

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD

SPRING 2014 BOARD MEETING

Wednesday
March 19, 2014

Marriott Hotel
Sandia Meeting Room
2101 Louisiana Blvd. NE
Albuquerque, NM

NWTRB BOARD MEMBERS PRESENT

Rodney C. Ewing, Ph.D., Chairman
Jean Bahr, Ph.D.
Steven M. Becker, Ph.D.
Susan L. Brantley, Ph.D.
Sue B. Clark, Ph.D.
Efi Foufoula-Georgiou, Ph.D.
Gerald S. Frankel, Sc.D.
Linda K. Nozick, Ph.D.
Kenneth Lee Peddicord, Ph.D.
Paul J. Turinsky, Ph.D.
Mary Lou Zoback, Ph.D.

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P R O C E E D I N G S

8:00 a.m.

EWING: Good morning, and welcome to the spring meeting of the Nuclear Waste Technical Review board. I'm Rod Ewing. I'm the Chairman of the NWTRB, and I'd like to start by saying how personally pleased I am to be back in New Mexico.

I first arrived in New Mexico in 1974 as an assistant profession at UNM. And, curiously enough, that was the year that, I would say, the WIPP project began in New Mexico. When I left the University of New Mexico for the University of Michigan in 1997; that was just before, if I recall correctly, the EPA certified the WIPP site for receipt of waste. And, of course, there was a little more controversy, so it wasn't until 1999 that waste arrived at WIPP. During my time at UNM I spent twelve years on the National Research Council's committee, which provided, I would say, continuous oversight and review of the WIPP project.

And so it's a pleasure to be back in New Mexico, and it's also very interesting for me to be dealing once again with the subject of salt as a repository medium.

Now, the Board meeting in New Mexico comes at a time when events at WIPP are creating even more interest than usual in nuclear issues, particularly for people who live in New Mexico. And I just want to say, as scientists and

1 technical experts, Board members and Staff share this
2 interest. However, it's important to note that this meeting
3 was scheduled and organized long before the recent events at
4 WIPP.

5 The Board's charge, as defined by the Nuclear Waste
6 Policy Act Amendments in 1987, is to follow DOE activities
7 related to spent nuclear fuel and high-level waste; and, of
8 course, WIPP is a geological repository for transuranic
9 waste.

10 And so our focus today is not on the incidents of
11 recent weeks or on transuranic waste, but rather we're
12 focused on salt as a geologic medium for spent nuclear fuel
13 and high-level waste. And, of course, we're very interested
14 to understand how the research and experience at WIPP might
15 be applied to this new application or new possibility of an
16 application.

17 The Board has organized an agenda that's designed
18 to inform the Board and the public of DOE's analysis of salt
19 as a potential repository medium for spent fuel and high-
20 level waste. We're meeting in Albuquerque because many of
21 the scientists with the expertise in this topic are at Sandia
22 or Los Alamos. And, of course, the public and the NGOs have
23 a lot of experience and opinions on this topic, and we're, of
24 course, very interested in everyone's opinion.

25 Now, let me help you understand the scope of the

1 Board's interest in these issues and give you a little bit of
2 history on the Board. The Board, as I said before, was
3 created in 1987 by the Nuclear Waste Policy Act Amendments.
4 We are to focus on spent nuclear fuel and high-level waste.
5 The Board reports its findings to Congress and the Secretary
6 of Energy. There are eleven Board members. They are
7 appointed by the President from a list of nominees submitted
8 by the National Academy of Sciences.

9 There is a one-page handout on the table at the
10 entrance, which describes in more detail the Board's
11 responsibilities, and also on the back of that sheet there is
12 a description of the Board members.

13 Even though we have that description, I'd like to
14 introduce the Board members to the audience and say just a
15 word about their backgrounds and affiliations; and I'd ask
16 each Board member to just raise your hand so that people
17 realize who you are.

18 Jean Bahr is a Professor of Geosciences at the
19 University of Wisconsin-Madison. She is also a member of the
20 Geological Engineering Program and is a faculty affiliate to
21 the Nelson Institute of Environment Studies.

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

25 Susan Brantley is a Distinguished Professor of

1 Geosciences in the College of Earth and Mineral Sciences at
2 Penn State, and she is also Director of the Earth and
3 Environmental Systems Institute at Penn State and a member of
4 the National Academy of Sciences.

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

7 Gerald Frankel is a Professor of Material Science
8 and Engineering and Director of the Fontana Corrosion Center
9 at Ohio State University.

10 Efi Foufoula-Giorgiou is the Distinguished McKnight
11 University Professor of Civil Engineering and Director of the
12 National Center for Earth Surface Dynamics at the University
13 of Minnesota.

14 Linda Nozick is a Professor in the School of Civil
15 and Environmental Engineering and Director of the College
16 Program in Systems Engineering at Cornell University.

17 Lee Peddicord isn't here yet, but I think he's on
18 his way, traveling. He's served as Director of the Nuclear
19 Power Institute at Texas A&M University since 2007, and he's
20 a Professor of Nuclear Engineering at Texas A&M.

21 Paul Turinsky is a Professor of Nuclear Engineering
22 at North Carolina State University and since 2010 has served
23 as the Chief Scientist for the Department of Energy's
24 Innovation Hub for Modeling and Simulation of Nuclear
25 Reactors.

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

5 And, finally, I am a Professor in Nuclear Security
6 in the Center for International Security and Cooperation at
7 Stanford University and also a Professor in the Department of
8 Geological and Environmental Sciences in the School of Earth
9 Sciences at Stanford. And I look forward to the game on
10 Friday night with UNM. My loyalties aren't entirely divided.
11 I have to confess I'm pulling for Stanford.

12 So all of the Board members serve part-time, but we
13 have a full-time staff. They are seated at the table just
14 against the wall. They provide not only expertise but
15 continuity to our efforts.

16 Please feel free to contact Board members. When we
17 have breaks, we want to interact with you, but also interact
18 with the Staff. So we look forward to those discussions.

19 Now, let me describe today's agenda. The first
20 presentation will be made by Bob Neill, who many of you will
21 know as the previous or the past Director of the New Mexico
22 Environmental Evaluation Group, or EEG, which conducted
23 independent review and technical evaluation of WIPP over many
24 years. Bob will provide some context for our discussions
25 that come later by giving us a short history of the WIPP

1 project. And most importantly from the Board's point of
2 view, he'll discuss the important technical issues that had
3 to be dealt with during the development of WIPP as a
4 repository.

5 Following Bob's presentation, Abe Van Luik, Senior
6 Physical Scientist and Director of International Programs at
7 the DOE Carlsbad Field Office, will present insights gained
8 from operating a repository in salt. Abe will also talk
9 about some of the early heater testing that was conducted at
10 the WIPP site.

11 After a short break, Kris Kuhlman from Sandia
12 National Laboratories will discuss the technical basis for
13 the disposal of spent nuclear fuel and high-level waste in
14 salt, followed by a presentation by Florie Caporuscio of Los
15 Alamos National Laboratory on brine migration experimental
16 studies for salt repositories.

17 After the lunch break, we'll have two presentations
18 on models of coupled processes, the first by Phil Stauffer
19 from Los Alamos on coupled thermal, hydrological, and
20 chemical processes, and the second by Guadalupe Arguello of
21 Sandia National Laboratories on coupled thermal,
22 hydrological, and mechanical processes.

23 Dave Sevougian at Sandia will then describe DOE
24 work on performance assessment modeling of a generic salt
25 disposal system for high-level waste.

1 And, finally, Frank Hansen will describe U.S. and
2 German collaborations on research and development
3 investigations of salt as a repository medium for spent fuel
4 and high-level waste.

5 We have set time aside at the end of the morning
6 session and at the end of the afternoon session for those of
7 you who want to comment or ask questions on the meeting
8 topics. If you want to comment, please add your name to the
9 list on the table where you entered, because I'll use that
10 list not only to recognize you but to apportion the time so
11 that everyone has a chance to make their comments.

12 If you prefer to make written comments or submit
13 other materials, those will be made part of the meeting
14 record. Written comments and materials, along with the
15 transcript for the meeting, will be posted on our Web site,
16 as we always do.

17 I also want to warn you that during the meeting
18 Board members will ask questions that may be taken to reflect
19 their personal views, and these are their personal views.
20 Board positions can be found by looking at our report that
21 represents the consensus of the Board on important issues.

22 And also we have the habit, the tradition, of
23 summarizing our comments and impressions of the day's meeting
24 in a letter to the appropriate undersecretary in the
25 Department of Energy, and those letters are also posted on

1 our Web site.

2 Finally, housekeeping details, please mute your
3 cell phones. I'll do my own in a moment. And when you
4 speak, please use the microphone, identify yourself and your
5 affiliation, because we're recording everything, and your
6 questions and the answers will become part of the permanent
7 record.

8 So those are the opening comments, and it's my
9 pleasure to turn the microphone over to Bob Neill to start
10 today's presentations.

11 NEILL: Thank you, Rod. Well, it's a pleasure to be
12 here to welcome this distinguished Board. I'm really
13 impressed with the credentials that all of you have in
14 addressing this seemingly intractable problem that has faced
15 our nation for, lo, these many years. The only other group
16 of academics that I think would have a greater probability of
17 success are those that attend that are teaching at Harry
18 Potter's school, namely the Hogwarts School of Magic, where
19 they might be able to accomplish more.

20 In 1978 the State of New Mexico had a number of
21 concerns about the WIPP project. This was a proposal by DOE
22 to dispose of transuranic waste in southeastern New Mexico,
23 but lacked the resources to address these highly technical
24 issues. Secretary Schlesinger of DOE said, "Tell you what
25 we'll do. We'll offer to fund an independent technical

1 review by the State. Do it completely yourself. There will
2 be no interference, no approval, or what have you." And
3 although DOE gets criticized for many things, they really
4 should be complimented for their willingness to do this.
5 There aren't many agencies--federal, state, or what have
6 you--who will fund a group to look over their shoulder and
7 come up with some recommendations.

8 Now, the purpose of EEG, which was set up for that
9 express purpose, was to do a technical review of the impact
10 of WIPP on public health and the environment. Subsequently,
11 we noted that there had been a nuclear weapons test called
12 the Plowshare test in that area where we were using nuclear
13 weapons for peaceful applications. The test called Nome
14 (phonetic) vented and released radioactivity in the area. So
15 it's essential to conduct monitoring in the off-site non-site
16 areas to avoid the specter of being accused of that being the
17 source of the radioactivity.

18 Now, the essential elements of the EEG reviews
19 absolutely would be objective, neither pro nor con. It was
20 essential to be independent with no review of the work. At
21 one point one of the governors was unhappy, thought we were
22 being a little bit too harsh on DOE, and took steps and--at
23 any rate, both Senator Domenici and Senator Bingaman, who we
24 regard as EEG's patron saints, reassigned a group from state
25 government to New Mexico Tech to enable the group to function

1 and complete the work.

2 Needless to say, it's essential to have senior
3 knowledgeable people on this. There's nothing wrong with
4 recent June graduates, but it is helpful to have people that
5 are knowledgeable. And the disciplines include, similar to
6 those on the Board, geology, hydrology, engineering. But the
7 focus is still on radiation protection, to recognize it. I
8 think that the approach of EEG is identical to the approach
9 of the Board, namely to be totally objective and not stack
10 the deck either in favor of something or in opposition to it.

11 Now, what we did was, rather than have meetings and
12 express our concerns to DOE, we published 90 reports and gave
13 widespread distribution of them to both the technical
14 community, the governor's office, the legislature, et al.
15 It's essential to have presentations at public and
16 professional meetings, testify at legislature. In New Mexico
17 we have a joint committee of four members from the House,
18 four from the Senate, a joint committee. And I don't know
19 how many times I did testify on it.

20 Also, field trips. Dr. Ewing participated in a
21 number of the field trips that we had with the NAS and the
22 University and Agency experts, people of dissimilar
23 views--and strongly-held views, too, I might add--and also
24 encouraged staff for key roles in professional societies. A
25 Dr. Jim Channell, who is with us today, was the president of

1 the Health Physics Society of New Mexico; and after I retired
2 the new director, Dr. Matthew Silva, hired George Anastas,
3 who was the president of the National Health Physics Society,
4 which is quite an endeavor.

5 Well, we concurred that DOE had met the standards,
6 recommended disposal, and I think part of the success of WIPP
7 is public confidence from our independent evaluation of the
8 impact on public health. It's to be noted that from the
9 get-go, the Carlsbad officials staunchly and strongly
10 supported this project. Senator Joe Gant, who is the number
11 two ranking person in the Senate, was really the ramrod for
12 this. The mayor, Walter Gerrells, as well as Representative
13 Jim Otts on the House side, were also supporters.

14 The governor and legislature committed to give the
15 project a fair hearing. In fact, Secretary Schlesinger asked
16 Governor King point-blank, "If you're really violently
17 opposed to this project, say the word and we'll pack it up
18 and leave tomorrow." The governor said, "No, we'll give it a
19 fair hearing," and that was done.

20 When I say that we were really good and objective,
21 it's nice to hear other people say it as well. And the Blue
22 Ribbon Commission made the recommendation that the health and
23 welfare interests of the people in the State of New Mexico
24 were being protected, and their concerns were being heard and
25 adequately addressed.

1 Now, just a real quickie here is that there needs
2 to be recognition that radioactive waste disposal is not
3 unique in exposing people to ionizing radiation. It's a
4 beneficial tool that we're not about to abandon, and I'm
5 speaking now for medical, nuclear, all kinds of things.

6 For example, on food preservation, I was on a panel
7 for the World Health Organization. And in parts of the world
8 where food spoils on the ground, people are literally
9 starving to death, that you can irradiate food and increase
10 the shelf life from a couple of days to several months. And
11 the cost to save a life is a dollar in contrast to several
12 million that we do for this.

13 Now, what is unique about--well, we all know this--
14 that predicting naturally occurring and man-made intrusions
15 in the distant future. When you tell your own brother what's
16 going to happen in 10,000 years, and this is the manner in
17 which people will dig down into this area for mineral
18 extraction or what have you, there needs to be a little more
19 humility on all our parts and also candor in discussing
20 problems that have come up--you never see papers being
21 presented where six out of the ten low-level waste sites had
22 to be closed in the first decade of their existence--and the
23 assurances that the standards will not change substantially.

24 In 1957 in the Public Health Service and also in
25 the Pacific with Joint Task Force 7, the allowable radiation

1 exposure during a test series was 3.9 roentgen, 3900
2 milliroentgen. Contrast that with numbers today that we're
3 using of 10 millirem or 25 millirem annual exposure to
4 people. These are somewhat dissimilar. That's 100 ergs per
5 gram of stuff for rad; whereas, a roentgen is 83.8 ergs per
6 gram of air. But they are roughly comparable in that
7 concept. The cost is substantial. We know that. And there
8 is no system to verify that what you've come up with is
9 correct and/or incorrect. And that needs a little bit more
10 candor in leveling with people.

11 And there is a demand, whether it's reasonable or
12 not, for greater standards or concerns about waste disposal
13 than on other environmental or public health hazards. I
14 mean, witness cigarette smoking of 420,000 deaths a year is
15 continuing, you know, and we accept this in our society.

16 Now, the most succinct summary I can come up with
17 on WIPP, which essentially doesn't tell you the project isn't
18 quite fair. It's a \$19 billion repository for the disposal
19 of 6.4 million curies of defense TRU waste, which includes
20 12.9 metric tons of plutonium-239. Note that from the very
21 beginning in the draft impact statement in 1979, DOE included
22 spent nuclear fuel. That was their desire to have it in
23 there. The chair of the House committee said, "Look, I don't
24 want NRC licensing on this defense project," and told DOE to
25 either get the high-level waste out of there or get another

1 committee. Well, it was deleted.

2 One thing to note on WIPP, in contrast to the high-
3 level waste, the waste is highly heterogeneous in contrast.
4 It ranges from overalls and contaminated clothing to
5 particulate fines less than 10 microns in diameter.

6 I want to note that, out of the 6.4 million curies,
7 about 1 million curies are remote-handled. And, as you know,
8 that means you have to handle it remotely; you can't put your
9 hands on the container. The remainder, about 80 percent, is
10 on the actinides as well as some fission products that are
11 present in there.

12 It is contained in a Type A DOT container, which is
13 carbon steel, and it's vented. It has to be vented because
14 of the problems associated with the potential generation of
15 hydrogen gas in the WIPP waste from the plutonium-238
16 disposed, and that's why the drums are all vented. Also,
17 that's why right now where you have TRUPACTs parked down in
18 Carlsbad at the WIPP site, there is a limit that NRC has
19 imposed that you either have to get rid of it down in the
20 mine to dispose or figure out something else.

21 Now, the lid they have for these drums are required
22 by DOT to stay on for a 30-inch drop test. The drums are
23 stacked three high, so recognize that this is potentially
24 problem. And also it's a fact that some years ago, out of
25 the eight rooms where waste is to be disposed, there was a

1 300-ton roof fall came down one time and landed in there.
2 Fortunately, no one was in the room at the time, although
3 there was a Sandia employee there a few days a week earlier
4 from that.

5 The waste at WIPP is respirable. It has not been
6 fixed in an insoluble matrix. That issue was debated, and
7 basically Sandia really found that you could model the stuff
8 with the solubility of the waste and meet the standards. The
9 standards on WIPP are probabilistic in nature where you have
10 to show that the probability is less than 1 in 10 that less
11 than 100 curies of plutonium-239 would be released per
12 million curies over 10,000 years and also 1 in a thousand to
13 10 times that wouldn't occur.

14 The isolation at WIPP is fundamentally based on
15 containment in the salt beds. There was no credit for
16 engineered barriers taken in the modeling and the supporting
17 evidence that EPA would certify that they met these
18 requirements.

19 Now, some of the technical issues that we have
20 addressed. From the beginning DOE had the responsibility and
21 the authority to self-regulate the disposal of these
22 materials. They've set up waste acceptance criteria. For
23 example, one of them initially was to stay two miles from a
24 deep borehole. Well, it was apparent that if you're going to
25 have a repository, you have to have a shaft to bring workers

1 right down into it in the immediate area. And the law
2 requires you to have a second shaft so workers could escape
3 if there was ever a problem. Similarly, you need holes to
4 bring the air in and also boreholes to release the air to
5 discharge it. So that was deleted.

6 The limit on respirable fines is one percent. And
7 this is critical, because the root of exposure which is most
8 likely is inhalation, not ingestion, and the inhalation
9 limits are quite stringent. But how do you measure or
10 determine that there is only one percent respirable fines?
11 Well, it would be unacceptable for the workers to remove the
12 lid, paw through the contents, and confirm that it's less
13 than one percent. So that limit was deleted. The ten-year
14 drum longevity had to go out the window, because the drums
15 were all considerably more than ten years.

16 Three of the raging geological issues that came up
17 initially were on the significance of brine reservoirs. This
18 is one--the brine reservoirs--we had an example of 200 feet
19 below the waste horizon that was proposed, we found a
20 15-million-barrel brine reservoir. And the issue of
21 dissolution, namely whether or not these soluble salts or the
22 sodium chloride or calcium sulfate or the phosphates in the
23 potash would be readily dissolved, and that was really a
24 raging issue as to whether or not this could cause the
25 overburden to be removed in time. And, of course, breccia

1 pipes were--you had these cylinders of brecciated rubble
2 stemming from the dissolution of more soluble materials
3 coming on down.

4 In fact, we held meetings on this--in fact, Dr.
5 Ewing participated in a number of them--where on each of
6 these issues, like on dissolution, you have one proponent who
7 is very, very concerned about the ravaging effects, and one
8 said it wasn't that bad. Ten minutes apiece should do that,
9 but then left a good forty minutes for discussion by the
10 panel, by the group, of the significance of that.

11 Well, we redesigned the monitoring equipment in the
12 stack; and, as I mentioned, the offsite, there never have
13 been issues--standards developed by DOE for the 10-100
14 nanocuries per gram alpha emitters, which are low-level
15 waste. And DOE has chosen to deal with those as TRU waste.
16 You take nine drums of 50 nanocuries per gram stuff, put it
17 in with one bona fide drum of 15,000 nanocuries per gram, the
18 average for the 10 is greater than 100, therefore, it would
19 qualify; and the EPA said this was acceptable.

20 One thing we argued with DOE on, and they
21 succeeded, was to delete the double containment requirement
22 for the CH-TRU shipping container. We believed it was a
23 requirement of NRC--and I still do--that this would enable
24 DOE to increase the payload, because you could increase the
25 diameter of the shipping container by perhaps three-quarters

1 of an inch, which didn't amount to much on six feet. And
2 also you could increase the payload, because you would no
3 longer have to have the inner containment vessel. Weight has
4 never been a major factor in the shipment of material to
5 WIPP.

6 Now, the 600-pound elephant in the room--I had
7 mentioned this thing on the release--today, again, there was
8 an announcement in the newspaper that there was another small
9 release. You can see the plutonium and the americium, those
10 two radioisotopes of 800,000 and 500,000 curies total
11 projected. Note that the annual worker limit of 5 rem, as
12 set initially by the ICRP, adopted by NRC and DOE and
13 everyone, is not a dose that if a worker gets is going to be
14 fatal or induce an injury or, you know, morbidity statistics.
15 It's not. It is a prudent value that you get off the job and
16 do other things.

17 But a note that the becquerels per year for
18 plutonium-239 and/or americium is 370 per year. A becquerel
19 is one disintegration per second, so the allowable exposure
20 from plutonium-239 would be one radioactive atom a day
21 decaying, roughly 370 per year. In microcuries it's .01, and
22 a microcurie is one-millionth of a curie. In terms of the
23 weight of that, it's something like .117 micrograms. You
24 take a gram, divide it into a million pieces, and then take
25 one-tenth of one of those. So even though it's recognized

1 that the releases that have been announced in the paper are
2 quite low--and indeed they appear to be--the allowable limits
3 are also similarly low.

4 Now, the past work in high-level waste, which I
5 think all of you are familiar with, is a system of screening
6 sites by listing, rating, and comparing the favorable
7 characteristics where you say, you know, the absence of
8 water, the absence of mineral resources and other things, you
9 list the criteria and come up with a list of five candidate
10 sites, then further sharpen it by getting it down to three
11 and then to one.

12 I have jokingly said at times that you don't do
13 that in selecting a spouse where you come up with a list of
14 desirable characteristics and narrow the field, and you tell
15 the candidates that you don't qualify on this or that. And
16 radioactive waste disposal is an equally serious business.

17 At one time we appointed a negotiator, Dave Leroy,
18 to negotiate with states to have one volunteer. Well, Leroy
19 was never given any authority to negotiate, to assure them of
20 jobs or what have you. Now, in 1982 Congress required, as
21 Dr. Ewing indicated, to evaluate the need for a second
22 repository. And DOE said, "You know, it's a lot easier to
23 authorize the increase in the first rather than develop the
24 second." I believe that. I was on the DOE advisory
25 committee on crystalline rock with Frank Parker and Susan

1 Wilcher-Kylee (phonetic), and we saw the enormous concern and
2 opposition raised in the eastern part of the U.S. on
3 crystalline rock. So even though it was easier to do that,
4 this is only true if there was a first repository. But since
5 there isn't a first repository, we really don't have a
6 second.

7 Another thing to note is that, up until 1970, DOE
8 had the authority to self-regulate the disposal of these
9 transuranic wastes, which are now coming to WIPP, and dispose
10 of them in shallow land burial in Los Alamos under three feet
11 of ground cover.

12 There is, I believe, an excellent paper by Dr.
13 Helen Neill, who is a professor at UNLV, currently an
14 associate dean out there and also is my daughter, and I'm the
15 junior author on this paper. But we recommend that DOE
16 evacuate or excavate the 20,800 curies of plutonium-239
17 currently under three feet of topsoil and ship it down to
18 WIPP. Now, understand that DOE is entirely, totally, and
19 correctly on this where they have the authority to do so, and
20 they exercise those authorities and responsibilities. And
21 I'm not inferring in any way that it was done poorly or
22 shabbily.

23 However, it's to be recognized that there is an
24 inconsistency here when you address a group of fifth graders
25 and say, you know, it's necessary to put this stuff 2,150

1 feet underground because of the hazard to people's health in
2 the long-term future, but it's okay for this stuff that's
3 under three feet of topsoil. As a minimum, we've urged that
4 DOE do the modeling to calculate what fraction would be
5 released in 10,000 years, which is the requirement for WIPP,
6 and see whether or not it's acceptable. We do know that at
7 other sites under three feet of topsoil, the waste has
8 leached out from that.

9 Now, the status, as you know, that we've--I think
10 the figure of 22 billion is probably low. I've been retired
11 for a number of years now. That's gone up considerably. The
12 efforts to date, all of them unsuccessful--and I don't argue
13 about whose fault it is and what we should do about it, but
14 there are some recommendation for the Board to address on
15 here. We lost a year and a half due to jurisdictional
16 disputes between EPA and NRC whose turf was involved. Those
17 things should be resolved promptly.

18 Bear in mind that states do not regulate
19 radioactivity, only the non-radiological constituents, be it
20 delegation by EPA--and Jim Channell did a very good paper
21 here, which was published, where the hazards associated with
22 the non-rad constituents are a factor of about a thousand
23 less than the radiological risks associated with it.

24 Now, the most important recommendation we've got
25 here is that the requirement to predict a radiation dose from

1 the particulate resuspension and inhalation over a million
2 years is meaningless and really does not do anyone any value.
3 I was on the National Academy of Science's committee on
4 uranium mill tailings, and we found that emanations from the
5 pile after about 25 years that the measured concentrations of
6 radon daughters varied from the predicted values of the
7 concentrations by a factor of two orders of magnitude. So if
8 after 25 years you get this kind of stuff, imagine what it
9 would be like for a million years. I think that the time
10 period should be more meaningful, perhaps like the one at
11 WIPP of 10,000 years.

12 Plutonium is considered to be the most hazardous
13 radionuclide at WIPP, although there are four other
14 radioisotopes of plutonium that are present: a 238, which
15 generates a considerable amount of heat, which is the one
16 associated with the problem of the generation of hydrogen;
17 239; 240; and then the beta-emitting plutonium 241.

18 Note that another argument against the million
19 years, the inventory, according to what I looked at, the
20 plutonium-239 on the high-level waste would be something like
21 25 million curies. That sounded 10-1/2 microcuries, a
22 millionth of a curie, and that's a needlessly restrictive
23 reduction. Note that basically radioactive decay does become
24 innocuous with time or it becomes innocuous--the toxicity
25 decreases, but a bucket of lead is as hazardous today as it

1 was a million years ago.

2 Now, another strong recommendation is to do two
3 sites. There are various proposed sites that have been found
4 to be unacceptable, certainly the one up in Lyons, Kansas,
5 right now; they wanted Yucca Mountain; the one in Deaf Smith
6 in Texas. For various reasons we're not pursuing those. And
7 I think the nation can ill afford to restart the clock
8 decades later, so we urge to take a fresh look at crystalline
9 rock, bedded salt, basalt, and tuff. In other words, do this
10 thing correctly, properly, and through the front door.

11 Now, the other problem is that the high-level waste for
12 disposal is bigger than the authorized capacity of the first
13 one. So common sense would dictate that if you've got more
14 stuff than the first repository could take, you really ought
15 to get looking for a second one. And this provides the
16 nation with a double benefit. It's a home for the second and
17 a backup for the first. And this recommendation is one that
18 all of our grandmothers would make, namely, don't put all
19 your eggs in one basket.

20 It's essential to have an independent state review.
21 I don't want to belabor that; but of the 90 reports, 4 of
22 them were co-authored by Thomas Sargent, who is known for his
23 mathematical rigor. These were on calculating the potential
24 of a catastrophic release from the hoist system at WIPP, and
25 Dr. Sargent and Dr. Greenfield co-authored this. NRC was so

1 impressed with the first one on this low-probability/
2 high-consequence event that they not only reference it in
3 guidance, but they reprinted the report in its entirety,
4 saying, "Hey, follow this position."

5 Now, Congress set up a really good system for high-
6 level waste disposal and then subsequently abandoned it. You
7 know all that. One recommendation: That Congress and the
8 administration need to agree to a system and stick with it.
9 Some of them might say, Neill, out of all your
10 recommendations, that one is the most absurd. But certainly
11 Congress ought to get cracking and hold hearings to specify
12 incentives for a state to volunteer as a candidate and look
13 at the--you know, the BRC report came out two years and two
14 months ago, and I'm not aware of any efforts by Congress to
15 address those recommendations.

16 Don't ask Congress to solve technical problems that
17 you can do yourself. DOE wanted to bring waste to WIPP
18 before meeting the EPA standards, and they said, "Well, we
19 can conduct experiments, which would be very useful in
20 providing confirming data for our predictions." Well,
21 Congress required it and agreed to this. They were without
22 merit. We recommended they be discarded, these bin and
23 alcove tests, and DOE had a Blue Ribbon or a Red Ribbon
24 Committee, which also agreed, and DOE did cancel them.

25 The only trouble is, the law stated you had to do

1 experiments in order to bring waste. So you had to go back
2 to Congress and ask them to change the law. Secondly, they
3 didn't like the EPA requirement of 10,000 years to predict
4 the behavior. Congress asked the Academy for views. They
5 believed 1,000,000 years to be more appropriate.

6 The moral is: Don't ask Congress to solve
7 technical problems that can be readily solved by the
8 technical community.

9 Also note that engineers and scientists should
10 present papers at meetings showing the merits of disposing
11 high-level waste in their home state. The paucity of such
12 research--there are some examples like Tennessee was willing
13 to consider a monitored retrievable storage facility to store
14 high-level waste in Tennessee. But, really, there have been
15 very few examples of where people publish reports saying
16 that, you know, the rock formations of crystalline rock are
17 really eminently suitable.

18 When I've told this to my friends in various
19 states, they say, "Hey, Bob, what are you trying to do, get
20 me fired?" You know, the paucity--and it's essential that
21 the public believes in the objectivity by their technical
22 community in order to have confidence.

23 This is one that's an interesting comparison. The
24 NCRP published--I think the slide in your Viewgraph is
25 incorrect--in 2006--for over two decades the medical

1 radiation exposures stemming from diagnostic applications for
2 CT scans, mammography, nuclear medicine increased by a factor
3 of 7.3 to 900,000 Person-Sieverts. That's an indication of
4 the population dose or insult via radiation, weighted by the
5 population, but where the nuclear power plants went down by a
6 factor of 5.

7 Now, the question comes up: Why would the public
8 accept this astonishing increase? The reason is--the belief
9 is that the benefits clearly outweigh the risks, and people
10 at times focus solely on the risks and not also considering
11 the benefits, and we need to discuss this.

12 And lastly is a point to note that the public
13 acceptability of activities in defense of the country is much
14 greater than acceptability for commercial high-level waste.
15 That's a fact that we all recognize.

16 Funding, basically we've dropped 13 billion on
17 Yucca Mountain to date, and I think there's 26 billion been
18 collected from rate payers, probably more. A number of the
19 utilities have sued and have won in court because of the
20 failure to take title to the spent fuel. And so it really
21 needs to be moved more quickly or rapidly, and the waste
22 requiring disposal--and this is hardly news--future funding
23 is going to get more difficult all the time.

24 Recommend certain things to the DOE also. Let's
25 get on to these potential rock formations in different areas

1 of the country; identify the incentives for states to
2 volunteer. It may well be that Tennessee or Michigan would
3 find very, very much in these economic distressed times to do
4 that, get better cost estimates for it.

5 Also, lock in on the maximum inventory. That also
6 will require you to address the issue of a second repository.
7 Publish a report about the status of funds. The DOE official
8 in charge of this at a symposium I was at in Tennessee said
9 that the money is not there any longer; it's an IOU in the
10 till. It's been spent to mask in part the deficit that we
11 had. And we need a greater candor and directness on it.

12 And it's very important to say, okay, if we don't
13 do something on this, what are the consequences if we
14 continue to fail to take title? Will this stop any future
15 power reactor from being built? Does this leave a site as a
16 terrorist target to fly an airplane into it?

17 Now, one question that is in the--this 600-pound
18 gorilla again--is this site suitable for New Mexico for
19 disposal? We don't know. The site has not been geologically
20 characterized for high-level waste disposal, and Congress
21 gave that job to EPA and NRC. It's not an ad hoc decision.

22 I noticed the local newspaper last week said, "Hey,
23 bring the high-level waste down here," very casually without
24 any reference to--note that the mineral resources in the area
25 are substantial. Many of the lists for the high-level waste

1 disposal say, "Stay away from areas like that." The thermal
2 loading for high-level waste is really high and the effects
3 of that on bedded salt, and the total curies are a factor of,
4 I think, a thousand greater than the 6.4 for WIPP.

5 This is an old map, 64 square miles. The area at
6 WIPP in the center, 4 by 4, around 16 square miles, covers
7 that, and it shows the footprint of the repository itself.
8 But it's ringed with either known potash reserves, mineral,
9 gas, and oil extraction.

10 And also in 1975 the National Academy of Sciences
11 recommended bedded salt for disposal of high-level waste.
12 And that is quite true, and some people are fond of quoting
13 that fact. However, that report also was dealing with some
14 other things that haven't been recognized. It was for liquid
15 high-level waste. That is off the table. We no longer are
16 considering it. They said, finish all your geological work
17 before you authorize construction; locate it in an area near
18 the power reactors to minimize transportation risks--that
19 essentially hasn't even been considered--and select cavities
20 at shallow depth to reduce room collapse; and check out a
21 large number of sites.

22 Well, those are the main points that I wanted to
23 cover this morning. I think it is an admonition here that
24 the selection of a high-level waste repository is going to be
25 a very difficult, complex business. There are any number of

1 cogent reasons and also imagined reasons why it is either
2 acceptable and/or unacceptable. So the challenges that the
3 Board has in addressing this problem are appreciated and
4 recognized, and we thank you very much for your efforts here
5 today to do this. Thank you.

6 EWING: Thank you, Bob.

7 So, just to remind everyone of the procedure, we'll
8 first allow the Board members to ask questions and then Staff
9 and then, time allowing, perhaps questions from people who
10 are in attendance.

11 Okay, from the Board? Jean?

12 BAHR: Jean Bahr. You mentioned the issues related to
13 brine pockets and dissolution. So as we're thinking about
14 salt as a repository medium in general, what was learned from
15 the WIPP experience about how do you identify the potential
16 hazards associated with brine pockets? How do you identify
17 where those are? Not thinking about WIPP specifically, but
18 thinking about bedded salt in general, what have we learned
19 about what needs to be done in site characterization and how
20 did they resolve the questions that were associated with
21 those risks at WIPP?

22 NEILL: A very good point, Dr. Bahr. Correct me if my
23 numbers are off a little bit, but over the years I think in
24 that area we have discovered or noted the presence of about
25 eight to ten brine reservoirs that have been picked up in

1 different locations in that area. We never did understand
2 exactly how they were created, but the resolution of the
3 problem was, if the modeling said, okay, you have a brine
4 reservoir here, what, if any, was the effect on the
5 performance assessment calculations or the modeling to
6 increase the likelihood or the quantities of radioactivity
7 released because of this?

8 And in that way we sort of--I don't want to say
9 bypass it, but address it by saying, well, how bad is this or
10 how much of a problem would it be? But I don't know if we
11 have any mechanism today--certainly back in 1980--of being
12 able to detect each and every brine reservoir in the area.
13 But at WIPP-12 this is just a couple of hundred feet below
14 the proposed repository horizon.

15 EWING: Other questions from the Board? Steve?

16 BECKER: Becker, Board. You mentioned that it's
17 important for the technical community to win the confidence
18 of the public, to establish confidence. I'm wondering--you
19 mentioned a couple of factors. I'm wondering if you could
20 elaborate for us on that. What kinds of things do members of
21 the technical community need to do? And, more broadly, what
22 sorts of things do agencies involved with waste management
23 need to do in order to win that public confidence?

24 NEILL: A very good question, but it's a real tough one.
25 One of the things that has to be done is to get the data out

1 there. Today there was an announcement in the newspaper of
2 another small release at WIPP, americium-241, no numbers.
3 And it's essential to get the numbers out there. I realize
4 that they are numbers that people are not familiar with. A
5 curie is 3.7 times 10 to the 10th disintegrations per second.
6 A Becquerel is 1 disintegration per second. We've gone from
7 this absurdly large number to absurdly small.

8 But it's essential to publish and get the data--you
9 know, in 1958 when I came back from weapons testing in Nevada
10 and the Pacific, I was given--and there was a great concern
11 about the numbers from fallout on St. Louis, strontium-90 in
12 milk. And the AEC was opposed to releasing these numbers.
13 Well, we published the results of all the measurements in
14 air, water, milk, and other biota and got it out there to the
15 public to see it. And that is essential.

16 I think that scientists and members of the
17 community really need to publish some papers. The last one
18 that I recall people talking about problems that we had was a
19 symposium in the Health Physics Society back in--oh, it must
20 have been 1978 when I first started the job, where they gave
21 a couple of papers on how the low-level waste facilities were
22 leaking, major problems, and there was a directness and a
23 leveling on it. And it's essential to provide this
24 information to the public, that the appropriate officials
25 really ought to be testifying before the legislature, giving

1 the governor information on it.

2 And in the absence of it, when somebody says, hey,
3 don't worry about it, it's a low number, that's really not
4 good enough for the public today. And that does provide
5 ammunition for some people that are violently opposed to even
6 considering this, and they say, see, they're not leveling
7 with you, and it's a simple thing to resolve and to address.
8 It doesn't take a rocket scientist to get this stuff out
9 there.

10 EWING: Other questions? Jerry?

11 FRANKEL: Jerry Frankel. I'd like to just follow on to
12 Steve's question. It sounds like the EEG should be applauded
13 for its role in developing trust with the public over these
14 many years. And I'm just wondering if you could hypothesize
15 what the situation would have been had you not had strong
16 support at various levels of government, say, if you were in
17 a state where maybe the senators weren't strongly supportive
18 of the activity even though maybe the local officials. How
19 would that have affected your experience and the
20 effectiveness of the EEG in performing its tasks?

21 NEILL: A really good point. The answer really is, I
22 don't know. But in some ways one could say, you know, the
23 greatest credit for WIPP going ahead was the support of the
24 local officials in Carlsbad. Senator Gant, Representative
25 Otts, the mayor, Walter Gerrells, really pushed the project

1 from the get-go. I like to believe that you really--in
2 providing this information to the public--and say, you know,
3 that we don't have all the answers; we're doing the best we
4 can; we believe in the concept of multiple barriers so that
5 if one fails, there are others. However, in WIPP you really
6 don't have engineered barriers other than magnesium oxide to
7 pick up the CO₂, if you define that as an engineered barrier.

8 But it is a complex in a relationship. And
9 although EEG's role and the Board's role is to address
10 technical issues, the technical issues are only one part of
11 the total. It's economic, certainly the fact that there are
12 1,000 employees down in Carlsbad who may well have their jobs
13 jeopardized if that mine is not able to reopen. So the
14 community does have some major concerns.

15 And so there's economic, there's social, political,
16 and it's a composite of all of these factors. And it varies,
17 and it certainly varies within various groups.

18 My daughter had a grant for looking at the Nevada
19 test site and as an economist came up with a unique idea--not
20 unique--but why not poll the people in the offsite
21 communities of their views? And she found there was a
22 bimodal distribution. There was one group in violent
23 opposition to a proposed high-level waste repository, and
24 there was another group roughly similar in size that said,
25 "Okay, let's consider it and go ahead." You do have 200

1 million curies from weapons testing in Nevada there, and you
2 have fairly complex issues that are seemingly difficult to
3 reconcile.

4 For example, for a year I've seen editorials in the
5 Vegas papers saying that, "We are violently opposed to high-
6 level waste disposal, but keep the work force there for
7 weapons testing if we continue with it." And it's almost as
8 though when you produce fission products with a bomb going
9 off, it's socially acceptable; but if you put it in a box, no
10 way.

11 And so we are inconsistent, but that's really the
12 price one has in a democracy, and it's a fair thing.

13 I didn't answer your question, but I'm not sure if
14 anyone else can.

15 EWING: So, Bob, let me follow that question and ask it
16 in a slightly different way and give you a chance to maybe
17 speak a little more to this issue. So the Blue Ribbon
18 Commission recommended a consent-based process. With your
19 experience, how would you, moving forward, blend a consent-
20 based process with the technical review process?

21 NEILL: Well, the ability to go ahead with a repository
22 is a mixture of technical, which we've all been looking at,
23 political, social, economic, and other factors. And that's
24 just the way it is. I think that you do have to have the
25 consent of the people in that community in that area to

1 proceed on stuff, but I'm not sure that that should be the
2 sole--in fact, it should not be the sole basis for making a
3 decision to go ahead, where people just say, hey, we're going
4 to be laying off everybody on the TRU waste facility when we
5 finish up placing the rest of the TRU waste, and your real
6 estate is going to be on the market, no jobs that potash has
7 offered railroads. But these are things that need to be
8 discussed and debated, argued, and explored fully amongst all
9 the different groups that are involved.

10 EWING: Okay, thank you. Paul?

11 TURINKSY: Paul Turinsky of the Board. Could you
12 comment on one or two areas of scientific information that
13 you've learned from the operation of WIPP, advances from the
14 experience?

15 NEILL: That we've learned? Well, we've certainly
16 learned quite a bit about the deformation of the salt beds
17 after you excavate a cavity. One of the problems in the room
18 where we were doing the experiments was that the floor was
19 coming up and the ceiling was coming down, and the bins and
20 containers would tilt. We certainly learned that. We've
21 certainly learned a great deal about the real estate for the
22 disposal of TRU waste. I'm not sure how much of it is
23 applicable for high-level waste. The numbers are so
24 dissimilar to heat loading. It was incredibly greater, and
25 certainly the number of curies involved has been greater.

1 But I have always been sort of disappointed--like
2 in Nevada, as I said, when 200 million curies are underground
3 as a result of nuclear weapons testing in both underground
4 and atmospheric, and I always said this is an ideal place to
5 model, to measure the behavior of actinides, fission
6 products, neutron-induced activity. We never really have
7 pushed that out there in Nevada, to my knowledge. Somebody
8 may jump up and say there's 17 reports on that, but at least
9 in the past they haven't been doing it.

10 EWING: Jean?

11 BAHR: Back to another technical issue that you
12 mentioned, the roof collapse that happened early on. So what
13 was learned about the mechanical properties of salt, and what
14 was done in response to that in the design of WIPP, if
15 anything?

16 NEILL: Good point. In fact, the NAS in '57 said, "Hey,
17 go for shallow burial to reduce the possibility of room
18 collapse," and that's not a viable alternative. But what has
19 been done since then after that was to put much longer roof
20 bolts in the roof of the rooms. Initially there were 12 feet
21 and then 16 feet, which would provide greater stability and
22 reduce the probability of a roof coming down. So the
23 approach has been to do that.

24 Of course, the reason that salt is a candidate or
25 desirable is that it does eventually enclose and deform. It

1 deforms without fracturing. When you have to model the
2 behavior of a radionuclide in a fracture of granite, it's a
3 tricky business; whereas, in bedded salt, hopefully it
4 deforms and forms a homogeneous matrix, which would minimize
5 the migration of a radionuclide.

6 EWING: Mary Lou.

7 ZOBACK: To that point on the salt deformation, several
8 of the rooms have been closed for quite some time now; is
9 that correct?

10 NEILL: Yes.

11 ZOBACK: And do they have strain meters in the room that
12 are being actively monitored? Is the rate of deformation
13 occurring at what was predicted by modeling?

14 NEILL: I'm going to beg off that one. I retired in
15 2000, 14 years ago, and that would be more appropriately
16 answered, I think, by a DOE official as to what the current
17 behavior is.

18 ZOBACK: Okay.

19 NEILL: But we keep learning from this stuff all the
20 time.

21 ZOBACK: Sure. As long as we collect data, we learn.

22 NEILL: Right.

23 ZOBACK: And publish it, too.

24 NEILL: Okay. And one last--oh, excuse me.

25 EWING: I was just going to ask if there are any

1 questions from Staff. Okay. And you had what?

2 NEILL: Just one last comment. I appreciate the
3 opportunity to give some of our perspectives. I don't know
4 how well this has served to aid you in your deliberations,
5 but I recognize the complexity and the difficulty of all of
6 these issues. And all I can say is, I hope that we certainly
7 do this properly and correctly and consider all of the
8 alternatives for it. Thank you.

9 EWING: Okay, Bob, thank you very much. We appreciate
10 it.

11 So the next speaker will be Abe Van Luik from
12 Carlsbad.

13 VAN LUIK: It's a great pleasure to be here in front of
14 the Board. It's a brand new Board. I only really know one
15 person out of all of you and--well, Jean I've met before.
16 But I do know quite a few of the Staff. And it's always been
17 a pleasure for me to be able to address the Board. I used to
18 work on the Yucca Mountain project, and so I met the Board
19 quite a few times.

20 In fact, Bob Neill's talk was very interesting for
21 me to listen to, because it reminded me of my own past. I
22 started out in the nuclear business as a consultant at
23 headquarters, reading the reports on the sub-seabed disposal
24 program, and then it went down the tubes. And then I got on
25 the crystalline program, and it went down the tubes. And I'm

1 the author of several documents on site selection in the
2 Northeast and upper Midwest of the United States from Argonne
3 National Laboratory.

4 And then from there I, of course, had to survive,
5 so I moved to the Yucca Mountain project for 24 years, and it
6 went down the tubes. And now I've moved to the Waste
7 Isolation Pilot Plant.

8 EWING: So we've found the root cause.

9 VAN LUIK: Anyway, it's interesting. By the way, if you
10 go to the WIPP Web site, you will see the number for the
11 latest disclosed release, and it's thought to be something
12 that basically was deposited by the original release on the
13 ductwork that has come loose and come into the filter. I
14 think it said 62 DPM was the number found. Just prior to
15 that there was no detection, and after that there was no
16 detection. So it's a one-time, very small particle. One of
17 the problems is that we know how to basically measure an
18 atom, and it's very difficult to put these things into
19 perspective.

20 But let me get on with what I'm supposed to be
21 talking about.

22 This is the valiant description of WIPP, a national
23 solution pilot. It has two meanings. It can mean something
24 small that then becomes commercialized. It also means the
25 ship that brings the larger ship into port, and so it's a way

1 to steer the nation into a solution. It's currently the
2 world's only operating deep geologic repository for permanent
3 isolation of any type of radioactive waste. And WIPP, as you
4 know very well, is restricted to defense transuranic waste.

5 In this particular picture you see what we have
6 proposed is adding to panels here, because right now we're
7 filling Panel 7; Panel 6 is done; all of these other panels
8 are done; and we have Panel 8 yet to be excavated. And then
9 we have paperwork in with EPA and the New Mexico Environment
10 Department for permission to do panels 9A and 10A there. The
11 experimental area is very far away from the waste area, and
12 the experimental area is here where we have physics testing.
13 And all of the testing has now been suspended, of course.
14 Nobody's going underground.

15 So what have we learned from the disposal of our
16 remote-handled waste that could be of some use or some
17 insight in disposing of other waste types? What we have
18 discovered is that our original idea, what we were doing--and
19 I'll show pictures later--is we would first open an
20 excavation, we would put boreholes into the walls, and we
21 would first take the remote-handled waste, the higher
22 activity waste packages, and insert them with remote
23 controlled--not remote controlled--but with shielded
24 mechanical devices into that wall and put a plug in. And
25 then we would come in with a contact-handled waste, of which

1 there is much more, and fill up the room after the room has
2 already got its capacity of remote-handled waste. This is a
3 great idea, and it worked to some extent. But the problem
4 is, there is so much more contact-handled waste than remote-
5 handled waste that there is actually competition for space.

6 The operation, it takes about 10 to 12 hours from
7 receipt to emplacement for remote-handled waste. It's much
8 more efficient for the contact-handled waste. The equipment
9 size, the physical equipment, that's shielded and can be
10 operated at a distance. It actually dictates the excavation
11 size, and the excavation size dictates the stability of the
12 room. So there is all kinds of issues.

13 The other thing is that it blocks access to the
14 drift. You cannot be disposing of remote-handled waste in
15 the side wall. Because that machinery takes up the whole
16 drift, you cannot bypass it and at the same time be remote,
17 putting contact-handled waste in the same room. So because
18 there is pressure, much more contact-handled waste coming in,
19 it caused a lot of boreholes to be passed over and go unused.

20 So what we have learned is that if we can do
21 on-the-floor disposal in dedicated rooms for remote-handled
22 waste and by implication other higher activity waste, it
23 would enhance operational simplicity and efficiency.

24 This is the emplacement experience. You see at the
25 top a container coming in with a shipping--this is the

1 shipping container. Inside is a container that has the
2 actual remote-handled waste. That container has to be
3 rotated up to be put down to a lower level and then rotated
4 back to put onto the facility cask that then brings it--and
5 here you see it on that device that then shoves it into the
6 wall and puts a plug behind it. Quite a complicated
7 procedure.

8 And this is what the rooms look like. Very nice
9 room right here with the MGO, the magnesium oxide, on top as
10 an engineered barrier to control CO2 if there is a brine
11 release into the repository, which is a very unlikely event.
12 And then we have the remote-handled waste in the walls right
13 here, and you can see this gentleman is standing right next
14 to it, because this concrete plug is very large and basically
15 blocks all radioactivity from that remote-handled waste
16 package. The problem is that all of these have to be done
17 before you can bring in the contact-handled waste.

18 So we think that a lesson that we learned, it's
19 preferable to have a very basic waste handling concept,
20 nothing so fancy as all of this equipment that's just hard to
21 maintain and difficult to operate. We would like to have a
22 system where you unload and transport the shielded waste in
23 single horizontal orientation--none of this flipping it up
24 and back--eliminate emplacement in walls or vertically in the
25 floor; emplace it on the floor unshielded and then backfill

1 with run-of-mine salt--that's our concept now--and accept
2 that retrieval of thermally hot or highly radioactive waste
3 would be possible but difficult. And I think, you know,
4 we're talking very possible but very difficult.

5 So the basic mining approach is minimal mining,
6 single pass when possible, if you can make the room so that
7 your mining machinery can just go in and out and be done
8 instead of right now we go in several times to basically take
9 out the roof and then take out the floor; angled entries so
10 that you--you know, that determines the size of your being
11 able to make a turn with your equipment; narrow disposal
12 rooms for stability. This would require minimum roof
13 support, just-in-time mining. All you'd have to really pay
14 attention to is maintaining the mains, your egress and--
15 incoming and outgoing. And then basically you mine and
16 emplace in the same part of the repository.

17 This is a picture of what we're talking about
18 conceptually. You'd be making a new drift here while you're
19 retreat emplacing in this drift right here. You'd have a
20 remotely-operated vehicle that brings in the waste container,
21 drops it--lays it down--I shouldn't say drops it. And then
22 we bring in run-of-mine salt and cover it and then the next
23 one and then the next one. So pretty simplistic.

24 This is basically showing the same thing, but
25 showing that the angles here allow you to turn your equipment

1 at the entry. And then we would basically be able to come in
2 to both sides and put run-of-mine salt at the front and the
3 back of the room. And the interesting thing here is the
4 ventilation air flow while you're actively working this room.
5 This would cut off most of the air flow, although there's
6 always some. But the idea is that you would remove moisture
7 the whole time that you're operating.

8 This is the same kind of thing. And we have been
9 consulting with companies that actually make equipment that
10 can remotely deliver rock materials. The idea is to do a low
11 back, maximize the stand-up time.

12 And this is a little animation. You put in the
13 waste containers and then blow in the salt, put in more waste
14 containers, blow in the salt. And I'm a little impatient, so
15 we'll move on.

16 So this experience of looking just at this part of
17 the problem, other people in the program have been saying,
18 "Why don't you think a little bit larger?" And maybe it's
19 useful to perform an engineering trade study. Now, I can't
20 emphasize that enough. You don't just come up with a bright
21 idea and say, "Let's do it." You do a serious trade study,
22 because there's always pros and cons.

23 But one of the serious suggestions has been to do
24 retreat emplacement on the whole repository rather than just
25 on a panel basis as we do it now. So that means that you

1 make your mains at the beginning, and they shorten with time,
2 because you can seal them up as you come back; and all the
3 panels can be permanently sealed as they are filled. You
4 don't have to do this, you know, sealing the openings
5 afterwards.

6 But a problem with that is that the initial extent
7 of the excavations is larger, which means there's an earlier
8 larger investment before you start emplacing waste and get
9 the payoff. And also the maintenance of those mains will--
10 you know, it's just a larger problem that you're creating
11 right up front. And then also, if you were retreat emplacing
12 on the whole repository, the flexibility for future expansion
13 or major design changes may be reduced.

14 Now, one thing that we have found and that I found
15 very interesting in a 15-year operating repository. And if
16 you look at the change requests that we have sent in to EPA
17 and to New Mexico, it has been a continual reevaluation of
18 how we do business and asking for permission to make design
19 and other changes, because optimization is something that you
20 can't do ahead of time. It's only after you start operating
21 that you realize, oh, this could be done differently; this
22 could be done more efficiently; this can be done safer. So
23 you don't want to be cavalier and say, this is my design for
24 all time; we're going to emplace from the back and move to
25 the front. But this is why you need an engineering trade

1 study to look at all the pros and cons and really think
2 through them.

3 Now, another area where WIPP has given insight to
4 the nation is, there were generic heater tests performed.
5 They were basically performed as surrogates for the Deaf
6 Smith County site in Texas. At that time we were looking at
7 taking these very large spent fuel and high-level waste
8 containers and putting them vertically into the floor of a
9 disposal room, and so heater tests were done in in-floor
10 borehole disposal. We found out that this invokes processes
11 that if you do it differently they can be mitigated.

12 Now, a lot of these processes are because the
13 vertical boreholes intersected. This is bedded salt, so it
14 would have layers of clays that are water-rich. And so
15 wherever these vertical boreholes intersected these layers,
16 there was water inflow. When you do a vertical borehole,
17 also it's a steep and very localized temperature and pressure
18 gradients, and a pressure gradient is what moved the water.
19 It's not particularly the heat.

20 In-floor borehole for large, heavy packages is
21 physically difficult, inefficient. It actually--just like
22 with our wall borehole disposal device, your equipment is
23 going to determine the height and the width of the disposal
24 rooms. If you have something that comes in horizontally,
25 then has to be tilted vertically and put down below, it's

1 going to determine the height of your room. It requires
2 heavy, complex shielded equipment to set containers upright
3 and lower them into holes.

4 So this is a picture from the heater tests, one of
5 them, one of many that was conducted at that time, and you
6 can see the vertical boreholes. Now, the reason that you do
7 vertical boreholes is you put a lid on it; just like with a
8 plug, we put a plug in the boreholes in the walls now. And
9 you can actually have waste down below and walk over the top
10 of it. We were looking at 18 watts per square meter, which
11 is pretty hot. We were doing also coupons, brine, and
12 temperature monitoring.

13 The peak temperatures in these tests were never
14 reached, because they were terminated rather abruptly because
15 of the Nuclear Waste Policy Act amendments that were passed
16 in 1986/7. They basically said, "We have found the site.
17 Stop working everything else." And there was forensic
18 examination, but it was not completed. It was limited.

19 So here is another picture. You have the disturbed
20 rock zone. You're putting this container in here, and the
21 formation pressure drives brine towards the higher porosity
22 into disturbed rock zone. The intact salt is not really
23 influenced, and ventilation air flow is not helping you very
24 much, because it's way over here on the top. So that's the
25 point I was making. Whether there is temperature gradient or

1 not, there is going to be water flow because of the pressure.

2 So our experience that is useful, I think, to
3 considering salt as a medium for disposal of other types of
4 radioactive wastes has two components. Our way that we
5 emplace the remote-handled waste in horizontal boreholes gave
6 us direct insight into a potentially more efficient, simpler,
7 and intrinsically safe emplacement scheme. And we have to
8 thank the people at Savannah River for suggesting this scheme
9 in the first place.

10 Our only past experimental work has yielded
11 insights into processes that are stimulated by high heat and
12 pressure gradients and how these gradients can be reduced.
13 Now, the one thing that I haven't really emphasized, which I
14 should, is if you do this horizontal emplacement and you have
15 ventilation going across the run-of-mine salt, you're
16 basically, with the heat and the ventilation, removing
17 moisture and really reducing the ability of these packages to
18 see a lot of brine.

19 So I've basically said this two or three times:
20 Put it on the floor, put run-of-mine salt over it, and you'll
21 have a good repository. Because as long as you're deep
22 enough, the salt will close in on itself and basically remove
23 all of the evidence, all of the fractures, and everything
24 else that you've created through operations and construction.

25 So that's basically the two items that we wanted to

1 contribute to this discussion. I have to emphasize that when
2 we reopen the site for visits, we hope that you will come.
3 We hope that you will ask us to take you up to the hot cell,
4 because originally the construction included a hot cell for
5 repackaging high-level waste if we needed to. If there was a
6 damaged container, we didn't want to put it back out on the
7 road and ship it.

8 So we have a beautifully, totally unused hot cell
9 that is completely operational. It is kept in pristine
10 operational condition, and people are actually trained to use
11 it in case something in the future actually happens. If
12 you've got it, you've got to maintain it. So will it ever be
13 used? No. But that's not the point. But maybe we can lease
14 it out and make some money.

15 I wanted to make a comment on Bob Neill's
16 presentation, which I enjoyed very much. EEG actually, even
17 though it was considered by some people in DOE--and I won't
18 name names--to be a pain in the butt with their 90 documents
19 that called into question many things, they also contributed
20 to the way that WIPP has been operated, they contributed to
21 the confidence of the public, and I think it was a necessary
22 ingredient in getting WIPP buy-in at more than just a local
23 level. And I appreciate that.

24 Today we have CEMERC, the Carlsbad Environmental
25 Monitoring and Research Center, run through the New Mexico

1 State University at Carlsbad, that is doing the independent
2 monitoring that was started by EEG; and it's continued
3 through that organization. And I think that with the recent
4 events at WIPP, they have stood up and basically helped keep
5 the public confidence that they do have a second opinion on
6 what's going on at WIPP.

7 I was only kidding about everything I ever touched
8 failing, although who knows? Thank you.

9 EWING: Thank you, Abe.

10 Questions from the Board? Sue?

11 BRANTLEY: Sue Brantley. Thank you for that. That was
12 great. The slides really helped envision what you're doing.

13 Can you talk about lessons learned in terms of the
14 actual deformation of the salt? Are some of the rooms
15 actually deforming around these waste packets? And also what
16 about the roof fall, that sort of thing? What do you know,
17 and what have you learned in that regard?

18 VAN LUIK: I am not as familiar as I could be had I
19 known that this was going to be of great interest, but I know
20 that we have hundreds of monitoring points, and we have a
21 model that takes daily, weekly, monthly readings on stress
22 and strain and movement. And that model predicts from that
23 data, keeps predicting forward, as to what's going to happen
24 next, so we have a very good idea.

25 The older excavations, you know, when you first

1 excavate a room, the movement is rather rapid, and then it
2 kind of slows. But it continues; it never stops. And we do
3 monitor that. There was a question before: Do you monitor
4 in the sealed-off closed rooms? And the answer to that is:
5 We monitor around those rooms but not in them. And maybe
6 that's a suggestion that could be made. But the idea is that
7 once the room is closed, we don't care. We don't care that
8 it collapses and closes, because we want it to. Within a
9 hundred years they should be--basically you're looking at
10 intact salt all around the waste packages.

11 Now, the other thing in my talk that I failed to
12 mention is that you will hear later--and you will see a
13 picture, I think, in Kris's talk--about salt basically
14 coating one of the heaters out of the heater test. And
15 Stauffer's talk that you're going to hear later, I think, is
16 going to suggest that that is evidence of basically a very
17 small-scale heat pipe where moisture is evaporating,
18 recondensing, bringing new salt back down, evaporating again,
19 and coating the waste packages with salt. So you don't even
20 have to wait--if you have a hot package and you have
21 moisture, you don't even have to wait for the room to close
22 for that package to be encased in salt. I think this is a
23 very interesting insight, but it remains to be seen
24 experimentally whether this is actually the way it works.

25 But we monitor the heck out of the place, and our

1 mining engineering people have a very active monitoring
2 program, and they think that they can predict within minutes
3 of when something needs to be bolstered up.

4 EWING: Other questions from the Board? Efi?

5 FOUFOULA: This--is this on?

6 EWING: Just remind Board members to identify
7 yourselves.

8 FOUFOULA: Efi Foufoula, University of Minnesota. So
9 are this data that you collect available? Are they made
10 available to other scientists for research?

11 VAN LUIK: I am not sure. I know that we do occasional
12 reports, but the raw data is a constant feed, and I don't
13 think that we have that available to anyone except the people
14 internally that interpret that data. But I don't know. I
15 would have to go back and find out.

16 EWING: Mary Lou?

17 ZOBACK: Mary Lou Zoback, Board. So just getting back
18 to--thank you for clarifying all of this. This was a really
19 helpful talk, as was Dr. Neill's.

20 The rooms that have been filled and closed do not
21 have strain deformation monitoring equipment. So even though
22 the models say a hundred years, there should be some
23 corporate memory. We won't know for sure in a hundred years
24 if that's true, because there's no monitors in there.

25 VAN LUIK: That's true, except that our experience with

1 Room 1, which was kept open a lot longer than we wanted to
2 keep it open because of decision making, this is also when we
3 learned that we should only open a room just before we start
4 using it. We lost the use of two or three--Panel 1--two or
5 three rooms in that because of the closure from both the top
6 and the bottom. And it was as predicted, but we didn't get
7 to put waste in it, so we had to bypass several rooms and
8 lost them.

9 So all of this information is incorporated into the
10 knowledge base that basically guides our operations.

11 BRANTLEY: And then, I guess, just a follow-up question.
12 You kind of quickly went through the animation. But is the
13 run-of-the-mill salt backfilled all the way to the ceiling of
14 the room? It wasn't clear. It looked like--

15 VAN LUIK: No. It was basically just a few feet of salt
16 on top of the waste packages as shielding, and then only at
17 the beginning and the end would you go all the way to the
18 roof. But it's physically very difficult to really go all
19 the way to the roof when you're just pushing salt. In fact,
20 we have a test ongoing in that vein right now. We can get
21 close, but as time goes on, the salt settles. But that's
22 when the room closure comes in, and it'll seal it up.

23 But the idea is that there is no shine from the
24 rooms as people go past to go to the next room.

25 BRANTLEY: And so is there any ventilation then in that

1 air gap?

2 VAN LUIK: There would be, yes. It would continue to
3 remove--at a very low rate it would continue to remove
4 moisture the whole time until the repository is finally
5 sealed up.

6 BRANTLEY: Thank you.

7 EWING: Jerry?

8 FRANKEL: Jerry Frankel. I found it really interesting,
9 the comment that you made--are you hearing it?

10 (Pause.)

11 Jerry Frankel. So you made the observation that
12 through years of experience you've come up with better
13 approaches, and that's very sensible. We'd like to think
14 that we will be able to engineer a process, the best process
15 to begin with. But, of course, that's not the way things
16 work, right? And so being the world's only operating deep
17 geologic repository for radioactive waste, I think there may
18 be lessons learned there about how to approach--you know, to
19 leave open the possibility for an evolutionary type of
20 processing.

21 So I guess what wasn't clear to me is that you have
22 this new procedure for excavating rooms and emplacing waste.
23 Is that being done now, or is that just a suggestion for a
24 plan for the future?

25 VAN LUIK: This is actively being pursued as the next

1 change we would like to make for the repository. We haven't
2 done it yet. We are basically going around the world
3 explaining what we have learned from the way we do things now
4 and how it could be done more efficiently. So we would like
5 to get permission from both EPA and the State of New Mexico
6 to go to this new approach as soon as we can.

7 FRANKEL: Right. So I guess that's the question is:
8 With that procedure, how is it going forward now? Are those
9 authorities open to changes in the processing? How does that
10 happen?

11 VAN LUIK: They are open to changes. They have been all
12 along. But we have to prove to them--or "prove" is not the
13 right word. We have to convince them that there is no
14 operational or long-term safety implications that are
15 negative. We can't back away from the degree of safety that
16 is required. So basically we have to do a new performance
17 assessment that accompanies this request for a change in the
18 way that we do business, and that's actively in process.

19 I think another thing: We have given this type of
20 presentation in several international venues, talking to
21 people who are embarking on repository projects, basically
22 shaking them a little bit, saying, "As soon as you start
23 operating, you will see opportunities for improving your
24 efficiency without sacrificing safety. This has been our
25 experience, and these are the changes." In fact, one of my

1 talks that I've given overseas lists about nine or ten
2 smaller changes that were made because we saw that what we
3 were doing was not optimized and that there was a better way
4 of doing it.

5 And I think it's a wake-up call, because when I was
6 on the Yucca Mountain project, we thought we could nail all
7 this down before we start. And now I'm beginning to see, as
8 you mention, that reality sets in and you say, "Oh, that
9 wasn't such a great idea after all."

10 I have to make a comment on Bob Neill's talking
11 about the brine reservoir. We did hit that one brine
12 reservoir. We've looked for others since. We are very
13 heartened that all of that deep drilling that you see around
14 the site, which was not there when WIPP started--it's
15 fracking that made all this possible---none of these wells
16 have intercepted a pressurized brine pocket. They've
17 intercepted brine but not a pressurized brine pocket.

18 So I think, you know, that's interesting.

19 EWING: Jean?

20 BAHR: Jean Bahr from the Board. You mentioned that the
21 earlier heater tests were terminated prematurely before they
22 reached the full temperature. There have been proposals to
23 start some new heater tests. Would those be with a different
24 configuration, or would they be vertical? And what do you
25 think you might learn from actually getting to the

1 temperatures that those tests were initially designed to
2 achieve?

3 VAN LUIK: We proposed to EPA that they give us
4 permission to do heater testing at WIPP. If you go to the
5 EPA Web site, you will see a description of the two proposals
6 that we have. One of them was a lower heat proposal for salt
7 defense disposal investigations, is what we called that one.
8 The other one was for a higher heat disposal scheme, which
9 was the SDI proposal. These are available still on the EPA
10 Web site.

11 The status of these programs is under review at
12 Headquarters, and the latest that we heard was that the
13 funding may become available in 2015, at which point there
14 will be a lot of discussion before that time on the actual
15 scope and what we hope to get out of these tests. And if you
16 want to talk about that in the future, you should invite DOE,
17 Bill Boyle, for example, to talk about it, because this comes
18 under their purview, per the legal mandates that NE and EM
19 have. But the proposals are there if you want to read them
20 under the EPA Web site. Everything that we proposed to them
21 goes on their Web site.

22 EWING: Mary Lou?

23 ZOBACK: Mary Lou Zoback, Board. Just a question about
24 the two proposed tests. In the new tests, are you proposing
25 that the waste be inserted horizontally rather than

1 vertically--or the heaters?

2 VAN LUIK: If you go on the Web site and look at the
3 scheme, we would do the heaters on the floor--

4 ZOBACK: Just on the floor.

5 VAN LUIK: --with run-of-mine salt on top of them.
6 That's the proposal.

7 ZOBACK: Okay, good. And just for geologic curiosity,
8 at what depth are they fracking for the shale gas?

9 VAN LUIK: I believe it is between 7,000 and 11,000
10 feet.

11 ZOBACK: So substantially--

12 VAN LUIK: Substantially below the salt. I mean,
13 there's no oil in the salt.

14 ZOBACK: Right.

15 VAN LUIK: One of the reasons the oil and gas are there
16 is because of the protective cap provided by the salt.

17 And I must say, salt is exciting. I did my Ph.D.
18 on the Great Salt Lake, so evaporite chemistry is my bag.
19 I'm home. This is Evaporite Chemistry 101, 202, 303. But
20 the thing that's exciting about this is we have also done
21 some research on the content of brine inclusions in the salt,
22 and the DNA signatures of bacteria from one place to six feet
23 away show that there has been no intercommunication between
24 those two pieces of moisture in that salt since the time that
25 the salt was laid down 250 million years ago. This is really

1 a strong argument that salt can hold things without ever
2 letting them go. I don't think we'll ever have a 250-
3 million-year standard. I hope Bob's common-sense approach
4 prevails. We'll see.

5 EWING: So let me follow up on the compliance period.
6 That was going to be my questions. Perfect segue.

7 So Bob made his comment about the million-year
8 standard, and you have the advantage of experience working in
9 the Yucca Mountain project with a million-year standard, WIPP
10 project with the 10,000-year standard. So could you describe
11 some of the difficulties of going from 10,000 to a million
12 years? And what would be your view on an appropriate
13 compliance period?

14 VAN LUIK: Let's see, how many months am I away from
15 retirement?

16 EWING: You can take the Fifth. That's allowed.

17 VAN LUIK: In fact, I have been on international
18 committees on this very issue where we decided that for
19 countries where there is no limit on the time, the
20 implementer has to suggest a limit, that the implementer
21 should suggest it, it should never go more than a million
22 years. And if you look at Swiss performance assessments,
23 it's interesting, because they will have white backgrounds up
24 to a million years, and then they'll go to 10 million years,
25 10 to the 7th years, and they will have kind of a blue

1 background and a little asterisk saying, "This becomes very
2 speculative." So, in my opinion, beyond 10,000 years is
3 already very speculative.

4 But I like the idea at the Yucca Mountain--the
5 original Yucca Mountain standard said, "Go to the time of
6 peak dose and report that in your EIS as a qualitative
7 assessment to give us an indication that there is long-term
8 safety." I like that approach.

9 Now, they were subsequently, through legal
10 maneuvering, forced into giving us a million-year standard;
11 and in order to accommodate their disbelief in a calculation
12 beyond 10,000 years, they gave us a higher limit. I don't
13 like that approach, because it basically says you're
14 discounting the future. But it was their way of representing
15 the fact that they had a lot less confidence in numbers
16 beyond 10,000 years.

17 And other countries have done the same kind of
18 thing. Some go to 25,000 years, some go to 50, some go to
19 100. I kind of like 10,000 with a qualitative going beyond
20 that. But when you do a qualitative going beyond that at
21 WIPP, you can go out to 250,000 years when the plutonium is
22 basically gone, and it's still the same thing. It's totally
23 dependent on human intrusion assumptions. So it's an
24 assumption-driven result, and you might as well argue the
25 frequency of human intrusion.

1 I have argued and not been heard that what we
2 should do, if there is a new repository somewhere in bedded
3 salt--I don't care where it is--that you do preemptive
4 drilling and remove the oil and gas beneath it, help pay for
5 the repository. And that will not stop future human
6 intrusion, but right now these oil companies know for a
7 hundred years past what has been found, and that'll be the
8 way that it is. So basically you slow down your frequency of
9 intrusions to a very low degree, because each dry hole or a
10 hole with miniscule resource becomes a marker for at least
11 200 years. So I like that idea, but nobody listens to me.

12 EWING: All right. Let me turn to Staff. Questions
13 from Staff? Yes, Bret.

14 LESLIE: Bret Leslie, Staff. I have three questions.
15 I'll just ask one right now, which is: Bob mentioned
16 something that there were no engineered barriers in the
17 compliance determination; and having lived through Yucca
18 Mountain, you know the NRC requirements for multiple
19 barriers. How does engineered barriers play into a potential
20 salt repository for high-level waste?

21 VAN LUIK: Interesting question. Other repository
22 programs, including the German program, working in salt
23 consider the sealing of the boreholes to be engineered
24 barriers. EPA has said, no, that's not an engineered
25 barrier. You're basically restoring the permeability of the

1 opening that you've created to the way that it was before you
2 started. Your engineered barrier--it will be the magnesium
3 oxide that you place in the repository so that when microbes
4 degrade all of the organic materials in the waste--and don't
5 forget this is a mixed-waste repository as well as a
6 transuranic repository--it's transuranic mixed waste--that
7 you will have enough MgO to basically absorb all the CO₂
8 that's created, and you will stabilize your pH. And that's
9 an engineered way to stabilize your pH in case of a brine
10 intrusion so that there is a limit on the solubility of the
11 actinides. So MgO is our engineered barrier by regulation.

12 Doesn't mean that we can be sloppy about sealing
13 boreholes, but that is the way that the regulation meets the
14 law. It's also the law that you have two barriers, natural
15 and engineered. Next question?

16 EWING: Other questions from Staff? Gene?

17 ROWE: Just a quick one. Gene Rowe, Staff. I have a
18 question on your last bullet there. Can you define hot? How
19 hot?

20 VAN LUIK: When we look at the inventory of the waste
21 currently managed and actually existing under the purview of
22 EM, we're looking beyond our current mandate here. This
23 whole effort to look at a different way of doing things was
24 spurred on by a motive within EM. What if we are asked to
25 dispose of our own waste forms? So the hot would include the

1 spent fuel that's in the EM inventory that's being managed
2 right now, and that includes some pretty hot stuff. Not very
3 much of it. Most of it is old, cold, and useless; but there
4 is some stuff that's still quite hot. It basically falls in
5 the mid-range of the commercial wastes, which are very hot.

6 ROWE: Thank you.

7 EWING: Bret?

8 LESLIE: Bret Leslie, Staff. Could you talk a little
9 bit more about the closure of the panels? So, for instance,
10 in Panel 6, when you say it was closed, is it no gap at all
11 or how long--once you say you've closed a panel, is there no
12 access to the mains?

13 VAN LUIK: The first few panels were closed with a very
14 elaborate closure system. We have permission from both EPA
15 and the State regulators to go to a--well, this is basically
16 still in progress, but right now we have temporary closures.
17 We have basically curtains that keep the ventilation from
18 going in and out.

19 And so what we hope to do once we get permission
20 from the State basically is to use run-of-mine salt to seal
21 these rooms permanently, and we will shove that salt in and
22 basically make contact with the whole system. And then there
23 will be settling, but at the same time we'll have the roof
24 coming down to compress that salt.

25 But this is all still in the works. This is

1 another one of those optimizations that we looked at, because
2 the original plan was for a very robust concrete barrier that
3 we see now, one, would not have been any more effective and,
4 two, would have been very, very difficult and expensive to
5 put in place.

6 So these are some of the changes that, as you go
7 along, you say, well, what we said at the beginning--the
8 point is, it's not necessary from a safety point of view.
9 What we were thinking might be the consequences of putting
10 waste in these rooms, through monitoring we have shown are
11 not the consequences. There's miniscule amounts of volatile
12 organic compounds coming out in the air out of these rooms,
13 miniscule.

14 EWING: Nigel?

15 MOTE: Nigel Mote, Board. Could you say something more
16 about magnesium oxide as an engineered barrier? If I saw
17 apparently from the picture, there's a bag on top of the top
18 drum; and over time the salt will close in around all of the
19 materials in the panel. But you said--and I haven't heard
20 this before--that microbe communities that are six feet apart
21 had no communication for 250 million years. So if the salt
22 closes around the drums in the panel like that and the first
23 perforation of a drum is at the bottom, how does the
24 magnesium oxide work in correcting the pH?

25 VAN LUIK: I wish I had the illustration that we used to

1 show that. When the roof comes down or the floor lifts up,
2 the first contact will be with the MgO sacks, which will
3 break, and the granular compound, the MgO, will then fall in
4 between the waste packages. And so it'll be distributed as
5 the roof is collapsing and the floor is coming and the sides
6 are coming in. And then this is only effective if there is a
7 brine flow from a human intrusion event. When that brine
8 comes in and begins to dissolve waste, the pH will be
9 controlled, because the MgO in the solution will absorb all
10 the CO₂ that has been basically created by the microbial
11 activity.

12 This is all very conservative. I mean, in my own
13 mind, I can't see this ever being invoked. But at the same
14 time, we have a requirement, we meet it.

15 But I hope I answered your question that it'll be
16 distributed as the roof collapses, as the roof comes in.

17 MOTE: Was extensive modeling done of how the--I take it
18 the magnesium oxide was granular.

19 VAN LUIK: Yes, yes, it's a pretty fine granular
20 material.

21 MOTE: So is there confidence it'll be distributed in a
22 way that does allow that sort of performance every time?

23 VAN LUIK: Yes. But if you're asking me if there has
24 been detailed modeling of exactly where it falls and how it's
25 distributed, the idea is that the entire room would be the

1 place where the CO₂ builds up; and when the brine comes in,
2 it would mix with the CO₂, and it would find the MgO in many
3 places. And so it's a room effect. It's not just a local
4 effect per package. It's an effect that spreads across the
5 whole room.

6 So we think that it's a very conservative approach
7 that we're using right now. And, in fact, we have cut back
8 on how much MgO we put in, because we were using way too much
9 in the past. But now we're trying to match it that it's 1.2
10 times the potential CO₂ build-up from whatever organic
11 materials are in the waste, and we actually characterize that
12 and evaluate it on a shipment-by-shipment basis.

13 MOTE: Okay, thanks.

14 EWING: Sue?

15 BRANTLEY: Sue Brantley, Board. Can you just talk a
16 little bit about what the observations are in terms of the
17 distribution of brine? Is the amount of brine the same in
18 all the different panels and all the rooms, or does it vary
19 from one spot to another? What can you say about that?

20 VAN LUIK: This is bedded salt. It's not domal salt
21 where it's been squeezed and basically purified by the
22 geologic processes, and so we have a certain content of brine
23 in the salt, which is pretty constant. But wherever we have
24 interbeds with clays, there is much more moisture there.
25 And, like I said, when they did the vertical borehole tests

1 for heaters, wherever they intercepted one of those lenses of
2 clay is where they had a lot of brine in-flow from the
3 disturbed rock zone. So if you stay away from the clay
4 layers, you have basically a very predictable amount of
5 moisture. If you intercept one of those clay layers, then
6 you have a less predictable amount of moisture coming in.

7 But if you go--you need to go into WIPP and look at
8 this yourself, because you will see that when you have a
9 fresh excavation, you immediately create a very large
10 pressure gradient that takes water from the salt in the
11 disturbed zone that you've just created and brings it into
12 the one-atmosphere-of-pressure regime; and you will see on
13 the walls that there are stripes of salt where moisture has
14 come in and evaporated and left the salt behind. You need to
15 see that for yourself to get an appreciation of it.

16 And then that stops. It doesn't continue, because
17 it's only the disturbed rock zone that contributes moisture.
18 When you get a little bit further out, moisture has a heck of
19 a time moving through that salt, because, like I said, the
20 salt that we have sampled shows that there is no
21 communication even from here to there.

22 BRANTLEY: And can you say a little bit more about this
23 idea that there is no communication? I mean, you mentioned
24 it before, but, I mean, what is it based on? I mean, you're
25 assuming that the DNA you're finding was there for 250

1 million years?

2 VAN LUIK: Oh, yeah, there is no question about that.
3 And, in fact, we have DNA characterization--and this is not
4 my area, so I'm just going off what I have heard in
5 presentations--and then looked at salt-loving bacteria and
6 Archaea today and seen that the DNA basically matches. Now,
7 if you have evolved to live in an environment like that and
8 that environment never changes, I guess you'll never change.
9 That's the way evolution works.

10 But the idea is that we can link the bacteria from
11 250 million years ago to what we see today in similar
12 environments. Not that they are totally identical, but their
13 DNA shows that they are very closely related to what we see
14 today.

15 BRANTLEY: Wouldn't that argue that the bacteria of the
16 DNA could be from much more recent bacteria?

17 VAN LUIK: No. You need to visit WIPP and get your own
18 sample with a fluid inclusion in a crystal. That fluid
19 inclusion hasn't gone anywhere. It's part of the original
20 Permian Sea that basically when the seawater evaporated
21 became enclosed by the precipitating salts around it. And we
22 need to find you a nice little rock sample, because once it's
23 in there, it is saturated. It's not going to move, because
24 it doesn't dissolve the walls around it, because it's
25 saturated. There is some interstitial water that's inside

1 the actual crystal. There is some intercrystalline water
2 that moves, especially when you create a huge pressure
3 gradient by drilling through the salt.

4 But I think the evidence--and other people who
5 actually do this work need to talk to you about this. But
6 they have convinced me that there is no movement of water
7 once that salt bed has been laid down unless you have
8 tectonic movements that squeeze that salt and actually purify
9 it. If you go to a domal salt, it has about ten percent of
10 the moisture that we have at WIPP. We have a much wetter
11 environment than the domal salts that are being used in
12 Germany.

13 And when I said WIPP is the only operating
14 repository, it's only because Morsleben is closed, because
15 the Germans had two operating repositories, Asse and
16 Morsleben.

17 EWING: Ewing, Board. I think that's the first time I
18 have remembered to identify myself.

19 Going back to the MgO question, it's very
20 interesting to me the limited number of barriers, actually,
21 in a salt repository, particularly at WIPP. So the MgO story
22 is, from a chemical point of view, a little bit complicated,
23 right?

24 VAN LUIK: Yes.

25 EWING: It's not so obvious that it would work as

1 described. So if it didn't work as planned, what is the
2 impact on the safety assessment?

3 VAN LUIK: The impact on the safety assessment--and
4 don't forget, the only way to get anything out of WIPP is
5 human intrusion.

6 EWING: Right, right.

7 VAN LUIK: Human intrusion that allows brine to flow
8 into the repository, which in itself is a low-probability
9 event. If there was no MgO, we would have less control on
10 the solubility. The pH could vary and fluctuate. And, in
11 fact, there are acid brines that would be carrying more; and
12 so you would have higher releases through the pathways that
13 are assumed to exist in order to address the regulations.

14 The regulations make us assume that the brine in
15 the aquifer or the moist section of rock above the repository
16 is actually an aquifer that can be pumped and used and drank,
17 which is ludicrous, but at the same that's the way that you
18 simplify the situation so that you can do a calculation.

19 If you dilute this brine, you--I must say, the
20 National Academy of Sciences, I think, in 2002 looked at
21 WIPP, basically took a relook at it, and made recommendations
22 for optimizations. And one of the things that they observed
23 was, we're not sure that this MgO is really necessary, but
24 EPA is the regulator. EPA says you will have this as a
25 barrier; therefore, we have it as a barrier. Some of us are

1 not that convinced that it's that important, mainly because
2 of the speculative nature of the scenario that invokes it in
3 the first place, but the point is, you do what the regulator
4 says, and you meet your regulation.

5 EWING: Right. You've described a probabilistic risk
6 assessment. I understand that. But the wide range in
7 probabilities in even the conservatisms can't be used to
8 explain away a barrier that's part of the analysis, right?
9 So the assumption is that it works as described. And I'm
10 just curious, how important is it that it works in terms of
11 the calculated dose from the analysis?

12 VAN LUIK: I don't know the answer to that question. I
13 think there were sensitivity studies done on that exact
14 thing, but I'm just not familiar with that work at this
15 point.

16 EWING: Okay, thank you.

17 Other questions? Jean?

18 BRANTLEY: You mentioned that there is monitoring of the
19 areas around the rooms to look for deformation and strength.
20 Are those data accessible from the surface, or do they have
21 to be retrieved underground? I guess I'm wondering if
22 anything has shown up on that monitoring network that might
23 inform the recent incidents.

24 VAN LUIK: We also do seismic monitoring, and we were
25 listening very carefully to see if anything with these

1 incidents showed up on the seismic monitor and then told that
2 the answer is no. We have two types of monitoring. One is
3 manual, and the other one is automated. The automated is
4 continuously fed to the surface. The manual is weekly and
5 almost daily inspections and measurements on strain gauges
6 and other things, and that information then is input to the
7 data system. But I must confess that I am not that
8 conversant with those particular data archives.

9 EWING: Okay. Abe, I want to thank you for your
10 presentation, but also thank you for indulging us through so
11 many questions. This has been very helpful.

12 If you want to speak in the public comment period at the
13 end of the morning session, please sign up at the table at
14 the door where you entered.

15 And also, I was remiss in not mentioning Wendell Wert.
16 Wendell, will you stand? Wendell was the Chief Scientist for
17 the WIPP Project for decades. I've argued with him over many
18 points, and I would say it was always a pleasure, and he
19 deserves a lot of credit for navigating WIPP to its opening.
20 I wanted to be sure that people who don't know him recognize
21 him and I wanted to thank him for being here.

22 So we'll end this session now, and resume at ten
23 after the hour.

24 EWING: The next speaker this morning is Kristopher
25 Kuhlman, who will be speaking to us about issues related to

1 disposal of high-level waste and spent nuclear fuel in salt.

2 KUHLMAN: Thank you very much. It's an honor to present
3 here to the Board and to the audience. What I am going to be
4 presenting is essentially a kind of a fast-paced history of
5 high-level-waste-related testing in salt.

6 So what have we learned over 50 years? And for
7 some of you that are familiar with this, this will be a trip
8 down memory lane. Hopefully, for at least a few of you,
9 there will be some new things you'll learn here about what's
10 already been done, because if you don't understand history,
11 you're doomed to repeat it. So let's hope we don't reinvent
12 the wheel too many times.

13 So the title of my presentation talks about a
14 technical basis. What exactly is a technical basis? A
15 technical basis is kind of the embodiment of our cumulative
16 understanding about a topic, and it's really achieved through
17 an iterative process where you basically--you go out and you
18 say, "I understand what's going on here physically. I
19 understand the processes." Then from your understanding you
20 try and develop some sort of models.

21 Then the key here, which is kind of the point of my
22 talk, is you parameterize and validate all your models with
23 data. You collect data. You say, "Do the models that we've
24 developed have any relation to reality?" Then you make the
25 next step and you quantify limitations and uncertainties in

1 these models.

2 But it's a very iterative process. As you get
3 data, you understand, oh, that wasn't a very good assumption.
4 And so you go back and you redevelop and you collect more
5 data. And so this process is how you derive a technical
6 basis. And the Step 3 here is--essentially what I'm going to
7 be talking about is the collection of data from both
8 laboratory and mostly in situ tests, which we then use to
9 validate our understanding and assumptions of the system.
10 So, really, it'll be a trip talking about all the highlights
11 in roughly chronological order of the high-level-waste-
12 related testing in salt.

13 And on each slide I try and give a little nugget of
14 what was learned or how did this test specifically or this
15 testing program contribute to the technical basis which we
16 have now for salt. And then in the last slide I'll kind of
17 sum up and hopefully mention a little bit of maybe what
18 remains.

19 You're not expected to read all this. This is just
20 supposed to be impressive, but, gosh, there's been a lot of
21 tests. The bottom axis here is time, and you can see that
22 testing started back in the late 1950s, early '60s, in Kansas
23 with Project Salt Vault, moved into Avery Island, a lot of
24 tests in southeastern New Mexico associated with WIPP. There
25 were tests in France at the Amelie mine, and there were a lot

1 of tests in Germany through the years in the Asse and other
2 places. But this is just to give you an impression of--this
3 is kind of what the rest of the talk is going to be about.
4 It's discussing in general these tests.

5 Starting back at the early history, the University
6 of Texas was doing laboratory testing on salt creep. During
7 the meeting of the--it met from 1955 to 1957, the National
8 Academy of Sciences Panel, which was already alluded to a
9 couple times. And their main recommendation, as was already
10 stated, was for the disposal of liquid reprocessing waste
11 directly into salt domes. And this diagram on the right here
12 is actually a cover page out of one of their reports. And
13 they show that there would be a nuclear power plant
14 co-located with a reprocessing facility on top of a salt
15 dome, and then you would just go ahead and inject it right
16 down into the ground. This was in 1957, and they were like,
17 okay, problem solved; let's move on. And we all know that
18 it's much more complicated than that.

19 But this still basically describes the processes.
20 I mean, they were understood back in 1957 from that National
21 Academy of Sciences Panel that we have radiation effects; we
22 have chemical solubility effects, thermal effects,
23 permeability of the salt; we understand the time effect and
24 stress. It's a simplified cartoon, but it really captures a
25 lot of the essence of the problems we still deal with.

1 And the University of Texas did some extensive
2 testing where they did creep tests in the laboratory. They
3 actually made salt cores and cut little cavities into them
4 and then squished them on a testing apparatus to see how a
5 miniature little repository would get squished. They did
6 some of the first permeability testing in salt where they
7 tested helium, brine, and kerosene flow through the salt.
8 And they were really--this is still the reference from the
9 late '50s where people point to that salt crystals themselves
10 are impermeable. They actually took a single crystal of salt
11 and showed that nothing really moves through it. It has to
12 move between the grains.

13 And they did some closure tests, and their salt for
14 their laboratory tests came from the Grand Saline Salt Mine
15 near Dallas, Texas, and that's a salt dome. And that's why
16 they were able to do creep tests up to 400 degrees C.

17 And these early tests, aside from historical
18 reasons, are interesting because a lot of the early
19 geomechanical tests where the theory was originally
20 developed--this report by Serata and Gloyna--Shosei Serata is
21 a famous rock mechanics guy, and I think he might have been a
22 post-doc when he did this. So this was kind of where a lot
23 of these tests--they came up with analytical solutions for
24 salt, elastic, and plastic behavior. Obviously these have
25 all been defined, but this is where a lot of the groundwork

1 was laid.

2 In affiliation with the University of Texas, Oak
3 Ridge National Lab was doing tests in Hutchinson, Kansas, and
4 this is in bedded salt. And they were operating still under
5 the assumption that we would be doing liquid reprocessing
6 waste into a salt dome, and so they were doing tests using
7 PUREX, which is a type of reprocessing--PUREX is a process
8 for reprocessing, so it's a type of waste. It's radioactive
9 isotopes in, I think, nitric acid.

10 So they built several tests where you excavate a
11 pit, and then you fill it with acidic radioactive waste, and
12 you heat it with a heater. And they did tests in a small
13 scale, medium scale, and then they did a large-scale test
14 here--you see this black and white picture in the bottom
15 right--where they had to build this rather complicated
16 system. You see a cutaway drawing here of what's going on in
17 the photo down below where they had to build a complicated
18 lid system to capture the off-gas that was created from
19 basically boiling liquid radioactive waste. And it was a
20 rather complicated system, and they monitored creep closure
21 in the room. They monitored an extensive amount of solid,
22 which was precipitated in the cavities, and the corrosion.
23 They put coupons in and monitored those, and they looked at
24 gas generation. And they found that liquid disposal is
25 really infeasible due to cavity stability and gas generation

1 issues.

2 And so this really wrapped up the liquid testing in
3 salt, and so we have since really moved on to, let's just
4 dispose of solidified waste. But it was all due to this
5 early testing in the late '50s.

6 And Project Salt Vault, which many of you might be
7 aware of, was--the actual title of it discussed the disposal
8 of solid high-level waste, because they realized we're not
9 actually sure how we're going to solidify it, but let's
10 assume it's solidified, and let's deal with that because of
11 all the complications that arose due to liquid waste.

12 And Project Salt Vault was in a different mine but
13 nearby in Lyons, Kansas, and they did a demonstration where
14 they were actually disposing of fabricated radioactive waste
15 and bringing it in from Idaho, bringing it down the way they
16 thought they were going to bring it down, trucking it in on
17 the trucks. It was actually a demonstration. And then they
18 took the waste out and took it back. So it was trying to
19 show that every step is possible.

20 A large number of tests were done there. I'm going
21 to highlight just a few. An important one was the hot
22 borehole test done at the very beginning where they took two
23 boreholes, one horizontally and one vertically, and they put
24 heaters in them and heated them with--they were 5-kilowatt
25 heaters, which is pretty hot. And they heated this bedded

1 salt up to 350 degrees C, and there was a huge explosion
2 basically, and all the salt decrepitated into the borehole,
3 and brine was released, and they were like, whoa, this is
4 bad. And that was basically where the recommendation came
5 from: We should never let a salt repository get above 200
6 degrees C, because, wow, this is bad.

7 So this test right here in 1962 was kind of the
8 test that that recommendation was based upon. And so then
9 the rest of Project Salt Vault was designed to--this test
10 was, you could say, kind of pre-Project Salt Vault. And so
11 these other Project Salt Vault tests were--they did these
12 series of three tests that were seven boreholes, like this
13 pattern over here, and they actually put radioactive sources
14 with heaters so that between the radioactive source and the
15 heater, it was about 10.5 kilowatts for this array.

16 They changed out the sources as they decayed, so
17 there was a fair amount of--it was kind of process testing,
18 you know, is this a feasible way to handle waste. And they
19 collected brine inflow into these boreholes. They looked at
20 creep closure. They looked at lots of things. Here is an
21 example. This graph down in the lower right shows brine
22 collection in these boreholes, and there was a fair amount of
23 brine collected.

24 They also did pillar creep tests where they took a
25 pillar between two rooms and put 22 heaters totaling 33

1 kilowatts around the base of it to try and make it creep
2 faster. And they actually developed some mathematical models
3 to describe that, and they were able to validate them.

4 And there was a lot learned. A lot of our
5 technical basis really comes from Project Salt Vault or
6 originally came from there. For example, that there is a
7 significant brine flow can happen from the non-salt layers in
8 bedded salt, and that decrepitation can really be an issue in
9 bedded salt, and that brine inclusions will tend to migrate
10 towards heaters. And these are the small brine bubbles,
11 basically, inside the salt crystals that Abe talked about.
12 In the laboratory they found that if they heated them on one
13 side, they could get them to migrate towards the heater
14 source.

15 And this was all without or with very limited
16 numerical calculation capabilities. This was all done in the
17 '60s, so it was--you know, everything was analytical
18 solutions, and it was what we consider now to be very
19 simplified analysis. But, really, they collected a lot of
20 the data and did a lot of the initial work that is the
21 foundation for what we do now.

22 Fast-forward to the late 1970s at Avery Island in
23 Louisiana. There were several tests done there. I'm going
24 to talk about two of them. One of them was a long-term
25 heater test done called Site C. It was a set of--you see

1 here is a photo. It's a central heater and then a ring of
2 guard heaters around it into the floor. Actually ran it for
3 five years uninterrupted. And they were doing salt
4 permeability testing using gas flow measurements, and they
5 were estimating the thermal conductivity of the salt in the
6 backfill.

7 And you can see here is a radial cross section
8 through the borehole. You can see here is the heater, and
9 you can see the temperature contours at the--I think this is
10 near the end of heating.

11 One thing they learned, though. They drilled
12 boreholes at different distances away from a steady-state
13 heating test, and they found that the salt permeability to
14 gas decreased by a factor of 10,000 during heating.
15 Essentially, there is a disturbed rock zone that develops
16 when you mine the room out; but then when you heat it up, it
17 tends to close back up, because the creep is accelerated by
18 heat, and also the thermal expansion of the individual salt
19 crystals tends to plug up all the holes which have opened.
20 And so here you can see that as the borehole temperature goes
21 up, the permeability drops quite a bit. And so you can see
22 that the heating actually kind of heals the salt or it speeds
23 the healing of the salt.

24 Some more Avery Island tests that were done. They
25 did an extensive brine migration test where they drilled a

1 series of boreholes, heated and unheated tests that were very
2 similar, and one that actually involved using deuterated
3 water. And they monitored brine inflow into these boreholes.
4 This is domal salt here; this is not bedded salt. And you
5 can see that even the unheated site did have brine flow, but
6 the heated site had more brine flow. And they found that--
7 you can see they turned off the heater here, and then a large
8 amount of brine flowed in actually the next day, and about
9 equal amount of brine flowed in the two days after heating,
10 as compared to the rest of the test.

11 And they actually did an interesting thing in one
12 of the heated sites where they actually took gas permeability
13 measurements around the heater in the days following turning
14 off the heater. So as they're stepping down the heater
15 power, they're doing gas permeability tests; and they're
16 finding that as the heater power is going down, the
17 permeability of the salt is going back up. So the healing
18 that occurred during the thermal expansion and the creep of
19 the salt is kind of reversed because of the tensile
20 fracturing of the salt. So as it's cooling, the salt grains
21 are kind of shrinking and pulling apart from each other. And
22 this is then accompanied by an increase in moisture
23 collection. So this bump right here corresponds to those
24 points up there.

25 And this is a very, very interesting test that

1 shows the thermal effects on salt. And typically this
2 cool-down period, you would say, would not happen maybe in an
3 actual repository, because the cool-down period is going to
4 be over hundreds of years probably during the radioactive
5 decay of the salt.

6 The deuterated water test was interesting.
7 They actually introduced deuterated water into the test, and
8 they were looking--they initially designed the test to
9 observe the effects of brine inclusion migration. But then
10 they found that the deuterated water actually diffused away
11 from the borehole rather than just migrating towards the heat
12 source, as they initially thought.

13 So they learned from this test that basically brine
14 inclusion flow, the tiny bubbles in the crystals, is not
15 really significant, that the salt behaves more like a porous
16 medium, and that permeability increase at cooling is really
17 what allows this brine to flow, because they have these two
18 datasets, and it's pretty clear that one is causing the other
19 then.

20 Switching now to a little bit later but in
21 Albuquerque, these are a few Sandia Laboratory tests that
22 were conducted pre-WIPP. One is kind of a large-scale
23 laboratory test. It's called the Salt Block. And they
24 heated a one-meter salt cylinder, so it weighed up 1700
25 kilograms; it's rather large. They actually heated it and

1 cooled it in steps. And so the red curve here shows the
2 thermal history, and the blue curve shows the brine inflow
3 history. And you can see they heated it with a central
4 heater. This is a cross section through the cylinder. And
5 they monitored temperature and brine inflow.

6 And the thing that they found from this, you see
7 that every temperature change both up and down corresponded
8 to a brine inflow. And the largest spike in brine flow right
9 here actually occurred when they stepped the heater power
10 down.

11 So they found from this test, really, that the
12 thermal response is pretty simple. They were able to model
13 that quite easily. But the brine flow really required a new
14 conceptual model, because the conceptual model at the time
15 really was incapable of recreating these short spikes that
16 then decayed away, because the brine inclusion migration
17 model would show a slow, gradual increase after each one of
18 these steps rather than a spike that decays away. So this
19 was known before, but this laboratory test gave us a really
20 good dataset to really prove that it wasn't some complication
21 due to field data that we weren't able to explain the data.

22 Another important lab test that was done at Sandia
23 a little bit later called the Salt Cracker test where they
24 heated two smaller cylinders of salt but to 200 and 300
25 degrees C. And they looked at brine release due to both

1 decrepitation, which is due to the inclusions actually
2 shattering because they get so hot, and due to cooldown and
3 then also at steps in heater power.

4 So you could see here--sorry these graphs are so
5 complicated, but I've color-coded the lines so maybe you can
6 understand them. The red line shows temperature going up
7 during heating and the temperature going down during cooling.
8 And then the blue line shows brine inflow. And you can see
9 that when the temperature reaches the decrepitation
10 temperature, there is a huge amount of brine that flows in,
11 and that's these brine inclusions suddenly becoming
12 available. The brine inclusions have shattered, and they've
13 flowed into the--now they're flowing through the salt like a
14 porous medium.

15 And then the green are acoustic emissions, so they
16 actually put a little microphone next to the salt, and they
17 could hear it shattering. And this was then used later--this
18 was a little test to kind of test this hypothesis, like, can
19 we hear the salt fracturing. And they learned from this that
20 the acoustic emissions really do reveal salt microfracturing
21 and that brine release at cooling happens even after the salt
22 has been decrepitated. So the brine release at cooling is a
23 porous medium effect, and it's because the grains are
24 shrinking and you now have increased the porosity and
25 increased the permeability, while decrepitation is the

1 release of intragranular porosity to intergranular porosity.

2 There were a few more tests that were done at an
3 in situ site but not at WIPP in preparation for WIPP, and
4 these were done at a potash mine in Carlsbad in the early
5 '80s before the first WIPP shaft was drilled, which couldn't
6 be drilled until the environmental impact statement was
7 finished.

8 So there was some early waste package material
9 testing, some heater and--here you see Marty Molecke looking
10 fashionable with a heater with some coupons attached to it.
11 Here's a drawing of it. You can see they put that down in
12 the borehole, backfilled with salt, poured some brine in
13 there, heated it up, and then looked at the borehole closure,
14 brine inflow, how the brine affected the coupons, all of
15 these things. It was really a dry run for WIPP, and they
16 learned a lot of the difficulties of working underground in
17 an actual in situ environment. And this was an actual
18 working mine, too, so there are miners going by mining
19 potash.

20 Now skipping to the Waste Isolation Pilot Plant,
21 which obviously you've heard quite a bit about from Abe. But
22 what I'm going to focus on is the North Experimental Area
23 here in red at the top where there were three primary defense
24 high-level waste test programs that were conducted. And they
25 were really conducted for a future Deaf Smith high-level

1 waste salt site, because at the time the tests were being
2 designed, WIPP had already been chosen. No high-level waste
3 would come to it, but it's such a good site, and it's
4 available already, so let's go forward with these tests.

5 So there were the thermal/structural interaction
6 tests, which were kind of the key tests that most people have
7 heard of and seen pictures of. There were also waste package
8 performance tests, which they looked at corrosion and
9 backfill materials, and then a plugging and sealing program.
10 And these three kind of major programs are what were related
11 to the defense high-level waste. There was actually quite a
12 bit of non-defense high-level waste programs that were more
13 related to WIPP itself. They did a lot of TRU tests for TRU
14 waste that involved--and brine flow tests in Room Q. They
15 did lots of tests that were not related to defense high-level
16 waste that are also famous, but I'm not going to talk about
17 those here.

18 So starting off with the TSI test, the thermal/
19 structural interactions test, in Rooms A and B, Rooms A,
20 which are these three over here in this zoom, they were
21 design rooms. The center room was kind of chosen to be just
22 like the design where you'd have two rows of boreholes in the
23 floor, and it was supposed to be the designed thermal load of
24 what the waste was expected to be, about 470-watt heaters.
25 And Room B, which was similar to one of these rooms but

1 isolated by itself, was a test where they put a lot more heat
2 into a single room to, you know, what happens under kind of
3 less ideal conditions.

4 So you can see that between Rooms A1, 2, and 3, if
5 you total up all the heaters, there were about 64 kilowatts
6 of heaters running. That's a lot of heat. But over here in
7 Room B there were almost 60 kilowatts of heat in a single
8 room. So this (inaudible) was an over-test. It was about
9 three times as hot as the other rooms.

10 There were also four brine migration tests. They
11 might be a little hard to see, but they're the green stars
12 behind the other--and these were boreholes that had a
13 piggyback test where they also looked at brine flowing into
14 the boreholes while there was a heater placed in the
15 borehole.

16 And there were eighteen waste package tests where
17 they put different materials into the boreholes, and then
18 seven of them were actually retrieved later. And I'll show
19 some pictures of that.

20 So a little more information about Rooms A, B, and
21 D. Rooms A and B, there were thousands of monitoring points,
22 monitoring continuously through time a lot of things, mainly
23 temperature, differential creep, creep at different distances
24 into the rock, oriented stress or pressure, brine inflow,
25 room closure, heat flux, heater power. Room D was a similar

1 room that was unheated, so we had kind of a control room.

2 And then here is some data. Over here on the top
3 right shows the thermal response in the salt between some
4 heaters in the middle of the A room. So this is the cooler
5 rooms. And you can see that it did pretty much--the
6 temperatures did reach what you could probably say is close
7 to a steady state. And you can see that the temperatures
8 here are not that hot, but they're hot, while if you look in
9 Room B on the surface of the guard heater, you can see that
10 this is the hot room. On the surface of the heater, things
11 got above 200 degrees C. So it was very hot.

12 And here it shows you the rapid pace of mining of
13 these rooms and then when the tests were turned on and off.
14 But most of the tests ran for four to five years. But, yeah,
15 they were mined out in 1984, and the tests wrapped up in
16 1990.

17 And one of the things that was learned, the roof
18 failure, which was alluded to as well earlier, was preceded
19 by a rapid closure increase. And I think Lupe will actually
20 show a little bit of this in his presentation, so I won't
21 talk more about that.

22 Here is another classic photo of Darrell Munson in
23 the central A room. You can see all the instrumentation,
24 wiring. These manhole covers are covering the individual
25 heaters. There was a lot of instrumentation going into the

1 walls, into the back, into the floor. Then there were also
2 situations like here where there was a denser array of
3 observations around a single borehole so that we see
4 small-scale effects, large-scale effects, all going on. An
5 incredible amount of information was collected from these
6 tests and reported. There were large, three-inch-thick data
7 reports covering all this date. So it's all out there and in
8 the public record.

9 Here are some defense high-level waste tests with
10 the waste package performance. Here is a photo down one of
11 the boreholes. You're looking down a borehole at the top of
12 a heater basically here. And that smaller circle is where
13 they grab it. It's called a pintle. It's what they grab the
14 heater with. And you can see the instrumentation going down
15 the boreholes. And then they ran the test, and this is what
16 it looked like when they pulled it out. Some of them they
17 were able to pull out. Some of them the creep had--the salt
18 had closed in around the borehole. And also, due to the
19 boiling off of water in some of them where they were
20 collecting the brine, there was salt precipitated in here.
21 And so they had to actually over-core, you know, run a
22 meter-size core barrel down there to pull these out. This is
23 before and after the heating in Room B. I'm not actually
24 sure this is the same heater, but this is kind of
25 characteristic of what it would look like.

1 The brine release tests that were done in Rooms A1
2 and B--and being a hydrologist I find this very fascinating--
3 but it was a very interesting dataset that was collected.
4 They flushed dry nitrogen through the boreholes and then
5 flowed the dry nitrogen through a desiccant canister and then
6 weighed the desiccant canisters every day. And so that's
7 what this data is here. And you can see that in Room B up
8 here where temperatures got up to 130 degrees C, we were
9 seeing 50, 60, 70 grams of brine per day per borehole--so
10 it's a pretty good amount of brine--while in Room A where it
11 was only 50 degrees C, we were seeing much less brine inflow,
12 you know, a factor of 10 almost, less, or a factor of 5.

13 So Room B produced, I guess, eight times more
14 brine, is the number, from the same geology but only a
15 difference of three times in temperature. So this is a
16 pretty good dataset to show you the temperature effects on
17 brine inflow.

18 But, as Abe pointed out, these are vertical
19 boreholes. They penetrated clay layers, and a large portion
20 of this brine actually was from the clay layers flowing into
21 the intersected boreholes. Actually, Clay F was the name of
22 the clay that intersected these.

23 We learned that a vapor transport of brine in
24 intact salt is insignificant. When I said that the brine
25 transport theory had to be rethought, then one of the first

1 things that were thought were, well, probably the brine is
2 being transported as vapor through the intact salt. But it
3 was found--they changed the partial pressure in the boreholes
4 for collection, and it really had no effect on how they
5 collected brine. So it's kind of proof that it's actually
6 the liquid brine flowing to the borehole under a pressure
7 gradient that's the main source of brine, at least in these
8 tests.

9 They observed brine inflow consistent with that
10 salt brine that I showed in the previous picture. They did a
11 chemical analysis of that salt brine and looked at the mass,
12 and they found that a mass balance was--the amount of brine
13 that we collected through this system was roughly equivalent
14 with the amount of salt that was deposited, and so we didn't
15 lose any brine. We were able to track it through the system.

16 And the thermo-poro-elasticity model of McTigue was
17 able to explain a lot of this data, so it's basically a poro-
18 elastic model, but you actually add thermo to it, and thermo-
19 elasticity, you know, you add poro to it. But basically
20 you're saying that it's a combination of the rock mechanical
21 response and then the actual thermal--the differential
22 thermal expansion of the brine and salt that causes brine to
23 flow into the borehole. And they were actually able to
24 explain it pretty well. That model didn't include brine
25 inclusions at all, and it was able to match the data.

1 Shifting gears totally now and switching to some
2 ANDRA tests that were done in the Amelie potash mine in the
3 late '80s and early '90s in France. They took boreholes in
4 a--it was a bedded salt potash mine in eastern France in the
5 border with Germany. And they drilled a series of boreholes
6 and filled them with different types of crushed salt that
7 were different grain size distributions to see if the
8 reconsolidation of salt was affected by--you know, if we have
9 the big, coarse pieces in there or if we just have almost
10 like table salt. And they found that with different heaters
11 it didn't really matter.

12 And they also did a test--you can see these guys
13 installing a heater here. They installed a 4-kilowatt heater
14 in a big borehole that reached pretty hot temperatures after
15 seven months of heating, and they monitored brine inflow and
16 all these things and found similar results to what was seen
17 at the bedded salt at WIPP. And they also did gas
18 permeability tests at other places in the mine.

19 And from these tests they found that boreholes, if
20 they had a heater and it had no--if they just put the heater
21 in an empty borehole and didn't backfill around it, it
22 complicated the heat transfer, because now have significant
23 radiative effects, and it's non-linear. So they found that
24 putting crushed salt in the borehole, it simplified the
25 ability to simulate it. And so they said, well, crushed salt

1 is there in the mine, let's just do it, it's simpler. And so
2 that was an interesting result that they took away from their
3 testing.

4 And they found that from these gas and brine
5 permeability that sometimes when you're looking at these very
6 low permeability rocks, you actually have to--you have to
7 evoke the viscoplasticity model, because just looking at--
8 you know, poroelasticity sometimes isn't enough. You
9 actually have to incorporate the creep term in there, too.
10 So they did some rather advanced tests and were able to match
11 them with some pretty advanced models.

12 Now, shifting gears again to the Asse mine, Asse
13 II, referring to the second shaft at the Asse mine in
14 Germany, they did a series of tests--and I'm going to talk
15 about a couple of them--but they did heater tests going back
16 to as early as 1968, and they were doing some of these tests
17 to determine in situ thermal properties of salt to kind of
18 demonstrate their systems, you know, kind of like WIPP did at
19 the Mississippi chemical potash mine. They are basically
20 kind of dry running some of their instrumentation.

21 That's actually a significant problem, you know,
22 because stainless steel corrodes heavily in the presence of
23 chlorine. So you have to rethink a lot of the--you know,
24 what you think is a robust system falls apart in salt.

25 They also were able to demonstrate quite a few

1 different geophysical methods to interrogate the heated salt.

2 All the references that I'm referring to are at the
3 last slide, so if you're interested in tracking any of these
4 down.

5 There was a heated deep borehole closure test that
6 was done in the late '70s where they drilled a deep borehole
7 from inside the mine and then heated it in individual places
8 and looked at the borehole closure both in time and in space,
9 using calipers. And Lupe will talk a little bit more about
10 that, too, because that's now used to validate some numerical
11 models.

12 They did a heated brine migration test and another
13 HAW, high activity waste test, which I'll talk more about.
14 And they did some crushed salt reconsolidation tests, which
15 I'll also talk more about.

16 The Asse brine migration test was philosophically
17 very similar to the tests done at Avery Island and at WIPP.
18 But Asse is a salt dome, so it's not bedded salt. And they
19 added additional complications where they had four identical
20 boreholes where there was a central heater and then a ring of
21 peripheral heaters. And two of the boreholes had cobalt
22 radioactive sources, and two of them were sealed and two of
23 them were open to the atmosphere. So they had kind of a
24 matrix of different tests. And they measured closure,
25 temperature, brine inflow; they sampled and tested the gas

1 content of the boreholes; and they monitored acoustic
2 emissions, as you saw in that previous Sandia Laboratory
3 test. They actually installed geophones and looked at it in
4 situ.

5 And they found--here is the brine inflow to these
6 boreholes through time. This right here is where they turned
7 the heaters off. Ninety percent of the brine during these
8 tests was collected after they turned off the heaters, which
9 was a surprise to them. But it showed that the mechanical
10 behavior of the tests is similar to bedded salt; that was
11 pretty well understood. The brine inflow was much less than
12 bedded. We're talking--this axis here is liters cumulative
13 during the whole test. So, you know, they collected less
14 than two liters of brine in a whole borehole that ran for
15 several years, while at WIPP they were collecting 35 liters,
16 I think, in one of the Room B boreholes.

17 And they also found that radiation had a minimal
18 effect on brine inflow. The radiation does slightly harden
19 the salt; and work hardens the salt, it makes it slightly
20 more brittle, but that seems to have really no--it's such a
21 minor effect, and it has really no effect on brine inflow.
22 But that's the point of this test, to show that those effects
23 are minimal.

24 The high activity waste test was interesting. It
25 was in a drift where they drilled a series of four boreholes

1 into the floor in these two galleries, and they had this
2 matrix of tests they were going to run with different
3 radioactive sources and electric heaters on the end here.
4 And due to regulatory problems, they were never able to do
5 the radioactive tests. But after this sitting around for a
6 while, they decided, well, let's at least run the electrical
7 tests. So they were kind of able to salvage it by running
8 the non-radioactive portion of the test. And you could see
9 here the temperature at the borehole wall and the different
10 radii into the salt from these tests.

11 But one of the more interesting things I find is
12 that then they came in at a lower level and excavated up to
13 one of the heaters, so the room that the heater was placed in
14 from is up above, and now they've excavated up to it. And
15 they actually--there were coupons mounted on the outside of
16 the borehole that were exposed to heat. And then they went
17 up and just physically took those coupons off and went and
18 tested them. And they excavated through a lot of different
19 sensors. There were different geophysical sensors that were
20 placed in the salt that then got excavated through. So that
21 was a fascinating dataset as well.

22 A couple of those boreholes that were never used
23 otherwise in the tests were then used for other tests. One
24 of them was called the set of DEBORA tests where they placed
25 a heater in a borehole. DEBORA-1 they backfilled around the

1 heater with crushed salt, and then they measured corrosion,
2 temperature, pressure, borehole convergence, and then the
3 permeability and porosity of the crushed salt by--they had
4 glass beads down here--or aluminum beads at the bottom and
5 top. And they injected gas into the bottom of the borehole
6 and then measured gas flow at the top. And so they were
7 able, as the test was running, to monitor the permeability
8 evolution of the test.

9 In the DEBORA-1 test, for less than a year they
10 heated this with a 9-kilowatt heater, and they saw the
11 porosity of the crushed salt go from about 38 percent down to
12 9 percent. And they found the permeability of the crushed
13 salt fell about two orders of magnitude during that same
14 period--this is one year--because you have borehole closure
15 and you have--it's a confined space.

16 The DEBORA-2 test was slightly different. They
17 took one of those boreholes, and they just filled it with
18 crushed salt, and then they put an array of heaters around
19 it, because they thought that maybe some of the problems here
20 were due to the limited space. But they saw similar results
21 in this test where they had 15 kilowatts of heaters located
22 around the borehole, and then they monitored the permeability
23 and porosity of the crushed salt through similar means, found
24 similar results, you'd say.

25 And they found that crushed salt reconsolidates

1 significantly in just months--both these tests were less than
2 a year long--in boreholes. It's to be expected.

3 Very interesting, in a long test that was done at
4 the Asse mine, it's called the TSDE, the thermal simulation
5 of drift emplacement. These two drifts were mined, and then
6 large POLLUX casks--which are casks--they were actually
7 transport casks, so they're quite large, but they put heaters
8 in them instead of waste--placed them in the drift and then
9 backfilled crushed salt over them as they retreated;
10 installed lots of sensors in the boreholes; backfilled to the
11 roof. And so a large thermo-mechanical time series was
12 collected. They watched convergence, they watched
13 temperature, evolution. And then they went in and excavated
14 out and collected samples for laboratory analysis. So there
15 was a large post-test dataset, too. And they found that the
16 crushed salt reconsolidated less than in the boreholes, but
17 that's also to be expected, because a large drift is going to
18 close--there's more to close than on a small borehole.

19 But there was an extensive in situ validation
20 dataset that was derived from this, a huge amount of data.
21 There's two large reports. One is called BAMBUS, and one was
22 BAMBUS-II. And the original BAMBUS report largely talks
23 about the datasets that were collected, the time series that
24 were collected. And BAMBUS-II is largely the post-test
25 laboratory analysis of all the results.

1 Here is just a snapshot of some of the BAMBUS data.
2 So these are basically the temperatures on top of those
3 heaters, so these are heater temperatures. And you can see
4 that they turned the test on, the test ran for nine years,
5 and it got very hot. And then it started to cool off even
6 though heated power stayed constant. And that's partially
7 due to the backfill thermal conductivity increasing with
8 decreasing porosity. So as you have less air in the
9 backfill, the thermal conductivity is going up. And that was
10 expected.

11 And then also the salt itself, even intact salt,
12 has a non-linear thermal conductivity. The thermal
13 conductivity or the ability of the salt to conduct heat
14 depends on temperature. And then you can see here that the
15 thermal behavior was--it basically reached a steady state
16 right near the heaters, but at the roof it didn't quite.

17 So, in summary here, the technical basis has been
18 approached a few times. Salt Vault was essentially kind of
19 the first stab at a technical basis. It was a culmination of
20 ten years of work. There was a giant Bradshaw and McClain
21 report that summarized it, and they basically tried to put--
22 they tried to make a report that would basically justify
23 putting waste in salt. And it was a pretty good report.

24 There were some NRC reports from the early '80s
25 that tried to do a similar thing slightly with more updated

1 data. The Deaf Smith site characterization plans are these--
2 it's an enormous 10-volume report that has lots of data that
3 was collected before--obviously Deaf Smith was never
4 constructed. As time went on, people kept collecting data.

5 Gorleben safety case, which was--the ISIBEL project
6 was 2006 to 2010. There's a lot of information in that.

7 I've been involved in some recent reports that have
8 gone through, and basically this presentation is summarizing.
9 These reports summarize a lot of the testing that's been done
10 in salt.

11 And so we could say, what's left? The technical
12 basis for heat-generating waste is not new. This is testing
13 that's been going on since the '50s, and even back in the
14 '50s there was a pretty good understanding of it. We're
15 refining it, and we're coming up with more sophisticated
16 tools to explain it, but the thermal-mechanical behavior of
17 salt is well known. And modern numerical models will allow
18 us to incorporate things we couldn't do before, but these are
19 not the technical basis themselves. Complex models are
20 really tools to help us understand and make sure that
21 everything makes sense, but they are not the technical basis
22 themselves.

23 Long-term viability of a salt repository depends on
24 the salt itself. The bedded salt deposit provides the
25 containment. Shaft seals then ensure that the penetrations

1 we drill through the salt don't compromise the salt itself.
2 And so the reconsolidation of backfill is important, because
3 that's typically how these seals are constructed; and seal
4 emplacement, the process of that is important.

5 Other repository features, they may be very
6 interesting, but I think they are of secondary importance,
7 like waste forms, waste packages, and brine migration through
8 the excavation, because if the salt contains it, what goes on
9 inside the repository is of secondary importance for the
10 long-term safety.

11 So this little matrix here summarizes the rest of
12 the presentation, and you'd see whether it was a bedded or
13 domal test in this column, whether it used crushed or intact
14 salt around the heaters, and then whether it was borehole or
15 in-drift here on the far right. And you could see that all
16 the different combinations have been tested except for maybe
17 bedded salt using crushed backfill in-drift rather than
18 borehole, and this is essentially what Abe has described.

19 So you could see that we've done a lot of tests,
20 and this one combination really--you know, the TSDE test in
21 Asse is very similar to what Abe described, but that was in a
22 domal salt deposit, which is much drier.

23 And there's all my references, which you can't
24 read, but they're there for reference.

25 Thank you very much.

1 EWING: Thank you.

2 Questions from the Board? Jean?

3 BAHR: So thank you very much. That was a very
4 informative talk. At the beginning of your talk, you said
5 that you were going to tell us at the end what remains to be
6 done, and--

7 KUHLMAN: Sorry, that was kind of--

8 BAHR: --I think I have sort of missed that.

9 KUHLMAN: Sorry. Well, I'm saying that there is not
10 that much--the technical basis does not have begats in it.
11 We're basically to the point now where it's like this
12 particular combination of conditions has not been validated.
13 We understand the thermal-mechanical behavior of salt pretty
14 well, so what's left is small, really.

15 I'm sorry if that was not clear, but that was kind
16 of the point I was trying to make with this last slide here.

17 BAHR: Just a couple of other questions. You mentioned
18 the difference in brine inflow in the case of domal salt
19 versus the bedded salt, and does that have to do with the
20 difference in porosity of those two--

21 KUHLMAN: It's a difference in the--

22 BAHR: --media or the different amount of interbedded
23 heterogeneities in the bedded salt versus a purer salt and--

24 KUHLMAN: The domal salt just has less water in it, to
25 begin with. If you take a meter block of salt and you say,

1 you know, what percentage of water is in here for bedded and
2 domal, there'll be less. There's just less water to begin
3 with in the domal salt.

4 BAHR: Is that because of less intergranular porosity,
5 fewer fluid inclusions?

6 KUHLMAN: Yes and yes. The domal started off as bedded
7 salt many millions of years ago or thousands of years ago,
8 and it's been deformed so much by geologic processes that the
9 water has kind of been worked out of it. And so it's been
10 kind of kneaded and purified to the point where there is less
11 water in it. And so you just expect less brine to inflow
12 from a drier rock.

13 EWING: Okay, thank you. Sue?

14 CLARK: Sue Clark, Board. So I just want to follow up
15 on your last bullet there about the secondary safety case.
16 You didn't say anything about any previous on the source term
17 itself. Does that mean it doesn't exist or you just didn't--

18 KUHLMAN: The source term. Sorry. Would you clarify?

19 CLARK: So the waste itself and its behavior in the
20 brine, its solubility, its release from the repository.

21 KUHLMAN: Right. So I think as long as the repository
22 is--you know, the salt provides an adequate seal for the
23 repository except in the conditions like WIPP where we're
24 forced to say, okay, you have to throw that all away and
25 assume someone is going to drill through and pull that out.

1 In those kind of situations you need to worry about the
2 solubility and those things.

3 But if you have an undisturbed repository, those
4 things really--you know, what goes on inside--you can
5 consider the waste to be a homogenized pool of--you know,
6 it's all been stirred up, it's all dissolved, you know, you
7 can kind of--because the salt is such a good barrier.

8 EWING: But just to follow up on that, because salt is,
9 let's say, co-located with natural resources, don't you
10 expect to be required to consider the case where there--

11 KUHLMAN: In those cases, then, yeah, you'd have to
12 consider the--I'm talking--you know, this is--we're talking
13 hypothetically about a site that doesn't exist.

14 EWING: Right.

15 CLARK: And just to follow up to clarify, are you saying
16 that that's a gap? There is no information or are you just--

17 KUHLMAN: Oh, no. Sorry, I didn't talk about it in this
18 presentation, really. Sorry. No, that's not a gap. There's
19 been lots of work on the brine chemistry and all these
20 processes--Phil and Florie are going to talk more about a lot
21 of these processes, which are very interesting and very
22 important for the short-term behavior inside the repository.

23 EWING: Other questions from the Board? Sue?

24 BRANTLEY: Sue Brantley, Board. I guess you're assuming
25 or asserting or something--I want you to clarify--that the

1 brine migration just isn't a problem. So, I mean, Sue is
2 worried about the waste dissolving into the brine, and you're
3 not worried about that because the brine isn't going to get
4 out even if it dissolves in there. So I'm just--I'm confused
5 about that. Why are you assuming the brine isn't going to
6 migrate?

7 KUHLMAN: Well, the brine that flows into the repository
8 is the brine from the salt immediately around the repository.

9 BRANTLEY: Right.

10 KUHLMAN: So you've basically taken the--you mine some
11 salt out, and you've taken it away, and you took some water
12 with that, but then it's the brine that's in the disturbed
13 rock zone, kind of a halo immediately surrounding the
14 repository--there's a limited amount of brine which is going
15 to flow into the repository, and it's going to dampen things
16 up slightly at the very beginning, but its conditions--like
17 at WIPP where we assume that a borehole is drilled through to
18 a brine reservoir, which then floods the repository, where a
19 lot of these solubility effects come into play. When you
20 have just a tiny amount of brine, you know, the native brine
21 from the repository, it's not enough to really cause a lot of
22 these processes in the first place. You have to have some
23 other source of a giant amount of brine to flood the
24 repository, because that's just really not going to happen
25 under the undisturbed conditions.

1 BRANTLEY: So what do we know about, sort of, slow brine
2 migration through these deposits? I mean, you know a lot
3 about let's perturb it, let's heat it, let's drill into it,
4 brine migration, but that's like the transient. What about
5 the--

6 KUHLMAN: Well, Abe discussed some of the recent tests
7 that have been done where they've shown these small brine
8 inclusions nearby each other have not--they're dissimilar.
9 There is also some--

10 BRANTLEY: Well, he said that they had DNA, and I didn't
11 buy that the DNA was--

12 KUHLMAN: There's other tests that have been done that
13 don't have anything to do with DNA that were done that
14 involve looking at brine inclusion chemistry or marker bed
15 chemistry. We're talking about layers that are a few meters
16 apart that are completely different chemistry.

17 BRANTLEY: And so why would that be, like, geologically?
18 Why would that be? I mean, I've worked in halite deposits,
19 and they precipitate from brine that has the same chemistry,
20 you know. Why would it be so disparate?

21 KUHLMAN: Well, you know, the different waters, the
22 geologic layers come in. A lot of these brine inclusions and
23 the non-salt layers are kind of--you know, as the salt is
24 forming, it's the sodium chloride that's coming out first,
25 and all these rarer things are kind of getting concentrated

1 into these last little nuggets of things that never
2 precipitated. And so you end up getting a lot of weird
3 isolated things that end up being different.

4 But, you're right, it was the same body of water
5 that deposited it all. But we see these isolated chemistries
6 meters apart that have been there for millions of years, and
7 so that's pretty good proof that there is not active regional
8 flow going on through the salt.

9 BRANTLEY: And how different are these little pockets?

10 KUHLMAN: I think Florie is going to talk about that
11 some.

12 BRANTLEY: Okay.

13 KUHLMAN: But this has been well published since before
14 WIPP was certified. They looked at the different--just
15 simple general mineral, general physical properties of the
16 water, you know, magnesium chloride ratios, simple things
17 like that. And the waters are vastly different between
18 different marker beds, different brine inclusions, different
19 seeps.

20 EWING: So I'd like to ask the last question, and then
21 we have to move on. Sorry.

22 So if I follow your reasoning about the role of
23 brine, then would your recommendation be that domed salt
24 would be better than bedded salt?

25 KUHLMAN: Domed salt is drier.

1 EWING: No brine pockets either; right?

2 KUHLMAN: The brine pockets are in unrelated geology
3 under the salt, so that would be probably a somewhat site-
4 specific thing.

5 FRANKEL: Just a very short question.

6 EWING: Okay, short.

7 FRANKEL: Jerry Frankel. Just a short one. I think you
8 clarified it for me, but, to me, this intrusion upon cooling
9 seemed alarming, and you're not alarmed by it because it's
10 going to heat up and cool down. But is it because there's
11 just a limited amount of brine and then those cracks are
12 going to seal up anyway? Is that what you're saying?

13 KUHLMAN: The amount of brine coming in at rapid cooling
14 comes because the salt or any rock has a very low tensile
15 strength. And so as it's shrinking, the capacity to shrink
16 is exceeding the tensile strength, and the salt grains are
17 pulling apart.

18 FRANKEL: The problem then that won't happen with slow
19 cooling?

20 KUHLMAN: No, but if it's cooling so slow that the creep
21 is able to keep up with it, then that won't happen. At least
22 that's what's believed to be the--so if you're cooling over
23 years rather than days or weeks, then it's--we've never done
24 a test over hundreds of years, but, you know, that's the
25 belief.

1 EWING: All right. Well, I'm sorry, we'll have to move
2 on, but thank you for a very comprehensive talk.

3 (Whereupon, a break was taken.)

4 EWING: The next presentation is by Florie Caporuscio--
5 Florie?--

6 CAPORUSCIO: Yes.

7 EWING: --where we'll continue to talk about fluids in
8 brine and salt.

9 CAPORUSCIO: I guess we're leading up to brine migration
10 in salt.

11 EWING: Yes.

12 CAPORUSCIO: I want to acknowledge my co-workers, Hakim
13 Boukhalfa and Mike Cheshire. Both work at Los Alamos with
14 me. This is primarily investigative work that was done last
15 year. It's very preliminary still, but appreciate the
16 opportunity to present this.

17 I have a different take maybe what uncertainties
18 may be in salt. First one, liquid/vapor migration in salt
19 seems to still have some unresolved issues. Roedder at the
20 survey did some tests: Was the brine moving toward the heat
21 source or away? He determined that it was going toward the
22 heat source. There have been other studies you saw, similar
23 responses.

24 What happens at the grain boundaries? There is a
25 lot of uncertainty there? Does it go through the boundary?

1 Does it get to the boundary and then migrate along the
2 crystal structures. Once again, decrepitation, if you really
3 heat the salt up at extreme temperatures? And then I'm going
4 to talk about some mineralogy. When you look at these inner
5 layer beds--clays, sulfates--do they dehydrate? How much do
6 they dehydrate? What temperatures? And do we get to certain
7 temperatures where you have phase transformations, and you're
8 not going to be able to go back to the original phase?

9 We know that clays can dehydrate and then
10 rehydrate. Vidal and Dubacq has a nice paper on that. These
11 types of changes in the mineral structure can affect the
12 ability to retain water and also their sorption/desorption
13 capabilities for clays. And above, depending on the type of
14 clay, between 300 and 400 degrees C, it turns into--does a
15 phase transformation into mica; and at that point you start
16 to lose a certain amount of stoichiometric water and volume
17 to the crystal structure.

18 The latter portion of the mineralogy, looking at
19 the sulfates, I want to key in on gypsum and anhydrite
20 transformation where you get a fairly large water release, 21
21 weight percent, and a significant volume reduction if you
22 make that phase transformation. Creep fracture, the rocks
23 above and below, that's a question. In a similar vein, you
24 may also produce a water channel at the interface between
25 these beds and the salt.

1 So for the experimental portion, we used a type of
2 clay that we recovered from WIPP called corrensite; we used
3 gypsum from Naica, Mexico; and then the other sulfates,
4 bassanite and anhydrite, we also collected from WIPP.

5 This is the outline. First, fluid migrations. And
6 these are in single salt grains. That was the capacity that
7 we were able to do last year. Single phase, two phase, did a
8 little bit on the conclusions then. And then talk about the
9 mineralogies, dehydration, phase change possibilities, and
10 then, finally a path forward, hopefully, and the research
11 end.

12 I'm an old geologist. I want to go get my own
13 samples, so we went down to WIPP. Photograph on the left:
14 my co-author on the very far left, Hakim; Brian Dozier, who
15 facilitated our getting the samples; myself. This is in
16 Panel 7. We were collecting large salt crystals--3, 4
17 centimeter crystals of salt--that we then used in our
18 experiments. On the right I'm indicating an orange marker
19 bed that's widely used at WIPP to locate themselves to make
20 sure that they're in the same continuity of beds.

21 The first thing we wanted to look at is temperature
22 profiles. On the left-hand the graph is for single salt
23 crystals; on the right it's for crushed salt. Both of these
24 were ramped up to 200 degrees centigrade. The first thing,
25 for the salt crystals especially, the single salt crystals,

1 in our experimental apparatus we had a low coupling between
2 the heat source and the grain face, so we lost some heat
3 there.

4 You'll notice in both cases that the temperature
5 drops exponentially away from the heat source. You can see
6 that in the one on the left for the single crystals, once you
7 get a centimeter away, you've dropped over 100 degrees
8 centigrade. So the temperature drops way rapidly from heat
9 sources.

10 We wanted to look at the brine chemistry of these
11 inclusions. One way--and it was very, very preliminary--we
12 did a couple tests, and there's still more to go. We used
13 LIBS, laser-induced breakdown spectroscopy, to drill down
14 through a crystal and then intersect the brine. So the
15 first--I don't have a pointer, but the first graph is
16 drilling down through the salt itself; the second graph--
17 sorry, I got it reversed. While we were drilling down--it
18 was this analysis, which is calcium chloride, the salt--once
19 we hit the brine pocket, the brine is enriched in magnesium.

20 We then went and looked at some of the compositions
21 of the evaporites left behind. We had decrepitation at the
22 top of a salt crystal. You heat it up, the inclusion bursts,
23 and what's left at the top of the salt crystal. There we
24 analyzed--and that's a magnesium chloride salt. In the SCM
25 photo on the right, we analyzed that; that's a detrital

1 quartz grain.

2 So, anyway, the thing you take away from this is
3 that the brine inclusions do vary within a salt crystal, let
4 alone a large mass of salt. It's dominated by magnesium/
5 sodium chloride brines, however.

6 So the next thing we wanted to do was--the heat on
7 the left-hand side, the red band, is 200 C.

8 ZOBACK: What's the time?

9 CAPORUSCIO: Sorry. The time total was 30 days.

10 ZOBACK: 30 days?

11 CAPORUSCIO: Yeah. So we've taken thousands and
12 thousands of video images and compressed it down for these
13 actual photographs and then compressed it.

14 So 200 degrees C was the heat source. Again, the
15 gradient is very non-linear. The first thing that happens is
16 when the inclusion gets aggravated, you see that you get a
17 movement to the portion of the inclusion on the cold side,
18 and then it starts to move towards the heat source. And it's
19 basically due to the heating of the inclusion and the
20 beginning of a convection cell. And then it starts to move
21 and dissolve and go toward the heat source.

22 SPEAKER: Could you play that again?

23 ZOBACK: Yeah, now that you've explained it.

24 (Pause.)

25 CAPORUSCIO: Especially watch the big grain on the far

1 right. It shows most clearly, you end up with little
2 channels coming toward the heat source, all those individual
3 stringers. And we're going to describe what we found.

4 So the come-away in the graph at the bottom is,
5 migration rate is mostly affected by the temperature, of
6 course, and the size of the inclusions.

7 I want to go back on that. Sorry.

8 These were the high-temperature tests. And, of
9 course, they move to the heat source faster. These other
10 two, this one and this one, those are more dependent on the
11 size of the inclusion. The one is moving faster than the
12 other. Turns out that the smaller inclusion moved faster.

13 So what happens inside these channels? Turns out--
14 this is a channel, this is a channel--they are approximately
15 10 micron in diameter. So when the bubble starts to move, it
16 doesn't come en masse. Creates channels, a whole array. And
17 one of the things we wanted to look at is how the composition
18 of the deposited evaporites are as it moves toward the heat
19 source. From the original site, we see in the upper photo
20 and the accompanying chemistry from EDEX (phonetic) that it's
21 a magnesium chloride deposition. And as you go closer to the
22 heat source, composition changes, and it becomes sodium
23 chloride right before it hits the heat source. And that's
24 pretty much discussed in the bottom one.

25 Here we have two more videos. Let me describe a

1 little, and then we'll go through them. These are the two
2 phase inclusions, so liquid and gas. These were run for 30
3 days also. The picture, which will be a video in a moment,
4 was run at 60 degrees, the one on the right 100 degrees. The
5 takeaways, brine migration starts at less than 40 degrees
6 centigrade. And this was modeled at--two-phase flow is
7 modeled by Anthony and Cline in '72. Liquid goes toward the
8 heat source, gas moves away from the heat source.

9 We did notice also in this one on the left, this is
10 a stringer of inclusions right along a cleavage. When you
11 run this for a very long time, the inclusions went right
12 through the cleavage plane. Those were emplaced before, and
13 the rock healed. I mean, water got into the cleavage, and
14 then it healed, and that's why you have the stringer of water
15 inclusions. Once again, the rate is going to be influenced
16 primarily by the temperature gradient.

17 If we can start the one on the left?

18 (Pause.)

19 Most of the action is going on right there close to
20 the heat source. You see the gas starting to move away
21 slightly.

22 (Pause.)

23 And that should be it. Not very exciting. But it
24 does show that it happens. There is movement at very low
25 temperatures.

1 If we do the one on the right, please? This is a
2 little more fun.

3 (Pause.)

4 ZOBACK: Was the right side encased in any way?

5 CAPORUSCIO: So to hold it in the visual field for the
6 microscope, we have two aluminum blocks. On one side is the
7 heat source; on the other side is--we tried to keep it at
8 ambient temperature. So it is constrained.

9 I would like to run this again, and I'd like to
10 point out a few things before we run it on the right.

11 So we have--this is going to generate a lot of gas,
12 and those are going to become stringers. Over here you're
13 going to see a large water inclusion, which has gas also, but
14 it primarily starts moving this way, and you'll see that once
15 again they move in discrete little 10-micron channels.

16 Go again, please.

17 (Pause.)

18 I think one of the nice things about taking these
19 long videos, whether they be 30 days or even longer, is some
20 of the inclusions overrun other inclusions. And this is
21 where Roedder had some problems in the original work in the
22 '80s was, they would look for an inclusion, they'd do it at
23 the end, but sometimes they lost data because it got overrun
24 by other inclusions.

25 Here is a still photo of that same one at high

1 temperature late in the event. So when we have two phases,
2 the brine migrates toward the heat source, but a small
3 portion of the liquid is captured by the gas. When it moves
4 to the right, it--this is not my area of expertise, fluid
5 dynamics, but I'm assuming that it's using the liquid as a
6 wetting agent as the gas moves away. Once again, these
7 10-micron channels, you see that clearly in the lower left
8 photograph here. That's perpendicular to the travel section
9 of an inclusion.

10 That's a really nice photo of what one of these
11 looks like when you increase the magnification. Here are
12 some of the evaporitic materials that are left behind. By
13 the way, that one--I'm sorry--is an oblique cut. But you can
14 see some of the evaporitic material left behind. We're
15 thinking that these are along dislocation sites, someplace
16 for them to deposit themselves. And, once again, as it
17 travels, you sort of release the magnesium chloride first,
18 and it becomes more sodium-rich as you go closer and closer
19 to the heat source.

20 We wanted to also look at some imaging techniques
21 to see if there were other capabilities that we could pull
22 from these sort of tests. Low-field NMR analyses, we got a
23 very good correlation, but we haven't done any calibration
24 yet of what we're seeing. I'll show you these difficulties
25 in the next slide.

1 And then we did a neutron tomography example. We
2 got really good results for the imaging itself. I think
3 we're going to need some refinement to be able to--we have
4 ten left? Okay. Hopefully, we'll get to the neutron
5 tomography video at the end of this.

6 So this is the low-field NMR. In the middle column
7 where you see the red and yellow, that's signifying that
8 we're seeing water in clay inclusions. I'm not going to go
9 through all this. We have a lot of things to develop before
10 we actually get any analytical capabilities out of this.

11 These are the brine migration results. We've
12 labored on these for a while. I'm going to skip forward to
13 the mineralogy if you don't mind.

14 So what can we look at in these seams of other
15 mineralogy? Clays, potential water loss, rehydration, phase
16 changes in the sulfates. We could incur an even larger water
17 volume loss, and that is if they phase transform into
18 anhydrite, either gypsum or bassanite.

19 We have a fairly nice lab where we have Bridgeman
20 sealed rocking autoclaves. We can go to 400 degrees C,
21 600-bar, within the safety envelope at Los Alamos. They do
22 go to higher pressures and temperatures. We're not allowed
23 to. They're getting to be scarce in America. We also do
24 work in the used fuel engineered barrier system, carbon
25 sequestration, geothermal tracers. Sometimes to get a run

1 up, you've got to wait in line to get these going, but this
2 is all under our domain.

3 We also have a nice little controlled XRD heated
4 stage where we can ramp it up to 300 degrees C. Shortly we
5 will be able to control relative humidity. And, of course,
6 we have the optical microscope and video capabilities.

7 These little gold capsules, if you fill them with a
8 charge, put them inside there, you can run multiple
9 experiments at once, as long as you don't want to worry about
10 the chemistry of the fluid during the reaction. It's a final
11 reaction product.

12 So we looked at the type of minerals that are in
13 the salts. Very simply, both the orange salt and the white
14 salt have a common set of minerals: corrensite, a clay,
15 quartz, magnesite, muscovite, hematite, anhydrite. Both of
16 them are dominated by halite. In the white salt we also saw
17 microcline, calcite, and bassanite. The microcline, I
18 believe, is probably detrital. However, we see two of the
19 three sulfates, bassanite and anhydrite.

20 The first thing we looked at were the clays in some
21 sort of detail. For those of you that aren't clay
22 mineralogists--and I'm not one, so I had to put this up--
23 corrensite is a smectite-chlorite-smectite layered structure.
24 At the repetition of these, you have interstitial water.
25 People talked about Clay Seam F at WIPP. This is it. Notice

1 how nice and linear it is. There is no deformation in
2 layered salt.

3 So we ran this at a bunch of temperatures. These
4 are XRD powder diffraction patterns. And we went from 25
5 degrees to 250 degrees C, and there is a real perturbation
6 between 25 and 100. There is a natural structural change.
7 So we then dove a little deeper. Between 65 and 75 degrees,
8 we lose the inner layer of water. And that's where you get
9 this expulsion of water. When they talked in the last talk
10 about something happening between 50 and 130, this is it.
11 We're losing the water at approximately 75 degrees C. It is
12 also reversible. If there is water around and you cook it
13 off, the water will go back into the structure.

14 In gold seals--in gold capsules--sorry--we put
15 corrensite, saturated it, ran it to 300 degrees C; it stayed
16 stable. So as long as the water is around, it will keep
17 hydrating, dehydrating.

18 Now I'm going to talk for a moment on the sulfates.
19 There is a one-step reaction, and there is a two-step
20 reaction. The two-step, gypsum to bassanite to anhydrite,
21 it's continuously dewatering. Some people put the first
22 transition at 76 centigrade and then the second one at 100 to
23 140. Others say that same reaction from gypsum to anhydrite
24 is 180. Bottom line, it's a large water loss and a volume
25 reduction of the crystal structure.

1 So, once again, we used the heating stage to look
2 at these. The top one, the most pertinent information is
3 that at 75 degrees centigrade most of the gypsum disappears,
4 and you see the growth of bassanite. By 100 degrees
5 centigrade, the gypsum is gone. Where you would see those
6 peaks, they're gone now, so you now have just bassanite. We
7 then heated it up. That same sample of bassanite from 100
8 degrees to--well, we went through a series, but at 275
9 degrees C it held steady for a number of hours. At 21 hours
10 we start to see the formation of anhydrite, and by 70 hours
11 we have anhydrite, and we have just remnant bassanite left.

12 We then took that same gypsum, trying to look at
13 the anhydrite transformation as a single-step process. We
14 looked at a nominally anhydrous gypsum sample and then one
15 that had 30 weight percent water in the capsule. In both
16 cases anhydrite existed at the end, starting from the gypsum,
17 and there was remnant gypsum left. There was more gypsum
18 when you had more water in the experiment.

19 These are the conclusions from the clay and sulfate
20 parts. Both initial reactions take place at a very similar
21 temperature. The corrensite dehydrates, and the gypsum-to-
22 bassanite reaction is about 75 degrees centigrade.

23 The real interesting thing--and I'm just going to
24 focus on this note here--Robertson and Bish did a whole
25 series of sulfate experiments modeling Mars. However, the

1 reactions were all very sluggish; they were quite dependent
2 on the relative humidity. And I'm going to stress that
3 further work needs to be done on the timing of these and at
4 appropriate PT conditions for a repository.

5 Okay, those are the research plans. Since we're
6 really low on time now, Rod, I'm going to let people read
7 these at their leisure and open it up for questions. And the
8 very last thing, I'd like to run that--well, let's run the
9 video of the neutron tomography and open it up to questions.

10 EWING: So you're going to run it?

11 CAPORUSCIO: Yeah. This is, what do you want to call
12 it, eye candy? Where did it go? It was hanging out on its
13 own. That's it.

14 You can obviously see the inclusions when you use
15 neutron tomography. The water shows up nicely. That was
16 unheated. It was just--that full thing is three centimeters
17 in longest length. There is a range of sizes of inclusions
18 also.

19 EWING: So thank you very much. It's very interesting.

20 Questions from the Board? Jean?

21 BAHR: Jean Bahr for the Board. In Kris Kuhlman's
22 presentation he noted that one of the things that they
23 learned from the Avery Island experiments were that inclusion
24 flow actually wasn't nearly as significant as porous media
25 flow along intergranular porosity. So, volumetrically, how

1 important is the water that's in the inclusions or that can
2 be released from clay dehydration or gypsum-to-anhydrite
3 formation relative to somewhat more mobile brine that's in
4 the salt?

5 CAPORUSCIO: Well, it's obviously a mass balance issue,
6 correct?

7 BAHR: Yes.

8 CAPORUSCIO: In dry salt we've been able to collect
9 about .2 weight percent water if we really heat it up, dry
10 it, and collect all the water. In the clay seam we got up to
11 6 weight percent water. So then it becomes a matter of where
12 you put the waste, close to a seam of sulfates and clays or a
13 little more distant. You saw that the temperature drops off
14 rapidly in the salt. These are decisions that'll really have
15 to be made based on those sort of mass balance
16 considerations.

17 EWING: I'd like to follow up on that question. So it
18 looked like the activated area by the heat on the one side of
19 the experiment was in the tens of millimeters; is that
20 correct?

21 CAPORUSCIO: That's where the--at really high
22 temperature, Rod, like 200 C?

23 EWING: At 200 C.

24 CAPORUSCIO: Yeah, it dropped off 100 C in just a
25 centimeter.

1 EWING: In just a centimeter? So if I imagined that
2 distance as a cube of salt a meter on the side, how much
3 water would I expect to get at the heat source roughly? I
4 mean, is it a liter or ten liters or--

5 CAPORUSCIO: Probably in the tens of liters.

6 EWING: Tens of liters, yeah.

7 CAPORUSCIO: I honestly haven't done it. We have a talk
8 this afternoon that's going to model some of the water
9 movement, and maybe that'll help you.

10 EWING: Okay, thank you.

11 Other questions from the Board? Efi?

12 FOUFOULA: Efi Foufoula, Board. I just wanted to ask
13 whether you have any insight in the scaling that you had, one
14 of the issues. Do we expect cancellation, linear type of
15 growth or amplification of all these effects?

16 CAPORUSCIO: That was one I skipped at the end, the
17 research path forward. That's what we want to look at next
18 are cores, that first we can start to trace these things as
19 they move across grain boundaries. Do they go through, do
20 they collect, do they pull, do they move along crystal
21 boundaries? Hopefully in a little more time we can then jack
22 at these things and confine the pressure and see what it
23 looks like under hydrostatic conditions. We'll see how far
24 these go. Hopefully they'll be interested.

25 EWING: Sue?

1 BRANTLEY: Sue Brantley, Board. Can you just put the
2 inclusion migration experiments into context? In other
3 words, there have been experiments like this done, you know,
4 for quite a while. So what question are you asking that
5 hasn't been answered in the literature before in terms of
6 those experiments?

7 CAPORUSCIO: For the brine migration ones?

8 BRANTLEY: Yes.

9 CAPORUSCIO: There was a lot of uncertainty in some of
10 those initial ones. I think we've captured a lot more data.
11 We're still sort of sifting through to get rates along with
12 fluid inclusion sizes and the type of water total amounts
13 that we'll get at the heat source over various times.

14 BRANTLEY: So it's an attempt to get more accurate rate
15 measurements compared to what was in the literature from
16 before?

17 CAPORUSCIO: Correct.

18 EWING: Mary Lou?

19 ZOBACK: Mary Lou Zoback, Board. The question I have is
20 just for clarification. These 10-micron channels, did I
21 understand you to say they're basically dissolving,
22 dissolution, going through--and they're just going through
23 cleavage planes, grain boundaries?

24 CAPORUSCIO: Not grain boundaries. Cleavage planes was
25 all we've been able to determine so far.

1 ZOBACK: Okay. And when they intersect a grain
2 boundary, do they--they looked remarkably uniform, the
3 streaks, as they were moving. And I can see a lot of moving
4 that I would expect to be representing around grain
5 boundaries, or is my scale off?

6 CAPORUSCIO: No, no. These were single crystals.

7 ZOBACK: Oh, okay.

8 CAPORUSCIO: Yeah. We were able to see things within
9 crystal size.

10 ZOBACK: Within a crystal. Okay, thank you.

11 EWING: Jerry?

12 FRANKEL: So in your future plans, your research plans,
13 you say you want to resolve the gas migration mechanism.
14 What do you think it is? What do you think is happening to
15 drive the gas away?

16 CAPORUSCIO: Well, no, I think that papers such as
17 Anthony in 1970 did a very good job of looking at two-phase
18 phenomena.

19 FRANKEL: Can you explain it to me?

20 CAPORUSCIO: No, I can't. Seriously, that's not my
21 expertise. But basically it was a convection cell, okay,
22 that they developed. And so the gas was moving toward the
23 cold side; the liquid was moving toward the warmer side of
24 this mechanism.

25 FRANKEL: But it's a dissolution precipitation type of

1 mechanism, and that's why you need water? Is that what it
2 is?

3 CAPORUSCIO: Right, yeah.

4 ZOBACK: The water still (inaudible) the channel--

5 CAPORUSCIO: Yeah.

6 ZOBACK: --even for the gas.

7 CAPORUSCIO: Remember I said that water was also wetting
8 the surface of the gas bubble?

9 FRANKEL: Right.

10 CAPORUSCIO: I presume that that's--

11 FRANKEL: But that same sort of dissolution
12 precipitation mechanism is driving the water--

13 CAPORUSCIO: One way.

14 FRANKEL: --in the opposite direction but somehow
15 facilitates gas to go the other way?

16 CAPORUSCIO: Yes. I don't know why.

17 EWING: Other questions from the Board? From Staff?

18 (Pause.)

19 All right, thank you very much, Florie.

20 CAPORUSCIO: Thank you, Board.

21 EWING: The next session is where we invite comments and
22 questions from the public. I have the sign-up list, but we
23 forgot to ask people whether they wanted to speak in the
24 morning or in the afternoon. So I'll go through the list;
25 but if you want to speak in the afternoon, that's fine, just

1 wait, and that way we can be sure that those who are here
2 only in the morning will have the opportunity to speak.

3 I'll just go down the list. Matthew Silva,
4 morning?

5 SILVA: Yes.

6 EWING: Okay, please. And no more than five minutes.

7 SILVA: No problem.

8 EWING: Okay. Identify yourself and affiliation.

9 SILVA: I'm Matthew Silva, and I've worked with the
10 Environmental Evaluation Group for fifteen years. For eleven
11 of those years I worked as a chemical engineer for Bob Neill
12 and the last four years as the director of the group.

13 I want to comment on a couple of questions that
14 were asked earlier this morning. One was on the independent
15 oversight. And I think it's fairly important that whatever
16 area is selected, one of the successes of WIPP was the fact
17 that the independent oversight was from the very beginning,
18 starting in 1978. It was not done as an afterthought.

19 Another question that came up was congressional
20 support, how important was it. It was absolutely essential.
21 The roles and responsibilities of EEG were defined under
22 Public Law 100-456, which was carried by Senator Jeff
23 Bingaman largely, and in that law the director determined the
24 scope of work. It was not determined by DOE or anyone who
25 had been influenced by DOE. The director hired the

1 professional staff, not someone else.

2 The results were all published. It was an
3 obligation that our results had to be published. And because
4 of this we were able to maintain the trust of not only the
5 public, but also the elected officials, having access both to
6 the elected officials and to the public.

7 Another thing which we talked about privately
8 perhaps was political cover. We had some very brilliant
9 political officials, elected officials, in New Mexico.
10 Governor Bruce King was one; Congressman Joe Skeen, who was
11 22 years in the Congress; and Senator Jeff Bingaman, who was
12 absolutely solid. And they recognized that you had to have
13 an oversight group to look out not only for the public, but
14 if they had questions, their staff could ask those questions,
15 knowing that we were going to give them the straight scoop
16 and that we were looking at the details.

17 Also for groups like this--the NAS WIPP committee,
18 EPA, NRC, and looking at transportation--relied heavily on
19 our review and our comments to help them to improve their
20 product. And also we were in a situation where we worked
21 full-time on this. Certainly one cannot expect you to work
22 full-time on the WIPP project, but is what we devoted our
23 efforts towards. So that was another advantage of having an
24 oversight group from the very beginning.

25 And the public may have some concerns about

1 individuals coming from other states that are trying to get
2 rid of waste or from individuals who rely heavily on the
3 Department of Energy to fund their research programs, whether
4 it be faculty or otherwise. So this helps to assure the
5 public that indeed someone else is looking at this.

6 There were two events that really--if I may bring
7 this up--that led to the demise of EEG. One was the 1999
8 putting of the EEG's budget under the Carlsbad area office.
9 That made it very difficult as a director to get our funding
10 without too much hassle. I ended up spending a lot of time
11 working on this.

12 And, second, in 2004 the law, 100-456, was gutted,
13 and the oversight group became essentially a DOE contractor,
14 and the Department of Energy would determine the scope of
15 work. They would determine the hiring; they would determine
16 whether or not the work could be published, and, only if it
17 was published, it had to be after their review; and they
18 would determine whether or not you could speak to a public
19 official.

20 Anyway, I hope that covers it. One other point I
21 noticed in the Blue Ribbon Commission report was that they
22 recognized that it takes two to five years, it takes a bit of
23 time, to get an oversight group started. It's not the kind
24 of thing where you hire somebody off the street and they are
25 immediately in the mindset. It does take time. And we do

1 look at seasoned professionals, and there's fortunately a
2 good supply of professionals in radiation protection in the
3 universities and other state agencies and in other areas
4 other than the Department of Energy.

5 So, with that, that's the sugar-coated version. If
6 you want to have a few drinks later, I'll be happy to discuss
7 it.

8 EWING: Thank you, Matt, very much.

9 SILVA: Okay, thank you.

10 EWING: Next on the list is George Danko, but you're the
11 afternoon, right? Thank you.

12 Christopher Timm.

13 TIMM: I'll do it this morning.

14 EWING: Okay.

15 TIMM: Thank you very much. Thank you all for being in
16 Albuquerque and listening to good input, we hope, for solving
17 the nation's rad waste disposal problems. I'm with Pecos
18 Management Services, and we were the follow-on, if you wish,
19 the independent oversight contractor for WIPP for 2005
20 through 2010.

21 So our oversight was not as much on the technical
22 side and getting it going as it was on the operations and
23 maintenance as to how they were doing and how could they do
24 better to, in fact, achieve what their mission was. And we
25 had good relations with both EPA and the State and, of

1 course, as well with DOE. And so we were able to work
2 through all the relationships.

3 Did approximately sixty studies, fourteen major
4 reports, which are available on the EPA Web site.
5 Unfortunately, they're not on the WIPP Web site, but they are
6 on the EPA Web site if you want to look at the different
7 reports that we did.

8 But I want to speak a little bit about this whole
9 idea of radioactive waste disposal. Both Bob and Abe really
10 talked about how the assumptions are important as to how to
11 get from where we are to where we're going. And assumptions
12 really need to be based primarily on--they need to be
13 realistic, and they need to be based first on the science,
14 the engineering, the operational knowledge and experience.
15 So we need to have our assumptions be realistic and be well
16 founded on those aspects. In other words, it's things we
17 know and we can prove rather than things we think might
18 happen. We need to really have those assumptions be as close
19 to what we know as we can.

20 The second major one is history. We've got to
21 consider it a human element, especially dealing with
22 radioactivity. So the assumptions going in--because any
23 model you have, I don't care if it's a ten-year or a ten-
24 thousand-year model, is only as good as the assumptions going
25 in. And we, frankly, have done a poor job in getting the

1 assumptions to really be based on fact in many instances for
2 WIPP. They were overly conservative; in fact, oftentimes
3 they weren't even founded on good science, yet they were
4 stuck with them. How I don't know, but that was the case.
5 So that's number one.

6 Secondly, the development of solutions must be
7 holistic. You can't just look at the science and the
8 engineering. You've got to look at the operational. You've
9 got to look at the environmental health and safety both of
10 what the situation is now--storage and independent spent fuel
11 sites around the country and tanks and so forth--as well as
12 what is it going to take to get those to one place like WIPP
13 and the aspects involved with that--health and safety,
14 operational, and so forth--as well as future. I tend to
15 think that this idea of deep geological disposal was
16 formulated as a future solution without really considering
17 the impacts on a day-to-day basis for getting it there.

18 There have been people hurt because of this
19 decision to, in fact, repackage and get stuff to WIPP. Does
20 that make sense? Maybe so. Are we more worried about
21 generations ten thousand years from now than we are about
22 ours or a hundred years from now? I think so. It's got to
23 be holistic. You've really got to look at the broad
24 spectrum. And while the NEPA does that, it doesn't do it as
25 well as it could. Personal opinion.

1 Finally, I really think that we should relook at
2 this whole recommendation for deep geological disposal.
3 Again, this Board is separate from NRC. NRC is in a
4 situation; they say you can keep stuff above ground for at
5 least 60 years in the hardened storage you have, maybe 300.
6 That whole concept, it's 60 years old now; that basically,
7 "Let's go deep geological" is 60 years old in terms of when
8 it really came into play. Is it working like it should? Are
9 we better off keeping it above ground where we can see it and
10 fix it as we go along?

11 I just think it's time to relook at the basic
12 premise, not to be locked into an idea and go forward
13 lockstep because that's the way it's always been done. We've
14 got to be open to new ideas. Abe talked about those. We've
15 got to be open all the way along.

16 Any more time?

17 EWING: Actually, no.

18 TIMM: Okay.

19 EWING: But thank you. Thank you very much.

20 TIMM: Thank you, And I'll stick around afterwards.

21 EWING: Okay. Don Hancock, did you want to speak this
22 morning?

23 HANCOCK: Yes. Good morning. I'm Don Hancock from
24 Southwest Research and Information Center. We're a 43-year-
25 old non-profit organization in technical assistance. I have

1 had the misfortune, I guess a lot of people would say, of,
2 for the last 38 years, spending a significant amount of time
3 looking at WIPP and nuclear waste disposal issues. So, as
4 Dr. Ewing knows, I can turn on for a long time, but I know he
5 will not let me do that. So let me try to make three points
6 that, I guess from my standpoint, haven't been made this
7 morning.

8 So first is: What is WIPP's mission? It's been
9 mentioned WIPP is for defense transuranic waste. What hasn't
10 been so clearly mentioned is the fact that the idea of--Bob
11 Neill mentioned the fact that there was interest in high-
12 level waste at WIPP from the beginning and interest in some
13 of the community folks in the Carlsbad area from the
14 beginning for high-level waste; but that was something that
15 was rejected and has been rejected consistently.

16 So when we start talking about consent, we also
17 need to talk about non-consent. How many times do you have
18 to say no before the answer is no? And it's not just from a
19 public standpoint. Congress has consistently for 35 years
20 said WIPP is for transuranic waste; it's not for high-level
21 waste. The 1979 law that Bob Neill referred to, the 1982
22 Nuclear Waste Policy Act, the 1987 Nuclear Waste Policy
23 Amendments Act all had opportunities to say WIPP should take
24 on--the '82 and '87 laws all had opportunities to say WIPP
25 should take on commercial waste or high-level waste missions.

1 Congress said no. 1992 with the WIPP Land Withdrawal Act,
2 Congress explicitly said no. Section 12 of the law
3 explicitly says no high-level waste, no spent fuel can come
4 to WIPP for any purpose, even temporary. So we have a
5 situation of--we have 35 years of policy, law, public
6 understanding, technical understanding, frankly, of what
7 WIPP's mission is.

8 So one of the things that's going to be important
9 going forward and one of the reasons I want to make the point
10 to this Board, who does look at more than just WIPP, is that
11 that becomes very important from my standpoint--and I think
12 from a lot of other people's standpoints--in terms of how to
13 deal with this difficult problem of what to do with high-
14 level waste and commercial spent fuel.

15 If we start from 1957, the National Academy report
16 that's been mentioned several times today, we're a long time
17 out, and we only have a series of failures in this country.
18 And WIPP clearly, as I say, is not a success, not going to be
19 involved in the high-level waste mission as well.

20 So that brings us then to the second issue that
21 relates to, again, WIPP's mission, which is to start clean
22 and stay clean for up to 175,000 cubic meters of defense
23 transuranic waste.

24 We don't know what happened almost five weeks ago
25 in the underground that caused a radiation release. That, in

1 and of itself, is very alarming. If we know as much about
2 salt, if we know as much about WIPP, the waste in WIPP, the
3 performance of WIPP, all the aspects of WIPP, as we're
4 supposed to know, it shouldn't take more than five weeks to
5 figure out what's happened. But we don't know the basics.
6 We don't know what happened. We don't know how much has been
7 released. We don't know how much more might be released. We
8 don't know more than so far 17 workers being contaminated.
9 There could be more.

10 None of these things were supposed to happen. From
11 modeling standpoints they weren't supposed to happen. From
12 environmental impact statements they weren't supposed to
13 happen. From permitting requirements they weren't supposed
14 to happen. From public assurances they weren't supposed to
15 happen. So while you may say, well, this is a WIPP-related
16 thing, but it goes to the fundamental basis of: What do we
17 know and how well can the Department of Energy and its
18 contractors perform in carrying it out?

19 So those are important issues that this Board knows
20 about, you've talked about in your reports over time. So I'm
21 not saying something you don't know, but we now have the
22 practical experience of a repository that was supposed to
23 operate for 30 years, starting clean and staying clean, and
24 performing for 10,000 years or more with no releases; and it
25 didn't accomplish that.

1 So that raises some significant questions that I
2 think need to be looked at. And among the things, WIPP is a
3 pilot plant in its name. We now have a situation that among
4 the things we don't know is how much contamination is there
5 in the underground and what will it take to clean it up, to
6 decontaminate it; what's the experience of decontaminating
7 radiologically contaminated salt mines in the world; what
8 kind of decontamination is going to be necessary on the
9 surface of the facility; what kind of decontamination is
10 going to be required offsite.

11 So these are very important questions that deserve
12 a lot of technical and public attention, and I'm hopeful, but
13 not overly optimistic based on my last 38 years of history,
14 about how well the Department of Energy wants to do that. In
15 fact, I would argue that now is one of the times that we most
16 need independent review of what's going on at WIPP. We don't
17 have the EEG anymore. We don't have independent technical.
18 We have regulatory agencies, EPA and New Mexico Environment
19 Department, that are very under-resourced to deal with these
20 questions.

21 So one of the things that the political and the
22 technical community need to look at now is: How do we
23 construct independent review of what's happening with WIPP
24 and what has to happen with WIPP going forward?

25 Which brings me then to the third point. I was

1 very interested in a couple of aspects of Abe's presentation
2 this morning. One is, as I understood what he was saying
3 about the understanding of the geology and the strength and
4 roof fall possibilities, etc., the option that there was a
5 roof fall in the WIPP underground seems to be off the table.
6 If it's not, if that's what happened, it raises major
7 technical issues about the technical understanding of that
8 facility. If it is off the table, though, then where does
9 that leave us with how much we know, and what else is
10 happening with the facility and the waste coming to it?

11 The other thing that he talked about, which was the
12 first time--and I'm pretty observant about things that get
13 talked about with WIPP--the first time he presented
14 apparently the current option for what to do with another
15 failure of WIPP long before what's happened in the last six
16 weeks, which is that WIPP cannot fulfill its mission when it
17 comes to remote-handled waste. The legal limit for remote-
18 handled waste is slightly more than 7,000 cubic meters. WIPP
19 has no ability to come anywhere near that.

20 So there has been discussions, but there hasn't
21 been any presentation about how to deal with that significant
22 failure and the facility being able to accomplish its
23 mission. So I am glad to finally start seeing what the
24 proposal is going to be in terms of handling remote-handled
25 waste at WIPP, but I'm disappointed that once again we're not

1 going through the kind of public discussion, technical
2 discussion kind of thing that should happen if we're going to
3 have successful geologic repositories, not only WIPP but
4 others, in this country. So I think that's a very important
5 issue.

6 So the last thing I'll say just briefly, you all
7 have raised some excellent questions about the kind of
8 technical review. The other kind of thing that needs to
9 happen to have credibility with the public is, there have to
10 be--the way I tritely put it is, the worst critics of any
11 project should be given an opportunity to show what they know
12 or don't know. And that's, again, something that in this
13 country we have primarily shied away from; that's the kind of
14 thing that needs to happen as well.

15 And I will give a plug to the Canadians, who are
16 trying to do it a little differently in terms of that kind of
17 thing. That's why I even went to Canada last September to
18 testify about their first deep geologic repository facility.

19 Thank you.

20 EWING: Okay, thank you, Don.

21 Again, if you want to wait until the afternoon,
22 just let me know as we go through the list.

23 Michael Loya.

24 LOYA: My name is Michael Loya. I sit on the Citizens'
25 Advisory Board, and I'm making comments as the sole source,

1 as an individual. I'm also a generational New Mexican. And
2 I had an environmental drilling business, and I've done work
3 out at the test site, and I've done work for the Army Corps
4 of Engineers.

5 I want to make a comment that Mr. Silva said
6 earlier about Senator Bingaman and Congressman Skeen. There
7 is also Senator Domenici. And we pushed for casing advance
8 drilling method when the lab switched to that back at the end
9 of 2007, and we pushed for that so they could eliminate the
10 drilling fluids. So the last thing that Senator Domenici
11 did, he got the funding for the lab. He got \$26 million for
12 the lab so they could go to casing advance. That was very
13 important, and that was a boatload of money, and he deserves
14 kudos for that.

15 I also want to make another comment--and I think
16 this is very important--knowing people from all over the
17 state, and they want you all to know that you need to be
18 cost-conscious. And I'm not trying to say this in a gruff
19 way or whatever, but there's a lot of money spent, and people
20 need to be more cost-conscious about this. You need to run
21 this like a business. And I think that that's very
22 important, because, you know, funding is finite, and it's
23 getting harder and harder to fund all these projects. And I
24 think that that's very important.

25 And I think by doing so and showing these people--

1 showing the public that you're--you know, you've got to win
2 their confidence. And that's very important. And you need
3 to make these presentations--and I know most of you all are--
4 you know, you're up there with Ph.D.'s and all this. But for
5 the regular public, you need to make them simple and just
6 precise so they'll understand--and bullet points--what's
7 going on. And I think that's very important.

8 I'll tell you something, my mother was born in
9 Carlsbad in 1917, and there's a lot of people down south--and
10 I'm from down south even though I live up north--that are
11 behind WIPP.

12 And I'll leave you with this. There's going to be
13 mining accidents. So, you know, you can sit there and bring
14 in all these consultants and they can say, well, this might
15 happen and that might happen. But you need to go in and zero
16 in and clean that up and get it operational again and move
17 this forward. And I think that that's very important.

18 And I'm glad that I got to spend this time and get
19 our point across. And I wish there were more farmers and
20 ranchers that are friends of mine that could have been here
21 to make these comments, and they will come if you make that
22 possible.

23 So I thank you very much. Three and a half
24 minutes.

25 EWING: Thank you very much.

1 Dave McCoy.

2 McCOY: I may need that extra minute and a half.

3 EWING: Okay.

4 McCOY: Hello. My name is Dave McCoy. I'm the
5 executive director for Citizen Action New Mexico.

6 We've been dealing with local problems here in
7 Albuquerque at Sandia National Laboratories and also at
8 Kirtland Air Force Base. And I look at WIPP and I see a
9 \$69 billion operation, is what I heard this morning,
10 engineered to protect us for 10,000 years. And we have an
11 accident, a release of americium, plutonium, other substances
12 into the environment; workers exposed; public exposed.

13 And then I look at the issue that I've been dealing
14 with for the last seven years, and that's the Mixed Waste
15 Landfill at Sandia National Laboratories. Very difficult to
16 get the executives from Sandia National Laboratories to tell
17 us when they're going to excavate that dump, if ever. It had
18 defective groundwater monitoring. They used the data from
19 defective groundwater monitoring to make a decision to leave
20 those wastes under a dirt cover. They're in unlined pits and
21 trenches, 119 barrels of plutonium waste, tens of thousands
22 of pounds of depleted uranium. There's beryllium, cadmium,
23 over a hundred different toxic chemicals, heavy metals,
24 solvents, all in a mixed waste form, leaching toward the
25 groundwater that supplies Albuquerque's drinking water wells;

1 vadose zone not monitored; information about the dirt cover
2 and how it's defectively constructed and monitored hidden,
3 suppressed by the New Mexico Environment Department. When we
4 asked for the information, Citizen Action was sued by the
5 Environment Department so we wouldn't get it. Information
6 about the faulty groundwater monitoring suppressed by the
7 EPA, the NMED, and the EPA Office of Inspector General, we
8 finally got it after we sued.

9 The public shouldn't have to go through this
10 exercise to have transparency, but we have to go through
11 that. And then when we find out the information, it's not
12 pretty. The Citizen Action is currently suing the
13 Environment Department because they're violating their own
14 order, their own final order, for the mixed waste landfill.
15 That said every five years there's supposed to be a review.
16 That order was in 2005. It was due in 2010. It's now 2014,
17 and the Environment Department wants to extend that for
18 another five years, so we sued them.

19 Who do we have to do this as the public? Why can't
20 we rely on these regulatory entities and the laboratories to
21 do the things that are necessary to make us safe?

22 I listen to this scientific information. I'm an
23 attorney, so a lot of it was way over my head, but it was
24 interesting. And all I can say is, from a public perspective
25 of looking at this, you know, you've got reality versus

1 models. You had all these scientific models that say it's
2 not going to happen, we're not going to have the exposure.
3 We got the exposure. Now I'm asking you to do something
4 about the mixed waste landfill. What kind of exposure can we
5 expect from that, you know? If you've got WIPP here that's
6 so highly engineered and you've got the dirt trenches and
7 pits out there at Sandia, we're asking Sandia's executives to
8 come out of their caves and speak with the public about this.
9 When are you going to get rid of that mess out there?

10 Thank you.

11 EWING: Thank you very much.

12 Last on the list, Robin Falko.

13 SPEAKER: She'll be here in the afternoon.

14 EWING: In the afternoon? Robin Falko.

15 Okay. So that brings us to the end of the morning
16 session. We'll reconvene at 1:10. So thank you all for
17 being here today.

18 (The lunch recess was taken.)

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AFTERNOON SESSION

1

2 EWING: Welcome to the afternoon session of the NWTRB
3 spring meeting. We'll begin immediately with a presentation
4 by Phil Stauffer from Los Alamos National Laboratory on
5 coupled models.

6 STAUFFER: So today I'm going to be talking about a
7 coupled thermal-hydrological-chemical process model for the
8 high-level waste repository in salt.

9 So the outline here we've got--first I'm going to
10 go over the in-drift concept to remind people of what that
11 entails, then look at the waste composition of the defense
12 high-level wastes by thermal load, which is very important to
13 understand for this project; some background on salt and heat
14 pipes; description of the simulator we're using that FEHM
15 developed at Los Alamos; a code validation example; some
16 simulations with only heat so that we can contrast the heat-
17 only simulations with simulations that add water and water
18 vapor transport; and then, finally, processes that are added
19 to couple the chemistry into the system.

20 So I think we've seen this before today, the
21 in-drift emplacement strategy. It's simple. It's a lower-
22 cost method. The backfill is readily available from the salt
23 mining. We put the waste packages in the drifts and fill
24 them back up with salt. These lead to much narrower rooms
25 than are currently being used. In a narrow room the rock

1 mechanics is such that there is less risk of the roofs
2 collapsing.

3 This slide was supposed to be first there. This is
4 some of my team members that helped with this. Dylan Harp,
5 simulation expert; I've got a Ph.D. student working on this.
6 We have a mesh generation expert; I'm going to be showing
7 some fancy meshes that I can't take credit for building.
8 We've seen Florie present today, and Hakim is on his team;
9 they did some of the chemistry experiments that we're going
10 to be putting into the model. And then, of course, Bruce
11 Robinson is our project coordinator, project leader.

12 So the distribution of heat loads that we're
13 looking at for this project, 90 percent less than 220 watts.
14 So these are not the civilian wastes that are 8,000 watts per
15 canister. These are much lower thermal loads. You can see
16 for the high-level waste, we've got over 16,000 expected
17 canisters in the less-than-50-watt range. And it's only
18 until you get into the DOE spent nuclear fuel that you get
19 some percentage that may be up in the 2,000-watt range.

20 So looking at this, you can see that if we can
21 figure out how to do the defense high-level waste, it's a
22 stepping stone towards the hotter civilian wastes. And it's
23 a good path to take because of that. We'll learn things, but
24 we won't be jumping straight in from non-heat-generating
25 wastes to the most heat-generating wastes, which are the

1 civilian loads.

2 So some background. We've already seen this.
3 Bedded salt has the favorable characteristics of the self-
4 healing rheology, the viscoplastic flow, very low
5 permeabilities in the intact/final states, and extremely high
6 thermal conductivity, 5 watts per meter kelvin.

7 We've seen this image before that Kris showed, and
8 some of the work done showed that precipitation of salt due
9 to the boiling front was found in this annular region where
10 they had backfilled with crushed salt. And we believe that's
11 evidence of the heat pipe that I had mentioned in the
12 outline.

13 And a brief description of what a heat pipe is in
14 the lower left here. We've got a hot waste package
15 surrounded by a boiling region. The boiling point for a
16 saturated salt solution is about 108 degrees Celsius. So
17 we've got a region around the 130-degree heater where we'll
18 have boiling. As the vapor moves away--the dark blue
19 arrows--vapor moves away from the heat source. Eventually
20 it'll condense when the temperature drops, and that
21 condensate will--the condensate has no salt in it, so that
22 will then requilibrate with the salt that's further from the
23 heat source, dissolving salt and flowing back towards the
24 heater, and it'll form a loop where it keeps boiling away and
25 then returning. And what you'll do is you'll build up salt

1 around the heat source and dissolve salt at a fringe away
2 from the heat source. That's a quick explanation of the heat
3 pipe.

4 So the simulator we're using for this work was
5 developed over 30 years at Los Alamos. We've got a bunch of
6 peer-reviewed articles on a range of different fields from
7 geothermal, nuclear waste, soil vapor extraction, a whole
8 bunch of different topics that we've used this simulator on.
9 And it's been benchmarked against sets of problems for the
10 Yucca Mountain project, and we've got dozens of physics and
11 chemistry problems that every time we make code changes we
12 run back through for the quality assurance to make sure that
13 by adding a new feature we haven't broken an old feature. So
14 we're always watching for that.

15 We've got fully coupled thermal, mechanical,
16 chemical, multiphase gas, water, water vapor, and rock. The
17 mechanical is infinitesimal deformation numbers, so we're not
18 talking about being able to simulate these rooms at WIPP
19 closing in over hundreds of years. We can do stress changes
20 where the deformations are very small. That's one of the
21 challenges of this salt modeling is some people have thermal-
22 mechanical codes; some people have hydro-mechanical-thermal;
23 some people have chemical-mechanical; and no one yet has
24 really pulled all of these things together. So there's
25 several teams around the U.S. and the world that are working

1 on this, and we're converging, but we haven't gotten to the
2 holy grail of being able to simulate all these things
3 together yet.

4 And, as I mentioned before, we have a powerful 3-D
5 grid generation tool. This example is from the Nevada test
6 site with high-resolution faults going through a mesa, and
7 this example shows that we can capture pinch-outs and complex
8 geometries.

9 So a code validation sample. This is just an
10 experiment that we set up at Los Alamos where we had a pile
11 of crushed salt sitting in a tub with a thermal heat lamp,
12 and we drove--we measured the temperature at the base of the
13 bulb, and then we had a thermal couple, and we were able to,
14 with an existing thermal conductivity as a function of
15 porosity model, we were able to match this fairly well.

16 So for the thermal-only simulations, we're looking
17 at calculations of a potential repository in-drift with the
18 waste packages lying vertically like this. This is map view
19 down. We've got intact salt surrounding them, and then we've
20 got rooms on either side so that we can draw a nearer
21 boundary around the system like this and reduce the number of
22 nodes we need to calculate the system. These are called
23 reflection boundaries.

24 So these are some examples for thermal-only
25 simulation with thousand-watt canisters at different

1 spacings, anywhere from three feet between the canisters,
2 which results in temperatures well above the 200-degree limit
3 that was mentioned earlier for cracking the salt crystals,
4 which we don't want to get into the regime where that
5 happens, which for the bedded salt is about 275 degrees.

6 Then this is just showing that through these kinds
7 of simulations we can make predictions about how far apart
8 you'd want to space the canisters in a repository that is
9 basically dry. So this would be with no water vapor, no
10 water. All we have is the intact salt, the crushed salt
11 backfill on top of it, with the known thermal properties of
12 that material. So you can see, to stay below 200 degrees,
13 we're looking at a spacing here of about six feet between
14 these canisters.

15 BAHR: What's the height of the canister itself?

16 STAUFFER: The canisters are two feet diameter, and
17 they're nine feet long.

18 ZOBACK: And they're laying horizontally on the floor?

19 STAUFFER: Yeah, in this--yeah. So these are nine feet
20 long, and they've got a diameter of two feet. And they're
21 just laid on the floor and then sprayed with run-of-mine salt
22 backfill.

23 ZOBACK: If they're nine feet long and you show twenty
24 feet, it doesn't seem right.

25 STAUFFER: Well, these might have been a little--

1 SPEAKER: -- two rows back there?

2 SPEAKER: No, they all look the same.

3 STAUFFER: No, this might have been with the slightly
4 longer canisters. The ones we're using now are nine feet.

5 So then this is another way of looking at it. If
6 we take the waste and say that it's all 220 watts, which is
7 more than 90 percent of the load, and we space them at .9
8 meters apart, what are the temperatures going to look like
9 for 55, 110, or 220? And most of the load doesn't--we don't
10 even get up above boiling here. So, you know, that says that
11 for most of the defense high-level waste, it's really not
12 that much different from what we're already putting into
13 WIPP. We're not going to be boiling and creating big regions
14 where there's dry-out and vapor transport.

15 But there are some--there is some percentage of the
16 canisters that are going to create those conditions, so
17 that's what the rest of the talk is going to be about.

18 So for the rest of the talk we're looking at a set
19 of five canisters lying in-drift on the floor. This is a
20 3-D picture. We've got access drifts in red pictured around
21 the edges. We've got our experimental drift going through
22 the center of this block. The greenish color is the run-of-
23 mine salt backfill. The canisters are red, and you can see
24 them here, five canisters.

25 So this is a comparison of results from the

1 thermal-only on the top versus the thermal plus water plus
2 water vapor on the bottom. This is for a heat load of 1500
3 watts per canister. So in this example I was trying to
4 create lots of vapor transport, boiling, you know, see what's
5 the system going to look like if we push it towards the
6 maximum impact given the waste packages that we're looking
7 at.

8 And so this is zoomed in on one, two, three of
9 those heaters so that you can see the contours of temperature
10 better. And what you'll notice in the top is that we have
11 fairly regular drop in temperature as we move off from the
12 center of the canister. Maximum temperature is 223 Celsius
13 in this case. What we see in the bottom figure, we have a
14 region where temperatures have homogenized. And that's where
15 we're getting this heat pipe where the vapor is moving up
16 toward the cooler regions or out toward the cooler regions,
17 condensing, and flowing back towards the canisters. And
18 that's classic heat pipe behavior creating an isothermal
19 region. And this was for a simulation that was for two
20 years. And the maximum temperatures in this case are about
21 195, 197 degrees.

22 So in addition to creating this region with a
23 constant temperature, we've also dropped the maximum
24 temperature at the canister. So the heat pipe actually could
25 be a good thing for the system. There is no guarantee we're

1 going to get it. That's part of the rest of the story that's
2 coming up.

3 ZOBACK: Can you help with the scale on that? So the
4 floor is--where would the floor be? Is it that green line
5 then?

6 STAUFFER: The floor should be right through here.

7 ZOBACK: And does the crushed salt extend beyond the top
8 of the model?

9 STAUFFER: Yeah, well, beyond the top of this picture.

10 ZOBACK: The picture, I mean. Yeah, okay.

11 STAUFFER: Yeah. In this figure you can see the
12 canisters sit here. They're two feet high. And this pile of
13 crushed salt we varied anywhere from four feet to eight feet.
14 The room is going to--you know, the experimental room was
15 proposed to be ten feet high. At first we thought, well,
16 we'll just make the crushed salt ten feet high, but the
17 logistics to getting it right to the (inaudible) are very
18 hard.

19 ZOBACK: It's tough, right.

20 STAUFFER: So then we started planning the different
21 depths.

22 BAHR: That model does not include the reprecipitation
23 of the salt around those.

24 STAUFFER: No, we're just--this is just with thermal
25 plus water plus water vapor. So we're boiling the salt water

1 around here; it's coming out across the boiling line, which
2 the 110-degree line is somewhere between the green and the
3 light blue, which is out about here; and so when the water
4 vapor drops across the boiling line, the water vapor pressure
5 drops considerably, and you start condensing out a lot of
6 water vapor.

7 BAHR: But you don't have any--there's no feedbacks.

8 STAUFFER: But there's no dissolution precipitation yet.

9 TURINSKY: So what is this, a two-phase Darcy flow
10 model?

11 STAUFFER: Yeah.

12 SPEAKER: You guys, would you identify yourselves,
13 please?

14 BAHR: Oh, sorry.

15 SPEAKER: Thank you.

16 STAUFFER: So then what I've done here is I took a
17 temperature difference between the thermal-only and
18 subtracted off the thermal-only plus water plus water vapors.
19 So what we see is, indeed, in the centers right above the
20 canisters we get--the thermal-only was 44 degrees Celsius
21 hotter than when we allow this vapor transport mechanism.
22 But there's also places in the field, once you get out past
23 the boiling line, where the condensation is actually sucking
24 up temperature, and the temperatures are lower than they were
25 in the thermal-only one.

1 So now I'm going to talk briefly about the many
2 coupled processes and feedbacks that are required to bring in
3 the chemistry changes, the dissolution precipitation.

4 So, first, changes in porosity can cause changes in
5 permeability. Porosity can also--if you change porosity,
6 you're also going to change the thermal conductivity and the
7 heat capacity of a block of rock. The ability of the vapor
8 to diffuse through the rock is impacted by the porosity. So
9 those are all feedbacks related to porosity.

10 Feedbacks related to temperature include thermal
11 conductivity; the solubility of the salt is a function of
12 temperature; water vapor pressure, as I was describing, is a
13 function of temperature; and brine viscosity is a function of
14 temperature.

15 So here are just some examples of thermal
16 conductivity. We added thermal conductivity as a function of
17 porosity and temperature of the model, based on data that
18 Kris showed from the previous experiments. We added salt
19 solubility as a function of temperature, Sparrow 2003 that we
20 found in the literature. Precipitation/dissolution of salt I
21 added about a year ago. We added water vapor diffusion
22 coefficient function that relies on pressure, temperature,
23 and porosity and then a permeability-porosity relationship
24 for run-of-mine salt. And these are all reported in this
25 deliverable to DOE.

1 So the vapor pressure of water is also not just a
2 function of temperature, but also a function of the amount of
3 salt that's dissolved in it. So as you put more salt in the
4 water, the vapor pressure goes down, so that boiling point
5 goes up as you increase the salt content.

6 And so we added this function to the code, and you
7 can see that the region of interest, because we're in WIPP
8 where the salt is always fully--the water is always fully
9 saturated with salt, we're in a fairly tight range here. We
10 probably could have gotten away with a constant value, but we
11 ended up coding up the complete function.

12 Some of the specific algorithms, we've got an
13 algorithm for radiation and convection based on heat transfer
14 calculations, and then we just use an affected thermal
15 conductivity. I'm going to show an example of clay
16 dehydration. And we also added a lot of diagnostics to the
17 code, because we are now changing things dynamically that are
18 so intensely coupled that if you don't watch, oh, yeah, you
19 know, permeability in the crushed salt is changing because my
20 porosity changed; my thermal conductivity should also change;
21 my water vapor pressure, there's another list that has
22 temperatures in.

23 And so you can go to these outputs that are now
24 coming into this green and do double checks all the time and
25 make sure that you're getting what you think you're getting.

1 In these models it's really easy to put in a function; and if
2 you don't look at it, you know months later you could realize
3 that you've screwed something up. The reason I do this is
4 because I have screwed things up in the past.

5 Here's a quick refresher on the heat pipe. We're
6 going to be looking at some of these, a section with the
7 liquid, a boiling region, a condensation region, and
8 flow-back. These heat pipes are used commonly in industry.
9 They have them on the space shuttle to dissipate heat.
10 They're in electronics. They're found all over the place.
11 We didn't expect to find one in a nuclear waste repository
12 for salt. And so when we started seeing this in the models,
13 it was like, wow, that's kind of neat.

14 So this is an example of a very high resolution, a
15 four-centimeter mesh, two-dimensional domain, that goes five
16 meters this way, three meters this way. We've got square
17 heaters--they started out as squares--and you can see by the
18 end of the simulation we're starting to deposit salt. This
19 is porosity. Zero porosity is red. The initial porosity is
20 this blue background color. So as this simulation is
21 running, water vapor is being driven off, crossing the
22 boiling line, dissolving salt, flowing back towards the
23 heaters, boiling again, and creating these rinds of almost
24 solid salt.

25 And this--yeah, it's a 2-D slice. And we get

1 increases in porosity across the boiling line and decreases
2 in porosity below the boiling line. And that boiling line is
3 dynamic. It moves out from the heaters. In this particular
4 example, I think it took 50 or 60 days for that boiling line
5 to move out to where it is. And then it reaches a pseudo-
6 steady configuration, so it doesn't move much after it got
7 there. It's still moving, though, because as you're packing
8 more salt into this region, the thermal conductivity is
9 changing, and that's going to change this so-called steady
10 temperature (inaudible).

11 So next I'm going to move to the 3-D thermal-hydro-
12 chem simulations, and this is where the mesh generation team
13 comes in really handy. We have heaters that are a lower
14 resolution sitting on the floor of the drift. We have air
15 surrounding the run-of-mine salt backfill. We have a damaged
16 rock zone and an intact salt surrounding that. The damaged
17 rock zone can have permeabilities that are many orders of
18 magnitude higher than the intact salt because of the
19 mechanical changes from mining the drift.

20 And so some of the parameters used in these
21 simulations, the backfill saturation natural range is from
22 one percent to about five percent. This is not gravimetric
23 water content. These would convert to--gravimetric water
24 content would be about one percent of five percent
25 saturation. As a hydrogeologist simulator, I use saturation,

1 and that's what's in all the models. What the
2 experimentalists measure is the gravimetric water content,
3 because you just boil off the water, measure the weight of
4 the water, the weight of the rock, you have your gravimetric
5 water content.

6 Porosity we fixed at 35 percent, which is in the
7 middle of the range measured. Clay content we explore zero
8 to ten percent. And we fix at the higher end of 30 degrees
9 Celsius background. The air temperature in WIPP ranges
10 anywhere from 15 to 30 degrees. The rock, if you dig into it
11 fresh, you're closer to 30 degrees. So that's why we picked
12 that value.

13 So this is a complicated figure, but I'm going to
14 walk you through it slowly. This is for five 750-watt
15 canisters at a relatively high saturation limit. We explored
16 a range of parameters, because we don't know exactly where
17 we're going to fall in the WIPP facility. There's variation.
18 There's places where there's a lot of clay, not so much clay,
19 higher water contents.

20 What we're looking at here are porosity saturation
21 temperature with time going from 10 days up through 460 days
22 of simulation. And you can see that by 60 days we start to
23 see a drop in porosity, increase in porosity across the
24 boiling line, and the heaters are starting to get salt
25 deposited around them. By 460 days we've created this

1 envelope of low porosity around the heaters. This is for a
2 fairly wet system. This process stops because you end up
3 drying out all the water that's around the heaters; and, as
4 you can see, the saturation goes to zero directly on top of
5 where that has happened. So water is still trying to make it
6 back there; but as soon as it hits the boiling front, it
7 boils off and gets redeposited as vapor up in this region.
8 And you can see the temperatures here, the boiling line is in
9 between the yellow and the green, which is coincident with
10 that envelope.

11 Porosity changes with higher heat loads. So as we
12 go from the 250-watt, we see almost no evidence of this heat
13 pipe. But as you go up to 750 watts is where we really start
14 to see this impact.

15 BRANTLEY: Excuse me, a question. Sue Brantley, Board.
16 So this is chemical equilibrium; there's no kinetic?

17 STAUFFER: There is no kinetic, no.

18 BRANTLEY: There is no kinetic.

19 STAUFFER: Not yet.

20 BRANTLEY: So where it precipitates is simply a
21 temperature function.

22 STAUFFER: Yes.

23 BRANTLEY: There's no surface area term or anything like
24 that?

25 STAUFFER: It immediately drops out, yeah.

1 BRANTLEY: Right.

2 STAUFFER: We have the ability to do that. We just
3 haven't gone there yet.

4 BRANTLEY: And sodium chloride dissolves and
5 precipitates so fast, you probably don't need to do it.

6 STAUFFER: Probably not. We have some experiments
7 planned for the future to help us get a handle on that.

8 So porosity changes more with saturation. So at
9 low saturations, if it's a dry repository like the domal
10 salt, we wouldn't expect to see this at all, because their
11 saturations are much lower. But if we get in a part of a
12 bedded salt that's wetter, we might see this.

13 So for clay dehydration we have experimental data
14 from Hakim and Florie that shows the clays giving off a
15 certain percent of their weight, and we've coded that up as a
16 function, and we've included that in some simulations. This
17 slide is showing a simple simulation where we have boiling at
18 one end, we have clay at the other end, and as the thermal
19 wave propagates through, you get these kicks in water being
20 released. So the saturation increases as that water comes
21 out of the clay. And this was to help QA.

22 The code, and then we applied this to the larger
23 three-dimensional system. The difference between no clay and
24 10 percent clay, you know, we see some differences, but
25 they're what I would call second order effects on the system.

1 And that's because the water is not free to begin with; the
2 thermal wave has to propagate through; and you have to get
3 the temperature change before you can release that water.
4 But this is all very new work, and we're still trying to wrap
5 our heads around this.

6 The vectors on here show the liquid flux--the vapor
7 flux on the top and the liquid flux on the bottom. And you
8 can see the vapors moving like a chimney through the system
9 from the outside coming in and moving up, very similar to Ed
10 Weeks' work on Yucca Mountain where the whole mountain
11 operated as a chimney heated from below. And the water is
12 always trying to--it's being condensed out here, and it's
13 always trying to flow back towards the drier high-capillary
14 suction agents.

15 Anyhow, that's basically it. I think I've covered
16 most of these conclusions.

17 And so for the future work we're looking at
18 numerically validating the heat pipe. We found a paper--
19 after we did this and saw these heat pipes, we found a paper
20 by the Spanish where they had taken a beer-can-sized
21 experiment and heated one end and cooled the other end, and
22 they got a heat pipe that redistributed salt mass. And so we
23 were very excited to see that, because that is experimental
24 evidence. But we want to do it at the scale of a meter or
25 two and eventually in an underground setting.

1 We've started adding isotopic tracers in the
2 simulations to fingerprint the water, putting enriched
3 deuterium to see where it goes. And we'd also like to--we're
4 starting to look at evaporation, barometric pumping, and the
5 impacts of the ventilation through these facilities where
6 you're drying out at different temperatures throughout the
7 year.

8 So that's it. Thank you.

9 EWING: Thank you.

10 From the Board, questions? I have one while you
11 think of your own.

12 Just so that I'm clear, what is the source of the
13 water in this model? Is it the fluid inclusions, the water
14 given off by the clays?

15 STAUFFER: Yes.

16 EWING: So it's everything in the system?

17 STAUFFER: It's everything, yes. Initially, we looked
18 at the total amount of water that could be available, and we
19 started with an assumption that, okay, let's say that's the
20 upper limit, the 10 percent saturated case, and we'll just
21 run in that window of possibilities to parameterize the
22 problems, say, if we had that much water problems, what would
23 it look like, because we don't have a good handle on how much
24 water is going to come in from the damaged rock zone. Those
25 little crystals that are sitting in the run-of-mine salt, as

1 the temperature wave moves through those, those inclusions
2 are going to move towards the edges of the crystals and
3 possibly be released.

4 So, as of now, you know, that's why Florie's team
5 is looking at that, like how fast does that happen? Can we
6 expect that water to be available for this heat pipe
7 mechanism? With the clays, we didn't include that water
8 until we added the clay function.

9 EWING: All right. And that's my next question. With
10 the clay function, when you say 10 percent clay, where is
11 that clay, and how is it distributed in your model?

12 STAUFFER: Homogeneously it's distributed throughout the
13 porous media. So it's as if, when the miner was going
14 through--

15 EWING: Right.

16 STAUFFER: --they mixed it up and then threw it back on.
17 And that particular load had 10 percent clay in it.

18 EWING: And do you consider that a conservative or
19 bounding--

20 STAUFFER: That's pretty high, because in this clay
21 seam, you get--in a clay seam like this, it's still got a lot
22 of salt in it.

23 EWING: Right.

24 STAUFFER: You know, it's not a solid layer of clay
25 that's this thick and just goes on forever.

1 EWING: But the geometry of these clay seams and the
2 concentrated amount of water that might be released along
3 that seam, doesn't that change the thermal model quite a bit?

4 STAUFFER: I should have been clear about this. The
5 clay is only in the run-of-mine backfill. We're not putting
6 clay underneath in a seam. It's as if it was mined in that
7 particular wheelbarrow load of salt that had 10 percent clay
8 in it.

9 EWING: So Marker Bed 139 wouldn't have been captured--

10 STAUFFER: Not in--

11 EWING: --or 138 or--

12 STAUFFER: That's future work. We're going to put in--
13 you know, one meter below here there is a bed that has
14 hydrous minerals.

15 EWING: Right, right.

16 STAUFFER: And we really want to simulate that, but we
17 haven't gotten to it yet.

18 That gets up to about 60 to 80 degrees, so it's right in
19 that first transition zone. And it could be interesting,
20 because that's a significant amount of hydrous minerals.

21 EWING: Right, right. And so when you say this is a
22 coupled model with the chemistry, actually the only chemistry
23 is the thermodynamic properties of pure salt. Is that--

24 STAUFFER: Yeah. And the precipitation--

25 EWING: Without precipitation and dissolution function.

1 STAUFFER: Dissolution and precipitation, yeah.

2 EWING: But not in any--only in the abstract sense in
3 terms of--

4 STAUFFER: And the clay dehydration, that's in the
5 chemistry part of the code. And it's a water source term
6 when you cross a temperature boundary.

7 EWING: Okay. So I think I've used my time. Other
8 questions?

9 BRANTLEY: Well, just as a follow-up--this is Sue
10 Brantley, Board--you said that the water comes out of the
11 fluid inclusions, but you don't have anything in there that
12 models the mechanism of fluid inclusion movement. You're
13 modeling this as porous flow--

14 STAUFFER: Exactly.

15 BRANTLEY: --through porous media that had the
16 permeability--

17 STAUFFER: We're saying that water is available from
18 time zero.

19 BRANTLEY: Right. So there's nothing mechanistic
20 related to what we saw this morning.

21 STAUFFER: Not yet.

22 BRANTLEY: I know you can model anything; right now what
23 you're modeling.

24 STAUFFER: Yes, right now.

25 BRANTLEY: And there's no texture or anything like that.

1 STAUFFER: No, no.

2 BRANTLEY: It's simply porous media flow.

3 STAUFFER: Yeah, we'll add complexities later.

4 BRANTLEY: Yes. Which is what you should be doing. I
5 mean, I agree with that. But it can be confusing, because
6 you said that the water comes out of the fluid inclusions.
7 That's because you have to have a certain mass of water in
8 your model, so you calculate that.

9 STAUFFER: Yes.

10 BRANTLEY: But you have moving inclusions in your model.

11 STAUFFER: No.

12 EWING: Other questions, comments? Jean?

13 BAHR: Jean Bahr. Just one more clarification. You're
14 also not allowing any water to flow out of the intact rock
15 mass into the cavities; is that correct.

16 STAUFFER: In some cases that is allowed to happen. The
17 simulations I've shown here, the damaged rock zone is fairly
18 low permeability, so I didn't have that complexity added in.
19 But you can start out with a drier pile, and you'd still get
20 a heat pipe if enough water can flow in from the damaged rock
21 zone. But from the experiments that have been done before,
22 those are like 35 liters into a room, and the pile starts out
23 with 250 liters in the 5 percent saturated case. So that
24 amount, you know, you really have to get a lot of flow from
25 the damaged rock zone to get that to be an important

1 contributor.

2 EWING: Please, Jerry.

3 FRANKEL: Jerry Frankel. So just back to the very
4 beginning, these two-foot by nine-foot cylinders, they're
5 meant to represent the stainless steel cans that the
6 vitrified waste is poured into?

7 STAUFFER: Yes.

8 FRANKEL: Is that right?

9 STAUFFER: Yes.

10 FRANKEL: So there's no--so what would be the effect of
11 some outer container? Those things have to be--I mean, in
12 this system they might not need any protective engineered
13 barrier, but they would be transported in some sort of a
14 container. So if you had a big steel container around it,
15 would that affect any of it or just make the initial radius
16 larger?

17 STAUFFER: It would make the initial radius larger, and
18 then that would make the temperatures at the interface lower.

19 FRANKEL: Lower because of the area, larger area.

20 STAUFFER: Yeah. I can't imagine it would be that big,
21 though, if it was steel or--

22 FRANKEL: I don't know how they're going to transport
23 them into your--

24 STAUFFER: I don't know either.

25 FRANKEL: --into your repository.

1 STAUFFER: This was the configuration we started with
2 was just the relatively thin stainless shell over a--and the
3 material properties on the inside of this, we just used
4 borosilicate glass as a thermal conductivity and (inaudible).

5 FRANKEL: That's included in your model?

6 STAUFFER: Yes, uh-huh. But, no, there's no flow
7 allowed in here. These are--you know, we're not trying to
8 model anything inside the wall, just into the wall.

9 EWING: And to follow up on that, so the thermal
10 conductivity for the borosilicate glass changes as a function
11 of the fracturing of that glass.

12 STAUFFER: We have not included that yet, no.

13 EWING: So you just took it out of the handbook.

14 STAUFFER: Yeah.

15 EWING: I mean, because it's available in the French
16 program, the change in thermal conductivity.

17 STAUFFER: We could include that function. I mean, do
18 you know how much it changes?

19 EWING: Quite a lot, yeah.

20 STAUFFER: Okay.

21 EWING: Other questions? Yeah.

22 BRANTLEY: So I've got to say this in real succinct
23 questions that are going to sound flip, and I don't mean to
24 be flip, because I think what you're doing is interesting and
25 important. But, first of all, why are you doing this? What

1 do you hope to be able to--what question do you hope to be
2 able to answer? And then why should I believe that answer
3 when you get it?

4 STAUFFER: Well, the why is because eventually there
5 will be a test of high-level waste in salt if the program
6 moves forward. And as part of that test, we will make
7 predictions. And if we can make predictions that are borne
8 out by the tests, then we will have shown that we understand
9 how the system behaves. We might do a dry pile and a wet
10 pile or hot pile and cool pile. But we need to have some
11 idea of what might happen before we do the tests, where to
12 put temperature sensors, what the gradients might look like,
13 what saturations might--how they may evolve. And so that's
14 the why.

15 And why should you believe us? Well, I wouldn't
16 believe this right now either.

17 BRANTLEY: I didn't say I didn't believe it.

18 STAUFFER: All we have is a beer can right now where it
19 happened in the beer can. The hydrologic properties of the
20 run-of-mine salt are not very well constrained. It's not a
21 simple granular material with the same size grains
22 everywhere. But our goal is to build one of these in the lab
23 at a scale where we'll be able to either prove or disprove
24 the models. And that's how these things go. You make a
25 model of the system, then you go look at a real system, and

1 back and forth. And we're in the very early stages here.

2 BRANTLEY: And have you done this for the WIPP
3 repository?

4 STAUFFER: Well, we're using a lot of data from WIPP,
5 because it's available. We have access to --

6 BRANTLEY: But, I mean, they have canisters down there
7 with--what do you call it--run-of-the-mine salt?

8 STAUFFER: Run-of-mine salt.

9 BRANTLEY: Run-of-mine salt. Something I've never heard
10 before. Could you model that, and have you done that, and
11 would that make sense?

12 STAUFFER: Well, that's what the experiment will be.
13 We'll take run-of-mine salt and put it in a big box and put a
14 heater in it.

15 BRANTLEY: But aren't they running the experiment in
16 WIPP right now?

17 STAUFFER: No.

18 BRANTLEY: Well, not with the high-level waste, I know,
19 but--

20 STAUFFER: Well, there's no heat in that, so it's not
21 very interesting. The current canisters are sort of the
22 background temperatures, so--I mean, yeah, I'd love to put
23 some hot canisters down there--

24 BRANTLEY: But, I mean, you'd like to do your models
25 simple and build in complexity, so here you have an

1 experiment that's being run that's not very interesting
2 because it's simple.

3 STAUFFER: Well, we've run background temperature; we've
4 run with low heat loads; so I don't know what we'd be
5 running. There's no heat being generated. It's just a
6 canister sitting in the background temperature field. I
7 mean, if we had barometric pumping, we could look at dry-out.

8 We do have--as of early February, we had some big
9 containers with run-of-mine salt in and water, you know, just
10 the initial water content at a very high-resolution scale,
11 looking at how much evaporation occurs on that through time,
12 you know, which is important. I was talking about
13 evaporation being something I want to--how much water
14 evaporates from the surface that's in barometric connection
15 with the atmosphere and the ventilation air.

16 So, yeah, we are looking at things we can do with
17 existing WIPP technology. The heat is really what's driving
18 everything here.

19 EWING: To follow up on Sue's question, one of the
20 previous speakers gave us a nice summary of all the previous
21 work, heater experiments in other countries, and so on.
22 Aren't those data somehow useful for testing your model and--

23 STAUFFER: Yeah. And I'm working with Kris to include
24 some of that.

25 EWING: Okay, good. Other questions? Mary Lou?

1 ZOBACK: This may be--Mary Lou Zoback, Board--may be the
2 same question, but just for my own edification, in the German
3 Gorleben mine, did they have hot waste down there?

4 STAUFFER: Yeah, they had hot waste, but the water
5 contents there are so low that--

6 ZOBACK: Oh, that's right. This is a dome salt.

7 STAUFFER: We're less than one percent here, so we
8 wouldn't expect to see anything. It's why this--there's one
9 piece missing. It's the hot waste in the bedded salt lying
10 on the drift floor with the crushed salt, because if you
11 don't have the crushed salt, then you don't have the porosity
12 with the boiling front moving through it to give you this
13 effect.

14 ZOBACK: Okay. Then a related question: When the
15 Germans began their program and they thought that that site
16 was going to work, what kind of monitoring did they put in
17 initially?

18 STAUFFER: Kris?

19 ZOBACK: Maybe we'll hear that in the later talk.

20 EWING: But, again, maybe a lesson from your modeling
21 is, the lower the amount of water, the simpler the system is;
22 right?

23 STAUFFER: Yes. Yes.

24 EWING: Yeah, okay.

25 Other questions?

1 FRANKEL: Do you have some--this is Jerry Frankel. Do
2 you have some measure of the overall impact of this heat pipe
3 effect on the macroscale on the proposed repository?

4 STAUFFER: You mean on the--no, we haven't--we've done
5 these calculations for this system, which is the five heaters
6 in one little drift. We have not gone--

7 FRANKEL: So even for the five heaters, is there some
8 measure that you can--other than the local gradients,
9 what's--

10 STAUFFER: Well, the maximum temperature--the impact on
11 maximum temperature was pretty dramatic, you know, but I
12 expect like in the three- to five-meter region away from
13 where these drifts are that the impacts are going to be
14 pretty small.

15 FRANKEL: But that means you'd be able to put them
16 closer then.

17 STAUFFER: Yeah, you can put them closer together if you
18 can rely on the heat pipe. But I would not suggest relying
19 on this heat pipe effect. It's really something we have only
20 seen in the simulations.

21 ZOBACK: Mary Lou Zoback, Board. That's much, much
22 hotter canisters than most of the defense waste liquid.

23 STAUFFER: Yeah, this is at the very high end. There's
24 only maybe 100 or 200 at that heat mode. That was back here.
25 Those are these guys over here, so there's less than 500.

1 But 500 is still a lot.

2 ZOBACK: Yeah, I know, that is--

3 EWING: Let me check and see if there are questions from
4 the Staff. Yeah, Bobby.

5 PABALAN: Roberto Pabalan, Board Staff. I'm just
6 curious. Can you take your model to a much smaller scale, a
7 scale of a single mineral scale that Florie showed earlier,
8 and then simulate what he observed, the movement of the
9 liquid phase towards the heater source and then the gas phase
10 away towards the cold side of the mineral?

11 STAUFFER: This continuum scale model is not the
12 appropriate tool for that. But on our team we have Qinjun
13 Kang, who does lattice Boltzmann modeling, which is at the
14 sub-millimeter scale, and he's got simulations of Florie's
15 experiments. He's been able to recreate the single phase,
16 but is working on the two-phase. It's a more dicey problem
17 to get the vapor going the opposite direction.

18 But, yeah, we're working on that.

19 PABALAN: Okay, thanks.

20 EWING: Other questions from the Board? Staff?

21 All right, thank you very much.

22 The next speaker is Guadalupe Arguello. It'll be
23 another coupled model, but this time thermal, hydrological,
24 and mechanical processes.

25 ARGUELLO: Thank you. It's an honor to be here before

1 the Board and talk a little bit about some of the work that
2 we've been doing.

3 I'd first like to acknowledge my co-workers, Jim
4 Bean, John Holland, and Jonathan Rath from Sandia, as well as
5 contributions from numerous others who are currently at or
6 formerly retired from Sandia, as well as many contributions
7 over the years from RESPEC. We've been doing this sort of
8 thing for a while now. Actually, I was hired on to the WIPP
9 project in 1985, and I've been on and off working with the
10 WIPP project since then.

11 As a brief outline, I'd like to talk a little bit
12 about Sandia's historical efforts related to salt
13 repositories, particularly from the geomechanics perspective;
14 talk about the next generation of high-performance computing,
15 the efforts and the technology that we are putting into that;
16 talk about additional work on salt for high-level waste
17 repositories; and then show you some demonstration problems
18 to demonstrate the capability that we currently have in our
19 codes; and then offer a summary and some conclusions for your
20 consideration.

21 So with regard to the historical perspective,
22 again, it's fortunate that there were several speakers that
23 already showed a schematic of WIPP. The only thing I want to
24 point out is the area up here. It's an early experimental
25 area, and so I'll be focusing or talking a lot about that in

1 the subsequent figures.

2 So here it is. Early on Sandia was tasked with
3 developing technology for predicting geomechanical response
4 of rock salt, in particular, looking at thermo-mechanical,
5 particularly with regard to creep models, how the material
6 behaves, and then as well as looking at solution algorithms,
7 codifying all of that into usable computer codes that we
8 could use for the prediction of the response out at the
9 underground.

10 In concert with that, there were these TSI full-
11 scale experimental rooms that were fielded at WIPP, and one
12 of the objectives of those rooms was to look and evaluate the
13 predictive models and the techniques that were being
14 developed. And I'm pointing out two rooms here. And Kris
15 has already talked quite a bit about Room B, but a twin room
16 was Room D. The only difference between these two rooms was
17 that Room D was an isothermal room, so you could do direct
18 comparisons between the isothermal case and the over test or
19 heated case.

20 This shows a schematic of what the stratigraphy
21 looks like around WIPP. So roughly this model includes 50
22 meters above the room and 50 meters below the room, and this
23 is the configuration typical for Rooms D and B. Again, Room
24 D is the isothermal case. Room B has heaters in the floor,
25 as was shown earlier by Kris. What you will note is that

1 this is a layered stratigraphy, so we've got all kinds of
2 material in here, including argillaceous salt, clean salt.
3 There is some anhydrite and some polyhalite. In addition to
4 that, there are multiple clay seams or stringers running
5 throughout the configuration here. And, in particular, for
6 the geomechanical model, these strings are modeled as signing
7 (phonetic) surfaces, so these can move relative to one
8 another as the deformation of the room proceeds.

9 ZOBACK: Mary Lou Zoback, Board. How thick typically
10 are these clay seams?

11 ARGUELLO: So the seams can vary from roughly three
12 millimeters to feet.

13 ZOBACK: Okay, thank you.

14 ARGUELLO: So all of the data that was taken for Room
15 B--and it was about 1,500 days' worth of data--was reported
16 by Darrell Munson back in '88, and that data is out there and
17 archived and available for use. And, in fact, we are using
18 it for the current state-of-the-art models that we are
19 developing. This shows an example of that technology
20 relative to the previous legacy generation of codes, and
21 these were some calculations put together by Darrell Munson
22 and RESPEC. And it shows that the model does a fairly good
23 job of doing room closure.

24 The second room is Room B. Again, Room B had a
25 heated 74.4-meter test section that was uniformly heated with

1 these heaters in the ground. There were also guard heaters
2 on either end, and here at the entrances were insulated doors
3 to preclude heat flow out of the room. Again, the data for
4 that is in this over-test for the simulated defense high-
5 level waste report, again put out by Darrell Munson in the
6 '88 time frame. And the figure here shows a picture of the
7 room as it was being constructed.

8 As with Room D, Room B was also used to look at the
9 predictive technology in terms of temperatures and in terms
10 of closure again. And this closure figure shows the
11 isothermal room relative to the heated room. One thing you
12 will notice is, for the heated room there were significant
13 deviations at some point in time. And what Darrell
14 attributed this to was that you started getting microcracking
15 right in here up in the roof, and then there was a full-scale
16 separation of a roof slab starting to occur in this region.
17 And, of course, the models that we had and that we currently
18 have in the U.S. are macroscopic models that account for only
19 primary and secondary creep. And we'll talk a little bit
20 more about that in a while. But they don't account for
21 damage or eventual rupture.

22 ZOBACK: So this is brittle failure.

23 ARGUELLO: So it is creep rupture basically. What
24 happens is--or what they think happened is that there were
25 separations at one of the seams at the roof, and you started

1 getting microcracking in the salt, and eventually the entire
2 roof separates.

3 So in addition to Rooms B and D, there were various
4 other WIPP experimental configurations that were also
5 simulated for comparisons with the measurements, and all
6 these were documented in this IJJM report from Darrell Munson
7 back in 1997.

8 Now, I should point out that development of our
9 models kind of stopped in the early '90s with the WIPP
10 licensing coming on board and the transition from a pilot
11 plant into an operating repository. A lot of the research
12 activity was no longer carried forward.

13 But since the mid-1980s there has been
14 approximately 30 years of software and hardware advances that
15 have transpired. And Sandia has built a new generation of
16 massively parallel multi-physics capabilities into a single
17 computational framework to support Sandia's engineering
18 sciences missions through the Advance Scientific Computing
19 Initiative. And most of the effort here is related to our
20 weapons side, so that was the real driver there.

21 What we're doing is, we have recently started and
22 are currently trying to adapt these tools for simulating
23 coupled geomechanics for waste repository settings. A lot of
24 this work is funded under LDRD and then, of course, the used
25 fuels disposition campaign. The figure down here on the

1 lower left shows an early panel seal calculation where we
2 actually started doing 3-D modeling. So prior to this, most
3 of the modeling was 2-D, because the computing capability and
4 all of the tools that had been developed were mainly 2-D. So
5 this was some of the earliest 3-D calculations that we did.

6 So in the recent past and relatively recent,
7 state-of-the-art is such that it integrates single physics
8 codes to achieve coarse spatial and time scale simulations.
9 And what we're doing is we are proposing SIERRA Mechanics as
10 the future by leveraging the more than ten years of ASC
11 development, and SIERRA Mechanics then provides the framework
12 for coupled multi-physics simulations in a massively parallel
13 environment; scalability from one to thousands of processors
14 on a variety of platforms; and we're using it as a launching
15 point for eventually getting to a fully integrated THMC
16 coupling with adaptive solution control.

17 In particular, for the repository side, we are
18 using two applications codes. One is known as ARIA that
19 handles the thermal, hydro, and chemical. And I say handles
20 the thermo-hydro-chemical; that's on the weapons side it
21 currently handles a lot of that. On the repository side, as
22 I said, we're working on that. And ADAGIO for the mechanical
23 part of it. So this is a quasi-static code.

24 So both of these and all of the application codes
25 within SIERRA sit on top of a foundational tool kit that

1 provides parallel (inaudible) utilities and services,
2 including fuel data management and transfers among the
3 various applications codes.

4 So here is how SIERRA Mechanics does the coupling
5 between the applications codes, at least what we're doing
6 currently on the repository side. So ARPEGGIO is the
7 transfer module that handles the transfers of data between
8 the two codes. So ARIA solves the conservation of component
9 mass (water and air) equations for two-phase porous flow plus
10 energy equation on a deforming computational grid. ADAGIO
11 solves the conservation of linear momentum equations for
12 quasi-static conditions. Imbedded within ADAGIO is the
13 constitutive model for salt that's been implemented in this
14 library called LAME.

15 And then temperatures that are used in the
16 constitutive model for the salt materials, that constitutive
17 model again is implemented within the LAME library with
18 ADAGIO. The displacements from ADAGIO are used to updated
19 the ARIA geometry, and then you proceed forward if it's a
20 thermo-mechanical calculation. If it's a thermo-mechanical-
21 hydrological calculation, then you can pass out the other
22 information such as porosity, thermal conductivity, and so
23 forth. And that will then update your pore pressures, and
24 you pass them to ADAGIO, and ADAGIO passes back the nodal
25 displacements and so forth.

1 Now, as I mentioned, these are all relatively
2 recent adaptations to SIERRA Mechanics. So one of the things
3 that we wanted to do was to actually run and do a preliminary
4 validation of SIERRA Mechanics against WIPP's Rooms D and B.

5 And if you can hit the top figure, that'll show
6 you--so this is the WIPP Room B calculation. And for the
7 first 384 days or so, nothing happens because it's
8 isothermal. You are getting some creep, but you can't see it
9 at that scale on the top. And there comes the thermal pulse
10 from the heaters being turned on, and you're approaching the
11 end of the simulation.

12 FRANKEL: Can you clarify what we're looking at here?

13 SPEAKER: What's up and down?

14 FRANKEL: Yeah, where are we?

15 ARGUELLO: Okay. So these are the heaters in Room B in
16 the floor. So we're looking at a slice through the middle of
17 the room. This is a symmetry boundary condition. So if you
18 flip this around, there is your room right in the middle.
19 Okay?

20 BAHR: So the little gray indentation--this is Jean
21 Bahr--that's the room?

22 ARGUELLO: That's the room right there, which, when I
23 zoom in, you'll see it here. Okay?

24 ZOBACK: Mary Lou Zoback, Board. That's Room B?

25 ARGUELLO: This is Room B.

1 ZOBACK: Even though next to it the plot says Room D?

2 ARGUELLO: Well, I've shown both. I've shown Room D up
3 on top and Room B here at the bottom.

4 ZOBACK: And X and Y are horizontal axes?

5 ARGUELLO: X and Y are--well, X and Z are horizontal
6 axes. Y is up and down.

7 ZOBACK: Y is the vertical axis?

8 ARGUELLO: Y is the vertical axis. Okay. So here is a
9 zoom of this area. And what you will notice is that there is
10 movement at those clay seams around the room, and you will
11 see it as soon as the heat comes on.

12 (Pause.)

13 So here comes the heat. You start seeing the room
14 really deform, and you start seeing some movement up here and
15 movement of the layers in here and down here. And these are
16 quantitative comparisons of room closure to data. So this is
17 for the isothermal room, so there is the vertical room
18 closure and horizontal room closure. And this is for the
19 heated room, again vertical closure compared to data,
20 horizontal compared to data. So this was the first
21 preliminary validation that we did against all the tools that
22 we had migrated into SIERRA Mechanics.

23 ZOBACK: I'm sorry, I'm trying to grasp this. It seems
24 important. Mary Lou Zoback. So in the unheated room--

25 ARGUELLO: Right.

1 ZOBACK: --the data points with the lines connecting
2 them are your--

3 ARGUELLO: So this is the prediction, the calculation.

4 ZOBACK: Those are the predictions.

5 ARGUELLO: These are the data that were collected from
6 the measurements.

7 ZOBACK: So you can't predict the deformation without
8 any heat, so why--I guess I'm confused why the model can't
9 even predict the no-heat situation.

10 ARGUELLO: Well, it depends on what you mean, you "can't
11 predict" it. You can't predict it exactly, and I think
12 that's always--

13 ZOBACK: Well, you don't show any error bars. It looks
14 to me like there's a--

15 ARGUELLO: Right, right. So--

16 ZOBACK: --10 percent--10 to 7 or 8 percent difference
17 in the simplest possible case.

18 ARGUELLO: Sure. So this was the preliminary comparison
19 against our code. We have since gone back and we can again
20 do pretty well on the vertical closure for the unheated room.

21 ZOBACK: I'm sorry, I'm skeptical of models. And, yeah,
22 once you have data, you can go back and add something to the
23 model to make it fit.

24 ARGUELLO: Well, what I can tell you is that in this
25 particular case in the preliminary calculation, we were

1 having some problems with the contact algorithm. And a lot
2 of the deformation of the rooms is, in fact, intertwined with
3 the movement of those surfaces (inaudible).

4 ZOBACK: So, again--Mary Lou Zoback, Board. And so you
5 have every one of those clay seams in as a sliding surface?

6 ARGUELLO: That's correct.

7 ZOBACK: (Inaudible) surface?

8 ARGUELLO: Not every one of them. We have the nine that
9 are closest to the room.

10 ZOBACK: Okay. And on the thicker ones, is there
11 sliding at the top and bottom or (inaudible) distributed--

12 ARGUELLO: No, only at the bottom.

13 ZOBACK: Only at the bottom.

14 ARGUELLO: Because typically up at the top they
15 transition into anhydrite or something that makes full
16 contact with the suggested salt.

17 ZOBACK: Okay, thank you.

18 ARGUELLO: Which gets back to the question. Modeling
19 salt behavior correctly is very important to us. Salt
20 constitutive modeling is very important, and it actually
21 forms the basis for U.S.-German collaborations. Our
22 constitutive model development effort, as I mentioned
23 earlier, stopped in the mid-'90s; but the German development
24 continued. The MD model, Multi-Mechanism Deformation model,
25 is currently in use in our high-performance codes in SIERRA

1 Mechanics.

2 There was some initial work done on something
3 called the MD Creep Fracture model, but it was very immature
4 when all of the development ceased. And so we never put this
5 one into the code, because it was immature, and it was not
6 robust at all. So our current situation is that we have the
7 MD model, which only models primary creep and secondary
8 creep.

9 So we need to assess the international
10 capabilities. We need to examine potential development of
11 our model and evaluate other existing models. So the German
12 models that continued under development have included
13 features including damage and fracture and so forth, and so
14 that is one of the primary reasons that we're looking at
15 them. So we want to identify the best features and the
16 deficiencies of these models, and so that's why we are
17 proceeding forward with this collaboration with the Germans.

18 Incidentally, this is--I noticed that, Professor
19 Zoback, you have something like this there on the front of
20 the desk.

21 ZOBACK: Well, it's over there now. We're passing it
22 around.

23 ARGUELLO: So this is the original core or an original
24 test specimen that was tested. This is triaxial test sample
25 of WIPP salt at 3 MPa confining stress. So when you apply

1 3 MPa confining stress and you triaxially test it, you get a
2 significant amount of deformation.

3 So the participants in the current collaboration
4 with the Germans on the behavior and healing of rock salt are
5 the following. There are several--well, there is a
6 scientific consultant, and there are several university
7 institutes as well as a private institute that is working on
8 this particular project. Sandia Labs joined in fiscal year
9 2010, as did the Technical University of Braunschweig.

10 So what this means is that we have basically have
11 access to six German groups and their models and their test
12 capabilities. The previous slide showed you a sample of a
13 triaxial test. That triaxial test is actually being
14 conducted by the Germans to fit the data to their models. So
15 that's WIPP salt.

16 So the joint project started out in 2010, and it
17 was supposed to go through 2013 and end at 2013. And, of
18 course, the focus was on thermo-mechanical behavior and
19 sealing and healing of salt. And so the sorts of comparison
20 calculations that we had on this particular collaboration was
21 that it was, of course, a benchmark comparison. The three
22 calculations that we were comparing were the borehole
23 conversions at the Asse mine, the same borehole that Kris
24 talked about earlier, and then the heater experiments
25 conducted at the Asse mine, which were conducted later in

1 time than this one but in the same hole, but now with
2 heaters--and I will show some of those results in a minute--
3 and then an in situ calculation of the so-called bulkhead
4 experiment at the Asse.

5 As I said, it was supposed to end in 2013, but
6 recently there have been some additions to the originally
7 three proposed problems, and we have included WIPP Room D and
8 Room B. And this was included as an extension from the
9 German Ministry of Technology to fund the Germans to perform
10 these benchmark calculations.

11 In addition to the benchmark calculations, there
12 were additional testing of both clean and argillaceous WIPP
13 salt that was needed for those models, and so they are
14 undertaking a series of tests. And I think Frank will talk
15 about more of the details of those in a minute.

16 BAHR: This is Jean Bahr. These drifts were excavated
17 over a hundred years ago, 1911, 1914?

18 ARGUELLO: So in this one, in this particular case,
19 remember Asse was a producing salt mine before they did
20 anything.

21 BAHR: Salt mine, right.

22 ARGUELLO: This particular one, this third one, the
23 drift was excavated then. And then they put in a cast iron
24 miner in there. And so this is being used as an analog to
25 what sorts of healing effects have occurred.

1 BAHR: Okay, I just wanted to make sure that wasn't a
2 typo and that this really was a very long-term deformation
3 experiment.

4 ARGUELLO: Right.

5 BAHR: Thanks.

6 ARGUELLO: So let me get into some of the demonstration
7 problems. So this is the first Joint Project III target
8 simulation. The so-called isothermal free convergence, so
9 it's that borehole problem, but the isothermal portion of it.
10 This is the borehole that Kris talked about earlier, and this
11 is where the isothermal free convergence test was run at the
12 lower part of that hole. A few years later they came back
13 and ran a heated borehole calculation up in this level, so
14 that means that you had to account for the isothermal
15 deformation of the hole here up until the time when they
16 installed the heaters and the subsequent deformation
17 thereafter.

18 Now, for the isothermal free convergence case, what
19 we did was we used the mesh details and boundary conditions
20 shown up here and then Asse Speisesalz properties but with
21 the MD model. And because the tests that were run on the
22 cylindrical samples for the Asse Speisesalz were from all
23 over Asse, it was permissible, according to the rules of
24 engagement for the benchmark problem, to go ahead and adjust
25 one of your parameters to calibrate your model for the

1 isothermal case. And so this is what this shows is that
2 we're calibrating the MD model to the isothermal case, and we
3 see it there. Once you--

4 BAHR: What parameter was that that you modified?

5 ARGUELLO: Yes, it was the secondary creep parameter.

6 So now let's go to the heated free convergence
7 probe test, so this is the HFCP test run at a shallower depth
8 in that same borehole. So there were roughly 1,309 days of
9 isothermal convergence of this hole. So what you're seeing
10 here is a sliver of the hole. In this section right here is
11 where the heaters were installed, and this shows the various
12 boundary conditions for that.

13 In addition, this shows you the meshing that was
14 used in our model for this. And what you see is that we had
15 to model the first 1,309 days of isothermal convergence, and
16 then from 1,309 to 1,328 it was heated at that specified
17 temperature. And then from 1,328 to 1,331 days it was
18 adiabatic. We just allowed it--the heaters were turned off,
19 and we allowed it to come back to its natural thermal
20 condition.

21 Let's see, if you can run the upper problem, so
22 this shows you that simulation. And I'm only showing you the
23 non-isothermal portion of it. We've got the isothermal in
24 there, but I didn't want you sit there and wait for 1,309
25 days for the heater to come on. This is a close-up of that,

1 and here you can see the borehole. And what you see is that,
2 indeed, there is more convergence in that heated area, as you
3 would expect.

4 Again, here is a quantitative comparison of how we
5 did and how we did relative to the German groups for the
6 thermo-mechanical case. So this is the data that was taken
7 by the ECN. It was a Netherlands--I can't remember what the
8 name of the group is. And these are the various
9 computations. And this is Sandia right here, that purplish
10 violet line.

11 So, as you can see, there is some scatter with all
12 the predictions. You can't expect it to hit right on.

13 ZOBACK: Can you just--Mary Lou Zoback--the dimensions,
14 how deep is the borehole? I have no idea what the scale is
15 (inaudible) looking at. I can't read it.

16 ARGUELLO: Sorry. So the modeled portion was 20 meters.
17 The central 3 meters were heated. And this was at an
18 elevation, let's see, of about a thousand meters underground.

19 ZOBACK: Oh, okay.

20 ARGUELLO: Because the hole was drilled from a chamber
21 within the Asse mine.

22 ZOBACK: Right, right, I got that. Okay. And the
23 diameter of the borehole?

24 ARGUELLO: The diameter of the borehole is roughly a
25 foot, .315 meters.

1 ZOBACK: Okay. So the displacement's convergence--

2 ARGUELLO: Right.

3 ZOBACK: --even though it looks like it's expanding the
4 way it--

5 ARGUELLO: Right, right, the way it shows it, yes.

6 ZOBACK: Thank you.

7 ARGUELLO: Yeah, so it's convergence (inaudible)
8 borehole.

9 ZOBACK: Four centimeters.

10 ARGUELLO: Right.

11 ZOBACK: In a one-foot-diameter hole.

12 ARGUELLO: That's right.

13 ZOBACK: Okay, thank you.

14 ARGUELLO: One final demonstration problem I wanted to
15 show you is a coupled thermal-mechanical simulation of a
16 generic high-level waste repository. So this was basically a
17 scoping calculation that we had done earlier, so I wanted to
18 preamble it as such, that it was simply a scoping calculation
19 that we did, trying to get some idea of how things would
20 behave down there.

21 So the sample geometry is based on a configuration
22 based on a 2008 Savannah River study using vitrified
23 borosilicate high-level waste glass canisters with an output
24 of 8.4 kilowatts. Now, we have since learned that that's
25 pretty high for typical waste that has been aged. But,

1 again, that's what we used because this was simply a scoping
2 calculation.

3 The technical challenges in this problem was high
4 thermal gradients, temperature dependent material properties,
5 large deformation salt creep behavior, contact modeling with
6 heat conduction and load transfer, and long duration
7 simulation to room closure. So we wanted to allow the room
8 to close completely; and by "close completely" we mean
9 whenever the roof and the floor touch, we're going to call
10 that closed. Now, that's not completely closed, but it's a
11 measure.

12 So this is what the repository plan view looked
13 like, so it's a bunch of alcoves drilled into the side of
14 these rooms or access drifts. And if we cut one of those
15 through the middle, then this is what the configuration looks
16 like. The high-level waste canister here is here in the far
17 back corner of the alcove, and then there is a drummage
18 canister here that we just included in the calculation.

19 The whole thing is covered with crushed salt here.
20 And, again, these are some of the details of the
21 configuration, symmetry planes here and here, symmetry planes
22 here in the back. This is the access drift coming through
23 here this way. So we're looking at one of the alcoves. Here
24 is the alcove itself, the waste canister, and then the
25 crushed salt on top of the waste canister. We used

1 experimental pressure-volume strain curves for crushed salt
2 at 200 degrees C just so that we--again, this was a scoping
3 calculation, so we wanted to get something reasonable. This
4 is the decay curve, normalized power curve, for the high-
5 level waste canisters.

6 And so the thermal analysis--and these were two
7 separate grids that were used, one for the thermal, one for
8 the mechanical. The thermal analysis had basically 905,000
9 nodes, 865,000 elements. The structural or mechanical
10 portion of the analysis had 295,000 nodes and about 280,000
11 elements.

12 And we actually used a couple of constitutive
13 models for this. One is the full MD model, which is more
14 expensive than something we call Power-Law Creep, which
15 includes only secondary creep. We wanted to--again, we had
16 just put a lot of this stuff in, so we wanted to get some
17 idea of what the differences were in performance for the
18 code, and so this was a way that we could do it. And then
19 what we did was we modeled PLC by itself but by setting some
20 of the MD parameters to zero so that it would mimic the PLC.
21 So that's kind of a preamble to what we're talking about
22 here.

23 If you can play this figure, and I want you to pay
24 attention to this, because it's going to--we're going to call
25 it closed when this comes in contact with this.

1 (Pause.)

2 Notice that there is still a gap here at the access
3 drift/alcove intersection, which would be non-intuitive. You
4 would think that at the intersection is where it would close
5 first, but the problem is, you see in the rib there it's
6 pooching out into the intersection and preventing it from
7 closing. And you wouldn't be able to see that without the
8 3-D model.

9 If you could play the next one?

10 So this shows you the response of the crushed salt
11 backfill as it compacts, and what you see are gradients of
12 porosity developing in the crushed salt. And these are
13 consistent with experimental measurements that have been
14 observed in the BAMBUS-II experiments. So we have a feeling
15 that we're doing things correctly here.

16 So I get now to summary and conclusions. So we've
17 made some significant strides in adapting SIERRA Mechanics
18 for repository applications. Basic multi-physics capability
19 has been demonstrated, but significant work remains to make
20 it more general and accessible in a production-type
21 environment. So we've got a code; we've adapted it to do
22 repository types of problems; but I think we need to harden
23 that into making it more robust and so forth before we claim
24 we have a production capability.

25 We've done some preliminary validation SIERRA

1 Mechanics, as I've shown. More is needed, particularly for
2 the non-salt part of it. So we're thinking of this as a tool
3 for any salt geology, but the most validation that we have
4 done to date is in salt, because that's what has been our
5 forte in the past.

6 We continue to work on providing state-of-the-art
7 leading-edge constitutive models for use in repository
8 applications.

9 International collaborations are very important and
10 are allowing us to leverage against many ongoing efforts,
11 particularly with the Germans, but we're also in contact on
12 the other side with, say, the French and the Spaniards on the
13 other geologies.

14 Testing and modeling of WIPP salt performed by the
15 German research groups is of enormous value to generic salt
16 repository science.

17 So, with that, I'll close and I'll take whatever
18 questions you might have.

19 EWING: Okay, thank you very much.

20 Questions from the Board? Jean?

21 BAHR: Jean Bahr. You showed comparisons of your model
22 simulation results with a number of German codes. Are the
23 differences in the results a function of different physics
24 that are in your models, different grid resolution or time
25 step issues, different parameterizations of the properties

1 and functions of how properties change as a function of
2 temperature and pressure and those kinds of things?

3 ARGUELLO: Yes, all of the above. So, for example, the
4 Germans use FLAC; they use ADINA; and there's one or two
5 other codes that they use. We use SIERRA Mechanics. They
6 had different--each of those six groups has a different
7 constitutive model, so there are different constitutive
8 models. And so there is those differences. Each of those
9 models is then parameterized from the data that you get from
10 these samples, and the parameterization of those models is
11 going to vary according to the different model.

12 And so, yes it's a combination of all of the above.

13 BAHR: So if you have different constitutive models or
14 sort of the underlying physics is different, how do you
15 determine which is the correct underlying physics? Because
16 each of the models has parameters and knobs that you can
17 twist to get a better fit, so it's possible that you could
18 get each of the models to fit quite well, and the goodness of
19 fit is therefore not a deterministic--is not going to
20 discriminate between which one is the--

21 ARGUELLO: Sure.

22 BAHR: --best in terms of the physics.

23 ARGUELLO: So the underlying physics in all of the
24 models is the thermo-mechanics and the solution of the
25 thermo-mechanical equation. So that is consistent across the

1 board. Now, the way that you model each of those processes
2 is slightly different because of different formulations of
3 what they're including in the models. Some are time-based
4 creep models; others are what people like to call first-
5 principles mechanistic models. And so there's those
6 differences. And, quite honestly, I would tend to believe a
7 more mechanistic model that you can trace back to something
8 like a mechanism deformation map or something like that.

9 So the MD model is based on mechanism deformation
10 maps; so is Humple's model; so is the IFG model. So those
11 are three models that I would say are trying to do something
12 other than CIRFE.

13 BAHR: Are there experiments that one could do that
14 would help you decide which of those models is the best
15 representation of the underlying mechanisms?

16 ARGUELLO: Yes. So all of these are macroscale models,
17 and so the tests that you're seeing done are either the lab
18 tests that are done--and so one of the first things that the
19 Germans do, for example, is to compare against lab testing,
20 against a multitude of lab tests. So there's a whole suite
21 of lab tests that are run, and they compare against those;
22 likewise with us.

23 And so is there a test that you can do to
24 differentiate among all of them? Not a straightforward one
25 that I know of.

1 EWING: Efi?

2 FOUFOULA: Efi Foufoula, Board. So the difference
3 between your presentation and the previous one and the long
4 title was one word difference, mechanical here versus
5 chemical. So my question is--and I would appreciate some
6 insight--how much do you coordinate? I mean, we heard new
7 innovations in the grid generation scheme that they start
8 this year and so forth, and there is a lot of common elements
9 in the platform of the modeling. Do you envision that
10 eventually will be a coupled thermal-hydrologic-chemical-
11 mechanical model?

12 ARGUELLO: Ideally, that would be the best option. But
13 the realities are that the structures of the codes are vastly
14 different. I'm not familiar with what the structure is there
15 with Los Alamos, but I do know that with Sandia we have tried
16 to incorporate the most current state-of-the-art things that
17 will allow us to do massively parallel. So you could go and
18 do a full-scale room and not have to idealize it as something
19 smaller because of the architecture of the software.

20 FOUFOULA: No, I fully understand that, and it's beyond
21 trivial to make two codes that have different architecture.
22 But my question addresses should we eventually look for a
23 common architecture and a modern framework for both
24 components, or they should be taking their own paths. That's
25 a longer--it's a philosophical question probably.

1 ARGUELLO: Yes. And it's probably beyond me, because
2 I'm not really a code developer. So I know kind of how the
3 code is developed at Sandia. Not being a co-developer, I'm
4 not familiar with how FEHM is developed or whether it has
5 parallel capabilities and all of that. And so it may not be
6 ideally--yes, we would like to do that, but it may not be as
7 simple as that.

8 EWING: Mary Lou?

9 ZOBACK: Mary Lou Zoback, Board. This is really good
10 work, and I sounded a little skeptical before, but I think
11 it's good to stay a little skeptical of models always. But I
12 want to applaud you for the close collaboration with the
13 Germans, because they've got strong interests, really good
14 lab capabilities, and access to data in the field. So I
15 think this is all great.

16 But getting to this idea--so I always forget that
17 Sandia and Los Alamos aren't--to me, they are all New Mexico,
18 but I think they're two separate labs, and you--I mean,
19 you're both computing temperature. Have you guys tried to
20 run the same geometry, same heaters, stay below the boiling
21 point so you don't get into vapor and all that stuff; and do
22 you get the same temperature fields?

23 ARGUELLO: No, we haven't done a common problem that I'm
24 aware of on the repository side. I know that in other areas
25 we have.

1 ZOBACK: Okay. It always helps to see the collaboration
2 between the labs. We appreciate that.

3 ARGUELLO: So in other areas we can talk about, we've
4 done that.

5 ZOBACK: Okay, good. Thank you.

6 EWING: So I have a little bit of a follow-up question
7 to previous questions. So this is very impressive, and, like
8 others, I would compliment you for the work and the work at
9 Sandia. And you've shown that you can apply these models to
10 a waste repository situation, and you mentioned applying the
11 model to other rock types.

12 But how focused are you on the problem of disposing
13 of high-level waste and spent fuel in salt? And what's
14 behind that question, what is interesting to me is that the
15 models involve taking a stainless steel container and putting
16 it in contact with brine, and yet that seems to be something
17 for someone else to do.

18 So do you think about the disposal problems, or is
19 the work focused on "my model can do a part of the problem
20 for waste disposal in salt"?

21 ARGUELLO: Up to now, because there isn't a site that
22 has been selected, we kind of have to do generic sorts of
23 studies.

24 EWING: Right, generic, but we know that bedded salt has
25 brine as small inclusions or as large pressurized brine

1 pockets. So if there's a fluid present, it will be a brine
2 most likely.

3 ARGUELLO: Right.

4 EWING: And just the juxtaposition of brine and
5 stainless steel strikes me as a question crying for a
6 program. And when you have it coupled to chemical processes,
7 that to me seems like a pretty relevant and important
8 chemical process that will change everything else in your
9 canister. So that's a rambling comment. But I think we have
10 to finally in the future as we go forward trying to dispose
11 of waste, that somehow has to be the end goal of these
12 studies, my personal opinion.

13 ARGUELLO: Absolutely, yeah.

14 EWING: Other comments? Mary Lou?

15 ZOBACK: I meant to ask this before, too. Can you
16 describe as much as you--well, in a limited time period--what
17 do you know about the rock fall that was in one of the
18 experimental drifts, and it happened how soon after the drift
19 was opened? And I didn't appreciate until your talk--I
20 hadn't heard from anyone the fact that there's these layers
21 of clay that are acting as shear surfaces.

22 So once it fell down, you could go up and look
23 where it fell from. Was it out of the clay? Was the top
24 boundary a clay layer? I mean, what did you learn from that
25 occurrence?

1 ARGUELLO: So the only one that I am at all familiar
2 with was the one in Room B, but--

3 ZOBACK: Room B. Okay

4 ARGUELLO: But Room B was an accelerated test, and so as
5 soon as--even before the top fell, they closed off the
6 workings.

7 ZOBACK: You mean they shut it off so you couldn't go
8 back in there?

9 ARGUELLO: Right. Right.

10 ZOBACK: But it happened after it was heated?

11 ARGUELLO: Yes. So the heating accelerated--

12 ZOBACK: And had the heater been shut off when it fell
13 down, or was it still heating?

14 ARGUELLO: I don't know if the heater had been shut off.

15 ZOBACK: Is there a paper we could read about this?

16 ARGUELLO: I don't know. That was in Room B, Peter?

17 ZOBACK: I thought someone promised us we were going to
18 hear about this later today, one of the early speakers. It
19 seems relevant considering what's happened in the past month.

20 ARGUELLO: Yes, sure. So this was, you know, in the
21 '80s. I presume that there was a report written with regard
22 to that, but I don't--

23 ZOBACK: Could someone from Sandia make it a task to get
24 us a copy of the report on the--

25 ARGUELLO: Yeah, okay.

1 EWING: Okay, thank you. Other questions? Jean? Oh,
2 I'm sorry, Jerry's been waiting.

3 FRANKEL: Actually, my question is related to--Jerry
4 Frankel. My question is related to Mary Lou's question about
5 the roof. You're using primary and secondary creep in your
6 model, and you show nicely this is just, like, collapsing
7 down together. But you talked about other models that have
8 damage and fracture components in the back. Your vertical
9 closure, you talked about creep rupture.

10 So if you have a chamber that you mine out and
11 leave it or heat it and leave it, will there be failure, or
12 is it just going to--

13 ARGUELLO: No, no, no. You will have failure.

14 FRANKEL: You'll have failure?

15 ARGUELLO: You will have failure.

16 FRANKEL: Failure by what mechanism then?

17 ARGUELLO: Well, it depends. If it's a bedded salt
18 repository, you're probably going to have the sides slabbing,
19 the roof dropping. But, you know, hopefully it's not within
20 the first five years or whatever.

21 FRANKEL: And those are gravity effects. So in your
22 vertical borehole--

23 SPEAKER: It's stress concentration.

24 ARGUELLO: Yeah, heat, stress concentration, separation
25 of the clays.

1 FRANKEL: But in a vertical borehole, would you expect
2 then--

3 ARGUELLO: No, you wouldn't--

4 FRANKEL: They would just--you would expect it just to
5 seal up?

6 ARGUELLO: You would expect it to seal up. You might
7 have some surface crumbling, but--

8 FRANKEL: And all the rock bolts that are holding the
9 ceiling up, it's just going to creep right around those rock
10 bolts? Would that affect your models at all?

11 ARGUELLO: Okay, so the way this works is, you get
12 relaxation around the openings. Here's your opening. And
13 that wave of high stress moves further and further away from
14 the opening, because what the opening is trying to do, it's
15 trying to get back into a hydrostatic condition. Once it
16 gets fully closed, then there's no more shear, so it won't
17 creep and in that setting.

18 So what happens is that the stress wave, if you
19 will, goes further and further out. At some point you will
20 go beyond where the rock bolts are. Now, if the stress
21 hasn't diminished to the point that that material can support
22 the weight that is being held together by those rock bolts,
23 then you will have a separation.

24 FRANKEL: You could have a big drop.

25 ARGUELLO: Right. And that is the mechanism for

1 encapsulating this. So you have a big drop; eventually
2 everything starts closing together again; and you get
3 eventually to a hydrostatic condition in salt.

4 FRANKEL: As long as you don't break anything while
5 you're dropping.

6 EWING: With deference to Jean, I am going to call the
7 questions to an end to keep us on schedule to save time for
8 public comment at the end. But, Jean, of course, after we
9 start the break, you can ask your question.

10 BAHR: Okay, sure.

11 EWING: So we'll have a break now, and we'll begin at
12 3:05 when we reconvene.

13 (Whereupon, a break was taken.)

14 EWING: The next speaker is David Sevougian, and he'll
15 be presenting Performance Assessment Modeling of a Generic
16 Salt Disposal System.

17 SEVOUGIAN: And Rod just stole my first line, which was
18 to read the title. Perhaps a more appropriate title would be
19 high-activity waste, since our first application of this is
20 to the disposal of spent nuclear fuel in a generic bedded
21 salt repository. And also much of what I will discuss is
22 applicable to either crystalline or argillite concepts.

23 I'd like to acknowledge a number of the other
24 participants in this activity, including our DOE colleagues,
25 several of our Sandia colleagues, including Geoff Freeze,

1 Payton Gardner, and Glenn Hammond. I'd like to acknowledge
2 Peter Lichtner and our colleagues from Los Alamos and
3 Lawrence Berkeley.

4 My first slide is the outline, and this is just a
5 brief summary of what I'm going to talk about today. I'm
6 going to first talk about the objectives of the activity,
7 some of the methodology for the model and code development,
8 including a discussion of a reference case for bedded salt.
9 I'm going to talk about development of the PA code in a
10 high-performance computing environment. Then I'll give an
11 example demonstration based on the reference case using the
12 modeling system. And my last slide will be a brief
13 discussion of some integration with a source term process
14 model that models spent fuel degradation.

15 So as far as the objectives of this work, I have
16 outlined three. Really, the main goal here is to develop a
17 flexible PA capability that readily evolves throughout the
18 program life cycle, and we have a long life cycle ahead of
19 us, including site selection, characterization, licensing,
20 construction. During all those phases of repository
21 development, we'd like this PA model to be able to evaluate a
22 variety of sites for disposal of spent fuel and high-level
23 waste. Right now these are generic sites, generic reference
24 cases.

25 Another important activity, an objective of

1 performance assessment modeling, is to support prioritization
2 of research, development, and demonstration activities, at
3 first generic, which is where we're at now, later site-
4 specific. And another key aspect of performance assessment
5 modeling is to support the safety case during all phases.

6 What I show on the bottom here is--I don't expect
7 you to read this. If you have a handout, you might be able
8 to read it. This is a diagram, a flow chart, of the
9 iterative performance assessment methodology that we've been
10 following at Sandia for 30-some years. You've seen
11 applications related to WIPP. We used the same methodology
12 on Yucca Mountain. And in some later slides I'm going to
13 focus in on some of these steps with another flow diagram.
14 And I'm trying to show here how the performance assessment
15 feeds the evolution of the safety case, so its iterative
16 performance assessment is a key aspect of the safety case,
17 not the only aspect.

18 BRANTLEY: Actually, you can't read the handout either.

19 SEVOUGIAN: Well, it's actually--

20 BRANTLEY: I can read it on the PDF.

21 SEVOUGIAN: Actually, I don't want you to turn to it,
22 but there is a backup slide with a bigger picture of it. So
23 if they printed the backup slides, and I can send it to you
24 anyhow if you'd like.

25 This slide, Slide 5, is really the crux of my talk,

1 so let me just spend a little time on that. The main thing
2 about the development methodology that we are working on is
3 to have a direct representation of multi-physics coupled
4 phenomena within the PA simulations, within the model, the
5 code, the simulations themselves, the idea being that this
6 minimizes the use of conservative assumptions,
7 simplifications, abstractions, and allows us to include a
8 realistic representation of spatial heterogeneity of
9 uncertainty of the features, events, and processes.

10 And what I'm showing here just in case people are
11 unfamiliar with this is the main parts about a probabilistic
12 performance assessment. We start with many input parameters,
13 because there's many processes, many domains. So we try to
14 accurately characterize the uncertainty, both the aleatory
15 and epistemic uncertainties; we have some kind of integration
16 or sampling routine; and then produce multiple
17 representations of the performance of the repository, here
18 shown as dose versus time. And the main point is to include
19 coupled multi-physics over a large domain and actually many
20 sub-domains over a probabilistic simulation. The use of
21 high-performance computing architecture will facilitate that.

22 One thing we always ask ourselves when we're
23 modeling performance assessment is: To what degree do we
24 include these phenomena in the performance assessment model
25 versus the supporting process models that you've heard

1 described today, like in the last two talks, Lupe's talk and
2 Phil's talk?

3 So the idea is that we use our process-level
4 understanding that's been developed over many decades to
5 determine what fidelity of the model components, geometry,
6 mechanisms do we need in the performance assessment code.
7 And in this regard, of course, performance assessment is a
8 much longer time-scale than some of the processes, so it's a
9 function of not only the importance of the underlying process
10 to the overall performance of the system, but also a function
11 of time-scales.

12 And I've just taken a couple of snapshots of Lupe's
13 movies that show the evolution of the backfill when heat-
14 generating waste is emplaced. And over a period of 200
15 years, the porosity decreases significantly; but 200 years is
16 a short time-scale over a span of a million years. The point
17 I'm trying to make is that with a high-fidelity multi-
18 physics-capable performance assessment code, we can then
19 analyze whether or not these processes need to be in the
20 performance assessment and in what fashion they need to be
21 included.

22 I'm going to switch gears a little bit here. I've
23 got my other flow diagram I'll go over in a minute. This is
24 the PA methodology flow diagram blown up, and I'd like to
25 talk first about the reference case that we've developed for

1 salt. The reference case is a surrogate for site- and
2 design-specific information that's not available right now.
3 It documents the information and assumptions that are needed
4 to evaluate a generic disposal system, and it helps ensure
5 consistency across the various modeling disciplines,
6 including performance assessment, process modeling
7 uncertainty, and sensitivity analyses of the results.

8 So the major steps I've shown are the reference
9 case, which again is a surrogate for the design and the site;
10 and then the FEPs process, which I'll go through in a couple
11 of slides; and then these developed guidelines for
12 constructing the model and the code. And then once that's
13 completed, then you have the disposal system evaluation.

14 So on the reference case the major components are
15 the inventory that we are using, various features of the
16 engineered barrier system and the natural barrier system, the
17 concept of operations, the biosphere, and the regulations,
18 which I'm not going to talk about the latter today.

19 The first part I'd like to talk about is the
20 natural barrier system in our reference case. And we've
21 looked at a number--I don't know if you can read this. These
22 are the major salt basins in the U.S. We've looked at those
23 and tried to develop reference or representative properties
24 for these basins to use in the reference case, including
25 stratigraphy, formation properties such as porosity and

1 permeability, information about the brine chemistry. And
2 then another important feature in a salt repository you've
3 heard about is the excavation disturbed zone. We've taken
4 properties for that from international studies from the
5 Germans and also from WIPP.

6 As far as the interbeds, again, you've seen a lot
7 of discussion about clay interbeds. We have properties on
8 the clay and dolomite interbeds, their location relative to
9 the repository, and we're also using a representative aquifer
10 as a connection with the biosphere.

11 In the reference case we have--a little strange at
12 this angle--this is the reference case engineered barrier
13 system and concept of operations. So we're starting with a
14 repository that is about 1,600 meters square. It goes 5
15 kilometers on each side. And I'll talk a little bit more
16 about the details in this drawing, but basically we're
17 assuming that the salt bed is about 700 meters--sorry--the
18 repository is about 700 meters below the surface. We've
19 assumed 70,000 metric tons with a burn-up of 60 gigawatt days
20 per metric ton. The drift spacing, the waste package
21 loading, and effectively the number of waste packages is a
22 function of the thermal limit we're assuming for salt. And I
23 think an earlier talk mentioned that. That was 200 degrees C
24 is generally what's assumed. That results in, for our
25 reference case, 12 PWR assemblies with 7.5 kilowatts per

1 waste package.

2 And as I was talking about the repository itself,
3 there are 84 pairs of 800-meter drifts with a drift spacing
4 of 20 meters in between and 10 meters between the waste
5 packages. We're using a crushed salt backfill engineered
6 barrier in the drifts, and we have sealed shafts.

7 For the demonstration problem, we're only using a
8 quarter symmetry, and this basically shows an anhydrite
9 interbed just above the repository and intact host rock and
10 then the aquifer here.

11 Okay, I'm going to move now to the FEPs process. I
12 see I don't have a--the last conference I was at, I had a big
13 timer that was--it was a countdown timer to tell me how much
14 time I had.

15 EWING: I'll wave.

16 SEVOUGIAN: Oh, you wave too late, because I'm only
17 halfway through.

18 ZOBACK: Mary Lou Zoback, Board. Could you define the
19 acronyms?

20 SEVOUGIAN: Yes. Which one?

21 ZOBACK: FEPs, for example. I know what it means--

22 SEVOUGIAN: I'm going to get to that--

23 ZOBACK: --but not everyone in the audience knows what
24 it means.

25 SEVOUGIAN: Right. I'm going to get to that in just a

1 couple slides.

2 ZOBACK: Thank you.

3 SEVOUGIAN: In fact, I'm going to get to it right here
4 on the title of this slide: Features, Events, and Processes.

5 ZOBACK: Thank you.

6 SEVOUGIAN: So this is the part I'm going to talk about
7 now, the FEPs process. FEPs analysis is--in fact, it's
8 essentially codified in the U.S. regulations in 10 CFR Part
9 63. One of the requirements for performance assessment is to
10 identify the features, events, and processes that are
11 important. They are potentially important to performance.
12 So it supports both the safety assessment and performance
13 assessment in the safety case. It helps with the development
14 of the system models. It helps with prioritization of
15 research. As I just said, it's needed for completeness of
16 the licensing case. It's used in all major programs,
17 international programs, the German program in Gorleben, the
18 U.S. programs.

19 So, basically, this diagram here shows the major
20 features in a bedded salt repository, including the
21 backfilled excavation drift, the disturbed rock zone, the
22 intact host rock and interbed and aquifer, the biosphere.
23 And then on the right are processes that would be occurring
24 within these features. So we like to say that processes and
25 events--and I'm not going to talk much about events--act upon

1 features of the repository.

2 Some of the processes would be waste form
3 degradation, waste package degradation, disturbed rock zone
4 evolution, salt creep; in the far field, advection,
5 diffusion, sorption; in the biosphere, these are just generic
6 processes, but water consumption for example.

7 Now, the two main parts about FEPs analysis are,
8 first, identification of the FEPs. So the first thing you do
9 is identify a comprehensive list of FEPs that capture the
10 entire range of phenomena that might potentially be relevant
11 to long-term performance. And here I like to use the example
12 that Geoff Freeze used at the Waste Management Conference.
13 He chose one from the Canadian program, which was: What is
14 the potential effect of using contaminated water in a curling
15 rink or ice hockey rink? So very comprehensive.

16 Later on, it's probably not important to
17 performance, so then you have the FEPs screening process,
18 which is to determine the set of important FEPs, those that
19 might potentially affect or contribute to long-term
20 performance. In general, there's three criteria for
21 determining that. One is low probability. There's usually a
22 probability screening level in the regulations that say if it
23 falls below that, then you don't need to include it. The
24 other is low consequence. If it's not going to move the
25 needle, then it need not be included in a performance

1 assessment. And then some are regulated.

2 Once you've decided which ones are important to
3 include, then it's important to review and analyze them in
4 various ways with process models, etc., to determine the
5 fidelity and dimensionality of including them in the
6 performance assessment. And I've just listed one here from a
7 FEPs database or table that we have in the Used Fuel
8 Disposition Program. We currently have 208. This one, the
9 first thing you have is a number, just an identifier, then a
10 name or description. This one happens to say,
11 "Electrochemical Effects in the EBS." Some additional
12 information processes that might be associated with this
13 particular FEP; this one says, "Enhanced metal corrosion."
14 And then some kind of screening decision. For this
15 particular one we did a preliminary screening for the bedded
16 salt and thought it was likely excluded, but we have to be
17 reevaluated once the design is decided upon.

18 The next step I'm moving to is the model and code
19 construction step, and I'm going to concentrate on code
20 construction once we have the reference case and the FEPs
21 screening. So I've already mentioned that high-performance
22 computing environment facilitates the use of three-
23 dimensional multi-physics over multiple realizations of a
24 performance assessment. It also facilitates future advances
25 in computational methods and hardware.

1 So we've developed these, essentially, requirements
2 or guidelines that we're working towards in the development
3 of our system. One of the more important ones is, we want
4 the software to be open source so it's sharable by multi-lab
5 experts, and stakeholders would have access to it. It
6 increases transparency. It should be flexible and extensible
7 so that it's easy to add either simple or advanced component
8 models. It should be scalable. I've just shown a picture of
9 scalability here. This is computer wall-clock time versus
10 number of cores. Ideally it would be linear. We want to be
11 able to leverage with our software the existing computational
12 abilities related to meshing, visualization, and solvers.
13 And, very importantly, it needs to be amenable to
14 configuration management and quality assurance.

15 So where does that lead us? Right now here's where
16 we're at. We have two key pieces to the performance
17 assessment code. They're shown in green. The top one is the
18 stochastic simulation part, and this one is the domain
19 simulation software.

20 For stochastic simulation we're using DAKOTA, which
21 is an open source software available. It's housed at Sandia,
22 does uncertainty quantification, stratified sampling,
23 sensitivity analyses, other things like optimization. So
24 it's kind of the driver code that then calls for multiple
25 realizations of the uncertain input parameters and then feeds

1 them to the domain simulation software, which we're using
2 PFLOTRAN, which integrates the simulations and does the
3 simulations in the domains.

4 Why are we using that? It fulfills many of the
5 requirements on the last side, which is, it's open software;
6 it uses sophisticated version control; it's modular
7 extensible, highly scalable in a high-performance computing
8 environment.

9 So the main components, the main uses of it, are
10 over the three major domains, the three major features I
11 showed in a previous slide, the far field for far field flow
12 and transport through the host rock and through the aquifer
13 above, for modeling processes near the waste packages in the
14 engineered barrier system.

15 The ones that are grayed out are ones that we're
16 not looking at at the moment, which is not to say we won't in
17 the future. Just for the first demonstration, we're not
18 looking at those.

19 Right now we have waste form degradation and
20 radionuclide mobilization in the far field processes. We're
21 also using PFLOTRAN for the biosphere at the moment. Later
22 on when a more sophisticated biosphere is decided upon for a
23 particular site, we can use another component model there.

24 So let me talk about PFLOTRAN a little bit. The
25 original developer was Peter Lichtner. I'd like to thank

1 Peter. He was kind enough to come down. He's in the
2 audience. Peter, thank you. And the lead developer is Glenn
3 Hammond, who is sitting next to Peter.

4 And it does multi-physics, multi-phase flow and
5 heat, multi-component reactive transport, biogeochemistry.
6 It is massively parallel, can do highly refined 3-D
7 discretization, probabilistic runs, and it's open source, as
8 I already said. It's domain scientist friendly, because it's
9 written in Fortran, modular Fortran, modern Fortran.

10 As far as the open source part, this is just some
11 logos of the people that are using it, a number of national
12 labs and universities. And I just showed a snapshot of the
13 source repository. It's on bitbucket.org, so anybody here
14 can go and pull down the source, look at it, and look at the
15 Wiki pages on the description of it.

16 And then the next slide is just a little bit more
17 about it. For flow it does multiphase gas and liquid flow,
18 has various constitutive models. It does advection,
19 dispersion, diffusion. It can do multiple interacting
20 continua, has thermal conduction and convection. And then
21 it's very sophisticated with its reactive transport.

22 Now I'm going to move to the disposal system
23 evaluation, the demonstration case, and you've seen this
24 picture before. Again, this is our demonstration reference
25 problem, and we're using DAKOTA for the Latin Hypercube

1 sampling of the input parameters. For the domain processes
2 we have 3-D flow and transport in our problem. The main
3 transport mechanism in salt is diffusion, so we have
4 diffusion in the disturbed rock zone and the bedded salt. We
5 do have advection in the aquifer here once it diffuses to the
6 aquifer. We have a realistic source term in the EBS, but for
7 now we're only using five radionuclides for the demonstration
8 problem. We're using a conservative tracer iodine and the
9 neptunium series decay chain so we can investigate the
10 precipitation/dissolution with a decay chain.

11 For the waste form model we are representing spent
12 fuel degradation, essentially UO₂, with a kinetic rate of
13 reaction. And essentially it degrades almost completely in
14 about 10,000 years in this salt environment. And then the
15 model has solubility limits for each element, and so they
16 will precipitate if they exceed the solubility limit.

17 This is a picture--this is the top half of the
18 previous picture. So what we did for the demonstration
19 problem is we took a slice, actually, out of the reference
20 case domain. We took a 3-D slice, so this 3-D slice goes
21 through one drift, one emplacement drift, in the repository
22 all the way out to a pumping well at 5 kilometers, so I've
23 shown a picture here. Of course, it has vertical
24 exaggeration. And there's a typo here. This should say 5809
25 here and here. So it's a 3-D slice. The width of it is from

1 a half pillar to a half pillar, 20 meters wide, which is the
2 drift space. It encompasses one drift just showing the
3 detail of 8 of the 80 waste packages that are in this part of
4 the domain. And that's what we simulated, 80 waste packages.

5 And, again, we're using our DAKOTA and PFLOTRAN.
6 The results I'm going to show are one--I'm going to show one
7 deterministic simulation that uses representative values or
8 mostly mean values from the sample distributions of uncertain
9 parameters such as porosity, permeability, sorption
10 coefficients, etc.

11 And then I'm going to show a 100-realization
12 problem where we sampled the nine uncertain parameters we
13 have in the demonstration problem. We ran it on Red Sky,
14 which is Sandia's essentially workhorse high-performance
15 computing cluster. It's not quite PetaFlop, but it's 505
16 TeraFlops peak, so it's reasonably fast. And PFLOTRAN has
17 the capability of nested parallelism so it can run many
18 concurrent realizations of these 100 at a time. And then
19 within each realization it does domain decomposition, so it
20 quorums out the domain, you know, the far field, near field,
21 EBS spatial domain amongst the processors.

22 This picture was just to show some of the detail on
23 the waste packages, so here was the 5,000-meter slice. And
24 this is showing 29 of the waste packages. You can't really
25 see them. What you're seeing is the full drift width. The

1 waste packages are actually at the center of this kind of
2 cross here. And this is neptunium dissolved concentration at
3 1,000 years, so it hasn't really started to move much.

4 Now what I'm going to show are two simulations from
5 the deterministic run, so this is with effectively the mean
6 values for the parameters. I'm going to show neptunium
7 dissolved concentration first. This is only 1,000 meters of
8 the 5,000-meter domain, so it's going to start at time zero
9 and then go to a million years.

10 (Pause.)

11 So it moves up a little ways. It moves a little
12 higher up the shaft. The shaft is on the right side of the
13 domain. It has slightly higher permeability than the intact
14 host rock. And for some reason it stopped at 700,000. I
15 didn't stop it on purpose.

16 (Pause.)

17 Well, maybe it won't go on this computer. It isn't
18 really showing anything different.

19 (Pause.)

20 That is amazing.

21 EWING: Just a question for clarification. Where did
22 the fluid come from?

23 SEVOUGIAN: We are assuming that--I'd have to look up
24 the porosities, but the salt has very low porosity. We're
25 assuming it's fully saturated. So basically we're assuming

1 instantaneous waste package degradation at time zero, so at
2 that point the domain is fully saturated with water, and it's
3 diffusing. So the fluid is in place, as we expect it to be.

4 The next one--maybe it'll go farther than 700,000
5 years--is the daughter of neptunium-237, uranium-233. I'm
6 showing the precipitated concentration, so it is one that
7 reaches its--now, see, this one only goes--this one
8 precipitates at different levels in some of the different
9 beds because of changes in material properties like porosity.

10 So if we go to the next one, this was the
11 deterministic realization. If we go to the next slide, this
12 was the multi-realization analysis. So, as I mentioned, we
13 sampled 9 parameters, ran 100-realizations. I am showing
14 here the results of neptunium dissolved concentration at a
15 point 400 meters, about halfway into the domain, in the
16 anhydrite interbed. And this is zero to a million years
17 effectively or .1 to a million years.

18 This is the range of output concentrations. If we
19 take a slice at 100,000 years and take those 100 points and
20 then do a correlation analysis with the input parameters and
21 plot the Spearman rank correlation coefficient, or
22 effectively how much does the spread in the output depend on
23 the spread in the input, we see that the disturbed rock zone,
24 DRZ, porosity and the neptunium sorption coefficient have the
25 most effect. And then I just plotted a scatter plot of

1 neptunium concentration versus the porosity in the disturbed
2 rock zone, and you can see the trend here.

3 EWING: Sorry to interrupt, but if we let time pass,
4 we'll be away from the slide. So how much uncertainty is
5 there in the neptunium solubility limit? I mean, at Yucca
6 Mountain this was a big issue.

7 SEVOUGIAN: Yeah, I didn't think of that one. I brought
8 the neptunium Kd distribution, but I've forgotten what the
9 spread was in the solubility.

10 EWING: It's huge.

11 SEVOUGIAN: Yeah, this is not oxidizing conditions.
12 This is reduced conditions. I'm not sure that it's quite as
13 big a spread as it was at Yucca.

14 EWING: But that's included or not?

15 SEVOUGIAN: The solubility is. We do have--one of the
16 parameters we sample is the--no? We just used deterministic
17 values for the solubility? Somebody's telling me we just
18 used one value, wasn't sampled.

19 EWING: But then correlating it with--

20 SEVOUGIAN: No, no, I didn't correlate--no, I have
21 neptunium sorption coefficient, not solubility. So, yeah,
22 I--

23 EWING: All right. I'm sorry to interrupt.

24 SPEAKER: Yeah, obviously it wasn't sampled--

25 SEVOUGIAN: Okay, I'll move on to the next slide, which

1 is--it's really the last slide. And I just wanted to show--I
2 entitled it "Example of Flexible Architecture." Basically,
3 right now we're using a kind of a simplified degradation
4 model that's implemented right directly in PFLOTRAN as a
5 kinetic rate. We have ongoing work on a spent fuel waste
6 form degradation model that's comprised mainly of two
7 components, a radiolysis model, which is on the time scale of
8 seconds, and then a mixed potential model, which looks at
9 oxidation reduction reactions at the UO₂ surface, along with
10 diffusion through the boundary layer, to determine--and also
11 homogeneous and heterogeneous reactions--to determine a spent
12 fuel degradation rate.

13 So basically the coupling between it and the PA
14 model is that the PA model will send the solution chemistry
15 from the near field to this model, which will then determine
16 a degradation rate to send back to the PA model, which will
17 then mobilize the radionuclides. So that's ongoing work.

18 My next slide is just a summary of what I've said.
19 We've developed a capability that is able to evaluate either
20 generic or site-specific locations with a high-fidelity
21 representation of coupled processes in three dimensions based
22 on high-performance computing architecture, adaptable to
23 future advances. We've informed it with our knowledge of
24 salt. It's able to represent uncertainty and heterogeneity.
25 We hope to be able to use it to prioritize research

1 activities, and we feel it will enhance confidence and
2 transparency in the safety case.

3 I've shown you a demonstration problem.

4 And then ongoing work this year includes further
5 code refinement as necessary. We're also working in
6 collaboration with WIPP on some analyses with PFLOTRAN; and
7 also further development of the reference case, simulations
8 and testing for salt as well as granite and argillite is
9 being worked on this year. And then I just mentioned the
10 integration with the spent fuel degradation model.

11 So thank you for your attention.

12 EWING: Okay, thank you.

13 So questions from the Board? Jerry?

14 FRANKEL: Jerry Frankel from the Board. I think that
15 your spent fuel degradation model, you should consider that
16 the instantaneous dissolution of the stainless steel canister
17 will result in a local chemistry with negative pH. So UO₂
18 degradation dissolution rate, I think, will be strongly
19 affected by that.

20 SEVOUGIAN: I didn't mention, in the reference case
21 we're assuming a carbon steel waste package, not stainless
22 steel. Carbon steel is more appropriate for salt. We have
23 iron--they do have in their model--they have an iron species,
24 so they had iron redox couples in their spent fuel
25 degradation model. So definitely be taken account of. One

1 of the most important parameters is the H₂ concentration in
2 the water.

3 FRANKEL: The H₂ concentration?

4 SEVOUGIAN: Yes.

5 FRANKEL: Not the H-plus.

6 SEVOUGIAN: Well, H-plus, yeah. But understand the H₂
7 affects the degradation rate strongly. It affects whether
8 it's a reducing or oxidizing environment.

9 FRANKEL: Right. But you don't need oxidizing
10 environment. The iron will hydrolyze also and generate--

11 SEVOUGIAN: Generate gas.

12 FRANKEL: --a gas acidic environment.

13 SEVOUGIAN: Okay.

14 EWING: And just a quick follow-up. Is your hydrogen
15 generation then connected to your radiolysis model?

16 SEVOUGIAN: The radiolysis model determines--you're
17 getting into not my area of expertise, but the alpha
18 radiolysis model deposits radiolytic products near the
19 surface. The main one is H₂O₂. And I forgot, what was the--

20 EWING: Well, if you're generating hydrogen from the
21 corrosion, that's part of the equation.

22 SEVOUGIAN: Right, that's part of the--I could put the
23 reactions back up, but H₂ is in a number of the reactions.

24 EWING: Okay, please, Paul.

25 TURINSKY: Paul Turinsky, Board. With the uncertainty

1 analysis, how are you doing the model (inaudible)
2 uncertainties? I mean, parameters are a part of the story,
3 but I would think when you're doing predictions out for these
4 times, there's missing physics. So how do you account for
5 that?

6 SEVOUGIAN: You know, you always--alternative conceptual
7 models is a key part of any performance assessment. In fact,
8 you know, it's in 10 CFR Part 63 that you need to include
9 alternative conceptual models. So if there is a model that
10 equally represents the data we have, we will include it in
11 the performance assessment. And if there is no other way,
12 50-50 is the weighting. Or you can do separate analyses, one
13 with this model and one with that one. But you definitely
14 would include it.

15 EWING: Jean?

16 BAHR: Jean Bahr from the Board. Can you clarify for us
17 what's different about PFLOTRAN compared to the FEHM model in
18 terms of physics that's incorporated, resolution? Yours is a
19 somewhat farther-field model than what we saw there. We've
20 heard about two models that are both THC models.

21 SEVOUGIAN: Well, there was a number of reasons to pick
22 PFLOTRAN. One was that it was open-source software. That
23 was very important to us. And I don't think the other one is
24 open-source. The other important part was we wanted to pick
25 one that had already been optimized on a high-performance

1 computing architecture. PFLOTRAN has been run in a number of
2 different applications. I think I have a backup slide on
3 that, and it's--

4 BAHR: Does it include all of the physical process that
5 are included in FEHM?

6 SEVOUGIAN: I think so. It includes thermal. It
7 includes multi-phase flow. Both of those are in FEHM. It
8 includes reactive transport probably to a higher degree than
9 in FEHM. There is a version of it that's including
10 mechanical effects, linear elastic effects.

11 BAHR: Has there been an intercomparison with benchmark
12 problems among those codes?

13 SEVOUGIAN: There could be. That wasn't really our
14 goal, because we're using the PFLOTRAN for performance
15 assessment. The FEHM is right now being used to look at more
16 detail on the processes.

17 BAHR: I guess I'm trying to understand why two
18 different models are being used.

19 SEVOUGIAN: Why two different models are being used?

20 BAHR: Are you at a different lab?

21 SEVOUGIAN: Yes.

22 EWING: Good question.

23 SEVOUGIAN: Again, we're using that one for process
24 modeling. We're using this for performance assessment.

25 EWING: Other questions? Mary Lou?

1 ZOBACK: Mary Lou Zoback. I do have a question. And I
2 applaud the use of open-source. I think that's great. But
3 the question I have is, you've created the model that runs on
4 high-performance computing, so let's say in the future
5 another EEG is set up and the independent advisory group such
6 as you had here in New Mexico. I'm sorry, I forgot which of
7 the two labs you're--would you then make that computing
8 resource available to--I mean, there's no point having open-
9 source code--

10 SEVOUGIAN: That's right.

11 ZOBACK: --unless people can run it.

12 SEVOUGIAN: That was our goal in having open-source. We
13 want the stakeholder to be able to use it.

14 ZOBACK: Fantastic. And you'll have training classes to
15 help them understand it?

16 SEVOUGIAN: You have to ask DOE, but I would be an
17 advocate for that.

18 ZOBACK: Great. I think that's a fantastic route to go.
19 Thank you.

20 EWING: Sue?

21 BRANTLEY: Sue Brantley, Board. When people run
22 reactive transport codes, your chemical reactive transport
23 codes, and try to simulate geological systems that are 10,000
24 years old, 200,000 years old, a million years, one of the
25 bugaboos is figuring out what the surface area is, surface

1 area of the dissolving phase. And I've actually had a
2 student to work with, Peter Lichtner, and we simulated a soil
3 out to a million years. And we ended up having to tune the
4 surface area parameters because we had nothing to hang it on,
5 I mean, basically nothing. We could start with observable
6 for the soil that had developed for short time frames, but
7 the older soils, you know, it was a tuned parameter.

8 So how do you deal with surface area in something
9 like this where you're trying to actually make a million-year
10 simulation?

11 SEVOUGIAN: I'm not an experimentalist. I mean, I know
12 that you can measure surface area with, I don't know,
13 nitrogen gas or something.

14 BRANTLEY: Well, you can measure it today, but if it
15 changes over time--

16 SEVOUGIAN: Oh, as devolving surface area?

17 BRANTLEY: Well, and also the surface area that's
18 interacting with fluid which is under-saturated. That is
19 something that has to be calculated by the code essentially.

20 SEVOUGIAN: So it's dissolving or changing, becoming
21 more surface area maybe? I'm not up on the literature. I
22 mean, I know in the chemical engineering field, they have
23 these catalyst reactors, they look at--

24 BRANTLEY: But they don't usually go out a million
25 years, right?

1 SEVOUGIAN: Well, okay, I'm not sure of the
2 distinction--sorry--for a million years.

3 EWING: Efi?

4 FOUFOULA: Efi Foufoula, Board. So, if I understand,
5 your rank correlation analysis shows that the porosity is one
6 of the critical factors affecting the model--with
7 uncertainty.

8 SEVOUGIAN: This is just for the--the preliminary thing
9 where I showed the output--

10 FOUFOULA: Yeah.

11 SEVOUGIAN: --which was very close to the repository in
12 the disturbed rock zone.

13 FOUFOULA: So this analysis basically will tell you what
14 are the most critical parameters contributing to the
15 uncertainty in the model.

16 SEVOUGIAN: Right. This is one of the main goals when
17 you analyze the results is so that you can then go back and,
18 if it's a key parameter, spend more dollars on reducing the
19 uncertainty.

20 FOUFOULA: And I ask you, this is really pure
21 uncertainty; it's not heterogeneity in the porosity.

22 SEVOUGIAN: This is--yes, right. It affects the
23 diffusivity. That's why it's important here. So this
24 represents the uncertainty range that we're using in this
25 example problem.

1 FOUFOULA: Okay, it's just an example. Okay.

2 EWING: Rod Ewing, Board. I have a few questions, and
3 I'll start with the most general. So it's become, I would
4 say, fashionable in the U.S. to do generic performance
5 assessments of different repository rock types. And the
6 question always is: Is this a useful exercise? What can we
7 learn? So you've presented a generic analysis for salt, but
8 I think most people would agree--and certainly the case at
9 WIPP--that it's the human intrusion scenario that matters in
10 terms of the release of radioactivity, and that's not
11 included in what you've done. Is that correct?

12 SEVOUGIAN: Yeah, I forgot to point that bullet out on
13 one of the slides. We're using just the undisturbed case for
14 the initial testing of the--

15 EWING: Right.

16 SEVOUGIAN: Because human intrusion is very--often it's
17 just specified by regulations. It's not to say we can't
18 model it. If we decide on a specific scenario that seems
19 appropriate, then--and we also have in our plan to start
20 modeling that next fiscal year.

21 EWING: But wouldn't it already be interesting,
22 particularly if we're supposed to use generic performance
23 assessment of different geology rock types, as we look at the
24 different geologies, the probabilities of mineral
25 exploration, tunneling, whatever activity, would be

1 different. And with salt it would be particularly high,
2 thinking of people looking for oil and gas in the future.

3 So wouldn't it be interesting to compare the
4 different geologies in terms of, say, a single scenario that
5 is human intrusion and see which geologies are least
6 susceptible in terms of the integrity of the repository and
7 which are most susceptible?

8 Another question would be that if you have a
9 drilling rate, WIPP has a compliance period of 10,000 years,
10 I've always wondered, well, if the compliance period was a
11 million years, what's the probability of, in some distant
12 time, oil and gas exploration penetrating the WIPP horizon?
13 And that becomes particularly, I think, a relevant question
14 when you look at all the holes around the four-by-four
15 excluded area for the WIPP site.

16 Are these issues that you'll address with your
17 generic performance assessments?

18 SEVOUGIAN: Well, I like your idea of--and that's our
19 plan to have a specific human intrusion scenario that could
20 be compared across the concepts. It's a very good idea.

21 EWING: Well, it should be different for each rock type.

22 SEVOUGIAN: Well, but it may be that it's just one
23 intrusion, penetrates one package, whatever is the
24 commonality, then use that and look at the different
25 concepts. It's a good idea.

1 EWING: Not the way--I don't want to send you in that
2 direction--

3 SEVOUGIAN: You're saying I'm not saying what you're
4 saying?

5 EWING: I guess with these generic performance
6 assessments, they may be generic, but still they have to be
7 relevant to the different geology types.

8 SEVOUGIAN: Right.

9 EWING: And so just picking one drilling rate and
10 applying it to all of the generic PAs wouldn't be very
11 insightful.

12 SEVOUGIAN: Well, until we have a specific site, we can
13 look at generic drilling rates. It must be pretty low in a
14 granite rock, but--

15 EWING: Exactly.

16 SEVOUGIAN: --probably pretty low in clay.

17 EWING: Maybe.

18 SEVOUGIAN: Yeah.

19 EWING: And then I'm just curious. You had your five
20 nuclides. Why not plutonium?

21 SEVOUGIAN: There was no reason not to do it. We just--
22 neptunium happened to be one of the major radionuclides in
23 some of the performance assessments at Yucca Mountain and
24 internationally for a long-term million-year--

25 EWING: Internationally it's not because of the reducing

1 conditions, so you seldom see actinides on the short list of
2 high-impact radionuclides.

3 SEVOUGIAN: Okay.

4 EWING: And plutonium, the reason I raise that with the
5 four oxidation states and a complicated chemistry, that would
6 be a real test of how that would be handled in a generic
7 performance assessment.

8 SEVOUGIAN: Again, this is our initial demonstration.
9 We just wanted to include one decay chain at precipitation/
10 dissolution reactive chemistry. Obviously plutonium is
11 critical to any performance assessment.

12 EWING: Right. Okay. I'm sorry to take so much time.

13 Other questions? If you don't have other
14 questions, I can keep going down my list.

15 I think we're near the end. So, Staff, any
16 questions?

17 All right. So thank you very much.

18 EWING: The last presentation for the day is by Frank
19 Hansen, describing the U.S. and German collaboration.

20 HANSEN: Well, thank you for your patience. I actually
21 volunteered to go last, because someone volunteered me. But
22 I know that it's difficult for you, because there are so many
23 questions. So I want to move fairly swiftly through my
24 formal presentation so that we can amplify the question
25 period. I, myself, was sitting back there champing at the

1 bit to ask some questions and answer some.

2 But I have to stay reasonably on the ranch, and to
3 do that I want to first start by thanking the Department of
4 Energy, because both EM and NE sponsor the U.S./German
5 international collaboration. And as you will witness as we
6 move through this, they get very high return on investment,
7 and we'll see that.

8 So I see someone deleted my co-authors on the first
9 slide, and I apologize for that, but I need to acknowledge my
10 co-authors, because I borrowed some of these slides from the
11 German colleagues. Enrique Biurrun is from DBE Tech, and DBE
12 Tech is a sole-source engineering firm that does all of the
13 repositories in Germany: Morsleben, Asse, the Konrad
14 facility, which is in iron ore--the first two are in salt--
15 and so on. DBE Tech is a very good company. And the other
16 co-author is the ministry--he works for the ministry that
17 sponsors the research within Germany, and his name is Walter
18 Steininger.

19 So I want to acknowledge those people, because they
20 are fundamentally important to our collaboration.

21 And I also borrowed these slides from DBE Tech.
22 DBE has demonstrated--they have actually demonstrated many of
23 the facets of salt disposal, so it's not like we're beginning
24 over. Direct disposal, the reference repository concept,
25 these cartoons over here show they have placed cans

1 horizontally, they have placed cans vertically, they have
2 shown feasibility studies, they have put heavy packages down
3 a shaft a thousand times successfully. Some of their big
4 tools, placement tools, are shown here. They have developed
5 the methodologies of modeling. They did a safety analysis
6 for Gorleben.

7 And this down here is just put in there because of
8 recent U.S./German collaborations. And I say recent, I don't
9 really mean recent. Recently it has been very fruitful. But
10 I've been working personally with the Germans since in the
11 former times; I worked with West Germany back in the '70s.
12 So the collaboration has been long-term, but it hasn't always
13 been consistent. Sometimes the road narrows; sometimes they
14 have a moratorium--they had a ten-year moratorium--and there
15 are other factors. But we've been working actively, Wendell
16 and others, with the Germans for 35 or 40 years.

17 And, of course, we have a lot of expertise here in
18 the United States thanks--in salt--largely to WIPP, it's
19 successful operation since 1999, current conditions
20 notwithstanding. Germany has a lot of salt facilities--you
21 may know, of course, of Asse--both famous and infamous.
22 Morsleben from the former East Germany is full of nuclear
23 material and other places. They have toxic waste in
24 Herfa-Neurode, which is salt that's chemotoxic waste and so
25 on. So they have a lot of experience in salt. And salt

1 mining is worldwide well-proven. We know quite a bit about
2 salt. It's the most important mineral for humankind.

3 And there is a lot of data here. We have the
4 Library of Congress full of work that has been done, volumes
5 and volumes, more than you could ever digest. And so this is
6 only a sampling platter here. We'll get through these rather
7 high-level platitudes on collaboration. And then, as I
8 understand, you want to dive deep on some things, so I've got
9 the sampling platter of some things that we can dive deep on,
10 too.

11 So this is a German slide here, because you'll
12 notice the choice of words. They had a moratorium, and they
13 were taken out of the repository business, and Gorleben was
14 in hibernation, in their words, for about ten years. So when
15 they came out of the moratorium, they came to us to, to
16 Andrew Orrell and me, and said, "Let's restart our U.S./
17 German collaboration," which we did in 2010. And it's been
18 wonderful. It's really fantastic. And it benefits in a lot
19 of ways, because they wrote the preliminary safety case for
20 Gorleben. So they have done a high-level waste performance
21 assessment. And, of course, we did WIPP, and we have
22 considerable experience in the civilian program as well.

23 And so we decided at the beginning, we can't do
24 everything all at once. And this particular collaboration
25 focuses on salt repository research, design, and operation.

1 So it's not everything. We do more of some things than
2 others, and a list of some of the things we do is here.

3 The safety case, of course, is number one to a lot
4 of people. Salt repository design and concepts, we talk a
5 lot about performance assessment. Well, performance
6 assessment requires a few components before you get started,
7 like inventory of waste, concept of disposal, and geologic
8 media. So we talk a lot about the concepts and the design.
9 Of course, there's groundwater modeling, radionuclide
10 transport.

11 Geotechnical barriers, I'll spend a little time on
12 this. It's near and dear to me. And I also brought some--so
13 we don't die of PowerPoint death, I brought some actual
14 hands-on sample that I'm passing around for several of the
15 things that I'll be talking about here. And you'll notice on
16 a lot of these slides I have a reference, and this is our Web
17 page. You can go on that Web page. You can find bios of all
18 the participants--not all the participants. My colleague,
19 Christy Lee (phonetic), said when she re-launches this site,
20 it will have bios of all the participants. But we publish
21 this. This is widely available, and you can simply go on
22 line and click on their proceedings, and you can see all of
23 the great science that we're talking about.

24 And this is also taken from my German colleagues.
25 We gave a paper, this one right down here, Steininger,

1 Hansen, Biurrun, and Bollingerfehr, because politically they
2 want to show that the collaborations are bringing home some
3 return on investments as well. So we gave this paper and
4 said, "Look, here are some of the great things that we're
5 doing, benchmarking constitutive models. This is just
6 fantastic."

7 And Lupe covered that very well. Good job, Lupe.

8 But just think about that. We're running up our
9 thermo-mechanical models with six German entities. And I can
10 tell you from personal experience that they are the best salt
11 mechanicians in the world, except for Lupe and the people at
12 (inaudible).

13 Also, we published fairly widely, American Rock
14 Mechanics Association, the Mechanical Behavior of Salt
15 Symposia, and so our Waste Management, less technical. We
16 also collaborate with the European Union on such things as
17 the MoDeRn project, which is: How do you monitor geologic
18 repositories?

19 Of course, we have done a lot of work on the safety
20 case. And we could talk about this a little bit more, but I
21 want to concentrate on salt, because I believe that we're
22 here to talk about salt, right?

23 And just to get through some of these high
24 platitudes, one of the things that we did recently--and it
25 largely was garnered because of our collaboration with the

1 Germans--the ministries wanted to sign an MOU, a memoranda of
2 understanding, with the American entities. And because it
3 was federal, the EM and NE signed a MOU with the German
4 ministry. And I think that's a very nice flagship to operate
5 under.

6 Most recently, because you know a beautiful child
7 has many fathers, the NEA was very receptive now to
8 sponsoring the Salt Club. Now, the Salt Club is not new. I
9 remember writing a prospectus for the Salt Club with Leif
10 Eriksson about 20 years ago, but we didn't get traction for a
11 lot of reasons. There was a slippage in Germany; the
12 Netherlands was reticent; Poland wasn't--but now that we have
13 this great collaboration going with the Germans, the NEA
14 said, yeah, the Salt Club sounds like a good idea today. And
15 it is a good idea.

16 Under the auspices of the Salt Club, the natural
17 analogues workshop--and I'm going to come back to natural
18 analogues, because I think we talked a little bit about
19 stakeholder outreach and how do you communicate with the lay
20 people--well, that's one. And it's powerful, and I think
21 it's important that we get there again.

22 Geoff Freeze and several others have developed this
23 Features, Events, and Process catalogue; really, really good
24 work. In fact, Tuesday morning we had a Videocon with the
25 Salt Club, with our partners, and they are very mature on

1 this Features, Events, and Process catalogue for the salt
2 repository.

3 And yours truly is writing with four German
4 colleagues--I'll get back to that reference in a minute--on
5 salt reconsolidation. This is a very important and
6 interesting piece of work. And then, of course, Kris Kuhlman
7 has done an outstanding job on this salt knowledge archive,
8 and his presentation today was just fantastic. And I have to
9 tell you, I knew almost every person that he mentioned in
10 that talk, so that shows you how long I've been working in
11 this business.

12 Now I wanted to--this is what really, I think, is
13 extremely interesting. This is the classic creep curve for
14 materials. And so I wanted to just show whatever we have
15 done. Lupe talked a lot about the constitutive model for
16 salt, and he talked about the mechanistic basis of that
17 model. And it's very, very important. And it comes from
18 first principles, which I will show you here. And, of
19 course, this is just a strain-time curve. It doesn't really
20 matter greatly. But the interesting thing about salt--and
21 you've seen some of this tertiary stuff. I'm not talking
22 about tertiary today. We could. If you want to ask
23 questions about it, we certainly can.

24 But today this is a paper I have for the American
25 Rock Mechanics Association meeting coming up, and it

1 documents the isochoric deformation of the salt. That means,
2 do you know how rooms close? The rock fall has almost
3 nothing to do with the room closure. The ribs come in, the
4 roof does come in, the floor heaves, but the reason it does
5 that, of course, is because of the plastic deformation out
6 here in the country rock. And that's what Lupe expressed.
7 That's why rock bolts don't hold the roof up indefinitely,
8 because what's bringing the roof in, what's bringing the
9 entire room closed, is the isochoric deformation of the salt
10 out there, which also is the very reason we use salt for a
11 repository, because it's impermeable. And it's isochoric; it
12 never increases that permeability out in the country rock.
13 But we will talk about where it does in the disturbed rock
14 zone.

15 So getting back to this, I'm going to give this
16 talk on this evolution of the substructure. How does this
17 happen? What's important? And the plastic deformation
18 occurs because of these mechanisms. And the fundamental
19 mechanism by which salt deforms plastically is the crystal
20 imperfection, is the dislocation. And we all probably know
21 that. But it's also augmented by glide, because it has--in
22 the perfect cubic system it has glide planes--and I'll show
23 you some very interesting things--and cross slip, climb,
24 which is a recovery process, and recrystallization and
25 annealing.

1 And these are the mechanisms that--I'm waiting for
2 somebody to say wow, because this is a wow photograph. This
3 documentation here of these slides shows you the
4 microstructure of the salt as it deforms as a function of
5 stress, stress difference, and temperature; and this is the
6 documentation of the substructure that you see. And what we
7 have here, these are--you see how they're cubic? These are
8 emergent sites of those crystal imperfections, those
9 dislocations. Those are emergent sites. And that's just
10 free dislocation. But free dislocations move easily by slip
11 along these 110 planes.

12 But before I get to that mechanism, I want to show
13 you this photomicrograph, because this is a grain of salt
14 that we plucked out of a deformed sample, and you can see how
15 it created its own draped fold. And those are those 110s we
16 were talking about. And this shows you the amount of
17 ductility that can be brought on by just slip, just glide.

18 But slip/glide by itself--and these are
19 interchangeable words--cannot affect the steady-state creep.
20 You have to be able to recover. You have to be able to--
21 among the recovery processes--you know, a cube has six 110
22 planes, so it actually is almost perfectly plastic just as it
23 starts. And I mentioned to someone earlier that most of the
24 deformation of salt, even in uniaxial compression, is
25 plastic. Damage doesn't contribute very much to the strain.

1 But the way you recover creep is by cross slip, and cross
2 slip is a thermally-activated process; so if you're gliding
3 on this 110 and another partner gets stuck, it just can step
4 over the--it has to have a little thermal activation, but--
5 and what we see here is an etched cleavage chip that show the
6 orthogonal intersections of two 110 planes.

7 And the reference for this work is here.

8 Okay, well, cross slip by itself could almost
9 affect steady-state creep. In fact, we've seen it in the
10 laboratory. If you go back to the classic curve, it goes
11 way, way, way out there and strain ten percent or more. But
12 ultimately it starts to recover, and here is a cross slip
13 with a climb component where climb is just the movement of
14 the dislocation into the subgrain array, which reduces the
15 strain energy.

16 And here is a substructure involved with a
17 polygonized sample. Now, this is a highly deformed sample.
18 These are the subgrains. Those are related to paleostress in
19 geology. And those are the free dislocations (inaudible)
20 dislocation density is not so high.

21 And, lastly, of course, if things go far enough,
22 you get grain boundary migration and recrystallization.

23 Now the Germans. I offered up that, because we're
24 trying to benchmark the constitutive modeling capabilities--
25 the hardware, the software, and the models--I offered up that

1 we had candidate models here in the United States at Room B
2 and D that Lupe went into detail on. We--Lupe and I--offered
3 that up to them and they said, you know, that's a great idea.
4 In Peine, Germany, I took the disk of all the tests that we
5 had run on WIPP, and I gave it to them, and they went through
6 the analysis and said, you know, that's really good, but we
7 have these other features. And we talked a little bit about
8 that earlier. These other features that they like, they have
9 damage, they have the damaged surface, the boundary of that,
10 and they were looking at that in more detail, and you're
11 already aware of that.

12 But what I show you here is, these laboratories,
13 the Technical University at Clausthal and the Institute for
14 Geomechanics in Leipzig, are testing 140 or more samples for
15 the U.S. for free. We're not paying for this whatsoever, and
16 we're getting some of the best geomechanics in rock salt
17 that's available in the world. And this is just the matrix
18 of the tests, and these test matrix are described by
19 confining pressure, strain rate, temperatures--you can see
20 the range--and then there are creep tests, too, under these
21 similar conditions. And these are all designed by the
22 Germans to probe certain features of the physics of the
23 deformation of the rock.

24 Now, we sent them 4,000 pounds of core, and this is
25 a picture of that core, thanks to our colleagues in Carlsbad.

1 This is 12 inches in diameter. When it arrived in Germany,
2 they said, "We've never seen core in that good of condition
3 before." So that's a tribute to our colleagues in Carlsbad.
4 In addition to that, of course, we sent about 35 gallons of
5 run-of-mine to the BGR, which is another entity. That's the
6 USGS in Germany, Geosciences Research Center.

7 So what else is fun? This shows some preliminary
8 data, and it's preliminary because we have not gotten
9 together and waded into this material. I wanted to show you
10 some examples of what kind of material properties are coming
11 out. And those of us that have deformed salt over time, salt
12 is a very well-behaved material. And this just shows you
13 some of the data. This is just one dataset. And this is
14 attributed to Salzer and these folks. And we'll meet with
15 them again in May, and we'll dive deep into this. I'm not
16 prepared to dive deep into the analysis, because we haven't
17 done it yet.

18 And this shows you a triaxial strength test. And
19 basically there is this boundary between isochoric
20 deformation and damage. And one of the things that the
21 Germans really like to do is explore that damage surface
22 coming from each direction. Now, this is an example of some
23 of the science that we didn't get done before we kind of
24 stopped, so this gives you some idea of the advancement of
25 the bases that we get from the German collaboration with

1 salt.

2 A long time ago, 25 years or more, the reason I use
3 this old plot is just so I remember to say this is old. The
4 original work here was 1993 or so. It's summarized in this
5 particular report here, which is now more than 10 years old.
6 But the deformation of salt--we had all these tests that we
7 had been running since the '70s, and one day Joe Ratigan
8 plotted them up and he said, "Hey, look at this." He said,
9 "If you plot up all these tests"--and we of course have
10 hundreds; this is just the discovery period--he said, "you
11 can draw a line between the damaging salt and the isochoric
12 deformation, and the line is separated. You can do it on the
13 stress and variance space. And if you do it on the stress
14 and variance space, then you can use all manner of stress
15 paths and all manner of load angles for this type of an
16 analysis." And, of course, we characterize this boundary in
17 stress and variance (inaudible) and the square root of the
18 second invariant and the stress deviator tensor.

19 So that's how we describe the DRZ, disturbed rock
20 zone. We describe it by the boundary that separates that
21 I_1I_2 space that I just showed you. So that's how you do it.

22 Interestingly, you can go to the underground and
23 you can measure it. You can look down the borehole; you can
24 take out core; you can probe it with velocity, sonic
25 velocity; and all of those measures have been put together.

1 And I think I summarized it in that previous reference, the
2 Hansen DRZ paper.

3 Why is this important? This is important, because
4 if you have an underground research lab--let's say we were
5 thinking about one at WIPP--what's important is that all of
6 these features start when you make the excavation. Before
7 that, salt is sitting down there very happy with all the
8 stresses equal. When you make the excavation, a room just
9 like this, the country rock out here is still at 2,150-psi at
10 WIPP, or 15 MPa, as you prefer. And before you disturb it,
11 it's impermeable, and it's been impermeable for a quarter of
12 a billion years.

13 So when we establish an underground research lab,
14 one of the fundamental things that we should do is we should
15 measure the evolution from the undisturbed to the disturbed
16 case. And we can do that if we're smart, but we've got to be
17 smart. You've got to think about it before the fact, which
18 is what I put on this slide. If you have a room that you
19 intend to excavate for experimental purposes, it can be any
20 experimental purpose, and it can be at any site. It doesn't
21 have to be at WIPP. And we are smart enough, I believe, to
22 place flow gauges and deformation gauges in the proximity
23 where you would expect the change. And we can estimate that;
24 we can calculate that. Then when you excavate the room, you
25 can validate that, should be able to.

1 So that's one concept I just wanted you to take
2 away. Some of my colleagues--in fact, it was Cliff Howard
3 and Kris Kuhlman, surprisingly--there he is again--we wrote
4 this up on how you would do that. But it's an opportunity
5 that you should take advantage of, that we should take
6 advantage of, if we move forward with any sort of underground
7 experimental lab.

8 Moving on, I mentioned the reconsolidation of salt.
9 This is really important stuff, because if you open up a
10 repository in salt, you have to show that you can button it
11 up, too. And it's that buttoning-up thing that has to do
12 with the reconsolidation of salt. I led the team that did
13 the shaft seal design, and that shaft seal design had several
14 components, but chief among them, of course, was our friend
15 bentonite. But we also developed that salt-saturated
16 concrete that's attached to the WIPP salt that is sitting in
17 front of you there, Paul. That's a salt-based specialty
18 (inaudible) mass concrete that was developed before we
19 submitted the certification application.

20 And the third component--there's salt-based
21 concrete, there's bentonite, but the third component is the
22 reconsolidation of the native material. It's perfect. It's
23 perfect, because it's already compatible mechanically,
24 physically, chemically. But I want to note, here is another
25 contribution from the U.S./German collaboration, and this is

1 a state-of-the-art paper on the reconsolidation of salt.

2 Now, why would you write this? Well, because at
3 our third conference with our German colleagues we had a
4 survey with the audience, and we asked about their level of
5 confidence in this. And, believe it or not, much to my
6 chagrin, they were not confident in these results. And I
7 thought, wow, how could that be?

8 And so I decided with our colleagues, Till Popp
9 from IFG, Klaus Wieczorek from GRS, and Dieter Stuhrenberg
10 from the BGR--those are research entities in Germany--we are
11 collaborating on writing the paper of the reconsolidation of
12 salt. It's very important, because we know where we've been,
13 and we know where we are, and we want to identify where we
14 need to go. All permeability--all porosity and permeability
15 are not created equal, by the way. The damage imparted in an
16 experiment or by Mother Nature in terms of the damaged rock
17 zone is not the same as the reconsolidation and the reduction
18 of the porosity and the permeability of the reconsolidating
19 salt. And that's just what this fandancy diagram over here
20 shows.

21 In the laboratory, when you experimentally deform a
22 sample that does actually have fracture in it, the
23 permeability jumps up radically with the volumetric strain if
24 you have damage. And that's because the fracture process is
25 oriented preferentially to the maximum principal stress, of

1 course, if it damages. And that porosity, as you might
2 witness here, is mighty darn small. And this is the--that's
3 aperture permeability from the damage imparted to an intact
4 specimen. And on this same graph is basically the porosity/
5 permeability function for reconsolidating salt. So that's
6 the point of that.

7 Now, the strength of analogues can't be
8 overemphasized. And this is important work by the Salt Club
9 and by us and our German colleagues. Analogues are very
10 important because we can show them permeability, we can show
11 them graphs, we can show them stuff, people that don't speak
12 salt, and they can't understand it. But if you can show them
13 for example, a Celtic miner that was encapsulated in a salt
14 mine 3,000 years ago and he still has his whiskers intact and
15 everything, they say, "Oh, I can see how salt encapsulates
16 the material placed within it."

17 These are anecdotal examples of the complete
18 encapsulation of a material put within a salt mine. And here
19 is just some work going on in the old salt (inaudible) at
20 Durrnberg. Here is a shot of a room that's closed in. You
21 can see the plastic deformation there from the Asse mine.
22 Here is some complete healing of the grain boundaries of
23 reconsolidated salt. And, of course, this is another shot of
24 the reconsolidation of granular salt.

25 What we have here is dynamically compacted run-of-

1 mine salt. This is after we--we ran this big test. It had
2 40 cubic meters of run-of-mine salt. And we tamped it in
3 this great big container, and then we drilled it and measured
4 the permeability of that. And then we took that core, and we
5 took it into the laboratory. Perfect. And we squeezed it
6 up, and this is the before, and that's the after, 10 percent
7 porosity, 3 percent porosity, 10^{-14} permeability meters
8 squared, no permeability.

9 So here are some of the questions--and, actually,
10 this work was done by Hansen and Knowles. Knowles is a
11 famous Sandia scientist and my wife. So this just
12 articulates a few of the questions remaining, and they are
13 only to remove the uncertainty and to answer some of those
14 salient features.

15 In closing, I would like to call your attention to
16 the references that are shown here. This Web site will be
17 very entertaining, and you can find a lot of things there.
18 The Germans, at the end of the VSG--that's their preliminary
19 safety case, Gorleben--said these are their primary questions
20 at the end of their report. And so I list them here, safety
21 case, number one; plugging and sealing, and that would be
22 concrete and reconsolidated salt, for example; salt mechanics
23 modeling; repository design--and this is a slide I used a
24 couple of years ago maybe, because it could be any URL.
25 Hopefully WIPP will have one that we can use for generic salt

1 research, but it could be any salt repository--and the other
2 issues in geochemistry, microbes, and hydrogeology. A little
3 bit outside of my field.

4 So then what do we do in our program here that the
5 used fuel has been sponsoring?

6 Oops, this is not the same--let me use this to
7 close out because this is the one I thought I had there. So
8 this is the list from the German R&D perspective and the VSG.
9 And they are interested in their particular Gorleben site
10 because it was glacially covered, so uplifted subrosion and
11 glacial channels. Well, we aren't particularly worried about
12 that. But if we look at the work we are doing, compaction of
13 salt, check; mass transport and two-phase flow, check;
14 retrievability--retrievability to them encompasses
15 geotechnical barriers and excavation damage zone--we're doing
16 that; numerical modeling, geotechnical barrier integrity,
17 we're doing that; conceptual improvements to the safety
18 demonstration, we're doing that.

19 Thank you.

20 EWING: Thank you.

21 Questions from the Board? Efi?

22 FOUFOULA: So you mentioned you collaborated with the
23 Framework 7 in your project. Do you know, in the new
24 follow-up of Framework 7, the Horizon 2020, is much nuclear
25 there--is it any funding and how much funding for nuclear-

1 related (inaudible)?

2 HANSEN: Good question. She's talking about the next
3 generation of our European collaboration. The technical
4 platform, of course--let me explain for the ones that may not
5 know--they have the IGD-TP. It's a disposal decision
6 technical platform. And all the European nations are
7 partners to that. And within that they have, of course, all
8 the rock types, you know, because Sweden is a partner, France
9 is a partner, Germany is a partner, all these partners in
10 Europe, and they have all these rock types. And their
11 vision, as you noted, is that in 2020 we shall have an
12 operating repository in Europe.

13 But underlying that is basically the breadth of the
14 science. And because they are looking at all the different
15 rock types, they are essentially in the same place we are in
16 the United States, because we're now back looking at all rock
17 types. So under that technical platform there are many
18 opportunities for collaboration between our repository
19 sciences and theirs.

20 Within the EU, of course, they sieve that down. I
21 know of only one that I'm personally working on, and that is,
22 you know, the acronym MoDeRn; it's a long, butchered acronym
23 that means repository monitoring. They have now a proposal
24 in the EU for the next generation of that MoDeRn program.
25 It's called post-MoDeRn.

1 EWING: Other questions? Okay, Mary Lou.

2 ZOBACK: Mary Lou Zoback. Thanks, Frank. That was a
3 nice summary. But I'm kind of braindead now. Can you remind
4 us of the status--there's Gorleben and Asse. They're two
5 separate places?

6 HANSEN: Yup.

7 ZOBACK: Are they both shut down? And which has waste,
8 which one needs to be cleaned up, and just the status? And
9 are they both domes? Is one bedded? I'm just--I've lost it.

10 HANSEN: Yeah, I don't blame you. I'll give you the
11 broad brush.

12 ZOBACK: That would be good to start with always.

13 HANSEN: The broad brush is that a few years ago Germany
14 had East Germany and West Germany. And West Germany in 1979,
15 they did this site evaluation, and they picked Gorleben.
16 Gorleben happens to be in the north right by the Elba River,
17 right there, so the repository itself probably would sneak
18 over into East Germany.

19 Gorleben is an underground facility that has now
20 been mothballed, and it probably will never again be used.
21 I've been there a few times back when they were doing R&D in
22 the underground, and Andrew and I were there recently. They
23 have a lot of facilities on the superstructure. They have a
24 place where they can reconsolidate waste, believe it or not.
25 Fantastic German engineering. They have a storage facility

1 that, I think, has one waste package in there. When they
2 moved waste to Gorleben a few years ago, it took every
3 policeman in West Germany to move it down the railroad
4 tracks. They lay it on the tracks, they cut the tracks in
5 half, and so on. Thirty thousand policemen were deployed.

6 So Gorleben is the identified repository in salt
7 for the former West Germany. When they reunified--and, of
8 course, these things all took a different texture.

9 So the Asse is a former potash and salt mine that
10 started operating in 1900, give or take, 1900. And it was
11 converted in the '60s to a research facility. And the Asse
12 mine actually has several rooms at the 800-meter depth that
13 are full of nuclear waste, and this is quite a contentious
14 issue for the German government. But they do have the waste
15 in the underground in those rooms.

16 And just to follow up on that, they had a survey of
17 what are we going to do with that, and the BFS, which is
18 their safety group, they said, Well, the only real assurance
19 that we can have, and they came down with a dictum that says,
20 We have to take it out. Now, you just pause and think about
21 that. They have to take it out, and then what? But they
22 haven't really solved that. But we visited Asse here
23 recently with the U.S./German collaboration, and that's the
24 party line. Asse is in the former West German area.

25 Now, when they reunified they got by definition

1 Morsleben. Morsleben was, of course, run by--

2 ZOBACK: This is the third one?

3 HANSEN: Morsleben is the third one. Morsleben is full
4 of waste put in there and covered over with potash and some
5 other things. It was largely waste that was under control of
6 the Russians. And it is under active closure. And it's just
7 across the border in former East Germany. And now they have
8 passed a law similar to the Blue Ribbon Commission law, or
9 whatever created the Blue Ribbon Commission, that says they
10 will now reassess everything. So now everything is back in
11 play, including other rock types besides salt.

12 But they also have other repositories. One is the
13 Konrad mine. Konrad is a former iron ore mine. The
14 repository proper is located in clay or--it's a very, very
15 dry--they're converting it. And that's for intermediate and
16 low-level waste. They also have chemotoxic and other
17 repositories for such materials in salt mines like Herfa-
18 Neurode, which has been in operation for 50 years or so.

19 So those are the ones that come to mind. I did ask
20 my German colleagues, I said, "Well, now that you've
21 reunified, does that change your selection of Gorleben?" And
22 you get decidedly different answers, depending on which side
23 of the country you asked.

24 EWING: Okay, thank you.

25 Other questions? Yes, Jerry.

1 FRANKEL: As a metallurgist, I always thought that
2 plasticity in ionic crystals was different because of the
3 electrostatic repulsion between anions and cations. So is it
4 the particular structure of the 110 plane that allows
5 dislocations to--

6 HANSEN: Yeah, because you're doing like for like. So
7 if you take the cubic structure and you draw the diagonals,
8 there are six of them, and those 110 planes--it's the easy
9 glide plane. What's beautiful about that is, no matter what
10 orientation the grains--many, many of these grains--no matter
11 what orientation, there is always some 110s ready to rock and
12 roll.

13 FRANKEL: Thank you.

14 EWING: Questions from the Staff? Yes, Dan.

15 METLAY: Dan Metlay. I was just curious about a comment
16 you made that Europe is in the same place we are. Could you
17 kind of expand on that?

18 HANSEN: Yes. And those are my words, because I believe
19 they're true. Europe has a European commission, European
20 Union Group. You think of them like the states or whatever.
21 But their policy is that each nation has to handle their own
22 waste, so they have many different geologic settings in which
23 to have a repository. So if you look at the United States,
24 we're looking at all different media now. And so in that
25 respect, they are identifying different media for a

1 repository; we're identify different media for a repository.
2 They have a technology platform that's exploring the various
3 underpinnings of science that go along with that; we're doing
4 the same thing over here. So in that regard they're similar.

5 Plus, we have pushed the restart button, and some
6 of them also have pushed the restart button, like Germany,
7 for example. Some of them like France, of course, have moved
8 along. They've made the commitment. Sweden and Finland have
9 made the commitment; they're moving along.

10 But, yeah, that's--okay, it wasn't a perfect
11 analogy.

12 EWING: Right. Sue.

13 BRANTLEY: Sue Brantley, Board. We were just talking
14 about Asse, and our understanding is that brine is coming
15 into Asse, and that's why they want to go back in and get the
16 waste out. Was that predicted? Is that understood? Because
17 why is brine getting in there if it wasn't expected?

18 HANSEN: I should have done away with all these
19 viewgraphs and just put a placard up here and drawn on it.
20 But the Asse mine is a--

21 EWING: Stay by the mic, please.

22 HANSEN: The Asse is a diapir, and they mine the flanks
23 of a diapir for product, salt, and I think it's mostly potash
24 in that particular mine. And these flanks then are like
25 skirts, and so the ore zones come down the side of the salt

1 diapir. Salt diapirs are the center. And it has a long
2 access, too, by the way. Most of those diapirs in northern
3 Germany are not like we have in the Gulf Coast.

4 So they mine these flanks. And when you mine for
5 product, you want to maximize the extraction ratio, because
6 that's where your profit. And, of course, it wasn't
7 converted into a research facility until it had been
8 operating for about 70 years. So they have a lot of void
9 space, all right?

10 And I wrote a paper on this several years ago about
11 why Asse is not the same as WIPP, because they tried to
12 retrofit an extensive mine, and that's probably not good
13 practice for a repository where you should start with a
14 design function, then the operation, and so on. Plus, the
15 extraction ratio of WIPP is miniscule compared to a real
16 mine.

17 So what happened was eventually, because they
18 extracted a great deal of material, then, of course, this
19 disturbed rock zone raised its head, and it connected to the
20 water-bearing areas that are on the flanks of every salt dome
21 in the world. And the in-flow has been 12 cubic meters--I
22 forget--it's been constant for a very long time.

23 METLAY: A day.

24 HANSEN: A day.

25 METLAY: Twelve cubic meters a day.

1 HANSEN: Yeah. And there are--I don't know the exact
2 number of the volume that's available. But it's an issue.
3 It's certainly an optical issue. It looks bad. We were
4 there--you can't really see it, you know, you can't really
5 see it coming in. But they've been refilling Asse for 15 or
6 20 years, refilling it with crushed salt.

7 BRANTLEY: But this brine was totally unpredicted then,
8 because they wouldn't have put the waste down there, would
9 they, if they had thought that the brine was soon to come?

10 HANSEN: That's a better question. If you had that
11 foresight, you would not have done that, yeah.

12 EWING: Well, I toured it in the early '80s and was
13 assured that this was a good site because of the absence of
14 fluids.

15 HANSEN: Well, the fluids didn't come from internal;
16 they come from external. And, of course, there is
17 fundamental discussion of--someone said, well, if the salt
18 dome is drier than bedded salt, why is it not better? It's a
19 good question. And the answer is, well, that's not the only
20 source of brine. And if you look at salt domes around the
21 world, they are surrounded by flanks that are full of water
22 and oil.

23 EWING: Right. And so whether that exploration takes
24 place before you put in waste in or after, one has to
25 anticipate some interest in economic deposits and the

1 consequences.

2 So any more questions? Because I want to be sure
3 to leave time for the public comments, but we have time for
4 one or more.

5 Okay, thank you very much.

6 So let's close the session with comments from the
7 public. And Robin Falko. Yes, please. You can come up to
8 the front if you want. And five minutes, please, for
9 everyone.

10 FALKO: Good afternoon. My questions are--they're
11 comments and questions, and they're more relevant to what is
12 going on right now. I was not aware that that would not be
13 addressed. So, of course, I have concerns, as do so many
14 people all around this country, about what the current state
15 of affairs is at the WIPP site and what is being projected
16 for the resolution of the problems there. If that has to be
17 sealed off, what are the other options? And my other concern
18 is the recent event that took place near White Sands by
19 Carrizozo that has information that has come out, but nothing
20 has been done as a follow-up for the public.

21 Are you answering questions, or am I just making a
22 statement?

23 EWING: A statement, please. I'll explain why when you
24 finish.

25 FALKO: Okay.

1 EWING: Or I should say, we're not in a position as a
2 Board to answer questions about these most recent incidents.
3 We tried to have a DOE representative here to answer such
4 questions but weren't successful. But your statements and
5 your concerns, you know, please express them. We welcome
6 them.

7 FALKO: Well, those are my concerns about the lack of
8 information, the degradation of so many nuclear sites around
9 this country. We're looking at problems with Hanford; we're
10 looking at problems with other sites in California; we have
11 New Mexico now; we have Port St. Lucie in Florida; there was
12 a recent event, I believe, in Kentucky a few months ago; a
13 few weeks ago Evanston, Indiana. I mean, there are a lot of
14 areas of concern. So my statement is about what will be done
15 to address this.

16 I know these are very expensive projects when it
17 comes to cleaning them up, shutting them down. But we can
18 see, as you've been mentioning about Germany, that the
19 Germans have stopped using nuclear energy. They're phasing
20 this out. There are other countries that are considering
21 this as well.

22 So my concern is, when does the United States come
23 up to speed with being more representative of the needs and
24 concerns of the people of this country? And people want to
25 have safe environments and not have to worry about the next

1 area that's leaking and spreading contamination.

2 So I'm disappointed that there are no answers, but
3 thank you for the time.

4 EWING: All right, thank you. So you're down twice, so
5 we have more time.

6 Judy Treichel.

7 TREICHEL: My name is Judy Treichel. I'm the executive
8 director of the Nevada Nuclear Waste Task Force. And I know
9 that we have had discussions, many of us in this room, for
10 years and years. And it always comes up, well, you don't
11 like Yucca Mountain; what would you do? And obviously I'm
12 not the one to answer that question.

13 But people say we've got to have nuclear waste
14 disposal. And my thought is: We don't really need a
15 disposal site as much as we need not to make an irreversible
16 mistake. And once you've committed to something that's
17 irreversible, you've got a far greater challenge than you
18 have when you're just doing studies and looking around.

19 And I'd like to know, after listening to the
20 presentations today where we've heard so much good things
21 about salt as a repository for any level of waste, what was
22 the research or what were the tests that should have been
23 done at WIPP to predict what happened five weeks ago last
24 week, whatever? Not the truck tire; I expected the trucks
25 would have a problem. But what could have been done in the

1 research field that would have shown this incident?

2 And there were hundreds of reports, tests,
3 documents produced; and I don't know that any of them came up
4 with this possibility. And I think part of the problem are
5 when the researchers do decide on what the FEPs are and do
6 probabilistic risk assessment and start to weed out or screen
7 out or decide what is not worth considering, and many of
8 those things that aren't worth considering are probably what
9 lead to the real problems that show up later.

10 I've got a file at home that I've had for many
11 years, and mostly it's just--well, now it's stuff off the
12 internet, but it started out with newspaper clippings, and
13 it's called "Things That Can't Happen." And it's actually
14 pretty thick. And that's why probably you've got YouTube and
15 all kinds of stuff, because a whole lot of things happen that
16 are very strange and weren't ever supposed to happen. But
17 when they do happen and they involve any sort of nuclear
18 waste, it's a lot bigger problem than many of the other
19 things that weren't supposed to be able to happen.

20 So my recommendation would be that, yes, you have
21 to have a consensual site. I don't know that there was ever
22 a test or an examination done on what would happen with
23 something like Yucca Mountain if the public just kept saying
24 no and if we had decent lawyers and were able to keep
25 fighting the thing. But it's now, I think, going to die.

1 But when you find a site where you do get some sort
2 of public consent, I think you need to involve them right off
3 the bat with the discovery, the selection of what the FEPS
4 are, with the probabilistic risk assessments, with all of
5 that sort of thing, rather than just pushing them in there or
6 inviting them in after you've done all of that stuff and you
7 have models to show. Because the actual public that walks up
8 and down the street kind of has a good horse sense about
9 things that can go wrong, things that they've had go wrong;
10 and I think they need to buy in all along during that time.

11 So thank you.

12 EWING: Okay, thank you, Judy.

13 Susan Rodriguez?

14 SPEAKER: She's not here.

15 EWING: Not here? Okay. Abby Johnson?

16 JOHNSON: Hi. My name is Abby Johnson. I'm the nuclear
17 waste advisor for Eureka County, Nevada. We're one of the
18 ten affected units of local government under the Nuclear
19 Waste Policy Act. I've been involved professionally or
20 personally or both on the nuclear waste issue since 1983.

21 I've been to a lot of Nuclear Waste Technical
22 Review Board meetings, and at some of those DOE and other
23 Yucca Mountain repository advocates have held up WIPP as the
24 repository role model both for Yucca Mountain and for DOE's
25 ability to perform, so I think it's entirely appropriate to

1 talk about WIPP when it's not performing.

2 We heard a lot today about WIPP, about experiments
3 in salt, but very little about what had gone awry at WIPP
4 recently. It is really unfortunate and telling that no one
5 from DOE accepted the Board's invitation to come and update
6 the Board about what is known and what is still to be learned
7 about releases at WIPP. I think that speaks for itself.

8 When I was driving to the airport yesterday, I was
9 listening to NPR, and I heard part of this quirky story about
10 a scientist at NASA who is now retired--maybe some of you
11 heard this too--who wants to retrieve a satellite that was
12 sent out there to find stuff maybe 30 years ago. I didn't
13 get that number, but we could do the math about how much the
14 boundaries of that would be. And he was talking about all
15 the challenges, and there's a time element--I guess it's
16 going to be close to earth in May or something--you know, the
17 software is outdated; it doesn't exist anymore. The
18 communication equipment apparently was sent to wherever they
19 send all the stuff when they don't need it anymore. And most
20 of his team is retired. He didn't say dead; he just said
21 retired. And, you know, NASA is essentially a single-purpose
22 agency. I mean, what do they do? They put things in space.
23 And that was about 30 years ago.

24 So today we've heard time frames. I think I heard
25 250 million years; I heard a million years; I heard 700,000

1 years, 10,000 years, 200 years, 100 years, 50 years, 30
2 years, the magic 15 years at WIPP, and 5 years. It's like
3 spinning a time machine wheel with all these different times,
4 time frames.

5 And one of the things that--I heard some of the
6 questions and that there was a little, really? You guys
7 don't talk to each other even though you're in the same
8 state? I want to really encourage the Board to keep raising
9 those questions and those kinds of concerns, because this
10 whole time element is a reminder that the technical
11 challenges, research, and progress are integrally and
12 essentially connected to the institutional and cultural
13 issues, including technology advances and obsolescence.

14 So the more I've observed this program, the more
15 I've understood that it's not the science; it's the
16 management, the institutional issues, the systems approach
17 that needs as much attention as the charts and the graphs.
18 And you can tell I'm not much of a scientist to begin with.

19 Finally, we, Eureka County, want to thank the Board
20 and Staff for being a consistent ongoing forum for these
21 important topics, for creating a public record, which is so
22 important for now and for the future, and for your commitment
23 to public participation. It's not often that people who know
24 stuff listen to people who know less stuff and we have a
25 dialogue about it. Those days don't happen too often

1 anymore. Thank you.

2 EWING: Thank you.

3 And I think George Danko. George?

4 DANKO: Thank you, Mr. Chairman. Thank you, Board, for
5 the opportunity to address this meeting. I came from--the
6 name is George Danko. I'm coming from the University of
7 Nevada-Reno, Mackay School of Earth Science and Engineering.
8 So I will be a little bit more concerned coming from Nevada.
9 The state of the Yucca Mountain project still the one which
10 was fully designed and submitted for permission. And it
11 might never happen, but what happened has been the
12 development of many useful models for analyzing the
13 performance of the repository, the design of the repository.
14 And then I saw today the homework of the New Mexican's
15 institutions on numerical modeling. What I was missing some
16 was the massive amount of work and models developed for Yucca
17 Mountain. So I haven't seen FLOC (phonetic), and I haven't
18 seen the model of TOUGH or NOFT (phonetic) or TOUGHREACT or
19 TOUGH-FLAC. Maybe these models may come back from the
20 cooperation with the Germans, because they used these models
21 maybe in their salt repository, I'm guessing. I've seen many
22 of those European institutes using the TOUGH family of
23 models. So it's interesting to see how local is this, and
24 maybe looking to cooperation inside the United States and the
25 other institutions would be beneficial to increase the

1 confidence of the models' work and start from a platform,
2 which, actually, the system models, etc., reached for the
3 Yucca Mountain project.

4 And one minor side comment on this is my area of
5 modeling ventilation coupled with thermal-hydraulic effects.
6 And then this is a unique model, which could be actually used
7 (inaudible) in an area which has been operating as a
8 repository being ventilated. Now, pre-closure ventilation
9 affects the post-closure performance in a way that it
10 provides the initial condition for that. And then that was a
11 lesson we learned from Yucca Mountain. We came up with a
12 fully qualified ventilation thermal-hydraulic model for Yucca
13 Mountain, ready to be used, and then something to consider
14 for this confidence-building and starting working if it is
15 the goal to emplace defense high-level waste or spent nuclear
16 fuel in salt deposits.

17 Thank you very much.

18 EWING: Okay, thank you.

19 I've exhausted my list. John, I think--John
20 Heaton.

21 HEATON: Thank you for being here. My name is John
22 Heaton, and I am chairman of the WIPP Task Force in Carlsbad.
23 And it's a task force put together by the mayor, and I'm a
24 volunteer, as are the other 45 people that come on--we were
25 typically meeting a couple times a week. Needless to say,

1 we're meeting every week nowadays.

2 But I wanted to express to you that the fear in the
3 community has been alleviated tremendously. Of course, when
4 it first occurred, I think that you all would recognize that
5 a certain amount of fear spreads through the community; and
6 that fear was mitigated primarily because of the Carlsbad
7 Environmental Monitoring Center. That was an organization
8 and a facility that was put together by the community prior
9 to WIPP opening. And we had intended that it would do flora,
10 fauna, soil, water, air monitoring prior to the opening of
11 WIPP and then whole-body counting for people in the community
12 to do epidemiologic studies and to know what the background
13 was. We're probably the only DOE facility that knows and
14 knew in advance what the background was in the community.

15 The release that occurred on the 14th, the
16 measurement right off the site, which is a sixth of a mile
17 away from the release right at the fence, was .64 becquerels.
18 If you stood in that position where the air monitor was for
19 15 hours, you would receive that amount of radiation, a dose
20 equivalent--a bitewing x-ray. And I think that between the
21 monitoring center and the people from the contractor, DOE,
22 explaining in layman's terms what these releases really meant
23 in terms of real-life experiences--dental x-rays, pan x-rays
24 of the mouth, chest x-rays, flights across country--and
25 comparing them and then also having confirmation come back

1 from the CDC for those 17 people that had an exposure, and
2 their fecal samples were positive, their urine samples were
3 all negative, but getting confirmation back from the CDC that
4 these were negligible exposures and that they represented no
5 more than a single chest x-ray over the period of 50 years,
6 and I think those kinds of explanations to the public make a
7 huge difference.

8 In fact, I envy you a little bit from a technical
9 perspective, because you can come to conclusions, and you're
10 speaking to knowledgeable people about these very esoteric
11 subjects to the public.

12 And so our job has become: How do we get
13 transparency? How do we get information out to the public in
14 a way that's meaningful? And the mayor and I met with Mr.
15 Klaus and Mr. Heisinge (phonetic). And Mr. Klaus, who is
16 second down from Secretary Moniz, has agreed to cut through
17 the red tape, and we now have a daily report that comes out
18 from WIPP, and you can find it on the WIPP Web page. For
19 those of you that don't know where that is, it's
20 www.WIPP.energy.gov--easy access--and it has all the
21 radiation numbers, all of those numbers that have been
22 collected from both the independent environmental monitoring
23 center, which is run under the auspices of the New Mexico
24 State University. We argued and argued about how do we get
25 independence in our reporting, and we believe that going to a

1 university was our best alternative in getting tenured
2 professors that can responsibly report data without political
3 interference.

4 And so that was the objective, and that's we have,
5 and I think that has brought a lot of confidence to the
6 community. And I can't tell you how difficult the challenge
7 is to manage what's going out in the press and in the
8 blogosphere and what's happening. On Saturday we had calls,
9 "How's the evacuation of Carlsbad going?" from towns that
10 were 160 miles away. And we said, "What are you talking
11 about?" Well, they had read something on some blog
12 somewhere, and they thought that all that was happening.

13 And this morning the release in the Carlsbad paper,
14 "Second release occurred at WIPP." It was not a second
15 release by anybody's interpretation. Probably the plenum
16 that feeds the exhaust system after it goes through the HEPA
17 filters probably had some collection of particles inside the
18 plenum, which were released. But, you know, it was a single
19 release, and then there was no more. So you almost have to
20 assume that that's how it occurred.

21 But until they go down in the mine and actually
22 determine what happened, how it happened, and fix it, then
23 they can go through the cleaning process. But I can tell you
24 that the community of Carlsbad is now--the fear essentially
25 is gone. There's still a few folks--believe me, I mean, that

1 will always occur, but the fear is gone. And the community,
2 from my perspective, from the mayor's perspective, is that
3 we're supportive of getting the WIPP facility opened up
4 again, cleaned up, opened up, and the plans put in place, and
5 they will become more transparent as they find out what the
6 issues really are.

7 But I wanted to make that clear to you. And the
8 ventilation system, I don't know how much you know about
9 that, but if you look at the picture of WIPP that's been up
10 here several times, the underground, the ventilation system
11 goes from the north--the top, if you will--down to the south.
12 It's always flowing at the back of the workers. We don't
13 believe that the north end, which is where all the
14 experimental activity occurs, has any possibility of having
15 contamination there. And there's been a probe put down that
16 demonstrated that there is no radiation picked up at the
17 bottom of the shaft. They put a camera down. They also put
18 an air quality monitor. That was also negative.

19 So the system is set to go down and go find out
20 what happened, isolate it, correct it, whatever they have to
21 do, and then figure out how they're going to deal with the
22 ventilation. But we believe that there is no reason that the
23 experimentation that's attributed to the north end should not
24 go forward, and we appreciate this meeting occurring, because
25 we think that--I still think that salt is unquestionably the

1 best medium. The geology is fantastic. Every time I look at
2 it, I get more impressed with it.

3 So, at any rate, just to clear up a couple of
4 things, you know, we heard earlier Congress said no, no, no.
5 Congress has not said no, no, no. Congress was responding to
6 the Nuclear Waste Policy Act amendments of 1987, which said,
7 If you have any exploration going on for a repository, it
8 can't happen; we can't fund it." So you automatically have
9 to put Section 12 in there, which says no high-level waste
10 can be moved to WIPP.

11 I mean, it's never been tested, never been asked
12 about. The technical analysis has not been in place to go
13 forward with it, and that obviously has to be the first step,
14 the things that you're doing. WIPP's mission of starting
15 clean, ending clean--every time industrial business opens or
16 a repository, a mine, they do a very complete safety
17 analysis. I'm not telling people in this room anything, but
18 they do a complete safety analysis.

19 It was always anticipated that there would be some
20 release at WIPP, even though we dearly prayed that it would
21 never happen, but it was always anticipated, and it was part
22 of the safety analysis, and it was part of how the
23 ventilation system was set up. And the ventilation system
24 worked as expected. There was a small puff because of
25 differential pressures on the damper that closes the air from

1 the atmosphere over to HEPA filtering; but, other than that,
2 it's working as expected. And now that damper is completely
3 sealed, and so everything goes through the HEPA filtration,
4 which is at 99.97 percent. So it's a very robust filtration
5 system.

6 So we never thought that something like this would
7 occur. We hoped it would never occur, but it was always
8 planned. And I think that's the important issue to talk
9 about. We had always thought there would be some disastrous
10 truck accident. I mean, we have gone to the equivalent of
11 going to the moon and back 28 times. That's a lot of driving
12 with a payload. And we are the envy of every trucking system
13 probably in the world, but clearly in the United States. And
14 that's a story all unto itself, but the point being is that
15 we expected that before the other. The probabilities were
16 all that there would be a trucking accident before an
17 accident in the mine itself.

18 And I'm not going to talk about the fire. The
19 report from the fire you can read on the Web. It's an
20 unvarnished report; and, actually, in mind, it's a scathing
21 report of the change in culture about safety that's occurred.
22 And it also, I think, is a scathing report on the lack of
23 performance assessment training and good management. And we
24 hope that it only existed on the mining side, which is where
25 they remove the salt, and we hope that that same report won't

1 be as scathing when we get over to the radiologic side of the
2 mine and the waste emplacement. We hope that there are two
3 different cultures even though it's concerning, very
4 concerning, to all of us.

5 So, at any rate, I just wanted to point that out
6 that the mine has worked, the system has worked as
7 anticipated, and there is no reason that it can't be either
8 new ventilation drifts, a new ventilation shaft, work under
9 HEPA filtration all the time. I mean, there are all sorts of
10 alternatives and clean-up and move on. And as you saw
11 earlier, two more panels are expected to be mined; and if
12 Panel 7 has to be closed completely, there is no reason that
13 you can't mine out another panel. There is no limitation on
14 the volume of panels that we can have at WIPP. There is only
15 a limitation on the actual volume of waste at 176,000 cubic
16 meters. So, as you can see from that, we've got a huge
17 amount of real estate for any kind of repository activity on
18 that site.

19 So, with that, I'm going to--I've gone past my five
20 minutes, Mr. Chairman. I'm sorry.

21 EWING: That's all right.

22 HEATON: But, at any rate, I just wanted people to know
23 that there is information available on a daily basis, going
24 to that Web site. And also there is a--we're going to have a
25 weekly town hall meeting. We've had three of them now, four

1 of them, and we'll have one every week on Thursday at 5:30.
2 And it's webcast so you can listen, you can ask questions.
3 So we want to be as absolutely transparent as we possibly
4 can. It's critical to any issue to resolve it publicly.

5 Thank you very much.

6 EWING: Thank you.

7 Let me ask, is there anyone else who would like to
8 make a statement?

9 All right. Then I would like to thank all of the
10 speakers today and also the audience for staying through the
11 entire day. I think it's been productive, and certainly the
12 Board appreciate all the information and perspectives that
13 we've received.

14 So thank you very much.

15 (Whereupon, the meeting was adjourned.)

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C E R T I F I C A T E

I certify that the foregoing is a correct transcript of the Nuclear Waste Technical Review Board's Spring Board Meeting held on March 19, 2014, in Albuquerque, NM, taken from the electronic recording of proceedings in the above-entitled matter.

April 2, 2014

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