A good example that illustrates the dynamic nature of energy and minerals is the principal rare earth elements, and it's received quite a bit of media attention in the last about two years. These elements are utilized in the defense industry for things like ballistic missile guidance systems, as well as commercial lasers, batteries, fluorescent lights and a whole plethora of other uses, and due to world economic and political considerations, it's been determined that we should identify and locate these minerals domestically and begin development of those as the demand--domestically for these materials and to secure our national interest. So, not long ago there was not much thought about these minerals, and that has changed recently in the last couple of years.

There's continued demands, additional demands, on water resources, agriculture and industrial, and water supply for drinking water, but the new energy, domestic energy, production is further straining these limited resources, and also the nation's groundwater and surface waters are being adversely affected by these development activities.

With regard to seismic updated information, in general, seismistic, across the U.S. has been increasing. There's two events that are precedent setting, or, one event and a series of other events. The east coast earthquake that took place at the end of last summer that's receiving a considerable amount of attention, and what will likely transform the Atlantic area seismic understanding in the future.

Additionally, the swarm of events in Youngstown, Ohio, as well as events in Arkansas, Oklahoma and several other states, related to energy development, are currently receiving a great deal of attention. And these events have been associated, particularly in the media, with hydraulic fracturing and induced seismicity from those hydraulic fracturing events. What the researchers and seismologists are really looking at right now is that these events aren’t from the hydraulic fracturing event itself, but taking place during injection of waste water disposal. So there are several upcoming studies aimed--that the USGS is teaming with both DOE and EPA to look at these seismic-induced events. And again, this may change repository siting from a standpoint of our induced seismic events constrained by the current seismic hazards maps.

Significant new information in research going on in climate change research related to sea level rise, but also potential changes in participation and temperature, as well as fluctuations from current levels of surface and groundwater. Energy development is resulting in even additional land use conflicts from the traditional ones, and this is also increasing pressure on critical ecosystem species and habitats, which there’s significant new information since the first repository siting process.

In summary, the first repository siting process relied upon extensive earth science inputs, scientific review of the first repository siting process legacy, which document is needed to determine if the conclusions reached previously are still valid based on our present-day scientific understanding, that implementation of early screening processes and supporting GIS platforms to distinguish earth, natural science and land used attributes will provide a scientific basis enabling identification of areas for either disqualifications of areas and regions from further siting consideration or that will identify additional areas and regions to receive consideration as a potential repository site in the future.

A comprehensive early screening process should be utilized that identifies disqualifying and adverse conditions, and the development of the criteria that supports that will standardize the process for identifying potentially acceptable sites, be economically advantageous, and provide for optimal utilization of resources and maximize efficiencies in the licensing process. There’s numerous geo-policy considerations and scientific and technical informed consensuses needed. Technological advances, long-term demand will continue to propel energy and minerals development, and there will be increased competition over the nation’s land uses, and finite natural resources will be challenged through the repository siting process. The BRC said that they estimate a fifteen-year site selection process, and, therefore, deciding criteria requires a futuristic approach to remain viable over this period.

And finally, the nation’s challenge is to develop an efficient and scientifically informed process leading to a site selection that consent of appropriate governmental entities, as well as current and future multi-resource users and is accepted by the public.

And that concludes my prepared remarks, and I will now take your questions.

GARRICK: Okay, George, and then Ron.

HORNBERGER: Ken, it wasn’t clear to me exactly why seismicity per se should be a red light for a deep mined repository, number one; and, second of all, I was curious whether glaciation was not part of your number of criteria by design or you just didn’t have time to present them all?

SKIPPER: You’ll find glaciation’s not one of them, but you’ll find some other examples in the handout of materials of potential adverse and potential disqualifying conditions. Time constraints did not allow for, really, expansion any more than the samples I tried to provide, but, certainly, you know, that is something that needs to be looked at.

With regards to seismicity, I think that we need to look at potential impacts in the underground from seismicity, and it would also, from a standpoint of stability of tunnels, and whether it is, in the case of Yucca Mountain, the potential for rock falls and stability sorts of issues, both in the operational period and whether, again, depending on the design, of how that would affect things like retrieval, if a retrieval option was maintained. And the pre-closure, certainly, the infrastructure support surface handling buildings, even transportation sorts of concerns, we would need to scientifically form the seismicity on those activities.

GARRICK: Ron?

LATANISION: Latanision, Board. I just think is an impressive demonstration of the wealth of information that is available, and I compliment you--

SKIPPER: Thank you.

LATANISION: --for the way you packaged all that, but I'm going to put you on the spot. Given all this information, and if, for the moment, we separate out the social engineering issues, where would you suggest we start looking? I mean, what is your reading on this? And you've got a lot of information, you've thought about this, you know what the history's been--where should we be looking?

GARRICK: Yeah, that's what I was curious about. Have you superimposed your templates?

SKIPPER: Yeah, this is where I would--

GARRICK: And--and--

SKIPPER: --clarify to the Board, this would be my comments and not necessarily represent the--

GARRICK: But I know--

SKIPPER: --U.S. Geological Survey, but I think that the process that led up to identification of areas in the Desert Southwest that there was a lot of scientific information considered in that, and I think from what you've seen today is that through an early siting process that looks at the information that is available, and I presented some examples of some of that, but certainly we have not gone through and done a, I'll say, credible job at this point to try to identify areas. But, certainly there are some areas that stick out to you that also resulted out of the first repository screening process.

LATANISION: Yeah, it's a very good political answer, I like that. Let me ask another iteration of this question. If we were to look back in history at the five sites that were at one point in play, and you were to look at all the information we have today, would those sites be viable sites for consideration in your estimation?

GARRICK: Or, more specifically, would Yucca Mountain be, come on.

LATANISION: Well, that was in my--that was in my thinking, yes. I'm must curious.

SKIPPER: I've not gone back and thoroughly reviewed all the information that I think that I would need to look at to be able to--

LATANISION: Yeah, I think--

SKIPPER: --to really answer that question.

LATANISION: --that would be a good exercise. I think that would be very instructive; in fact, at one point in history we did identify sites, and it would be interesting to know, given all the information you have available to you today, whether those sites would be sites that looked promising or not if we were to go back and revisit that history.

SKIPPER: Yeah, again, that was the part that I was trying to get at in my presentation, really going back and validating and invalidating the conclusions that were reached based on today's scientific understanding.

LATANISION: Yeah. Thank you.

GARRICK: And there's a lot, as you said, there are a lot of templates that you did not consider, such as national parks, national monuments, national forests, et cetera, et cetera.

SKIPPER: Yeah.

GARRICK: It would be really interesting to in fact superimpose all of this information and see. I tried to do it mentally and I was favoring eastern North Dakota, and a little bit of Minnesota.

ARNOLD: Didn't you get to--

GARRICK: I thought--

ARNOLD: Did you get to Tarrytown?

GARRICK: Huh?

ARNOLD: Did you get to Tarrytown?

MOSLEH: I thought right under the Capitol Building in Washington looked promising, but I'm not so sure that would work.

ARNOLD: Okay, thank you.

GARRICK: Yes, I agree, that was--that's a very interesting discourse. Any other questions? Yes, Rod?

EWING: So again I'll echo what others have said, it's a really impressive compilation of data and it's good to know that these data are available. But there's an interplay between, let's say, the geologic criteria and the engineered barriers, and so my question is if we were able to take credit for the engineered barrier, even for a relatively short period of time, say just several thousand years, would that change your geologic criteria? And what I'm getting at is during the 2,000 years, the heat load is dropping, the inventory is changing in a really dramatic way, in terms of the mobility of some of the radionuclides, so if you went back and said, "Okay, I'm going to look at the geology but for wastes that have been effectively disposed of for 2,000 years," do you think that would change the criteria very much?

SKIPPER: I would answer that question a little bit more broadly in that that's why I listed examples of geo-policy considerations. I think there are a range, and I think one of the first ones there that was listed was engineered barriers, and reliance on engineered barriers, natural barriers, and question mark. And I think that there was, you know, a scale there on each end of that. You rely 100 percent on the natural barriers, or 100 percent on the engineered barriers, and I think that, you know, it's an informed society, technologically and scientifically advanced, that for defense and death we would try to utilize a mix of those. And I think, to answer your question specifically, it really depends on, to me, the site, and the site characteristics and what we would be trying to achieve with those barriers, and also what the natural system is there.

GARRICK: Okay. Yes, Andy?

KADAK: Yeah, I'd like to follow up a little bit on that. What these studies basically show, and I was also trying to do this overlay, and I think the same places that John identified, North Dakota and Minnesota, up in there, but have you prioritized the disqualifiers in terms of importance? Because if you start thinking about what's really important for a geological repository, you might include some things that you've now summarily excluded because, you know, the aquifer, for example, there’s water everything, I mean, obviously. And the question is how deep is it and all that stuff, and so I think the next step for your organization is to answer the question I tried to ask you and that is if there’s a volcano in the area what is the zone around which, you know, it becomes exclusionary, and if, in the seismic event, you know, you said this category 3, I’m not sure it was the right scale, but what--let’s get some more specificity in some of these criteria so that you can actually do something with the information that you have. Putting up these broad maps make one think that there is no place on this planet that has a repository, when in fact we know that that’s not correct.

SKIPPER: Yeah, I certainly agree with what you just said. Currently the USGS has no mandate within the waste program to undertake that, and a fair amount of resources would be required to pursue some of those, but I believe that is what needs to be done.

KADAK: Does that then get to the question of you really can’t make real progress until you actually look at some site-specific information?

SKIPPER: I don’t believe so. I think that there is a lot of information that exists regionally, that--and it doesn’t--there’s a lot of site-specific information as well within the states. The state geological surveys, many of them have oil and gas and mineral agencies, and all that information, or a lot of that information, is now online and readily accessible. The USGS in many areas is working with those state agencies to tie their databases with the USGS databases, and so I think there's significant information out there that is existing and I think that that would be a step long before site-specific information from actual on-the-ground activities.

KADAK: Is DOE looking at the kind of criteria, for example, if it's a volcanic--if there's a volcano in the area, how far away from that volcano would it be acceptable to even consider such a site, or other things, like, you know, but I'm just focusing on this one.

BOYLE: William Boyle, Department of Energy. Not explicitly, if you will, but, fundamentally, this gets at a point I brought up. You know, the DOE partly got through the 10 CFR 960 process, but did not take it to completion because of the Nuclear Waste Policy Amendments Act. Using this subsystem-based approach in which one could put in you can't be within a certain radius of a known Quaternary volcano or something like that, that is an approach that was in 960, if you will, that subsystem approach, and it worked up to a point and then it stopped. But then came the NAS recommendation to adopt a systems-based approach, and I would offer up that--and I did--that using that as an example, if one use a systems-based approach of evaluating all these things Ken brought up, rather than as viewing them as go/no-go criteria on their own--

SKIPPER: Uh-huh.

BOYLE: --but as inputs to an evaluation of the whole system, then use that answer, which would be judged against some, you know, already established criterion or criteria. That would be the approach to go. So where we are in DOE is we don't know today which approach will be in place for any place other than Yucca Mountain, where, you know, the NRC and EPA have been--it's been recommended to them to re-look at this, but it's we'll do whatever comes out of it. Personally speaking, I like the systems-based approach myself for the very reasons you all brought up here. If you go out from a subsystem-based approach, you run the risk of throwing out what, in the end, might be a perfectly acceptable site, based on one of the subsystem criteria.

GARRICK: Rod?

EWING: Ewing, Board. Just a comment and suggestion. You know, earlier we heard the recommendation for a consent-based approach, and so that means a community has to decide whether they want to interact with a federal agency and become involved in this process. So it would be very helpful, even if these aren't regulatory criteria, to cast this in a way that the public could use; that is, communities could go to a series of maps and ask, "Well, are there any apparent difficulties or potentially disqualifying aspects to sites we have in mind," and that might be a good way to instigate, to begin a discussion, with the community. You wouldn't disqualify a site but it would tell the community what are the critical issues. Is it seismicity, is it water? And it would almost be a checklist for the beginning of the discussion.

SKIPPER: Yeah, let me answer that, Bill, and then I'll turn to you, but USGS has interactive products on our website. There's a ground motion one that--and I'm not an expert in that area, and I'm not sure how long it has been on but there is basically one where you can plug in either coordinates or addresses, and you--it will ask you a series of questions and then give you what the ground motions of a specific area are. So there are some of those interactive tools.

There are--going back to the volcanics, there is a volcanic hazard map the USGS has. It wasn't clear to me exactly the specifics on that, as far as what that was relating to so I chose not to show it here, but there are a number of both interactive and specific hazards maps that then address some of the things we talked about today. Bill?

BOYLE: Yeah. So it may fall on the Department of Energy, or it may fall on Waste Management Organization, not

DOE, to do what you're suggesting of, you know, communicating to the public. You know, everything else being equal here, positive attributes, negative attributes, and we may need that sooner rather than later because I think it's well enough known that the southeast part of the State of New Mexico has expressed an interest in potentially taking more than what they currently take at the existing WIPP facility, and Chancellor Carnesale mentioned the letter from the Governor of South Dakota, who expressed an interest in at least being willing to consider research.

And then I wanted to bring up a letter that was sent yesterday by the County Board of Commissioners of Nyde County to Secretary Chu of the Department of Energy, and in that letter Nyde County said, essentially, I'll paraphrase it, yeah, they're willing to volunteer under a consent-based approach. So, notwithstanding the difficult time that David Leroy had however many years ago it was, there seems to be any number of groups that are willing to at least come forward and entertain the idea. And, you know, it's, I think, the people at WIPP, for at least a 10,000 year period in the waste they have, I think they have some confidence in offering up that, you know, if those rules stayed the same, they already have a facility that's been approved. I don't want to put words in the Nyde County Board of Commissioners, but they must feel that they felt that Yucca Mountain was demonstrated, at some level, to potentially be safe. It becomes a trickier place for cases that never received as much scrutiny, like Tarrytown, New York, or some other place like that.

GARRICK: Thank you. Okay, any other questions? If not, I think we will recess until 1:00, but I’m told the hotel has arranged a buffet in the restaurant to facilitate the quick turnaround here, but we have quite a bit of time, and we’ll expect everybody back here at 1:00 o’clock. Thank you.

(Whereupon, the meeting was recessed for lunch.)

AFTERNOON SESSION

GARRICK: Let’s reconvene the meeting and start with the technical evaluation report on Yucca Mountain. Larry.

KOKAJKO: Thank you. I am very pleased to be here today; and I, along with Tim McCartin, who will be doing a portion of this presentation as well, are grateful for the opportunity to come and talk to you today. On behalf of Cathy Haney, the Director of the Office of Nuclear Materials Safety and Safeguards, we appreciate this opportunity to tell you about what we did over the last number of years upon receipt of the Yucca Mountain license application and how we got to the point where we developed three knowledge management tools known as Technical Evaluation Reports.

I also would like to make an advertisement that--right now I think it’s tentatively scheduled for April 10th back in headquarters--there will be a Commission meeting where the staff will give its perspective on the BRC report. We are preparing a paper now on that as well as, I believe, we have invited members of the BRC to make a presentation to our Commission, in this case the NRC, and I invite all of you to attend. I hope you get a chance to listen in on that if you can.

Also, I wanted to make one more plug as well. There’s been a number of discussions this morning about the International Engagement, and I want you to know that NRC has started reengaging internationally in a much bigger way than before. We had always maintained context within the IEA and NEA, but now we are--given that the program is changing to a different strategy, we have started visiting Sweden, Finland, France, German, the U.K., Japan, South Korea, as well as the participation in DECOVALEX activities as well. Some of you probably are associated with that in some way. I might also point out that we have participated in peer reviews of the Swedish program--disposal program--and our contractor, which is the Southwest Research Institute Center for Nuclear Waste Regulatory Analyses, has been invited to assist in Swedish efforts as well as advise the European Commission. So we are engaged in a lot more activities than just looking at the disposal program.

Have I talked long enough to get the slides up there? Thank you. Pretty good, huh?

I'm going to talk--just go over the review timeline at a very high level, and then I'm going to talk about our preparations, our review approach and lessons learned, and we'll have a summary. And in the middle I'm going to have Tim McCartin come up and speak explicitly on some of the technical evaluation reports and how they came to be.

And this is just a very generalized timeline. The license application for the proposed Yucca Mountain repository came in in June of 2008. It came in on June 3rd, in fact. I remember it because it was my son’s birthday. And we had done a lot of preparations up to this point, which I am going to explain a little bit more, but over time you see where some key dates--and there’s a few on here I’d like to point out. After DOE submitted their application, we accepted the application roughly three months later in September. We sent out additional requests for information in 2009, but prior to that the notice of hearing came out, and there were 319 contentions, I think, at last count--I think that’s the final number--with 14 parties ultimately admitted to the proceeding. And I say 14 parties, I’m speaking broadly. They could also have been interested affected units of local government as well as actual interveners.

We then come to March 2010. DOE sent a motion to withdraw the application to our hearing board. Later the hearing board denied DOE’s request, and they gave a lengthy statement of why they thought it could not be withdrawn. In June 2010 we were advised that we should keep to the schedule--and, by the way, the funding is going to be cut further--and ultimately we came up with the idea of developing a knowledge management tool known as a Technical Evaluation Report as the closeout activities for the program. Closure activities began at the beginning of the fiscal year 2010, and as of September of 2011 all nuclear waste fund activity--all nuclear waste-funded activity has ceased.

A couple of points, though, to note that on September 9th the Commission found itself evenly divided and told the Board, the ASLB Board, to close the program. On September 30th it did so. It suspended the proceeding and noted that the Board decision still stands but there was no further funding to continue that effort, and there still are 288 active contentions at the hearing board itself. As you know, there is no funding right now for the continuation of the program. Virtually everything we are doing is all non-Yucca related, and there is a Court of Appeals case that is going on, which I understand will be hearing oral arguments in May.

As a result of that, I have to be constrained in some of the things that I can talk about, but I think I can talk about the development of this knowledge management tool that I think is very helpful, not only for us today, but also for the future, because I look around this room, and I bet the average age is probably closer to 60 than it is to 30. And how are we transmitting this information to these people? I am very concerned about that. And that has been one of the key things that I've been trying to do at the NRC is to maintain the focus of trying to transmit this information to younger people and get them engaged in this, because I think this is a worthwhile problem, and it's a worthwhile career to devote oneself to. So there's my advertisement as well.

One of the first things we did--and this started or was implemented in 1987--was that we wanted to develop a contractor that was conflict-of-interest-free, and we ultimately decided on using an approach allowed by a federal statute called the Federally Funded Research and Development Center that would help us in our preparations for the review of whatever application came in. And we got the contract set up with the Center for Nuclear Waste Regulatory Analyses at Southwest Research Institute. We have been using them for over 20 years since 1987. They have been involved in our laboratory and field investigations, our detailed process models, and they have helped us to refine our performance assessment codes and, of course, gain the risk insights from them.

At the same time we have set up this expertise, we have also developed our regulations and implementing guidance. One of the things that was discussed this morning was watching DOE evolve to 963. Well, our comparable one was, we evolved from Part 60 to Part 63; 63 is dedicated exclusively for Yucca Mountain, whereas Part 60 would have the subsystem requirements and the like. That alone is important, but I think it's equally instructive that we developed the Yucca Mountain Review Plan, and this plan took over three years to develop, and it did have many public comments and comments from those outside the organization. And I might also add that we also developed interim staff guidance to augment our Yucca Mountain Review Plan, because we realized prior to the application coming in that we had found issues that we thought needed to be addressed further before we could take on the application.

And one of the final things we did was--well, among the many things we did--we interacted extensively with DOE and stakeholders. I've seen faces here who I know have been in some of the technical exchanges before we ever got the license application, and these technical reviews were very helpful in preparing our staff for understanding what would be required of us once we receive this very complex application. The Nuclear Waste Policy Act envisioned that we would have these interactions, and I think they were very successful. I recall a meeting several years ago. Steve Frishman was in Nevada, and I think we both were mentioning that we miss those days, because it was a chance where you could have a chance to freely express your views about what was going on. Maybe he didn't like them as much as I did, but I think he was nostalgic at that time.

Also, the public understanding of the NRC's role, we met with state, county, and municipal elected officials, appointed officials, as well as employees of those entities to try to explain the NRC's unique and independent role in this process. If there's one thing I might do differently in terms of preparing the staff is, I wish we had interacted--although we had legal people with us all the time, I wish we'd have done more with the legal staff. I think that was the one thing--it would have helped us as we developed our evaluation documents to understand their role, because lawyers can edit like all get out, if you know what I mean.

And one other thing--we did plenty of this but always there's room for improvement--we did do training qualification of the staff. We had qualification boards; every member of the staff who did an evaluation was a qualified person who other people had signed off on their ability to do that work.

Process. I can't say enough about our project managers. At one point roughly one-third of our staff was dedicated to project activities, project management activities, and they helped us to organize into project teams; they helped us to develop a project plan with a detailed breakdown structure; they also helped do the writing, reviewing, and eventually publishing the evaluation reports. This is just some of the things that they did. There were other things as well such as they helped to set up the meetings, make sure that the public process was followed. They helped to do training and tabletops to help prepare the staff. And one of the big keys--and it's in the second bullet--is they helped to manage the Licensing Support Network. The Licensing Support Network was set up under the auspices of the Atomic Safety and Licensing Board Panel. The thing that's of interest about this, while it was under their auspices, it took a full-time person on my staff just to be able to help put the documents there, to monitor it, and to evaluate it as it began to become more and more useful as a tool, not only to the board but to members of the public and also to the people who were participating in the hearing. At some points it was two or three non-panel members were having to do work on the licensing support program. And I've already mentioned the Yucca Mountain Review Plan with additional interim staff guidance to help us in our efforts to review.

I'd like to point out one other process that we don't talk about a lot, but I think it's an admirable one. We developed our own internal processes to raise issues where people disagree. You get professionals in a room, they're going to have disagreements; right? Well, this was no different. We knew that this was going to come up, but we needed to have a way that people could raise them in a framework that they wouldn't feel that they were being cut out or they weren't listened to, and we did develop some internal processes to do just that. I might note that the Agency adopted this more broadly over time, and I think it was a very helpful aspect of our safety culture that we could raise differing opinions within the context of this program without having people feel threatened or intimidated, and they could do so and get their voices heard. And I'm glad we did, because some of those voices needed to be heard and changed our views and perspectives with time.

A big piece of our success, I think, was the acceptance review. When the application came in in June, by the time we knew it was coming in, we knew that we would have some time to look it over before we started our review, and we knew we needed some--we needed to do a focused review, because if we accepted something that was not quite good enough, we would be criticized; but if we accepted something--if we took too long to accept it, we would be criticized for that.

The application, as you know, was 8,000 pages. There were millions of other pages that provided supporting information, and we thought, well, maybe what we should do is dedicate a team that would look at this. This would be a subset of staff taking experience from multiple areas to try and take a look at it to see if it was okay and using some of the principles and other parts of the NRC to see if that could help us. We did that; and even though we had dedicated three months' time to do that, I think we were all surprised how necessary it was. It was a massive amount of material that had to be looked at by many people who had to consult with many others in order to say, Is this good enough or is this good enough? And ultimately we were successful, and I think that was a big benefit to have a goal to determine if this information is acceptable for review, but also to determine whether or not or how it could be reviewed in the future, and that was the secondary benefit. We could have early detection of a request for additional information. We identified key areas for integration and, of course, potential resource issues. In fact, as a result of that, we did make some shift in some of our manpower because we knew we needed expertise elsewhere.

You might say, well, if this was a small dedicated team doing this, what were all the other staff doing? Well, we were requiring them to go through their sections. They might be consulted to help a member of the team determine if it was acceptable, but at the same time they were to prepare, because, in anticipation that this was the application that we would review, they needed to hit the ground running, because there was a clock that had started once the acceptance review was complete.

As a result, all the staff were involved at the start. And, of course, many of the people who were in our program, not on just this team, came from other parts of the Agency and had different experiences; and we were able to bring different perspectives to bear on this. As I mentioned, we had qualification boards and training; we had weekly team meetings in anticipation of all of this stuff; but I think--if I could do it again, I think I would actually have more focus training on this. Our tabletops did not look at this as example exercises. I wish we had done that, because I think there were some improvements to be made.

I'm going to go into this, and Tim is going to provide a little more perspective on generating RAIs in a moment when he talks about the evaluation reports, but we--like all regulatory issues, an application can be acceptable for review, but still you may have some questions, or you may see something that has changed from your understanding and you need some clarification on it. We wanted to find out--we knew we had to develop a process for preparing these, because these things could get out of hand very easily, and we did come up with a process to do that. And we had to make sure that it would be focused enough that we'd get our work done in the time we fashioned, but at the same time it had to be open enough where the people could feel that they could get their questions resolved. We came up with that process, which had the safety integration team that any request had to go through first, and we had weekly meetings to continue to train staff to know all the attributes of the application, mainly because, if you look at a performance assessment approach, you’re going to have to have an integrated perspective on your review.

One other thing that is not necessarily stated, although it’s implied in the second hash mark, we said you had to start writing your safety evaluation, and we required that they show us where that request for additional information detail--where it would go in that evaluation. We required them to do that, because we wanted to see the thinking of why that information was necessary. This cut down on some of the requests for additional information, but also it focused the thinking on how to approach first their work.

We had over 600 RAIs, and we still maintained a tight schedule, and it was a great transition to writing the evaluations. And there was very limited need for a second round of requests for additional information. There were some, but I think we helped to limit that, and I think it also helped DOE to focus its resources where they thought they had not done--had not expressed or explained why they did what they did.

Again, areas of improvement, the first one is maybe we should have had a different risk-informed perspective on how to address that at the beginning. That may have helped us to focus our review a little bit. And the interesting thing is, possibly too many authors. Well, you know, when you get a hundred people writing, they’re going to have a hundred different styles, they’re going to have a hundred different perspectives, and you get two or three hydrologists they’re going to have a different way of approaching the problem, two or three seismologists. It’s all--these are the types of things you would expect in a complex review process with very dedicated and very knowledgeable individuals.

Instead of taking any questions, what I’d like to do now is turn it over to Tim McCartin to talk specifically about the evaluation reports and how they came to be; and then at the end we’ll both take questions if you would like.

McCARTIN: And what I’ll try to give is a perspective from the trenches of developing the TERs, and I had a couple different roles in developing the TERs. I was the lead author for the post-closure compliance chapters, but I also was integrating both the post-closure volume and the pre-closure volume, trying to keep a consistency among them.

And generally our approach for developing the draft technical evaluation reports--and I guess I should make one disclosure on this. We did not begin developing technical evaluation reports. We were developing safety evaluation reports. At some point the program changed and they got turned into technical evaluation reports. For the convenience of the meeting today, I’ve just called them all TERs, and there wasn’t a lot of difference from a technical standpoint. In terms of saying whether you met a regulation, there is obviously a big difference between the two; but in terms of the technical work and the process we went through for developing them, whether I call it a TER or an SER, it really wasn’t that critical. But we did start out with SERs, not really TERs.

Yes?

KADAK: Kadak. Could you explain the difference between the technical evaluation and the safety evaluation? You seem to imply it’s determining whether or not you met the regulation?

McCARTIN: The safety evaluation report is what we do for our licensing proceeding, and that would be whether they have met the regulation. The technical evaluation report is not drawing a direct comparison to meeting the regulations, but it is commenting and talking about the technical evaluation of what was submitted in terms of the YMRP. There isn’t a lot of difference. At the end in the conclusions you won’t see was this in compliance with 10-CFR or 63.102. That would not be in this technical evaluation report. It would be in a safety evaluation report.

KADAK: And this was a management decision not to take it to the next level?

McCARTIN: Correct. There was a decision made, and we were directed to produce a technical evaluation report.

KADAK: Okay.

H. ARNOLD: Just a quick follow-up. Arnold. Could you just take an SER and redact parts of it and get a TER?

McCARTIN: There isn't a lot of difference between the two, but there are some--having read through both the pre- and post-closure volumes at least two times in this process cover to cover to make sure we took out everything, you are doing some selective editing, not just, say, at the conclusion part. But I would say they're 95 percent the same. You know, it's a very high percentage of--you would see very little difference, because most of it is a technical aspect of evaluating the technical merits of what was done.

And, with that, our approach for generating the draft documents was, there was a lead author that coordinated the input from many authors, and then there were some designated staff that filled the role of integration between chapters. And clearly there was--that turned out to be a larger challenge than we originally thought, because when we first began, we--as Lawrence indicated, we probably had--I don't know if we had a hundred, but we probably had at least 50 authors scattered to the four winds to start writing to meet the time schedule that we were on.

But there were--and I'll point to the post-closure with the waste package. You had rock fall that could affect the drip shield, which then could affect the corrosion of the waste package. And so there were a lot of things--someone writing on the rock fall versus corrosion of the waste package, etcetera. There were a lot of things that these chapters had to use similar information, especially when REIs were put out there, did anything change. And so the communication was quite large to make sure everyone was operating with the same current information. That's why we had weekly meetings to review the status and resources; that's the project managers Lawrence was talking about. It was very important--you know, things changed weekly. Something would come up, we needed more people over there, less people over there, and juggling resources. I hate to think back to the schedule we had by chapter, and there were pages and pages of when things were due. And so there were just a lot of things to keep track of and make sure it kept on time. That was the weekly meeting just for status and resources.

Then we had the weekly meetings for all reviewers to discuss the issues. And this is where--for example, in the climate area and the infiltration at early times--early times I will call in the first 5,000 years--a lot's going on there with the thermal effects; and they might be looking at certain aspects of that. But if you step back and say the drip shield is intact and that it's not going to contact the waste package, maybe you don't need that detail. Now, is the drip shield intact? You need to talk to the rock fall people. Do we find the information DOE provided on rock fall that might affect the drip shield? And so that's where--those meetings we tried to discuss things, especially as RAIs came in and sometimes the information changed.

In addition, there was--I'll say we all probably thought we were good technical evaluation writers when we started. I think we all, by the end of it, learned quite a bit and where a lot of our weaknesses were in writing a technical evaluation report. And we spent a lot of time what I will call training. We talked a lot. We thought we understood, but sometimes you hear the same words and you have a different idea in mind. And we continued, I would say, all the way through to continue to bring up good examples and bad examples.

And the key is, DOE in the license application had to describe how they understood the repository to work and the basis for that. Our job was to look at that information, decide if we believed it held together, and make a basis either for or against the granting of construction authorization. And I will say--for some of us, I would say--I don't know what the average time people had in the program, but we had developed the capability over a long time period. I'll say many of the people had 20 years of experience either at the NRC or at the Center in terms of working in Yucca

Mountain.

And the initial reaction for developing this draft report is, people sometimes want to say everything they know about Yucca Mountain. That’s not what we do. We write the basis for making our decision, and it’s a much smaller subset. And that’s part of that training: What’s the focus of the review? But I will say at NRC and at the Center we’re all better at it today. It was a painful process, and you can imagine with on the order of 50 different authors, there were many different views of what detail and why. And then we had special teams that we set up on an as-needed basis for some of these issues, be it the rock fall, shield, waste package release, that all were interrelated.

In terms of the outcomes, it required constant vigilance and discipline to stay on schedule. We had project managers that--I like an angry project manager. He kept people in line. And we had a few of them that appropriately, “Where is it? It’s due today. It’s not due tomorrow.” And there were just a lot of deadlines. But if you started missing deadlines, the snowball effect was extreme; and so we didn’t miss many deadlines. And there were red flags brought up for the people that missed them, but it was constant.

Understanding the safety significance was key. At the end of the day Lawrence said we had a process for people bringing up disagreements. And we never had to go very far beyond the staff level, but obviously there were disagreements; ultimately it came down to: What does it matter to safety? That was the only way we got that resolved.

I will say--and just a slight aside in terms of the subsystem requirements that Bill Boyle brought up with respect to Part 60. Part 63 does not have separate quantitative subsystem requirements. There is a reason it doesn't. We walked away from that in 63. I thought we made it clear when we published 63 that we said the only reason they stayed in 60 was, it was a matter of efficiency. We weren't going to bother to change it, because there was no need for 60, but I believe we tried to make it clear that the NRC has no intention of ever going back to quantitative subsystem requirements.

I would maintain the first thing that we had everyone read for post-closure was the descriptions and the capabilities of the barriers. Everyone had to read that. They could not do their chapter until they read that first. And I will say no one really knew exactly how well that would work or not work, but I would maintain it was absolutely, without a doubt, the best thing we did in terms of revising the regulations. There were things in those descriptions that if we tried to put things in the regulations like that, you'd never think of them.

DOE described corrosion products. They described a lot of different failure modes for the waste package, be it ruptures from faulting or corrosion patches, and so there was just a tremendous amount of information that we drew upon to then, okay, what should we now look at in more detail? And that was critical, and I would maintain that that--it was the last thing DOE could write, because they had to understand everything in the PA, but it was the first thing we read, and it did provide a basis for a lot of the post-closure discussions: Does it matter? And that's--I can't say enough about that, but that was the approach, and quantitative subsystem requirements, I can't imagine ever going back to something like that.

The ability to perform independent calculations over the years, we had developed an internal capability to do PA calculations in addition to a lot of other calculations, be it geochemistry, etcetera. We used independent calculations for inside the waste package with respect to adsorption on the corrosion products, solubility limits. It's unfortunate Rod's not here to hear me plug the source term like that.

We also did calculations with respect to rock fall. One of the ways packages failed was by seismic events, and rock fall had an influence on those, so rock fall was an important part. And ultimately in the compliance chapter we did a simplified calculation, and this was to get at--would anyone believe this massive GoldSim model that DOE put together with thousands of little nodes of computation. How do you know there’s not an error there?

And one of the ways we--what we did--now, DOE had to do that complicated model first. We could not have done our simple model without that; but having taken that, we took the big pieces, put them together, and did a simplified calculation and got a dose that was comparable. The reason for that, if there was something horribly wrong in the DOE calculation, we’d say, well, where is it? Because these pieces hang together in a more simple way. And I do want to add once again that we were not ever trying to say, gee, the PA should be this simple Excel spreadsheet. It was possible because the DOE had a very complex model that looked at a lot of things; we were able to extract from that.

In terms of our lessons learned, areas of improvement, I think we could have done better in being risk-informed. We all thought we were risk-informed, and we all thought we were on the page. Yeah, we read the barriers description; we understand how everything sort of fits together. I think we would have been well served if we would have had a very large meeting, mandatory for everyone in the program, to go through and--and maybe it would take two weeks--go through and just walk through the repository system and see what is causing the most significant aspects of performance and do we all understand it the same way, let people raise issues, etcetera, and then go start writing. I think that would have helped quite a bit.

What is needed versus what a reviewer wants, there is always a challenge. And the easiest way I thought it was put to us--and I thought Jack Davis said it well one day. He said everyone would like one more data point that would remove all the uncertainty. That would be fabulous. It doesn’t exist. We pay you people a good salary. We hire very educated people. If there is uncertainty, you have to decide whether it’s safe or not safe. And, you know, you’re not going to get more data because there is a limit. And I think that was a--a lot of people just wanted more. Well, let ask another “more” question. And, you know, in terms of--the uncertainty can only be narrowed so much, and I think there is always that challenge between what’s needed to document the basis for our decision versus what someone wants.

And along those same lines, I think that that transition from development of RAIs to the evaluation was made difficult, because when we developed the RAIs you were in a questioning mode. You kept on asking more questions. And then it was, okay, now you need to make a decision. We all have different views of how decisions are made, and some people wanted--well, I need more information. Well, no, you know--and it was a challenge, and that was part of those meetings. Every week there were challenges in terms of why do you need that piece of information? What is it going to do in terms of helping you make a safety decision?

For the final reports, there was a legal review. That turned out to be extremely useful. The lawyers really pushed us hard. And some of the people that, in terms of, okay, you've told me a lot of good things; I don't see a decision; I don't see a basis for why you--why did you come to this conclusion? And so the lawyers were pretty good at forcing the staff to narrow it down to: What's your decision and what's your basis for it?

Then there was management review that had a more global look and certainly helped with the integration. And then what we ended up--then, from all those many authors, we probably had about ten individuals that, when we were going through the legal and management review, those ten individuals were making the changes. And that meant for a little greater consistency across the board.

In terms of the lessons learned, I'll say our results, our outcomes, we did meet the deadline. I don't know if there is anyone that thought we could meet that three-year deadline, but we did. There was a broad range of regulatory perspectives. I think it enhanced the final reports, those meetings, those weekly meetings where fairly freewheeling people brought different perspectives. We had the lawyers there. We had other people. We brought in people who had done other SERs to help out. There was a broad range of discussion that I think strengthened the document.

If there's an area of improvement--and let me say, for three years we could not have worked harder. So when I say, gee, it would have been useful to get to a final report sooner, I believe it would have been helpful. I just don't know if it was possible, but I would have liked to have tried. In the sense that--I think the first year we probably, I won't say, wasted more time, but spent a lot more discussion time trying to get people to get to a decision; and I think getting to a final report, it would have pushed people a little harder. And I think it would have been a-- the discussions later on would have gone quicker, I think. But, like I say, it is hard to imagine that we could have done it any faster.

How was it accomplished? Vigilant project management. We had a lot of very good project managers that didn't let anything slip, and they weren't just sitting there with a stick beating you over the head saying, It's due tomorrow; when am I going to get it? They did a lot of helpful things along the way. They helped write some things.

They helped all kinds of aspects of the review. So it wasn't just someone with a stick.

Creative Division management. I guess I don't have to tell many people that the last two years of the review were--I don't know if we got a challenge every week that was different. It sure seemed that way. And how we got by changing resources and various hurdles that were put in front of us to get the job done was truly a tribute to Division management.

Dedicated legal and technical staff. I think everyone did what they had to do. Sometimes you were there until 9:00 o'clock at night. Sometimes you were there on the weekends. Sometimes you didn't know when that was going to happen, and everyone--I don't anyone said no.

Flexibility and understanding from everyone. Everyone understood, Yeah, I wanted to get it to you yesterday, but I'm going to get it to you at 10:00 o'clock tonight. Can you look at it by tomorrow morning? Yes, generally was the answer, yes. And it took that kind of effort.

Also, the 20 years of work paid off. We were a well prepared, highly trained staff; we knew the issues; and I think between ourselves and the Center it was a very strong team. We read the newspapers. We never lost sight of our mission. We did an independent safety review that we could defend, and we never--I think--the part that’s most amazing to me--I have a lot of friends throughout other parts of NRC, and whenever they see me, I know, for the last two years, they said, “Well, what are you even working on?” And I said, “Well, I’m working pretty hard.” And they just figured we’d give up. Why do the job? Why work hard to get this done? And you never know with the team you’re on how many people are going to continue to work hard. And it was like nothing was going on on the outside. We had a job to do, and it was to do the best technical review we could that we believed we could defend in court. That’s what we did; that’s what we accomplished; and I think for both the people at the Center and for the NRC staff, I think we all walked away very comfortable with what happened in terms of our effort. We did our job.

In terms of lessons learned at the end, I think, as I’ve stressed a few times, detailed project management was a necessity. I think early agreement on the level of detail would be very useful. We bounced around quite a bit in the first year getting to, well, how much do I write to? For some people, when you’ve studied a subject for 20 years, you wanted to say everything you could about that subject; and that wasn’t what we wanted to do.

The ability to quantify safety significance was critical for resolving concerns. When we got to concerns, it was, well, does it matter to safety? And sometimes you get, well, no, but they should do it this way. Well, if it doesn't matter to safety, you might prefer DOE to do it one way; it doesn't matter. They can do it that way if it's still safe.

The input from the legal reviewers and management was helpful.

Consensus on the regulatory concepts was important. That was a constant challenge. Everyone looks at the regulations, and sometimes you read something different into it. And so we had a lot of discussions over time in terms of what was needed. One of the topics I'm sure would not be surprising to people is the concept of how much design detail do they need now versus at the license to receive and possess; and that was a discussion, you know, is this sufficient design detail today.

Technical preparedness was critical. The 20 years, maybe we could have done it quicker than 20 years, but certainly you do need a long, dedicated time to understand a complex problem like this and be ready to do a review in a three-year period.

And, as I said, I think consensus meetings, especially with the risk information, at critical times would have probably helped out in a few critical times.

And, with that, that concludes my talk, and I know

Lawrence and I are happy to answer any questions.

GARRICK: Okay. Let me ask a question right off. If you were to write a geologic disposal review plan that would be generally applicable, how different would it be from Part 63? And did that exercise change your views on how you would even write Part 63 if you were to do it over?

McCARTIN: In general terms--this is me speaking, not the NRC--I think 63 would stay substantially intact. I believe there were--there are parts of it in terms of how the performance assessment is to be conducted in terms of the FEPs that I think we could improve to reduce some of the ambiguity and, you know, make for a more--I don’t know if it would improve the--reduce the contentions, but I think there was some area of the PA that were misunderstood and some of the contentions, and it would be useful to clarify that. But I think in terms of having a dose-based standard with a probability cutoff and certainly a description of the barriers and their capabilities as the foundation of the regulation, that--

GARRICK: So, from your perspective, you’re saying that--and I realize this is your opinion--that you’re really in a pretty good position to write a review plan that has general application pretty efficiently; right?

McCARTIN: Yes. Now, having said that, I will say I believe the review plan we had for Yucca Mountain, as it turned out, was more detailed than we needed, and it was an impediment.

GARRICK: Now, the only other thing I want to ask is--I know NRC was pretty proud of Part 63 because it was kind of the first real attempt from the bottoms up to write a risk-informed regulation. If you were to do it again, would there be the same amount of emphasis on making it risk-informed, less emphasis, more emphasis?

McCARTIN: I think it would be about the same.

GARRICK: About the same.

McCARTIN: You know, if it leaned any more, I would think more risk-informed rather than less, because, I mean, at the end of the day--I mean, I can give you an example in pre-closure. I know someone was complaining--I think DOE--for one piece of equipment they use, the reliability value for an elevator switch, and they weren't happy with that. And they knew the equipment they would be using. They said, That switch is going to be much more reliable than that. And they wanted them to cite the more--and at the end of the day we said, well--but they were able to screen it out with the reliability of the elevator switch, which--if you know that that's--they can easily attain that, it's not a matter of safety; and they agreed with that. And so at the end of the day, I think where we ran into questions that people wanted different things, when you could turn it back to safety, which to me that is the risk-informed approach, it was a way to resolve issues and move forward.

GARRICK: Okay. Other questions? Yes, Bill, then Ron.

MURPHY: This is Bill Murphy of the Board. Thank you, Tim. I personally tend to be more interested in the results of your review than in the process of your review, and so maybe we'll hear more about that later. But, for example, I want to ask you to tell me whether or not the license application meets the standards. But, on the other hand, you said you wished that your staff had taken time to consort among one another to establish what the most important issues to safety or to performance are. Did you come to a conclusion of what those most important things were?

McCARTIN: Oh, yeah, yeah, very definitely.

MURPHY: Would you summarize them in a few sentences?

McCARTIN: What I was primarily referring to, I mean, we always discussed that, but I think we didn't do it in enough detail, carefully walking through quantitatively, which might take a couple weeks rather than a two-hour meeting. And I think that would have got us further ahead, but--well, at the end of the day, I mean, the DOE waste packages, there aren't a lot of failures. They are mainly by cracks, and for the cracks you have technetium releases that is going to--they're going to go fairly rapidly, but you have a staggered failure of the waste packages. So once you have larger openings such as breaches, which at the end of the compliance period--you've got a million years--there's approximately ten percent of the waste packages have large breaches. There you have the potential for a neptunium/plutonium, but you also have corrosion products that help delay the release. Even the failed waste packages continue to limit the amount of water that comes in, and then for the radionuclides you have the southern and northern part of the unsaturated zone.

And I'll probably get this wrong--I haven't said that--but I believe the northern part is the more permeable, but I could be wrong. And so you have saturated matrix flow, and so things are delayed more there than in the southern half. And then in the alluvium you have sorption there. And that's, you know--what we did in the compliance chapter, we went through those main attributes, be it the water getting into the repository, the failure modes of the waste packages, releases from the waste packages, and then transport through the unsaturated zone and saturated zone. Those were the elements of our simplified calculation that was based on DOE's GoldSim model, but obviously a much simpler version. And at the end of the day, if you look at the numbers, the simplified calculation matched things reasonably well.

And so, at least in terms of the performance assessment, it hangs together in a reasonable fashion. There would need to be something drastically wrong in one of those boxes for the doses at the end to be different. And having said that, I mean, I'll say our report stands out there on its own merits. We did not defend it before a licensing board. I personally looked on that as a fun thing to do. I was not afraid of the licensing hearing. I mean, I look on it--you have to go into it with an open mind. We provided--like I said, why am I not disappointed in what we did? We couldn't have done any better. And if during the hearing something comes up that we didn't consider or failed to consider and changes things, so be it. We'll consider it. And so--

GARRICK: I noticed, in follow-up to your comment, Bill, that in spite of the fact that they disclaimed this as a safety evaluation report, there's frequent reference in the conclusion statements to the review plan--

McCARTIN: Yes.

GARRICK: --and it's pretty much in accordance--in other words, there are conclusive statements in reference to the review plan.

McCARTIN: Correct, but we have not made a regulatory finding in the--

GARRICK: Yes, I know, I know.

McCARTIN: And Lawrence will save me.

KOKAJKO: Kokajko, NRC. Tim is correct. And this is where I'm a little bit reluctant to get into a lot of detail, but in discussions with OGC and senior management and leadership at the Agency, we agreed that we would finish with a technical evaluation report which would address the technical merits of the application exclusively, no regulatory conclusions and no regulatory findings. We could not do that. Because the SER is a licensing document, it could--and in this case would--have gone before the Board.

Now, Tim viewed defending that to being fun. For him to have fun, I have to be fearful, and I was--well, I think that all of the staff wanted to see that move forward because that's the process. We knew that by this time, as we evolved the TER, that we could not do that. But we needed a knowledge management tool, and that is an important consideration. And that's why a mere redaction of what had been prepared to that point would not have been meaningful. It would have been too staccato in reading. It would not have had a lot of the information and the flow that would be the requisite requirements to help train younger people. And so it had to be a knowledge management tool that was readable, understandable, that had the technical merits addressed without addressing the findings. And, yes, it does--there are references to the YMRP, and I think that those were valid, but the YMRP does not have the force of law. It's the regulations only that have. It was just staff guidance to help us.

I might point out, the YMRP--to do it again, I think we would change the YMRP. It would be a little different document, because it did create problems at points. But it was problems that we did not anticipate when we first developed it. We learned. As a learning organization, we recognize there needs to be improvements, and we would continue to do that under a new situation.

GARRICK: Thank you. I'm sorry I took so much time. We are running late. But go ahead, Ron, and then Ali.

LATANISION: If we could turn to Slide 12. That second bullet--oops, there we go--that's an interesting call whether, you know, a reviewer needs something or wants something. How did you go about making that judgment?

McCARTIN: Safety.

LATANISION: Huh?

McCARTIN: Safety. And let me qualify. Maybe it's not the best choice of words. I mean, if they wanted it--if they needed it to make a safety decision, one might argue, well, they wanted it also. And I guess I will go back to Commissioner Rogers, probably ten, twelve years ago. I have never forgotten his fateful words to us that one of his biggest concerns was, as he put it, "the insatiable appetite of the staff for information." And I tend to agree that, as curious technical people, you always want more. And so you continue to ask questions. And all it is is that we're in a mode now that the Department has given us this information. We need to make a decision. If you can't make a decision, you will deny the application or--I mean, if there is a RAI that could produce it, you know, you could ask it but--

LATANISION: Latanision. Your comment is actually where I was going with this. It would seem to me that implicit in that statement is, we accept what we've got, and we've got to make a decision on that. And if it's not enough information, we're not going to go back and ask them for more; we're just going to deny it? Somehow that doesn't seem like the--

McCARTIN: Well, if we can't make a safety decision--I mean, if we don't know whether it's safe, we would deny the application.

H. ARNOLD: Or submit another RAI.

McCARTIN: Yes. I mean, it is possible. And that's generally the way NRC gets applicants to withdraw. They ask enough questions, and then they get, Gee, we can't answer those, well, we actually don't end up going to court with them. They'll withdraw the application because the questions can't be answered or they're too difficult.

LATANISION: I have one other short question. Given all the insights that you now have, how will you preserve this institutional memory? It'll probably be, regrettably, another 20 or 30 years before you see a license application, so how are you going to preserve this?

McCARTIN: Well, I was hoping to live to a hundred, but maybe not making that, well, we've done what we could to document--the TER stands by itself. Now, in addition, we have, I'll say, 40 or 50 knowledge capture documents that we've produced, and we do continue to produce some further documents pretty much on our own time that capture some of the insights, which now--a lot of the insights need to be what I will call regulatory insights with respect to, gee, if you were to revise the regulation, how much you revise it and why and aspects of how did we end up with the YMRP the way it was, those kinds of things.

We're still in the process of documenting that, but, yeah, I guess the only thing I'll say, though, when I was--I was the technical lead for revising Part 60 into 63. There was a NUREG, the infamous NUREG-0804, that was a compendium of responses to comments with respect to Part 60. We relied on that quite a bit, and so that document, even though it was on the order of 15 to 20 years old, we relied on that. So it's possible the document we've produced now will find some use by future staff members, which I certainly do not intend to be at NRC 15 years from now.

GARRICK: Okay. Lawrence Kokajko wants to make a comment.

KOKAJKO: Yes. Kokajko, NRC. We are concerned about that. That has been one of the major focus areas is: How do you maintain and transfer this knowledge to younger members? One thing I'm trying to do is, besides the documentation which Tim spoke to, we are also trying to maintain a dedicated core team of disposal experts or who have had some experience on the Yucca program, but also to bring in new people and transfer that institutional memory, that institutional history. We recognize that's not going to be the best way, but I know that--I've talked to others in other countries, and they've had trouble with that, because it goes so long. We are aware of it; we're trying to take steps to do it; and, again, my strategy is to maintain a disposal component that is able to talk. And it will be someone that Tim can help train and try to do it that way. But we are trying to maintain a disposal team to keep that together.

GARRICK: Thank you. One last question, Ali.

MOSLEH: Okay. Mosleh, Board. Reflecting on your experience with PA--and granted this is a simplification based on the models you have seen at DOE--but isn't an implicit message there that actually a simple or relatively simple model would do the job in terms of safety determination?

McCARTIN: I'm very reluctant to agree to that. I think all the hard work that went into developing a model that had a lot of different processes, a lot of different aspects, and then running it and see what comes out of it, I believe you learn a lot in developing that. Can you then step back and provide a relatively simple explanation? If there aren't too many counterintuitive things, etcetera, etcetera, at least that would be--because I could put repository performance in just one parameter if I had to. I mean, what we saw was, if you avoid it, a large number of packages failing at a single moment in time, just about everything else looks--you know, limited packages failing over time? It's not a problem. So you can distill it down, but I--

MOSLEH: But do you have to have that--

McCARTIN: Yes, it's all that experience and understanding you've built up from developing the model, running it. And it'd be nice if there was a simple seven-parameter PA model that would do everything, but I think you have to do the big one first, and then you can do the smaller one.

GARRICK: Okay, Andy, I didn't mean to cut you off. I know you have a question. I just ask you to keep it short.

KADAK: It's very short. In terms of the process of reviewing the subsystem versus the surface facilities, in our reviews we had a lot of difficulty with trying to reconcile building a surface facility, which is reactor lifetime-based, not a million-year standard, to something that is subsurface million-year standard. Were you able to make a distinction between the design needed for a fuel handling facility compared to that which is needed for a repository in your review?

McCARTIN: I thought so. That wasn't--that didn't pose that large a problem. The one area where we had to be careful is, seismicity was used both for the design of the facilities, and you want it to have--you did not want to be inconsistent or at least you were interpreting data similarly in both cases. And that's the one area, certainly for the surface facilities, the design of the buildings for seismicity is the one area where you'll see there were some interesting aspects of our review, probably the most challenging for the pre-closure operational phase.

KADAK: Would that be a lesson learned for the future, if you will, to segregate the surface facility operations, which arguably have limited lifetime from that of a--

McCARTIN: In terms of the--

KADAK: Like a one-in-ten-thousand-year return period versus a one-in-a-million return period for seismic as an example.

McCARTIN: I'm not sure what you mean by separate them. I mean, they--

KADAK: Treat the surface facility as a surface facility like you treat a reactor, design basis.

McCARTIN: Well, it is treated separately. I mean, there isn't--

KADAK: But not in the risk approach, given the modeling of the likelihood of events.

McCARTIN: Well--

GARRICK: This sounds like a corridor discussion, so I think--

McCARTIN: Yeah, they have completely separate portions of the regulation, so--

GARRICK: Yeah, okay, well, we really appreciate what you and Larry have presented with us. And we've got some real insights. It's a long TER. I've been reading it while we've been talking. And 613 pages--is that a record?

McCARTIN: I don't know. It is for geologic disposal at NRC.

GARRICK: In any event, thank you very much.

(Pause.)

SWIFT: It's a pleasure to follow Tim and Lawrence. Thank you guys very much. And, personally, thank you for reviewing that information. Thank you.

All right. So I am going to also--Tim's remarks about simplified PA were just a perfect lead-in to some of the things I'm going to do. I actually am going to try and present a seven-parameter PA. So first I want to acknowledge the co-authors here, Geoff Freeze, Teklu Hadgu, Joon Lee, Mark Nutt, Palmer Vaughn. Mark Nutt is here. I don't believe any others are here.

And quick outline of what I'm going to try to cover here. The topic is generic performance assessments. In the past what we've done are detailed performance assessments for actual sites and actual design concepts. But we have now a need; we have a full range of repository design concepts to work from and different media. We don't, however, have the basis to do a detailed PA; so, instead, we're left with simplified system level analyses. We have to use representative design concepts. We can work from the existing literature for inputs and input values and designs. What we can do with this, we can feed--we can support evaluating concept viability and identifying R&D needs at a generic level.

So the approach we've taken: representative design concepts from international experience; inventories, whether you're putting in the repository, that's based on available projections for the U.S. inventory; material properties for media from international experience; and simple models focused just on the key properties and processes.

I'll offer a couple of examples from our ongoing work. I don't have time to talk about all the ones we're doing. I am going to say a few words about what we can do at the generic level. We're talking about analyzing the comprehensive set of features, events, and processes, the FEPs analyses. And I'm going to give calculational examples from a deep borehole disposal concept and from a salt repository and then a few words at the end about the path forward for improving our generic performance assessment models and using the insights from them to support concept evaluation and site screening, selection, and characterization.

First, what is performance assessment? This definition comes from the EPA regulations, 40 CFR 191. Actually, first, my own definition there, just a method for estimating how a disposal system will perform over geologic time. But it’s got a regulatory definition; it has several regulatory definitions. This is the EPA’s. This is the one that was applied to WIPP. It is still on the books. It would in principle apply to any other repository except Yucca Mountain.

You identify the processes and events of interest; you examine their effects on performance of the system; and you estimate--for Part 191 it’s not a dose standard. You estimate cumulative releases, and you consider the uncertainties caused by all those events and processes, and caused by your uncertainty associated with their behavior. And you present your results as a probability distribution.

For Yucca Mountain the EPA and the NRC both redefined performance assessment in terms of annual dose; but, other than that, the definition is fairly similar. It’s a probabilistic representation of annual dose, taking into account the uncertainty in the characterization of the processes and events that affect the system.

Internationally, there is an analogous term “safety assessment” that’s used.

A quick slide here just to outline the elements in the process. We do think of performance assessment as a process, not just a--it’s a method for estimating the uncertainty in the performance. It’s not simply building a model and running it. The top row here, you have to know something about what it is, the system you’re trying to work with. You need a goal, and generally that’s a regulatory standard. What is it we’re trying to achieve here? Is it a cumulative release? Is it a dose standard we’re working towards?

And you need to know the three major parts of the system. What is the waste, what’s the facility design, and what’s the site? Right now in the U.S. we only have one of those four things to work with, the waste. We don’t have a facility; we don’t have a site; we, therefore, don’t have site characterization data; and we don’t have a regulatory standard. Okay, we’ll keep moving.

You identify the scenarios of interest that you want to analyze, and those are a function of the upper tier there. You build a system model that can actually simulate those scenarios, maybe more than one system model. You use the parameters in that model to characterize the uncertainty. That basically lets you do Monte Carlo simulations. Some will object that ruse is all uncertainty to parameter inputs and Monte Carlo analysis, and there is some justice in that criticism. We have to be self-aware of that, but there's a lot you can do simply with using parameter uncertainty in a Monte Carlo analysis.

From that you run sensitivity analyses. You can go back and prioritize research and go back to site characterization. You iterate through the process. Eventually you end up with something you can go back and compare to a standard.

The key steps in that--what I've done here is I've laid out the steps that are sort of specific to what the applicant can do once they have the regulation and a site defined. And in italics I've laid out what we can do in a generic sense now. So for identifying and screening potentially relevant features, events, and processes, well, the final FEPs screening is certainly going to be site specific. We can't say now what processes will have to be included and what do not matter for a different site. We don't know what the site looks like.

But there are a lot of questions we can address at the generic level: Develop models and abstractions along with their scientific basis. And, of course, this little clause here, along with the scientific basis, is where decades of research lives. Ultimately the scientific basis has to be site specific. Evaluate uncertainty in model inputs, there the sources of uncertainty are both generic and site specific, generic in the sense that they come from the inventory, they come from the host media that you've chosen. Those are things we can deal with at a generic level.

You build the integrated performance assessment model and run calculations using it. Here we can do something. We can build models that are stylized for those aspects of the system. They're site specific. In other words, we have to make assumptions and stylize the model. But for much of the model, it makes sense to treat it generically. You'll see examples here. Some things are ultimately going to be site specific, far-field transport in the geologic system; that's going to be a function of the local geology. Biosphere pathways, again, that will be site specific. But take salt, for example. Flow and transport in salt is something you can reasonably conceptualize in a generic sense without knowing where your salt is.

Evaluate the total system performance, incorporating uncertainty through Monte Carlo simulation, again, the only uncertainty we can actually deal with there is that which is generic and embedded in things like the host rock properties.

What a generic PA is not. And I put this slide in because I was hoping that Professor Ewing would be here to see it.

EWING: I’m here.

SWIFT: Good, very good. There he is. But this is not the one you’re going to like. This is the Yucca Mountain performance assessment, for those who may not have seen it. This is an enormously complex set of models linked together. Each one of these bubbles over here is a large piece of software that simulates a particular process such as rock mechanics or multiphase fluid flow or thermodynamic stability of the minerals in the near-field. And these all pass information back and forth, and then they’re fed into a system simulator that in itself—that’s the GoldSim model in the middle there. Quite complicated and it cranks out dose estimates. So this is not what we’re doing.

We’re also not generating thousands of pages of documents. We’re not producing something, in other words, that the NRC could review. This figure here just shows a list of underlying documents that supported the total system performance assessment model report, which in turn was a supporting document for the 8,000 pages of the license application that went to the NRC. Each of these little boxes on here in itself may be a thousand pages or more of documentation. So that’s not it either.

This is the slide that I was hoping that Rod Ewing would actually like. This is the most simplified model we could come up with. I thank Geoff Freeze for the figure. What actually matters here, you can reduce it at its smallest to the observation that in most existing long-term performance assessments, the dose estimates turn out to be controlled by only a few key processes and parameters. The initial inventory of the radionuclides--or their parents obviously--the rate at which radionuclides are released from the waste packages, that lumps everything together into the source term. It includes both waste form degradation and waste package degradation, solubility effects, but basically how fast things come out of the waste package. And then the third key parameter is the transport time, and here we’ve lumped transport in both the engineered system--i.e. the near-field right around the waste packages--and in the natural system, the geosphere, and all the way out to the biosphere. And the types of processes there--advection, dispersion, diffusion--and put radioactive decay there, it also applies up here in this one.

You end up with a very simple model like this where there’s no scale, although it is linear on both axes. Time going out that way and dose going this way. Think of the origin here as the time at which releases begin from--you’re starting to release out of the waste package. That's your transport time. If you've got a very fast release out of the waste package, fast-degrading waste form and a package that fails all at once, you end up with a high brief spike. And if you have a waste form and waste package that together release very slowly, you end up with a long slow release.

In the example shown here, there's an assumption that radioactive decay is long enough that it does not affect the release. The areas should be the same here. If you had a short-lived species, that would be true, say, for I 9129. If you had a short-lived species, you would see this curve drop off as decay function.

In truth, there are examples out there of repositories that fit this type of model in different ways. For example, the WIPP as it sits now, though it isn't regulated on a dose standard, but basically it relies on an extraordinarily long transport time. The regulatory time period is still well to the left of any dose on the WIPP from undisturbed performance. Alternatively, the Yucca Mountain repository relied on a long-lived waste package to keep the release down that way. This figure obviously turns out to be too simple, but it's a useful way to sort of frame long-term performance.

What we did is we took that very simple concept and put it on a one-dimensional model. And, again, Geoff Freeze and Joon Lee did this work. So you move conceptually from the waste form to the biosphere, left to right here, and you can actually build a one-dimensional computational model that will do this. And you need, you know, properties and characterization of each of these steps along the way. You can build such a model.

Now, one example of--and I think this is probably simpler than what the NRC team did with Yucca Mountain. But we took an existing complex performance assessment. This one happens to be the French performance assessment done by Andra in 2005 for a clay repository. We took--it's not--I think not as complicated as the Yucca Mountain model, but this is not a simple performance assessment. But we reduced it to what we thought were the bare minimum of the inputs that we needed, and this is a dose result that they calculated and published. And we built a one-dimensional model. Had only three radionuclides. We didn't bother with the ones that didn't transport. We had the advantage of seeing their results in advance and knowing what did transport.

And we had only five cells in the model--and one-dimensional diffusion was the only mechanism we considered--and reproduced their results with pretty good accuracy. This is the kind of thing you can do after the fact. As Tim pointed out, you don't want to build this model and trust it until you know someone has done the detailed job here. But once you know this, once you have the full detailed model, you have a lot of insights to strip it down to those things that actually do matter. And there's an insight worth knowing here, that if you have a rock that is low enough permeability that diffusion is the only credible mechanism for transport, you've got a very simple problem, and you really can do it like that. The trick then is to assure people but yourselves that diffusion is the mechanism of concern.

Okay. Now I'm going to switch gears a little bit here and talk about what we can do generically with trying to make sense of the features, events, and processes. First of all, what is this? What are FEPs? It's the attempt to demonstrate completeness, have we thought of everything. And internationally what's done--this work has been going on for decades now--you simply make a long list of everything you can think of and catalogue it, organize it as best you can, and demonstrate that somehow you have thought of everything.

And I just give you one example here of a potentially relevant feature, event, or process: microbial activity in the engineered barrier system. We ended up with what we believe is a comprehensive list of 208 generic features, events, and processes that, taken as a set, encompass the full population of those things of interest. Now, obviously you can subdivide that. You could have thousands of things identified and still be all in the same population space. It's a question of how coarsely you want to aggregate them. We think this list of 208 we've got is actually a pretty useful list. You actually--I think you already have it. We published this in the back of the disposal R&D roadmap report that Mark Nutt presented before in September. It is publicly available, and if you don't have it, we'll get it to you.

So what can we actually do with this list once we have it? If we had a license application and we were ready to go forward with it, we would actually be detailing for each of these 208 things how we had dealt with it in the analysis, whether it was important, whether it was not, whether it was explicitly modeled or excluded and, if so, on what grounds. You can't do that without a site, but we can answer this question: Is current understanding sufficient to evaluate the importance of each FEP for each disposal option? Will improved understanding be needed for future decision points?

As we move forward, for example, is our understanding of microbial activity in the engineered barrier system sufficient now to support the viability of a disposal concept in, let's say, salt? Do we know enough there or not? And if we know enough to say yes, it's viable, that's not the same as saying we know enough to go to licensing. So we may say we know enough now that microbial activity might not be a key R&D area now, but we do know, let’s say for example, we’re going to need to know more at a future decision point when we’re ready to go to licensing. It’s a way of prioritizing the R&D on each of these things.

We’re not in any way ready to go to site-specific screening, because we need regulatory criteria and site- and design-specific information.

And one last point here. The disruptive events, external factors, generally do turn out to be site-specific, and there’s not much we can do with them now at the generic level. Be aware, of course, that things like seismicity, volcanism, etcetera, are--they’re important, but they’re not amenable to generic analysis.

This is just a mapping of the 208 FEPs that we’re tracking to each of the major components of a simplified generic modeling system.

Now, the rest of the talk I’m going to take and talk about two computational examples, our deep borehole disposal model and a salt repository model. We also have done similar work in clay and granite; and, in the interest of time, I didn’t bring those two. I just thought this would be a useful place to start.

On the deep borehole, first, we have a whole session later on this afternoon, and Bill Arnold and I have coordinated this part of my talk with his so that I hope there's not an overlap. I hope this is complementary to what Bill Arnold is going to tell you later about deep boreholes, but we thought it was useful to put it in here.

The concept that we analyzed, nominally a five-kilometer deep borehole with a 45-centimer bottom hole diameter down there, and, of course, that requires a telescoping design where the hole is wider up at the top. Bill will talk about that. We assumed waste packages that could hold one pressurized water reactor assembly or three boiling water assemblies without fuel rod consolidation. As Bill will say later this afternoon, we are now looking at cases which do call for consolidating fuel rods. It lets you get the hole narrower, and it's more efficient.

We used the--in this analysis we used the lower three kilometers entirely in crystalline rock. Didn't matter what was above that. In other words, the upper two kilometers could be crystalline rock. We had rocks or other high-grade metamorphics all the way to the surface, but it's the bottom three kilometers we're interested in. The lowest two kilometers are the emplacement zone, and that gave us a one-kilometer minimum of a seal, a plug, which conceptually was a packed bentonite in concrete. Oops, sorry, back up one. The last point there, this is not essential to the performance assessment analysis, but it's worth noting that you've got--in that two kilometers there, it would take about--that's actually quite a lot of disposal space. Think of it as a two-kilometer-long emplacement drift that just happens to be vertical. It takes fairly small waste packages, though. We estimated that the entire Yucca Mountain inventory could be emplaced without rock consolidation in about 600 such holes. Or, alternatively, another way of looking at it is that a single light-water reactor's entire life cycle of spent fuel, a 60-year life cycle could be fit in about ten such holes.

The model domain--this is a model we're getting to here. The upper borehole zone up here, which we assumed was essentially an aquifer and had a withdrawing well in it pumping water out, that's how we get the exposure pathway; a seal zone; and waste disposal zone. The groundwater flow in this model is driven by the thermal-hydrologic effects from the waste itself; and there are two of them of interest, thermal expansion--you heat the water, it expands--and thermal buoyancy. We assumed there was no ambient gradient in fluid potential. Bill Arnold did that work outside of the PA; he'll talk more about that later.

Groundwater flow in the upper part of the model, i.e. the withdrawal well, we assumed it was driven by 3D radial flow towards the water supply well. If you don't have a water supply well, you have no gradient in this upper zone, no way to bring it to the surface. You put a well in, you pump it. The faster you pump it, the greater the gradient is from here up there, but you also get more dilution. So there's a tradeoff there in how you choose to treat the withdrawal well.

And we assumed that the flow and transport in a one-square-meter cross-sectional area that included both the borehole or, in the borehole seal area, the seals and a disturbed zone surrounding the seals. We didn't attempt to subdivide material properties between the seal and the disturbed rock around it. Basically we assumed it was acceptable for this model to treat it as a single medium.

A whole series of assumptions we made here, which I won't go into. Some of them are--well, a few of them here. For this model we assumed waste canisters failed immediately. Obviously that is conservative. We don't know how conservative it is, just it's a model assumption. We decided we were not going to try to argue that the waste canisters survived after the time the hole is plugged.

We used a constant waste-form degradation rate, and that's a fractional rate. And since in these analyses we're using the spent fuel itself as the waste form, we used data there from reducing environments from the Swedish program where uranium oxide fuel is pretty stable, degrades very slowly.

Solubility limits, sorption coefficients, transport processes of advection, dispersion, diffusion, sorption, we had decay ingrowth in the model.

The groundwater flow rates, which are critical, we calculated them separately in a 3D thermal-hydrologic model, which Bill Arnold will talk about a little later, but he simulated a 9-hole array to investigate the effects of-- thermal effects competing among multiple holes in a disposal field. We held groundwater flow rates constant in the upper borehole zone and surrounding aquifer; in other words, this was a million-year analysis that the withdrawal well pumped constantly for a million years. We used an IAEA-referenced biosphere, and we did the model in GoldSim.

We disposed only of used nuclear fuel, commercial fuel. We did assume that it was all pressurized water reactor fuel with a relatively high burnup. This is at the high end of anything that’s out there right now, I believe. It certainly is higher than the Yucca Mountain average. We did assume a 30-year cooling period after discharge.

There are the dissolution rates we used. Those are essentially the same as used in the Swedish program. We did not include the instantaneous gap fraction release. This is the volatile and mobile species that end up in the gaps between the uranium oxide grains and between the fuel and the cladding and are released quite promptly. We did not include that. That's a refinement we want to make.

We did look at three different flow cases in this model. We had a base case with a deep rock permeability in the disposal zone of 10^{-19} meters squared--I think we're going to hear more about this one later on in the afternoon--and a disturbed zone borehole permeability of 10^{-16}. We believe the 10^{-19} is a plausible value for favorable conditions in deep basement. We're not offering that as a typical average value, but if we choose a site well, we think that's an achievable value. And this, we believe, is definitely an achievable value for a compacted bentonite seal that's a kilometer long.

We had a low permeability case where we used the same host rock permeability, and we lowered the seal permeability to what we believe is still achievable, but that would assume we'd gotten a highly effective seal system; and a high permeability case where we pushed the host rock permeability to the upper end of what we thought was a plausible range, and we allowed the borehole itself to degrade to--essentially fully. This is the equivalent of fine sand, and conceptually this would be a fully-failed seal system of an unanticipated and essentially complete failure of the disposal system.

So here are some results. I thought about showing here some of the results from the 3D hydrology model. Bill will show them later instead. These skip straight to the dose results; but, as a caveat, they are quite driven by that 3D hydrology, how much water moves up through the seal. For that lower permeability case where we had the so-called highly effective seal, it’s zero. Stuff does not get out. For that base case where we had what we thought was a reasonably achievable seal and a favorable rock condition, these are very small numbers. Please note they’re not for comparison to regulatory standards. In some ways it’s almost, you know, a shame to even put a scale on this, but there it is. That’s 10^{-8} millirem per year, so that’s a very low number. And so for that so-called base case, Iodine-129 is the mobile species of interest, Chlorine-36, and a little bit of Technetium-99.

With the fully degraded seal system, this is the--basically the system has failed. And here we’re still--at the top there, that’s a tenth of a millirem, so these are still very small even if the system fails essentially fully. And, again, it’s an Iodine-29 dose.

What did we learn from this? It’s a robust system, in this analysis anyway, but you really want a--you want that seal system to work. So we learned something. It’s a good thing to know. And I aim to get us back on time, I think.

The salt model that we worked on, this model was based on the WIPP experience. Now, as I said, we used existing data to build these models. We started off with the French one. Here's one based on WIPP. So we have a hypothetical repository here in bedded salt with an overlying aquifer, interbeds within the bedded salt that have higher permeability and represent potential release pathways, a human intrusion scenario that may or may not penetrate a pressurized reservoir--brine reservoir within the evaporites below. This is very close to what was actually analyzed for WIPP.

The key points here, we do assume that the disposal environment is water saturated and reducing, in other words that, although the initial excavation is dry, we do assume there is sufficient water available within the porosity in the salt to eventually wet the system. And we chose--well, we didn't just choose to. We didn't have an option here; it's a simple model. This is an isothermal model, and that limits its relevance during--I would say during the thermal period, and therefore we're not capturing quite a lot of the effects related to the heatup of the salt and possible liberation of trapped brine during heatup. What we're interested in here and like we do get adequately is the long-term performance, the, you know, thousands of years out after you've gotten back to ambient temperature.

For the undisturbed scenario, we look at radionuclide releases into and through a one-meter-thick interbed below the repository, and I believe that flow path is also a meter in the model. And we use--the flow in the interbed, we actually calculate a time-dependent two-phase interbed flow there that’s a function of a separate set of calculations we did using the WIPP models to calculate generation of gases, hydrogen gas in the repository from corrosion of steels, irons.

We also look at a disturbed scenario with a single borehole penetration and sampled a number of waste packages it affected and allowed a steady-state flow into the overlying aquifer through the intrusion borehole from the brine reservoir below. We did not include waste brought to the surface during drilling. That’s consistent with the Yucca Mountain regulations. Basically we are looking for regulatory guidance on how to handle human intrusion.

Here again we used a large inventory here, essentially the full commercial inventory at the end of the life cycle. Nominally we converted it all to high-burnup PWR fuel for the purpose of the analysis, and we used a moderate-sized waste package. There are the spacings we used. Again, this was isothermal, so things like the size of the packages, it’s important for that human intrusion release but not important for the thermal-hydrology.

No waste package containment. Again, because it’s a reducing environment, we have a slow degradation rate for the spent fuel. We treated the disposal area as a mixing cell without sorption. And we did--when we got up into the solubility limits associated with reducing conditions in the repository and the overlying aquifer, we had a range of conditions that were more oxidizing. I think I've covered all of that.

Again, we used a IAEA-referenced biosphere. Obviously a site-specific biosphere might change the results, but for all of our analyses we're just using a referenced biosphere to sort of take it out of the analysis.

For the undisturbed case, the only releases in this model were diffusion-dominated transport in the interbeds, and doses are, again, 10^{-14} or something. These are extremely small numbers. Again, Iodine-129 and Chlorine-36 are the only species of interest.

Human intrusion, however, gets us back to something that looks a little more like Yucca Mountain. This allows transporting radionuclides into that overlying aquifer where oxidizing conditions--more oxidizing conditions allow their transport, and you see a whole array of things getting out, the actinides, the high one there, Plutonium-239, Neptunium-237, Plutonium-242 was the low I think.

So what did we learn from that? That whether or not human intrusion occurs does matter. That's a question that's essentially outside the scope of what we can do in a generic PA. However, in this system the releases through the aquifer are still pretty small; and if this were a regulatory analysis, those wouldn't be compliant.

KADAK: Peter, what is the scenario for human intrusion?

SWIFT: What is the scenario?

KADAK: What would you assume, yes, for human intrusion?

SWIFT: We assume a single borehole looking--nominally it's an oil and gas exploration hole looking for resources deeper below the salt, which is--that's appropriate for salt pretty much anywhere in the world. Bedded salt tends to have oil and gas resources somewhere in the area below it.

And, as I said, we did not include releases at the land surface. That's consistent with National Academy guidance and Yucca Mountain. We did assume that there would be a source of pressurized water flow up the hole, which is not always found but is sometimes found in evaporites, and we allowed that flow to be constant for the whole million-year time period.

KADAK: So it's horizontal drilling?

SWIFT: The horizontal flow in the overlying aquifer, and the doses were calculated at a site boundary downgradient with an assumed water withdrawal well.

KADAK: Thank you.

SWIFT: And I am actually just about done here. So we're going to keep going with these generic PA models, and we're just going to proceed in parallel with the Used Fuel Disposition Campaign. That's the R&D arm of the DOE office that Bill Boyle described earlier. So as the Campaign's mission evolves--and basically it's as we have a national repository program that evolves--we're going to keep developing these models. Our five-year goal is basically to have something in place that can support full uncertainty analysis for site-specific disposal options. I don't think we'll actually have sites in five years. I hope we do. But if we do, we'll have models ready to go out and do site-specific analyses.

In the meantime, disposal option viability, site selection and screening, identification and prioritization of research needs, we have actually made good use of that one already, and I did that just at the level simply of looking at generic features, events, and processes; that's a conceptual piece of work described in the roadmap report. We're starting to get sensitivity analysis results out of these simple models that are useful. For example, we have done work on that borehole model that wasn't ready in time to report here. But you can see sensitivity analyses done across the sample parameters and across the different cases for rock permeability, and no surprise. The assumptions about rock and seal system permeability turned out to be important, and waste form degradation turned out to be important. If you can justify a long, slow degradation of that spent fuel environment, you get very few releases.

In parallel with ongoing PA development, continue development of scientific models and databases at a deeper level of scientific fidelity and sophistication. For that, I’ll refer you to the next presentation by Carlos Jove Colon.

And a specific point here. We are developing a performance assessment computational framework took that--basically it’s a modeling tool. It’s something that modelers would like to have. We don’t have it right now other than the GoldSim tool that did great service for us in Yucca Mountain, but it’s time to move on. We want something that we can use to link scientific models00i.e., the types of models that come out of here--link them in a common environment, ensure consistent pre- and post-processing, meshing, uncertainty and sensitivity analysis tools, built-in QA and reproducibility.

This is achievable, and it’s a fairly straightforward piece of work to put this together and hopefully be able to plug models of this type into it and allow analysis at multiple levels of detail, anything from deterministic to probabilistic, system, subsystem, and to be able to do simple models on a desktop or to take advantage of high-performance computing tools we didn’t have a few years ago.

And my conclusions. All right. So we have first-order insights now about the processes and parameters with the greatest impact on performance in different disposal concepts. Relative importance of engineered and natural barriers, release rates, transport times, that comes back to the simple slide that I showed at the very beginning. We can now, with some confidence, say which--for example, in a system like clay or salt that relies heavily on the very slow transport through the natural system, justifying, being able to defend those very long transport times, is critical. For systems that rely on the slow degradation of the waste form--and all of them take some benefit from that in reducing environments; but in, for example, granitic systems which I didn't show here, that turns out to be pretty darn important.

The relative importance of the redox state, we already knew that from Yucca Mountain, but we see it again in the results from the salt site that if you get the release directly into an oxidizing groundwater environment, you transport a whole different suite of radionuclides.

Thermal load management strategies, I didn't talk at all about them here, but you had a presentation by Ernest Hardin in January on that. A key point there that, because we are able to do those models, focusing on a specific thermal target constraint, you would decide what it is, but once you've decided it, let's say you want to keep the waste package surface temperature below a hundred degrees C, makes for a much simpler modeling problem, because you don’t need to worry about radionuclide transport. Those all go away. It simply becomes a thermal management model. And we have those models. We presented them back in January. We’re continuing to work on those. In particular, we are now working on other options. The question came up earlier from Andy Kadak about are we working on options for disposing of larger waste packages that present thermal challenges in closed environments such as a high-granite or clay repository, and the answer is yes, we are working on that.

Prioritizing R&D needs, these are straightforward points, and they follow from what I just said. These generic models do help confirm viability of concepts; they’ll mature into site-specific models that we believe when we’re ready, the program is ready to go to licensing or to guide site characterization before getting into licensing, our models now will evolve into the tools needed then.

And the last point, these models do not and should not be used to identify the best concept. This is something that I feel fairly strongly about, that we’re not making these models so that someone can decide that a deep borehole is better than salt or better than granite or clay is the right way to go. Those are essentially programmatic and policy decisions. The work here is intended to help inform them but not to make those decisions. And I'll stop there.

GARRICK: Okay, thank you very much.

Questions from the Board? Yes, Sue.

CLARK: So tell me--Sue Clark, Board. Tell me about your generic waste package.

SWIFT: Actually, Carlos in the next talk will be able to say more about that. But in the two examples I showed here, we actually took no credit at all for the waste package. In our granite model we were using--essentially using the Swedish waste package. But in both of these we chose examples where it seemed simpler just to say the waste package does not perform. Generically, it's got to be something that meets transportation requirements, handling requirements. It's got to be robust and strong. But we're not worried about how it performs in the local environment, which is underground. In the borehole case it's conceptually--Bill will talk about that. It's the same kind of steel they would use in a drilling operation. You put the fuel rods inside it and you weld the end caps on.

GARRICK: Ali.

MOSLEH: Yeah. Mosleh, Board. On Slide 3, your second bullet and third item, you end the bullet by saying that these estimates should be incorporated into an overall probability distribution of cumulative release to the extent practicable. What do you mean by the last two words? What would be limiting?

SWIFT: I didn’t spend a lot of time agonizing over those two words. Both the NRC and the EPA--this is the EPA’s version--both regulators have taken some care to make it clear that absolute--they recognize absolute proof is not possible. There are irreducible uncertainties. These are, at best, estimates. So I would interpret that to mean that they don’t expect you to have the definitive answer on the probability distribution. I’ll take--I mean, heck, I could return that question to Tim McCartin, who may have helped write those words for all I know.

No fair, Tim? Sorry.

GARRICK: I have--oh, go ahead.

MOSLEH: I think, in principle, you can always do that, you know, based on more or less evidence, but you can always express it.

SWIFT: Sure. I agree completely. You can assign a probability distribution to anything. The question of how meaningful it is is a different--it needs to be thought about--

MOSLEH: So I was wondering if you have some insight as to what is practical and not--

SWIFT: In my experience on both WIPP and Yucca Mountain, in practice that turns out to be something that gets reviewed case by case. A regulatory reviewer will tell you, We don’t think that you handled uncertainty correctly on that one. So I don’t think there’s going to be a generic answer to the question.

MOSLEH: So--quickly, John.

GARRICK: Yes.

MOSLEH: That means, you know, in terms of the limitation of knowledge and practicality, there would be parts of the analysis that would be left qualitative as part of the assessment?

SWIFT: Yes.

GARRICK: Probably yes.

SWIFT: If it isn’t practicable to treat it quantitatively, it will be qualitative.

GARRICK: Of course, I disagree with that point of view. I think it’s practical to be quantitative always. I have a myth on Slide 4, and it is just a myth.

SWIFT: Okay.

GARRICK: When you say “define the goal,” it is not what is acceptable performance. That’s not the goal. The goal is for you to calculate the performance. The goal for you is to calculate the risk. You don’t need to know anything about what is acceptable to do that.

SWIFT: I accept the correction. In this context it would be better to say, define the metrics that you’re trying to assess.

GARRICK: Yeah, right.

SWIFT: I agree with that--

GARRICK: Yeah, okay. Bill.

MURPHY: This is Bill Murphy of the Board. I'm curious if in your generic PA modeling your effort is really devoted toward your best estimate of what might happen or a conservative bound on it, which is frequently the case, and momentarily you said that in one case you had just completely ignored the waste packages. And so I suspect that what you're, in fact, doing is calculating a conservative limit on what the system is. It seems to me that you might have an opportunity in doing a generic study to target the most realistic scenario rather than a bounding scenario.

SWIFT: Going back to the very simple model, I hope that once we've figured out what the key limiting steps in the process are--the processes that limit the release--that we haven't conservatively thrown those away. So let's take the no-credit-for-the-waste-package one. In that deep borehole environment, I have no idea how long a piece of drill steel is going to last. It clearly is going to last something on the order of years, but probably not something on the order of millennium. The uncertainty is somewhere in that range. But if it doesn't last long enough to have a larger effect than that slow degradation rate of the uranium oxide fuel, then it doesn't matter. So I don't think I've actually skewed the--at a local scale that was a conservative assumption, but I don’t think it’s likely to have an impact on the overall estimate.

Does that answer the question?

GARRICK: It does. And so you would say that your philosophy is to generate a model that’s realistic rather than conservative or bounding?

SWIFT: Simple but realistic? I hope so. But I’ll accept that one way to get to a simple--maybe the only way to get to a simple analysis is to pick up those things that don’t have a large impact on the final result and conservatively set them aside. So, yes, there are unavoidable conservatisms in it.

GARRICK: To a risk analyst, Bill, you’d never make sense to talk about a bounding risk assessment. The whole reason this discipline was invented was to tell the whole story as best you can and as realistically as you can.

Any other questions?

(No response.)

Thank you very much. Thank you. We are right on schedule. Thanks to Peter for helping us get back on schedule. We’ll take a break until 3:25.

(Whereupon, the meeting was adjourned for a brief recess.)

GARRICK: All right, we’ll resume our afternoon session, and Carlos Jove Colon is going to talk to us about DOE’s research and development activities related to the development of engineered barrier systems for different geologic media. Carlos.

COLON: All right, thank you very much. My name is Carlos Jove Colon. I’m from Sandia National Labs. I’m the used fuel disposition lead for EBS. I would like to thank the Board for allowing me the opportunity to show the work that we are doing as part of the Used Fuel Disposition Campaign on engineered barrier systems. This is a concerted effort between various groups of people and various labs, including Sandia National Labs, Los Alamos, Lawrence Berkeley, Lawrence Livermore, Argonne National Lab, Pacific Northwest National Lab. So, yeah, a lot of people there; right?

So let’s start with the first slide here. What is the engineered barrier system? Well, for the U.S. Nuclear Regulatory Commission, engineered barrier system means the waste packages and the underground facility. You can go to another definition given by the NEA State-of-the-Art Report on EBS, essentially saying the engineered barrier system represents the man-made engineering materials placed within a repository--pretty much similar meaning there--including waste form, waste canisters, buffer materials, backfill, and seals.

And, just quickly here, I want to show you what a typical multi-layer EBS looks like. This is the Belgian radioactive waste repository concept, and basically the multi-layer EBS--this is, of course, clay rock, and the waste canister is in the middle surrounded by a layer of buffered material. And then there is a liner, and then there is actually other types of backfill. Sometimes people actually call it buffer as well. And then, of course, you know, the disposal gallery linings.

So what has been done for EBS? Well, in the USA there are various examples. We know some of them very well, I guess, the Deaf Smith and WIPP site characterization studies, most of them on the thermo-mechanical properties of salt consolidation, etcetera, for both intact and crushed salt. Here there is a photo. I don’t know if you guys can see this well, but there’s actually an experiment on consolidation with salt, in this particular case crushed salt. These are actually the alcoves for placing waste in the WIPP panel. Also, there has been extensive research in terms of nuclear waste encapsulation, glass waste form like borosilicate glass, cementitious waste forms, low-level waste, and, of course, research on noble waste forms.

Also, as part of Yucca Mountain, we got a drift-scale test facility, and here is actually a cartoon depicting the drifts. And the main purpose was to actually study the thermal environments in disposal drifts. Also, as part of Yucca Mountain, we have waste package studies, drip shield, and transport, aging, and disposal concepts as well.

Now, internationally, well, there's a list here. I'm not going to go in detail where all the underground research laboratories. They have been conducting research in terms of engineered barrier systems for some time in various types of media, for example Mt. Terri, Opalinus Clay in Switzerland. In Switzerland as well we have granite in the Grimsel site. We have salt at the Gorleben site in Germany. We have, for example, the FEBEX in-situ site scale study, which is actually--I would call it, actually, one of the main pieces of research that is actually driving much of the studies in bentonite clay, and they use bentonite, actually, as a buffer, as backfill material as well. An example of FEBEX is actually here where you see the steel canisters right in the middle and then surrounded by blocks of compacted bentonite.

There is also international collaboration, for example DECOVALEX. I think that there is some mention of some of the international programs that have been around for some time. This one in particular is quite useful in terms of the development of coupled models and their validation against experiments. And I must note that, actually, some of these experiments are conducted these (unintelligible); and, of course, there is the NEA integration group for the safety case. That was part of the EBS project.

Let me go to the next slide here. What are the UFD needs for EBS? Actually, as far as the knowledge gaps and R&D prioritization highlighted in the UFD Campaign’s Disposal R&D roadmap, we actually have a bunch of issues. And, for the most part, these were actually mapped in terms of FEPs, and there are a bunch of them. But we ended up ranking them, and the highest ranking ones are, for example, waste form, thermo-hydrological-mechanical processes, waste container, radionuclide speciation and solubility, and buffer and backfill material properties.

When you actually look at these as a whole, you realize that they are all related in terms of coupled process phenomena, thermal, hydrological, mechanical, and chemical. And what is important about this or what I outlined this to be important is because a lot of the interactions that happen in the engineered barrier happen in terms of interactions between different interfaces where you’re talking about crushed salt, which is a porous medium, or is in clay. This cartoon here actually depicts some of that. And this is actually modified after Olivella, in which you have solid, liquid, and a gas; and sometimes you have one of them or two of them. But, in any case, you have all these processes going on. Heterogeneous chemical reaction between solid and liquid, you have liquid evaporation, condensation, etcetera, plus heat and pressure.

One of the things that I want to talk right now is the work to date as far as the UFD campaign in terms of coming up with design concepts in backfilled disposal scenarios. We don't have a design per se right now. We are actually focusing on developing the tools needed to examine these design concepts. The way I would like to present this is we can look at different types of EBS; for example, we have the host rock in here. This is actually probably the most simple one for a backfill scenario. We have the canister with the waste in the center, and this is a single-domain backfill/buffer surrounding it. But then you can actually increase complexity by adding other types of layers and actually even more and if you have more liners, etcetera, for support. The purpose of actually using different types of backfill/buffer is to actually, you know, for example, there are some mixtures of buffer material that you can mix with sand and graphite, for example, just to enhance thermal conductivity, etcetera. So these are actually exercises in optimizing the design, and that's actually key for the evaluation of generic EBS design concepts; and also provides the basis for flexible EBS design optimization.

Another thing in terms of work to date, one of the things we would like to know is: What are the hydrochemical characteristics of waters in deep-seated environments? We have compiled data from various repository research projects. We also are working pretty hard on the expansion and maintenance of thermodynamic databases. Those are key inputs to a lot of our models, for example, to determining solubilities and quantify--actually, we are between different phases. We actually--going back to Yucca Mountain, this type of development, we actually are going to use similar tools and methods, for example, questions of say temperature extrapolation algorithms, etcetera. But now the focus is actually in the refinement, expansion, and also focus on materials that are going to be used in the engineered barrier system like clays, and for that we need to focus more on clay thermodynamic data and hydration models.

Also, there is an inherent and always present facing EBS, which are cementitious materials. And we need to actually expand on what was done in the Yucca Mountain project thermodynamic database in regards to that. The Europeans also express concern about this; and, actually, they have put out even databases for--thermodynamic databases for cementitious materials. So our intent here is to expand and actually evaluate these types of data. Also, we need to study how to use that data in terms of quantitative models. You know, we have an exercise in modeling code tool identification, EQ3/6, which is a code that was used in Yucca Mountain. There are actually other codes around, Cantera-Dakota, which is a Caltech Sandia development, and evaluation of solid solution models for cementitious phases. This is important because these phases, actually they don't dissolve congruently; and if we want to model leaching of cement, basically we need to resource ourself to those models.

Also, thermo-hydro-mechanical modeling in clay, we have Berkeley actually successfully working out the coupling between TOUGH and FLAC codes and implementation of the Barcelona Basic Model, which is actually a mechanical model for soils, but it has been tailored to actually model bentonite. And they also managed to study various scenarios in which they have thermal management and peak temperatures, buffer saturation. They also study tunnel and canister spacing and elevated peak temperatures, as I just mentioned.

And some of the results that actually they have carried out are presented here, for example, temperature/time profiles in different parts of the near-field environment; also, liquid saturation in different parts of the bentonite buffer. For example here, this red curve here is for bentonite canister interface.

We also have done work in reactive diffusion on clay. This is also Berkeley's work by Carl Steefel, in which he is trying to assess a problem of having multicomponent diffusion in clay. As you may know, diffusion in clay is probably the main mode of transport, and he has come up with an implementation of an analytical solution model, basically an analytical solution of the Poisson-Boltzman equation to actually characterize transport. For example, in this case it's a chloride transport as a function of compaction, and the compaction here is represented by the dry densities of the clay. The Y axis represents the ratio between chloride in the micropores in the clay versus chloride in the bulk plotted against external chloride concentration, which is actually equivalent to chloride concentrations in the bulk. And, as you can see, he has been having some success in fitting the data. However, these models actually still need some refinement. There are some refinements to be done.

Also, we have disposal system evaluation framework and thermal analysis. From now on I am going to refer to it as DSEF. And DSEF basically allows for efficient, however high-level, evaluations and comparison between fuel cycles, repository designs, EBS materials, fuel types, and it's actually implementing tools that are familiar to users like, for example, Microsoft Excel, etcetera. However, there is coupling with all our codes, in this case where a thermal analysis is interfaced with analytical solution implementing Mathcad.

And, actually the main purpose of DSEF is just to provide a rapid evaluation of many processes. For the EBS, one of the things that we're going to do with it is to examine thermal analysis on the different types of multi-layer engineered barrier systems that we can come up with.

Another thing that I would like to mention here is the exploitatin of sophisticated modeling and simulation methods. For example, one of the things that I would like to show you here is molecular dynamics studies in clay. These methods have been developed for some time; and now that there are computational power plus the massively parallel types of codes available to conduct these analyses, allows for accurate studies of clay swelling behavior, for example as a function of relative humidity. Also, we would like to capture this type of clay behavior in clays having different end-member composition. And, of course, at the end we would like to compare that to data.

Another type of research here is coupled thermo-hydro-mechanical calculations in salt media. And this is, again, ongoing research. The kind of scenario that, actually, we're involved right now is that one that has intact salt. There is the crushed salt alcove here; here in the red is the waste canister; it's the heat source. There is the skin of the excavated disturbed zone around the alcove, and then there is the crushed salt here in the excess drift. We are using SIERRA Mechanics, which is a high-performance computing platform. We are actually using constitutive models that represent both intact and crushed salt. They are quite different. We are going to focus in terms of moisture transport within the crushed salt.

And the final product of this is to actually couple the salt permeo-porous properties with mechanical deformation and, of course, hydrological transport; in this case it will be the moisture transport. For that we're using the codes ARIA and ADAGIO, and the couple between both is ARPEGGIO.

Thermodynamic databases. Well, I mentioned something about it already. One thing that we are actually doing right now in terms of the ongoing efforts is to take the whole Yucca Mountain database, import it into the Cantera code in terms of the input format. Implementation of solid solution models for C-S-H using a Margules type, (unintelligible) using Cantera. This effort will allow us to model leaching behavior of what we call Ordinary Portland Cement. We also are conducting thermodynamic properties of clay phases, so we are in the process of actually not only reviewing but updating models and, of course, data focusing on clay hydration.

Disposal system evaluation framework, I think that we have a virtual model ready; however, we are actually expanding and refining some of the algorithms for doing the thermal analysis. Also, there is a development for the cost algorithm using literature information, and then we're aiming at having a test case for a multi-layer EBS and use it in the form of an exercise with this EBS design optimization.

Integration activities, we want to actually keep integrating with other activities in the UFD Campaign, for example, the one that Peter just mentioned, GDSM. And we also initiated a development of the web-based information management tool, and this is for database cataloging where we are talking about many kinds of database including documents, etcetera.

Another ongoing research is about--it's an expansion of the Barcelona Basic Model that I just mentioned previously. After the FEBEX experiments it became clear that there is actually some things that you need to consider in terms of, well, I would say feeding the data. But since modeling and experiments go hand-in-hand, there has been this expansion on the modeling, which they recognize two types of structures. One is the porosity in the clay particles, and this is the porosity between the clay particles, and that is something that they want to implement within the model. Basically this model enhancement will serve as a framework for further expansion in terms of the thermo-hydro-mechanical and also chemical behavior. And that is--you know, it's aiming towards actually coupling more of the chemistry within this process. I also should mention that currently there is participation in the DECOVALEX project to validate the thermo-hydro-mechanical model, and that's for the HE-E heater test at Mont Terri.

Another ongoing research activity is to actually experimentally characterize Uranium-6 sorption and diffusion behavior in terms of chemical solution conditions, and that is pH, ionic strength, degree of clay compaction. And this will actually develop the needed experimental data for validation of the reactive diffusion model. This work is being conducted at Lawrence Berkeley.

Another work related to that is the complete implementation of the Poisson-Boltzmann analytical solution in the reactive transport simulator and actually do tests against the full range of diffusion data that exists. They actually have been working pretty hard on this. Also test this against uranium transport experiments in the ones that I just mentioned now. And something that actually came out of this work is development of a fractal, multiple-size model. This actually was presented at the (unintelligible) conference last year.

Experimental work on clay barrier interactions, we actually highlighted that canisters are important and, of course, you know, the interactions with clay. We are actually conducting experiments in waste container materials, stainless steel, copper, and then we are actually conducting hydrothermal experiments in bentonite-metal interactions. And, actually, there are two types of experiments, you know, clay-water just to study what happened to the clay at the elevated temperatures of 100, 200, 300 degrees C, as well as clay-metal-water interactions. One of the outcomes of this kind of work is to study the phase changes and what kind of interaction we might expect having, you know, clay dehydration or transformation or phase transformation of the clay to other materials in the presence of canister materials.

Another thing that we are looking at is, actually, used fuel degradation, and this is actually currently in the form of electrochemical studies. For example, they want to evaluate the importance of noble metal particles that exist in the used fuel, and actually they can play a role in scavenging oxidants, and that is, you know, hydrogen oxidation.

Also, we are looking into implementation and use of the mixed potential model as a base for UO_2 fuel degradation. This is the model developed by Shoesmith.

Also, we are looking into all this in terms of a full system characterization. This is actually work carried out at Argonne National Lab, and we are looking at in-situ x-ray absorption studies, the usual, electron microscopy and, of course, solution chemistry. PNNL has also been working this in terms of looking at these kind of interfaces here. Talking about important EBS interfaces, this one between the used fuel and the canister surface and what kind of redox environments are actually generated here when you have radiolytic generation of peroxide. But also on the other side you have actually corrosion; you are actually generating--reducing the environment and how those two interact. And I think that--well, the purpose here is to actually identify that in the form of electrochemical studies.

Here is a photograph of studtite with--I'm sorry--studtite growing on top of UO_2. This is actually a nice photo sent--one of the members of the team, and this photo is by Edgar Buck.

Okay, so I guess this is my last slide. So what is the expected future work here? We would like to see expansion of the modeling activities for coupled processes. We also would like, of course, to expand on experimental activities to research key processes in EBS and used fuel degradation. Those are actually difficult experiments. Sometimes it takes time, but although we have a strong reliance on models, we need experiments.

I think it is very important and it has been outlined before today, the increase in level of international collaboration with international partners, particularly in underground research labs involving field- and lab-scale experiments. There is a lot of knowledge that we can leverage from those collaborations, and I think, in my opinion, they are very important.

We also need to have a continuing enhancement of level of integration between various UFD activities, for example continued support to the GDSM and actually increase integration of DSEF with other used fuel disposal campaign activities. And, of course, that's possible in our fuel cycle technology campaigns.

This is my talk. Any questions?

GARRICK: Questions? Yes, Howard.

H. ARNOLD: Arnold, Board. Are you doing anything on the waste package that was designed for Yucca, looking at drip shields anymore, or anything like that?

COLON: Not currently. We are actually looking at some of the materials, I mean, like the stainless steels and copper; but we're not looking at some of the material--

H. ARNOLD: The Alloy-22?

COLON: I think--okay, Peter would like to--

SWIFT: We are not doing any design-specific work for Yucca Mountain at all any longer. We are wrapping up the corrosion tests that we started in Yucca Mountain some time ago, and some of the Board has been briefed on that, I think. But basically those Alloy-22 corrosion tests that we started, what, in 2006, 2007, we are bringing those to an orderly conclusion and documenting the results on those. And we're using that same lab now. We're transferring it to focus more on other metals, particularly stainless steels, and which we use actually as controls in the Alloy-22 tests. They are very relevant to storage corrosion issues, humid air corrosion on storage canisters. So we're continuing that work.

GARRICK: Yes, Bill.

MURPHY: This is Bill Murphy of the Board. I was just curious about the effects that would result from putting a clay buffer material in a clay rock. It seems that the clay rock itself or a shale would tend to buffer the chemical conditions of the environment and that there would be a strong potential for the buffer material to equilibrate with the host rock. Have you looked at that? Have you considered the ion exchange processes or water exchange processes that might ultimately affect the properties of the clay vacuum?

COLON: We actually--in terms of the modeling, that's one of the things that we want to address. This is actually in particular for the clay that is going to be used to buffer backfill material, which is--it's going to be a little different from the clay in the rock. The clay in the rock is going to be already--I mean, an argillite is not going to be the same as a bentonite that you just mine out. One of the things that we're going to be looking at--and that's actually why I want to do this molecular dynamics studies--is to see or understand better how clay swells. I mean, that swelling is dependent upon how you exchange. For example, you exchange magnesium, you're going to have three--two layers of water in the interlayer. You exchange cesium, you only have one. So those properties can be assessed. I mean, there is so much experimental work in there, but they can be assessed through this kind of modeling.

GARRIC: Ron and then George.

LATANISION: Latanision, Board. Slide 16, can you go to--yeah, I'm not aware of the first item here, the objective of looking at the noble metal particles. What is the concept there? I'm not aware of what Dave Shoesmith had done and what exactly you're trying to do.

COLON: Well, one of the things that we are trying to do in terms of the electrochemistry, the way they want to do this is to create like electrodes made of these particles and see how they can actually affect the redox of the interface between a film of solution and how that could affect UO_2 degradation. I am not the--

LATANISION: So the electrode is a UO_2 electrode that--

COLON: Well, they have one--I didn't put a caption here, but actually they have one that isn't just made of noble metal particles, and they will try to implement a similar approach using an electrode made of UO_2 fuel. But here it’s just--the main purpose here is to understand what kind of redox effects you might have by depressing of these particles of the interface of the fuel. And I wish I was the expert in this and giving you a more clear explanation, but that’s actually the aim, and this is all part in terms of how this might affect used fuel degradation in general.

LATANISION: Where is this being done?

COLON: This is Argonne National Lab.

LATANISION: Argonne?

COLON: Yeah. And then PNNL is also working along with them also in the development of sim-fuels for this kind of experiments.

GARRICK: George.

HORNBERGER: So DOE funds the Cementitious Barriers Partnership that they’re looking at some models, too, for leaching through cementitious barriers. How do you guys connect with them?

COLON: Well, I talked to David Carson from Vanderbilt University, if I’m not mistaken. And essentially they have a program, I mean, and we have talked in terms of a potential collaboration, etcetera. My goal here is more like in developing databases and models that actually can be used for representing leaching cement. They were actually interested in that, and I’m more than welcome to, you know, share that kind of information. Likewise, David Carson say, hey, you know, we actually have reports. We are focusing also on experimental work as well. So that's actually, in my opinion, the main difference here.

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

EWING: Ewing, the Board. On your last bullet, radiolysis models and simulant fuels, so these are old topics. I mean, in the Swedish program a lot of effort was devoted to radiolysis effects from fuel, simulated fuel, sim-fuel. This is decades ago that that started. Are you plugged into those communities and taking advantage of what's gone before?

COLON: Yeah. Actually, the purpose in here, number one, is to develop a comprehensive radiolysis model. Radiolysis is not an easy thing to model--

EWING: Not at all.

COLON: --because you have--even for pure water, you have I don't know how many kinetic reactions, etcetera. So Edgar Buck, which is actually leading this, has been very connected with those people and, in fact, some of the results that they are getting in the model that they are developing. And the work actually was done in Sweden by other workers. So, yeah, there is a connection in there.

EWING: So let me ask the question in a different way. Is there a need to advance the models, or is the need greater in terms of experiments that would verify the models?

COLON: I don’t know, really, the details in the radiolysis model, but I know that sometimes in order to model radiolysis you have to go through a whole bunch of assumptions.

EWING: Right, right, there are a whole series of half reactions. So it might be that the models are as far as they can go in the absence of detailed experiments, so--

COLON: There is another aspect of this. As new data comes in, you know, like a radiolysis model for pure water doesn’t behave the same as a radiolysis model for when you put nitric acid in there.

EWING: Right, sure.

COLON: You start developing a whole new set of radicals, etcetera. So I think they are actually looking at how you can have a much more improved model, especially when you want to plug this to a lot of the work that’s done in terms of the electrochemistry rate.

EWING: Okay, thank you.

GARRICK: Any other questions from the Board? Any questions from staff? Audience?

(No response.)

Thank you. Thank you very much.

All right. We are now ready to hear about geological and practical aspects of deep borehole disposal.

Bill Arnold will start off.

B. ARNOLD: I'd like to thank the Board for the opportunity to speak to you today and to acknowledge teammates at Sandia Labs on this effort, in particular engineering and drilling technology contributions that went into some of these studies and also some of the collaborative work that we're doing with Dr. Driscoll and his students at MIT.

So this is the outline of the talk. I'll start out with a brief description of a deep borehole disposal concept; talk about geological aspects of the disposal system and then present a reference design and operations for deep borehole disposal that we published last fall; talk about some practical aspects of this disposal method; and then conclusions.

In principle, deep borehole disposal is a relatively simple concept. It consists of drilling a borehole or an array of boreholes into crystalline basement rock to about 5,000 meters. And Peter did a good job of summarizing this concept, so I'll go over this relatively quickly. But some of the particulars, you could dispose about 400 waste canisters emplaced in the lower 2,000 meters of the borehole, and then the upper part of the borehole would be sealed with compacted bentonite clay and cement plugs.

And there are several factors that suggest that this disposal concept is both doable and safe. The first one is that crystalline basement rocks are common in many stable continental regions, so there are many locations where potentially favorable conditions exist. Existing drilling technology permits the dependable construction of boreholes that could be used for this disposal method at acceptable costs. And low permeability and long residence time of high-salinity groundwater in deep continental crystalline basement suggests that there is very limited interaction between the deep subsurface and the shallow subsurface and then with the biosphere. Deep borehole environment is geochemically reducing, which limits the solubility and enhances the sorption of many radionuclides. And, also, in stable continental regions there is often a density stratification of saline groundwater underlying fresh groundwater and that this would oppose thermally induced groundwater convection, because basically you’re trying to convect denser saline groundwater upwards as opposed by overlying fresh groundwater.

This is an illustration of the disposal concept; and, really, the distinguishing characteristic of this disposal concept is the relatively great depth of disposal. So this figure shows a borehole here with the waste disposal zone from 3,000 meters depth to 5,000 meters depth. For comparison, this is the approximate depth of the WIPP site. Also, for scale, this is the tallest building in the world in Dubai, so we’re talking about a very deep disposal system. And our expectation is that the isolation increases with depth, and it increases dramatically with depth for depths that are this great.

This is a figure that was created by Frank Perry and his team at Los Alamos National Laboratory, using GIS information showing the depth to crystalline basement in the continental United States. The location of commercial reactors is shown with the square symbols here. The color scale indicates the depth to basement rocks where the green colors from light green to darker green are depths that are less than 2,000 meters to the basement. The red color indicates outcrops of crystalline rocks. And, as an explanation here, the white areas are undetermined depth to crystalline basement; and this is primarily a function of limited data for the depths to the basement and structural complexity, particularly in the western United States. So there may be some locations here where the depth to crystalline basement is less than 2,000 meters, but it’s just not really defined on this regional scale analysis.

So the point here is that there are large areas within the continental United States where the depth to crystalline basement is less than 2,000 meters, particularly in the central part of the country here, which is an area that is far from tectonically active regions, volcanic activity, etcetera.

SPEAKER: Tarrytown looks pretty good, too.

B. ARNOLD: So some considerations in geological aspects of borehole siting and safety. Any location would--or any site would have to be characterized to a basic extent geologically. It’s not possible to characterize the 5,000-meter-deep environment in a borehole to the extent that one could characterize a mined repository at a few hundred meters depth. But it’s our feeling that geological characterization should really focus on conditions that are undesirable or unfavorable for deep borehole disposal concept and waste isolation. And I’ve listed some of those here, and there is some overlap with what Ken Skipper presented earlier today, but some of them are particular to the deep borehole disposal concept.

The first would be the presence of young meteoric groundwater at depths of greater than 3 kilometers. This would indicate deep circulation in the system. Such conditions would be, actually, unusual and unexpected in a continental region, but it would indicate an active--a relatively active groundwater flow system to great depths.

The second one is low-salinity oxidizing groundwater at depths of greater than 3 kilometers. This is the same indication of deep groundwater circulation, and also we are removing some of the favorable characteristics of the high-salinity groundwaters and reducing conditions that are favorable for waste disposal.

The third one is economically exploitable natural resources at depths of greater than 3 kilometers. This is clearly unfavorable from the standpoint of future human intrusion at the site.

The fourth one is a significant upward gradient in fluid potential--that is, overpressured conditions--from below 3 kilometers depth. Overpressured conditions can exist from a number of geological processes. Some of them can be--some locations one would guess a higher probability of overpressured conditions than others, and they can be avoided. And some of these geological environments would be actively compacting sedimentary basins, tectonically active zones, convergent plate margins, but these would be avoided anyway. At any rate, an upward gradient would create a situation in which you have a persistent--over geological time scales, a persistent potential for flow upwards in the migration of radionuclides via this spectrum. Another would be a naturally interconnected zone of high permeability from the disposal zone to the shallow subsurface such as a major fault zone. I think this would be unfavorable as a potential fast pathway for flow. A high geothermal heat flow, this would be unfavorable from the perspective of potential human intrusion from geothermal resource exploitation.

So in the absence of these unfavorable features, the most likely scenario for release of radionuclides is thermally driven groundwater flow through the borehole or the surrounding disturbed rock zone. In fact, this is the scenario that was analyzed in the performance assessment calculations that Peter Swift described.

And to examine this release mechanism, we've done some thermal-hydrologic modeling in 3D and then also some mechanical and thermal-mechanical modeling of the disturbed rock zone around the borehole, and I'll describe that next. This is the 3D coupled thermal-hydrologic model, and it simulates waste heat in the disposal zone for multiple boreholes. The figure on the right shows the model domain, and it shows temperature plotted with the color scale. So the variation in temperatures shown here is primarily natural geothermal gradient from cool temperatures at the surface to higher temperatures at 6 kilometers depth in the bottom of the model. This model uses a variable resolution mesh and quarter symmetry boundary conditions. It uses hydrostatic boundary conditions on the outside of the model domain, and you can see the thermal pervoration (phonetic) in several lines here that represent the boreholes. So this is after ten years of time, and you have a temperature increase of 30 to 40 degrees centigrade in each of these boreholes.

So these simulations are conducted using the FEHM software code, and there are several objectives here. The primary one, though, is to provide simulated groundwater flow rates as functions of time and depth for use in the PA modeling.

Here are some of the results from that 3D thermal-hydrologic modeling. The figure on the right shows time on a log scale versus vertical groundwater flux in meters per year, and there are a number of curves here for different depths in this system. And this is for the case where there are nine boreholes and they're spaced 200 meters apart. Some example curves, at 3,000 meters depth, which is the top of the waste disposal zone, the blue curve shows the flow rates. They start out high almost immediately and then decline. They actually go below zero and then come back again at much later times. The red curve, solid red curve, is for 600 meters above the waste disposal zone, and that's this curve right here you see of a peak flow rate and decline. Then it shows up again much later. Our interpretation of this is that groundwater flow is induced by waste heat at early times by simple thermal expansion and focusing of flow within the higher permeability zone of the borehole and at later times by buoyant free convection.

And also I should point out that these upward flow rates are overestimated because the salinity stratification that we would expect in this system is not included in the model. There are also some aspects of the boundary conditions which tend to overestimate the flow rates that are calculated here, and these are the results that were used in the PA model, as I mentioned before.

Now, shifting gears, this is a two-dimensional model of--this is numerical modeling of thermal-mechanical effects around the borehole and how those effects would potentially impact the permeability in the disturbed rock zone. The table here just lists the parameter values that were used in these calculations. The same thermal parameters were used in the 3D model that I presented earlier. The figure on the right shows the model domain, the curvilinear grid, high-resolution grid near the borehole--the borehole is in the center--the mechanical boundary conditions here for two cases of isotropic stress and for anisotropic stress or differential in horizontal stress, which is encountered at most locations to some extent, and plays an important role, as I'll show you in the results here. It's a linear elastic model and thermo-elastic model, and it also is implemented with the FEHM code. George Zyvoloski at Los Alamos is the author of that code.

KADAK: What is the heat load assumed?

B. ARNOLD: The heat load that was assumed in the calculations that I'm going to show you are for a single fuel assembly, and it's an average Yucca Mountain fuel assembly. So I'm not exactly sure of the burnup for the average Yucca Mountain assembly. It's somewhat less than 60,000-megawatt days per--

KADAK: So is it--you know, I don't know at what age you dispose of it. What is--

B. ARNOLD: Oh. And it's been aged for 25 years.

KADAK: So what is the cubic heat load, if you would? You don't know what that is, I presume.

B. ARNOLD: No, I don't. I don't have that number.

KADAK: Okay, thank you.

B. ARNOLD: I should point out that the 3D thermal-hydrologic modeling that I showed earlier used a different thermal source. It used the reference fuel assembly from the Used Fuel Disposition Campaign, which is a 60,000-megawatt day per metric ton burnup and 30 years of storage time. So the thermal source in this model was somewhat lower than in the 3D model. Oh, and so this is a two-dimensional slice through the borehole at a depth of 4,000 meters.

The first results that I'm going to show you are just the mechanical modeling. This is without the heat source. So the figures on the right show the heterogeneous elastic modulus field that was used, so there is heterogeneity in the host rock. A fracture network is simulated here with elastic modulus that is a factor of 5 lower than the average granite elastic modulus, so we're trying to build some geological realism into this model.

And for differential horizontal stress--that is, the anisotropic case--the host rock is placed in compression in the direction of the maximum horizontal stress and in extension in the direction of minimum horizontal stress. And that's shown in the lower figure, which plots the volumetric strain that's calculated. Warm colors are positive volumetric strain, so rock that's placed in compression; the cool colors show extensional strain. And generally we have warmer colors in this direction, which is the maximum principal horizontal stress; and we have extension occurring in the minimum principal direction. And you can see that the stress is concentrated at the borehole walls and concentrated in the fractures that are close to the borehole.

I should also point out that this is an elastic module; it does not simulate borehole breakouts which, for a high degree of differential horizontal stress, can occur where you actually have failure of the borehole wall and the borehole is no longer circular but becomes oblong.

So the permeability will be increased by extensional strain and decreased by compression. And this is a--the permeability changes are a complex function here, but the sensitivity is amplified by the cubic relationship between permeability and fracture aperture.

So kind of the conclusion here is that you'd have a significant reduction in the permeability of the fracture network on this side of the borehole and this side of the borehole, and you could have a significant increase in the permeability of the fractures or the rock disturb zone on these sides.

Okay, now this is the thermal-mechanical case, so this is with the heat source for a single fuel assembly that we discussed a minute ago. So a couple thermal-mechanical modeling in the same heterogeneous field is shown for PWR fuel assembly five years after disposal, and the upper plot here is just the temperature field. The highest temperatures are near the borehole obviously and then symmetrical heat conduction outward. Higher temperatures near the borehole and related to thermal expansion of the granite places much of the host rock in compression and decreases the permeability, so we're expanding the host rock around the borehole. We're placing it on average in compression.

However, for this heterogeneous domain, you can see even though the average colors here outside are the warm colors and in compression some of these fractures near the borehole wall remain in extension and would still have an enhanced permeability in spite of the thermal compression created by the heat.

So let's shift gears here now and talk about the reference design and operations. This is the report that was published last October. And the overarching objective here was to come up with a relatively simple but achievable design that's internally consistent for deep borehole disposal, and we would expect to meet regulatory and safety requirements.

We had some secondary goals here that I've listed. One thing that I should point out is that there are clearly numerous design alternatives that could be considered here. And this reference design does form a base, though, around which those design alternatives could be evaluated. And this reference design also provides a reference design for a performance assessment and risk analysis. This reference design was completed after the performance assessment modeling was done that Peter described, so we're talking about future performance assessment modeling.

This is the borehole design. The figure on the right shows the borehole design. This is not to scale, but it does show the telescoping design that goes downward. A very large diameter borehole drilled down to 457 meters, a somewhat smaller diameter down to 1,500 meters, then down to 3,000 meters. The waste disposal zone is the lower part of the borehole here. The borehole is cased from the surface all the way to the bottom of the waste disposal zone for emplacement of waste canisters.

Testing and logging of the large diameter specified in this nested borehole design may be difficult to achieve, so leading us to consideration of a pilot hole at a specific site first followed by these disposal boreholes. And this liner casing that's placed will help assure against stuck canisters and facilitate potential retrieval, at least until the liner is pulled and the seals are set, and I'll describe that later. But some of this casing will be pulled out of the borehole so that the seals can be emplaced in contact with the rock in the borehole walls.

This is a slide on the waste canister design. This is a very simple design. The engineering drawing on the bottom shows that this is basically steel tubing that can hold fuel rods welded shut at the ends. It's connected to overlying or underlying waste canisters by this coupling design; this is an existing design. It's carbon steel tubing. The thickness of the tubing is such that it can withstand projected hydrostatic pressures in the borehole and mechanical loads of overlying canisters and for the thermal-- for the higher temperatures from the waste heat. Our reference design also includes rod consolidation. It can fit 367 fuel rods inside of this waste canister. And the design requirement here is that the waste canister retain its integrity until after the borehole is loaded and sealed. A design objective is not for long-term corrosion resistance for this canister design.

This is a slide about waste canister emplacement. There have been studies done in the past about this. There is Woodward-Clyde study from 1983. This figure is taken from there about what that emplacement--drilling rig and emplacement rig might look like. The canisters would be transported to the site by tractor-trailer. Surface handling would rotate the shipping cask to a vertical position, move it over the borehole, then strings of 40 canisters would be attached to a pipe string with a J-slot assembly for releasing the canisters and lowered to the disposal zone.

So multiple strings of canisters would go into the disposal zone. A synthetic oil-base mud with a high bentonite concentration would be present in the disposal zone, forming a grout around the waste canisters; and then each canister string would be separated from overlying strings by a bridge plug and a cement plug. So the lowermost waste canister in the waste string would only have to bear the weight of 39 additional waste canisters on top of it, not the weight of the entire 400 waste canisters that would go into the waste disposal zone.

There is practical experience with this kind of an operation. Engineering feasibility has been demonstrated, and this was at the Spent Fuel Test-Climax at the Nevada Test Site in the early 1980s. Spent fuel assemblies from the

Turkey Point reactor were transported to the Nevada Test Site. They were packaged in canisters. They were transported to the testing facility. This was a thermal test in granite conducted underground where these fuel canisters were emplaced in the floor of a gallery, underground gallery, that was 420 meters deep. But the way in which these canisters were lowered to the facility was through a borehole, so very similar to what we're talking about.

So these packages were lowered 420 meters in the borehole; they were emplaced in the thermal test facility for three years; and then they were removed to the surface via the borehole. And waste handling and emplacement operations were conducted within operational safety requirements and without incident, so this is a clearly achievable engineering task.

This is a slide on the seal design. The reference design is for 1,500 meters of the borehole above the waste disposal zone to be sealed with a combination of compacted bentonite seals, cement plugs, backfill, and cement. And, as I mentioned earlier, the casing would be withdrawn from this 1,500-meter segment of the borehole for setting these seals. The compacted bentonite seals would swell by uptake of water and would be set by either extrusion from a container or emplacement of a perforated tube so the bentonite could swell outward against the borehole walls.

This is the cost estimate for the reference design. The table on the right shows the breakdown for the cost. The drilling and casing cost around $27 million; waste canisters, construction, and loading on the order of $7 to $8 million; waste canister emplacement $3 million; borehole sealing about $2-1/2 million; for a grand total of $40 million for a single borehole. This sounds like a lot of money. These boreholes are expensive; but if we compare that to the nuclear waste fund fee, this $40 million translates into about $158 per kilogram of heavy metal. And this is compared to a nuclear waste fund estimate of roughly $400 per kilogram. The estimated time for drilling the borehole, completion of the borehole, waste emplacement, and sealing is about 186 days, so somewhat less than six months to complete one of these boreholes.

Some of the practical aspects of deep borehole disposal. We’ve analyzed the number of boreholes that would be required for various inventories of waste, and that’s presented here. Now, these are based on data from the Used Fuel Disposition Campaign report on projected fuel inventories, and we’re looking at a couple of different scenarios here. One is the No Replacement scenario in which the last commercial power plant goes out of operation in 2055, and these are the inventories for PWR and BWR assemblies. So in 2010 we had a total of about 65,000 metric tons, the inventory. We go up to 140,000 tons by the middle of the century under this scenario.

This is the maintained current nuclear generation scenario, so existing power plants, as they go out of operation, would be replaced by new power plants; and that makes a projection out to 2100 for a total inventory of 270,000 metric tons.

So these scenarios form the basis for some of the analysis shown in the next slide, which is the number of boreholes that would be required for these various scenarios. The 2010 current inventory of 65,000 metric tons could be disposed of in 273 boreholes if rod consolidation is used for both the PWR and the BWR used fuel. Without rod consolidation, it would require 568 boreholes. So at $40 million per borehole, you can see a considerable--there would be a considerable difference in cost using rod consolidation versus not using rod consolidation.

And I’ve also brought--if there’s time and there’s interest--a two-and-a-half-minute video from the pilot conditioning plant at Gorleben in Germany that shows their fuel assembly disassembly procedure, and so that’s there after my talk if you’re interested.

At any rate, other scenarios that we looked at was the No Replacement scenario; Maintain Current Generation Capacity Through 2100 scenario, and the relevant number of boreholes that are required; a Slowed Replacement scenario in which we do not replace existing plants as fast as they come off line, but only at half the rate at which they come off line; Maintain Current scenario but retaining 40,000 metric tons as a strategic reserve for potential reprocessing in the future. And this number was chosen because a kind of large reprocessing plant of 2,000 metric tons per year. This would be a feedstock--20-year supply of feedstock for such a reprocessing plant.

And then a Slowed Replacement scenario with the strategic reserve maintained through 2100. We actually feel that this might be the most likely scenario and the number of boreholes that would be required with rod consolidation, without rod consolidation, and with rod consolidation only of the PWR assemblies.

So just to summarize here in my conclusions, to reiterate, we feel that the most important undesirable or adverse geological conditions for deep borehole disposal should be the focus of site characterization. The most likely nominal release scenario has been evaluated with thermal-hydrologic and performance assessment modeling. Mechanical and thermal-mechanical effects on the disturbed rock zone have been modeled, and there is clearly a significant volumetric strain and altered permeability associated with differential--with high differential in horizontal stress around the borehole.

A feasible and simple reference design and operations have been developed and presented here. Estimated costs here, as I've stated earlier, about $158 per kilogram of heavy metal, well below the roughly $400 per kilogram from the waste fund fee. And the current used fuel inventory could be disposed in 273 boreholes using the reference design. The 2055 inventory in the current reactor fleet could be disposed in 585 boreholes. And this sounds like a lot of boreholes, and it is a lot of boreholes. But, to put it in perspective, that's roughly five to six boreholes per reactor, so it's not a large number of boreholes on a reactor-by-reactor basis.

So thank you.

GARRICK: Thank you. Howard.

H. ARNOLD: Arnold, Board. Seems to me the key parameter in this whole thing is that 17-inch diameter. If you were able to get that larger, these numbers would improve dramatically. However, that's a state-of-the-art number on drilling technology?

B. ARNOLD: We feel that that's close to the edge of what's dependably feasible at this point.

H. ARNOLD: But if somebody got serious about this and were going to spend a lot of money on it, that's the first place I would look is to see if I could make bigger holes.

B. ARNOLD: It’s possible that we could go to larger diameter holes.

H. ARNOLD: But you’re not assuming any R&D on the drilling process itself.

B. ARNOLD: Right, right.

GARRICK: Bill.

MURPHY: This is Bill Murphy of the Board. In natural systems the pressure on the water phase is dominated by the mass of water on top of it, and so you have a hydrostatic pressure. But as you go deeper and deeper in the earth and the porosity goes down and the connectivity between the pores is diminished, eventually the pressure on the water rises until it’s under a lithostatic pressure due to the mass of the bulk rock above it. Can you generalize, in the case of cratonic rocks, where that transition from lithostatic pressure to--or from hydrostatic to lithostatic pressure occurs? And is that an issue in a 3- to 5-kilometer-deep system then? And if indeed at 3 to 5 kilometers you have lithostatic pressure on the pore waters, would your seals be able to keep that down?

B. ARNOLD: I think Steve Ingebritsen is going to talk about that very topic in the next talk. I’ll just say that, yeah, we think--and the data indicates that--these depths were--we should be well above the zone where we sort of--within the brittle zone of the crust in which fluid pressures are going to be closer to hydrostatic pressures than with the static pressures.

MURPHY: Thank you.

GARRICK: Yes, Rod.

EWING: Ewing, Board. Thinking about your cost estimates and the number of holes required, don't you imagine, at least in the early stages of such a project when you would want to dispose of things at great depth, that you would have exploratory wells, that you would be required to study the geology of depth, recover core, and also wouldn't there--or shouldn't you include the possibility of failed holes in your cost estimates?

B. ARNOLD: Yeah, that's a good point. I think that's something that we were not decisive in our report. We began to realize that it may be more cost effective to drill a pilot hole at a site and use that pilot hole for scientific investigations and testing followed by later disposal boreholes. We're not real clear on that question at this point. There also definitely has to be allowance for abandoning boreholes that do not meet siting criteria or do not meet safety standards. Another possibility is to abandon portions of a borehole. If there is a fracture zone with a high permeability, that can be grouted closed and there would be no waste disposed in that zone. So that's another possibility. And those factors that you're talking about would add to the cost; that’s correct.

EWING: And just to follow up, you know, the normal sequence would probably be--you might imagine one exploratory hole. But in studying or characterizing hydrologic systems, usually you need more than one, right, to see if the flow is connected and so on, so at least initially the effort in characterizing rock and the conditions at that depth would considerably increase the cost estimate.

B. ARNOLD: Well, that depends on the degree of characterization that’s required here.

EWING: Right.

B. ARNOLD: These are very deep boreholes. This is not the kind of disposal system where it’s practical to drill multiple boreholes and, for example, conduct tracer tests between boreholes and so forth. I think that this concept depends on characteristics that can be measured in a single borehole as a general indication of the safety of the site.

GARRICK: Would boreholes have any implications on the decommissioning of reactor sites?

B. ARNOLD: Decommissioning at sites--

GARRICK: Yes. Suppose you wanted to decommission a reactor site for unrestricted use. What’s the implications of a site that has boreholes with respect to that?

B. ARNOLD: Well, I think that potentially a site could be used for other--safely used for other activities following deep borehole disposal. These wells would be plugged all the way to the surface. There's no reason to think that there would be any exposure at the surface. From a political and social standpoint, I'm not sure how acceptable that would be. This may have to be a surface site that is controlled for long periods of time. But from a strictly technical standpoint, I don't think there's any reason that the site could not be reapplied.

GARRICK: But that issue hasn't really been researched.

B. ARNOLD: I'm sorry, what?

GARRICK: But that issue has not been researched?

B. ARNOLD: No, it hasn't.

GARRICK: Yeah, okay. Any other questions? Yes, Andy?

KADAK: Apologize for having to leave the room briefly, but it looks like, as I recall the chart, you need to take apart the fuel assemblies and reconsolidate them in your canister--your disposal canister.

B. ARNOLD: That's the--

KADAK: Have you looked at the risk of doing that? Because I remember the original MIT proposal was basically to take the fuel assembly and put it right down in the hole and not have to worry about the consolidation. Can you just comment on that?

B. ARNOLD: Yeah, the reference design does call for a consolidation. And I should point out that the reference design is not large enough to accommodate an intact PWR assembly.

KADAK: I see.

B. ARNOLD: It could accommodate a BWR assembly.

KADAK: Okay.

B. ARNOLD: This decision to recommend rod consolidation came out partly from our sort of realistic analysis of the drilling and what kind of borehole diameter is achievable and then what kind of casing you could set in that borehole, what kind of connectors, and what kind of thickness of canisters, and all of that. When you consider all of that, you're restricting the interior diameter of the waste canister. So when we realized that a single PWR assembly would not fit in this waste canister, that was one consideration. Another consideration is just the very large cost savings and savings in the number of boreholes required associated with rod consolidation.

KADAK: Well, how about the risks of taking apart who knows how many hundred thousand or two hundred thousand spent fuel assemblies?

B. ARNOLD: We haven't analyzed that. We depended on a couple of reports from the 1990s that looked at the costs and the operations for dismantling fuel assemblies and rod consolidation. They came up with quite different cost estimates. We went with the study that came up with the higher cost estimate. I believe those studies also looked at safety considerations as well. And then we also know that this is part of the strategy in Germany, and they have this pilot conditioning facility in which they anticipate being able to disassemble these fuel assemblies.

KADAK: Just as a background, the Board generally was concerned about fuel handling and repackaging in the repository. You’ve just escalated that by a factor of about 20 relative to pin-by-pin versus assembly-by-assembly. So I think you should consider the risk associated with that and the real costs of doing that.

B. ARNOLD: Yeah, that’s certainly worthy of further analysis.

GARRICK: Any other questions?

B. ARNOLD: And if there’s any interest in the video, too, we have--

GARRICK: We have a question from the staff. Gene?

ROWE: Just a quick question. Rowe, staff. Did you look at a criticality analysis of packaging those fuel rods so close together?

B. ARNOLD: We did kind of a back-of-the-envelope calculation that indicated that criticality is not an issue. We’re talking about a waste canister that only has an interior diameter of, like, 22 or 23 centimeters. So even though there are quite a few fuel rods in there, that’s not a very large diameter.

GARRICK: Okay. We're doing very well. And thank you, thank you very much.

We'll now hear from Steven Ingebritsen, and he'll talk about fluid flow and permeability in the upper crust.

GARRICK: Oh, I forgot about the video.

GARRICK: Yeah, maybe we better see the video. Do you mind?

INGEBRITSEN: No, not at all. I'd like to see it, too.

(Whereupon, a video was played.

SPEAKER: Do you want to have a discussion on that video?

GARRICK: Pardon?

SPEAKER: Do you want to have a discussion on that video?

GARRICK: I don't know. It looks pretty complicated to me.

SPEAKER: I think we ought to make the hole bigger.

GARRICK: I think we'll let Steven go ahead.

INGEBRITSEN: Thank you very much. I think that nuclear waste disposal is one of the more important issues that earth scientists in this country can contribute to, and I appreciate the opportunity to be here today.

What I'm going to do is briefly review some of what we know about fluid flow and permeability in the upper crust.

Both overall hydraulic architecture of the upper crust and the natural patterns of fluid flow within the crust are relevant to the deep well disposal option that Bill just outlined. I’m going to talk first about the permeability of the upper crust and its transient variation, and then I’m going to review what we know about the maximum depths of circulation of meteoric water, then talk briefly about some of our experience with actual fluid injection and its effects on seismicity and permeability. The deep well disposal scenario doesn’t involve actual fluid injection, of course, but there will be some fluid sourcing, I think, by dehydration and by heating, as Bill mentioned; and I’m going to conclude with some discussions of how to estimate those effects.

So I’m going to start with some general points about permeability as a hydrogeologic variable. It’s the most important hydrogeologic variable because it varies over a huge range, about 17 orders of magnitude in common media, and it controls the occurrence of important geologic processes like advective heat transport and advective solute transport and the potential for elevated pore fluid pressures.

Well, direct measurement of permeability is usually limited to the upper few kilometers, maybe a maximum of about 10 kilometers depth in a few of the European research drill holes, and deeper permeabilities are estimated sometimes by inference. For instance, about ten years ago my friend and colleague, Craig Manning, and I looked at geothermal and metamorphic permeability data on a crustal scale, and we saw a good deal of coherence essentially to the base of the crust. I remember somebody mentioned UCLA earlier. Craig is the chair of the Earth and Space Sciences department at UCLA now.

I'll say just a few words about where these data come from. These geothermal data, these yellow squares, come from studies in which researchers fitted coupled models of groundwater flow in heat transport to geothermal observations. These were essentially Peclet number analysis done numerically, and they determine the value of permeability, the little K here, needed for a system like this to be advectively perturbed to a certain degree. And I compiled these particular data from the literature.

The metamorphic data, these green squares, are from prograde metamorphic systems, and Craig compiled them. The metamorphic data rely mainly on site-specific estimates of metamorphic fluid flux. And what this is is a cumulative fluid flux for the duration of a metamorphic event, and the time integrated fluid flux, the big Q in this version of Darcy's law, can be converted to a time average permeability through estimates of the fluid viscosity, the duration of metamorphism, and the driving force for fluid flow during metamorphism.

And those two quite different data sets proved fairly compatible. These metamorphic data represent a depth range that isn't really relevant for our purposes today, but they do sort of help define the overall shape of this permeability depth relation. And both these metamorphic data and the geothermal data represent some sort of average values over long times and in the case of the geothermal data over large volumes as well. And since then several other crustal steel permeability depth curves have been proposed. They're all fairly similar. Ours is the blue one here.

Craig and I started talking about this stuff again a couple years ago. Again, these are some sort of mean values. Were there any actual data that led us to find upper and lower limits for postulated cycles of permeability buildup and decay? Well, it turned out there is considerable evidence for transient permeabilities, much higher than these mean values. And on this slide the blue curve, again, is the best fit to our old geothermal-metamorphic data set. And the evidence for these larger permeabilities is essentially event-related, and it includes rapid migration of seismic hypocenters, enhanced rates of metamorphic reaction in major fault or shear zones, a recent study suggesting much more rapid metamorphism than had been canonically assumed. And here we’ve also included the permeability associated with anthropogenic seismicity such as that at the Rocky Mountain Arsenal and at the Soultz Enhanced Geothermal System site. And so a curved fit to these data is roughly parallel to and about 2 orders of magnitude offset from our own original curve, which again was that blue line here.

Hydrologists like me and Bill Arnold and George Hornberger were trained to think of permeability as a fairly static property, at least over the time scales that are of interest to us. In fact, George and I were actually trained by the same person, the wonderful Irwin Remson. However, it’s clear there is a dynamic link between fluid pressure seismicity and permeability and, of course, reactive transport as well, though I won’t talk about that today.

I really like this slide, because I think it helps to explain that relationship between stress, fluid pressure, failure, and permeability. And what it shows are the shear and normal stresses on individual fractures in several deep boreholes in the western U.S. One of these--I’m not sure which one--is from Yucca Mountain. And the filled samples--excuse me--the filled symbols here are for hydraulically conductive fractures, and the open symbols are for non-conductive fractures. So you can see that most of the conductive fractures are in a state of insipient failure given a coefficient of friction of .6 or greater, and the non-conductive fractures are generally not in a state of insipient failure.

So most hydraulically conductive fractures are critically stressed under the existing state of stress, and this implies that any small increase in fluid pressure could trigger failure on some appropriately oriented fractures. The earth scientists on the panel will recall more diagrams on the principle of effective stress. The fluid pressure is going to shift each of these points to the left on this diagram. So that’s one way that these higher permeabilities might be generated.

Now, there’s reason to believe that these higher permeabilities are localized and transient, including a pretty strong thermal argument, but I’m not going to go into that here. Instead, I’m going to turn to what we think we know about maximum depth of circulation of meteoric water in the continental crust. Unexpectedly deep circulation of meteoric water was first demonstrated about 40 years ago by the oxygen isotope composition of hydrothermally-altered rocks that are now—that were once buried deeply but are now exposed at the land surface. And more recently there has been direct evidence of near-hydrostatic pressures to nearly 10 kilometers depth in a couple of the European research drill holes. And meteoric fluids can penetrate as deeply as that near-hydrostatic gradient persists. The ultimate limit may be the brittle-ductile transition.

You know, to try to follow up a little bit on Bill Murphy’s question earlier, there are not a lot of samples, but this paper by Huenges--if I’m pronouncing his name right, I’m not sure--and colleagues--in JGR in ’97 was titled something like “Hydrostatic Pressures to 9.7 Kilometers Depth in the Crystalline Crust,” and Zoback published a paper in one of the German journals making the same point that in crystalline crust they thought hydrostatic pressures were the norm to the brittle-ductile transition. And then that was sort of the basis for a paper that--the premise of a paper that Townend and Zoback wrote in Geology appears later called “How Faulting Keeps the Crust Strong.” They basically were saying it’s these critically stressed fractures that release the fluid pressure that would otherwise weaken the crust. So, sorry, that’s a bit of a--more of a digression I should have made perhaps.

We’ve seen that the permeability tends to decrease with depth. So does the fluid-driving effect of topography; however, magnetism can introduce an additional driving force of depth, fluid density variation, and drive deeper flow cells; and that’s a reason why about 5 percent of the rocks now exposed at the surface in our Pacific Northwest and in Southwestern Canada show some evidence for deep circulation of meteoric fluids in terms of water oxygenized salt composition.

And I'm just laying this out to provide some broad context. I'm sure that deep well disposal would avoid areas where there is any chance of magnetism in the next mega-annum or so. But, again, there is some evidence for deep circulation even without the drive of a magnetic heat source.

And now I'm going to review some of our experience with actual fluid injection and its effects on seismicity and permeability. Again, the deep well disposal scenario doesn't involve actual fluid injection, but I think some of our experience was that a deep well injection is potentially relevant. For example, the data from the Rocky Mountain Arsenal showed that injection-induced failures there were occurring at relatively low fluid pressures. The initial fluid pressure in the injection zone was probably about 270 bars at 3-1/2 kilometers down, and the pressure increase required to trigger failure was only about 30 bars.

So just to remind you of the particulars of the Rocky Mountain Arsenal case, in the early '60s the U.S. Army was injecting waste from munitions production into Precambrian gneiss beneath the Denver basin. This rate amounts to about 10 liters per second, and one consequence was over 1,500 recorded seismic events, and the quakes were up to magnitude 5-1/2. And the important cautionary note from the Rocky Mountain Arsenal, I think, is that these rocks seem to have been failing when fluid pressures were still subhydrostatic relative to the land surface. The hydrostatic pressure at this depth would be about 350 bars.

So the Rocky Mountain Arsenal experiment shows that absolute values of fluid pressure don't have to be that high for failure to occur. And various examples of seasonal variations in low-level seismicity and of reservoir-induced seismicity, in fact indeed a growing number of examples, suggest that the causal pressure or stress change can sometimes be much smaller than that value of 30 bars from the Rocky Mountain Arsenal. It might be bars or even perhaps tenths of bars. And you can maybe understand this behavior in light of that coolant failure diagram that I showed earlier.

Experience with so-called enhanced geothermal systems technologies, arguably relevant, because the target depth range here is similar. It's 3 to 5 kilometers. And for those of you who are unfamiliar with an EGS, the concept is to extend geothermal resource potential by reservoir stimulation. In geothermal exploration it's proved to be much harder to find permeability than it is to find hot rock, so the EGS concept is to forget about finding permeability; instead, let's just drill into hot rock and use hydraulic stimulation to create enough permeability.

And, again, here are those several crustal-scale permeability depths relative to the EGS permeability and depth target. You probably need to be at least 3 kilometers deep to reach requisite temperatures, and the enhanced permeability has to be at least 10^{-15} m^2 in order to produce enough water. You need to be able to pull out about 100 kilograms per second for economic viability.

As some of you probably know, the Basel, Switzerland, EGS site was shut down by seismicity, and here's what that seismicity looked like. As at the Rocky Mountain Arsenal, seismicity began at a relatively low fluid pressure. These magnitude 1 earthquakes started when the well bore pressure at the injection depth here was about 120 percent of hydrostatic.

And this slide shows the reservoir permeabilities at Basel in the context of our global compilation both before and after six days of reservoir stimulation there. And the prestimulation permeability of Basel was about 10^{-17} m^2 at 5 kilometers depth, sort of consistent with these global average permeability estimates. The stimulation increased permeability about 400-fold and placed it near these high permeability curves. And at this scale this red arrow is actually fat enough to encompass both the Basel and the Soultz EGS experience.

Now, on this slide my USGS colleague, Colin Williams, has expanded the vertical scale to focus more closely on these EGS examples. And here Colin plotted permeability data from a number of EGS sites from Hajori Japan, Rosemanowes in Cornwall, Fenton Hill in New Mexico, two different depths at Soultz, and I've added Basel. And the open symbols are pre-stimulation; the closed symbols are post-stimulation. And the pre-stimulation permeabilities again seem to fall pretty close to our old geothermal metamorphic permeability curve. And here the high permeability curve, which fits most of the post-stimulation values, comes from a shear dilation model for slip-induced permeability.

So both the Rocky Mountain Arsenal example and the EGS examples, I want to reiterate, involve actual fluid injection rates on the order of 10 kilograms per second. And, again, I recognize there's no actual fluid injection in the deep well disposal scenario, but there is going to be some fluid sourcing related to heating, as Bill mentioned, and also, I would assume, to smectite dehydration.

This table, which is from a paper by my colleague, Chris Neuzil, summarizes sources and sinks of fluid in geologic environments, so these are sort of natural sources and sinks. And he categorizes these sources as being actual or virtue--virtual--excuse me. Now, the design schematics for the deep well disposal show bentonite packing, and I assume--I may be wrong--that the smectites are going to lose much of their inner layer of bound water when temperatures reach 100, 120 degrees. If so, that’s an actual fluid source sort of comparable to--conceptually similar to devolatilization in a contact-metamorphic setting. And there would also be, as Bill discussed, thermal expansion of pore fluids around the well. And that’s what Chris here has termed a virtual fluid source, conceptually similar to the effect of heating in a contact-metamorphic system. I haven’t tried to estimate the fluid sourcing rates for the deep well scenario, but Bill has modeled them to some extent, and it should be pretty easy to estimate the sourcing rates for these carefully engineered systems.

Chris Neuzil is showing us a very easy way to estimate the potential for elevated pore fluid pressures due to fluid sourcing. This is a dimensionless form of the groundwater flow equation, and elevated fluid pressures are expected if the value of this dimensionless sourcing is greater than 1. And I should note that this upper-case K here is hydraulic conductivity. It’s similar to permeability in that it represents the ease of fluid flow under unequal pressures, but this is the permeability multiplied by the specific rate of fluid and divided by its viscosity.

You may recognize here--it seems to me there’s a sort of a tradeoff associated with host rock permeability in this scenario. The lower the permeability, the better you’re isolated from the biosphere. But also the lower the permeability, the more likely you are to generate elevated pore fluid pressures and perhaps fracturing by dehydration and heating. So I’m not sure--it’s not obvious to me that the lowest permeability case is necessarily the best case here.

So, just to summarize, meteoric fluid circulation is a potential issue anywhere above the brittle-ductile transition; and, therefore, site-specific and geologic and hydrologic data are going to be needed. And Bill Arnold has told us that acquiring this kind of information would be part of the overall plan. And, finally, our current limited understanding of transient fluid flow poses a technical challenge, I think.

Just to elaborate on this point a bit, if we know the initial permeability structure, we’re going to be able to predict pressure changes with some confidence, but we don’t know very well how to translate pressure changes to shear offset or translate shear offset to changes in permeability. What Bill showed us was sort of a partial mechanical analysis; it was a linear poroelastic analysis. It didn’t really take into account the possibility of shear failure.

I don’t think that this is going to prove to be a disqualifying issue. The stimulus here is going to be so much less than an EGS, for example. EGS has shown that we can increase the bulk permeability of about a cubic kilometer of low-permeability rock a hundred-fold or so by injecting about 10 kilograms per second, but the effective injection rate here, if you will, is probably several orders of magnitude lower. So I expect this is going to prove to be a manageable issue. But I do think that some folks in the scientific community are going to have questions about it and perhaps the public as well in light of the publicity that's attended fracking and EGS.

So, once again, thank you very much for the opportunity to be here, and I hope I've left plenty of time for questions.

GARRICK: Okay, George, ask him a bunch of questions.

HORNBERGER: I do have one question, Steve. The deep circulations at 10 kilometers, what's the time scale?

INGEBRITSEN: I don't know. And I should have studied up on that some beforehand. I guess you can--okay, I'm going to take a stab at it. The longevity of the biggest--I can say something about the magmatically-driven systems, I guess, which are nominally to be avoided. But the biggest magmatic heat sources that we know of essentially cooled to ambient in about a million years. That means they have set up a convective circulation system in less than a million years. The norm for, say, the mid-crust is going to be an early stage of expulsive fluid flow driven by thermal expansion and perhaps devolatilization. And then at some time after that there's going to be a buoyancy-driven flow system set up. There must have been to get the oxygen isotope shifts in the rock. And that all must have happened in certainly less than a million years, because for the small intrusions you can probably say less than a hundred thousand or even less than ten thousand years to set that up, because that's all the longer those things are going to be much hotter than ambient even if they're cooling is purely conductive. Now, you know, that's--and I would assume elsewhere much slower, because that magmatism is the only thing that will put a strong driving force deep in the crust.

HORNBERGER: So I noticed--I think it was Bill in his base case or perhaps it was Peter. And I think their base case was a 10^{-21} square meters--

SPEAKER: Minus 19.

HORNBERGER: Minus 19 was it?

SPEAKER: Yeah.

HORNBERGER: So that does fit--that fits pretty much with what you said?

INGEBRITSEN: You know, I would have said the mean permeability at those depths is something more like 10^{-17}, but I don't think that's a deal breaker, because you showed even if you put it up to 10^{-16} there weren't disqualifying rates of flow. And, you know, most of the data for the mid-crust is very inferential obviously. But the data from the EGS systems are what hydrogeologically we'd consider real; they're based on well testing, and they're pretty compatible with the inferential data both before the stimulus--they're compatible with sort of the mean data--and after the stimulus they're compatible with these sort of what Craig and I have been calling disturbed depressed values.

GARRICK: So, to you and Bill, from an earth science perspective, what is your opinion of the deep borehole concept for the disposal of spent fuel?

INGEBRITSEN: Well, the part I thought about was what might happen in the surrounding formation, because that's sort of my area of technical confidence, such as it is. And the biggest issue that's crossed my mind was the possibility of causing shear failure, and that's something that is hard to address in a quantitative way still and hasn't been addressed yet. Again, I don't think it's going to be disqualifying, because if you think of EGS as an extreme example of doing this kind of thing, even there where we're trying to create permeability by injecting large amounts of fluid, you end up with a stimulated volume of about a cubic kilometer that's still encapsulated by a lot of low-permeability rock.

GARRICK: Do you want to add anything, Bill?

B. ARNOLD: Bill Arnold from Sandia. More in terms of just a general impression of the potential for deep borehole disposal, I think it does have potential. The amount of effort that's been invested into the concept is really quite limited compared to mined repositories, so some of these issues that Dr. Ingebritsen has raised should be examined. The poroelastic effects and shear failure, changes in permeability, that's something that should be analyzed further.

GARRICK: Now, what about the mechanical problems, the emplacement, the mechanical handling on the surface, the emplacement of the waste? It seems like this is a mechanical engineer's heaven to design this monster. Who's working on that? Do you know?

SPEAKER: Bill.

GARRICK: Bill?

B. ARNOLD: Well, the work that's been done to date is what's documented in our reference design report, and that's been pretty limited, but it's given us confidence that these are pretty straightforward engineering challenges. These are the kinds of operations that NRC regulates on a regular basis. Maybe Peter wants to add something.

SWIFT: We do have--Peter Swift, Sandia. We do within the DOE program--and Bill was speaking from the point of view of a laboratory research program at Sandia and not part of the DOE R&D program. But within the DOE program that Bill

Boyle manages, we do have an activity just starting up now to actually document a roadmap and what it would take to get us from here to a field demonstration pilot hole and then perhaps a full-scale hole. But that's work ahead of us in the future, and that will be done in collaboration with people from the drilling industry.

GARRICK: I keep thinking of issues like a fuel canister hanging up about a kilometer down, and then what do you do?

SWIFT: Sure. And we think about it, too. The operational success rate in getting things up and down holes in the oil industry once the hole is cased, it's really very high. There's a lot of experience there. There are miles and miles--thousands of miles of oilfield holes out there. That would be the reason to put casing down the hole first to make sure that you had as low a likelihood of having something stuck as possible. If the canister were to stick, hang up within the disposal horizon--say, below 3 kilometers--well, you leave it and then you plug the hole. Then you've lost the full capacity of that hole, but the particular canister is in the right place. If it's above that, then you have to go after it and retrieve it. And this is where the drilling industry, the oil industry, has a lot of experience in getting stuff out of holes.

EWING: But there's a lot of stuff left in the--

SWIFT: Absolutely, yeah.

EWING: I mean, they've left a lot of tools and--

SWIFT: Sure, as have I. I'm familiar with that. I don't want to leave the wrong impression on that. The oil industry doesn't always have the incentive to fish things back out that we would have in this case. But you're absolutely right. These are serious questions. You need a very high success rate on operating the hole.

GARRICK: Thanks, Peter?

Andy?

KADAK: I just have three questions. We've spent a lot of time this morning about public acceptance of geological disposal, and have you guys tested at all what people think about boreholes and where they might be placed? The second question: It seems like, you know, the way it's presented today is there's really nothing really wrong with this idea, and you are the only one that I've heard so far that says, well, I've got some questions about meteoric water at 5,000 feet per kilometer, I guess it was. And the third question is: I'm an engineer and I'm trying to figure out, how do you measure something at 10^{-22}?

SPEAKER: Well, you can try that. You can pick the last one and go first.

KADAK: We're not talking atomic stuff here, I don't think.

INGEBRITSEN: Well, okay. In the work that Craig

Manning and I did, which I was referring to, we actually never found numbers that low and--

KADAK: Well, 10^{-17}.

INGEBRITSEN: Yeah, 10^{-17}--

KADAK: That’s close enough.

INGEBRITSEN: 10^{-17} is sort of a process-limiting value in that if permeability is much higher than that, you’re not going to have elevated pore fluid pressures. They’re going to--the rate of, kind of, generation of fluids in a subsiding sedimentary basin or a metamorphic aureole, it’s not going to be high enough to cause elevated pore fluid pressures unless permeabilities are below that value. So that’s sort of a one-sided limit on permeability. If you’ve got elevated pore fluid pressures, you know that they’re less than about 10^{-17} m^2 in a natural geologic environment.

We also rely on positive evidence for flow; about 10^{-18} m^2 turns out to be what you need to accommodate rates of devolatilization in a regional metamorphic environment and those rates are approximately constrained by geologic data. Again, we’re talking in an order of magnitude sense here quite often when we’re talking about permeability.

KADAK: So is it like a back-calculation of an observed phenomenon? I’m try to see how does one--

INGEBRITSEN: Yeah, a lot of the examples on our curves are back-calculations of one kind or another.

KADAK: Okay. How about the other question about--

HORNBERGER: You could also just give him a number in microdarcies, and then he won’t have to--

KADAK: So what are the challenges? And I’ll leave this open to the other gentlemen, too. I mean, why not do this if it’s so great? In other words, the doses are so low, no problem drilling a hole, we can case it, no problem, we’ve got a nice cool video of all this consolidation going on. So what’s the problem?

GARRICK: But there is a risk problem with respect to the handling.

KADAK: Well, okay, but--

GARRICK: The handling is probably the greatest risk associated with the repository.

LATANISION: May I ask a question--

GARRICK: Yes.

LATANISION: --that puts a different perspective? Latanision, Board. You know, I sometimes ask outrageous questions, and this may be one of those moments, but that’s not a new experience.

GARRICK: Go at it.

LATANISION: Okay. You know, I used to have this feeling that we’re talking about something in terms of geologic time. Can you envision circumstances, any of the speakers, where the pressures may change, the fluid flows may change; under what circumstances could you imagine these waste forms being ejected from these? I mean, you know, I'm quite serious. I know there are plugs and seals, but is that not a possibility that you could imagine?

SWIFT: I'll start. This is Peter Swift. You would want to avoid geologic regions of that level of tectonic activity. Some parts of the earth's crust do move at speeds of centimeters per year; others don't. Go to the interior of the continents and I don't think you're going to have that kind of rate problem. Major geologic crustal things happen over tens of millions of years in the interior of the continent, not over thousands of years or even millions of years.

Steve, do you want to try that one?

INGEBRITSEN: Yeah, well, you know, another useful limiting value of permeability and one I really sort of set some stock on and believe it is--you know, in upper crustal conditions permeability needs to be less than about 10^{-16} m^2 to prevent heat advection from being significant.

LATANISION: Prevent what?

INGEBRITSEN: To prevent heat advection from being sort of the dominant process rather than conduction. And we know that, you know, at kind of mid-crustal depths heat transport is conduction-dominated; therefore, the permeability is normally quite low. Higher than 10^{-16} tends to be a local or shallow anomaly when you're talking on a crustal scale. Of course, hydrogeologists aren't interested in anything with permeabilities that low, but I think it's--you know, you used 10^{-16} as sort of one of your upper limiting values. I think that it's very unlikely that you're going to encounter permeabilities much higher than that in the general case, and those are pretty isolated over geologic time.

GARRICK: So the good news is, in tens of millions of years we'll be past the peak dose.

SWIFT: Peter Swift again. I wanted to add one more comment on trying to measure permeabilities in those extremely low ranges, you know, 10^{-19}, 10^{-20}. We actually do have field experience from that in the WIPP, trying to measure permeabilities in intact salt. And, yeah, there we had the advantage of being able to drill small holes laterally in from a drift and put in packer systems and do a thorough packer test on it. But that's hard to measure, you're right. I think the people who did that work would argue they were getting meaningful values in the range of 10^{-20} m^2.

INGEBRITSEN: And people get the same sort of values on little bitty lab tables with the same material. And usually you worry about that translation from lab to field scale, but in this case there is some corroborating field scale data.

SWIFT: Sure. But that was in relatively pure halite, which is an unusual rock material.

INGEBRITSEN: In shale I think there's--

SWIFT: Yeah, sure, and shales.

INGEBRITSEN: This is not granite, not granite.

SWIFT: Yeah.

GARRICK: I think George has the right idea, just change the units.

KADAK: So how about the public acceptance of boreholes?

GARRICK: And that's probably a Peter Swift or a Boyle.

KADAK: William Boyle.

BOYLE: I don't know that we've actually posed that question to anyone. I could ask Hank Jenkins-Smith. My guess would be--I bet there are people in this room who might end up saying, I don't care how you got it down there; whether you used a mined geologic repository or boreholes, I don't want it here. So I think there is a significant part of the population that will always be the answer. It's not clear to me that how it gets there would really make that much of a difference to some people. It probably wouldn't make much of a difference to proponents of repository either.

GARRICK: We may get a sample of a response, because we're going to hear from four members of the public in just a few moments.

Okay. Any other questions? Thank you. Thank you very much. And we have come to the point in our program where time is being made available for public comment. I have a sheet that says we have at least four people that want to make comments, Judy Treichel, Don Hancock, Abby Johnson, and Steve Frishman. And I guess we might as well just go in that order. Judy?

TREICHEL: Judy Treichel, Nevada Nuclear Waste Task Force. And, no, I don’t want a borehole. But I already--I was already eliminated when you started looking at the tectonics and seismicity and all of the stuff that was why Yucca Mountain wasn’t supposed to be there either.

As far as what I wanted to say in response to what we’ve been listening to today, I think it’s really, really important and a key thing to get this new public/private corporation or whatever the thing is going to be called that would be the entity that would take over waste management from the Department of Energy. I think it’s a terrible mistake that the DOE is already starting out--Bill was talking about the things in the blue writing that they were going to be doing with some money that they had, like creating communication packages to be taking to potential hosts for, I guess probably, storage, because he said you had described the attributes of consolidated storage. And once that starts and you don’t have a new entity, you’re already into the mistake-making mode immediately. When you go out there as a salesman for something to try and sell it, people see through it right away. And that's why you're looking for volunteers. You don't start out trying to convince somebody, because they're just not going to be convinced when the prize is nuclear waste.

So I think it's very important the DOE not get in front of the train. If it's difficult to get this new entity, then just wait, because nuke waste disposal and storage takes a long time. We already know that. And it's not going to end because DOE came up with a new package to circulate around.

I also think that some of the history that we learned today--sorry, Bill, it was you that was up here--that we heard about today, the lessons that need to be learned maybe aren't, because a lot of the conversation that went on was that what we're doing better now is that we can do it cheaper and quicker. And the real problems, the real mistakes, weren't that it took too long or it cost too much, from the point of view of Nevadans where all the action was; it was just a real mistake for a very long time, and nobody was willing to admit that it was a mistake. We were told that the rules were there and Yucca Mountain had to meet them, just as we've seen with the new thing that's supposed to start now, but Yucca Mountain didn't--and Yucca Mountain and the people pushing it didn't go away; the rules went away.

So I think it’s extremely important that, before a new program or project starts, you have the new entity, you’ve got new standards, and you’ve got new siting criteria, and they can’t change. The one thing you’ve got to do when you go out to talk to people, if they have volunteered, is that here are the rules. The thing has to meet it. If it doesn’t, we’re out of here; or if you want to be willing to talk about how the rules could be slightly different, we can negotiate that with you, but we don’t impose something different on you.

And I think once you’ve got those three things, you’re ready to go, and then you have to get into the deal which looks like a real cart-and-horse sort of system, because, as the USGS presentation showed, with all the overlays for the things that you would probably want to avoid if you’re talking about a repository or deep borehole, you’re going to come up with sections of the country where you’d really like to be and where you’d like to see those volunteers. And I don’t have the answer. I don’t know. I don’t know if you should look for the volunteers first or the kind of ground you want first or how that works, but I do think you have to have the new entity, you have to have the new standards, and you’ve got to have some criteria that people can understanding, and then it’s up to them. You don’t do a sales job on them.

So those, I think, are the really important things to have learned from Yucca Mountain, because that's what happened there. Thanks.

GARRICK: Thank you. Thank you very much, Judy.

Don?

HANCOCK: There is a handout being passed out that I am going to refer to. But before I get to that, I'm Don Hancock with a different Southwest Research than the one you heard about earlier from the Nuclear Regulatory Commission. Southwest Research and Information Center is based here in Albuquerque, although we have people in other places. We're a 41-year-old non-profit organization that work on a variety of environmental health, environmental justice issues. We got involved in WIPP 40 years ago this coming August when the Atomic Energy Commission, Frank Pittman, came to New Mexico and announced what was going to happen. And so we sort of thought, oh, good, something's going to happen in New Mexico, we ought to look at it.

So I want to reflect--I have also been involved a lot with the first and second repository programs in the '80s, so I have maybe a little different perspective. But I want to focus specifically on WIPP, because I've spent a lot of time for the last 35 years and a lot of time for the last 12 or 13 years trying to, from the outside, push on WIPP's safety. It's operating--it's important that it operate as safely as possible and trying to push on those kinds of issues. Not to say that the people who founded the WIPP site and the truckers aren't interested in safety. They are. But, in some cases, I think some of us on the outside can help them do better.

So in talking about WIPP, I actually--and I know, Dr. Garrick, this isn't proper, but I would like to ask a question to you all first. Did some of you go to WIPP yesterday?

GARRICK: Nobody went to WIPP.

HANCOCK: Okay, fine. Because at one point there was discussion that some of the Board was going to go to WIPP.

Well, one of the issues that doesn't get talked about with WIPP and needs to get talked about from an operational standpoint and from a performance standpoint. As I think I know, a number of you know, and perhaps all of the Board knows, WIPP is for defense transuranic waste, contact-handled and remote-handled transuranic waste; and there is a significant problem with WIPP being able to meet its remote-handled waste mission. And that's related to the fact that with the design that has been in place all along, the remote-handled waste, boreholes are drilled in the wall, and a canister of remote-handled waste is put in the wall, a plug is put in, and that's done before the contact-handled waste is placed into the room.

Well, we're about halfway through in placing the contact-handled waste; and, as the chart that I passed out showed, we are not even to 500 cubic meters of remote-handled waste in. So when you look at that chart, there is not going to be capacity left--there is about--the maximum capacity left with the current design for remote-handled waste is about 3,500 cubic meters. The current inventory that the WIPP project says and DOE says of remote-handled waste for WIPP is about 5,300 to 5,500 cubic meters, so there is a significant lack of capacity for the remote-handled waste that's supposed to come.

Now, this is not to say that their, you know, engineers can figure out other ways of dealing with this, but it's long since time, from my perspective, that the WIPP folks should start the technical and public and regulatory discussion of how to deal with this problem. It's a significant problem. And it hasn't been dealt with, and one of the reasons I am concerned about it is because it's going to relate to safety. As several of you have said, the handling of the material and particularly the handling of the remote-handled waste, which does have a lot more radioactivity than the contact-handled waste, has the highest risk for transportation and the workers at the site, and it needs to be dealt with.

Another reason I am concerned about it is, I, unfortunately, was the first person to discuss the matter with Dave Huizenga, the new head of Environmental Management in Washington, after he had visited the WIPP last year. And he came back and I asked him, “Did anybody talk to you about this remote-handled waste issue?” and he said, “No, what are you talking about?” So I then met--and I appreciated him saying, “Well, you know, I’d like to know more about this; let’s have a conversation.” So I had a conference call with headquarters and myself and various people at the WIPP site who, of course, confirmed what I was saying.

But it’s unfortunate that we’re in a situation where basic fundamental issues related to the WIPP performance aren’t being discussed in technical arenas, in public arenas, or in regulatory arenas. So I understand this is not you-all’s bailiwick per se, but I’m past being tired of there not being any discussion of something very fundamental to the WIPP mission that at this point is not going to be able to be fulfilled; WIPP is not going to be able to perform all of its mission; let’s start having some discussion about what to do about that both at the site level--because a lot of this remote-handled waste is at Hanford. Hanford’s not ready to ship it. That’s a basic reason that contact-handled waste is going in, remote-handled waste isn’t going in, but what are we going to do about that problem?

Second issue I want to talk about briefly is a concern--oh, I'm sorry. The flip side--flip the piece of paper that I--the other thing I wanted to say is, the problem is getting worse. The chart on the front side of the capacity assumes that all of the remote-handled waste capacity in Panel 6, the one that's being used now, would be filled; but, as you can see, they're not even drilling the remote-handled for all the remote-handled boreholes in the design. And then they're drilling--so if you look at Room 6--or I'm sorry--Room 7 of Panel 6, they drilled 45 remote-handled waste boreholes and only filled up 33 of them, so the problem is getting worse. Room 6, they only drilled 37, way under what the design is, and filled up only 18 of the 37. So this dwindling capacity for remote-handled waste is getting worse on a regular basis, and this chart that I passed out is the current what's going on in Panel 6 as of March 1st, just last week. So this is very current data of the situation that I've just described that not enough capacity is actually getting worse as we go forward.

Second issue I wanted to talk about real briefly is SDI. I appreciated very much the fact that the Board had discussion of that. I appreciate the fact that the Board sent their January 6, 2012, letter about this subject to the Department of Energy. My specific concern that I want to be sure that the Board is aware of--and Dr. Boyle is here--my understanding is that last summer there were some independent peer reviews done of the SDI program. And, to me, good scientific practice is that scientific information like that ought to be made available. I asked Dr. Boyle, and he refused to make it available. I asked the WIPP site to make it available, and they refused to make it available. So there is technical scientific feedback, discussion of the SDI program that hasn't been made publicly available. I don't think that's a good public process, and I don't think that's a good scientific process.

And this Board doesn't act that way; a lot of good scientific process doesn't handle things that way; and that's one of those reasons that people have concerns about how the Department of Energy operates. Why should this information not be publicly available?

Which then goes to my third point about this public acceptability question and what's going on and the issue that Dr. Carnesale raised. The first point of his conclusion this morning is, the overall record of the U.S. nuclear waste program has been one of broken promises and unmet commitments. That was the consensus of the Blue Ribbon Commission. I totally agree with that. I think probably many people in this room agree with that, which then comes to, what about that consent in New Mexico and what about that consent for WIPP? Which I think is clearly then demonstrated in many ways, including two federal laws and lots of meetings, lots of hearings in New Mexico over the years.

The WIPP site is for, by law, defense transuranic waste. And what the Department of Energy now is planning to do this year, this year, not when there is a new entity, not anything, is to make two proposals that are directly contrary to the commitments that have been made to New Mexico and to what existing federal law is. WIPP is for defense transuranic waste.

One is, after going through a two-year environmental impact statement process, in which New Mexico and WIPP weren't even considered, and issuing a final environmental impact statement on how to store 10,000 metric tons of mercury someplace in the country, through the whole EIS process draft, hearings nationally, final environmental impact statement, they are now going to decide, oh, let's reopen this whole process and do it all over again with, guess what, site to be the surface storage site for 10,000 tons of elemental mercury, you guessed it, the WIPP site. Now, I don't know what you-all think the reaction is going to be in New Mexico, but I think it's going to be pretty dramatic and pretty are-you-crazy, kind of thing. But that's the Department of--this is the current Department of Energy proposing that.

Second thing the Department of Energy is going to propose this year, by their schedule, is that greater than Class C waste, commercial waste, again, explicitly excluded from the WIPP site, that the WIPP site be the preferred alternative for greater than Class C waste.

So, again, we have a mission, a commitment, a promise about WIPP; and when WIPP hasn't fulfilled its mission, still in process, we're going to change and/or add to that mission. I think what's going to happen as a result of that is the controversy that some of you are aware of--Dr. Ewing, for example, was here in the '70s and '80s and '90s when there was lots of controversy in this state about WIPP--is going to be--re-come up again. And I think that's going to have implications for this long-term consent-based approach you're talking about, because WIPP and New Mexico are supposed to be the example of consensus basis. And, you know, then that gets all upset. So I think it's going to have implications in New Mexico, and I think it'll frankly have implications in other parts of the country. If the technical work and the laws and the promises don't mean anything in New Mexico, that they can be changed no matter what the agreements are, why is anybody else in the future going to think that that won't happen someplace else? \

So I think that's a very significant problem, and I think the public acceptance question is going to come back up again in New Mexico this year, as early as that, because of what the Department of Energy is doing, and it’s totally unnecessary, shouldn’t be happening. But the Department of Energy’s activities now--continuing activities now are going to make more difficult public acceptance in New Mexico and other places for this kind of consent-based approach. Thank you.

GARRICK: Thank you. Thank you very much.

Abby?

JOHNSON: Hi, my name is Abby Johnson. I am the nuclear waste advisor for Eureka County, Nevada. And what I would like to do today is report to the Board on Eureka County’s Lessons Learned Video Project. We started it in January of 2011, and we decided that instead of starting at the top down, we’d work from the grass roots up. We decided to interview key observers and participants in the nuclear waste program from our point of view as a transportation county and an effective unit of local government.

Lawrence Kokajko several times today mentioned the need to transmit information to a younger group of people to the next generation and to ensure that the information is accessible, and we agree. And we thought about that a lot when we were doing our project. We did video interviews, we did written PDF transcripts, and then we edited the video interviews into three-minute YouTube what we’re calling nuggets. And so if you go to our website, yuccamountain.org/

lessons, you will find the YouTube videos and the transcripts. We are making the DVDs and a full set of written transcripts available to researchers and archivists, and we're also making a DVD just of the nuggets, which will be able to be available to the participants and other people that are interested. It's been a very interesting process. It's actually one of the funnest things I did last year and actually the most fun thing I did last year for work.

One of the final interviews that we did was with Russ Dyer, retired from the U.S. Department of Energy. I think most of you know him. And it was a good interview. Russ spoke to the issue of the guidelines that we are talking about today, and basically he said that one of the lessons that he would take away or offer to others is that developing the guidelines and schedules before you understand the site is a mistake; and that's obviously opposite of what Judy Treichel just said. But I think it's worthy of consideration and also opposite of what the BRC said, but I commend his interview to you as well as the other interviews. It's good reading, and it's fun watching. The other way to find the same information is just go to yuccamountain.org, go to What's New, and on the right-hand side of the What's New page you can find it that way, too.

Finally, I just want to say that we hadn't known exactly what was going to emerge as themes; we weren't really looking for themes, but they kind of emerged. And the thing that came out in many of our interviews one way or another was that the downwind effects and the issue of the effects of above and underground nuclear weapons testing kind of is threads that are woven through at the local, county, and state level and seem to influence and color people's thinking about the Yucca Mountain project and about more nuclear projects in Nevada. And so, as you watch those, look for those sides, too, because we were very interested to see how many times it came up.

Thank you very much for your attention.

KADAK: Could I just ask a question? What was the goal of this interview process? I'm sorry, I missed it.

JOHNSON: The goal was, as part of the lessons learned process, in parallel to the Blue Ribbon Commission on America's Nuclear Future, we thought it would be useful to be--while it's still fresh in people's mind, to be able to interview people and get their observations and wisdom and concerns to capture them now; and so it's kind of a companion piece to our written report that we submitted to the Blue Ribbon Commission. And we also sort of announced the launch of it at a Blue Ribbon Commission meeting in October.

KADAK: And how were these people selected for being interviewed?

JOHNSON: We selected them based on our understanding of their either involvement in our program or their--because they were involved as, like, a county commissioner or a staff person or somebody who had been involved that way. We interviewed several people who live in the northern part of our county, which was considered for a rail spur to Yucca Mountain, the Carlin Rail Corridor. And so we interviewed a number of people who had been involved at the time of the Department of Energy's Environmental Impact Statement hearings and had participated in those.

KADAK: Were there any people on both sides of the argument or just one side of the argument?

JOHNSON: Well, in the northern part of Eureka County there was overwhelming opposition to the Carlin Rail Corridor. In the southern part of our county it's a little bit more neutral. Our county never took a position for or against the project, and we chose people who we felt had a particular either involvement or perspective. And we wanted--we knew a lot of people are going to interview governors and senators and representatives, but no one else is going to interview the people that were involved from our perspective.

GARRICK: Thank you. Thank you very much.

Steve Frishman.

FRISHMAN: I'm Steve Frishman with the State of Nevada. First I guess I have to respond to Lawrence. I may be nostalgic, but I don’t miss it. I wanted to talk about two different things that came up today. One of them was, Lawrence and Tim both walked you through the difference between the technical evaluation report and the safety evaluation report and explained from the Agency’s perspective what the difference was and why it was done the way it was; and I just wanted to elaborate on that a little bit from our perspective as, aside from being the State of Nevada but also being a significant part to the proceeding, the licensing proceeding.

The SER is a regulatory document, one that is integral to the licensing hearing process; and the SER is intended to state the position of the RSE staff as a party in the hearing. And that position is one of defense of their decision, that the application has provided reasonable assurance of compliance with the regulations as the ultimate licensing decision would have to say.

The TER, as Lawrence emphasized, is a knowledge retention tool. And it’s just fine that it is. It’s based on the Yucca Mountain Review Plan. The Yucca Mountain Review Plan was written to coincide with the requirements of 10 CFR Part 63. So if you read the TER, you know what the NRC staff thinks about the site in terms of the license application relative to the requirements of 10 CFR 63. The reason that it can be done that way is because it does not have those final little paragraphs that specifically say, We the staff believe there is reasonable assurance of dot, dot, dot.

Well, the SER should not be out there as a stand-alone document. The SER is part of a continuum in the licensing process, and the important part is, that SER is the staff's document that goes into the adjudication. Well, we also have 219 contentions that go into the adjudication, and the staff will use the positions they've developed in that SER as part of that adjudication in order for the hearing panel to make decisions about our contentions relative to the license application and the staff's position relative to the license application that, if you look at the TER, is in almost all instances supportive of the license application.

So it's a regulatory document that is meant to be part of a contested adjudication. It is not meant to be the NRC's view of whether the site--the Commission view of whether the site meets the requirements of their rules. So it would be, really, not useful, I think, to have a document out there that was intended to be part of a contested hearing and have just the NRC's staff's position out there when the contested hearing part is all of a sudden ignored.

So the TER, I think, if they want to use it for knowledge retention, I think it's important that they retain, through what's going to probably be generations of staff--at least how they did it this time--it is reasonable to have the

SER standing alone out in the world of nuclear waste repositoryism is a disservice to everyone, because what it does is it makes a mockery of the licensing process.

All right, that's the end of that point.

The other is, you heard Bill Boyle talk about how, in his view, because of the National Academy Panel's technical bases for a Yucca Mountain standard, how that sort of led to this change from some regulatory compliance reliance on subsystem performance requirements versus system performance assessment. That went on--that report was published in 1995, and it was sort of the Panel's response to the way things were evolving with NRC, DOE, and EPA. And I don't think that they ever gave an either/or strong position about that. They saw what DOE was doing in terms of total system performance assessment. They also were aware of the fact that the subsystem performance requirements, at least one of them, was a real problem for the Yucca Mountain site.

They also--part of the reason they came up with the period of geologic stability and the emphasis on we have to look out at where the peak dose might be in time was because they saw the total system performance assessment curves that the Department of Energy was doing. So they sort of understood how that all worked. But in a similar period of time this Board was talking about the use of total system performance assessment as a compliance measure, and this

Board many times expressed the idea that it should not be the sole performance--or it should not be the sole compliance tool. This Board was fairly emphatic about how a total system performance assessment is a good tool to tell you what you know and what you don't know about a site being characterized and the extent or the level of knowledge in what you know and don't know and to guide the characterization in a direction of increasing knowledge where it can be increased or reducing uncertainty where it can be reduced, so it would seem as a tool in a greater system of compliance.

Now, what we saw today was that the Department is continuing on a generic basis to further and further refine the concept of total system performance assessment and further embed it. But now if we go back to the Blue Ribbon Commission's recommendations, one of the recommendations is that sort of embedded in the system is that you need understandable and reliable and consistent regulatory standards before you ever go into any type of a volunteer or consent-based siting.

Well, in order to have a basis for a community or a state or whatever it's going to take, they have to understand what these standards really mean. And a performance assessment, as you saw described today, you would expect a community--if the idea from the regulations was that this is the way we’re going to determine whether this site is suitable and safe for nuclear waste disposal, it you look at just that scheme, all you could get was that the regulators are saying, Okay, we’ll give it a try. Because there’s nothing in that that will give anybody any confidence that you can look at a site on a screening basis, not necessarily an ultimate licensing basis but on a screening basis, there’s nothing there that would tell you that it’s reasonable to go further into screening or it is not.

And I think what you’re going to have to have is you’re going to have to have something akin to subsystem performance requirements as an understandable mechanism for early screening in order to even attract any possible volunteers, because they’re going to have to understand what it is they’re getting into and it’s going to have to be some level at which--you know, if people are faced with the possibility of volunteering, it’s not out of the question that community leaders and governors maybe will come to you and ask you, How should we look at this? How should we know whether there is any, you know, safety viability in our site? And I doubt you’re going to tell them, Well, wait for the performance assessment; it’ll tell you. I doubt you’re going to be able to tell them that with a straight face. You’re going to have to be able to tell them that there are certain characteristics that would not only say that you might want to go forward, but certain things that might tell you, No, you don’t, because we know that this is adverse if not, in fact, disqualifying. So I think that just being--on a generic basis, just looking towards performance assessment as the way of measuring even early screening-type compliance tests isn’t going to get it.

And, finally, sort of related to this, Bill said--when he was pointing out the difference between the subsystem performance requirements versus total system performance assessment, he said, “My preference is for performance assessment.” Now, that’s fine. You can have the preference. Tim went a little bit further. He said, “NRC has no intention of ever going back to a quantitative subsystem performance requirement.” Well, with the BRC recommending that maybe we need to take another look--in fact, we do need to take another look at regulation and the whole regulatory philosophy--I think it’s fairly damaging for the NRC staff to be out there saying never. And, at the same time, it kind of cools the system to the point where, if you want to begin building confidence as the BRC has said must happen, then you can’t have a regulatory agency that is absolutely stuck in one position without even being willing to discuss it.

And, at the same time, there has to be enough flexibility in the whole process to where, as these regulations and screening-type criteria are developed, that if somebody asked you, you can at least give a credible answer and you don’t have to say, Well, geez, I guess we’re sort of stuck with total system performance assessment because the NRC said they won’t look at anything else even on a screening basis. You don’t want to be in that position; I don’t want you in that position; and certainly no governor wants to come to you as a trusted neutral body and get an answer like, The regulator won’t let me do it.

So it’s just something to keep in mind. It relates back to this Board’s own past history. And also now what we see--and I don’t know whether Tim is representing--or I don’t know really what Tim is representing when he says that, but it’s certainly disingenuous in the effort to try to find a new way to get at maybe public acceptance of methods for dealing with what you’re here because we have a big problem about.

So that’s my talk for today.

GARRICK: Thank you, Steve.

Are there any other members of the public that would like to make a comment?

McCARTIN: Mr. Chairman, if I could?

GARRICK: Okay, yeah.

McCARTIN: Tim McCartin with the NRC and just a comment, Steve. I didn’t mean to imply we’re that inflexible, but what I did mean to imply is we spent a lot of time looking at quantitative subsystem requirements. The NRC spent almost 20 years trying to implement subsystem requirements, found them not helpful, difficult to explain, and so we walked away from those requirements.

In contrast, I will say that the information we got from the Department of Energy described in the capabilities of the barriers was incredibly useful to understanding how they understood the system worked, and so I think we moved to a much better place. Twenty years from now, if there is information to suggest there is another approach that's better, we would consider it. We listen to all comments, and I think that, to me, that's one of the problems in setting standards and regulations. The NRC has always--if we learn that our regulations are not doing what we intended them to do, we change them; and that's the part that I think there has to be an expectation out there. Science does move forward. And as you get smarter, you may find a better way to keep something safe from a regulatory standpoint and you revise the regulations, and NRC will always do that, and we always entertain comments from the public and anyone else who suggests that our regulations aren't doing what they're intended to do.

But I do apologize if you took it that way. I didn't mean to say, Oh, we would never consider anything else. That was not my intent. But I do believe that we moved on with a better regulation.

FRISHMAN: I just have to tell you, if it was not your intent, you need to carefully scrutinize the transcript of what you said.

GARRICK: Any other comments?

(No response.)

I want to thank all the presenters. We had an excellent day. It was very lively at times, and that's what we like. And we got some very useful information, and that's what we like. So, with that, and if there's no further questions or comments, we will adjourn. Thank you.

(Whereupon, the meeting was adjourned.)

C E R T I F I C A T E

I certify that the foregoing is a correct transcript of the Nuclear Waste Technical Review Board’s Spring Board Meeting held on March 7, 2012, in Albuquerque, New Mexico, taken from the electronic recording of proceedings in the above-entitled matter.

March 19, 2012

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