UNITED STATES

NUCLEAR WASTE TECHNICAL REVIEW BOARD

TRANSCRIPT

FALL 2013 BOARD MEETING

Wednesday

November 20, 2013

Embassy Suites
1250 22nd Street, NW
Washington, DC 20037

OFFICIALS OF THE NUCLEAR WASTE TECHNICAL REVIEW BOARD PRESENT

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Dr. Steven M. Becker
Dr. Susan L. Brantley
Dr. Sue B. Clark
Dr. Gerald S. Frankel
Dr. Efi Foufoula-Georgiou
Dr. Linda K. Nozick
Dr. Kenneth Lee Peddicord
Dr. Paul J. Turinsky
Dr. Mary Lou Zoback

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P R O C E E D I N G S

8:00 a.m.

EWING: Welcome to the Nuclear Waste Technical Review Board's fall meeting. I'm Rod Ewing, Chairman of the Board, and I'll say a little bit about the Board's mission, introduce the Board members, and then preview what we'll be hearing today. A number of you attended our work shop for the past day and a half, and so I'll be repeating some of the boilerplate, introductory material. So just bear with me because I think for those who are just joining the meeting, it may be of interest.

The Board's an independent agency of the executive branch. We are not part of DOE or any other federal agency. The Board was created in the 1987 amendment to the Nuclear Waste Policy Act. Our charge is to perform objective, ongoing, and independent evaluation of the technical and scientific validity of DOE activities related to implementing the Nuclear Waste Policy Act. These activities include transporting packaging and disposing of spent nuclear fuel and high level radioactive waste.

The Board reports its findings to Congress and the Secretary of Energy. There's a one-page handout on the table outside that describes the Board's mission. And on the back of that page you'll find a list of Board members and a little bit about their backgrounds. Let me introduce the Board members now.

Jean Bahr--if you'll just raise your hand as I mention your name--is a Professor of Geosciences at the University of Wisconsin, Madison. She's a member of the Geological Engineering Program, and a faculty affiliate to the Nelson Institute for Environmental Studies.

Steven Becker is a Professor of Community and Environmental Health in the College of Health Sciences at Old Dominion University in Norfolk, Virginia.

Susan Brantley is a Distinguished Professor of Geosciences in the College of Earth and Mineral Sciences at Penn State. She's also the Director of the Earth and Environmental Systems Institute and a member of the National Academy of Sciences.

Sue Clark is a Regents Distinguished Professor of Chemistry at Washington State University.

Jerry Frankel is Professor of Material Science and Engineering, Director of the Fontana Corrosion Center at Ohio State University.

Efi Foufoula is the Distinguished McKnight University Professor of Civil Engineering and Director of the National Center for Earth Surface Dynamics at the University of Minnesota.

Linda Nozick is a Professor in the School of Civil and Environmental Engineering and Director of the College

Program in Systems Engineering at Cornell University.

Lee Peddicord is a Professor of Nuclear Engineering at Texas A&M and has served as Director of the Nuclear Power Institute at Texas A&M University since 2007.

Paul Turinsky is Professor of Nuclear Engineering at North Carolina State University. Since 2010 he's served as a Chief Scientist for the Department of Energy's Innovation Hub for Modeling and Simulation of Nuclear Reactors.

Mary Lou Zoback is a Consulting Professor in Environmental Earth System Science at Stanford University. She is a seismologist and a member of the National Academy of Sciences.

Finally, I'm a professor at the University of Michigan in the Department of Earth and Environmental Sciences, Nuclear Engineering and Radiological Sciences, and Material Science and Engineering.

All of the Board members serve part-time, but we have a talented, full-time staff that provides support as well as continuity to our activities. The technical staff are seated against the wall just behind the Board members.

A few words about today's program, this meeting is focused on current--on the current research program being supported by DOE's Office of Used Fuel Disposition Research and Development including research of long-term storage of high burnup, spent nuclear fuel, assessment of the potential introduction of standardized spent fuel container sizes, and the evaluation of spent fuel and high-level radioactive waste disposal options.

We'll also have an overview presentation of studies on advanced separations and waste form technologies being supported by the DOE Office of Fuel Cycle Research and Development.

As I mentioned earlier, today's meeting was preceded by a one and a half day technical workshop organized by the Board on the impacts of dry storage canister designs on future handling, storage, transportation, and geologic disposal. I'd like to thank everyone here who participated in the workshop. I think it was successful. And you'll see that some of the topics today carry forward from the discussions from the workshop. For those who didn't have the benefit of attending the workshop, we'll begin today's presentations with a brief summary of the workshop by two Board members and a staff member.

Moving on to, more specifically, to today's agenda, the first DOE presentation will be by Bill Boyle, Director of DOE's Office of Used Nuclear Fuel Disposition Research and Development. Bill will update us on DOE's R&D activities related to spent fuel storage and transportation. Bill's overview will be followed by two technical presentations related to fuel storage and transportation, one by Dr. Michael Billone from Argonne National Laboratory on the ductile-to-brittle transition temperatures for high burnup pressurized water reactor cladding alloys. And the other will be by Bill Boyle on a test plan to investigate the performance of fuel cladding and storage container systems during extended storage of high-burnup fuel.

Just before lunch we'll hear a presentation by Andrew Griffith, Director of the DOE Office of Fuel Cycle Research and Development. He'll report on DOE studies on materials recovery and waste form development.

After lunch, we'll hear from Bill Boyle for the third time. He'll give us an update on ongoing and planned R&D activities related to spent fuel and high-level waste disposal. This will be followed by three technical presentations. First, by Dave Sassani of Sandia National Laboratories on the inventory of waste forms and disposal option evaluation. Second by Peter Swift who's the National Technical Director of the DOE Office of Nuclear Energy Used Fuel Disposition Campaign. And the third by Joshua Jarrell of Oak Ridge National Laboratory on integrating standardization into the nuclear waste management system.

So it's a full day, and the focus is clear. And I think it's--will be a nice addition to what we've been discussing for the past day and a half.

Today we'll make time available for interested members of the public to comment and ask questions on meeting topics. And at the end of the afternoon we'll have a period for public comment. I should say we'll revert to the old procedure of my asking Board members or giving Board members the opportunity to ask questions, then staff, and as time allows we'll turn to the public. But at the end of the day, if you want to make comments or ask questions, please sign up on the sheet outside the door and you'll certainly have that opportunity.

If you prefer, written remarks and other materials can be submitted to the Board, and this will be made part of the meeting record. All the meeting materials, presentations, and comments will be posted on our website along with the transcript of today's meeting.

The usually disclaimer, during the meeting Board members will freely express their personal views and opinions. We certainly encourage this, but we also want you to know that the comments of individual Board members during the meeting should not be considered an official Board position. The Board positions are found in our reports and letters to Congress and Secretary of Energy which are posted on our website.

You know that the Board often follows up its public meetings with letters to the Department of Energy summarizing our impressions, sometimes making recommendations, and those letters will be posted on the website as well.

Finally a few housekeeping details, please, mute your cell phones. I think I've done mine. And when you speak, use the microphone, identify yourself and your affiliation so that that becomes part of the transcript.

So those are the introductory comments, and we'll begin with the summary of the workshop. And I believe we're start with you, Lee, and then Jerry, and then--no. Okay. Just the two.

PEDDICORD: Thank you, Rod. I'm Lee Peddicord, member of the Board. I serve as a Professor of Nuclear Engineering at Texas A&M University. I want to welcome you to Bill Boyle Day here at the Nuclear Waste Technical Review Board. We're still working on the fourth function for Bill--with Bill Boyle on the agendas. He said he wanted to host a reception in his Winnebago for everybody out in front of the hotel, but he's still working on the parking permit. And we're not going to do it unless he gets some Shiner bock beer from Texas to do it, but so still a work in progress.

What I would like to do then is step briefly through some of the activities yesterday in the workshop. This was a new endeavor for the Board, at least in terms of the--my affiliation with the Board in which the Board endeavored to have a format to allow a more extended discussion on a couple of particular topics and allow time for quite a bit of dialogue with the participants. And I think among the Board members, it was something we found very, very useful and very helpful. It ran over the first two days of this week, Monday afternoon and yesterday, and it began with some presentations on Monday afternoon to provide some technical background.

The activity, as Rod mentioned, was to really look at couple of the options going from the reactor to the disposal site and particularly to consider two options, one of direct disposal of the storage canisters, and the other one was then to look at the implications of repackaging along those lines. And so on Tuesday the Board focused on obtaining input from participants for those two scenarios. And this was done by having two breakout sessions, three hours in length, to go through these, have again quite a bit a discussion.

There was then a reporting back from the sessions with additional discussions. For all participants for those of you that were there yesterday for that, I'm pleased to report I'm ambulatory after my report to the combined group. It was an interesting and exciting endeavor. It's like going over to Austin and talking to a bunch of Longhorns. And then Bret Leslie collected some general input, and he will--I think you're going to be talking about that or Jerry will at the end of this.

Kind of also for your background, and we had some charts, I guess we didn't get them up, but we're kind of working to these two notional set of flow charts for these two options. This is the direct disposal one; this is the one Jerry Frankel is going to talk to. And then this is the one with repackaging with multiple paths from the reactor to the spent fuel pool and then finally on to disposal. And so the two sessions, we had two Board rapporteurs: My colleague Paul Turinsky from North Carolina State University was the other rapporteur for the session, one on the repackaging. And Dr. Gerald Frankel and Dr. Sue Clark were the Board rapporteurs for the Session 2. So Jerry will be talking about that.

So what I'd like to do is step through about a dozen points that emerged from Session 1, the repackaging. These are not necessarily all encompassing, but give some idea of the insights, the impressions, some of the conclusion that came out of that. So the first one is as evidenced by this flow chart using the repackaging option. It is a complicated process and many directions and options in there. And because of decisions already taken, what utilities are doing, their choice of technology and so on, that ultimately there may not just be one path that goes from the reactor to the disposal site. More than one of these may have to be, in fact, employed.

I think a quite significant point is the idea that half--had we more information on the ultimate repository in terms of the geology, some--the design, the requirements, then some of these previous steps could be defined much more sharply, elucidated in more detail, and it would be extremely helpful. We don’t have that piece of information, so it really broadens out what DOE has to consider and even choices being made by the utilities.

The next conclusion or insight was the transportation issues for repackaging. These also are a complex choice of canisters, containers, packages and so on and again, just makes this a considerably more challenging endeavor given the context in which we are collectively working as a nation. We have the stranded sites and the shutdown sites, again, with a wide variety of characteristics as these. The ability to repackage, again, complex shows up yet again in this summary. And depending on the facilities and infrastructure, moving them offsite if there's still spent fuel pools there. And so these are going to be quite significant challenges.

High-burnup fuel as utilities move to greater and greater use, almost exclusive use of high-burnup fuel. This is still being understood. We're going to hear from Mike Billone on some of the issues of this in terms of the longer term performance. A lot of research is underway under fuel cycle technology program. To understand this, we now have widespread introduction of the advanced clad materials which brings in some new dimensions. Ultimately, we might be getting to things like accident tolerant fuels and so on. All these things are going to play into this plethora of options and things that must be considered.

There--it was noted many times about--I guess, conflict of interest is the way to characterize this--that the party responsible for the storage, that is the utilities, the reactor owners, theirs is a different set of drivers, of course, than the party responsible for transportation and disposal, currently DOE, perhaps after congressional legislation, a new disposal organization. And so they have different drivers and different considerations and different constraints. And that is a major factor in determining a lot of what's going on.

There, of course, is a need to factor in over the life cycle of a fuel--over the life cycle of the endeavor, the fuel cycle, when making decisions.

And finally on this page, we are already well aware of the diversity of dry storage cask and canister designs. This feathers out into all the downstream operations at every stage, whatever path or paths through this diagram we might use and add, again, complexity and costs.

There are inconsistencies, well-known and well-recognized inconsistencies between storage, transportation, repository requirements in terms of criticality, thermal limits, and so on. Something the participants from the NRC acknowledged and is under consideration and review perhaps with an objective of perhaps harmonizing those.

A very sensitive point is when and where to repackage, where along these steps this might happen, at the utility sites, at a consolidated fuel storage facility. And this, and of course, impacts on the fuel storage facility design, certainly pros and cons of dry versus wet packaging, things like the hydriding phenomena. Certainly one of the interesting points that came to me yesterday was a comment by one of the organizations that kind of looked at the dry versus wet repackaging and had reached a preliminary conclusion that cost-wise these might be roughly similar. That was quite interesting.

And finally, from Session 1, this point of how do decision's made in the near term regarding the storage packaging--repackaging, impact fuel performance, and the repository? Our diagram had--we had a matrix where it said repository, and one of the key points that was made by Chairman Ewing is that that is a very involved box that needs a lot more elucidation in terms of the implications and the process and so on of the performance of this facility over a near term, a medium term, some number, hundreds, thousands of years, and a very long term.

So these were some of the points that emerged from Session 1. I want to thank Paul Turinsky and all the participants that were involved in that. And I have to say for me, it was an extremely interesting session. I learned an awful lot, and it was very helpful. And I think this new format, again personal opinion as Rod said, it was something of great interest to me as a Board member and one I hope maybe we can utilize again in the future on other issues like that.

So with that I would like to pass the clicker on to Dr. Gerald Frankel. He has a lot better insights in things like that, but when you've got an undefeated football team, you've got a vast staff from the athletic department to help you out at these things.

FRANKEL: Thanks, Lee. We might be undefeated, but we don't have the standing Heisman Trophy winner like the Aggies do. So maybe the next one.

PEDDICORD: No, no.

FRANKEL: We do have the only two-time winner for the moment you know.

Okay. I would like to spend a few minutes talking about breakout Session 2. The comments that I will give are a shortened version of what I spoke on yesterday. Actually, a lot of what Lee talked about is perfectly applicable to the discussion of direct disposal, and, in fact, a lot of the comments I'll make are equally applicable to the situation regarding repackaging. We're just responding to the comments that we had in our individual sessions and reporting on that.

Okay. I guess that I should first define direct disposal as being not repackaging if that's what we're calling direct disposal for the moment. And furthermore, an interesting point is that it's not either/or. There might be situations where one or the other would be more appropriate and it might be possible to go along both pathways as appropriate. That said, there seems to be advantages to direct disposal that I won't go into without repackaging, so it's worth considering and addressing.

And as Lee mentioned, the lack of the final plan impacts everything and makes the discussion rather difficult without knowing the details of the repository. But even without that, there are comments that can be made and thoughts that can be brought together which I think happened quite well yesterday.

There was some discussion, and this again, both these points again are applicable across the board, but discussion about how any programmatic decision, but certainly one for direct disposal, could help to harmonize or bring together the various stakeholders in this endeavor meaning the Department of Energy, the NRC, utilities, and others such as watchdog organizations or environmental people, and allow, with some focus, allow the discussion to move forward to finding the best solutions where at the moment the discussion is rather discordant and everyone doesn't really know where things are going to go, so they're just operating in their own best interests.

We spent some time talking about how it might be possible to separate out the existing loaded canisters that are in dry storage already and future canisters as they might be handled separately which will allow us to maybe take these loaded canisters, deal with them in one way and the future canisters differently, maybe through regulation or site selection criteria to require certain characteristics of the canisters that would be advantageous for direct disposal including storage transportation and even maybe final disposal. But this is, I think, an interesting way to view the situation and think about what's important.

And then we identify certainly with the help on the first day from a presentation by Tito Bonano, identified the technical issues and talked about them and the implication of them for direct disposal. Weight effects meaning that some of the packages that exists already, the canisters are large and heavy and hot and so there are--there could be some engineering difficulties associated with that. But then again, there might be engineering solutions that are not necessarily impossible or complex.

There are thermal effects. As I said, some of these packages are hot. And this might be complicated by high-burnup fuels, so we talked about the possibility of needing to think carefully about cooling times before disposal. That might be important if we are going to be emplacing these large canisters into a repository. Certainly, these thermal effects will need to be considered for hot canisters in terms of site selection, the geology of a formation as well as the drift spacing or the spacing of packages along the drift which would be important for dealing with high heat.

There's some issues that could come from criticality as the designs for some of these canisters haven't considered long-term criticality effects, and there would need to be some careful analysis of the situation, the fuel in these canisters. And certainly if the need is required, then repackaging would be the best way to go.

And finally, we think that you need to consider carefully the environmental stability. So if these storage or storage transportation canisters are going to be emplaced into an environment for a long time, hundreds of thousands of years, we need to make sure that the required engineering barriers are effective. And depending upon the particular environments of the decided-upon repository, it might be necessary to use overpack materials that could provide that stability, but it seems likely that there are solutions that are available for all of the various possibilities. So that there are a lot of issues involved with direct disposal. None of them are necessarily insurmountable. But clearly there needs to be some serious thought about what's the best way to go.

I personally learned a lot from this session, from the workshop. The session involved constructive comments and discussion, and I think they were all helpful in trying to put together an interesting summary of the issues. And again, I would like to thank the participants in that workshop, in particular, my co-rapporteur, Sue Clark.

Okay. Now, it's my duty to report on some key points that came after the--well, at the end of the day, yesterday. The workshop audience was asked to provide what they thought were key points from the workshop. Those points didn't necessarily summarize all of the workshop highlights which is why Lee and I decided to give our own summaries. But this page shows some number of those. There are more. But these are selected points that were raised by the participants during that final session.

So while things are getting more complicated with time, and that's going to--it's the whole process without a focus is diverging and will make things more difficult. There are new designs and materials, and the issue of the high-burnup fuel is one that complicates everything. I talked about harmonizing the interests and well, while that would be a good thing, it's not clear how that's going to happen.

These again, are not Board comments but reporting on comments from the community. Our role as a Board is to focus on technical aspects, but there are lots of other forces at play here: policy, programmatic uncertainties, political certainly are going to be important in moving forward. There's a comment here about the DOE spent fuel where there's more flexibility. We'll be hearing shortly about the DOE spent fuel. But the point here is that as--it seems to be not to be in large packages, that there's more flexibility as to how to move forward with it as opposed to the commercial spent fuel that's being stored in large canisters primarily.

Again, the high-burnup fuel is an issue here highlighting transportation. There's no clear path of how to move forward on this, hence the discussion that's going to have to take place. And I think we received a lot of feedback that the workshop on this topic was important, that these are issues that were out there and had been known, but bringing them out to the public, giving everyone a chance to come together and talk about it was useful certainly for the Board. But it seems that other people in the audience agreed with that.

Okay. So I think those are the only points that we're going to summarize. There were others, and they're all going to be put together. There is an opportunity to provide additional input, and it's not shown up here, but there is an e-mail address that is on the Board website that was given yesterday. So we're interested in feedback about the specific workshops but also about the style of the meeting. There was a lot of discussion about how to appropriately discuss this and report on it. As mentioned the Board thought it was useful and a lot of people did. But any other input that you might have is of interest, so please provide any additional input.

Oh, well, here's something about the Board website. Yeah, okay. The information will be available on the website, and the transcript, it'll be available in mid December. The Board will assemble all of the inputs, and in due course after proper consideration, we plan to come out with a report as is our style on things. So it's not clear that that will happen, but as it's ready it will come out. So that's the plan. I believe that's the end of it. And we can have some discussion I think; right?

EWING: Right. Thank you. So first, any additions or comments from Board members? All right. From the staff? The lack of questions reflects the fact that we had lots of time yesterday for discussion; correct? Yeah.

So now from the public, Bob.

EINZIGER: Bob Einziger of the NRC, the Senior Material Scientist and Technical Lead for the Extended Storage and Transportation Program. This is more comments than questions. Harmonization, you've got to be very careful in the use of the word, especially when you're including the NRC because we are a public--an independent review board. While we can talk to the DOE, we can make suggestions to the DOE, but ultimately the decision on regulations and final decisions on approval of licenses will be done by the commission based on staff recommendations and public hearings. So we don't want the public to get the feeling from the word "harmonization" that we're all a nice, happy group that's going to come to some consensus. We're going to make sure whatever is done is safely done.

The other next one is with respect to transportation of high-burnup fuel. We can transport high-burnup fuel, and we will let the public know we can transport high-burnup fuel. We have licensed casks to transport high-burnup fuel. We just have not licensed anything in the configuration that it's now sitting in. So transportation would have to be in other casks with possibly significantly less loads, possibly partial loads which would have more operational and more expense in terms of dose, time, and money.

And the third thing is with respect to the DOE fuels. While you're not considering them here, the DOE fuels got around most of the issues you're talking about by just putting the fuels in a very robust canister which would be very expensive for high-burnup commercial fuel.

Just a few comments.

EWING: Thank you. Other comments?

Yes, Judy.

TREICHEL: Judy Treichel, Nevada Nuclear Waste Task Force. That presentation wasn't available as a handout. Will it be the website?

MOTE: Nigel Mote, staff. It will be on the website, and it will also be available in printed form, hopefully this afternoon.

TREICHEL: Okay. Good. And last night, several of the other public interest people and I were meeting and talking, and we will write in by the deadline time about our views that we think that there should be some thought given to the idea that fuel may stay on site. Because at this time I don't think you can assume that legislation, federal legislation will pass. And there is no centralized storage spot. And there is no disposal spot. So I think you should also add in there the idea of extended storage at reactor. Thanks.

EWING: Okay. Thank you.

Other comments? Oh, please identify yourself.

BLEE: Sure. David Blee, U.S. Nuclear Infrastructure Council. Looking at the agenda, I can't stay the whole day, unfortunately, but it just--it seems bereft of anywhere kind of private sector perspective or the utilities, even EPRI, NRC is missing. I see them in the back there. But what are your plans in the future to involve the private sector?

The Nuclear Waste Policy Act requires the maximum utilization of the private sector. Clearly utilities are working with technology companies, doing the bulk of the work today. So I was just curious in terms of future agendas, what we want to encourage is more private sector input into your activities and your discussions.

EWING: So what I would say is we welcome the input, but I would simply remind everyone that our charge is to review DOE activities. And so today's agenda reflects our effort to identify activities that we want to review and to look carefully at what DOE is doing. The workshop was, in fact, a new effort by the Board to get a broader interaction. And so we did our best to invite as many people as possible. It's been pointed out for the workshop agenda; we would have benefits by having presentation by someone from the utilities explaining the issues from their perspective. And so that was--

BLEE: Well, I would encourage also the majority of the work, actually, in terms of loading the casks, designing the casks, are not done by the utilities.

EWING: Right.

BLEE: So that's the supply chain to that end. But again, I think any discussion--you're getting one story with dealing from the DOE. I would encourage a 360 viewpoint--in terms of your--if your charter is to review the DOE, you want to get as many perspectives as possible. And I just don't see that in this program today.

EWING: Right. Right. Point well-taken.

BLEE: Okay.

EWING: I'll follow up by saying the opportunity for additional information is there related to the workshop and the report to follow. So, please, where you see gaps in our knowledge, send us the information.

BLEE: Sure. Well, I hope we don't have to send it to you--

EWING: Okay.

BLEE: --necessarily. Thank you.

EWING: Okay. Thank you.

Other comments? Questions? All right. Thank you very much. We're a little ahead of schedule, but we'll proceed.

Bill.

BOYLE: All right. Good morning. And as already has been mentioned, this is the first of three talks. And Nigel Mote, the staff director, he thought it might be useful if I explained why. And it simply comes down to dollars, money. It's for--I know none of the Board members were on the Board during the time of the Office of Civilian Radioactive Waste Management, but some of the staff members were present then. It's the appropriations for our group and the Office of Nuclear Energy are only a small fraction of what OCRWM used to get. So there isn't as much money available.

My duty station is in Las Vegas. I would have much preferred to have Tim Gunter and Ned Larson make some of the talks today, but like me, they're in Las Vegas. And so it's simply a question of travel dollars which are--it's not really related to the GSA issue, it's much more related to continuing resolutions, sequestration, things like that. I'm not complaining, it's a fact of life. And I will offer up where the meetings are held obviously influences everybody's travel expenses. People who work here in Washington didn't have to pay anything to show up. Some cities are cheaper than others. Like, I have heard that the Board may have a meeting in Albuquerque. I know for somebody coming from

Las Vegas, it's certainly less expensive than Washington.

And then the last point I'd offer up is it is the 21st century. There is video and web casting, and various DOE and the NRC use them in Yucca Mountain Licensing. So there are other options, but it was simply a matter of travel dollars.

So with that, this is my first talk, and it's going to provide an overview of what we're doing in research and development related to storage and transportation. Okay. Ned Larson did this. This is just an overview of what--I'll first speak a bit about our organization, the campaign, the organization we use to get work done, and then some of the R&D activities. But this is called a Wordle. And if you've never seen one or if you'd like to create one, just Google Wordle and you'll get access to the website. But what this represents is somebody took the effort to feeding DOE strategy for the BRC report through some software. And the size of the words reflects how frequently they were used. So with--here we have storage, and there we have transportation.

So, as I said, I'd talk a bit about the organization. This work is done in the Office of Nuclear Energy headed by Dr. Pete Lyons. He was here on Monday. Monica Regalbuto is the Deputy Assistant Secretary The work I'm speaking about is I'm the director of this box in red. Andy, who will speak later, he's the director of that box.

So we both work for Monica.

Further delving into the organization that Monica is responsible for, there's the group I'm responsible for, research and development. Jeff Williams, responsible for the planning projects, the line is shown as going this way right now, but the wheels are turning, and eventually the line will go that way instead. At one point it did go that way and that way, but now it's going back that way.

But these are the people on the federal side that are responsible for the work. We do have a campaign. We're not the only campaign in the Office of Nuclear Energy. These are functional groups set up to address certain topics. But our campaign is the Used Fuel Disposition Campaign, and in short, we're responsible for doing the research and development, looking at storage, transportation, and disposal, and trying to help solve the issues related to the storage, transportation and disposal of spent nuclear fuel and high-level waste.

And for the campaign it's a mixture of federal staff and national laboratory staff. As I mentioned, Ned Larson is a supervisor who works for me; he's the Federal Campaign Manager. Peter Swift of Sandia, he's been here since Monday, he's the National Technical Director. Each of the campaigns in the Office of Nuclear Energy has a National Technical Director. His deputy is Shannon Bragg-Sitton from

Idaho National Lab. And we've divided the work into two major bins. I'm talking about the storage and transportation R&D right now where Ned is the leader of that group, and the lab people who he works with are Ken Sorenson who isn't here today, but Sylvia Saltzstein who is, and they're both from Sandia. Tim Gunter, another supervisor who works for me, he's responsible for the disposal R&D. And he interacts with the lab leads, Kevin McMahon and Bob MacKinnon, both from Sandia.

Okay. So this is how the management and business aspects of the campaign are set up. There is--whoops--we do have an account for campaign management under Peter Swift. And then for storage and transportation there are five control accounts. And I'll have more on each of these in the subsequent slides dealing with field demonstration, support, experiments, analysis, transportation, and security.

Now, back to the workshop of the last two days. And it was even mentioned this morning about the wide diversity of these storage systems. And this is a photo from Diablo Canyon, and if you look closely you'll see that there's little flanges down here because I'm pretty sure it might be unique for the disposal systems at Diablo Canyon. I don't know that other sites have done this. They're bolted down. It's the others--like the ones at North Anna rocked in the earthquake of a few years ago, that large earthquake here on the East Coast, and for seismic reasons the ones at Diablo Canyon are bolted. So, again, it's just they come in all different shapes and sizes and even minor variations like bolted or unbolted to the concrete slab.

Now I'll focus in on some of the more detailed work we're doing, focusing first on our objective. Our high-level objective is we're doing research and development, helping to prepare for the eventual large-scale transport of spent nuclear fuel and high-level waste. Based upon Judy Treichel's comments, I think there's probably a lot of people who don't want it sitting where it is now for forever. So we're doing research and development to prepare for the eventual transportation and also the safe storage presently. And you'll hear more, you'll probably see more photos of this type from the talk after mine. Dr. Billone from Argonne National Lab, does a lot of testing. This is a photograph of cladding and yielding results like this.

We really are focused on doing research and development to gain a better understanding of just what is happening in storage including degradation. And we have identified data gaps that we intend to fill to help support extended dry storage. We're doing material testing to support modeling. And we participate with industry and others, and this will be the second talk I give today about what it is we're doing in full-scale high-burnup demonstration project.

Okay. So now I have slides on each one of our five control package areas. The first one was experiments. And so we do actively perform experiments, a lot on cladding and other materials used in the storage systems, stainless steel, and we do the experiments to get a better understanding of just what is happening to the materials. And so, again, Dr. Billone, he will talk about some of the experiments that have been done. And on the left it gives some more detailed examples of some of the work we've been doing.

The second area is engineering analysis or modeling. We can't possibly test everything that we need to know. We do use a lot of modeling, and we link a lot of the testing to the modeling. A lot of our testing is done to help ensure that the models that we're using are good. And so here's an example of modeling. It was in the session yesterday, the one on direct disposal where it was mentioned that there was a need for data. I think it was Andrew Sowder of Electric Power Research Institute who mentioned that there are in-service inspections at times, and we in our campaign have participated in those. And these are--this is an analysis. I'm pretty sure it's of storage at Calvert Cliffs where we, DOE, and the national labs participated with the utility there. Where they opened up their storage system, we made temperature measurement in the field and made other observations and also did modeling of the expected conditions in that storage unit. So we do an awful lot of modeling, and it's very useful and helpful, always tying it back both to laboratory measurements and the field observations.

Our third area of concentration is transportation. The photo here, that's a shaker table. That is a surrogate fuel assembly. This is a close up of it. It's not a real fuel assembly, that's copper. The cladding material is typically zircaloy. And it's also, it's not irradiated. But this was a test that Sandia did. And they went to great care to try and appropriately match the material properties such that the tests would provide useful results. But this is a specific example of some of the work we're doing in transportation, what strains would be imposed upon the material during it's transportation on highways or rails in the United States, and what might happen during the transportation, if anything.

Our fourth area is field demonstration work. I've already mentioned in part one effort in field demonstration where we participate with industry. When they open up one of their storage systems we work with them and make measurement and do analysis. I also have--you'll see this particular photo again in my talk on the high-burnup dry cask demo, so I wouldn't focus that much on the dry cask demo. This slide is essentially repeated there. But it is an ongoing effort.

There is a recognition that more data would help as the industry is moving to high-burnup fuels that gathering more information about the storage of high-burnup fuels would be useful. So we interacted with industry, and we're marching ahead. And I'll cover more details in my second presentation.

Our last area is security. And this is--the figure down here is the important one. For years and years--okay, so the Y axis is the dose rate in rems per hour I'm pretty sure. And this is the cooling time of various storage systems with various amounts of burned up fuel in them. And the premise was, this horizontal line right here, no sane person would get anywhere near any condition above the line. The dose rate is so high that it would be very harmful, so this spent fuel was viewed as self-protecting. Anything above that line it was so radioactive you didn't have to worry about it as much with respect to security.

Well, some people have come to the realization not everyone around the world is as sane as everybody else. And so the presence of this line may not mean anything to some people; suicide bombers are an example. So we only have a minimal effort here. Spent fuel and storage is not an inherently an attractive target, you know, people, they can't shoplift it; right? They're bolted, closed, they're welded, that sort of thing. But we do have an ongoing effort to pay attention to what the security people do in terms of, like, would there be proposals to move that threshold up here or somewhere else? So our participation in this area is we're mainly just staying plugged in.

I think that might have been my last slide. No, no it wasn't. There was one more, but there it is. All right. So in conclusion, I was asked to provide an overview. We're working on storage and transportation R&D. I gave some examples. It's quite interesting work. If any more details are needed, you'll get some in the next talk by Dr. Billone on his specific area of testing materials related to storage.

As a matter of course as we finish our major deliverables, we do post them at the Nuclear Energy website. And so it was Steve Frishman, he made this request, oh, a year or so ago, and I'm happy to say and he's happy with the result that we do post our major documents as a matter of course when they're finished on our website so people can follow what it is we've been doing.

EWING: Okay. Thank you, Bill.

Questions from the Board?

Paul.

TURINSKY: Bill, could you describe your collaboration with other nations? Seems to be an area that, yes, there are some commercial interests, but they're not as strong as other areas of the fuel cycle. So it would seem like there would be an opportunity to have R&D collaboration.

BOYLE: Yeah. I will. I actually--for the disposal area, I have a whole slide on that. So I'll come back to that. But focusing in on storage and transportation, one big effort we have is we, Department of Energy, we participate in the Electric Power Research Institute's ESCP, their Extended Storage Collaboration Project. And many other countries participate as well, Germany, South Korea. So that's one example, and that is a major effort for us in storage in particular.

Also we in storage and transportation, again, focusing more on storage, we're part of a much broader bilateral effort with the Republic of Korea, and that's only started recently. And it's related to disposal and storage, but we have some ongoing collaborative work with Korea on their storage issues.

EWING: Okay. Efi.

FOUFOULA-GEORGIO: Yeah. You talked about the five task areas. Could you give us a little more insight as to how collaboration is done among these test areas? A little more insight on the horizontal axis? Does your model then inform your data collection and how?

BOYLE: Yes. A very good question. And I'll go back to this effort in particular, the field service inspections. The modelers and data collectors work together at Calvert

Cliffs. They know each other. They work together. Another example is the big demonstration project that I'll talk about later. They're commonly colleagues of each other working at the same laboratory or even across laboratories, but they do get together and work together. And even this was inherently a collaborative effort that involved tests, but then people--the test was done with the intention of modeling it as well. So they do work quite closely together.

EWING: Okay. Lee?

PEDDICORD: Bill, a couple of questions. Lee Peddicord from the Board. On your second to last slide where you talked about the security aspects and that lower, right hand graph, if I can read the fine print, it appears that your line current is set at about 1000 rem per hour.

BOYLE: You know, I have heard it and there's probably--I have a more readable version here. 100.

PEDDICORD: Oh, 100, okay. So yeah, okay. So that would make sense. I mean, at some point, if some level sanity has nothing to do with it, it's just--a dedicated diverter would be incapacitated in a radiation field of some level. Would that be the driver in which you would set some sort of limit from a self-protecting security perspective?

BOYLE: That's my understanding, yes. That that's how the 100 came up. People viewed it as that was a high enough dose rate that it would incapacitate. Most people would start feeling bad and they'd stop. Right? But there are other people, again, the suicide bombers as the example, that that dose rate might not be enough. And so that's why the security people are considering moving that limit higher.

PEDDICORD: Well, typically a number--you know, we tell the students stay away from 500 rem per hour, you know, that takes care of half the population. The other question is on the area of technology development that you might be able to undertake. One of the very impressive things from the presentation on Monday, I guess it was from Dr. Thilo von Berlepsch from Germany, was the extent they have been able to development, test actual equipment for these various functions.

Now, in view of funding constraints and so on, but where do you see DOE along that path of building things to see if they work and so on?

BOYLE: I'll offer a bit of a historical observation and then somewhat of my own personal take on it, and I'll try and make it clear if I'm not speaking for the Department of Energy. But historically, when the U.S. had a site in contrast to Germany--remember they had that one ten-year moratorium on the site and now another one, that they--it makes sense. Right? If you can't work on a specific site, well, what can you do? And they went into testing equipment. Historically, when the U.S. had a site, we did less of that sort of--I won't say none--but we did less than the Germans did because we were more focused on a site.

But we in the United States now find ourselves in a similar position as Germany, so that sort of work that was presented on Monday, absent the site, that sort of work starts to come up higher in priority lists. It makes a whole lot more sense provided you have some concept of what you want to do. Like, for example, the beautiful work the Germans did on a hoist is of no use to the French who are going to use a ramp.

So again, you're back to that problem. If you don't know what the end state is, it's hard to perfectly optimize the work.

PEDDICORD: Thank you.

EWING: Jerry.

FRANKEL: Jerry Frankel, Board. Thank you for the summary, Bill. I know that in a few moments we'll hear about cladding, degradation. I wonder if you could summarize for me where the material degradation work is being done? You talked about some different topics.

BOYLE: Yeah. The bulk of the work, obviously, Argonne National Laboratory for us, but also Oak Ridge, particularly when dealing with irradiated materials. That's not every lab is prepared to work with something like that. So a lot of our lab testing and Argonne and Oak Ridge on the metallic specimens and that sort of thing. But as I showed the shaker table, Sandia has an effort as well.

FRANKEL: What about the dry cask storage canister degradation work? Where is DOE supporting work on that?

BOYLE: You mean like the stainless steel?

FRANKEL: Uh-huh.

BOYLE: I don't know.

FRANKEL: That's not through your office?

BOYLE: No, it is. It is. Yeah. But I just don't know offhand. I'd have to go in and look it up, which one of the labs. Odds are it's one of the national labs.

EWING: Are you through, Jerry?

FRANKEL: Thank you, yes.

EWING: Mary Lou.

ZOBACK: Mary Lou Zoback, Board. Just following up on Jerry's question. Obviously, the fabricators of the casks and the fuel rods are doing work too. Do you work collaboratively with them?

BOYLE: Yes. In any number of ways. Again, Electric Power Research Institute's ESCP program, they participate in that as well. But also as you'll see in my talk on the high-burnup demo, the group that we hired to get it done involves one of the manufacturers of a storage system and also a utility. And I'll speak more about that in that presentation.

EWING: Just follow up?

FRANKEL: Yeah. Just to follow up. Jerry Frankel. So I think there are NEUP programs.

BOYLE: Oh, yeah, yes.

FRANKEL: They get coordinated through your office as well; is that correct?

BOYLE: Yes. The technical aspects. For NEUP, for those who don't know, it's Nuclear Energy University Program. And I have colleagues in the office of Nuclear Energy who are responsible for the infrastructure, you know, collecting the--issuing the RFPs, collecting the proposals. But it's my staff for my area, Andy Griffith's staff for his area, working with the national labs, we supply the technical input. Like, when the RFP goes out, my colleagues who run that infrastructure, they turn to me and ask what would you like the request for proposals to say?

So that is another area of work that I didn't focus on here on any of my slides. But it is a significant amount of work by the Office of Nuclear Energy, it's roughly in round numbers, somewhere in the vicinity of 20 percent of the Office of Nuclear Energy's money ends up going--their appropriation ends up going into that university program. So there are universities working on corrosion as well.

FRANKEL: Right. Right. My interest is more there but maybe you can speak generically. So I'm just interested in how well that is coordinated, the communication, oversight to those programs, do they integrate it into what's going on in the laboratories with the, say, the corrosion degradation or do they just sit out there and send reports in annually?

BOYLE: No. It's not quite that way. Some of them are more integrated than others. And for example, there's basically two fundamental types of award. The much larger ones, the IRPs, Integrated Research Projects, and those are multimillion dollar, multiyear. And then there are the others in the hundreds of thousands of dollars.

And so the big IRPs, by their nature are more integrated. But that isn't to say the others are not. Like, for example, at this annual meeting that the Fuel Cycle Technologies Group has, the last few years part of the invited group includes the people working on the IRP. Dr. Peddicord was there, so he knows, he's experienced that we have a presentation on these large projects at the universities, but we also have presentations by university researchers. So we are aware of what it is they're doing. We're the ones who do the reviews and decide who are the winners. And so it is integrated into the work that we do.

EWING: Rod Ewing, Board. I want to follow up on this. So with this investment, do you have some idea of the number of students that are--I'm thinking of workforce training. How many students are supported? Do you have any idea?

BOYLE: My colleagues that run the program, they would probably know. I do not.

TURINSKY: Okay. So you have to report the students?

BOYLE: Yeah. On quarterly reports.

EWING: Right. Right. But that would be I think a really, very important thing to know and follow because hopefully you're creating a educated workforce who can carry forward with these topics.

BOYLE: I'll say this, I usually focus in on the storage, transportation, and disposal. We get an awful lot of proposals. We fund, you know, a fair number. And my colleagues could come up with the exact count. But when you look across the other parts, Andy Griffith's area and the other parts, it's a big Excel spreadsheet.

EWING: Right.

BOYLE: I'll tell you, there is a lot of money spent, and, therefore, by definition, a fair number of students are being supported, students and professors. I just don't keep track, but it's a lot.

EWING: Okay. Jean.

BAHR: Jean Bahr, Board member. A comment related to this idea of what kind of research you do, whether you have an active repository or not. We saw in France last summer, an excellent example of where they have an underground site, but they're also doing a lot of surface testing of the equipment. So I don't think it's an either/or.

BOYLE: Yeah. It's not binary. Right, yeah. But Yucca Mountain did some too. It's like the name of the company was Joseph Oat and so they did--my colleagues on the preclosure side did mock-ups of full-size waste packages and that sort of thing, what might it take to weld them, heat treat them. So it's just that historically the U.S. did not do as much as the Germans do.

BAHR: Yeah. And just a point of clarification. The handouts that we have for your presentation didn't match the slides. Will we be getting updated versions of your slides?

BOYLE: They didn't?

BAHR: At least not in my packet.

ZOBACK: We actually got two versions and neither of them were.

BAHR: We got two versions of the same one.

SPEAKER: I got the one.

EWING: Maybe you got the Boyle number two and three.

ZOBACK: No. The title was the same.

EWING: Okay. All right. Mary Lou.

ZOBACK: Since it is Bill Boyle day--

EWING: Mary Lou Zoback.

ZOBACK: Oh, Mary Lou Zoback, Board. I'm going to take this opportunity to pick on you a little bit, but it's really to all the DOE presentations. When you put up a plot of data or model results, it would really be helpful to be able to read the axis. So that black diagram could have been in the lower left corner, and you could have doubled the size of the figure.

You know, we're scientists. We like to see data and we like to be able to read the axis of the data. So all of you, for the future, start working at editing your PowerPoints. Thank you.

BOYLE: Believe me, you should have seen some of these before I made the same request.

ZOBACK: Well, it was telling when you had to go and flip through your paper thing.

BOYLE: Yeah, they do turn out better when printed. I will say that. Some of it--but still, you people are here looking at it on a screen. They do come out much clearer when printed.

ZOBACK: Yeah. If we had that.

EWING: Sue.

BRANTLEY: Sue Brantley, Board. I'm sitting here thinking about all these casks around the country stored sometimes for longer than originally anticipated, made by different companies, in some cases bolted, sometimes not, other--I mean, all the diversity. And then I'm thinking, you know, granted, in Pennsylvania dye base in Pennsylvania weathers differently that it does in California. What about all the meteorological differences? How do you think of this aging problem and degradation problem, and how do you get the kind of information that you need about all the different climatic variables, seasonality of rain, you know, all those kinds of things? You know, how does that information feedback to your scientists so that you can really tell the public that you know what degradation is happening regardless of what site?

BOYLE: Yeah. That's a very good point. First of all, for any of the storage sites around the country, they would have to include information related to their specific environment in their application to store it to the Nuclear Regulatory Commission. But what we're doing about it is, like the storage sites near the coast, Diablo Canyon, San Onofre, Calvert Cliffs, on Chesapeake Bay, Oyster Creek, New Jersey, they're supposed to saltier sea air. Right? And so it's known today that the coastal sites have different environmental conditions relevant to stress corrosion, cracking of stainless steel. And people do work on that.

So yeah, like, we've discussed in the future, again going forward to the dry cask demo, we're only limited, if you will, by time and money on how many we might be able to do. And it might make sense to do one at a coastal site next time because, specifically, for the different environmental conditions.

ZOBACK: But just as a follow-up, so you feel confident that the diversity of environments that these casks are stored in at the surface around the country, that diversity is being incorporated into your DOE R&D so that you can adequately predict degradation given that diversity?

BOYLE: Yes. So far, yes. Some of the diversity probably doesn't matter, but there's the example of the salt spray for stress corrosion cracking where it's known that it is very relevant. So when we're aware that the difference in environment makes a difference in performance, we look into it.

EWING: Other questions from the Board?

Okay. I have one. This will be the last from the Board, then we'll go to staff.

So there's concern about high-burnup fuel. You have your mock-up experiment underway, and we'll hear about that later. I'm wondering what is the status in the United States of our ability to examine real fuel? And by examine I mean actually do analytical work on it and to learn something about what high-burnup fuel actually is?

BOYLE: Sure. And that will come up a bit in the presentation on the high-burnup demo. The smaller the piece you're looking at, the more opportunities there are, even if it's irradiated, you know, it's the smaller. I would say in the United States, the biggest potential challenge is to take one of those large, dual purpose canisters and open it dry in a hot cell somewhere. That that capability, we're not done fully checking into it, but that is a much more limited capability in the United States.

EWING: Do we have the capability at all? Or--

BOYLE: It's possible. I only became aware at the annual meeting in Argonne that NNSA at the Savannah River site has such a facility that might be useful for us. But if you have ever dealt with NNSA, their mission comes first. Right? There's no doubt about it. And that's the way. So they have not given us permission to use it. We might not ever get permission to use their facility, but they have a facility that if it were available might suit our purposes for opening one of these large, dual-purpose canisters.

EWING: Right. So I guess my comment, my personal comment is that, you know, in terms of research, there are kind of broad themes and needs, and unless we can routinely examined low burnup, high-burnup fuel, then we're in a tremendous disadvantage in understanding the results of the experiments.

BOYLE: Yeah. And again, the smaller the piece, the easier it becomes. There's multiple facilities, Oak Ridge, Idaho, Argonne. We do have an activity underway of considering whether an existing facility at Idaho National Lab could be modified such that it would permit the opening of some of the large, dual-purpose canisters, but that's just an evaluation at this point. But your point is infrastructure in general in the United States perhaps needs a look at, and the DOE infrastructure also, potentially.

EWING: Okay. Thank you.

Questions from staff about this?

PABALAN: Yes. Roberto Pabalan, Board staff. Bill, can you describe the work and maybe some of the results of the status your office is doing related to deep borehole disposal?

BOYLE: It will come up in my last talk today. Yes.

EWING: Other questions from the Board?

Nigel.

MOTE: Nigel Mote, staff. Bill, I'm not sure if this is a question for you or for the next presentation, but you'll know that the performance of advanced fuel clads, typically the ones used in high-burnup fuel has departed from projection. Take the MOX demonstration assemblies at Catawba for example. What are you doing to take account of the only experience we've got on those is short-term in reactor and short-term storage, and what we're looking at is extended storage? And we don't have the ability to examine fuel that let's you correlate as closely--I'm sorry, let's you correlate experience to projection.

BOYLE: Yeah. I don't know the details on that particular topic, but it is a specific example of a general problem you raised with respect to storage that many lab tests tend to be of a shorter duration but the storage is long. And that problem is only compounded in disposal. I had planned on bringing this topic up with respect to backfill performance in the disposal talk. But it is a challenge that people have to deal with.

EWING: Other questions from staff? Well, Bill, you've given us plenty of time for questions so just stand there.

BOYLE: Okay. And I'll ask Monica in the audience.

REGALBUTO: Monica Regalbuto, Department of Energy. More comments than questions, one regarding the NEUP Program, the university program. That is a--we've been really working very hard to fully integrate that program in all of activities in what we call NE5, which is Fuel Cycle Research and Development. We do periodic reviews. Normally, we alternate on a annual basis. We take one area and we fully match what we're funding at the laboratories and we're funding at the universities. We want to make sure when they're--not overfunding one area at the expense of underfunding another one, and also taking advantage of the capabilities that the universities have that are normally less expensive than you can do in a national lab environment, for example. But the fact that radiated materials have to be done in a national environment, we try to bring the students in and take advantage of that synergy.

So that is done normally. Andy has gone through a number of reviews already. And we make sure that we cross ref periodically. We don't do it every year, but at least we do it in a two-year cycle just to make sure.

There is an NEUP website. If you just Google NEUP where you can see the statistics of how many universities are funded, where are they funded, how much research proposals were submitted each year, how many were funded, how many students are participating, and all those details are in the website. Unfortunately, you know, we don't manage that, so we don't have those numbers in our head. But they're all there, and you're welcome to look at the numbers.

We do invite the students periodically, and it is our intent to develop a workforce. I mean, that is clearly one of the objectives of the NEUP program.

My second comment is regarding facilities. And I know Bill was nice enough to say we're looking at it, but to answer your question, no, we do not have the facilities. Okay? We lost the TAN facility a few years ago in Idaho which was--

SPEAKER: Test Area North.

REGALBUTO: --Test Area North, yeah. Which was really our only large hot cell facility where we could have opened a dry cask, especially as the casks become bigger and bigger.

So we do not have that capability anymore. Facilities at Savannah River and facilities at Idaho all need to be retrofitted. We have crane shortages. We have a number of infrastructure issues, and we also have aging facilities that today you have to bring them up to code. So it's a significant handicap that we have. It is working on a shoestring budget. We do not have the ability to invest in infrastructure. With that said, we recognize that the only way to move this program forward is to have that ability.

And I'll give you a quick example. If you want to open wet, we have to open in a pool. Okay? If you want to open dry and continue to conduct a study that says what happened in dry storage and then, you know, take a few pins out or whatever assemblies and then put it back, you’ve got to open dry. We do have the capability of taking a whole spent fuel assembly, cut it into pieces and examine it. What we don't have is the ability to open the cask, neither a utility or a national lab.

So we can handle full assemblies. We can handle partial assemblies at the national labs, but somebody's got to get that assembly out of the dry cask. And that is where we don't have those capabilities, and we need them and we need them desperately because our fuel is going to be in storage for a while, and we need to collect the data.

So that is the one thing that the, you know, unfortunately our budget is not for infrastructure and is something that we recognize is a weakness. We have mentioned that as a weakness. Unfortunately, today I do not have a program that can say I'm going to build a capability to address this issue for the next 100 years. I simply don't have that.

EWING: Thank you very much.

Other comments from the audience?

All right, Bill, you can rest up. We'll see you again in a moment. We're a little ahead of schedule, but we'll push ahead, and that'll give us a little more time at the break. So the next presentation is by Michael Billone at Argonne National Laboratory on the ductile to brittle transition for high-burnup fuel.

BILLONE: Okay. I'm Mike Billone from Argonne. And I'd like to acknowledge my colleague, Yung Liu, who helped me put these slides together. We'll be talking about cladding, high-burnup cladding which means cladding from high-burnup fuel rods and in particular ductile-to-brittle transition temperatures for these particular materials using pressurized water reactors.

I want to make two overall comments because I'm going to forget to say this at the end. All materials have a ductile-to-brittle transition temperature, so you shouldn't be shocked at the fact that cladding does, number one.

Number two, just because--oh, thank you. Just because you dropped below that temperature and your material is brittle doesn't necessarily mean it fails. So what it means is you have to change the material properties and failure limits that you use to analyze a fuel assembly.

All right. With those overall comments, maybe I'll say them at the end also, but to give you a brief introduction, discuss the materials, experimental methods that we use, a quick summary of the results, conclusions, and future priorities. The last slide in my presentation is a list of publications for those of you who would like to read more about this particular subject and the data we've generated.

Bill kind of touched on these, but let me say it for emphasis, the objectives of the storage and transportation R&D are to develop the technical basis for demonstrating useful integrity for long-term storage, fuel retrievability and transportation after long-term storage that’s low in high-burnup fuel, and then particular emphasis on transportation of high-burnup fuel, that means fuel greater than irradiated, greater than 45 gigawatt days per metric ton of uranium.

Also, and Bob Einziger could talk more about this, one-on-one, NRC has expressed some concern about high-burnup cladding, embrittlement after 20 years of storage. I believe the current licenses for storing high-burnup fuel are for 20 years. And then there's a concern expressed about transporting high-burnup fuel below cladding ductile-to-brittle transition temperature. And from here on we're going to be using DBTT. I apologize for acronyms, but it's just easier to say.

Okay. There's only a couple of points I want to cover on these slides because I suspect you're familiar with what's in the Code of Federal Regulations. But basically in deciding how to run our experiments, we looked at criteria for transportation and ambient temperature of minus 29 to plus 38 degrees C, whichever is the most unfavorable is supposed to be used for analyses and for testing purposes. And that helped us set a goal, a target, that if we could find conditions of drying a storage for which the DBTT was less than or equal to 20 degrees C because the fuel is going to be hotter than the ambient, that would be pretty good relative to that requirement.

Also in our testing we used the Interim Staff Guidance-11, Revision 3 which set a limit of 400 degrees C for drying and transfer and storage of high-burnup cladding. The embrittlement concerns for high-burnup cladding is higher everything. Everything is higher. So you have higher hydrogen content which may by itself embrittle cladding that's sitting in the pool before you've ever taken it out to dry if the hydrogen content gets high enough.

You have higher decay heat which may lead to higher, drier unit storage temperatures. Higher internal gas pressure leads to higher peak hoop stresses. And the emphasis of our work is under what conditions will these hoop stresses and to pull the cladding apart and make it easier for radial hydrides to precipitate. And these radial hydrides would cause embrittlement in response to hoop stresses.

Okay. This one is a simulation of what a fuel assembly might look like after a side drop or during a side drop. You've got the bending in the axial direction which causes axial stresses, but also at your grid spacers you have local loads on the cladding. And so I've enlarged this. These types of loads, these pinch-type loads cause hoop bending stresses. And in particular, if you had a PCI, a pellet clad interaction flaw or radial hydride, you'd have stress concentrations at those points, and you could get failure of the cladding. You could also get relief by the fuel taking up some of the load. But I have to caution you not to feel too comfortable by this picture because pellets are fairly short, and there's over 500 pellet-to-pellet gaps in a fuel column where you're not fully protected by the fuel.

The testing that we're going to be doing, and I'll be showing you results, is going to be focusing on the radial-hydrides. None of our samples had PCI flaws, so it's not included in on our study. And we're going to be simulating this type of loading in our testing.

If we can just hit the highlights in red. There are data needs. There are data gaps that have been identified. And we're not filling all of them; we're filling as many as we can. But the data needs include the tensile properties of the more advanced alloys, the Areva M5 alloy which is a Zyrc-1 niobium alloy, ZIRLO, the Westinghouse alloy which is Zyrc-1 niobium 110 as opposed to Zyrc-4 which is basically a zirconium 1.3 tin alloy.

And this would be describing the behavior of these materials as they sit in the pool and then looking at what happens to them following drying and storage. For all these cladding materials you need to define conditions under which radial hydrides may embrittle cladding such that you never get to the plastic deformational regime, you fail in the elastic regime. So the failure limits are important for all alloys.

In our program we're developing a family of ductility curves following slow cooling from 400 degrees C under decreasing hoop stress conditions. And this hoop stress is due to gas pressure inside the rod. For each of these conditions, we determined the DBTT, and our goal is to particularly look for conditions under which our DBTT might be less than or equal to 20 degrees C. And in my personal opinion, it means you wouldn't have to worry about embrittlement if you had these particular conditions.

Okay. There's two types of hydrides we want to talk about. This would be the as-irradiated cladding with high hydrogen content, at low hydrogen content. It's textured to give you precipitation of hydrides in the circumferential direction. It's just a small segment of cladding. So these are high--this dark region here is a hydride rim. These are individual hydrides. They're pretty much all oriented in the circumferential direction. This is high hydrogen content. This is lower hydrogen content. The primary difference is in the thickness of the hydride rim. So these are circumferential hydrides. If you get too many of them you can embrittle the cladding, even before you send it through the drying and storage process.

Once you've sent it through and had hoop stresses that are high enough at 400 degrees C and then let it slow cool, you can get the hydrides that dissolve to precipitate in the radial direction. And these are really platelets, but that's what I mean by radial hydrides. So if you're pulling in this direction and that direction, they act as a site for flaw initiation and crack growth.

Okay. Quickly, on experimental methods, but I do want to emphasize we're not dealing with simulated materials. We at Argonne have a stock pile of cladding materials from commercial reactor fuel rods, irradiated and commercial reactors to high-burnup levels. So let's call it the real stuff. And this table is much too detailed for this presentation, but I just want to identify the three alloys that we've studied, the M5, the ZIRLO, and the Zirc-4.

I didn't define RXA which means recrystallized annealed. This particular heat treatment of the cladding makes it more sensitive to radial hydride precipitation, so it's important to associate that. These two materials are cold-worked, stress-relieved. They're textured to make the circumferential direction the preferred direction for precipitation. And you can see these are burnups all above the licensing limit of 62, but burnup alone is not the critical parameter. The critical parameter, the cladding, is what is the hydrogen content. And it's small for M5 because you have a very small corrosion layer that builds up. And it can be larger for ZIRLO and Zirc-4.

The red is just a code for me. Those were the conditions under which we did get the DBTT to be less than 20 degrees C, but we'll come back to that point.

Experimentally, we take a segment of cladding that's been defueled and we form a pressurized rodlet by welding end caps. There's a breathe hole at the top for pressurization, and then we laser weld that little, tiny hole shut so we have a sealed and pressurized rodlet. And we take it up to 400 degrees C. And by laboratory standards, we cool slowly at 5 degrees C per second. This just shows you how the pressure would change based on the ideal gas law and slight differences in ambient pressure between the furnace and the fabrication facility. And then once you have this pressure, this will give you your hoop stress in terms of the cladding inner radius and the wall thickness of the cladding. So we, under cooling conditions, we have decreasing pressure and decreasing stress conditions.

All right. To simulate the pinch-type loading we use an Instron machine. This is our cladding segment which is about 8 millimeters long. And for typical cladding it’s about 9.5 millimeters in outer diameter. When you apply this type of loading, you induce hoop bending and you tend to get your maximum stresses under the load and above the support. You also get maximum tensile stresses out here and out here.

So the stress will vary. But I want to emphasize what we're doing is simulating a type of loading and using this test as a screening test for ductility. So when I talk about ductility I'm going to be talking about ductility of the structure. And in simple terms, it starts out round, you squeeze it and release the load. If it is oval before it cracks, it's ductile. If it remains round and cracks while it's still round, it's brittle. And that's over-simplifying the situation. We don't deform this all the way to failure, we deform it 1.7 millimeters to get about 10 percent permanent displacement. That would be relative change in diameter from starting to ending condition.

Okay. Let me summarize the results in case I talk too long, we're never going to -- we want to get to this point. What we found in is studying the three alloys is in terms of susceptibility to radial-hydride precipitation meaning radial-hydride fraction and length of radial hydrides, it was fairly low for high-burnup Zirc-4 cladding. It was moderate for high-burnup ZIRLO. And it was very high for high-burnup M5 due to the microstructure of the material and the low hydrogen content of the material. But that's not the bottom line, you shouldn't really stop here. You should go ahead and test see susceptibility to radial-hydride induced embrittlement.

And we get the same results for Zirc-4, but we switch. It's moderate for M5 even though you have a lot of radial hydrides, they're spaced farther apart as I'll show you, and they are thinner radial hydrides.

So we found ZIRLO to be the highest susceptibility to embrittlement. And I'm going to show you curves, but basically the testing we ran was basically peak stresses, hoop stresses of 140, 110, 90, and as-irradiated. That's the range of stresses at 400 degrees C. And for M5 we got a DBTT at that stress of 80 degrees C. It went down to 70 degrees C when we lowered the stress. And we got a huge change in going for 110 to 90 megapascals. And we got less than 20 degrees C DBTT for that material. And that's why I say moderate susceptibility to embrittlement. If you look at that and contrast it with ZIRLO, the DBTT was quite high, 185 degrees C at the high stress level. And it went down significantly to 125 degrees C and 110. And then going down to 90 again, we're right at 20 degrees C ductile-to-brittle transition temperature.

The Zirc-4 was more complicated because at the high stress it was 55 degrees C, and then it dropped to less than 20 degrees C at 110. But you have to look at the total hydrogen content at the bottom. Zirc-4 is not as susceptible to radial-hydride embrittlement, but it's, at higher hydrogen contents, it's susceptible to embrittlement due to circumferential hydrides.

That's a lot of words, so let's back it up with some figures and results. This is offset strain of the ring that we're squeezing. You can think of it as a change in diameter normalized to the initial diameter of the material. And this would be prior to getting significant cracking in the ring. And basically, as I said, the M5 at the higher stress level, you're very ductile at these temperatures, and then you get down to about 80 degrees C--let's put it another way. At 90 degrees C you have high ductility, at 60 degrees C you have very low ductility, you're brittle. And the transition is about 80. You don't gain much in dropping the stress from 140 to 110; it goes from 80 to 70. But you gain a tremendous amount in going from 110 to 90. At 90 megapascals, the M5 behaves like it doesn't even know it went through the drying and storage process. It doesn't even know it has some radial hydrides. It behaves the same way as the as-irradiated material sitting in the pool.

And this shows you in the as-irradiated condition, again, as the M5 would sit in the pool, low hydrogen content, mostly short circumferential hydrides, some indication of some radial hydrides, but they are benign. They don't contribute to embrittlement. And then you see what happens to these hydrides as you go to the high stress at 400 degrees C. They pretty much all line up in the radial direction, but they're spaced fairly far apart.

If you drop the stress, the reason you didn't gain a lot in terms of embrittlement is you still had long radial hydrides, you just had fewer number of the radial hydrides.

All right. We did a lot of work with ZIRLO because this was--we started out doing this work for NRC, and at these conditions, we got the 185 degrees C, ductile-to-brittle transition temperature. We also did this testing for NRC. We went from 185 to 125. And then for DOE we concentrated on the lower stresses. We did the as-irradiated condition and then we also did drying stresses of 90 and 80 megapascals. The 90 megapascals seemed to be low enough such that we pretty much hit 20 degrees C as a ductile-to-brittle transition temperature. And then of course things got better at 80 megapascals.

So what is going on with the material? These two microstructures were problematic. You saw them before, but basically this is your as-irradiated material. This is sent through the drying process and then cooled slowly, and you get as much as 80 percent of a wall covered with radial hydrides. So it's not a shock. You also get a lot of radial hydrides and connection of the circumferential hydrides.

This material behaved better, 125 megapascals. And you can see clusters of radial hydrides that are not as long as they were up here. They're about 36 percent of the wall.

Okay. Zirc-4 was more complicated because, again, these are the tests we ran for NRC. At the high stress level we first of all noticed this is not the S-shaped curve you would expect for a ductile-to-brittle transition temperature. This is just a gradual change in ductility with temperature. So it's not being driven by radial hydrides. But we got 55 degrees C for the 140 megapascal case, and then we got an improvement with the lowering of the stress. But I have to caution you that we went down about 100 weight parts per million in hydrogen content. And is seems to be that the hydrogen content and the circumferential hydrides dominate.

So we were surprised when we did our baseline studies of as-irradiated cladding that we tested up to 90 degrees C and the material was all brittle because the as-irradiated cladding sample we chose happened to have a large hydrogen content of 640 plus or minus 140 weight part per million. It's worth it to say that this is not uncertainty in the measurement; this is actual variation of the hydrogen content as you go around the circumference of the material and you go from one axial location to another. There's huge variations in the cladding.

So to make sure that what everyone knows was confirmed, we chose a low-hydrogen content sample of Zirc-4 of 300 ppm, and that sailed right through our tests with full ductility and no cracking. So it just confirms the fact that it's the high concentration of radial hydrides that's causing the embrittlement of the Zirc-4.

This would be our baseline studies, and you can see, it's different than pictures I showed you for ZIRLO. You get the hydride rim starting here to be less dense and to go extend more into the material. You get short hydrides at the high stress like this. If you lower the stress, you get even shorter hydrides.

So this is basically repeating what I said earlier. We distinguish susceptibility to radial-hydride precipitation to susceptibility to radial-hydride embrittlement. And as I said before, I added a few words; it was low for Zirc-4 in terms of susceptibility to radial hydrides, however, circumferential hydrides, locally greater than at 800 ppm of hydrogen cause embrittlement of this material. The drying and storage conditions for which we did achieve our goal--and I didn't think we could but we did--to get a DBTT of less than or equal 20 degrees C which I'm hoping is sufficient, for both high-burnup M5 and ZIRLO, a peak hoop stress of less than or equal to 90 megapascals was sufficient to achieve that goal. And with high-burnup Zirc-4, we did achieve it, but it depended on the total hydrogen content as well as the local hydrogen content.

So 90 megapascals looks good. It begs the question, what is the question of high-burnup fuel rods with peak hoop stresses less than or equal to 90 megapascals under your drying and storage conditions? And really there's an insufficient database to answer that question. To give you some idea of what I'm talking about, there are hundreds of thousands of high-burnup fuel rods that have been irradiated.

So what is available in the open literature for the end-of-life gas pressure which would include the helium fill pressure that you fabricate the rod with, the xenon and krypton that's released, and then for some designs there's additional helium that's released from a burnable poison that's put on the fuel rod.

And in addition to gas--number of moles of gas increasing, the volume of the plenum decreases and the free volume for the gas decreases. So out of the hundreds of thousands of PWR rods, EPRI published data points for 25 fuel rods that were above 45 gigawatts days per metric ton, not enough to give you a warm, fuzzy feeling of even what the trends are.

So working with EPRI, the ESCP Fuels Subcommittee of which I'm the chairman, this year we expanded the database from 25 to 60 fuel rods. We identified additional data and felt very proud of that. But it's really still insufficient. We're going to continue this effort and try to get greater than 100 data points for end-of-life fuel pressures. There's other work we're doing with EPRI within the context of the ESCP Fuel Subcommittee, but let me save that for another time or discussion.

Let me jump to what we're planning to do this year, and you'll hear this from every researcher under DOE, there is data gaps that should be filled, and then there's budget. And there's a need to prioritize, and we can't do everything. So one of the things we'd like to do is support planning and implementation of industry high-burnup demo projects. And as

Monica mentioned and a few people mentioned, there's the issue of you let the cask sit for 10 or 15 years, you want to pull some fuel rods out, do you do that dry or do that wet? There's tremendous advantages of doing it wet because of dose rate concerns. And that has to do with just getting an assembly out of the cask.

So we can simulate the various histories of after 10 or 15 years suddenly immersing the cask in water and rapidly cooling, does it affect the hydride distribution? Does it affect anything I've talked about so far? And that's one of the simulations, experimental simulations we'll be doing this year.

To continue establishing the technical basis for extended storage and transportation, that 400 degrees C that I mentioned, that came from my SG-11, Rev. 3, vendors generally don't get up to 400 degrees C. They use very conservative thermal analyses, and all they care about is staying below 400 degrees C in their operations. It's more likely that you're peak cladding temperature is more like 350 degrees C.

In terms of how much hydrogen is available for precipitation, you ask how much to dissolve, and at 400 degrees C you get about 200 weight part per million hydrogen dissolved, that's available. Just dropping the temperature to 350, the 200 drops to 120 weight parts per million, so the amount of hydrogen available for radial-hydride precipitation decreases. It's possible that with less hydrogen available, you might be able to go to higher stresses. It's prudent to be able to establish you can go to higher stresses because we do not have a sufficient database to tell you what stress you're at right now.

We'd also like to evaluate--once we finish this work evaluate the affects of multiple drying cycles at greater than 90 megapascal hoop stress and 350 degrees C. We have the ability and material to measure mechanical properties and failure limits of the ZIRLO and the M5 advanced cladding. And as I say, this has to be prioritized because currently there's not enough funding to do all that work.

So thank you very much for your attention and your patience. Any questions?

EWING: All right. Thank you. Questions from the Board?

Jerry.

FRANKEL: Jerry Frankel, Board member. Thanks, Mike, for the talk. It's a very interesting subject. I have to admit I'm confused though, and maybe it's a nomenclature thing. All right, so ductile-to-brittle, you started by saying that all materials exhibited ductile-to-brittle transition.

BILLONE: Right.

FRANKEL: But, you know, the classic ductile-to-brittle transition has to do with deactivation of slip systems and that's with a very sharp temperature for BCC materials.

BILLONE: Right.

FRANKEL: That's not what this is. This is really hydrided-induced embrittlement which is not exhibited by all materials. Is that right?

BILLONE: Because it's not a homogeneous material. And--

FRANKEL: But the embrittlement is because of the hydride distribution, hydride cracking; right?

BILLONE: Correct.

FRANKEL: You get--it's nothing to do with the ductility of the metal but really the ductility and distribution of the hydrides that are in the metal; is that right?

BILLONE: No. You're correct, but the concern is does the cladding crack or does the cladding not crack.

FRANKEL: Okay. So it's just to me it's a strange name even and a confusing name for the phenomenon.

BILLONE: Okay.

FRANKEL: So the hydrogen exists because of corrosion in the reactor; is that right?

BILLONE: Right. The water-side corrosion.

FRANKEL: The water side. So there's some fixed amount of hydrogen that--let's say in dry storage you're not considering that there's more corrosion going on from residual water?

BILLONE: Oh, no.

FRANKEL: So that's not the issue. So there's some fixed amount of hydrogen--

BILLONE: It's in reactor.

FRANKEL: --fixed amount of hydrogen that distributed in the cladding in some way--

BILLONE: Right.

FRANKEL: --and then gets redistributed is the problem.

BILLONE: That's correct.

FRANKEL: And then gets susceptible to cracking because of orientation. Right?

BILLONE: So far so good.

FRANKEL: Okay. You know, it's just--so now you heat it.

BILLONE: If I--time out. If I said it that way which is more accurate, I'd put a lot of people to sleep.

FRANKEL: Yeah, okay.

BILLONE: So I'm using DBTT because it's a catchy--

FRANKEL: Catchy, okay.

BILLONE: It's catchy.

FRANKEL: Yeah, all right. But accuracy is important too.

BILLONE: But material does go--the material is a composite.

FRANKEL: Right.

BILLONE: It does go through a ductile-to-brittle transition.

FRANKEL: Fine. Okay. But it gets heated; the heating to 400 is because of the drying cycles only.

BILLONE: Yeah. If you vacuum dry, if you pull a vacuum and try to get to your goal moisture level of three torr for 30 minutes of moisture. The decay heat will continue to heat up the material.

FRANKEL: So all those micrographs that you showed were room temperature micrographs; is that right?

BILLONE: That's correct.

FRANKEL: So you heat up and the hydrides dissolve. They go into--the hydrogen goes into solid solution; is that right?

BILLONE: Yeah. But there's very little hydrogen in solution above 200 degrees C. So it's true, I've showed you room-temperature micrographs, but in our testing, we tested from room temperature to about 200 degrees C. Those--the pictures of the cladding--the hydrogen is pretty much frozen in the material because the solubility is so low at 200 degrees C.

So what I'm showing you is results after X amount of years in dry storage where cladding temperature would drop below a certain amount. And so as a guide if the cladding temperature has dropped below 200, it pretty much doesn't matter whether it's 20 degrees C, 100 degrees C, or 200, the pictures are going to look pretty much the same.

FRANKEL: So there's a stress-induced reorientation of the hydrides.

BILLONE: Right. You're making it easier for the material to precipitate in the radial direction. And precipitation is a lot more difficult than dissolving. You dissolve hydrogen very fast. But the hydride has a higher volume, a lower density. And it has to literally push the cladding to make room for it. So for radial hydrides, if you're already pulling in the radial direction, you're making it easier for the radial hydride to precipitate. But I interrupted you.

FRANKEL: So right. So you have this situation where there's a cooling --

BILLONE: Right.

FRANKEL: -- from this treatment, but then it's also sitting around hot in the storage. So with time it's cooling some degrees per hour, okay?

BILLONE: Yeah. And the 5 degrees C per hour is more the cooling rate if you stopped the drying process, reimmersed it in the pool, and then pulled it out and started again, that's more typical of multiple drying cycles. Obviously, it's much slower during storage than I've shown you.

FRANKEL: Okay. So you have this decreasing pressure and temperature.

BILLONE: Right.

FRANKEL: And slow reorientation--

BILLONE: Slower than our experiments.

FRANKEL: --slow reorientation of the hydrides. But the cracking, when does the cracking happen in that scenario as opposed to your testing scenario where you are holding your sample at the fixed temperature, applying a stress until fracture?

BILLONE: Yeah. In reaction-controlled displacement, but it's the same kind of thing.

FRANKEL: Okay. But so does it work the same way? So it's the kinetics of the precipitation that as soon as you might get this reorientation then cracking will occur if the stress is high enough?

BILLONE: Well, our testing is done in two phases. One is you simulate the drying-storage process. And at the end of that, all you have is gas pressure inside the rod, not enough to do any damage to our little rodlets. And that's cooled to room temperature, and then we cut a number of rings for hydrogen analysis, for metallography to get those images, and for squeezing.

Where the load would really come in, we don't expect under storage conditions to have much load on the cladding that would challenge the cladding. And under normal transport conditions after storage, the loads may not be high enough. We don't know exactly. But that's what we're simulating. We're simulating really what might happen during transport, normal, and off normal, an accident where you would get a one-foot drop under normal accident conditions that you have to allow for or a 30-foot drop, a 90-meter drop.

FRANKEL: So the microstructure is really frozen in.

BILLONE: It's frozen in.

FRANKEL: It's frozen in, and susceptibility then depends on the subsequent--

BILLONE: Right.

FRANKEL: --mechanical stresses.

BILLONE: And in our studies if you're transporting above 200 degrees C, regardless of the cladding alloy, this should not be a problem. The materials should behave in a ductile manner. And then it's alloy dependent where you might have an issue of where you have to branch off in your failure criteria and use a different set of failure criteria for cladding below a certain temperature.

FRANKEL: Okay. Well, I would again say that for technical accuracy, ductile-to-brittle transition doesn't really describe it, what's happening. From--

BILLONE: If you're raised in the tradition of a homogeneous material and how that term is applied for that, I would possibly agree.

FRANKEL: This is a hydride-induced embrittlement is what it is.

BILLONE: Yeah. Just because the mechanism is different, and I want to say it's directional. We don't know fully, but we have enough data that if you apply an axial stress to the material, you don't get the same effect.

FRANKEL: Thank you.

EWING: Mary Lou.

ZOBACK: Mary Lou Zoback, Board. I'm familiar with hoop stresses around boreholes in the earth.

BILLONE: Okay.

ZOBACK: So similar mechanics apply. And this discussion has helped me a lot to understand exactly what it is you're doing, but I still have some questions. And one is that as I understand your test you just took a little ring of the rod and you subjected it to a load.

BILLONE: Right.

ZOBACK: A point load. And because the hydrides are there due to the hydrogen that was there, they embrittle the material, and you get tensile failure. I guess I want--you know when of you hoop stress you have a maximum tensile failure in the direction of the applied point load, but at 90 degrees, you've got maximum compressive. So are you getting compressive failure or tensile failure?

BILLONE: It's tensile because we have to look at the bending stress. The actual compression loads are trivial. And you're changing the shape of the material from a circle to an oval.

ZOBACK: Okay. Yeah, that's right. You're actually ductilely deforming.

BILLONE: And the bending stresses dominate.

ZOBACK: Okay. So you're ductilely deforming the ring first, and then that's what's dominating. But in the real situation you've got gas inside. So you've got an internal pressure as well.

BILLONE: Which by the time this happens is low, yes.

ZOBACK: Okay. So you can effectively ignore it?

BILLONE: Well, we try not to ignore it because our failure criterion isn't cracking all the way through the wall, it's cracking greater than 50 percent of the wall.

ZOBACK: Right, right.

BILLONE: And that allows us to have material left over for--to resist extra gas pressure loading and axial bending. So we try to compensate for what's not in the test and our failure criteria.

ZOBACK: Okay. And then the other question I have, early on you had a little cartoon that I think was meant to show a fuel rod and the little bracing between segments of it. You showed the fuel rods drooping.

BILLONE: I know where it is. I'm sorry. I just passed it.

ZOBACK: Yeah, okay. So does that argue we should be storing these high-burnup rods vertically as opposed to horizontally?

BILLONE: Well, regardless of whether you--I mean, some are storied vertically, and some are--

ZOBACK: Well, I know, but you're getting incredible bending stresses.

BILLONE: This is transport.

ZOBACK: But they've already bent before you've transported them?

BILLONE: They've already been stored either vertically or horizontally.

ZOBACK: But if you stored them vertically, wouldn't you minimize that bending?

BILLONE: This has nothing to do with what happens in storage. This is in transporting a cask--

ZOBACK: Well, in terms of the stresses that are leading to the embrittlement, a vertical storage would minimize that sort of bending; right?

BILLONE: Right. But now you're going to transport. And in transport you have to allow for an end drop of cask and a side drop of the cask. And so it seems like no matter how you choose to orient the cask during transport, you have to--

ZOBACK: No. I understand that.

BILLONE: Okay.

ZOBACK: It seems to me the process you're describing, and unless I really misunderstand it, is something that kind of got locked in as it cooled from the amount of hydrogen that was around.

BILLONE: That's correct. And then after that you're going to transport the fuel. And we want to know under this type of loading, has the cladding maintained its ductility, or is it going to behave in a brittle manner in response to these types of loads? And in particular, you will have this pinch-type load at the grid spacers where there's springs and wherever there's contact between one rod and another rod dynamically. And that's really what we're trying to simulate.

This type of load as we said, the compressive loads, due to the F forces are trivial. It's the bending loads that we're simulating. So we're really simulating what we--very fast over a period of a week, the whole cooling process for drying and storage. And then we go to a second phase of testing where we apply a load at various temperatures to look at what the ductility is of the material.

ZOBACK: Okay.

BILLONE: The methodology is sound. You have to be careful in applying it. You can't jump to conclusions.

ZOBACK: Okay.

BILLONE: Next question.

EWING: All right. Jean.

BAHR: So I'm going to--Jean Bahr, Board. I'm going to step back a second. So if the cladding fails, what's the consequence? And so we're talking about failure during transport. Does that--but you still have this--you have a canister that encompasses the fuel rods. You have a transportation cask that's outside of it. So is the hazard to the people that are transporting it, or is it a hazard that would be created if you subsequently opened this up? And what you have to open up for it to be hazardous, do you have to open the canister or the surrounding cask?

It sort of gets to some of the issues we were talking about yesterday about packaging or repackaging or not. Is this mainly a hazard if you ultimately have to repackage this?

BILLONE: It's mainly a hazard if you open the cask and if you want the most flexibility at the other end--which I won't say what the other end is--you would prefer to have intact fuel rods.

BAHR: Okay.

BILLONE: The issue of retrievability from storage and transportability, do you do it by fuel assembly, individual fuel assemblies, or do you do it by canister? I believe this is something that NRC has opened up for public dialogue.

Industry's position is very clear. Since they care about the storage process and they think retrievability by canister is sufficient. There are others who feel like retrievability and transportability by assembly, assuming that you’re going to open and repackage before you transfer. At the other end you would like the option of reconfiguring your fuel assemblies.

BAHR: Okay. Thank you. And just to follow up on Mary Lou's question, I think what you were saying is that the bending that's illustrated there, that's what happens if something drops during storage. So it's not already bent when you--

BILLONE: No.

BAHR: --when you start to transport it.

BILLONE: It's a dynamic situation.

BAHR: Okay.

BILLONE: But even bouncing along on the railroad tracks will--

BAHR: But the bending is a consequence of the transport. It's not a consequence of the storage and the embrittlement that happens during that--

BILLONE: I don't expect seismic loads to really challenge the material in storage.

EWING: Okay. Sue.

BRANTLEY: Sue Brantley from the Board. In your third to last slide, you have a whole bunch of bullets about--well, first of all you talked about how unhappy you were with 25 data points, and how happy you were that you got it up to 60. And then there's--

BILLONE: Oh, I know which slide you're talking about.

BRANTLEY: --bullets about very little data in the open literature, but the extensive data sets among vendors. Can you just talk about data availability and what the issues are there? Just kind of educate us about that. Why was it so hard to get from 25 to 60? Just as an example.

BILLONE: It would fit more in my talk if I just focus on this. Is that what you're asking about?

BRANTLEY: Well, I want you to educate me about data availability. Why it's so hard to get it? You know, what data is out there?

BILLONE: Oh, because well, I simplified a little bit. Of these 60 data points that we have, 14 are restricted by the fuel vendor and EPRI. They're not available to the public. So there's more data out there, but it appears in EPRI reports that you would pay 300 to $600,000 for the report if you're not a member of the EPRI club. So industry has more data that the general public. They share some of this data with NRC for licensing purposes.

What we're trying to do is we would like to know what the trends are. What's kind of the average gas pressure that's measured? What's the two-sigma limit on it? And in working with EPRI we can get there without ever showing the data points that are restricted. We could use those data points to establish trends. What's the difference between the pressure at 40 gigawatt days per metric ton and 60 and 70? We could answer those questions.

But it's a problem in all this work depending on what your affiliation is. I happen to be privileged in the work we did for NRC where the vendors worked directly with me, supplied me with information to help me design experiments; and I could never use that data that they provided me, so I know it exists. In some cases we generated the data for the vendors, but I can't say anything about it because it's proprietary.

So I would say this is an insufficient database to draw any conclusions about trends. We're trying to increase it, both what's publicly available, searching it out. There's probably not much more than what we've found. And then there's all the restricted databases that we would like to include at least in an average plus or minus two sigma type configuration where we could never show the data points. I don't know if that make sense, but the same thing is true in mechanical properties.

BRANTLEY: I think I understand. I'm not sure if it makes sense, but I understand.

BILLONE: Okay.

EWING: Just to follow up on that. What is the rationale for restricting the data?

BILLONE: It's a competitive business.

SPEAKER: --among the vendors.

ZOBACK: So this is a fuel rod? Mary Lou Zoback, Board.

BILLONE: This would be Areva. Most projects, hot cell examination projects, the ones done in this country, the ones down in Studsvik and those places, are jointly funded by EPRI and some fuel vendor that made the fuel in the first place. So Areva-EPRI would be a team to generate data. Westinghouse-EPRI would be another team who would generate data.

The results go into proprietary EPRI reports which in five or ten years the material might be determined to be not so sensitive anymore, and it might be released publicly.

EWING: All right. But I'm sorry. What's sensitive about the data?

Well, I know the vendors are very, very, very sensitive about cladding fabrication variables and the exact thermal mechanical treatment that they use and the exact alloy composition. That's highly proprietary.

And then the performance of the material, you know, I can't answer for the vendors.

EWING: Right. Right.

BILLONE: I just know what is restricted and what is open.

EWING: Okay. Paul.

TURINSKY: Paul Turinsky, the Board. Two questions, one is why no Zirc-2, the BWR material?

BILLONE: There's two reasons, one is a sound reason and the other is not so sound. We had Zirc-2 in our proposal for work to do this year. There's just not enough funding. That's not very scientific. Zirc-2 has in general, because it has a lower system pressure, and it has a lower internal gas pressure. So we think the range of relevant pressure is for PWR cladding, which is not Zirc-2, would be 80 megapascals to 140. For the Zirc-2 it would be more like 60 to 120. So you're starting out with a lower internal gas pressure, a lower stress.

On the other hand, it's like the M5 I showed you. It's recrystallized-annealed, a higher sensitivity precipitating long, radial hydrides. And a lot of it has low hydrogen content that really makes it sensitive. It also has the inner 10 percent of the wall is a zirc liner which has a very high affinity for hydrogen.

TURINSKY: Right.

BILLONE: So if you cool really slowly, there's a possibility that all of your hydrogen would go to the liner, and you would not get a dramatic radial hydride effect.

So scientifically there's maybe a little less motivation, also the Japanese have studied Zirc-2 and published results. But there's this kicker that all of it is lined with zirconium in the inner 10 percent. And that makes your experimental results really sensitive to cooling rates, that you cool really, really slowly and give that hydrogen enough time. It may move all to that liner or most of it to the liner and you may not have a problem.

But I still go back to my first answer, there was no funding to do the work.

TURINSKY: Okay. And then the second question is the use of this data, which I understand is still limited, but people must be picking up and trying to do some mesoscale models informed by microscales to understand hydride formation, to be able to do some predictions?

BILLONE: Yeah. There are a lot of people trying. It's difficult. It's very challenging work because--I didn't emphasize this, but not only is it very sensitive to the material and the behavior to that material in the reactor--how much hydrogen does it pick up--it's also sensitive to operating conditions. And how much are you pushing this fuel rod such that your coolant temperature is a little higher; your heat flux is a little bit higher?

And one of the things we're trying to do with the ESCP Committee is what is a typical radial distribution of hydrogen hydrides across high-burnup cladding. And in our test program we have two extremes: a very dense hydride rim with very little hydrogen below the rim, and then a more diffuse hydride rim.

And that's another issue where industries got data. They're not really eager to publish data. They're very sensitive about the hydrogen issue.

TURINSKY: And do codes like FALCON, FRAPCON, do they have hydride models built into them?

BILLONE: They have a hydride pick-up fraction which is not a very good--right now industry is tasked by NRC for the local work, not for this work, to come up with a better hydride pick-up fraction meaning a lot of measurements are done on the corrosion or oxide layer on the water side of the cladding. Of that hydrogen that was released in that process, 10 percent, 15 percent, how much went into the cladding?

And that answer really varies if you take a

144-inch fuel rod. It varies at different locations and it varies with burnup. So I think that's challenging. And that does not even deal with the fact that as you get to higher hydrogen contents, you have small axial--circumferential temperature gradients around your rod.

And with our Zirc-2 we had locations with 400 ppm of hydrogen. 180 degrees from there we had greater than 800 ppm. So the efforts are really to come up with a hydrogen pick-up fraction that tells you the average hydrogen content. And that doesn't really deal with these large--

TURINSKY: Yeah, the second--okay. All right. Thank you.

EWING: Other questions?

Lee.

PEDDICORD: Mike, a couple of questions as well starting with this slide. If I understand you're dealing with--in your work is it nominally a population of 25 rods or samples from 25 rods with which you’re dealing?

BILLONE: No, no, no, no. In our work we're dealing with fewer fuel rods than that, and we're not measuring gas pressures.

PEDDICORD: Okay.

BILLONE: And this is not DOE research. This is our efforts to work with EPRI and the ESCP Committee to identify one of the data gaps that we would like to help fill. And we've identified end-of-life internal gas pressure. Whatever the database is, is something we would like to expand upon. So these--very few of these rods came through Argonne.

PEDDICORD: So the rods with which you’re dealing, you've noted, for example, variations around the length, even as--

BILLONE: Right.

PEDDICORD: So out of say a particular rod, how many samples, the little ring samples might you look at for a particular rod?

BILLONE: You know, if you count our loss of pool and accident work and our spent nuclear fuel work for NRC, and if you count the useful disposition work we're doing currently, I would say we've concentrated on the fuel midplane to one meter above the fuel midplane. And we have a lot of characterization.

PEDDICORD: So you've done a lot of samples--

BILLONE: We've done a lot of samples for different purposes.

PEDDICORD: --in that roughly meter-length and all.

BILLONE: Yeah.

PEDDICORD: And this is a little tangential. Are you looking at things like crud build-up or has that been all--

BILLONE: The crud was pretty much removed from the rods except for the BWR rods has some tenacious crud--

PEDDICORD: Then back to slide 5 if you would, where Mary Lou Zoback was raising the question. This is nominally a sketch of what the fuel assembly would look like. But in the sketch, something I'm a little puzzled about it is the size of the grid spacers, in fact, would have roughly the same dimensions of the end nozzles, wouldn't they? And in terms of the width and so on, these appear to be smaller. I'm a little puzzled by it.

BILLONE: This cartoon. I--

PEDDICORD: Yeah. Those grid spacers, you know, the rods go straight through there when they're fabricated, and so the end nozzles determine the dimension. So it seems that this is maybe a little more dramatic to the spaghetti diagram than--

BILLONE: Yeah. This appeared in a Sandia report in 1991. It's a little bit dated.

SPEAKER: Time for a new drawing.

PEDDICORD: Peter Swift was taking a little literary license, poetic license here and all.

BILLONE: I borrowed very literally to go from this.

PEDDICORD: But a question, what are, for the high-burnup rods, what is the typical internal pressure, gas pressure?

BILLONE: That's the point. If I have--

PEDDICORD: Well, I mean, you've got models suggesting--I mean--

BILLONE: If I have 60 data points and you ask me what's typical of hundreds of thousands of rods, I can't tell you.

PEDDICORD: Okay.

BILLONE: I mean, I could tell you where we are now. At room temperature it's more like 4 plus or minus 2 megapascals.

PEDDICORD: Okay. Yeah. Okay. That's giving a ballpark.

TURINSKY: Yeah. I think the rod has to be less than the nominal primary system pressure because the zirc will creep out otherwise.

PEDDICORD: It'll creep out otherwise.

TURINSKY: So that's the design criteria. How close they come to it, I don't know.

PEDDICORD: Then on slide 7 if you could go forward two slides here. On these now, are these--these are samples of irradiated rods?

BILLONE: Yeah. This is from--fuel rods irradiated to 70 gigawatt days per metric ton.

PEDDICORD: Okay. And then as you go from the Zirc-4 to ZIRLO, M5, and so on, the hydriding--it's zirc hydriding is what you're dealing with.

BILLONE: Yeah.

PEDDICORD: But do those hydrides change at all because of the different constituents in these different clad materials? Or does it--

BILLONE: So far we can't see that. And probably a more exhaustive study with nonirradiated materials that have been prehydrided where you just have zirc and one weight percent niobium and nothing else in it might give you a better clue as to what are the effects of niobium on the hydrogen precipitation.

We don't see it because we don't have the same conditions meaning all the high-burnup M5, the corrosion layer grows no more than maybe 20 microns and it just levels out. And the hydrogen is generally below 100 ppm. And so we don't have a comparable Zirc-4 and ZIRLO to the M5 to make that comparison.

PEDDICORD: Okay.

BILLONE: We do have an interesting difference in ZIRLO and Zirc-4. We don't think it's due to the niobium.

PEDDICORD: Also there was some interesting discussions yesterday. The impression one leaves when you were talking about failed fuel, and it was pointed out by the NRC that it is impossible, in fact, to transport fuel, failed fuel, that was with pinholes or so on. After storage for some period of time, you know, with pinholes or anything like that, there's nothing radioactive really to come out.

BILLONE: No. I mean--

PEDDICORD: Fission gases are gone.

BILLONE: Krypton 85 is the last fission gas to have any activity. NRC allows, as I understand it, they don't consider pinhole or hairline cracks as failure.

PEDDICORD: Yeah. And this was a distinction what happens I believe in Europe where they have to be separately containerized. But then you get to the question of if this fuel is in storage for a very, very long time and then you get to fuel rupture and things like that where the fuel rods have failed in a very significant way. You've got material that has come out maybe, where you are dealing, you know, retrievability, what's going to be in that. But the stuff you're doing doesn't really allow many conclusions towards that kind of question. That is a question to you.

BILLONE: Well, I mean first of all, it can. But I don't expect the fuel rods to be challenged during storage. The gas pressure is going to continue to decrease. I don't think creep is a major issue. The assemblies and the rods will be challenged during transportation.

PEDDICORD: And again, even if it's gone through Dr. Frankel's ductile-to-brittle transition I'm sure with the asterisks on it, that doesn't necessarily mean that you're going to have these more significant failures.

BILLONE: Right. What we would like, ideally, is our work to be a piece of the puzzle. If you're going to model the behavior of fuel in a cask during transport, we would like our results to go into the failure criteria and the material properties that you used to do the analysis.

So this is still a part of a bigger picture. We need to know what the loads are for normal transport and for off-normal transport in order to do the calculations and use this. So this is not the whole answer. This is a way to help the modelers say, okay, if I'm below this temperature for this material, I really have to look closely at the effects of radial hydrides on what my failure strains or stresses might be.

PEDDICORD: And then finally in the trends to higher burnup, has that trend in your opinion been pretty much utilized, exhausted? Are there any drivers to extend high-burnup beyond what is the current industry practice?

BILLONE: There is pressurized water reactors, I'm sure there's an effort to go--the decision to go to 62 gigawatt days per metric ton is because industry requested it as I understand it. At the time there was no sound basis for it in the accident domain, of the loss of pool and accident. And we completed that research and 62 was fine.

I think there was a push to 70 gigawatt days per metric ton. Most of the rods we've examined are lead test assembly rods that went to about 70 gigawatt days per metric ton. BWR might be pushing to 65. I'm not sure.

PEDDICORD: Thank you.

EWING: Okay. Jerry.

FRANKEL: Yes. Jerry Frankel. I have a follow-up to our discussion before.

BILLONE: Are you going to hammer me about DBTT?

FRANKEL: No. I'm not--I'm digesting what you said.

BILLONE: Okay.

FRANKEL: So this is a hydride cracking problem.

BILLONE: Yes.

FRANKEL: And you said that the microstructure is sort of frozen and the same over a rather wide temperature range. So is--

BILLONE: The hydride morphology is, yeah.

FRANKEL: Morphology. So you show, for instance in one of these slides, there's a huge difference in ductility between say 80 to 60. But the hydride morphology is the same.

BILLONE: Correct.

FRANKEL: So the question is why the huge gradient in ductility? What's the mechanism that's causing this--

BILLONE: I think that's a great question. I don't have an answer because I suspect statistics come into this. We covered a broad range of conditions but did not repeat tests under the same conditions. So if I go to what I think you're referring to--

FRANKEL: That was--13, for instance.

BILLONE: Right there.

FRANKEL: Yeah.

BILLONE: It's not clear that this data set and this data set aren't necessarily different data sets. If we reran this test five times and got five data points at each of these temperatures and did the same here, it's possible that these two curves would overlap.

FRANKEL: But you're still getting a huge difference. So you're saying that you aren't confident then in the 10 percent and 1 percent strain the ductility? So, for instance, the 110 MPa at 400, so is the scatter so large that you're not confident of that difference or--

BILLONE: No. Here's my problem. If I go around the circumference--this is the one at 140--if I go around the circumference of the cladding, this picture changes. The location of the hydrides, whether they're in the middle and are benign, how many contact the inner surface. How many contact the outer surface. So you're loading affects--the direction of the loading relative to the material affects the results.

FRANKEL: Okay. But the value of that transition is important. Now, you want to base your transportation decisions on the fidelity of that value. So, you know, wouldn't it--are there other ways to simulate this, you know, with structures that are more controlled? And then to understand the mechanism, right? That understanding the mechanism often helps just to prevent--

BILLONE: Well, I mean, you could run a pressurized tube test which would be an irrelevant loading mechanism. But the pressure would affect every part of cladding the same. And you could increase the pressure until you fail.

FRANKEL: So what is your confidence in that value, the transition temperature value?

BILLONE: I think the answer is better what is NRC's confidence in that value. And I think Bob would say as he said to me is the database is not robust enough. But it's an indication that gas vendors who are looking for licenses for transport need to provide more data in showing the effects of radial hydrides and what's called the ductile-to-brittle transition temperature.

You know, I'm biased because we did the work. But I also, being honest, we're trying to cover a broad scope of materials and test conditions hoping somebody like an industry picks it up and goes back and does multiple tests under those conditions and develops a more robust database.

FRANKEL: Is there anyone studying the mechanism, the detailed fundamental mechanism behind it? Is there any--

BILLONE: There are people trying, but there's also--missing from my talk is a very extensive worldwide effort sponsored by EPRI to study the same thing we're studying, and that's all proprietary data. So there's more than Argonne studying this. But again, you won't hear a talk on it at a meeting like this, at a public meeting. So at best all I can do is be brief on what those results are. Are our results consistent with those results? What are the data trends? And that's the most I could offer.

FRANKEL: Thank you. Thanks.

EWING: So I'm surprised to say we've run out of time. I mean, we're well ahead of schedule. But this is good. And I really appreciate the very technical discussion.

BILLONE: Really great questions, so I appreciate your interest.

EWING: So, and I'm sorry we didn't get to the staff, but if you have a pressing question, we won't let him out of the corner for a few moments. So please be sure to get the information you need. Well, we'll have to stop now, so let's stop. It's 10:30, and we'll reconvene at 10:45. Okay? Thank you.

(Whereupon a brief recess was taken.)

EWING: All right, Bill, take it away.

BOYLE: This is my second presentation today. And I am aware that the title on this slide does not match the title in the agenda, but I view that as the same as Bill and William. Right? I go by either. I'm the same person. The slides are the same; it's just that the title changed.

And so I'm here to talk in large part about this high-burnup cask demonstration project and at the end of the talk, specifically talk about the test plan as mentioned in the title in the agenda.

So this is work on the storage side of the house, so it's under Ned Larson. And the goals of this R&D project is--our near-term activities are focusing in an experimental and analytical work that can be done immediately, work that's relevant to the storage issue. But the long-term activities are to focus in on a program that's looking at full-scale, real, spent fuel in storage. And the ultimate goals are building confidence, and you notice that first bullet, the green bullet, is linking back to modeling. There's no escaping that people need models, but we need models that are related to real measurements.

So why did we come up with this? Of the 1700 or so dual-purpose canisters out there or even single-purpose ones, by definition designed, constructed, and licensed to be "mute" is my word. They're designed to not leak anything. They're impenetrable in many respects. They're supposed to be as to keep the bad stuff inside. But in doing so you also make it more difficult to get information out of. So for run-of-the-mill storage, there's no criticism implied or anything, they're rather inert with respect to providing relevant data. So people want more data related to the high-burnup fuel that's going into storage. So this is an opportunity to get that data.

And the way it came about is what we're going to do is--or we're in the process of doing, fall backup. The department went out with a notice of funding opportunity I think it was called last year and said, "Industry, we have money. You have fuel. You're going to put it in storage. You've got a license to store. Would you be interested in working with the department on modifying the conditions of storage such that we'll maximize the amount of information we get out of it?" There were multiple responses to the notice of funding opportunity. So then we went out with a request for proposal and eventually did select a winner, and that's what I'll be talking about today.

And it was all fundamentally premised upon the department doesn't, as a general matter, does not have commercial high-burnup fuel utilities. The department doesn't store high-burnup commercial fuel, utilities do. So the whole premise of the RFP was dear utilities and your partners, you bring a reactor, you bring fuel, you bring a storage license, we'll bring the money. We'll do as much as we can prototypically, store it at your site, but in the process we'll modify things a bit to maximize the information we're going to get out of it.

And so that's what this slide describes. It's a photo from a crane manufacturer site. We actually don't know which reactor this is, but that shows fuel being put in storage. We're headed down a path of the first of these. There is a possibility as time goes by and if funding is available, we could load a second cask.

And this last bullet is where I deal with the issue that came up in the earlier talk. It's of the lack of hot cell facilities in the United States in which to reopen any such canister, dry. Where and how it will be opened will be solved at a later date.

As Dr. Billone mentioned, we're actually funding work for the eventuality that even ten years down the road there's no place in the United States where we can open a dry. We're doing research on, okay, if we have to do it wet, what are the effects? Does it ruin anything? Does it mask something? And that sort of thing. So down the road, if all works well, we will have a hot cell somewhere in the United States capable of bringing the cask back in and opening it up and taking the assemblies out.

And we did get multiple proposals. The winning proposal came from this team, Electric Power Research Institute, Dominion is an electric utility across the river in Virginia, and Areva is a vendor of many things including storage systems. So back to David Blee's remark earlier, his comment earlier today about having private industry participation. In a sense they are in that test plan is being developed is being developed by these non-governmental entities with 80 percent of the funding coming from the government.

We awarded the contract earlier this year, April 16th. This gives some details about the contract. Again, we specifically asked for a pressurized water reactor to start with. You know, we had to start somewhere. There's more PWRs, pressurized water reactors, in the U.S. than boiling water reactors, so we chose PWR.

We requested that there be the ability to look at multiple claddings. As you saw in Dr. Billone's talk, there are multiple claddings and they have different properties and they behave differently. So Dominion had these multiple claddings available.

The demo cask is an Areva Transnuclear 32. It's one of the bolted ones. It does not sit in concrete. That's supplied by Areva Transnuclear.

In the proposal Dominion said either their Surry plant or their North Anna plant; it looks like it will turn out to be the North Anna plant. The original contract duration, five years; roughly $20 million in round numbers of which the government is putting up 80 percent and the industry is putting up 20 percent. So the government's share is, round numbers, 16 million.

And so here's the work effort over the length of the contract, if you will, with EPRI and Dominion and Areva. But the first task, and I'll have more slides on this, is prepare a draft test plan. And here's what I mean by that.

As I've already indicated, the conditions of storage of this demo are not the typical run-of-the-mill daily storage conditions. We want to get more information out. So this is the first time we're going to do it. If there's funding we might do more. But who knows what the future provides? So we want to make sure that we get the maximum value out of this. So we went into this deliberately planning to have a draft test plan that we would make available for public comment. I mentioned that on Monday in the afternoon and gave the website, and I will again on a slide. So that was fundamentally part of our strategy here was to issue a draft test plan, let anybody who wanted to comment on it comment on it with the goal of being that we're going to come out with the best test plan we can get to achieve our goals for the amount of funding and time that we have.

So the first task was to prepare the draft test plan. That's been done. We're in the midst of--we've asked for comments. I don't know that we've actually received any yet, but when we do get them, we will handle them appropriately. And then based upon the final test plan, we would complete the final design for this storage system, identifying the sensors, where they would be in the cask, data acquisition requirements, and that sort of thing. And all that would be then built into Dominion Power's license amendment request because this would not be like their other storage units. They have to go to the Nuclear Regulatory Commission and say, it's modified a bit. We think it's safe. Here's how we're showing you it's safe. And then the NRC gets to weigh in.

And then eventually, and I'll come to when the loading might take place a couple years down the road, it would be loaded. And then we would start data acquisition. On a parallel path we would take other assemblies or rods from other assemblies that are very similar and ship those off for lab measurements. You know, this would be a fully loaded cask with 32 assemblies, but we would, to the best of our ability, identify similar assemblies, similar rods, and do lab testing on those.

So it's not just that industry team that's involved in this. As part of our interaction with the industry, we committed the DOE to bring the expertise of our national labs to be part of this as well, bringing in their lab facilities. A lot of the laboratory testing would take place at Idaho National Lab or Oak Ridge, Argonne, and also the tremendous modeling and analytical capabilities of the labs. And so here are some of the activities. And the three main labs we have involved are Sandia National Laboratories, Idaho National Lab, and Pacific Northwest National Lab.

But the lab staff has already supported our review of the draft test plan. On many tasks, like I mentioned earlier today, like on the field service inspections, the lab staff with DOE, we do collaborate with industry and collaborating to develop the right monitoring and inspection technologies that would be used in the demo, collaborate with industry to link that full-scale demo with the ongoing, the separate effects test. Those are lab tests to focus in on one variable at a time, if you will. The lab staff would be used to help select, okay, of the 32 assemblies, which ones are we going to put in? They'd be involved in the process of loading and drying the casks, analyzing the data, and monitoring and there we are.

So we do have a draft test plan. That's North Anna right there. And you can see it already has--these again, are the bolted steel ones. They're not inside the concrete. Draft test plan, there's the cover of it. It has been delivered to DOE. I'll get to the day of it on the next slide.

Okay. You're all free to read the plan. We really would like comments. And I'll just give you a heads up now.

This is, as we in DOE even looked at it, the plan is quite good on discussing the why we're doing this. It's quite good on the what. The how, some people may say, I want more details. And that may be a reaction by some of the reviewers. But in part some of the details as of this moment are missing because the plan by the industry team was that would be forthcoming in the licensing process. Right?

And inherently there's a little bit of a--oh, issue is too strong a word even--but it's we can't be perfectly specific about everything that--here's what it's going to look like, because it has to go through a licensing process. Right? And things that go through a licensing process are somewhat subject to change. There's questions from the staff. There might be interveners that file contentions. You never know. So in some ways it would be close to impossible today to specify this is what it's actually going to look like the day we put it out on the pad.

But somewhere in between is where we are. So some of the how is to come later. But if any of you reviewers, if you choose to review the draft test plan, it's fair to make that comment, you would prefer to see more of that detail now. It's fair to make any comments you like, and we encourage you to make comments.

Okay. Here's an unreadable federal register notice. But this is the federal register notice that told the public it is available. It was delayed from when we wanted to do it by the shutdown of the federal government. We in DOE continued to work, but it affected our ability to get it into the federal register. It led to quite a--it led to, in round numbers, a whole month delay. The shutdown of the government affected this.

So it went in on November 12th, and comments are being accepted to December 12th. And then we'll evaluate all the comments and a final test plan will be issued. Now, because this is unreadable, I'll repeat it as what I said on Monday, www.id.energy.gov. And when you go there, on the left-hand side is a column. And only one of those links is in red on my computer, public interaction opportunities, you click on that. It'll take you to the web page at the top of which is not only the draft test plan, but also the comment form if you wish to submit comments.

And that's--this is our schedule as of today looking out into the future. The cask would look something like that, modified for any data acquisition that we might build into it. Modifications to the lid are already been designed. The schedule for getting fuel pins of a similar nature such that we could test them in the laboratory, we may pull them this year or next year. And they could be shipped 2015 or 2016.

When is this all going to happen? When is this going to get loaded? I don't know that we have any utility people here, but the utilities run on tightly controlled schedules. And the loading of either this storage container or one of their run-of-the-mill ones is intimately tied to the operation of the reactor and their outages and refueling and that.

So for our winning bidders, the first opportunity we're going to have is related to these two scheduled outages at North Anna and 2016, and it will lead to a cask loading in 2017. And the EPRI contract runs until 2018, and I'm sure like many government contracts there's probably a possibility of extension and that sort of thing.

But so far things are going well. We hope to get good input out of the public comment period. This is our first chance for something like this to get as much out of it as we can. So again, I encourage people in the audience, the Board as an entity is free to comment, the Board members as individuals. You can go read the test plan and provide us comments. And I think that's the last slide.

EWING: Okay. Thank you, Bill. I'll exercise my privilege as Chair and ask the first question because it follows on the conclusions.

So could you give us some idea of what properties you'll be measuring with these sensors?

BOYLE: Yeah. One of the--temperature, that's one thing. We're really strongly interested in being able to tell what's going on inside. As I mentioned these are inherently designed, the run-of-the-mill ones, to be mute so to speak. So temperature, any insights on to what is going--you know, they're backfilled with gas, insert gas, and it's, like, did that go okay? There was--Dr. Billone mentioned that even the technical standard for how dry these have to be when they're vacuumed dried but there's questions related to, well, did some amount of water, did we get it all out or not? Or was there actually something in there that the water was bound to and we didn't vacuum it out, but later the water became unbound? And so it's temperatures and a lot of what's exactly in there, and is it behaving like we thought? So it's a composition-type thing.

EWING: So you'll have chemical sensors for water, hydrogen--

BOYLE: We'll see. Yeah. That's--in the end, we'll see. Those tend to be a bit more challenging in that they tend to be premised upon an opening into it and, you know, it's--we'll see. But yes, it's a possibility in the final test plan.

EWING: Okay. Questions from the Board?

Jean.

BAHR: Another clarification, if EPRI's contract runs out in 2018, who's going to be doing the actual monitoring for the ten years that you planned?

BOYLE: Yeah. As I mentioned, it probably has the possibility for extensions. Government contracts of this size or complexity are commonly done for a base period and then some way, shape, or form of extensions, either on an annual basis or something like that. And that's probably true in this case as well.

EWING: Sue...I'm sorry, Mary Lou.

ZOBACK: I'm getting all kinds of names. Mary Lou Zoback, Board.

This is exciting, Bill--data. So you mentioned a little bit about the sensors. I'm kind of curious about how you're going to get the data out.

BOYLE: Yeah. And that is a big challenge. And we have other research ongoing with that. It's fundamentally difficult, you know, to figure out--to measure something inside under those high temperature and high radiation fields. And we've had ongoing research, and we plan to fund more to look at innovative ways to get that out. In the end if we have to put ports in it that allow insertion of measuring devises, well, that's a possibility. But ideally we would like to come up with things that could figure out what's inside without putting holes in it.

And I've discussed it with Ken Sorenson on the slide I showed earlier. In my earlier talk, he's one of my lab leads. I compared it to the drift scale heater test at Yucca Mountain. And I said in many respects, our 3G of physical techniques to measure water, where was the water inside that rock mass is very similar to trying at a high enough level to figuring out how much water is in one of these and where it is.

And so we're going to have a meeting on instrumentation, I think it's next month. And I volunteered to Ken I'd be willing to come there and explain. I don't know if the geophysical techniques we used at that heater test with rock work, but what they were was we used neutron probes to measure where the water was in the rock close to the borehole in which we put the neutron probe. But we also used ground penetrating radar which is looking at the dielectric constant which is affected by the water. And so it was able to look in feet--it was able to look at rock that we cannot see and give us information on the water content.

And the third method was electrical resistance tomography. We put electricity through it and measured--because it--what did we get on the other side. And it also allows us to look into rock that we can't see. And so I posed to Ken, in some ways that problem is analogous to this one. You want to get information on water on something you can't touch, you can't see it, but there are ways with rock to do that, and there might be ways to do that here as well.

ZOBACK: There might be also just clever data transmission techniques that could go through the cask.

BOYLE: Oh, yeah.

ZOBACK: And I certainly hope you're thinking about MEM sensors of the scale of a million sensors inside that canister. So one is like your one shot to the moon, put everything in there you can.

BOYLE: Yeah. And one of the big challenges is--one way to go about it is put a power source inside the thing which they typically don't have. And so people--there's reasons why not to go that way. But then there's--they are thermally hot. Are there ways to get sources in there that use the inherent heat being put out as the power source and that sort of thing?

ZOBACK: I think if you issued a competition and got bright young people, you would come up with some very innovative solutions.

BOYLE: We are considering in one of the upcoming cycles of the NE University Program, issuing one of these large integrated research program RFPs related to that topic, instrumentation for situations like this.

EWING: Okay. Lee.

PEDDICORD: Yeah, Bill, Lee Peddicord from the Board. Looking at the plan here--and the website does work, well done. A little--well, we won't go into that. So when, at what stage are you going to have to make decisions on what you're going to use for instrumentation? And then over the course of it, will you be able, do you think, to design such to introduce technology development on some of the measurement approaches that might occur through one of these programs we talked about or lab work or so on?

BOYLE: Yeah. As a former applicant to the Nuclear Regulatory Commission, you might get different answers to that question from different people. Dominion would be the applicant. As a former applicant I can tell you I know what answer Dominion would give which is this is it right now. No changes, right? But we'll work with Dominion on that because we do--this is one opportunity to do it correctly. And in some ways it--we don't have a drop-dead date yet. So if somebody were to come up with something tomorrow or six months from now, it could still be potentially put in.

PEDDICORD: And I haven't gotten a chance to read this in detail yet, but is there an opportunity for noninvasive techniques, radiography or something like that?

BOYLE: Sure.

PEDDICORD: Okay. Good. Very nice.

EWING: Other questions?

Jean.

BAHR: Just a comment on things like GPR or neutron probes, those are--if we're looking at a relatively large water contents that are going to induce those kinds of changes, and I think you're looking for very small amounts of water. And they're also fuzzy techniques, so my guess is that neither of those would be very productive.

BOYLE: I know. But that's why I brought it up in the same spirit. I agree. They are fuzzy. That's why we use three of them just in the hope that they might tell the same story and give us an idea of the trend. But you are correct. Even at the test at Yucca Mountain, as soon as the water dropped below a certain amount, the techniques quit working. And as Dr. Billone mentioned, the drying effort is quite intensive. They try to get it all out.

But there is this open question, yeah, but how much remained? So I brought it up only in the sense that it's analogous as a problem. You can't touch it. You can't see it. Is there a way to interrogate it without actually going inside it?

EWING: Right. Paul?

TURINSKY: Yeah, Paul Turinsky, Board. Is this cask qualified for shipment as there actually will be loading high-burnup fuel into casks?

BOYLE: In theory I think it is a DPC. As to where it stands in its licensing process as a cask already made, that I don't know. But believe me, Dominion wants that to leave their property someday. So in that sense I'm confident that they're--it's a dual-purpose canister, I just don't know the status on the transportation side.

EWING: Other questions from the Board?

Mary Lou.

ZOBACK: Mary Lou Zoback, Board. Just a quick question. Is it bolted or welded?

BOYLE: Yeah. No, it's bolted. Right.

ZOBACK: Oh, I didn't know if you meant it was bolted to the ground or bolted--okay--bolted on the top.

BOYLE: Yeah. And we specifically wanted that because we know we're going to reopen it.

EWING: From the staff, any questions? Comment?

Monica.

REGALBUTO: Just an additional comment and that is we hope that this is not our only test. We really would like to do a sequence of tests for high-burnup fuels. This will be our opportunity to learn. We are starting a new area in instrumentation because of the need to develop that. And as Bill mentioned, you know, we're going to hit every community. We will hope to have an opportunity announcement on the NEUP program because we really to want get the electrical engineers working with the nuclear engineers. And, you know, a lot of innovation comes from those collaborations.

We're also--we'll be reaching out to the Navy who has a significant amount of instrumentation. And we will be reaching out to any community that has new ideas. There is obviously the issue with materials and extreme conditions, high heat, high temperature, and also radiation. But we can be clever and start thinking about this. We may leave a port just for people to come and test as they develop their work and see how it really does that. It's still in development. But that will be my comment on the test plan. I would like a well so I can have people test.

But ideally we would like to load another cask after we have those learnings, and in a different--somebody mentioned environment. And we will be targeting marine environment, if we find a utility that is willing to bid on another funding opportunity announcement.

So we really hope this is not the first or only test. We would like to have a sequence of tests. We'll see where the program goes, but it's certainly one of our first priorities and the top priority for us is high-burnup fuels because of the lack of data. And we are very committed to supporting that effort.

EWING: All right. Thank you.

One just random thought or thought that comes to mind is if you want to interact with the community that develops sensors for high radiation environments, NASA would be a group to consider.

I think, Bob, you wanted to make comments?

EINZIGER: Yeah, this is Bob Einziger from the NRC. Couple comments and then one question. First comment is when the license application comes in, this is going to be reviewed in terms of safety, and whatever comes in is going to have to meet all the safety requirements. But remember, this is one isolated cask. It's not licensing a whole fleet of casks where there's going to be 30 here and 30 at another site. So that may affect the risk-based analysis of the system.

Also with respect to Monica's maybe doing one in a marine environment, the inside of the cask isn't going to know what the outside environment is. And we've got lots of casks already that have been out on the pads for 15 or 20 years in those kinds of environments. And we encourage the DOE to examine many of those in many ways to look for all potential failure mechanisms of the cask and corrosion mechanisms.

But my question is there's something new that come up in here that I didn't notice. You said there's two scheduled outings for cask loadings. Why would they load this cask during an outing? An outing is a time where there's a lot of activity in a reactor. They're taking fuel out of the core. They're putting fuel in the core. They're doing repair. I would have thought that the cask loadings would have been between casks outages.

BOYLE: Yeah. The outages are in 2016, and they lead to the loading in 2017.

EINZIGER: Right after.

BOYLE: Yeah.

EINZIGER: Okay.

BOYLE: And at any--and these sorts of--it is Dominion's license. It's their fuel. They do have some amount of say in terms of picking the schedule.

EWING: All right.

WILLIAMS: Jim Williams, Bill. I have a--

EWING: And your organization?

WILLIAMS: Western Interstate Energy Board.

EWING: Thank you.

WILLIAMS: I have a clarification question. You said you're going to monitor inside the cask; right?

BOYLE: We'd like to.

WILLIAMS: And but inside the canister you may monitor with techniques not yet created, is that it?

BOYLE: Yeah. You know, I'm one of those people--I forgot who it was on Monday, maybe it was Jeff--I never keep track of cask, canister, you know, it's too complex.

WILLIAMS: My understanding is that we really cannot monitor within a canister on any--that is not being done now. Except maybe in your special case.

BOYLE: Correct. Right. And we'll see where we end up with the final test plan. People, ultimately, when we take the bolts off ten years from now, hopefully in a hot cell in the United States--

WILLIAMS: Right. Then you will--

BOYLE: --we get to see it and make measurements. But there's a desire, why do we have to wait ten years? Right? Is there any away to either interrogate it remotely and get the information, or if we have to either have something in there potentially permanently.

WILLIAMS: So it's--right now, inside the canister it's a ten-year test until you open it up after ten years. I mean, so you'll get the real data after ten years.

BOYLE: Well, certainly at the end of ten years, whatever information we've gathered in the ten years, what we would get if we open it in ten years is the visual just very similar to what was done at Idaho National Lab years ago with the commercial spent fuel that is stored there, low burnup, it was opened. And people saw that well, it hadn't turned to sawdust. It hadn't turned to green cheese or anything else. It looked like the day it went in.

And there's actually even great value in that. That's what people expected. But being able to take the lid off and go, oh, yeah, it's just like we thought, that's what we would get in ten years.

EWING: Okay. Any other comments? Yes.

FRISHMAN: Steve Frishman, State of Nevada. First of all, pleased to see this test plan. And I actually have looked through it a little bit, and one of the things that looks to me like it may be the biggest question with the license amendment is that plan itself calls for through-lid ports for data collection lines. And it also says that that's going to take a while to get done. So I don't see how this fits into your schedule with all of the other indefinite things about what you're going to test and how you're going to test it. That looked like about a two-year job.

BOYLE: Well, it's not being loaded until 2017 which is four years down the road. So we have--

FRISHMAN: But I'm looking at--you know, the cask is there right now, available.

BOYLE: Yes. It does exists. Yes.

FRISHMAN: And the plan talks about a fairly near-term, unprecedented modification of the lid, if I can give you the big words.

BOYLE: Yeah. That bullet right there. Right. And that's--but that is subject, if you want to comment on it that you have either concerns or a better way to modify the lid, that's fair game.

FRISHMAN: Well, I'm just wondering how that fits in with what you're saying about what we may ask the world in a contest for how we do this.

BOYLE: Yeah. This is being designed now. That doesn't necessarily mean that's the way it will end up. Right? Based upon public comment or other considerations, things may change. But we needed to move ahead anyway, so we're going ahead with a design. Whether that turns out to be the final design, we'll see.

FRISHMAN: Okay. Again, it was just a logistics thing to me because it sounded like you were eager to find a new way.

EWING: Yeah. Let's--we have the point. Thank you. So let's move onto the next speaker.

Thank you, Bill. And we'll see you one more time after lunch.

So the next presentation is by Andrew Griffith from--he's director of DOE Office of Fuel Cycle Research and Development, Office of Nuclear Energy, and he'll be speaking on Material Recovery and Waste Form Development.

GRIFFITH: Well, good morning everyone. I'm Andy Griffith; I'm Director of Fuel Cycle Research and Development. And I just want to say how happy I am to be here for Bill Boyle Day. You know, it's a great privilege to be part of Bill Boyle-Palooza.

EWING: We're as happy as you are.

GRIFFITH: So let me just start by talking a little bit about the title, Materials Recovery and Waste Form Development. Historically, this program has been better known by Separations in Waste Form Development, and we felt a need to change that title recently because of the utility of this technology. It's much more than just separating uranium, plutonium, other things for recycling in fast reactors. And so the name I think better reflects that. And I might be using it interchangeably with Separations in Waste Form today because we are going through a transition in that. And you'll see some of the documents have that title as well.

And let me say also that this presentation is a little bit different than some of the previous presentations, that this is a programmatic overview. I've got some technical detail in there, and I'm happy to go into that during the Q&A, but the emphasis of this presentation really is on the programmatic nature of our work.

So with that I'll go over the introduction. I'll talk a little bit about the campaign structure. And then I'm going to go into kind of a snapshot of several key areas that I think are relevant to your task as a board and certainly relevant to the system's aspect of this technology and how anything we do during this function, this type of technology, that the objective is that we know it has an impact on the storage, the transportation, the repository, you know, how the waste forms are managed, how the material is managed in subsequent steps. And then I'll talk a little bit about the partnerships, and I'll summarize.

So we're guided by a number of documents that I think you're well-acquainted with. And I think the other key point--now, taking Monica's slide here, you've probably seen this in the past, but this really reflects how the requirements of our program evolved down from the DOE strategic plan. We're all about securing our nation, and it involves enhanced nuclear security through defense, non-proliferation and environmental efforts. And that, of course, flows down into our Office of Nuclear Energy R&D road map which keeps nuclear as a source of capable--making capable contributions, considerable contributions to the U.S. energy mix also mindful of the supply, the environmental energy security needs and so forth. And that flows down to the key objective out of the NE road map is developing a sustainable fuel cycle for our nation in the future. So what we're really talking about here--now between Bill Boyle's efforts and Jeff Williams efforts, Jeff Williams has a much more immediate operational project-oriented need especially in the separations waste form--the material recovery waste forms area, we're really focusing on having options available to us and comparing those options, refining those options so that if we move away from a once through nuclear fuel cycle to one that is a closed nuclear fuel cycles where we recycle material, that we have a well-thought out approach to do that and we have a foundation in technology that enables us to do that, not only meeting our national needs but doing it with high performance and it has to be economical, and of course safety is always the underpinning consideration.

So these missions are broken out into near-term activities which include addressing the BRC Commission recommendations, an increase on accident tolerant fuel which is also under my area, and then it goes into some longer term objectives.

I want to talk about our organization a little bit here. And this is tied to--Bill presented the boxes of our organization, but let me just break it down into some functional activities that we do. We do have front-end uranium resources where we're extracting, we're developing technology on extracting uranium from sea water which I'll talk a little bit about because it has a chemistry connection with the Material Recovery and Waste Forms Campaign. We have fuel fabrication function which includes not only advanced fuels for fast reactors in a recycle mode but also enhanced safety LWR fuels with increased accident tolerance.

We've the reactor function here. That's not under Monica. All these functions are under Monica Regalbuto in the Office of Fuel Cycle Technology. But the reactor is clearly here because anything we do on the front end, anything we do on the back end has to take into account this central function here and emphasizing the systematic nature of this technology.

Interim storage, clearly a step after the reactors. Jeff Williams and Bill Boyle have scope of work in there. Then we get back into the recycle or the material recovery and waste forms activities and then the disposal function. And of course the safeguard and security by design, that is an integral element to every one of these steps in the nuclear fuel cycle. That also, the work in our office falls under my organization there in that respect as well.

And then the system has to be optimized and that really leads me to this flow chart. This is a simplified flow chart for the nuclear fuel cycle where if you want to look at a once-through type of process, you're going across the top here. And of course that would end up in geology X of which we don't have a complete nuclear fuel cycle because we don't have a geology yet there.

But if you were to start recycling steps or for example--and I'll use a couple examples here and it reflects really the considerations as we develop our technology--the question of what do you do with damaged fuel? That came up in Monday's comments. Clearly, the approach now is overpacking the containers. And there's nothing to say that overpacking the damaged fuel is not the final best answer;

however, in the spirit of having options, if we discover ten years, fifteen or more years down the road that we might to want rethink that approach, then you could take an element of the Material Recovery and Waste Forms Campaign, and you could pretreat or condition that damaged fuel and put it into a form where it is much more stable in longer-term storage. And I'm not saying that that's what we're going to do, but it is an option.

Another example I'll use of how this system works together is we are looking at developing light water reactor fuel that has improved accident tolerance. Anything we do in the advanced fuel area we know, for example, if it might perform better in a reactor, however, it has differences in its performance in a certain geology, or it has different performance in its storage configuration. For example, if we have a cladding that requires a slightly increased enrichment, that's going to have a difference in the utilization of the uranium on the front end. It's going to have a difference in the storage configuration at the reactor before it goes in the reactor. It's going to have a difference in configuration when it's in the used fuel pool and so forth. And so any technology that we're developing, we recognize that we have objectives within each one of these vertical areas to improve that performance, but we recognize that the performance, and there's other factors, that affect the rest of the nuclear fuel cycle.

Okay. A little bit more about the Material Recovery and Waste Forms Campaign. I've got it broken down into technologies, capabilities, and people, but really it's more than just nuclear fuel cycle applications. Clearly we have that, but there are environmental considerations, there's technology. We're working very close with our colleagues in the Office of Environmental Management. There's a lot of technologies that could be applied in nuclear fuel cycle, but also applied to the environmental issues that they're wrestling with.

We are also working quite a bit with the National Nuclear Security Administration on some of the common technologies between our program and some of the things they're looking at from a national security perspective.

And we also, before I leave the slide, let me emphasize the people. There was a PCAST report in November of 2010 that identified radio chemistry as one of the critical technical areas that our nation needs to preserve. And that unless we do something differently, we are going to give ground on that, and we will cease to become the world leaders. And so we're taking that to heart. And we've got a lot of emphasis on engaging with the universities and making that not only work for us as a program, because that's why we get money from Congress, but also bringing the young talent of the nation along with us.

This is the leadership of the team. Terry Todd is the National Technical Director. His deputy is John Vienna. John is also the lead on the waste forms work that we're doing.

And then also Jim Bresee is focusing on the aqueous processing technologies as well as he's got a vast background. He used to be part of the Office of Civilian Radioactive Waste Management. So he's got a great perspective on what we've done in the past when it comes to separations and how that interacts with the geology technology.

Stephen Kung is focusing on our electrochemical processing, pyroprocessing, and Kim Gray is responsible for the--has the lead on the waste forms area from the DOE perspective.

The campaign has an implementation plan. It has--I'm not sure if that's too much of an eye chart for you--but it has a number of functional areas. And the idea here is that we're not just planning each year incrementally. We do have long-term objectives that we are proceeding with. Clearly our pace is dictated by the level of funding we get from one year to the next or other kind of changes that happened that might cause to us rethink our areas of emphasis. But this is a way that we use to structure the program and give us some long-term planning in this technology.

Also from a technical thrust area, we do have some near-term activities that we're focusing on. And clearly the uranium from sea water, while it's near-term here, the question is how long are we going to be doing this? We've made some good progress. I'll talk about that later.

Tritium separations treatment, not only does it apply to a closed nuclear fuel cycle, but there are some needs that require some attention and so forth. And I'll talk about each one of these things in subsequent slides in my presentation.

Okay. This is a really interesting area. And I think it really embodies the Office of Nuclear Energy's movement toward a science-based, engineering-driven research program. When we started in 2010/2011, we set the goal of doubling the standard absorption capacity of the materials that were developed by Japan. And we took a look at it. We looked at some of the basic technology, the ligand design, thermodynamics, kinetics, structure, the nanosynthesis of the absorbents, the grafting process, actual testing and so forth. And really, we've made a lot of progress, not only advancing our understanding, but using that understanding to rather than getting into numerous iterative trial and error types of activities, but can we target some specific ligands?

Can we target some specific approaches that will advance this technology? And actually, it's resulted in three times the capacity that Japan had demonstrated back in 2010.

Some of the areas we're--and clearly it's not economic yet. We don't have the performance or a defined path to commercialization yet. But it's showing just by the significant progress that's been made in the three years; it shows a lot of potential. And so we're taking some of the preliminary cost economic analyses that have been performed, and we're targeting where is the potential? Where are the biggest gaps of the technology and the various steps of developing and testing this technology?

And so we're focusing on the bio following aspect of this technology. Is it accumulating bio life while it's in the ocean? Can we discriminate to uranium so we track more uranium and less materials that are non-uranium? How do we recover the uranium? And then how many times can we reuse the absorbent material and so forth? Just for a graphic here, this was the Japanese performance, and this is where we ended up last year in--well, last fiscal year, fiscal year 2013.

The next area I'm going to talk about is tritium from high volume, typically in an aqueous environment. Commercial reactors today do have--I wouldn't say an issue--but there are some questions being raised about the leakage of tritiated water from existing commercial plants. NRC is looking at this. They haven't made any determination yet, but they have it identified as an area that they're going to monitor. If there is a need to remediate any of that, some of the technologies we're looking at could be used for that. Clearly, the events at Fukushima and TMI where you have a high volume of cooling water that was used and then collected, what do you do with it? Are there technologies that can be used to clean that up and get it from a tritium that's very low concentrations but large volume, find alternatives to capture that, accumulate it, and put it into a much more manageable waste form?

And then, clearly, while our objectives in the nuclear fuel cycle is to capture the tritium up front, what if you're not successful in capturing all of it up front in the material recovery process? What if you have some in subsequent streams? You want to be able to deal with it because you don't want--one of the challenges of existing fuel recycling plants is the presence of tritium downstream in the process.

Next I'm going to talk about some of the technology in the fuel recycling aspect of our technology. We have at present--we've got some functional areas that we're stepping through to get to the future, and I'm not going to talk about this really but the cost of one of the key aspects of this is not just the technology performance, economics is going to play a role. So we've got this recognized, but I'm not really going to talk about that aspect.

Starting out I'm going to talk about two of the Sigma Teams. We've got two of them that were formed, and these were rather focused efforts, multidisciplinary, multilaboratory teams of experts. We basically cherry-picked the best talent we could from those who were available, and we formed two Sigma Teams. One, the Minor Actinide Sigma Team, was formed in 2009, and the Off-Gas Capture was formed in 2010. Dr. Bruce Moyer from Oak Ridge leads the Minor Actinide Sigma Team, and Dr. Robert Jubin, Bob Jubin, leads the Off-Gas Capture Sigma team. And we've got a number of players that are contributing significantly to this effort.

The Minor Actinide Sigma Team, we're looking at separating americium primarily alone, but then also some--we're looking also at including curium in there as well. Really, this boils down to if you're familiar with the Global Nuclear Energy Partnership. It was a very aggressive program, and the recycling aspect of that had a--what I would call a tailored, high-fidelity approach to pulling off a variety of materials. It ended up with four solvent extraction processes in series with, in some cases, very narrow bands of operational specification. It would have been an extreme challenge to--if that was to stay in place and there wasn't any opportunity to refine it to look for optimization of the process, that would have been a very--as I think our studies proved before GNEP was disbanded, it would have generated a lot of waste, a lot of volumetric waste. It would have been very expensive to operate, covered a lot of real estate, and the plant and so forth. So we had to find a better way.

We knew from that experience that if we are looking at alternatives and possibly in the future to recycle fuel in the U.S., we had to find a simpler way. And so that's kind of the bottom line of what the Sigma Team is looking at, and they made some good progress.

Now, why do we want to separate the minor actinides? Well, after the first 300 years, then plutonium and americium start driving the heat considerations for a geologic repository. Also, if you can minimize the volume of high-level waste that would be destined, that would have to be stored, transported, or whatever, for a repository, those are all things that factor into it.

And just to reflect some of the national decisions made by others, France, they're basing their used fuel management on recovering not only the plutonium but also the americium as part of their high-level waste. And they believe that's going to reduce their burden on the repository. The U.K. just came out with their nuclear road map. They, right now, are focusing on the recovery of plutonium; however, they reserve--they're exploring, looking at the minor actinides as possible enhancements to their--to reducing the burden on their repository.

Major accomplishments to date, we have demonstrated a good approach for extracting americium, and getting back to some of the operational constraints, the approach that's been developed has more forgiving operational constraints. Obviously, the trick now is to translate it from the laboratory through a scale demonstration to demonstrate that what we believe we've accomplished is still sound when you scale up the technology.

It appears that we do have an approach to move the recovery of transuranics and separate out the lanthanides in one step. It looks like we're successful in doing that. Again, the demonstration phase is going to be essential in how we move forward with that.

Talking a little bit about the Off-Gas Sigma Team, one of the challenges we face here is that the regulatory drivers on gas emissions from any plant like this, 40 CFR 190 was developed right as West Valley was shutting down, Barnwell suspended their efforts to start up. And so the regulation was finalized at a time where there wasn't any active reprocessing activity underway in the U.S. It's very conservative. It puts a lot of constraints on the process.

I know EPA is considering opening that regulation up for revision, and they're going through the process of collecting public comments on that. I'm not sure exactly where that stands. But if we were held to the standard today, we would have a lot of challenges, specifically with the tritium, the iodine 129, krypton, and potentially carbon 14. So we're going through the steps of addressing those challenges. We have made good progress on the iodine. I'll talk about that in a little bit, and we're making some progress on addressing the krypton emissions as well.

About the iodine, we've got a number of alternatives that have been developed using largely--and they range from using largely more mature technology--the silver mordenite is a fairly well-established material in application--to developing aerogels and then looking at some other capture media such as apatite or silicon carbide.

We've demonstrated demobilization in the silver zeolite in a glass-ceramic matrix, and we've started the performance studies. In a nutshell, the progress is proceeding pretty well. A lot of potential there. But there's a lot more questions to answer in terms of what is the cost of the technology? Clearly, if we can capture this in an economical way, and some of the challenges--because this is such a long-lived radioisotope and when it goes into the geology it tends to be somewhat mobile, if we can capture it up front we believe that this can be a big impact on the repository performance.

All right. Next I'm going to talk about the electrochemical recycle pyroprocessing. This is an effort led by Mark Williamson at Argonne National Laboratory. And essentially this is focusing on the metal fuel that would be recycled in a fast reactor. However, it is being applied today for the waste form, that sodium bonded fuel that was generated in the past fast reactor programs. Idaho is processing it today primarily to deal with the sodium reactive constituent in the sodium-bonded fuel so that it can treat the RCRA aspect of the waste. And it can be--since Yucca Mountain was not planned, it was not designed to be a RCRA repository. It kind of clears that waste up for disposal there.

However, in the future, we're looking at improving this technology specifically with the cathode. The existing technology has a liquid cathode, and one of the challenges there is that it allows a lot of lanthanides to get through the separations process. Lanthanides tend to make the fast reactor fuel perform--it doesn't meet our performance standards, at least in high quantities in terms of it will limit the ability to achieve higher burnups in the sodium--in the fast reactor fuel. So by limiting the amount of lanthanides in there, we can improve the burnup, improve the length that we keep the fast reactor fuel in the reactor, extend the periods between outages and so on. So we're moving to a solid cathode with some cathode deposition capabilities. And we're making good progress, but we're too early in it to really draw many conclusions at this time.

Here's a system slide or a slide that emphasizes the connection between various aspects of our program. Here we have a number of considerations for waste characteristics in the separations of fuel fabrication, disposal, and burnup and cooling of the--these all feed into the players here. And actually there's a circle missing here, and I think it was brought up earlier today; we should have some recognition of the involvement of industry and with our Materials Recovery and Waste Form Campaign because they are playing a pretty significant role I think. But then you have the players up here between used fuel disposition separations, the university program, our interaction with the Office of Environmental Management, Office of Science, and then we have our international collaborations. And they--the idea is that they all feed the various products that this campaign is going to be pursuing.

Waste forms, it really boils down to you need to have the technologies. It needs to perform. We need to improve the performance. But then ultimately, we have to make sure that those improvements in performance can be achieved in an economical manner because they have to perform together. If you develop the perfect waste form but it's so expensive you can't afford it, then there's no point in pursuing it.

So these are some of the accomplishments recently. They have developed a silicate-based glass ceramics that shows some very promising performance data. And I think you can see those units on those axis. In addition to that, we've made some improvements in the synroc formulation with the desired--forming the desired phases. And then also in the area of zircaloy recycling, getting some good purification results on laboratory quantities of zircaloy recycling.

We've had quite a major effort, especially internationally on defining the glass corrosion or establishing an international standard on glass corrosion that can be accepted not only in the U.S. but in other countries pursuing borosilicate glass or glass waste forms. And this is truly an international effort where everyone's bringing something to the table based on their experience.

Something also that plays into this is we were successful in getting a sample of Roman glasses, a wine bottle that was sunk in the Adriatic. We had the sand that it was in contact with on the ocean floor, and we were able to bring that back. And we're in the process of doing experiments or measuring the 2000 years of corrosion to that glass. And that's clearly going to be playing a--some actual, providing some actual data for our program.

There's also a successfully modeled experiment results from a 26-years corrosion study using the micro-continuum reactive transport model.

And next I'm going to talk a little bit about the universities. I know there was some discussion earlier today with Bill's talk, but we really do appreciate what the universities bring to our program. You can see the distribution around the country. We got a lot of good ideas, and Monica has encouraged us to reach out to them and make sure that they really are engaged with our program, actually not only with the Materials Recovery and Waste Form Development Campaign, but also the other campaigns under me. We had a specific review in September where we went through each and every one of the NEUP awards and asked ourselves a question, are they engaged? If they're not, how can we improve that? Also if they were at the near--if they were near the end of their NEUP activity, the question was okay, what about next steps? Is this a technology or is this an idea that can graduate up and we can perform in the national laboratories? Or could it use some more work at the university level? Or is it something that was very interesting? It was awarded--we awarded it at one time and now our program's either moved on or it didn't seem quite as--to get the results we were looking for and we can package that in a way that can be archived or be accessible in the future.

One of the key things I think that's important is that we not only publish or we not only record our successes, but we have to record, you know, where did we fall short of the objectives. Because there's probably more lessons that you can dig out of those types of activities if they're properly documented at the end of the research than if you just, you know, tout your successes and move on.

And here's a reflection of all the awards that were made 2009-2012, and how they connected with some of the functional areas in the Materials Waste Form Campaign. And here's the same, you've got them your packet; it was for the 2013 reviews.

Let me just say a couple comments. There's a lot of uranium extraction from sea water because this is the kind of work that's really compatible with the level of research at universities. Also this was identified in what we call the mission support activity where the funding level is a little smaller, and you can adjust it from three to two years. But what it enables is a little broader distribution of ideas. These are about $400,000 apiece over two to three years. These are about 800 to $900,000 apiece over three years.

This slide talks a little bit about our international collaborations in this area. Clearly, you know, it's not everyone that we reach out to or that steps up to us to talk about recycling used nuclear fuel. They have to be--they have to have an infrastructure politically, and national security-wise there has to be a reason. So these are the, quite clearly, the obvious players, you know, France, Japan, Russia, China, European Union. Germany once was a part of this activity. Clearly, Germany has moved on. But Germany has some expertise that we still want to engage with, so we're able to do that with European Union collaborations. And then there's some others such as United Kingdom. As I mentioned their new road map to nuclear has really reenergized this technology in their nation, and there's some potential for some very good collaborations with the United Kingdom going forward.

Okay. That was a really quick broad overview of this technology area, but I really wanted to emphasize that this is about--it's not just about closing the nuclear fuel cycle because that's not our objective. Our objective is to keep that as an option, and if we decide to go in that direction, we want to be able to do it with our eyes open, with some technical competence, and some appreciation for the economics that's involved in that.

Also along with the science-based, engineering-driven aspect of this, this is a technology that can really benefit with some more thoughtful look at the fundamentals. And we can't afford the large demonstration facilities, so we have to be much more thoughtful in the laboratory experiments iterating between what we think will work and what will work. But then also we want to develop the future expertise in the nation as we go along.

This is not a one-laboratory-has-everything type of technology. Clearly, we tap into a very diverse set of expertise from across the entire DOE laboratory complex. And collaborations with other federal agencies, other offices within DOE, and industry, international partners, it's also very important to this.

And we're not just about developing nuclear fuel cycle for implementation in 40 or 50 years, it's about looking at those opportunities to spin off and apply the technology now. Not that we would take lead in that, but we want to be able to engage with those efforts that could implement this technology sooner. And if we can pass it off to them, then we'd like to do that. But we'd like to support them in the process because of the utility of this technology.

So with that, I'm happy to answer any questions.

EWING: All right. Thank you very much.

Questions for the Board?

Jean?

BAHR: Maybe I missed it, but what's the motivation for the separation of uranium from sea water? Is this is a source of uranium that we need for reactors, or is this more to do with cleanup of contaminated sea water?

GRIFFITH: No. It's definitely to feed into the nuclear fuel cycle as a fuel source. And in theory, depending on who you talk to, they will tell you that we will run out of available uranium from mined sources in 100 years, in 300 years, or some other number. So there's--and this is, of course, depends on how quickly nations like China deploy new reactors and put a greater demand on uranium for fresh fuel.

Conceivably, if we are able to extract uranium from sea water at an economical cost, for one, it can put a cap on sometimes volatile uranium market. But second, it can make the open fuel cycle virtually sustainable because there's vast quantities almost--even though it's a very low concentration, there's a vast quantity of uranium in sea water today. It's almost inexhaustible.

EWING: Just to follow up. I think it's--there are many estimates of the resource, and the assessments are tied to the expansion of nuclear power, and they're roughly in agreement that worldwide you could double, perhaps triple the nuclear power generation. And the presently known and nearly assured resources would take care of 100 years.

And if you look carefully at the future resources, I think there's general agreement that it's not uranium from sea water but rather in situ leaching that has the biggest bang for its buck because there are lots of low-grade uranium deposits. And this is a technology that has developed very rapidly within the last decade.

So the rationale I think seems a bit thin to me.

GRIFFITH: Yeah. And of course it depends on, you know, where you put the greatest amount of confidence in the figures being discussed. But this is a fairly--oh, you just say this is a fairly small effort right now. And it's really in the spirit of keeping the option open. It's made great progress. The question is how long are we going to continue it.

EWING: All right. Other questions?

CLARK: Sue Clark, Board. So I have two questions. And one has to do with the change in your name and materials recovery. All right. So is there, do you ever think about materials recovery or resource recovery in terms of like precious metals, medical isotopes, any of that kind of work?

GRIFFITH: Well, that's clearly one of those types of spinoff applications that this technology would be applicable towards.

CLARK: But you're not--

GRIFFITH: But medical isotopes for organizational responsibilities, that is in the Office of Science. And there is a new hub.

Is it formally a hub, Monica?

There is a new emphasis on critical materials which is, you know, heavy metal or rare earth and assuring their availability in the future. Clearly, and this is where the extraction of uranium from sea water could--you could take the same approach towards extracting rare earths from the ocean as well if there was a need. So that's an example of where this technology could be applied for a different purpose.

CLARK: And so that hub that you mentioned is within NE or within Office of Science?

GRIFFITH: No. It's in--

EWING: Office of Science in Ames.

GRIFFITH: It's in Ames Lab. Yeah.

CLARK: Okay.

GRIFFITH: Ames Lab leads it.

CLARK: And then my second question, it relates to your slide number 6, where you had the fuel cycle as a system. And it's a little hard to think about it this way right now because we don't really have a repository, but do you ever stop and think about the system in the reverse order where you would start with the disposal and work your way back?

And does that ever impact what happens there in your separations technology box?

GRIFFITH: Yes. Absolutely. It's an iterative effort. There is actually a lot of discussion, not only between the disposal research and the separations research, but also between the separations research backwards to the advanced fuels activities. And that's--let me just answer it a little bit more by referring back to a--we had an outside panel of experts come in and perform a relevancy review on the Materials Recovery Waste Form Program. And one of their observations was that, yeah, there's a lot of discussions there, but we haven't done a good job of defining okay, where are the handoff points? What are those kind of specifications? You know, how much lanthanides can the fuels program accommodate and vice-versa?

And so one of the efforts that we're going to be focusing on is defining where are the--what are the specifications of those hand-off points where you go from one area to another? And that encourages the discussions, well, if you can relax this standard, it can save me--you know, it make this process more economical. Or if you can improve--if you can shift that specification in another direction, then it makes my performance so much better. And if you can use that as a discussion to look at the give and take and the implications of changes to your step and how that interacts with the other steps in the fuel cycle. That's what we're trying to encourage.

CLARK: Well, and another--I guess another one I would add to that list would be if you started with prospective disposal and you decided it was going to be the spent fuel itself, and then you worked your way back, is that--you know, if you look at the difference between the older fuels and the high-burnup fuels, how does that change? What would happen?

GRIFFITH: Absolutely. If you go back a few years, the performance of Yucca Mountain, I know when I was in the Office of Environmental Management it drove how things were done to prepare the DOE fuel for disposal in Yucca Mountain. When you nail down that geology X, that's going to have a significant rippling effect to the technologies that we're considering further up in the fuel cycle. Absolutely.

EWING: Lee.

PEDDICORD: Lee Peddicord from the Board. As I understand it, is it correct that you all are expanding collaboration and the research side with South Korea? And does that fit into any of these programs here?

GRIFFITH: Expanding--we have--

PEDDICORD: Is this not a new agreement I thought? Or maybe--

GRIFFITH: There is a fairly robust agreement. Monica is well-engaged in that.

REGALBUTO: The collaboration with the Republic of Korea is already finished phase one, so it's already on the third-year effort. And it concentrates on developing alternatives. It's called the Alternative Fuel Cycle Study. And it develops the alternatives for the management of used fuel which includes Bill's program, storage transportation and disposal, and it also includes recycling. It is focusing on electrochemical at this point. But it is part of an ongoing effort, so we're in year three on that.

GRIFFITH: And I would say that they're looking at their inventory of oxide light water reactor fuel. So it is applying the electrochemical process to the oxide fuel.

EWING: I have a question. So first I'm impressed by the array of topics and universities, national labs, and so on, but I'm also--this is a comment--concerned that we're mistaking work that was done long ago for work that is portrayed as being new today, and particularly in the waste form area. I point out the Roman glass that you have, the French have published papers on this at least two years ago. This is--you know, it's good that we have a bit of this glass now and can do some work, but that whole approach of using anthropogenic glasses, natural glasses, comparing it to waste forms, that's been a whole field for many decades, three, four decades. The glass model you showed with the initial rate of plateau and all, that diagram now is two decades old.

So in your review of programs as you look at what you want to pursue, how assiduous are you in determining what's new versus what is just new on the American scene?

GRIFFITH: And I can't speak to the specifics, but my understanding is there's new data coming out of the Roman glass experiment, especially it might have something to do with it being found in the sand media that it's been in contact with.

EWING: Well, I'm sure we can take that glass and apply a new technique and get new data, but the issue is how is that wrapped up in a program of applying natural materials or man-made materials to the question of long-term durability? And that's a whole field. It's more than just a few bits of new data.

GRIFFITH: And you talked about some of the international players there. I mentioned that the international interaction on the glass corrosion studies was robust. And so I think that the objective is building on those past studies. It's not replicating them or not doing it for the sake of looking at something that's 2000 years old. I can certainly look into that and talk with the folks and give you a more complete answer.

EWING: And the areas where I know something about the subject, this is a deficiency that I see. And it makes me wonder if the areas where I'm less well informed don't suffer from the same difficulty.

GRIFFITH: Well, I did mention that the objective of that work is to establish a world standard, an agreed upon world standard. So I think that is something that is kind of bringing the decades-worth of collaboration to a good result, a good end. And that is our focus.

EWING: Okay. Other questions?

Jean.

BAHR: So with a lot of the separations technology, you end up with a new waste form. And are you thinking about how that impacts what ultimately goes to the repository? Are you separating things, but are you then just sending it all to the same repository in slightly different forms, or are you actually going to be quantitatively reducing the burden on the repository by the things that you were able to get out?

GRIFFITH: Yeah, I think it really goes to matching the waste form with the geology. And through our studies of looking at different waste forms that have improved performance, you have to take into account where it's going to end up. And what is it like to manage it in terms of storage and transportation in the meantime? So yeah, it's not a one-waste-form-will-fit-all, but at least at this point it's a matter of developing alternatives and then seeing how those alternatives perform in the various geologies as we go forward.

So but I think going back to Professor Clark's comment that once a geology is decided, and this is--if the nation was to pursue a consensus-based and a community was successful in advocating and being designated as a location, then that geology would become a critical factor when evaluating these various waste forms. And so how that waste form performed in that geology would be critical to locking in on a high-level waste form.

EWING: Other questions from the Board? Staff?

LESLIE: Bret Leslie from the Board staff. I have three questions, two of them about the electrochemical separations, and then the second or the third one is probably going to be all--Bill Boyle, Monica, and you because I don't know where the answer lies. And it has to do with the conditioning of DOE spent nuclear fuel. Bill had talked about commercial, and I'll come back to DOE spent nuclear fuel.

On your slide 20 you talked about effectively being recycled at Idaho. The inventory of fast reactor fuel is on the order of tens of metric tons. There's a deadline for the spent nuclear fuel to be removed from Idaho in 2035. And the historical processing rate is 100 kilograms. So you can do the simple math to say that is potentially problematic in meeting it. And I guess also for the Fermi fuel, the record of decision said DOE reserves the right to figure out what they're going to do with that in terms of different technologies. Could you update us and tell us how this all fits?

GRIFFITH: Sure. The rate at which you quoted, it was largely tied to the blanket fuel which is lower in content. There is some effort being taken to move the driver fuel in through the process, but clearly we're not doing this behind curtain or trying to fool anyone. We are in communication with the state who we have the commitment to remove the material from the state by 2035 as well as get the fuel that's in wet storage out of wet storage by 2023.

And so the objective is we're going to meet that date; we're going to meet our commitments. Clearly it would involve stepping up, going to more shifts than just day shift, however, right now, we're not in a position to do that. But it's definitely not out of sight.

On the Fermi blanket fuel, that belongs to the Office of Environmental Management, and yes, I understand that there was not a decision on that fuel with the programmatic--or the EIS this material back in the--I'm thinking '98 time frame. They are still evaluating the technology appropriate for that. And, you know, the bottom line is this is not a cheap operation. And with the amount of sodium and the design of the Fermi blanket fuel, the--it probably does not need a treatment process that's as expensive.

LESLIE: Thanks. I have a couple more questions. So the--and this is type--and built upon Jean's question. Right now there's a waste acceptance systems requirement document that guides which waste forms would be acceptable for disposal. Are the waste forms that are being produced by the electrochemical process qualified under the waste acceptance requirements document for disposal?

GRIFFITH: I don't know--I don't know the answer. They're designed to meet that, but I don't think they're part of the license application.

REGALBUTO: Yes, they were. For the Yucca license application, the waste forms coming out of PIRA (phonetic) were part of the package. So those were bounded under the license application. Towards your comment on the throughput, I recall that facility is for research and development not for processing. It is being stretched to the limit. We do have a different electrochemical design that is called PEER. And it has a much, much higher throughput than the one that you have. So you know you're like in Gen 2 in that facility and the new facilities are in Gen 4, but there hasn't been a place in there. A couple of things are issues of budgets. But there's also an alternative to put that on dry cask and move it.

LESLIE: Thank you. And the last question has to do with conditioning of the fuel. Much of the fuel at Idaho would have to undergo conditioning before it could be transported. And Idaho is kind of--has cats and dogs, lots of different things. And I think Gary DeLeon in 2011 made a presentation internationally that basically said we don't know how to condition these things. And I'm wondering where is the program either in your shop or in EM that's working to figure out how those fuels could be conditioned?

REGALBUTO: It's not only that one. If you hold your comment towards Peter's presentation. When we did the analysis, as I mentioned last year we did the analysis of all the commercial spent fuel, and this year we did the analysis of all the defense high-level waste which includes the Navy fuel and also includes the DOE old fuel. So everything that DOE is responsible, DOE managed. Right?

Peter will show which of the different waste groups that we looked at have that issue. And they have been flagged. So that's a good question and a good observation, and it's a little bit more than that, but Peter will cover some of that. Okay?

LESLIE: Thank you.

EWING: Thank you.

Bobby.

PABALAN: Yeah, Roberto Pabalan, staff. I have a question on your slide number 4. The slide indicates one of the near-term objectives is to down select fuel cycle options for further development. My question is does near-term mean five to ten years? And secondly, if it's five to ten years does it mean DOE will decide on whether to pursue continuing work related to limited recycle or closed fuel cycle in five to ten years? I was thinking it's going to take about 25 or 30 years before you guys make a decision.

GRIFFITH: That bullet is referring to what we refer to as the fuel cycle screening options or fuel cycle options screening activity. And the idea here is that it will identify the most promising fuel cycles for the nation going forward. And the intent of that--and Monica, please jump in here if I'm not--because this is not my area, but the idea here is this will identify the most promising fuel cycles that will enable us to guide our research activities toward those technologies. It is not to decide any future fuel cycle because that's policy makers. But it can be used to inform that process as our nation goes forward.

REGALBUTO: It's not a down select. It's really a focusing R&D effort. Because we cannot fund everything. So for example in the area of fuels, we already--advanced fuels, we are no longer pursuing oxide fuels, we're just focusing our efforts on metallic fuel, and we exchanged information with the French on oxide fuels. So we decided to split the effort and learn from each other because resources are not there. So that helps guide the R&D going forward.

Pabalan: Okay. Thank you.

EWING: Gene.

ROWE: Gene Rowe, Board staff. Could you talk briefly about the krypton capture program and progress you're making?

GRIFFITH: Well, in a nutshell, it's basically--it looks like the concept of metal-organic frameworks can work using non-cryogenic means which obviously is a benefit economically. The question is because krypton is a short-lived isotope, what is the ability to retain it in that metal-organic framework for a long period of time? How is that--what kind of materials are used to containerize that waste form? And so on. So those are the types of things that we're exploring.

But in terms of just the capture, the initial capture standpoint it's quite promising.

ROWE: So it's it still basically just to capture and hold it until it decays?

GRIFFITH: Yes.

EWING: Other questions from staff? Board? One question from the public to keep this on schedule.

Okay. Monica.

REGALBUTO: If somebody has a question--you can put back the slide, I guess the uranium and the--

EWING: C1?

REGALBUTO: No. Not the C1. That--I just want to present a comment because it really is a challenge for all of us. And it looks very nice and integrated in that picture, but it really is not. It only works in different countries where all the front end and the back end of the reactor are owned by the government or by a consortium of companies. Right? And you heard NRC Chairman saying yesterday that we need to do a more integrated approach which is very well recognized, but we do have a certain number of challenges.

And, you know, conventional production of uranium is one industry in this country completely divorced from everybody else. Fuel fabrication is another industry, reactors is the utilities, and we own the rest, the back end. So any optimization that we do in the back end that requires the front end in the reactor to do any changes is normally not embraced. Okay? Because what everybody does is they do a local optimization in each of their little systems which is shown as rectangular boxes. And anything we do on the back end that will help the front--I mean, anything that you request the front to do to help the back is at a cost.

So it's a very challenging system, but it's a system that normally happens in democratic countries. In other types of countries, when the whole enterprise is owned the by the government, they can certainly afford to do that. So my point that I want to make is some solutions that you see internationally make perfect sense in the context of how they are organized. But in our country it doesn't make sense because we don't own the whole enterprise. So that's just to keep in mind as you go through this is it's a little bit more challenging than normally is.

GRIFFITH: Okay. Another aspect, if we roll out technologies and any one of these stove pipes that have implications elsewhere, the transition from the status quo to a new approach is not always embraced, even if it might improve the performance of the entire system.

EWING: All right. So I'd like to thank all of the speakers and Monica for being here to add to the information. Yes, we'll adjourn now and reconvene promptly at 1:45. So thanks to everyone.

(Whereupon, a lunch recess was taken.)

AFTERNOON SESSION

EWING: So welcome back from the lunch, and we'll go immediately to the program which, surprisingly enough, involves Bill Boyle.

BOYLE: For the last time at the podium today I think though, but we'll see based on the questions. So now we're at the back end of the fuel cycle, the back end of my talks. Disposal is the topic, and so I'm going to give an overview of the research and development we're conducting related to disposal and give some examples of some of the work that we're doing.

And the first however many it is, the first six slides are essentially the same as from the storage R&D presentation earlier today, so I can go through them quickly. The reason I duplicated these slides is these presentations end up on your website, and they stay there for forever. And so if I hadn't--if I had taken an approach of well, I've already covered that in one talk and somebody only opened this talk and I didn't have the slides, they wouldn't see it. So I can go through them quickly.

So we have the Wordle again of the strategy. And there is disposal right there, so it was in the strategy. So again, the organization responsible, Peter B. Lyons, Monica, Andy, my group. And again slightly more detail for fuel cycle technologies, Monica's group. Andy's over here. I'm here. This line is being changed to go back that way. Again, Andy showed his campaigns, campaign implementation plan, and I showed it for storage and transportation but here it is again. All the campaigns have them. And for disposal our objective is to do good technical work now to help inform any future decisions related to disposal in the U.S.

Here's the campaign again. For the overall campaign, Ned Larson is the federal manager. Peter Swift is here as a national technical director. Shannon Bragg-Sitton from INL is the deputy. This talk is going to focus in on the disposal research and development. Tim Gunter is the federal manager supported by Kevin McMahon and Bob MacKinnon of Sandia.

And here is a new slide. This one I'll take a while to go through. I had a similar slide for the storage and transportation R&D. This is how we have our work broken out in terms of business management and that sort of thing. So just like storage and transportation there is a management function. And Peter is in charge of that. And for the rest of the accounts it's Kevin and Bob. And I'll go through each one of these now and provide some examples, descriptions of what it is we're doing. And then in the later slides I'll focus more on our long-term higher priority topics.

So argillite disposal, whether you call it argillite, clay, or shale, it's one of the geologic options we're looking at in the United States. People call it different things, but the basic fundamental premise of this repository concept is the rocks are inherently so tight with respect to fluid or gas movement that they would be good candidates for a repository. In many circumstances, these are the same rocks that have formed caps that trap oil and natural gas over geologic time periods. They're that tight that the gas or liquid cannot get through them. So the Belgians and French and Swiss are looking at disposal in rocks like this. And so now we're looking at it as well. And an important aspect of this rock type and this repository concept came up in some of the slides that Tito Bonano showed on Monday.

With respect to thermal limits for those analyses that Tito showed, there was a lower thermal limit associated with these rocks than with salt, for example. Which in terms of--that tends to, everything being considered, to be a negative factor. It leads to bigger repositories which cost more money and that sort of thing. So what is driving the thermal constraint for the argillite repositories? And it's a perception that the higher temperatures could lead to fracturing of the rocks which would then ruin that very nice feature of them which is their tightness with respect to the movement of fluids.

But what we're doing, work now, is looking at well, maybe we can have sacrificial zones if you will. Like, for example, if we had a lower temperature limit for an argillite repository and induced little to no fracturing with increased permeability, we would still have to have a seal for the entrance, you know, whether it was a shaft or a ramp. For every hole we had poked into it, we would have to rely ultimately on a seal to work to some degree.

The U.S. is lucky in that we have some very large deposits, very thick, that we're looking at the concept well, perhaps we can go with higher temperatures in these rocks, crack some of it, but it's in such a massive body, we just move the seal a little further up, and in the end we're still counting on a seal. Like, we could live with potentially some fracturing within the shale mass itself but still have a nice tight roof and floor if you will. So we've investigating that.

So for some of the slides that Tito showed, those analyses were done with a 100 degree centigrade limit, but we're trying to do work to see if we could move that limit up which would then, everything else being equal, tend to make this repository concept look a little better.

We're also doing work on mined repositories in crystalline rock, very similar to what Sweden and Finland are considering. Other countries, it's a common choice around the world. So we are doing work there. Now, a common feature in the crystalline repositories, again, it gets back to temperature limits, those rocks also, the rocks themselves tend to have very low permeabilities, but they also tend to be more fractured than the shale rocks tend to be. So they do have these conduits. And so if you look at the Swedish and Finish repositories, they're contemplating using bentonite clay backfills. And that's a common feature for crystalline repositories.

And also associated with those is a common thermal limit of roughly 100 degrees centigrade. Well, we have work going on there as well. We have both modeling work, but more importantly lab-related work to see if we can go to higher temperatures with the bentonite backfills. The main concern there is with the higher temperatures and the presence of water, the bentonite, the smectite clays will convert over to illites and lead to greater--higher permeabilities, greater ease of transport.

But Los Alamos has been doing lab work, some of which indicates well, perhaps we--that might not be as bad a situation as people think. But the tough situation here are the extended time frames in a repository versus what takes place in a laboratory. It might be a very slow potentially almost unnoticeable process in a lab, but given a million years, it might take place in a repository. So we have to worry about that.

Also one of our other geologies we're looking at is salt, sodium chloride, both bedded and domes. The Germans, they're looking at dome salt. The U.S. has both deposits we could consider. For those who have been to WIPP, it's a bedded salt deposit. We do do work cooperatively with our colleagues in environmental management down at WIPP. We do studies and work together with them on salt.

Deep borehole disposal, now inherently this is in crystalline rock, so in some way--we count it separately from mined geologic repositories in crystalline rock. And I'll have another slide later on dealing more with deep borehole disposal. But one thing I want to make clear to people, the concept for the repository is the mined repositories are very commonly, worldwide, you're looking at a depth, 2,000 feet plus or minus, maybe a little deeper, maybe a little shallower. Whereas these deep boreholes, we're considering going down five kilometers. There's not a technical reason to not go another millimeter farther, that's just a number we picked. We could potentially go even deeper. And the fundamental tradeoff here is for the mined repositories, their footprint at the ground surface tends to be bigger because their shallower. With this concept because you're going to much greater depths, the aerial footprint becomes smaller which might be attractive for some circumstances.

I also to want contrast the concept of disposal, you know, what might go in that with the deep borehole demo I will talk about later. I want to make it clear that the deep borehole demo is just a test. No waste will go in it, it's just yet another test, whereas any deep borehole repository would actually take waste. And so we haven't defined all the conditions of the deep borehole demo yet, but it may or may not be driven by consideration of what waste might eventually make it into a deep borehole or not.

I will have a slide on the R&D we do with other countries. We're not the only country facing the disposal challenge. So we do work interactively with them.

We do work generic disposal system analysis. That's doing preparatory work for a total system performance assessment by another name. We had a total system performance assessment tool for Yucca Mountain, and we're developing our--and it was specific to that rock type and that situation. And now we're doing work that would allow such a tool to be applied to these other rock types as well.

The task we call regional geology, what that gets down to is work that's related to making information available to decision makers on well, what are the geologic conditions in the United States? If somebody were to turn to us and say, well, what parts of the U.S. are underlain by salt that's at least 1,000 feet deep and no more than 3,000? And we're developing databases like that so that we can call up that information to shed light on where--if that was your choice of a repository, we could show you well, these are the sites. Similarly, we're working on distribution of crystalline rock at depth and things like that.

So in some ways it's related to a siting tool which even with all the litigation related to Yucca Mountain under the Nuclear Waste Policy Act, there would be a need for a second repository. So ultimately, a lot of this work, the geology is not going to change between now and 20 years from now, so a lot of this work would be useful no matter what the path forward is.

We also do a lot of laboratory work and modeling related to engineered material performance. I'll give you one example. Now that we're back to considering other geologies for the mined crystalline repositories, both Finland and Sweden are looking at copper-based waste packages because their geologic conditions at depth, the water is reducing. And under reducing conditions, copper doesn't do much. Except that there were some experiments done in Sweden, oh I don't know, years ago related to the Swedish repository concept that showed under certain circumstances copper was corroding under these reducing conditions.

So Sandia National Labs, we’ve undertaken a task that's proven to be very challenging to examine whether or not that corrosion of copper in a laboratory with reducing conditions was actual an artifact of the test or was it real. And it's proving to be a challenging study because the corrosion isn't much to start with. And we ran into a similar problem on Yucca Mountain. When you have things that don't corrode much at all, it's all of a sudden the test artifacts can swamp a lot of the useful information. But we do do work on other materials as well. That was an example where we're looking at copper related to that repository concept.

Spent the last two days discussing some of our work in this area which is the direct disposal of the existing or future dual-purpose or dual-means storage and transportation canisters used in the U.S.

And this last topic, used nuclear fuel and high-level waste disposal options, the presentations by Peter Swift and Dave Sassani later today are related to that work package as is the work that Dr. Lyons mentioned on Monday afternoon related commingling, all that work is done here. And as you'll see in Peter's and Dave's presentations, what we looked at was okay, for the non--well, we even looked at commercial spent fuel but focused a lot more detail on the Department of Energy's materials. Given all those different waste types, given these different geologies and the borehole concept, do some of the waste types perform particularly well or particularly poorly? And you'll see the details, particularly in Peter's talk. David's talk will focus a lot on well, what is the inventory of stuff we considered? And Peter's talk focuses more on the actual assessment of that inventory.

And as I've already mentioned, such an assessment of--well, does the Department's own waste forms perform particularly well or poorly in certain repository concepts is ultimately relatable to the question of commingling the Department's wastes, defense wastes with civilian waste that Dr. Lyons mentioned on Monday.

So that was--examples for all the areas we're working in. At the highest level, our objectives as I had mentioned earlier it's--and it's very similar to the storage R&D--develop a technical basis now to help with whatever one of the options in the future is selected, we'll have a good technical basis for selecting it. And in the course of developing that technical basis, we certainly hope that we'll increase confidence in the robustness of these various repository concepts that we have.

And here's some more readable on paper, harder to read here, diagrams of these four concepts using information from around the world as the illustrations. As I mentioned, we're looking at three basic rock types for mined repositories, granite, salt, clay. And to represent an option in granite, we're showing the Swedish concept here where it's in-floor disposal of a copper-based waste package surrounded by bentonite backfill. Relative to our discussions on dual-purpose canister disposal, you can see they use a spiraling ramp to gain access to their proposed repository.

The French are looking at an argillite-based repository, and it's not shown in this slide, but their access--they have some shafts here, but they'll also use a very shallow inclined ramp similar to what was used at Yucca Mountain. But an inclined ramp in contrast to a spiraling ramp. And here is an example from Germany of a repository in salt. And our last example is for deep borehole disposal. Crystalline rock, this right here says mined repository. And over here, this shows the emplacement depth in the concept from kilometer three down to kilometer five. So you can see that there is the much greater depth, and it leads to a smaller surface footprint versus a mined repository.

Yes, and so this slide is labeled key activities. I'm going to have a slide each. These are our long-term priorities right now. I would certainly say as a near-term priority, the work that Dave Sassani and Peter Swift are going to present, for the time period that we're in now, that is a near-term priority. It was actually in some ways even higher than this. And the commingling work is currently a higher priority as well. But that's of a fixed duration.

We'll finish that work. We'll largely be done with it. These three activities will tend to go on a little bit longer, and so I have a slide on each of them.

Deep borehole disposal, I've already described the concept. Here's some figures again. The emplacement zone is from three to five kilometers depth. Canisters surrounded by backfill. Seals above to seal off the hole from heat or anything going out or coming down in.

Our next biggest task, we've pretty much done paper studies to date. The next big step would be to do an in situ borehole demonstration, heater test, whatever else we need out of the test, full-scale, in the field somewhere. It's currently estimated it would take five years and cost as much as $75 million which is a lot of money, but we have hopes of going forward with it. I was in a meeting yesterday where there's always the possibility that we can have some cost savings by working with other parts of the Department of Energy, most significantly the geothermal part of DOE. They are commonly looking at crystalline rock themselves. They tend to want crystalline rock that's more fractured than we want. They tend to want rock that's hotter than we want. But for a test we could probably live with the hotter rock. But still, there's a possibility we might be able to do something with the geothermal R&D Group in DOE.

Another high priority for us is our international work. And we participate in Mont Terri in Switzerland and Grimsel in Switzerland. I use those two examples of we participate in those because there's a tremendous cost savings for the United States. We didn't have to pay for any of the excavation of those facilities. We have to share in the cost going forward as part of the tests and that sort of thing. But we don't have to spend the money to put an underground facility in granite or in argillite; we just get to work with them. So that's one of our reasons for participating in these in--we don't have a site to work on. So a generic site, it doesn't matter if it's in Switzerland or some other place, it will work for us.

Another important task we've participated in for almost 20 years now I'd say is DECOVALEX. This is probably up to 12 countries now where a common feature across all of these repositories is they're heat producing. So this group works on coupled processes and their validation against experiments where all the models have capital T in them, temperature effects. This whole group is dedicated to looking at what are the temperature effects on some combination of the water, the rock, and the chemistry.

I received an e-mail this week that indicated Jens Birkholzer of Lawrence Berkeley National Lab has been selected to be the vice chairman of this group and eventually become the chairman of DECOVALEX. And he's continuing--some of the prior chairs have included Chin-Fu Tsang and John Hudson and Ove Stephansson. So it's quite an honor for Jens to be selected for that chairmanship.

We are doing work with South Korea. You see here initially it's on borehole geophysics. It's like what tools are available to help understand the fracturing in a rock mass. But in a recent meeting with Korea, they're also very interested in our borehole demonstration project and borehole disposal in general. It's this--they're not as big a country as the United States, so this benefit of the borehole disposal shrinking the aerial footprint because you're going deeper is very attractive to them.

Another reason they're interested in borehole disposal is something like 40 percent of the country has crystalline rock outcropping at the ground surface. So they have a lot of granite available to drill in.

And the final reason it's of interest to South Korea is--I'm not a reactor person--but they use CANDU reactors. They're switching over to the more conventional--conventional in the United States--pressurized water reactors. But the CANDU reactor fuel elements are circular in cross-section and not actually that much bigger than the cesium/strontium capsules that the Board members who were on the tour at Hanford in April, you saw the cesium/strontium capsules. That's an example of a waste form that's very amenable to borehole disposal. The CANDU fuel elements are larger diameter, but they're smaller diameter than you would need for disposal of a pressurized water reactor fuel assembly from a United States reactor. So Korea is quite interested in borehole disposal and any work we might do there.

And we also interact with SKB. That's the Swedish group. We're taking advantage of their underground laboratory. And there's been a long interaction with Germany on salt. We do now, but the WIPP people have for a long time, and we're also--we have the memorandum of understanding with the French disposal implementer to work on shale rocks.

And we had a workshop the last two days on this topic. This is a very high priority one for us because no matter how challenging it is, and that's the message we heard this morning, which ever route the U.S. chooses to repackage or directly dispose, it might be complicated. And again, whichever route is chosen, there's a lot of money potentially at stake. Who pays? I don't know. But if it could ever be shown that we could directly dispose some of the existing dual-purpose canisters that might be a very useful bit of information in terms of going forward. So it is a high priority topic for us.

Again, I finish up with a slide where I give the website here--http://energy.gov/ne/office-nuclear-energy. As we finish our important deliverables, they go up as--we have an automated process to review them and get them up. And any questions?

EWING: All right. Thank you, Bill.

Questions from the Board? I can start. I'm sure others will follow.

Bill, looking at the list of research topic, particularly those dealing with different geologies, I can't follow--or I'd ask you to help me follow your reasoning. What, basically you're doing is looking at hot repositories in different rock types; right? I mean the question always was the heat.

BOYLE: Yeah. I'll agree with that. The heat is always a factor, period.

EWING: Right. But I guess trying to--you know, if I were you, let's put it this way, and I looked around the world at successful repository programs in shale or granite, I would ask myself what makes them successful in terms of the barrier functions and long-term performance and moving forward? The one thing I would discover is that there are a lot of advantages to a cooler repository. So why is that not on the agenda, that is pursuing those options? Because it's not heat you're disposing of. It's radioactivity.

BOYLE: It is in a sense. I don't want to give a mistake in impression that we're pursuing a hotter repository. We're just trying to get information. Like embedded in the information that Tito showed on Monday, if you remember for those analyses, for the conditions in which they were done, for the repository concepts that had the lower temperature limit the storage is--right, it ran out potentially over 100 years, maybe 200. Right?

I mean, so that's a tradeoff. So we're just trying to get all the information so that people are aware of that. If you go cooler, you might have longer storage. Here's the upside and downside to that. If you go hotter, you might have a smaller footprint. Here's the pluses and minuses.

EWING: But I didn't see in your research program if we go cooler. What are you doing in that area?

BOYLE: I would say it comes more out of like the logistics things. When the logistics studies, in part, along the lines of what Tito showed, as long as we have a range of temperatures, he showed--I think it was for the hard rock with a spacing of 10 meters and 20 meters, and on that one slide you could say well, here's the implications for that.

So we're getting at a range of temp. And from that you can infer, ignoring everything else if that's all you're looking at was the spacing, that provided input on a cooler one and a hotter one. Right? And you can extrapolate in either direction.

So I would say I don't think we really have a bias.

We're just trying--we have this huge universe of data points to try and fill in, in some fashion, such that we can gain insights into, okay, cooler is over here. Here's the pluses and minuses. Hotter is over here; here's the pluses and minuses.

EWING: Right. But you didn't list the cooler over here, pluses and minuses.

BOYLE: No. But we usually, like in any test, any terminal test, you got to go through the cooler before you get to the hotter. Any lab test that you're going to run at elevated temperature, you go through the cooler temperatures first. And you usually have the data acquisitions--

EWING: So your experimental programs look at the low temperature response as you go?

BOYLE: I sure hope they do. I would be surprised if they're not. If I'm going to test a rock at 100 degrees C, and it starts--we're at about 20 C here or so, they've got the data acquisition on before they turn the heaters on. And so they get some information relayed at the lower end.

Or you also, like in a heater test, like an in situ heater test, if you're more interested in the cooler temperatures responses, again, look earlier in time at any point or just look farther away. And the higher temperatures haven't got--using the heater tests at Yucca Mountain, we had plenty of information on the lower temperatures because we had thermometers and all kinds of other sensors further away from the heat source.

EWING: Right. But did you carry that through to a performance assessment at lower temperatures?

BOYLE: Well, the performance assessment considered the entire life of the repository. And most of the thermal perturbations are in the first 10,000 years or so. But again, one of Tito's slides, you show that there's a rapid temperature increase and then a slow temperature decrease. And many of the functions in the--either in the total system performance, a total system performance assessment, or in the underlying models that feed it are functions of temperature across the whole range.

EWING: So let me change subjects and still with repositories. For the deep borehole disposal, I mean, that's a very different alternative to mined geologic disposal. So what problems are you solving? If that works, what--why are you going in this direction?

BOYLE: There's a number of problems that it may or may not solve. Like, for example, if one can discern that where the material is stored today actually has good enough crystalline rock beneath it, you could maybe--you would eliminate transportation from the issue.

EWING: Okay.

BOYLE: If the rocks worked out. And people have actually looked at this. I'm not advocating this; I'm just saying what was the result. When they looked at the power plant sites in the U.S., most of the reactor sites, not all of them, many of them actually do have favorable crystalline rock depths that would accommodate this.

EWING: So this would be driven by the risk associated by transportation.

BOYLE: Well, that's one factor.

EWING: What would be others?

BOYLE: Well, cost. It's not only risk, but cost.

EWING: So this would be cheaper than a geologic--

BOYLE: According to the work we've done to date, borehole disposal concepts for things that can fit in a borehole do tend to be cheaper. And I think that shows up in--just think about--I saw the ad again this morning on television. It's an environmental group of some sort. And they show this short clip from the mining of the tar sands up in Alberta. And it's a big mess, you know, a big pipe spewing water and it's a big mess. But the reason I bring it up is there's an example where hydrocarbons are actually mined. And that's a rarity. The oil business is premised upon boreholes. Why? It's cheaper. You know, if you want to get something from 10,000-foot depth. It's a whole lot cheaper to go--

EWING: So this--I'll stop, but this captures to the reasoning for this direction?

BOYLE: Well, people have put pencil to paper, and the cost estimates show that borehole disposal is potentially significantly cheaper for things that will fit in a borehole. Right? You've got to always have that caveat. It's potentially cheaper.

EWING: All right. So I'll defer. That's all--maybe.

Mary Lou.

ZOBACK: Mary Lou Zoback, Board. I had the privilege of attending the meeting at Sandia sometime in 2012 where we discussed this proposal and got input from a number of people. So I have a lot of questions, and I'm sure other people have questions of you. So I don't want to monopolize.

One question I have, I think it's a little disingenuous to talk about the smaller footprint. You also have to talk about the much smaller volume of waste you're going to be able to accommodate in a borehole. Like, if you were extremely lucky, you could put 400 canisters, half a meter--.4 meters in diameter, 5 meters long, that's all you could put in it.

BOYLE: Yeah. The point is well-taken. It's, again, back to the study that looked at well, if you put boreholes at a reactor site for a typical reactor, how many boreholes would it take? And it's not one, that's granted. There might be other waste streams. Again, back to the cesium/strontium capsules at Hanford, they would actually fit in a borehole.

So but for spent fuel which is not a prime option for this disposal concept simply because of the large size required, it would tend to make it more technically challenging, yeah, it would take or more than one hole. But still, the surface footprint is smaller for these concepts.

ZOBACK: Well, I think we should probably talk about surface footprint divided by--normalized by the volume of material that you could actually accommodated and then extrapolate.

BOYLE: Yeah. There would be more than one footprint, I'll grant that.

ZOBACK: And there's restrictions on how close you could put the boreholes. One, you can't drill a borehole perfectly straight, and you certainty don't want to be intersecting filled holes. But the only reasonable way to consider this for spent fuel is repackaging, consolidating, whatever you want to call it, creating a much denser concentration of the fuel assemblies.

So does that mean if this is a favorable option for spent fuel, you'd have a facility at every reactor site to do this?

BOYLE: Again, spent fuel is not the prime consideration here.

ZOBACK: Well, I think you guys keep using it in every report. You keep saying spent fuel. And all of the vitrified waste, what's the diameter of the canisters of vitrified waste, .61 meters?

BOYLE: Yeah. They're bigger.

ZOBACK: Yeah. So if you want to talk about this option for cesium/strontium capsules, that's one thing. To talk about, to say it's a better option, I think you need some more pencil to paper on that one.

BOYLE: This gets back to one of the first points I made. There's a test and there's a concept. The test is just a test. It has no biases. It doesn't care what gets disposed in some repository later. I would be an advocate of given that there are waste forms larger than the cesium/strontium capsules, so that if you drilled--if you did a test only for cesium/strontium, and I'm not saying that you're advocating that.

ZOBACK: No, I'm not.

BOYLE: But if you did, then the questions would come, and they already have, what about that other waste form? Why not bigger? I've been in the room where senior decision makers have already said, why not bigger? You know at least for the test. And as a technical matter, they're--to me it's easily understood, okay, test it at the limits. If you think that's the biggest thing you might ever consider putting down, go with that size or larger just as a matter of test to provide data.

ZOBACK: So I just want to make one other point. We only got the report last night, and I just have looked through it quickly, but I couldn't see the exactly diameter that's planned. But at this meeting where there were a number of drilling engineers present, I thought we left with a consensus that for this pilot program there would need to be a pilot hole before a really large diameter hole is drilled which has always been the case in any of the scientific or geothermal holes.

BOYLE: And we're still considering that.

ZOBACK: So the pilot hole is part of the plan?

BOYLE: We're still considering that. We don't have a final plan yet.

ZOBACK: Okay.

BOYLE: Yeah, but that has come up, yes.

ZOBACK: Okay. Thank you.

EWING: All right. Steve.

BECKER: Steve Becker, Board. Bill, I think perhaps some of the confusion here arises from slide 12 which describes the deep borehole disposal concept as one involving the emplacement of spent nuclear fuel. And it says provides a potential alternative to mined geologic repositories.

BOYLE: Yeah. But mined geologic repositories take everything from greater than class C waste, cesium/strontium capsules, glass, they're not--they don't exist just for spent fuel. And if this--yes. And these studies started, when they first started, they explicitly looked at spent nuclear fuel, and that's in the concept, in the disposal concept. It has been considered. And, you know, it's probably at the far reaches of what would ever go down a hole, but that's where it started.

And again, spent fuel as of our--it's not all the same. U.S. spent fuel assemblies tend to be larger than, like I said, the CANDU spent fuel assemblies in Korea. They're much more--they're very interested in this concept.

BECKER: So is it viewed as a complement to geological repositories, an alternative, or are you saying could be either?

BOYLE: Could be either.

EWING: Other questions from the Board?

Jerry.

FRANKEL: Jerry Frankel, Board. Regarding the copper corrosion work at Sandia, I'm not going to ask you any of the technical details. I did receive a report that came out of that lab from August, I think.

BOYLE: Yeah.

FRANKEL: I just would like to know what the plans are. Will that work continue? Is there funding to continue that work?

BOYLE: I don't know off the top of my head, but by--I am not aware that we have stopped it. So it's--because they haven't gotten to a definitive answer yet. If you've read the report--

FRANKEL: I did. Okay. Thank you. Yeah. If you could continue it.

EWING: Other Board questions?

Jean.

BAHR: Is there someplace easily accessible on your website where you break down the particular activities with respect to this list, in particular we’re planning next spring to focus on salt repository work? And so it would be really helpful if there was sort of a comprehensive list of the work that's going on in that domain.

BOYLE: So one thing that we started, I don't know, six months ago, eight months ago or so is within fuel cycle technologies--which is not just my group, it includes Andy's and other groups as well--there are monthly management meetings where--you know, how much money has been spent? Are you on schedule? What work products have you developed? We have these monthly meetings and it leads to two documents being prepared related to them. They automatically go to the Board, so--to the Board staff.

BAHR: Right. Yeah, I think we get those. I was just wondering if those were broken down into the tasks that you listed.

BOYLE: Yes.

BAHR: You have ten different--they're actually listed on the--

BOYLE: Yes. They are. If you know the number code and that sort, but there's usually some words to help you out. But yes, they are.

EWING: Paul.

TURINSKY: You know in the fuel cycle study that's coming to a conclusion when I started with, I don't know, a billion or 2 billion fuel cycles, they were multiple attributes. And somehow or another they combined all those attributes to rank these different fuel cycles.

BOYLE: Yes.

TURINSKY: Is there any plans to do a similar thing for geological, different geological repository forms?

BOYLE: It's been done historically in the past by the department when it went--I forget at which stage it did them explicitly and documented them--but when they went from nine sites to five to three, there were multi-attribute utility analyses behind those decisions. Like, when I went to three, Yucca Mountain, Hanford, and Deaf Smith in Texas there was very similar, you know, in spirit analysis. I do know in the history of Yucca Mountain, more than one similar-type study with respect to shedding light on what should the repository layout look like or what should a test layout look like, similar studies were done. I always think of them as multi-attribute utility analyses. That's the term they were called when I started. But they've been used historically.

Now going forward, there aren't any plans right now to do anything like that. We don't have anything to wait, like, you know, should we go salt? Should we go crystalline? We don't have anything planned like that. We're still gathering data. You might--anybody personally might start going down that path based upon some of the results that Peter Swift will show you. You will see that for some waste forms not all geologies are equal, that some waste forms perform better in some geologies than others.

EWING: Okay. Other Board--

Susan.

BRANTLEY: Sue Brantley, Board. This is just a quick question. You talked about regional geology, kind of an overview, gathering.

BOYLE: Yes.

BRANTLEY: Just wanted to ask you how you interface with the U.S. Geological Survey on that? I mean, they would be the leaders, wouldn't they? I mean, there must be interagency synergy or something.

BOYLE: Well, the people at Los Alamos do that work for us. And I think they liberally use publicly available data sets from the USGS.

BRANTLEY: But no direct interaction with the survey people that figure out where our shales are and what the resources are?

BOYLE: I'm not aware of any but that isn't to say that they haven't occurred.

EWING: Other Board questions?

I'd like to pursue my previous line of discussion just to that I'm very clear on the approach. So it's true you could take the cesium and strontium capsules and put them down a deep borehole. I mean--

BOYLE: As a technical matter, right.

EWING: Well, just as a matter of fitting--

BOYLE: Oh, yeah.

EWING: --a circular object into a circular hole. So that's true, but if one envisions a repository that can be licensed, a repository that works, one could equally well-envision using--taking these capsules and putting them in a slightly larger capsule and putting them in a repository.

BOYLE: Yeah. Yucca Mountain--

EWING: And my point would be that the repository if it works would be licensed out to hundreds of thousands of years. The half life of cesium and strontium are short enough that, except for cesium 135, that any successful repository would certainly be a good location for these cesium and strontium capsules. So what's the basis for the alternative? What does it buy you?

BOYLE: For all I know it might be quicker to do a single borehole for cesium/strontium than to wait for a mined geological repository. Because I agree with your premise. The cesium/strontium capsule contents, they were going to Yucca Mountain. They were--it's going to be put back in the glass, and it was going to be put in big waste packages, get them out, and so yeah, it's obvious it can go in other repository concepts.

But potentially it might be faster to go the route of a single borehole. I don't know. But we're just doing technical work to present to decision makers if they want to segment, you know, to have these various options, here's the pluses and minuses.

EWING: All right. Staff?

Dan.

METLAY: Dan Metlay, Board staff. A couple of years ago the Board was involved in evaluating a proposal. I believe it originated with EM having to do with heater tests in salt.

BOYLE: Yeah.

METLAY: I'm just curious, since you are collaborating with EM on salt issues, what's the status of that test? And what's happening?

BOYLE: Yeah. That test, the SDDI or the SDI, I forget what the acronym stands for--the acronyms--but it's still under consideration by Environmental Management. We still consider it in the Office of Nuclear Energy. As of this moment we have not agreed to participate it in.

METLAY: So let me just follow-up. Dan Metlay again. When you say "under consideration by EM," does that mean they have not decided to fund it either?

BOYLE: Well, ultimately EM has to get its funding from the United States Congress. So if EM had a blank checkbook, I think the tests would be underway. But they don't have a blank checkbook.

METLAY: So are there things of higher priority?

BOYLE: Yes.

EWING: Bret.

LESLIE: Since you--Bret Leslie, Board staff. Since you did bring up the multi-attributes in talking about alternatives or complements, have you kind of looked at deep bore hole in the same vein? For instance, if you were to try to apply the site characterization requirements in Part 63 or Part 60, would you have the same thing? Have you taken into account that not one repository but multiple repositories would be licensed if you did deep borehole? And programmatically, was deep borehole ever thought of in the environmental impact statement for spent nuclear fuel?

BOYLE: In the 1980s in that programmatic EIS I do believe boreholes were considered in that. And a downside to multiple repositories based on boreholes is one of the areas you brought up. I described it as a gigantic make-work program for attorneys. If you had to have a licensing hearing at each one of the power plants related to a repository based on boreholes there, that is an awful lot of work. It would also potentially be a lot of work for people in the probabilistic seismic hazard analysis and that sort of thing. So there are pluses and minuses associated with it.

EWING: Other questions from the staff? Board? Any public comments, question --

Yes, Monica.

REGALBUTO: -- I just want to remind everybody that we use spent nuclear fuel very generically. Okay. But it does constitute multiple things. Okay. We have the commercial, PWR, BWRs, we have the DOE managed which includes large packages like the Navy fuel. We also have the production reactors from Hanford and Savannah River, different type of fuel. And we also have the fuel take back program from NNSA.

So when we say spent nuclear fuel, it's not the big spent fuel assembly. We do have a lot of little categories in between that. But generically it's referred to as spent nuclear fuel, same way as high-level waste is not only cesium/strontium capsules, zipper plates, you name it, Peter will show the inventory. Unfortunately, we do have a lot of things under those two names.

BOYLE: Yeah. I was going to bring--

REGALBUTO: So keep that in mind.

BOYLE: Yeah. Dave Sassani will show the inventory as well. And back to this differentiation, in the Yucca Mountain license application to the extent that it's relevant, there were two different acronyms, CSNF for commercial spent nuclear--and DSNF for DOE or Defense.

REGALBUTO: For DOE. It's not defense.

EWING: All right, Bill. Thank you for making yourself available for such a large part of the day. All right.

REGALBUTO: We're going to miss Bill.

EWING: The next speaker is Dave Sassani, a member of the technical staff at Sandia, and he'll be discussing the inventory of waste forms and disposal option evaluation.

SASSANI: Thank you, Rod.

You can tell I'm not Bill Boyle because I need to pull the microphone down a little bit. I have the dubious honor of actually beginning the second half of this day of meetings that does not include any presentations from Bill Boyle. But he has been instrumental in this work as well.

This is me, I'm Dave Sassani. I am the technical lead on waste form degradation in the used fuel disposition campaign. And today I'm going to talk to you about the inventory for the waste form disposal options evaluation. I'll go through some introductory materials. I'll talk a little bit about how this was put together, and then I'll go into our methodology for grouping a large set of waste types.

Our scope here is larger than what was covered perhaps in the last two days of the workshop in terms of what goes in dual-purpose canisters, but it is not quite so large as what Andrew Griffith referred to this morning in his presentation which spans a lot of materials or waste forms that are potentially to be developed.

So the goals of this study were to catalog the inventory of the U.S. spent nuclear fuel and also the high-level radioactive waste. There was the group that was placed into categories based on examination of their characteristics that are potentially or directly relevant to disposal of those waste. Then what we wanted to do is to identify potential disposal options for each of the waste forms in those groups that we categorized.

Disposal options are looking at a particular waste form or a waste group and pairing it with a particular disposal concept--and I'll go through that a little bit more in detail--and then evaluating how those work together or don't work together, what are the pros what are the cons.

And importantly, this study, we wanted to provide answers to a series of questions that were in the charter about does a one-size-fits-all repository work? Does it seem like a good option to pursue? Also do different waste forms, do different waste groups, do they perform differently enough in one disposal concept versus another disposal concept to actually matter?

And lastly, looking at it from a disposal concept side, do some of those work better if you exclude a particular waste form or waste group from that concept itself? Is there any benefit to that?

So in September we delivered to DOE a draft report, on September 30th. That's just a picture of the cover. That was the first draft in this work. That work is ongoing. There's a current review process happening. We delivered a second revised draft of the report to the Department of Energy on the 18th of this month. So I can't have that in the slide because the slides had to be done last week. So in any case, this is a draft report. It's still ongoing, still in process.

Well, how did we do this? Well, this is potentially the most important slide that I have in this presentation. And what we have was 44 individuals from 14 different organizations that were contributors in one way or another to this activity. This represents an enormous amount of expertise from a number of national laboratories, from universities, from the Department of Energy, and from private industry that put together the materials and input to this evaluation. Where we have individuals that know a lot about glass waste; about the tank waste that will become glass, become vitrified; a lot about the DOE managed spent nuclear fuels, a wide variety of those exist; about commercial spent fuels. This set of contributors represents an amount of expertise that I don't have in my head. Some of them are in the audience, and I can't take--you know, I can only take credit for any mistakes I make today, so all the good credit goes to the folks that actually provided the contributions here. So I'll do my best. And most importantly, I want to point out that Bill Boyle was part of this.

So doing this evaluation was based on a number of fairly major assumptions. And I just want to back up on this. The evaluation and the work we're doing here is not a detailed performance assessment of any of these options. This is an 80,000-foot level view. And in fact, later on I have a slide in my presentation which looks like it was shot at 80,000 feet because you can't read anything on it. So the major evaluation assumptions that we worked through to put this together was that what we considered for the high-level waste and spent fuel was restricted to existing materials and those reasonably expected to be generated.

Well, what does that mean? That means that we only took the materials that actually currently exist or are part of a very planned, current fuel cycle as we go forward to 2048. So we did not look at any enhanced or advanced fuel design, cladding design, other potential fuels, even for types of reactors that we already considered that have current waste forms. So we restricted it. So it was limited. We had to kind of put a box around it. And that's a fairly big box because there's a lot of materials in here. And then we had to figure out how do we get our arms around the vast array of materials to assess them in a fashion that was consistent and we could go forward with.

So the technologies under consideration include both those for waste treatments and disposal concepts that can be deployed in the near future. So it was both on the waste form side, the waste type side, and the disposal concept side. We did consider programmatic constraints, for example, legal, regulatory, and contractual. But I want to emphasize, those were just considered and noted. We did not utilize those in terms of coming to decisions about how do the disposal options look. We used those just to note if you find this to be an attractive option, there's other work you're going to need to do in these areas to deal with creating that option in reality. But the evaluations that we did were primarily from the technical standpoint. Can this be done? Does it look like it can be done?

In this area, the RCRA-type issues came up, and we noted those, but we did not restrict ourselves to saying this can't be done because of RCRA aspects of the waste form.

The evaluations are primarily qualitative. We considered a large amount of quantitative information, but the assessments were done by a subgroup of the entire 44 contributors which I'll show later. And it was based on discussion and weighing those options, pros versus cons, and that's how we came--we had a set of criteria in metrics that were put together and agreed upon by the group. Peter will talk about those in detail.

This was based in large part from insights due to past experience in waste management and disposal programs both in the U.S. and throughout the world. And Bill showed some of those disposal concepts that were plugged into internationally. So these disposal concepts that are identified in this study were those from the Used Fuel Disposition Campaign, and we adopted those as useful and representative, not necessarily comprehensive.

You've seen this slide before. It's a little bit larger here. You can read, you can actually read the subheaders. But we considered mined repositories in clay/shale like in France, in salt such as in Germany, in crystalline rock such as in Sweden, and then also deep borehole disposal concepts which are a somewhat more differently flexible-type of concept versus a specific mined repository.

So not only was our scope in this evaluation limited to the particular disposal concepts that we studied and looked at, but we also then had an evaluation scope for the waste types. So for the spent nuclear fuel we looked at existing and reasonably foreseeable projected out to 2048, spent nuclear fuel from existing commercial, defense, and research reactors, and the Wagner, et al., 2012 report goes into a large amount of detail covering the bases there.

What's very different between the Wagner, et al., report looking at the SNF and this study is the Wagner report emphasized the wide variation in these various commercial spent nuclear fuels in particular. And here, what we did was to look at these spent nuclear fuels in terms of how similar they are to each other relevant to disposal of those in deep geologic disposal.

For high-level waste, existing and projected as of 2048, high-level waste from that Savannah River site, West Valley, Hanford, and the Idaho National Laboratory. Some of these waste types that we looked at are not presently planned for direct disposal without further treatment, so we looked also at these waste types, how they were expected to be treated, and what they were going to be turned into from the treatment in terms of a waste form. But we also--so for example, calcine waste at Idaho National Laboratory, cesium/strontium capsules at Hanford, these are not necessarily destined for direct disposal. They have disposal pathways which are treatment either from hot isostatic pressing for calcine or potential vitrification of the cesium/strontium capsules. But in our evaluation each of these, we looked at the other potential pathways for disposal such as direct disposal as well.

So those would be two discrete disposal option pathways for these waste types. Some of them have multiple treatment options including that direct disposal and they result in multiple possible waste forms for a particular waste type.

In the report we identified 43 waste types, and we ended up having 50 different waste forms that were possible from those 43 waste types. And in fact a large portion of it is involved with going through and consolidating those into a manageable number of ten waste groups for analysis, again, based on similarity of properties of the materials that went into those groups.

The report, besides the body of the text, includes a fuel listing of all the details of these in the appendices which give you a lot more specific detail than the discussion in the report does.

So I'm throwing around waste types, waste forms, waste groups. It can get a little confusing. It's kind of like the whole cask/canister collection of terms. So just to be a little bit more specific, this is an example using high-level waste glass on that terminology. And this emphasizes the discrete way we broke these terms down. A waste type is what exists today, right now, or for projected wastes what would be produced from the process. So this would include, in fact, tank wastes and existing high-level waste glass, like West Valley glass, or the glass that's been produced already at Savannah River.

The waste form is what is the thing that you're going to put underground and dispose of in a geologic system. So for example, the canisters of high-level waste glass for glass from multiple sites and sources that would go into package and be put underground for disposal. This, in fact, is an image of the West Valley Development Project glass waste canisters in storage.

And then a waste group is the aggregation of waste forms with similar characteristics. So what you'll see later, one of the waste groups in fact is all high-level waste glass regardless of the origin.

So we wanted to maintain the inventory counting of what is it. We don't exactly have a very detailed listing of where it is currently, although that does exist in the database. But we wanted to maintain what it is, what can it become because there's different pathways for some of these, and then how do we group these together and keep track of which waste group is mutually exclusive of portions of other waste groups because the different waste forms can be in different waste groups. So you just have to maintain that tracking throughout.

So what did we look at? So this slide shows the volumes of the main waste forms existing and projected to 2048. There's a lot on this slide, but what we have in general, these are by volume in cubic meters of waste being disposed of. So this is what would be getting put underground.

And on this left-hand portion is both the spent nuclear fuel and high-level waste shown in a pie chart in terms of how much exists currently, over here broken out into slices, and how much is projected. The primary aspect to notice here is that the projected commercial SNF is 85 percent of this slice, spent nuclear fuel all together I believe is 88 percent of this pie, and the commercial and DOE managed SNF and high-level waste amount to about 217,000 cubic meters; 47 percent by volume of this total exists today. That is about 97,500 cubic meters of the spent nuclear fuel which is the DOE and commercial exists today. So that's volumetrically we can see that commercial spent nuclear fuel is by far the largest aspect of the waste that we need to dispose of.

Then what we've done here is to take the high-level waste which is shown here in the purple in two slivers, one where about one sixth of it is already existing, five sixths of it is not. And we're taken that high-level waste and projected and blown that up into this pie chart here. So this pie chart is specifically just the high-level waste that is considered in the report, both the existing which amounts to less than 15 percent at the Savannah River site, existing glass primarily, and the West Valley glass, and then some glass that was made for the Federal Republic of Germany and is at Hanford. So about 3200 cubic meters of high-level waste glass exists today.

There are some assumptions that go into these things because when you have different waste streams that you can consider in order to calculate the volume of what's getting disposed, you have to make those assumptions of what form is it in. So the assumptions behind the high-level waste here primarily are it assumes that all the calcine is treated by hot isostatic press--that's shown here--which makes up about 12 and a half percent of the high-level waste. The sodium-bonded fuels undergo electrometallurgical treatment that was discussed earlier. And those are shown here. And then the--all the other high-level wastes are considered to be vitrified in terms of these volumes. So these are existing glass and then the projected glass as vitrified.

The other assumptions in this chart are that we use a constant rate of nuclear power generation. This corresponds to scenario 2 in Carter, et al., 2012, in terms of the production of materials through time in the commercial.

Also for simplicity's sake, all the DOE spent nuclear fuel is shown as existing. That's not exactly true. Approximately 3500 cubic meters of Naval spent fuel is remaining to be generated, but it is actually included in here. It's just shown as existing for simplicity.

So what are these volumes? I mean, these are large volumes. You got 217,000 cubic meters. I'll try to put these in a little different context. And I looked at different ways of putting this in context. Somebody had suggested what's the volume of the Empire State Building. Well, that was a little too large. So then I was looking at what's the volume of the Goodyear Blimp. That was a little too small. But there's an appropriate volume that was--that actually exists here in Washington, D.C. which is the Capitol Building rotunda. And the Capitol Building rotunda has a volume of about 37,000 cubic meters.

So if we use the volume of one rotunda of waste, then you got about five rotundas of spent fuel and one rotunda of everything else. Sorry, five rotundas of commercial spent fuel all the way projected through 2048, and then about a little less than one rotunda of all rest of the waste. So about six rotundas of waste is what we're talking about disposing of. You know, that may be a very appropriate unit given Congress' performance recently, or it may not. So this is the commercial spent fuel, the DOE spent fuels, and again the high-level waste.

I'm just going to focus in very briefly then on the DOE spent fuel to show you kind of the simple takeaways from that. This is the slide where if you had your optometrist here you could have your eyes checked with it. So forgive me. It's not very readable. But primarily what you come away with is 84 percent of this is one DOE spent fuel group, and it is basically mostly the N-reactor fuel that's in that waste group.

And then what you can see is there are 33 I think 33 other DOE spent nuclear fuel categories which are very small amounts and make up the remain being 16 percent. This plot is shown in metric tons of heavy metal. It's not a volumetric plot. So this is directly the masses involved. We felt this was more appropriate for the spent nuclear fuel. I think in the appendix of the report, the volumes are also shown. But again, there are more assumptions that go into that.

So there's a vast array of these. They span oxide fuels. They've got metallic waste forms. There are hydrides. There are zirc. There's MOX. There's carbide fuels. There are the TRISO/BISO coated particle fuels that are in here, there's a vast array of types. And our job was to try to simplify these into a set of categories that could then be assessed against different disposal concepts to assess disposal options.

So how did we do that? Well, what we did from a large standpoint was to go through the characteristics for grouping these, primarily the radionuclide inventories, the thermal aspects--and these are for the waste forms--the chemical aspects of those. And chemical aspects have a two-fold role here. One is primarily in postclosure in geologic system, what do we know about how this material might behave over geologic time, i.e., what is it's waste form performance likely to be? Can we--do we have any information on that or not? How we did those assessments, Peter will talk more about with the metrics.

But the other aspect of the chemical is this material, if it's accessible and reacting with the ground water, does it have any other potential impacts on materials around it? Rod was talking about cesium/strontium capsules earlier, one of the things that come out of this, and I don't want to go to too many results because Peter's going to cover those. But cesium/strontium capsules are cesium chloride and strontium fluoride. Cesium chloride is extremely soluble. From a waste form standpoint, if you directly dispose of those, there's no waste form performance. Water gets into it, it dissolves.

Strontium fluoride, less soluble, but there's probably not as much strontium in most of these systems to saturate the phase. So you'd probably end up doing calcium/strontium exchange, some kind of ion exchange. So the waste form itself would react and probably kick the fluoride up in the system. Those types of chemical aspects were considered as well as the actual performance of the waste form.

Physical properties of the waste form. A lot of those DOE spent nuclear fuel types are broken pieces. One of the categories has the Three Mile Island fuels in it, if you could still call them fuels or magma, reactive material.

The sizing, the condition, the cladding condition, all of those aspects were discussed in the method that we went through to try to come up with categories. And you look at all these materials and you can come up with about 30 dozen ways to group them. In fact we come up with three or four before we put out a straw man to the group, and then we redid it completely when the group got together.

The packaging. The packaging itself is going to go underground and be disposed of. So we wanted to have some discussion of how we're going to package these materials. How large are the packages? How hot are the packages? Can you handle them? Can they go in this configuration or that configuration? Are there any other considerations?

And then of course, safeguards and security aspects of each of these waste forms and in conjunction with the disposal concept, you know, delivering to a borehole, at the surface, or taking them to a repository have very different considerations to be thought about.

So these were the kind of characteristics that we walked through as a group to figure out how to define those waste groups. And the evaluation subgroup, in fact, defined the final set of waste groups that we came up with. And we did it together because we wanted to have a common set of information. We didn't want to give people, well, here's all the details of the report. You go off and come up with your categorization and then we'll get together and meet. We wanted to actively discuss the materials at hand because we had such a vast array of expertise. There were one or two or three people that were experts on one particular waste form in the group whereas they had no basic expertise in some of the other areas that were contributed by other folks. But we all discussed it internally so everybody had the same information at hand.

In fact, some of the waste groups rely on only one where sometimes more than one distinct aspect. A very good example of that, we considered direct disposal of the metallic sodium-bonded fuels. There are other metallic fuels, but the sodium-bonded fuels have very distinct chemical characteristics, and they went into their own group.

Alternate waste forms fall into different groups. I mentioned this earlier, for example, vitrified/ceramic, HIP calcine versus untreated calcine, direct disposal of calcine, very different materials to consider for disposal. One which, the untreated calcine actually has some RCRA-associated issues, but the vitrified/ceramic HIP, in fact, takes those off the table. But you don't have to treat this, so you have tradeoffs. And that's kind of how we did things.

So let me go on to the subgroup itself. Again, most importantly, Bill Boyle was a part of this. So even though he's here still physically, he's also here in spirit.

And we had not quite the 44, the cast of 44 contributors, but again, a very large, wide-ranging set of contributors working directly to create these waste groups and then do the evaluations. Not only do the evaluation but also when we went through this and then walked through the criteria and metrics, we had everybody get on the same page with those before we did the evaluation.

There was the possibility as we went through that if there was dissenting opinion we would document that, but we tried to reach consensus. In fact, I don't think we ever had a dissenting opinion that was strong enough that they felt it had to be documented. So we did pretty well in terms of consensus.

So this is how we put the groups together and this next slide shows the ten waste groups that we have defined. I'll go through some of the highlights here. The first two waste groups, 1 and 2, are all commercial spent nuclear fuel packaged in purpose-built disposal containers. So this group right here would correspond to the repackaging scenario that was discussed in the workshop because you would have to open up the dual-purpose containers and repackage them into purpose-built disposal containers. This purpose-built terminology means these are containers that are tailored to some extent to the particular disposal concept you're using. And I believe Josh Jarrell will talk in detail about these types of containers in the next talk.

The second waste group which is completely mutually exclusively with the first--so these are two end members--is all the commercial SNF disposed directly in dual-purpose canisters. So the current DPCs dispose of them directly, package everything in terms of commercial SNF into DPCs in the future and dispose of them. These are end members, so this is the direct disposal scenario right there. These are two end members. What can end up happening is you could do anything from one to the other, everything in between based on what is actually the best strategy for handling these things. But we wanted to split these out to highlight the pros and cons of each of these particular pathways.

Waste Group 3 is all high-level waste glass, all types existing and projected. Again we felt these were similar enough in terms of their postclosure behavior to go ahead and put them together in a group by themselves.

Throughout the rest of these, a lot of them--so we had 43 waste types, 50 waste forms, and here's the 10 waste groups. Some waste types mapped to more than one waste group.

Sodium-bonded fuels, well here's Waste Group 6, sodium-bonded fuel. That's direct disposal, and Peter will talk about the results for that. The sodium-bonded fuels as they're processed also are in other engineered waste forms which includes the glass-bonded sodalite from the salt waste stream of the treated sodium-bonded fuels.

So electrometallurgical treatment results in a salt waste stream, and it results in a metallic waste stream. The salt waste stream ends up going into sodalite which is then encapsulated in glass. The metallic waste stream is actually mixed with zirconium and depleted uranium I believe and is made into metal ingots. Very little of this has been made. None of the glass-bonded sodalite has been made at this point. There is salt waste that has been produced from the electrometallurgical treatment. And as far as I can recall, I think a single metal ingot was produced in 2012 up at Idaho from these processes.

So these existed, in fact, this salt waste stream, one of the considerations that we made for it was to take the salt waste stream and directly dispose of it in these repository concepts and look at those disposal options. And so this salt waste stream for the sodium-bonded fuels is also in Waste Group 8. So obviously this salt waste stream is the same as this one, so these are somewhat mutually exclusive. So as you go forward you just have to keep track of those.

So the 34 DOE fuel groups end up mapping into five waste groups which are exclusive to those. Waste Group 10 is the Naval fuel. Waste Group 9 coated particle fuels. Waste Group 7 are DOE oxide fuels. Waste Group 6 is the sodium-bonded fuel. And then Waste Group 5 is the metallic and what we refer to as nonoxide spent fuels. These are carbide fuels and the hydride fuels and other things like that.

So these are the ten waste groups that we ended up coming up with. We evaluated these against four different disposal concepts, so for each thing there were 40 disposal options looked at.

This is a slide kind of summarizing some of the major observations about the spent nuclear fuel and high-level waste inventory. These pie charts you saw earlier when you could actually read the notes on them. And the commercial spent nuclear fuel is the largest volume of waste. It's 85 percent projected out in 2048. About half of that exists right now.

High-level waste will be the second largest volume. The other DOE managed wastes have a wide variety of characteristics, and most of them exist in a relatively small volume. There's a range of volumes and sizes to those materials for the DOE spent nuclear fuel, and so within one of those waste groups there are portions of it that might actually fit or would actually fit in a deep borehole that had about an 11-inch diameter constraint, and there are portions that won't fit. Peter will talk more about how we handled those.

Some waste types can have multiple treatment options, and some potentially can be disposed of without planned treatments. Now, again, this work is a very high-level evaluation. It's looking at a lot of different materials with some very course criteria. So if one of these looked very attractive, a follow-on study with the details would need to come about.

But no waste posed any unusual safeguard and security concerns with the exception of some considerations for granular and powered waste forms and small capsules especially when they might be sitting out in a location where they could not be put directly underground.

So that, in fact, those are kind of our major conclusions about the inventory itself. Peter will talk in detail about the metrics of the study, the actual execution of the evaluations, and the results from that. So I'll take any questions. Thank you.

EWING: Thank you very much. Questions from the Board?

Sue.

BRANTLEY: Sue Brantley from the Board. Has this never been done before?

SASSANI: It actually appears to me that it's been done a number of times before but not necessarily all in the same place. So I was amazed at one of the utilities of this study was to bring the material all into one location, to work as a starting point. But the Yucca Mountain license application did a lot of this.

I don't think we found any large surprises with this evaluation. There have been other performance assessments that have been done from INL and from materials there. This, other than the Yucca Mountain license application enumeration of all these, this is the only location where I know that all of these are considered simultaneously. This is kind of the other side of the coin though because it's looking at all these saturated environments not an oxidizing environment and tuff.

BRANTLEY: And you talk about a report as the product, but did you also make a relational data base?

SASSANI: There's not a relational database. There exists a number of databases out there. This, the closest thing we have are spreadsheets that are in the appendices that list all the information, but there is no relational database that we put together.

BRANTLEY: And why would you not you put it into a relational database?

SASSANI: Primarily because it wasn't part of our scope, but if we think that's a good idea or I would say if DOE would like that to be done, we could do that.

BRANTLEY: Well, I mean, a relational database then gives you the ability to query different things like strontium or anything else, whatever you put up here.

SASSANI: Absolutely. I'm not saying it's a bad idea, just we have not done that.

EWING: Other questions from the Board?

Yes, Jean.

BAHR: Jean Bahr from the Board. I see that there's a table in the supplementary material.

SASSANI: Yes.

BAHR: In our handout, Table 3.1, and just looking quickly at it there's a column that says quantity of waste type. And what may make this difficult to use is that the quantities in some cases are listed as metric tons of heavy metal and other cases as gallons, in other cases as canisters of undisclosed dimensions. And I think Sue's comments about a relational database in that kind of a system you could cross-reference these things with volumes, with amounts of radioactivity of different types.

And I think one of the things that would be interesting to see, in this you showed us some volumes, and you showed us some metric tons of heavy metal, but not all of these things are heavy metals and seem where--where is the activity? And where are the long-lived versus the short-lived nuclides and those sorts of things would be another way of sort of parsing this.

SASSANI: Absolutely. And the table that's in the back of the handout is part of the document. The tables and the appendices are much more complex and comprehensive, but, in fact, this is where all your activity is. You've got some interesting activity in some of these other aspects, but here's most of your activity. Those listing are in there. The appendices give enormous amounts of detail. But one of the tricky things with this is all of these different particular types of waste come into this in that vastly different set of forms. And the most synthesis we did was in terms of putting it into volumes for disposal because the waste forms that exist themselves, some of them are tank wastes; they're gallons, millions and millions of tens of millions of gallon with an activity concentration. That information is in the appendix, but it's not been distilled into here's your total layout of radionuclide budget across these. That would be an interesting way to look at it.

BAHR: Yeah. I think that would be a useful thing to do.

EWING: Just to follow--Rod Ewing, Board. Just to follow-up on that comment, there's a very nice report done in 1997 linking legacies, where they have similar pie-shaped diagrams. But then they also show you the radioactivity, the volume, and they go a step further. They show the general change in composition as a function of time. And so it's a very powerful story that you can pull from such diagrams.

SASSANI: Absolutely. And the evolution of this out to 2048, we have some of the information in the appendices for the evolution of the high-level waste. The spent nuclear fuel was projected out in terms of its decay. Those are in some detailed plots, not pie charts but more details of the actual radionuclide loading in those and how they change over that time period.

In fact it would be interesting to look at those even further than the projected 2048. It would be interesting to look at those into the postclosure portion. I think with the cesium/strontium capsules you alluded to earlier, most of those, the only radionuclide of long-term importance there is cesium 135 which contributes almost nothing to the thermal load of those capsules. So yes, I agree with that.

EWING: In fact this may be an area of where spending time with someone who specializes in visualizing data, setting up something that you can just set and interrogate would be very, very interesting because as an example, I think about one-third of the total activity at Hanford is in the cesium/strontium capsules.

SASSANI: Yes.

EWING: Or at least it was. It's decayed a little bit. And so you can begin qualitatively to set some priorities.

Other comments from the Board? Or may I continue to have a comment and question?

So, Dave, I think I understand what you did, but it's also a little bit of a surprise in the following sense. If I understand your definition of waste form, the vitrified waste in the canister is the waste form.

SASSANI: Well, in fact, the vitrified waste in the canister in the package really would be the waste form.

EWING: Right. And so the first thing I'd point out is this kind of a new use of that expression. Usually when we're speaking of waste forms, we're talking about the material that incorporates or encapsulates the waste. And the result of your new definition, which is fine perhaps for your purposes, is that as an example with glass again, all glasses look the same in the analysis. And yet we know from international programs the composition of the glass has profound effect on long-term durability, and the French and others work hard to stay within certain compositional range.

And so this becomes also inconsistent with the previous presentation on the waste form program because there you're developing apatite for iodine, the krypton material, and the metal oxide frameworks, and so on. So on one hand DOE's developing an array of waste forms presumably with the hope and intention that their performance will improve the safety of the system. But that would be lost in this analysis.

SASSANI: Yeah. I'll agree and clarify a little bit. It is a little bit different, and it's kind of a schmoozey definition in terms of the waste form at this point. We needed a distinction between the waste type, the stuff that's out there right now, because not all of it is in its waste form.

EWING: Right.

SASSANI: We also needed to group things, and, in fact, let me just go back here to the ten waste groups. Because I agree with you, Rod. In detail, specifically for glass, the different compositions of glasses, their behavior in postclosure, they can be different.

One of the things that we discussed here in terms of the waste form lifetime, if you will, was a broader range of that where in most of these reducing systems, commercial SNF, if we drop back to the classical waste form definition, commercial SNF can be very robust and long lived. Whereas in almost any of these systems, something like the direct disposal leaves salt waste; cesium chloride is not going to have any waste form lifetime whatsoever.

So within that range, from there to out to maybe a million years there's a middle ground where waste form lifetimes are about perhaps your waste package lifetime. So our differentiation was primarily on does the waste form lifetime look to be longer than your expected waste package lifetime or much short or about the same? In other words are you going to be relying primarily on your waste form for containment, or are you going to be primarily relying on a waste package and engineered barriers?

When we got into actually defining the waste form, there was a discussion of the physical aspects but also its packaging. And so packaging became a portion of the waste form definition because of aspects of considering volumetric disposal and other aspects like that. So it is--it's kind of schmoozey in between there.

But the discussions of the actual waste form behavior do speak directly to is it spent fuel? Is it glass waste? But within this range, all the high-level waste glass performs kind of about the same. So that--these--I won't say that these groups are perfect.

EWING: If you use the seven-day test, the PCT, everything looks the same.

SASSANI: Yeah. In terms of being very different from salt behavior versus spent nuclear fuel behavior.

EWING: Right. Okay. Thank you.

Last chance for the Board. Staff?

Gene.

ROWE: Gene Rowe, Board staff. I don't know if, David, if you're the right person to answer this. I've asked this question to multiple DOE people and have yet to get an answer.

The N-reactor fuel at Hanford is presently in MCOs. The MCOs was not included in the Yucca Mountain license application in the preclosure portion of the license application. And there's a note in the table in the back of the license application that says that the event sequence was not evaluated. So my question is two-fold. Why was it not evaluated, and two, can those things be transported?

SASSANI: I'm not the right person to answer that. So I can't answer the why, and I can't really speak to the transportation aspects. About the only thing I can do is slide back here and say in our assessment we did not look necessarily at those. We may have noted those. We may have noted where transportation, there might be issues that exist. But from the technical standpoint we discussed does this look any different than transporting things that work? Is it technically going to work? And if the answer was "yes," then it was good to go.

EWING: Other staff questions? From the audience?

Yes, Monica.

REGALBUTO: I'm going to be like Bill.

Just a point of clarification, and I think I don't want to leave you with the impression that the programs are not coordinated. We respect your comment on the waste forms. This is the existing inventory. This is enough to fill up one repository today with the current as we say credible predictions up to 2048.

What Andy is working on is future fuel cycles which you will not see that waste coming out until, like, 2100. It's another repository where looking at the attributes and doing different types of waste form may facilitate a disposal. If we could rewind to 1950 we should done that exercise back then. But we didn't do it, so now we have to live with what we have which is what they analyzed. And Andy is looking at this. We deploy a different fuel cycle which, like I say, you will see the result in 2100. What would we do that could possibly benefit the disposal?

So unfortunately, they're mutually exclusive because of our timing and our reactor fleet that we have today. So I just want to make that point.

And the other point that I want to make and that is going back to the cesium/strontium capsules and the one-third of the activity. One aspect that is not in here but it is real is okay, what is the current disposal path for that material? And that is put it back in glass. Why would we put it back in the tanks when we just took it out of the tanks? And it's just morally wrong. So to me that is like why don't we deal with the cesium/strontium capsules as is because why will we increase the risk to Hanford when we already have them packaged together?

So even though, you know, sometimes these things hypothetically look okay, the reality is we took it out of one place, why would we put it back in there?

EWING: I couldn't agree more.

REGALBUTO: Yeah. So that's--and some of those little waste categories that you see there came from those same tanks. And if the disposal path is to put it back in the tanks at either Savannah River or Hanford, I will say I have a really hard time putting things back in that site. I am in favor of moving things out of those sites.

So that's just something that we don't see when we just see the raw data, but it's something to keep in mind. You know, what is the alternative? And the alternative is increase the risk to a site where we're trying to reduce the risk. So we have to think about it that way.

EWING: Right. Okay. Thank you. Other comments?

So, Dave, thank you very much.

We'll take a break now and start promptly at 3:45 with Peter Swift.

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

EWING: If you want to be on the NWTRB mailing list and be notified of activities and reports, please fill out one of these cards that can be found on the table outside.

The next presentation is by Peter Swift from Sandia National Laboratories. It's, I take it, a follow-up to Dave's presentation. And so, Peter, the floor is yours.

SWIFT: This is really a continuation of the presentation that David Sassani started, and as the earlier speaker did--and I'm only sorry that Bill couldn't be here to give this presentation--but as a previous speaker did, I repeated, just for the completeness in your website record, I repeated the first seven slides from David's talk. I'm not going to go through them all.

But this one I will just take a minute on this one to again emphasize the type of analysis this was. This was a lot of people. And in some ways it's a little bit like the workshop the Board just went through in the last two days. We deliberately cast a broad net to get a lot of people into the room, to get the right expertise there. And one of the things you get back in a tradeoff like that is that it's a very qualitative and very subjective analysis. We're combining the best judgment we could get from this body of people. It is not a quantitative modeling study. It's not a performance assessment. It's also it's not a down selection. We're not trying to give you the answer; we're trying to give the DOE the judgment of these people.

And also, the work started basically in May. So it's a relatively short period of work. And one person in particular I want to call attention to who has not been acknowledged this meeting yet, Laura Price.

Laura, can you raise your hand back there? There you are, back in the corner there.

Laura--second row of names up there from Sandia--Laura did much of the work of compiling the results part of this. She did a great job of leading the essentially the elicitation, the group discussion that led to the evaluations. So when I get hard questions, I'll be looking at Laura.

You've seen that. You've seen that. Keep this one in mind though or maybe just pull it up in front of you from the previous presentation. This is exactly the same slide that David had in his talk. Ten waste groups built out of, in the end, 50 waste forms defined the way that David described.

And you've seen that before. All right. This is the first one I think you haven't seen. It's the approach we use in doing this qualitative evaluation of the disposal options. And first, the definition of disposal option, and definitions do matter here. We defined a disposal option to be a pairing of a disposal concept, i.e., a clay/shale repository or a crystalline repository, with any one of those ten waste groups. So, you know, each one of those possible pairings then become as an option that we evaluated qualitatively against--"we" being the group, the subset group that David put up earlier in his presentation--against these criteria.

First point, the evaluations are qualitative, informed judgment, and we color coded them, so nice, quick, simple. And honestly, the colors there, they're deliberately broad and the scoring is coarse. That's intentional. This is qualitative. There were, in fact, a few places where if we'd allowed pluses or minuses they might have showed up and made a difference, but in general we didn't want them. We wanted to focus on pretty simple categories.

Green means strong; we thought it was a good idea. Everything looked bright for it. Moderate, weak, or uncertain, and the red, we reserved that for things that we thought simply were not feasible, a no-go. When we came up with a red score for something, we took it off the table and moved on, didn't score any other criteria for that option.

And David made this point earlier, current laws and regulations are noted, but we did not treat them as prescriptive. And that's not to suggest that we want to disregard current law, but we didn't want it to limit us in the choices we were able to--now, this is a technical evaluation. If we didn't have the current prescriptions, what would still make sense.

We do have a section where we talk about cost. We decided not to try to use that as a metric. The logic there was that, first of all, any cost estimates are highly speculative. And second, they actually are or were then anyway, a point of litigation with the waste fee work and the Fee Adequacy Report the DOE delivered back in January. So we basically relied on that Fee Adequacy Report where we could, and we kept our discussions of cost qualitative.

So the criteria and metrics that we used, and you'll see these again, but disposal option performance, i.e., could it comply with standards? By which we mean primarily long-term, postclosure standards. And I'm not entirely sure what those standards are, but that didn't stop us from being able to score that one.

Confidence in expected performance bases, so yes, we believe, for example, that it could comply. How confident are we in that belief? And this is basically the technical basis. How strong a case can you make?

Operational feasibility, worker health and safety, physical considerations.

Secondary waste generated during treatment of existing waste. And one example just so you have it in your head as to what we're getting at here, repackaging of the existing commercial spent fuel into what we call purpose-built canisters of which Josh Jarrell is--standardized canisters that Josh is going to talk about are one example. Will that repackaging generate secondary waste? It generates new, low-level waste in the forms of the internal components of the DPC and the DPC canisters themselves.

Technical readiness, we already had an assumption which came up, Rod, in your question at the end. But we're not looking at things that are purely projected. But we are considering things for which technology isn't quite ready or in varying degrees of readiness, for example, deep boreholes. And until someone has demonstrated it can be done, you'll see soon, not to jump ahead, but they're all going to score, at best, yellow.

Safeguards and security issues, there are two issues/topics there of interest. First, are there safeguard issues associated with special nuclear material that are unique to that particular disposal option? And second are there radiological dispersion concerns, diversion of materials for use in radiological devices? And in general the answer is--well, we'll get to that.

So the results, and I'm going to jump right in here and go straight back to those first three questions that David had that were actually in the charter that--and Monica drafted some of these questions herself. We worked the charter with her back in April. Is a one-size-fits-all repository a good strategic option? And one-size-fits-all means a single repository at a single location.

So here are our conclusions. Technically, it can be done. We did think it had potential cost savings. That's nothing more sophisticated there than noting that, all other things being equal, one repository is cheaper than two. We're not commenting on whether a salt repository is cheaper than a granite repository, simply noting that if other things are equal, if your choices are one or two in the same medium, one is going to be cheaper.

It would have to be a mined repository. So for those who think we're going to put everything down a deep borehole, no. If you're going to do it all in one, it's mined.

It may be advantageous to segregate some waste forms from others in some disposal concepts. And David touched on this, the halide-bearing wastes, it's not just the cesium/strontium capsules, but they're an excellent example of it. But you don't want those halides, those salts, in contact with waste packages, waste package material, in the adjoining packages, in a disposal concept that relies heavily on waste package performance. So if you're going to put them all in one repository, think about that. Just think about how one waste form will affect the other and segregate them. That doesn't mean they have to be in different repositories, it just means they have to be far enough apart in the same repository; they're effectively isolated from each other.

Last point down here, we were asked about a one-size, single repository, but multiple options are viable. And the strategic aspects of this, we were asked is it a good strategic option? And we kicked that one back. We decided we were a technical team, and strategic decisions were outside our scope.

Second questions, do different waste forms perform differently enough to warrant different approaches, differently enough in different environments? And the short answer is no. We did not identify any waste forms that actually required a specific option with one exception, the untreated sodium-bonded fuels, we did not know enough. And that team of 44 people did not know enough to conclude what option would work for them without treatment. That's not quite the same as saying we have to treat it. It's saying we didn't have the right people in the room; we didn't have enough information.

This point I already made with the halide-bearing wastes. It doesn't mean they require a different disposal option, it just means think about it and keep them isolated from other packages if your concept relies on long-lived packages.

Small waste forms, they are candidates for deep geologic disposal. And specifically, we started out with the reference design that Sandia has published. It's simply a nominal reference design. It's up there as a straw target for people to comment on. But that called for a 17-inch bottom hole diameter that would allow emplacement of a waste package after you put casing in the hole, and then a waste package around your waste form. It would allow for about just under a 12-inch waste form which would for example allow the things listed here.

Salt wastes from the electrochemical refining process, granular solids, calcine, anything that is still granular and essentially unpackaged is a candidate to be put into long, thin packages; so calcine as is being included as a candidate. The cesium/strontium capsules, and that was one of our waste--that's a typo, that should be a G, Waste Group. Editorial mistake, and it's mine; it appears several places here.

Waste Group 8, some DOE managed spent fuels, those in particular, those that have not yet been packaged, those that are in the multi-canister overpacks, the MCOs, and that's most of the end reactor fuel, are too big. So they're not a candidate for that.

And the last group there, waste forms that have not yet been made although designs exist for them, so obviously, any existing glass waste. The Savannah River glass doesn't fit. And we talked about this at some length, and frankly, the glass people do not want to redesign their glass process. I don't blame them. And it's not as simple as saying we'll pour thinner cylinders of it. It cools at different rates. They have to think it through pretty carefully, but it's not impossible. You could go back and reengineer those engineered waste forms that have not yet been made.

Other major conclusions, you've probably read ahead here. Salt, no surprise here. You saw this here in this workshop Monday and Tuesday of salt. Salt allows for more flexibility in managing the high heat waste.

With respect to mixed waste, the waste that has RCRA constituents in it, we didn't find any technical issues there. We recognize there are regulatory issues, but we didn't find any technical ones. We did note going back to the sodium-bonded fuels they do present regulatory issues, and that was not the reason we didn't know what to do with them. The reason we didn't know what to do with them is because they're highly chemically reactive. So there we saw that as a technical issue not as a regulatory one.

And that last point, we concluded that direct disposals, disposal of dual-purpose canisters in any of our disposal concepts was going to be a challenge.

So think about what we did, and much of this, the actual face-to-face evaluations, were done in August. And we went through a lot of the same debates in our group that this group here went through yesterday morning.

And all right, do some disposal concepts--the last question--perform better with or without specific waste forms? As David said, that turns it around, looks at the question from the repository's point of view. Would the repository be happier if you left something out? And no. But confidence in a technical basis for some disposal options is definitely lower. And that brings us to--you've probably already jumped ahead--brings us to many pages here of tables summarizing the evaluation.

And to start off by the format of the tables, they're going to follow--each one of them follows the same organization with the criteria vertically here, disposal option performance, confidence, feasibility, secondary waste, technical readiness, and safeguards and security. And in the lower box down here are the types of metrics we considered in the discussion.

In the appendices to the report you'll find tables that--basically the notes that were taken during the evaluation, you'll find entries for every disposal option for each of these metrics or most of them anyway. But for the purposes of the summary you simply present them in a form like this. And so this would be for a mined repository in salt, and each of the ten waste groups there, and each of the six metrics and six criteria here. And honestly what we expect you to do is look at this and go, "Wow. That's a lot of green." Or maybe you're the half-empty person. You know, you look quickly at the purple and go, "Oh, there are your trouble spots. That's not a purple, that's a white."

And you'll see that there's some patterns that jump right out on all of these. And I'm not sure what the best way to go through them is, but first of all you'll note that not all of them really relate to the repository. The safeguards and security column is repository independent. Once you're in the repository, the disposal system, they all look pretty secure, pretty safe. The one waste group that raises a flag with our safeguard and security people, and we had representatives there in the, were those powders. Basically anything that's small--and David mentioned this--but the idea that you're going to be moving a whole lot of small cesium/strontium capsules around the country or you're going to be moving powdered calcine around the country, that didn't get us to a purple or a red, it just got us to a moderate, let us pay attention.

The other things that will jump out at you, the purples which are, aside from the reds and the only place we see reds turns out to be in deep boreholes. The purples--okay. Let's look at this one. Secondary waste generation from repackaging everything, all the existing dual-purpose canisters, to repackage them into purpose-built creates quite a lot of secondary waste. We felt that rated a weak recommendation on that box. But turn it around--and that by the way is independent of disposal type. That should look the same on every page.

Operational feasibility, getting the big DPCs in Waste Group 2 into the underground, that's the hoist question there. And that got us to a purple score.

Confidence in expected performance bases you know a yellow, a moderate, that has to do with uncertainty about how the salt will manage the heat.

Other things, just you'll notice across the board on all of them, where applicable everything is green in disposal option performance. And that's true of the other mined repositories. Frankly we thought they would all comply. The question then becomes the important question is how confidently can we make that case? Essentially, how easy is the licensing case to make? So don't expect to see anything in this analysis but green here. Look instead where the yellows are here, and look at the operational feasibility.

So other points to make here, on all of them you'll see sodium-bonded fuels with blank, unknown, except that our safeguard and security people weren’t that worried about them. Another point you'll see on all of them I think everywhere, you'll see that Waste Group 2, the direct disposal of dual-purpose canisters has the same scoring pattern as the Naval fuels.

And there's no great surprise there. You can look at the Yucca Mountain license application where the Naval fuels were essentially treated in the analysis to have the same properties as the commercial fuel. Commercial fuel was basically a surrogate in the analysis for the Naval fuel;

large packages, high heat generation. I think I covered everything there.

Crystalline rock, a little bit different there. Over here on the right-hand side I think you'll see these are essentially the same. These are not necessarily repository dependent. The left three criteria columns are.

So confidence, the issue here, why did we get a purple score for dual-purpose canisters in crystalline rock? It's the heat effects on the bentonite clay backfill. The crystalline concepts, and for each of these we had a basic reference design in mind--the Swedish concept for crystalline, the French concept for clay/shale. We actually went all the way back to the 1980s and the DOE civilian repository concept for bedded salt in Deaf Smith County was basically the model we looked at there. But surely for salt we drew on the German experience and the on the WIPP experience also. So and anyway these, the crystalline concepts do rely for performance on a clay backfill around the waste that gets hot with a high heat load. We saw that as a problem.

Operational issues, crystalline rock moved up. Salt was purple here. The crystalline rock moved up to yellow. It clearly has advantages over salt for emplacing big packages, but nobody would say it was green and a strong case. I'll come back to any of these and field question on any particular box in here.

Clay/shale, and I'll admit it wasn't the first thing that jumped out on me and hit me from this until Monica pointed it out to me, but this is exactly the same as salt. And this is the place where had we allowed pluses and minuses we probably would have seen a little--a plus on salt and maybe a minus here in clay/shale. But the reason that clay/shale is preferable to say granite which was purple there--I wasn't supposed to jump ahead to that one--granite had a purple box there in our confidence in the repository performance, and clay/shale was only yellow. The point there is that you have a whole lot more clay to rely on as a barrier. With granite, when you lose your let's say a meter of clay backfill, and if you're releasing directly into a fracture into the granite, you have relatively little sorption barrier. And in a clay/shale repository you still have a large effective barrier, natural barrier there.

Deep boreholes, and here our waste groups turned out not to be all that well-planned out for the deep borehole question because in many of the waste groups there are some waste forms that are small enough to fit in a deep borehole, and there are some that are not. And that's why under operational feasibility, if it was basically greater than 12 inches in diameter we just put it red and said don't even talk about it. Take it off.

And you'll note that we gave repackaging of commercial spent fuel a purple there. That is, well, if you wanted to rod consolidate, you could get it under 12 inches, but why would you want to do that, and made it purple. But we really were reserving red for things that simply don't fit geometrically. And once we scored any box red, we just took that fraction out and didn't bother to evaluate it further. So where it was conceivably possible to put some things into a borehole operationally, we went over and looked at the other questions.

So what that leaves us with there, that's basically small waste forms, salts, granular solids, powders, cesium/strontium capsules--and as Rod said, that's a third of the activity at the Hanford site--unpackaged DOE fuels and--so large quantities of anything--large quantities go back to the pie charts earlier--disposing of large quantities of the inventory means going to the commercial spent fuel, and that would require extensive redesign and did not get a particularly favorable response.

All right. Well, that's basically it from here. I think this might be my last slide. Before I claim it is, I better look. Yep. So restating the conclusions of this study, all wastes could go to one mined repository. No specific disposal concept required for any of the waste. There's nothing that we say that has to go to salt. We need to think more about the sodium-bonded fuels or else treat them. And we don't give a compelling basis here for choosing one medium over others. All those media that we considered are viable.

And, you know, to me that's a strong statement. We're not trying to down select. We're not trying to say it's time to decide it's going to be salt. Or it's time to decide it's going to be something else. In all fairness, crystalline repositories look like there is more work to do, but they're viable. And last point, deep borehole disposal only scores well for a small, physically small items, and they happen to, therefore, also be low volume.

And I'm happy to take questions on that.

EWING: Okay. Thank you, Peter.

Questions from the Board?

Sue.

CLARK: Sue Clark, Board. I guess, was there anything in this that surprised you?

SWIFT: What surprised me was that this hadn't been done before. I agree. I think--didn't I just state some fairly obvious things? I think so.

CLARK: Well, you say it's preliminary conclusions. What's the future? I mean, what happens when this finally--

SWIFT: Where do we go from here?

CLARK: Yeah.

SWIFT: This is--obviously, that's a DOE policy question. I know Monica will comment in a minute here. And I'll keep talking for a minute Monica, until you figure out what you're going to say.

I think simply saying that it's not time to down select, it's not time to say we must have a salt repository or we must have a granite repository. Let's keep our options open. Repositories are a fairly robust concept, and we don't necessarily need exotic waste forms to make a repository work. That's one of the conclusions of this group anyway.

There are some waste forms that people would cringe when we talk about moving them. And that may be for good reason--the calcine right as it is. If you can get it underground, fine, take it underground and leave it there. It's not a very stable waste form. It's going to dissolve quickly. But you can put it in a place where it'll still perform well. You can put it in a long-lived package. You can put it in a place where water doesn't move or moves very slowly. There are ways to do this.

CLARK: So is there any plan to increase your granularity, not so much from the perspective of trying to down select or eliminate something, but to give more fidelity to the overall considerations in each category?

SWIFT: I would welcome suggestions on that. You know, I've thought quite a lot about this, and I'm not sure how to do it without actually having a site.

At the generic level--this is not exactly answering your question, and I apologize--but at the generic level we start off by making some big assumptions about how the rock type might work. For example, buried in our generic assumption about salt is that it's impermeable, there are no pathways out of it. If you assume you have pathways out of it, your analysis looks very, very different.

And so until you get a site, things--you know.

CLARK: Well, I think one thing we've learned from Yucca Mountain is you can answer your very first question on disposal option performance by doing very expensive things like titanium drip shields; right?

SWIFT: Yes.

CLARK: So you can make anything work if you have to. And I think you just reconfirmed--

SWIFT: I wouldn't have said anything. I don't disagree.

EWING: So to follow-up on Sue's point, well, first I note that the granite, shale, and salt, just looking at the colors for the first--what did you call it--well, the waste form group which is commercial spent fuel, properly packaged.

SWIFT: Yeah. Purpose-built packages.

EWING: Purpose-built packages. So the color schemes are all the same, so at least with this granularity of analysis, as you say it's too early to pick and choose.

SWIFT: Yeah. Well, that's a great example because we interpreted the word "purpose-built" to mean we get to choose the package material after we know what the local environment is. In which case, obviously, we're going to choose a good material for that environment.

EWING: Right. So my suggestion kind of following on the heels of Sue's observation is that as I look at your 44 individuals, very distinguished group, I know many of them, it's heavily weighted towards the waste form.

SWIFT: Correct.

EWING: And yet the question has to be addressed in your analysis is what are the properties of granite, shale, and so on? So the first suggestion might be that another group probably--or could have a different perspective. And if you were considering another group, then it would be even more interesting to have people from international programs who are very familiar with clay, granite, salt because there you would have people with real experience with these geologies as potential repository sites.

SWIFT: Rod, I think that's a great idea. I'm not convinced you'd get a different answer.

EWING: Well, that's the question. I don't know.

SWIFT: And it would be a complicated and costly endeavor. The other thing is you wouldn't get--and this is why we cast the net broad on the waste form people--we wanted to make sure there weren't exotic waste forms out there in the DOE inventory that really were going to pose a problem. And you're not going to get that experience outside the DOE complex.

EWING: Well, as an example, your statement that with granites, once you lose the bentonite, then the sorptive capacity of the rock drops off. That's true in a very general way, but matrix diffusion, the trapping of nuclides, it works pretty well. And certainly the Swedes have looked at that in detail and have analyzed the behavior of their rock without the bentonite.

SWIFT: Sure.

EWING: And so having someone in the room who says well, wait a minute, it's not so simple as whether we have bentonite or not made add some insight.

SWIFT: And since you gave me a chance to talk more--thank you. I'm actually a bit of a fan of granite myself, but--however, I'm not down selecting. The way we structured this, we started out by assuming we had a fractured granite. And we started out assuming we have an unfractured and impermeable salt, so the playing field isn't level. And yet those are both reasonable assumptions. Salt is unfractured in nature, and granite generally is at those depths. So it's not an unreasonable one, but when you get into actual site-specific characterization, the granite examples are likely not to get too much worse. We assumed it had fractures; we're likely to find it has fractures. So anyway, there are some advantages to going after a granite site.

EWING: All right. So I should let others speak.

BAHR: Jean Bahr from the Board. Following up on that with the purpose-built canisters, you didn't specify what those were for the different environments just you looked at the feasibility of doing that. And another question that you could ask is what kind of purpose-built canister would you need, and are there bigger challenges or bigger investments in creating purpose-built canisters for the different types of environments? And granted, you're not doing it for a specific site, but I think you know enough generically about salt, about clay, and about granite that you could probably speculate on what kind of canister you would need for those environments, each of those environments.

SWIFT: And some of that, not specifically environments, but some of the questions will come up in Josh Jarrell's talk later.

With the observation that if you're going to build a standardized canister now, you would be designing an overpack specific to each of these environments. And actually we already have a pretty rich literature in the international community on what types of metals basically work well in what geologic environments, and we would draw on that.

BAHR: But I think that that could inform this comparison to some extent if the type of overpack you need in one environment is much larger or--

SWIFT: A little more expensive.

BAHR: --more expensive, that that might make a difference. You can say, yeah, we can put titanium canisters around things everywhere. But--

SWIFT: Cost is huge. I mean, it's not necessarily what we want to think drives this. But I think one of the biggest cost factors would just be how many packages you have to make. And so you can go to deep boreholes which have the largest number of packages, or you could go to direct disposal of the big, dual-purpose canisters which has the fewest number but which didn't score so well. And, you know, somewhere in between, you know, you can find the answer.

EWING: Right. Jerry.

FRANKEL: Jerry Frankel. I must have missed something in your introduction. It seemed you didn't analyze any scenario that would be equivalent to Yucca Mountain--

SWIFT: Right.

FRANKEL: --unsaturated, crystalline rock. So why was that then? I mean, no, just stick to the possible even if it isn't Yucca Mountain that we might have a similar geology.

SWIFT: We have a very good analysis of a Yucca Mountain analogue which is the Yucca Mountain license application.

FRANKEL: Right. So what would your evaluation look like? Would it all be green?

SWIFT: It would all be green. We submitted a license application.

BAHR: That's the answer.

FRANKEL: Okay. Thank you.

EWING: Mary Lou.

ZOBACK: Mary Lou Zoback, Board. Just a quick question. I didn't see retrievability as one of the criteria. And I'm not sure if it's under operational or security, but did you dismiss that?

SWIFT: There is a discussion in the report. I'm sorry I didn't include it here. We also--human intrusion is another one you could have asked. But we took those two out and discussed them separately because they are--they have such a large social and regulatory component that we just didn't know quite what to do with them. In that discussion we do note that, for example, sedimentary formations have a higher likelihood of having competing natural resources that should be taken into account, but we didn't know what to do with it in this context of this evaluation.

ZOBACK: And deep borehole?

SWIFT: Yes. And deep borehole would be up there, and obviously not what you want if retrievability is at the top of your list.

EWING: Okay. Sue.

CLARK: I just want to follow back up on something you said and then something Jean said. So you said that one of the things you learned is that you don't need exotic waste forms. But then at what point does one of these purpose-built canisters become an exotic waste form?

SWIFT: You're right. I'm guilty of just what Rod pointed out. I'm sliding my definition of waste form from the old version to the new version. You're right. We do treat the canister itself as part of the waste form here. And the difference would be that we're not considering any canisters that aren't already being considered by some program in the world. So copper, iron, the alloy 22 from Yucca Mountain, you know, they--there is a pretty good basis for those.

EWING: Other questions from the Board?

Jerry.

FRANKEL: I just want to clarify. So you know, you have, for instance, the dual-purpose canisters are yellow in your two best scenarios. But that would be green for unsaturated, mined crystalline--

SWIFT: Oh, I'm sorry. Absolutely not. Because that wasn't the Yucca Mountain licensing basis. You're right. That would have to be blank in Yucca Mountain. That is not feasible because it wasn't in the licensing basis. You're right.

FRANKEL: But you could make an assessment.

SWIFT: I was being too or--

FRANKEL: You could have made an assessment, an equivalent assessment. And again, are you assuming then that any similar type of geologic formation would be similar to Yucca Mountain? Is that right? So, you know, a category that's not listed here and didn't need to be analyzed because--

SWIFT: I would say Yucca Mountain is probably an okay analogue for other hard rock, unsaturated settings. But you're right. We haven't actually looked too hard at that. That's not one of our research focuses because it's so close to Yucca Mountain.

One other point just quickly to make there is that Yucca Mountain did look at the question of taking dual-purpose canisters directly into Yucca Mountain. That was evaluated several times in the late 1990s, and again in the early 2000s, and then again in 2008. And each time they concluded that it was better to go with a slightly smaller package. And what we ended up with, so-called TAD.

FRANKEL: So the readiness of, for instance, salt being moderate or clay, you know, a lot of yellow in the readiness whereas for Yucca Mountain would be green.

SWIFT: Yes.

FRANKEL: Because those waste forms--waste groups aren't relevant, haven't been studied in those--

SWIFT: There was one--

FRANKEL: All I'm saying--let me just finish this--is that for instance, Sweden has done a pretty good job of analyzing clay, and Germany, salt. So are you suggesting that the analysis of Yucca Mountain exceeds their analysis in terms of technical readiness, or it's just that they didn't look at those kinds of waste groups?

SWIFT: Most of the rest of the world does not have things beyond Waste Group 3. I mean, there are--other countries have research fuels, and the French certainly do have a pretty broader range of things in their inventory. But basically from Waste Group 4 on down, we're dealing with things that are unique to this country.

And one more point of clarification, the sodium-bonded fuels, in the end they may have been qualified to be in Yucca Mountain--the treated sodium-bonded fuels, sorry. They'd be up in here. They have been qualified to be in the Yucca Mountain inventory, but they weren't actually there. So we can't say Yucca Mountain could have taken them. Presumably there would have been an amendment proposed to the

NRC to take them at some point in the future, but the 2008 license application did not include them in the inventory.

EWING: All right. Any questions from the--well, sorry.

Sue.

BRANTLEY: Isn't it--this is Sue Brantley from the Board. Isn't it safe to say that if you were to look at the unsaturated zone tuff at the same level of, you know, detail as you did here, then you would have a diagram that looked somewhat like this. In other words, you can say that the license application would have filled this mostly with green, but that was because you spent however many years studying it and putting in--you know what I mean? Like, it's not really a fair comparison.

SWIFT: All right. It's not. We did spend 20 years studying Yucca Mountain.

BRANTLEY: So, I mean, in terms of Jerry's question then, it would look something like this. It would have--if you did the same level of study.

SWIFT: All right. Okay. Let me try it this way. If we hadn't done 20 years of work on Yucca Mountain and we proposed it right now, I think you'd see a lot of yellow on it. We worked off those yellows over all that time of working on it. If you took one of these concepts and tried to talk it all the way through to licensing, I think probably the DOE would want to see a lot of green before they actually were willing to submit a license application.

So it is a function of the years of work put in on Yucca Mountain, and I think confidence would have been low relative to these 20--oh, I can't say that either. I wasn't there 20 years ago. I won't say it.

BRANTLEY: And, you know, isn't the take home message--I mean, this is what I'm thinking, but do you agree? You have put together a group of people that their expertise is in the waste form, and then you did this evaluation. And it seems like the take home is that the multiplicity of waste forms isn't really what's important in terms of where we should be looking and putting all of our effort. The multiplicity isn't really going to be where the hang up is.

SWIFT: Personally, I agree with that. The team wasn't all waste people. I'm a geologist myself. David Sassani is. Bill Boyle is. We had plenty of--

BRANTLEY: Okay. Well, that was my mistake then.

SWIFT: We had plenty of repository experience in the room.

BRANTLEY: I got that from the conversation earlier. I apologize for that.

SWIFT: No. But basically I do agree with you. Fundamentally I believe that repositories are a pretty robust concept. And once you've got one that is safe for some of these waste groups, it's probably safe for nearly all of them.

EWING: Okay. One last question from the staff.

BAHR: Can I just follow-up on Sue's?

EWING: Okay.

BAHR: You did 20 years of work on Yucca Mountain, and you turned things green for a specific site. But do you think that if you went to another unsaturated, hard rock site that was not Yucca Mountain, you could immediately fill all those boxes with green?

SWIFT: No.

EWING: So Peter, thank you very much. And we should move onto the next speaker. All right.

This is Joshua Jarrell from Oak Ridge National Laboratory on the standardization of the nuclear waste management system.

JARRELL: Hello everyone. I'm Josh Jarrell. I work at Oak Ridge National Lab, and I appreciate you inviting me here to talk the last presentation of the day. I'm going to talk about the potential to integrate standardization into the nuclear waste management system. So I'm going to go back to the commercial use fuel after we looked at all sorts of nuclear waste in the last two talks.

So first I want to note that this is a technical presentation. It does not take into account the standard contract. And according to the standard contract, DOE does not consider spent fuel in canisters to be an acceptable waste form, absent a modification to the standard contract.

So the current dry storage inventory is very diverse. I think we've heard that in the workshop over the last two days. As the pools at reactor sites started to reach capacity, they're been re-racked, reached capacity again, and then the assemblies have been moved out of the pools into dry storage. There have been 26 designs the NRC has looked at for dry storage, five of which were cask, 21 of which are these dual-purpose canisters systems.

I want to just clarify we use the word "cask" and "canister" throughout. When I mean canister, I mean the actual stainless steel metal liner which is this with a basket that you would put assemblies into. And then it would go into a storage overpack or a transportation overpack. A cask is generally all kind of one piece. It has the shielding in it. And we talk about bolted cask systems.

So there's many different designs. There's many different sizes. With those designs, they range anywhere from 10 feet to up to 16 or 17 feet. They've ranged in weight from anywhere from 25 to 30 tons to over 50 tons. And the storage may be either horizontal or vertical.

So a horizontal storage module, these are done by Transnuclear, and so the metal canister will actually get slid into the HSM. And then a vertical storage unit looks like this. They're vertical. And both NAC and Holtec use a vertical storage system.

There's three main vendors today. I'd say these percentages are changing. It's a competitive business. But each of the vendors has multiple designs, and they continue to bring multiple designs to the NRC for licensing.

And so again, very diverse inventory. And one of the reasons that we have such a diverse inventory is because we don't have an integrated waste management system right now. Each utility makes decisions based on their own site-specific needs. And this has to do with the reduction of dose to their workers, reduction in costs, and reducing the number of operations, maybe cask lifts. So the utilities are really focused on dry storage.

Because there's no recognition of this disposal in the current system, the utilities have optimized on dry storage, not transportation, not disposal. And this has resulted in larger and larger DPCs. The DPCs I'm going to talk about, they can either be PWRs or BWRs you can put in them. But I'm going to talk about generally PWRs just because it's an easy reference point. They range in size from about 21 PWR assemblies in a cask to upwards of 32 and now 37. And as these DPCs have gotten bigger, the thermal loads in them have grown. And the issue with a larger thermal load is that it may not be transportable for many years. So there is a higher storage limit on heat loads than transportation limit.

And, for example, this is a plot from Sequoia of a 32 PWR NPC. I think we can read the axis. And the storage limit is up here, about 28 kilowatts. The transportation limit is 20 kilowatts. And so they were loaded around 24 kilowatts. And it took about ten years to get down to 20 kilowatts. Now, if they were loaded closer to 28 kilowatts, it would take longer. And this--the even bigger canister sizes, these 37 PWR, Jeff Williams mentioned in the workshop last week, are on the order of over 40 kilowatts is their limit for storage. So they may have to sit for 40 plus years before they are ready for transport. So that's one issue for the DPCs.

Another issue that we've discussed over the last days is that if you don't use the DPCs for final disposition, if direct disposal is not found to be feasible, the DPCs are really an extra cost on the system. Not only do you have to purchase the DPC, you have to load it, then you have to repackage the assemblies in the DPC into some disposal canister. Then you have to get rid of the DPC generally probably as low-level waste. So that's an extra cost to the system that would be avoided if you could be loading these disposable canisters initially.

And when I talk about disposable canisters, what

I'm really thinking about is a standardized canister system that could do storage, transportation, and disposal. And this is a method to introduce integration across the system.

So canister systems, the complete system, are not the only place that standardization could be used. You could introduce a standardized storage overpack. You could either have a single vertical storage overpack for all canisters if that was possible. You could potentially have a vertical and a horizontal overpack, or each vendor may be able to develop their own standardized storage overpack. And this would simplify the operations at a storage facility or repository aging pad just from a perspective of less equipment that would be needed, simplified procedures, and training for the workers there.

Another option is for a transportation standardized overpack, a single overpack potentially for all canisters, or for each vendor. And these benefits include simplified receiving operations at any waste facility that would be accepting these packages, be it a storage facility, a repackaging facility or repository.

Simplified rail car designs and operations, the rail car is a challenge right now. And having a standardized overpack would greatly simplify the development of the rail car, and you could reduce the total number of inventory of overpacks. So there are a few canisters that would have just a single overpack that would only--transportation overpack that would only be able to be used a handful of times and no longer used. If you had a standardized overpack, it could be used over and over again, and, therefore, you could reduce the amount of inventory of the standardized overpacks.

And so but the really big opportunity for standardization that we think about is a complete canister system. So that would include the canister, the overpacks, and any equipment needed. And there are a number of potential benefits from standardization of the canister system.

Reduced overall system costs, I'm going to talk a lot about system costs, and we want to focus--when we think about standardization, we want to think about a top-down approach to system costs. So this would be the cost of the entire system, not just individual pieces throughout the system.

So like I mentioned, you could avoid these extra cost of DPCs that are not part of the final solution. There's also operational efficiencies that you could gain which would include--well, operational efficiencies including training procedures, not having to deal with what we call these cats and dogs of 26 different designs; increased flexibility or reduced sensitivity to future decisions or changes to the waste management system; simplification in waste handling and licensing at a storage, repackaging, reprocessing, or repository system including reductions in the amount of equipment, procedures or training. You could also--another potential benefit is reducing the uncertainties associated with waste acceptance and how the system will perform, and you have the potential to minimize repackaging requirements and the cost and dose associated with them.

And this last point is a time-dependent point. This is a benefit that is going to be maximized the sooner we do standardization. And what I mean by that is in this image the blue line is what we project the actual discharge through 2060. So we're looking at about 140,000 metric tons. And the orange/yellow line there is the amount in dry storage right now.

Our current status quo is to continue to load DPCs generally. Right now there's only about 20,000 metric tons out of well, right now there's about 70,000 metric tons. 20,000 of them are in dry storage, and 50,000 is in wet storage. So there's still 120,000 metric tons that do not necessarily have to go into DPCs. Now the longer we wait, the more goes into DPCs, into dry storage. So if you wait until 2035, you have 70,000 tons or so in dry storage. Now, you still have 70,000 tons that you could avoid of DPCs worth of extra cost you could avoid in 2035. But this is a diminishing return on investment.

And so, you know, the when is really important, and the where is also important. And, you know, the when, this reduced return on investment really is something we need to think about. But I'll note that without disposal requirements, it's a challenge to design and incorporate a waste package function with certainty. So what I mean by this is if we had a--if we moved to a standardized package right now and it turned out that it was the wrong standardized canister system, we would be running this system suboptimally. So without disposal requirements, there's this potential.

Like I mentioned, the where to incorporate standardization is also important. If you incorporate it at the operating reactors soon, the extra costs of DPCs could be avoided. But we want to recognize that there's what we'll call an "assembly throughput" at reactors. And what that comes down to is the reactors have only so long to load a dry cask. And loading smaller casks may impact their ability to remove assemblies from the pool as fast as previously. So we need to recognize there is the potential to impact what we'll call the assembly throughput at the reactors.

So once the reactors are no longer operating, the assembly throughput issues are dramatically reduced. They have access to the pools more. They have access to the equipment, so you could do it once they shut down, you can start loading these standardized canister systems. So there would be some extra costs from the DPCs if they continued to load while operating, but once they shut down, there would be the potential then to load standardized canisters.

And finally you could do it at an interim storage facility. There would be significant extra cost if everything got loaded up into DPCs before it moved to a storage facility or a repository, however, this extra cost could be minimize if you could begin bare fuel transportation directly from reactor pools. And what I mean, bare fuel, what I'm talking about are transportation bolted casks that are meant to take assemblies directly from reactor pools and move them somewhere else, a storage facility or a repository generally. There's issues associated with that, but that is the way that you can mitigate some of the extra cost risk of doing this standardization at a storage facility or a repository.

So this is not the first time that we thought about standardization. In the 90s the DOE developed or looked at a multipurpose canister system as a way to consolidate--or sorry--as a way to integrate the waste management system. And then in the 2000s they developed this TAD design which has been mentioned a few times. TAD is just Transportation, Aging, and Disposal Canister, and it was seen as a way to integrate the waste management system. And I just want to note here that in 2007, NEI stated the industry supports the TAD initiative for a number of the benefits that I mentioned earlier in the presentation. And they also note that this would increase stakeholder confidence that on-site storage is temporary. So they recognized that this was the first step toward integrating the overall used fuel management system.

Now, this was 2007, and they had the advantage of a known geology. Things have changed since then, but there still is a desire to pursue standardization. So the Blue Ribbon Commission came out and said we should promote better integration of storage into the waste management system including standardization of dry cask storage systems.

NEAC in 2013 said a new standard recognize storage, transportation, and disposable canister should be developed for the large amount of fuel in the cooling pools. And this Board in 2007 recognized some of the potential benefits, including safety, handling, system simplification and cost. And at that time they did note that TAD designs should be of the same size as the dual-purpose canisters being used.

And so there's also opposition to some of the standardization. In 2011, NEI, which you'll remember in 2007 was pro TADs, had changed their thinking there and said they do not agree that standardization will improve the waste management system and reduce overall cost. And they were really focused on until the requirements for the disposal of the waste package are specified. So without a repository, they did not support it.

EPRI had a similar statement in 2011 to the BRC that said useful standardization can only be done with the details of storage and disposal in hand. And they recommend the current industry approach of independently selecting the storage and transportation systems.

So in this past fiscal year, the NFST, the Nuclear Fuel Storage Transportation Planning project, led by Jeff Williams asked advisory and assistance contractors to look at a standardized canister system, a STAD design. Two contracts were awarded. There was an Areva-led team and an EnergySolutions-led team. Each team developed a design concept for a STAD or a family of STADs with the help of utilities and cask designers on their teams, and they performed some system analyses.

So first I want to--they came out with a few major recommendations. So Areva's first recommendation was carry forward three canister options through the preliminary design phases. So basically, keep your options open because we don't know the repository characteristics. And I want to highlight here that their sizes; they said a small, a medium, and a large, but their small was a single PWR which would provide the most flexibility, and their large was a 21 PWR.

So Energy Solution actually came back with similar recommendations. They suggested a small, medium, large, but their small was 4 PWRs and their large was 24 PWRs. So similar recommendations but they did not agree on the sizes.

Now, the point they did agree on was realizing the need to maximize assembly throughput at reactors. And I noted this earlier, but currently the utilities have small windows, a few weeks, generally, per year devoted to their dry cask loading campaigns. The rest of the time is used--the cranes and equipment and space is used for other purposes devoted to operating and producing power and making money for the utilities. And the current procedures--and looking at the designs that EnergySolutions and Areva suggested, with current procedures, small canisters would take generally the same amount of time to load as larger canisters. So even though a smaller canister may only hold four assemblies, it's not necessarily going to be--and a large canister may hold 32, it may not necessarily be eight times faster for the process. And so the impact for assembly throughput is there.

And if those windows are impacted, the operations could potentially be impacted. And so both Areva and EnergySolutions said wait until the reactor shuts down before moving forward with standardized canisters at reactors. And EnergySolutions specifically said that once an operating site is shut down, the site operator will have flexibility for loading the fuel from the spent fuel pools into the canister.

And so both of these reports really highlighted two big issues: assembly throughput and lack of disposal requirements. And so we think right now is a good time to change the way that we're thinking about this. Let's change this conversation. So we realize that assembly throughput at the reactors sites is a key challenge and we get it.

And so can we work with industry to address some of those concerns? Can we mitigate some of those issues? So are there types of innovation or research that could be looked at? There's been ideas of canister-in-canister designs where you'd have maybe four or five small canisters and a bigger canister. Then maybe the throughput could be faster.

Are there faster methods for welding or drying these canisters? So that's something we would like to look at.

Are there ways to do some operations in parallel? Can we drive--can you drive five small canisters at the same time. So there's not a serial process.

Or could you reduce the operational impacts inside the building? Is there ways that you could free up some of the equipment such as a crane at some of those times? We want to get at those points because we want to think of ways that we can mitigate that impact.

The other point that was brought up was that standardization has risk without disposal requirements. So we want to change the fact of we can't do anything until we have disposal requirements to--what's the result? What are the impacts if we move down a path and then later on we have to change what we're doing? And so what I'm thinking here is what if we decided to load small canister for ten years and then realize we could have loaded big canisters? What is the impact to the system as a whole by doing that? And vice-versa, we continue to load large canisters, and we realize we can't dispose of them. And so we have to switch to small canisters. We need to understand from a cost perspective, from a dose perspective, from an operational perspective what some of those impacts to the system are. Not, we can't do it, but what are the impacts of moving forward with some of these options?

So we think right now that the status quo is working so you don't have an integrated system. And we think now is the time to start laying the groundwork for an integrated system. So let's use this period what I'll call uncertainty in the back end of the cycle to look at some systematic analyses to form a basis for future decision. Let's do some analysis. Let's lay the groundwork that says, you know, what are the impacts of moving out in one direction and then that changes? We need to understand that.

So there are a number of questions right now I think we can answer or I think we can look at and hopefully answer. I'm going to go through here, just pieces of the system, and then I'll talk about some of the questions from a system holistically.

The canister, we need to look at what are the performance requirements at an operating reactor? You know, what is the assembly throughput that they're generally seeing? What are those requirements? What are some of the requirements at the repository? And then we need to think about are there innovative ideas for improving canister designs in both requirement sections or the canister processes that I mentioned earlier?

From an overpack perspective, what are the cost/dose/operational benefits of the standardized overpacks? We haven't done the analysis, but we can definitely answer that question. And then are these overpacks technically feasible and licensable? Can you make a transportation overpack that would fit any canister system using spacers? You know, we just don't know right now. And then from a timing perspective, when should these things be deployed? What are the impacts of deploying them later versus earlier or changing them down the road? And then also a location. Where should these canister systems be deployed?

So these are the individual pieces to the system that I think have some questions that could be answered. But from a total system's perspective I think there is--we need to look at the operational effects of loading small canisters. It's not just a cost perspective, but you're going to have more transportation. You're going to moving more canisters around. You're going to be building more canisters. So we need to understand some of the operational effects of having--are we able to load that many small canisters or receive that many small canisters? Can we mitigate some of those effects?

And then the total system cost, you know, what are those really sensitive to; the sizes, the numbers, you know, how many overpacks, the cost of the overpacks, when we do it? So we really need to get a handle on what the sensitivities are of the system to the different variables that we're able to change.

So we need to understand also the benefits of avoiding repackaging. I know we've talked about some of the dose associated with potential repackaging. But we want to get a handle on that and look in on that some more.

And then finally I think I've mentioned this a few times, you know, how would a system with standardization be able to respond if requirements change? And I think this is the really important thing. How flexible is a system that employs standardization? And so I think now is the time to answer some of these questions. You know, I mentioned earlier, we have current concerns. Assembly throughput at reactor, that's an important issue. There's--we don't know the disposal requirements, and there's this debate over should you move towards standardization or shouldn't you?

And so to move forward we think we need to perform a quantitative assessment, a systematic quantitative assessment of different options to understand the impacts. And we think this will establish a basis to help future policy decision in regards to standardization. And like I said, this type of assessment would compare different scenarios. Again, I'm highlighting this again, but these scenarios will include what if we are wrong scenarios, the flexibility of a system that has standardization. We really need to get a handle on that.

So this is what I think we're looking at is this quantitative assessment, and so I just to want lay out the steps toward this assessment. You know, we want to develop a team. We want to get a group together to look at this. And then we want to--the first--well, the most important step is to get this plan nailed down, so define which scenarios and assumptions should be looked at. And then we need to develop a metric to determine how we can compare the results of those scenarios.

Then we would need to look at what capabilities and tools we have and do those need to be improved to do these types of assessments? What type of information and data do we need, or do we need to verify? These things part of the plan.

We want to then develop some enveloping design requirements, and we'd like to look at that for potential disposal media. And then look at operational performance requirements at reactors, and then initiate some generic designs based on those requirements. And then we need to initiate any activities that will help improve our level of confidence in some of the information that we need for the assessment or some of the targets--sorry, the challenges that we've noted in the assessment.

You know, once we've laid out the plan, we want to execute the plan and those activities associated there. We want to do the analysis and understand the sensitivities in that analysis.

The next point I think is key is to have an external type of review that looks at the assessment that we've done and makes sure that we're on the right path. The scenarios make sense. That we're doing--the data is accurate.

And then finally, we're going to finalize those results providing a quantitative--that's the metric--and qualitative comparison of the options. And so we think that once we're done with this, we'll have laid the groundwork for providing a basis for future policy decisions in regards to standardization and integration. We're going to get a lot more information about how the system would look with standardization. And I think now is the time to do that.

But I want to leave here with this final conclusion--well, not leave here, but finish my slides with this conclusion that any change to the waste management system would be a major policy decision. That's a big deal. And you've got to have a firm basis for it. And I think that our quantitative assessment is the first step towards that basis. So that is all, and I will take your questions.

EWING: All right. Thank you very much. Let me ask the first question. So you've posed all the questions. You've outlined the steps to getting the answers. So what's the status of this effort?

JARRELL: We are in the process of getting our team together to develop the plan. This has just started.

EWING: And how long will it be before you have results to present?

JARRELL: We hope to have a preliminary assessment results by the end of the fiscal year, so the end of September.

EWING: All right. Thank you.

Efi.

FOUFOULA-GEORGIO: Efi Foufoula, Board. So if we did a word cloud of all your talk, cost would come as a big word there. Probably second one will be overall system. Safety will not appear at all. I think safety showed one time in the Technical Review Board 2011. So if you were--I mean, if you present this as the framework within which policy decisions will be made, it will not only be cost. So how--can you give us some insight? How you incorporate in the same qualitative and quantitative way, safety metrics?

JARRELL: Well, I would say from a safety perspective, you know, there's one thing. There's dose. All right. That's a big thing that we're thinking about from a safety perspective. There's the actual, I would say operational safety impacts from loading more canisters or less canisters, so there's some operational safety impacts as well as some dose impacts that I think you can quantify. By I would be more than happy to take any other ideas for other ways to quantify different safety impacts.

EWING: And just to follow on and throw you a very difficult question, once you calculate dose in operations, of course, finally successful disposal is the question. And so how would you weigh the dose that results in 100,000 years from a geologic repository, how would you weigh that against dose today?

JARRELL: Well, I don't think--

EWING: You don't need to give me the answer, I'm just saying that's--

JARRELL: So one of the pieces there is developing of metrics, of how you would do this. And so I would hope the team could come together and we would think about that, absolutely. But that's not something I can answer by myself.

EWING: Right.

JARRELL: This would be a team thing. We would to want think about that, but we absolutely will.

EWING: All right.

Sue.

CLARK: So Sue Clark, Board. I just--on your previous slide you say you want to provide both a quantitative and a qualitative comparison, and on the next slide you say it must have a firm basis and it must be quantitative. So what's this qualitative thing that you're talking about?

JARRELL: Well, you want a quantitative thing too, but you do need a qualitative piece to this. You need to be able to, as a team, look at things not necessarily just from a numbers perspective. So--

CLARK: You have to have a firm basis.

JARRELL: Right. But then that's quantitative. But there's also a qualitative and we've talked--I mean, other people have talked about comparing different options. And there's going to have to be some qualitative comparison.

Somebody is going to have to come up with those metrics.

CLARK: And it will have more fidelity than the other qualitative analysis we saw; right?

JARRELL: Sorry. I'm going to--

CLARK: Since you haven't done the work yet, I would encourage you to try to have more fidelity. Okay?

JARRELL: Okay. I will take that into account.

NOZICK: Linda Nozick, Board. Who's on your team? Not people but organizations.

JARRELL: We have a number of national labs that we are--we're in the process of developing that team right now. And we plan to have people from around the DOE lab complex as well as members of the Nuclear Fuel Storage and Transportation Planning Project as well as government subcontractors and people that have knowledge of some of the industry and vendor concerns.

NOZICK: Yes. So my concern is really the industries. Yeah. There can be quite a bit of differences around here, and you might end up missing some--a solution might look good on average, but there's a whole big population it wouldn't fit for one reason or another.

JARRELL: Absolutely. We definitely want to make sure we incorporate the industry perspective on the initial team as well as external reviews. You know, I think it's been very clear that I'm trying to recognize that assembly throughput is a big deal. The industry really cares about that.

NOZICK: Right.

JARRELL: So as we're doing metrics and moving forward, we definitely want to capture that. And we do have people that we're trying to bring onto team that have experience with that.

NOZICK: And will you be able to say something about the cost impacts to the utilities for whatever your new standardized plan looks like? Where the costs might occur in the system as this transition occurs.

JARRELL: Right. So we--I mean, we want to look at this from a total system perspective.

NOZICK: Right.

JARRELL: But I do think that at the end of this you would have those types of comparisons.

NOZICK: You're going to have to be able to answer that.

EWING: Steve.

BECKER: Steve Becker, Board. Just a follow on. Josh, I suggest following Linda's question and some of the other lines of questioning that your step 4 would be best moved up prior to execution so that you have an opportunity for the standardization assessment plan to be looked at by stakeholders and by independent experts prior to its execution.

EWING: Paul.

TURINSKY: Yeah, Paul Turinsky, Board. Your third sub-bullet under two, are you going to have an enveloping design requirement that covers all eventual geological formations? Or are you going to have one for clay, one for salt, et cetera?

JARRELL: I would hope that we could--well, it's a good question. The team will come together and look at--that--if there is a way to do an enveloping design over everything or if it's going to have to be a media-specific.

TURINSKY: Well, if you do envelope and you try to do all three geologies, I think you can wind up with a billion-dollar cask.

JARRELL: Okay. We will consider that.

EWING: Other questions?

Jerry.

FRANKEL: Jerry Frankel. First of all, I loved the presentation and the, you know, the enthusiasm. It's easy to be enthusiastic when you know you're right as you obviously do. Were you around on Monday and Tuesday in the workshop?

JARRELL: I was.

FRANKEL: So it seems to me as I look at this that doing this in the absence of a similar analysis for, you know, ignoring standardization but direct disposal or repackaging is kind of senseless. Right? You have to--why isn't this type of quantitative analysis being done for these other scenarios using some assumptions which you're going to have to make anyway here?

JARRELL: I do think there are--I mean, there is ongoing work looking at direct disposal. I don't know the details about that. I don't know if maybe Bill or John could speak to the level of detail for direct disposal.

BOYLE: William Boyle, Department of Energy. It's a good suggestion. We, on the direct disposal side, we're focused more on the technical challenges not going to this next step of well, what are the benefits?

One thing to consider with respect to the comment by Professor Becker, moving number 4 up, maybe one of the comments is okay, consider a standardization of the existing DPCs; right? It is a way of standardization, and then it gets--it addresses your concern as well. I don't know if that will happen, but that's a possibility.

FRANKEL: It's just that any comparison is going to have to be compared to what? And if you don't have that same level of analysis on the alternatives then--

JARRELL: Right. I definitely think one of these scenarios will involve large, dual-purpose-sized canisters.

EWING: Jean.

BAHR: Yeah. Just following a little on Paul's question. I wonder how different would the optimal package be in different environments. Is it really just a question of size? Or is it really a question of composition? Or could it be that you could vary disposal overpacks at the end of this but have a standard canister for--that wouldn't have to be repackaged. It would just have to be overpacked but that would serve all of those systems. And I don't think--I don't have a clear idea of how different the requirements might really be for different kinds of repositories. We keep hearing that we can't make any of these decisions until we have a repository, but are they really that different?

JARRELL: I think, well, I think a number of people actually have touched on this kind of throughout the day, but my personal view is hopefully that you could do different overpacks based on different media. But to be honest, I don't know the real details there. I don't know maybe Ernie or Rob, do you want to add anything?

HOWARD: Yeah. I think you--this is Rob Howard, Oak Ridge National Lab. You hit on the two points, the internals, and those would probably be associated with criticality control and chemical interaction in the waste form to whatever the fluids are that would eventually come into the waste package, and then the overpacks. So I think in all of our standardization thoughts to date as well as the DPC disposal thoughts to date, we would contemplate some sort of disposable overpack. Now, the performance allocation, if you will, to what that overpack had to do in the total system--the repository total system would be variable depending on the repository design.

EWING: Other questions from the Board? Staff questions?

All right. Thank you for your enthusiasm. Good luck with this analysis, which we need.

We've come to the end of the day, but not to the end of the comments. So this is where we go into the public comment session. We have two people who have signed up.

So first, Judy.

TREICHEL: Judy Treichel, Nevada Nuclear Waste Task Force. First, I have to say, I would like the weapons complexes to stop making nuclear weapons today. And I'd like to hear a shut down plan for nuclear reactors. So I want to stop making waste. I'm not cooperating with the generation of more waste when I give opinions.

The first thing that would happen if you knew when you were going to stop is you'd know how much waste you were going to have, and you'd know what it was. And I think we've seen over the last three days terrific cart and horse problems. Nobody knows what's at one end, and nobody's too sure about what's going to happen at the other end. And so the way--the only thing that we really know is that the pile of waste is growing, and we're not sure what we're going to have when we get done.

But it seems to me very hopeful that there is research being done right now on the waste, on its character, on its long-term--what you can hope to expect or what--to try and reduce the kinds of surprises that you may get if you have waste stored or have a disposal site. So I think it's very good that there is work being done on that.

But at the same time, I think that there should also be the establishment of the regulations by EPA and NRC. And of course, the Board has nothing to do with that. But at a time that there is a search for volunteers to have consensual sites, I think you should be able to go out and say with the basis of this research, here are the geology types that we think might work.

And I guess preceding that, it would be great to have a map that shows the U.S. And you could tell people we're looking for areas, and these are the sorts of areas that we think work rather than waiting for people to come up and say we've got a tribe or we've got a county, and we'd love to have some money. So do you think you can make this piece of ground work? I think it should go in the other direction. But when you get there, you'll know something about that ground because you will have done this research. You'll have made the map. And then if you have regulations, you can tell people what the rules are.

At Yucca Mountain for 30 years we watched people changing rules as they ran into barriers or impediments or whatever, and that should never happen to people again. They should consent or volunteer knowing what the rules are, and if they can't be met, then whoever showed up with the great idea goes away.

So I would just say that I think some of the stuff that's being done is good. I don't want anything done that just helps the generation of waste. So thank you.

EWING: Okay. Thank you, Judy.

The next person is Kevin Kamps.

KAMPS: Good afternoon, everyone. My name is Kevin Kamps. I serve as radioactive waste specialist at Beyond Nuclear, and I'm also on the board of directors of Don't Waste Michigan representing the Kalamazoo chapter. And I largely second what Judy just said about putting a cap on the problem, both on the nuclear power side of the coin and on the weapons side of the coin.

It's hard to comment on the trees after three days. I was here the whole day on Monday and most of yesterday and just caught the tail end today. But there were a few things I wanted to comment on.

With the news of NRC resuming the Yucca Mountain licensing proceeding, at least partially with what little money is left, it seems like there are some people who have not given up on screw Nevada, you know, after all these years, going back to 1987. But something that occurred to me yesterday as some comments were made about, for example, public service commissions not approving smart canister designs in the present because it costs more. The phrase occurred to me, screw the future. That's really what a lot of our groups are concerned about. But it's not just future generations that are at risk.

I come from West Michigan. And at the Palisades Atomic Reactor where I got started in these issues in 1992, it's such a microcosm of the problems. You've got serious degradation of the pool itself in terms of neutron absorption. NRC wouldn't divulge the details for security safeguards for some reason, but they have cited the company for that over recent years.

You've got dry casks there, the ventilated storage casks, VSC 24s where the quality assurance is negligible, very dubious. We've known that since the mid 1990s. You've got a cask pad, that has--this is the one nearer the lake that's at risk of liquefaction in an earthquake. To the best of our read it's in total violation of NRC earthquake safety regulations. And we have Dr. Ross Landsman who's the retired NRC dry cask storage inspector for the Midwest who called that to our attention in 1994. Those casks are still there even though there was some indication they'd be moved.

There's a defective cask on that old pad that was loaded in June of 1994, and incredibly the company said that they would unload that cask to live up to its word, not only to the public but under oath in court. That if there were any problems with cask load--with loaded casks they would simply move the waste back into the pool. So next June, that will be 20 years ago that a cask with defective welds is still sitting fully load on that pad. But the newer pad at Palisades is also in violation of earthquake safety regulations, the transmissibility or transmission portion of the regulations.

So I just wanted to counter what Rod McCullum from NEI said yesterday, that they're just going to keep loading canisters into the foreseeable future. And the figure was just given in the last presentation of 140,000 tons. And I think to, you know, to quote one of our Board members, Dr. Judy Johnsrud with the Environmental Coalition on Nuclear Power who's been at this issue since the early 1960s, over 50 years. This may be a problem, radioactive waste, that's beyond our ability to solve, at least in any good way. And I think it's remarkable that some, you know, 71 years after Fermi fired up the first reactor in the Manhattan Project and 56 years after Shipping Port started up, I can imagine that a lot of these same discussions and questions were asked by NAS in 1957. So it's just remarkable to me that we're still kind of back at square one in a lot of regards.

But some good news I got to stand on is that Judy's point about stop generating commercial radioactive waste, there's been some good news this year. Kewaunee was the first one to announce closure, San Onofre two and three, Crystal River in Florida, and although it's still operating right now, Vermont Yankee. And I think there is a longer list of reactors that are right on the brink of closure. And that's going to cap this problem, and so at least that. The reactor risks go away, that's tremendous.

But the radioactive risks that remain, hundreds of environmental groups for over a decade now have been calling for hardened on-site storage which is a phrase Dr. Arjun Makhijani was here the first two days from Institute for Energy and Environmental Research. He coined that phrase at a gathering in April of 2000 in Connecticut, right on the eve of the big Yucca Mountain votes in Congress as an alternative to that bad idea.

But of course, you know, now we're looking at 70,000 metric tons of commercial waste that's already been generated. We can't undo that. So what is an interim safety and security upgrade? That's what we're getting at, is hardened on-site storage. Move the waste out of the pools into casks that are at least living up to earthquake safety regulations for one thing, that are designed against terrorist attacks, other security threats, have basic monitors on them, are in appropriate places. I mean, there's a lot of places where this may not be appropriate. Prairie Island, Minnesota, always tops that list. But the Lake Michigan shoreline, drinking water supply for tens of millions of people.

So I guess that's what I'll end on is that we need to stop making radioactive waste. And for what exists, we've long called for immediate safety improvements. And I think the just begun fuel removal at Fukushima Daiichi Unit 4 is a warning that we should be doing this before catastrophe strikes.

There's a reactor in Michigan that has a lot in common with Fukushima Daiichi Unit 4. It's Fermi Unit 2, a Mark 1 design that can't get the high-level waste out of its storage pool because structural welds were not put in place 40 years ago to support the weight of the crane and the 100-ton transfer cask. They've had dry cask storage permit for several years now. And presumably they're putting those structural welds in place so that that fuel move to the dry cask can happen.

But I guess one last thought I do want to comment on. I didn't know that figure until the last presentation about what fraction of the dry cask storage business Holtec has. That's very troubling because I learned of problems with Holtecs on January 1st, 2003, when I first met Oscar Shirani, who is a--unfortunately, he's not with us any longer. He died in 2008, but he blew the whistle on Holtecs within the system starting in 2000.

He led a quality assurance inspection, a Holtec user's group inspection, of the fabrication and design at U.S. Tool and Die in Pittsburgh. And it's a long story, but one of the things that happened according to Oscar, if his word can be trusted--and I very much trust Oscar's word--was that his signature on the sign-off, on the QA audit was forged in August of 2000 I believe it was. He never signed off on quality assurance on the Holtecs.

I sat with him for two days at the Office of Inspector General at NRC as he gave his testimony to three NRC investigators who said they didn't disagree with his observations but could see no wrongdoing by NRC. So Oscar's phrase was he questioned the structural integrity of the Holtec sitting still let alone going 60 miles per hour down the railroad tracks of this country.

So I think there's some serious problems with dry cask storage in this country. And a lot of this is coming out at the nuclear waste confidence public comment meetings that are happening tonight in California and a couple days in California. There's a few left before the December 20th deadline. So a lot of folks are trying to get the site-specific concerns on the record of that proceeding.

Thank you very much.

EWING: All right. Thank you. So this brings us, unless there's--let me ask, are there any other comments? All right. So this brings us to the end of today's open meeting. I want to thank the audience, particularly those of you who have been with us for now three days. And I have to thank Bill Boyle for three days of talks in one day. So thank you very much. And we appreciate the input and the interactions. And enjoy your evening and drive safely going home. 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 Technical Workshop held on November 20, 2013, in Washington, DC, taken from the electronic recording of proceedings in the above-entitled matter.

December 15, 2013   s/Scott Ford

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