

Official Transcript of Proceedings ACNWT-0205

NUCLEAR REGULATORY COMMISSION

Title: Advisory Committee on Nuclear Waste
184th Meeting

Docket Number: (n/a)

PROCESS USING ADAMS
TEMPLATE: ACRS/ACNW-005
SUNSI REVIEW COMPLETE

Location: Rockville, Maryland

Date: Tuesday, November 13, 2007

Work Order No.: NRC-1861

Pages 1-83 ✓

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UNITED STATES NUCLEAR REGULATORY COMMISSION'S
ADVISORY COMMITTEE ON NUCLEAR WASTE & MATERIALS

November 13, 2007

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This transcript has not been reviewed, corrected and edited and it may contain inaccuracies.

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON NUCLEAR WASTE AND MATERIALS
(ACNW&M)

184th MEETING

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TUESDAY,
NOVEMBER 13, 2007

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VOLUME I

The meeting was convened in Room T-2B3
of Two White Flint North, 11545 Rockville Pike,
Rockville, Maryland, at 10:00 a.m., Dr. Michael T.
Ryan, Chairman, presiding.

MEMBERS PRESENT:

- MICHAEL T. RYAN Chair
- ALLEN G. CROFF Vice Chair
- JAMES H. CLARKE Member
- WILLIAM J. HINZE Member
- RUTH F. WEINER Member

1 NRC STAFF PRESENT:

2 LATIF HAMDAN

3 NEIL M. COLEMAN

4 DEREK WIDMAYER

5 MYSORE NATARAJA

6 JIM RUBINSTONE

7 TIM McCARTIN

8 BUCK IBRAHIM

9 BRITT HILL

10

11 ALSO PRESENT:

12 JOHN PYE

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P-R-O-C-E-E-D-I-N-G-S

10:00 a.m.

1
2
3 CHAIR RYAN: The meeting will come to
4 order. This is the first day of the 184th meeting of
5 the Advisory Committee on Nuclear waste and materials.
6 During today's meeting, the committee will drift
7 degradation and a staff review approach and capability
8 and a discussion of ACNW letter reports, actually W&M
9 letter reports. Neil Coleman is the designated
10 federal official for today's session.

11 We have received no written comments or
12 request for time to make oral statements from members
13 of the public regarding today's sessions. Should
14 anyone wish to address the committee, please make your
15 wishes known to one of the committee staff. It is
16 requested that speakers use one of the microphones,
17 identify themselves and speak with sufficient clarity
18 and volume so that they can be readily heard. It's
19 also requested that if you have cell phones or pagers
20 that you kindly turn them off at this time.

21 Feedback forms are available at the back
22 of the room for anybody that would like to provide us
23 with his or her comments about the meeting. I hear
24 that we have some folks on the bridge line. Would you
25 please introduce yourselves and we have a video hookup

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1 with you as well. It said mute on the far end.

2 (Telephone participants introduce
3 themselves not audible)

4 CHAIR RYAN: All right, thank you very
5 much. We appreciate your participation with us today.
6 Are there any other participants on the bridge line?

7 (No audible response)

8 CHAIR RYAN: Without further ado, I will
9 turn this session over to our cognizant member. It
10 showed my initials on the agenda, but in fact, it will
11 be Professor Hinze that will leading us in this
12 session so without further ado, Professor Hinze.

13 DR. HINZE: Thank you very much, Dr. Ryan.
14 The Committee has had a long-term interest in this
15 issue of drift degradation at the proposed repository
16 and has written a letter to the Commission on this
17 topic. As I understand it, we have not had a briefing
18 from the NRC staff for about four years on this topic.
19 So it is appropriate that we bring ourselves up to
20 date.

21 There has been significant activity at the
22 Center and at DOE and DOE/NRC interaction on this
23 issue as well as a report that has been issued by the
24 Center. This issue has been specified as of medium
25 significance and the Risk Insight Baseline Report and

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1 so this is an important topic to us. Some of the
2 important questions that we may consider is the cover
3 question of what is the potential risk from drift
4 degradation. We are also interested in what are the
5 relative role of the seismic ground motion, the
6 thermal stress as well as the gradual weakening of the
7 material of a rock around the opening with time.

8 And we are very much interested in the
9 timing and the rate of progress of drift degradation.
10 The risk, of course, is controlled by what eventually
11 happens to the drip shields as well as the waste
12 canisters and so we're interested in learning more
13 about that. Unfortunately, DOE has decided not to
14 support this meeting, but representatives of the
15 Committee attended a DOE/NRC Appendix 7 meeting on
16 this topic last month. A report has been written on
17 that by the representatives attending that meeting and
18 the Committee has a copy of that report.

19 That report explains that there are
20 considerable differences, potential differences,
21 between the DOE and the NRC and hopefully, we'll be
22 hearing something -- about some of that from the staff
23 today. In addition, we have learned that the Electric
24 Power Research Institute has recently issued a report
25 on drift degradation associated especially with

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1 thermal mechanical effects and stresses and we will be
2 hearing a report on that at our next meeting and we
3 look forward to learning what their views are as well.

4 Today we have joining us John Pye, an
5 expert on rock mechanics, who is a staff member of the
6 Nuclear Waste Technical Review Board and we thank the
7 Board for permitted John to participate with us and we
8 thank you, John, for coming and lending your expertise
9 and background on this topic to us. With that, I will
10 turn it over to whoever I should turn it over to, Jim
11 or to Mysore Nataraja and Raj, you're becoming a
12 familiar face to us. You were prominent here at our
13 last meeting and we welcome you here and look forward
14 to your comments, briefing on this topic. Thank you.

15 MR. NATARAJA: Good morning. I'm becoming
16 too frequent here. I don't know whether it's good or
17 bad but I certainly I'll be fulfilling my obligation
18 of meeting the objectives of this presentation. I
19 would like to first of all acknowledge my colleagues
20 at the Center. Two prominent members of my team, Dr.
21 Goodluck Ofoegbu, I don't think he is present there,
22 I can't see him, and Luis -- Dr. Luis Ibarra, are the
23 two key members who have contributed to our current
24 understanding of this subject of drift degradation.

25 And what happened to the slides? So I

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1 have mentioned the names of those two people but there
2 are many other people. I'm going to be showing you
3 during the course of my presentation, the various
4 disciplines and it's a fairly complex topic. There
5 are numerous people, you know, both here as well as at
6 the Center who have helped us over the years to
7 crystalize our thought process on the issue of drift
8 degradation.

9 I'd like to mention at the outset that we
10 are going to present this more as what our approach is
11 rather than comparing and contrasting with what's
12 going on with DOE, although we are very familiar with
13 the published reports and the contents thereof. So
14 I'd ask for your indulgence in trying to understand
15 this process and how we are going to review this
16 complex topic when we receive a license application.

17 As you can see, in the outline, there is
18 a fair amount of material that I would be covering
19 today. I'm going to first explain the purpose of my
20 briefing and then I will provide some context in the
21 form of background material and there is a fair amount
22 of history for this particular topic. I'm going into
23 the significance of drift degradation process. I'll
24 discuss some staff activities later to the license
25 application review preparation and I'll describe what

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1 our current understanding is of the -- this particular
2 process of drift degradation how DOE has addressed it
3 in its documents and whatever documents that have been
4 available to us in public domain. I would then
5 discuss the process, as we understand it based on some
6 of our own limited independent analysis, focused
7 analysis, then talk about our approach, the staff
8 approach for the review of any analysis that we might
9 see as -- in support of DOE's claims and conclusions.
10 I'll briefly touch upon our capability to conduct this
11 review in an efficient and risk informed manner and
12 finally, I'll conclude my presentation.

13 I'm on Slide 3 now. I have identified two
14 broad objectives forming our presentation today.
15 First, to present our current understanding of this
16 process, drift degradation process and then in the
17 context of the mechanical performance of engineered
18 value system because we are not going to look at just
19 the process of drift degradation in isolation. We
20 need to see what its impact is on the mechanical
21 performance of the primary barriers and how that might
22 impact the overall performance of the system.

23 And second, I'll try and describe an
24 approach that we have developed to review the contents
25 of reviewing license application. Okay, now, I'm on

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1 slide 4, the background. And under this background,
2 I have about I guess seven or eight slides and this
3 somewhat long background discussion is actually the
4 body of the discussion. We thought this was necessary
5 to bring everybody to the same level of understanding
6 so that you can better appreciate our approach for the
7 review that we have developed.

8 So I will take you to where we have been
9 in the past and where we are today and where we want
10 to be when we receive the license application and I
11 will be touching upon some of the past activities,
12 really into the past, like maybe a decade or so but
13 briefly and then I'll get into some of the recent
14 activities and I'll mention all the disciplines
15 involved and I'll go into some of the uncertainties
16 and in the context of what we know as the current
17 conceptual design of the underground facility.

18 I will try to make a distinction between
19 the pre-closure aspects of this -- where this impact
20 is pre-closure and where post-closure comes into the
21 picture and my focus today is the post-closure part.
22 And I'll only mention pre-closure to help you to make
23 sure that we do understand there is an impact but
24 we're not calling it a investment impact. I will
25 define some terms so that we can all be on the same

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1 page when we talk about this issue of drift
2 degradation and I'll also say that we're going to be
3 at a fairly high level at this presentation
4 intentionally to keep this from going over the
5 objectives of our presentation rather than going
6 through specific details of some of the studies that
7 we have conducted.

8 Okay, I would like to mention as a part of
9 this background something about the key technical
10 issues. If you'll follow the family of what we used
11 to call KTIs and the -- I want to make sure I'm on the
12 right slide. Yeah, I'm on Slide 4 still. The -- if
13 you remember, the key technical issues, there are a
14 number of KTIs that had a relationship with this issue
15 of drift degradation and its impacts on the EBS. One
16 of them was the containment life and source term. The
17 other one was the various activity and there was the
18 faulting and seismicity issues and criticality also
19 came in the picture although in a minor fashion.

20 All the agreements related to this
21 particular topic and what the staff did and what
22 source of information was requested and how the
23 information was supplied to us to close the
24 agreements, they've all been documented in what we
25 call the IRSR, the Issue Resolution Status Reports.

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1 I'm sure you're familiar with those. And most of the
2 technical discussions related to the -- what we call
3 drift degradation today used to take place under the
4 RDTME, Repository Design Thermal Mechanical Effects
5 TKI. And we did not make a distinction at that time
6 between pre and post-closure. Both those aspects were
7 handled under RDTME and in the '90s there were
8 numerous discussions between NRC and DOE both formal
9 as well as informal and most of those questions that
10 were raised had to do with the importance of the data
11 from the site characteristics, lab testing and
12 modeling. And then in the 2000 and 2001 time frame,
13 we documented all these agreements and the resolutions
14 in the IRSRs and I think Dr. Hinze was present in one
15 of those meetings where we came up with numerous
16 agreements and later to the topic.

17 And after that, the next phase was what
18 was called the AMRs, the Analysis and Model Reports
19 and there was a major effort by the Department of
20 Energy in writing a voluminous document on this issue
21 of drift degradation in 2002/2003 time frame. And I
22 believe it was in 2003/2004 that we -- the staff both
23 here as well as at the Center, spent an enormous
24 amount of time reviewing this particular AMR and we
25 were -- in fact, we spent about two weeks concentrated

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1 time at the Department of Energy looking at this
2 particular AMR and documenting our comments in great
3 detail.

4 Because of the complex nature of this
5 issue, we decided that we also should conduct some
6 independent analysis if our own to develop an
7 understanding of this process and how this process
8 might impact the performance of the engineered barrier
9 system so over the period of last 10, 15 years, we
10 have probably written a dozen reports that we have
11 developed on the various topics related to the
12 subject. Slide 5, please.

13 In addition to the independent analysis
14 that we performed, there was -- it was clear to us
15 that we needed to look at this particular topic in an
16 integrated fashion. So we arranged for an internal
17 workshop between the NRC and the Center Staff and we
18 spent about three days on all effected ISIs, when I
19 say ISI it would be Integrated sub-issues and we had
20 moved from KTI to ISI in that time frame. So all the
21 effected ISI teams participated in this particular
22 workshop and then as a result of those discussions
23 during those three days, we developed a common
24 understanding and that information has been documented
25 in a report which is publicly available, you probably

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1 have seen that. And that's the summary of current
2 understanding of the drift degradation process.

3 And that workshop was held in March of
4 2006. And in addition to looking at the rock
5 mechanics aspects of the thermal mechanical impacts of
6 drift degradation, we also looked at the structural
7 performance of the engineered barrier system. We
8 started off with what sorts of loads might be expected
9 and what might be the impacts of those loads on the
10 mechanical and structural performance of drip shields
11 and would the drip shields perform as intended. If
12 not, what would be the impact? Would the failure --
13 potential failure of drip shields have an impact on
14 the performance of the base package. So we did a lot
15 of work and there are a number of reports related to
16 the mechanical performance of the engineered barrier
17 system.

18 And the last thing we have done is the
19 abstraction of all this information into the
20 performance assessment exercises that we are doing
21 internally and in the last presentation both Chris and
22 Britt made presentations to you and gave examples of
23 how drift degradation is handled in the TPA.

24 Finally, the most recent activity in this
25 particular issue is an informal discussion we had with

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1 the Department of Energy. This was just last month
2 and ACNW representatives were present in that meeting
3 where we heard some information which we had not been
4 exposed to. So there is recent information out there
5 and some of which has become public information now.
6 We have just started looking at the Supplemental
7 Environmental Impact Statement. Some of the
8 discussions we heard in that Appendix 7 meeting in
9 October has been summarized in the Supplemental EIS,
10 so it has become public information and also there is
11 a consequences, a seismic consequences document which
12 is also now available but what I'm trying to impress
13 upon you is that there's a fair amount of review that
14 we have done of the publicly available documents and
15 there is a fair amount of history of discussion and
16 interactions between NRC and DOE on this topic dating
17 back to more than a decade and even in the recent
18 past, like in the last month, we have had a
19 discussion, informal discussion with the Department
20 where we heard the most recent information.

21 And I'm not going to claim that we have
22 digested all the information that is out there because
23 there's still quite a bit of information we have to
24 review but we have a reasonable level of understanding
25 of what has been done to date. Slide 6. This is just

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1 basically to give you an idea about the various
2 disciplines involved; geology, seismology, rock
3 mechanics, structural mechanics, mining engineer,
4 earthquake engineering, material finds and performance
5 assessment. And each one of these disciplines has its
6 own unique way of dealing with uncertainty. So you
7 have to realize that when you come to the last level
8 of the performance assessment, you have received
9 inputs from various disciplines which deal with
10 uncertainties in their own unique fashion and then we
11 have to integrate all that and look at it in the
12 overall context of what this might mean to the
13 performance of the engineer barrier system and the
14 depository as a whole.

15 Now, let's get into Slide 7. What I will
16 do is I will skip Slide 7. I'm trying to look at 7
17 and 8 and we have one screen here. It is better to go
18 to eight but I'll use the description on the seven to
19 look at what we have there. This is basically one of
20 the figures that we have taken from one of the viewing
21 documents. This is probably a picture that you have
22 seen in many of the conceptual designs. Some details
23 here could change, but, you know, it's not -- it's not
24 going to really factor a discussion if the spacing
25 between the waste packages changes a little bit, the

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1 spacing between the -- the clearance between the waste
2 package and the drip shield increased or decreases,
3 but this is probably current information but it's
4 sufficient for our discussions today here.

5 As you can see there, you've got a 5.5
6 meter diameter excavation. You do not see the
7 excavation here. What you see is the inner most skin
8 after the excavation is complete and that is -- that
9 consists of a perforated sheet that is part of the
10 ground support system as designed today for the
11 underground facility for the emplacement drifts.
12 What you don't see here is also the radially placed
13 bolts, the rock bolts that go radially into the rock
14 which will be the first thing that that they place and
15 then the perforated sheet that you see, which is a
16 continuous sheet basically to prevent any rock pieces
17 from falling onto the EDS or to protect the workers
18 and also for the safe operation of the early pre-
19 closure period. And these drifts are about 81 meters
20 center to center which is an important piece of
21 information for calculating the heat load, et cetera.

22 Now, the -- what you're seeing here is the
23 as-built, fresh immediately after installation of the
24 ground support system. However, you have to realize
25 that the blue thing which is the drip shield, would be

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1 the last thing to be placed after the -- you know,
2 after the decision is made to close the repository.
3 Just before the closure the drip shield would be
4 placed unless a decision is made that the requirements
5 are being met and you don't have to do any more
6 operations there. So between the actual construction
7 of the initial phase of the emplacement there's going
8 to be a long gap for the emplacement of the drip
9 shields. So there could be improvement, changes to
10 the design, et cetera in the field, so we have to keep
11 that in mind.

12 So now let's look at the -- Slide 9 now.
13 Yeah, okay. All right, now what I would like to
14 explain here is a little bit of what might happen to
15 the drip with time. Now, keep this figure in mind.
16 I'll go to the next slide and then come back to this
17 slide again. Let's go to -- all right, what happens
18 when we construct a repository is you first start off
19 with a 5.5 meter diameter hole excavated in the rock,
20 using a TBM, which is the tunnel-boring machine. So
21 as you know, that before you do anything to the rock,
22 the rock is in equilibrium and it is under some kind
23 of in-situ stresses like what we refer to as the in-
24 situ stresses. There is a horizontal component, a
25 vertical component.

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1 Normally the vertical stresses are higher
2 than horizontal stresses and there are exceptions but
3 they are very few, but in any case, the rock -- you
4 take the tunnel boring machine, make a hole and then
5 you disturb the condition. As a result of this
6 disturbance, these places are going to be
7 redistributed and this is what we call the mechanical
8 effects of the construction so the redistributed
9 stresses what we call the excavation induced or the
10 mechanical stresses, are now superimposed upon the
11 redistributed existing stresses.

12 Then you go back and put in the waste and
13 the emplacement bolt, that starts generating heat.
14 There's going to be conduction, convection, radiation
15 and so on and so forth. It starts heating the rock
16 and generates the thermal stresses. That's what I
17 call the heat or the thermal stresses and this causes
18 a gradient and this is superimposed on all the rocks
19 that are heated in the near vicinity of waste
20 emplacement hole.

21 Then at which time there could be some
22 random seismic events that take place of different
23 magnitudes and they, in turn, induce what we call the
24 seismic stresses and there's going to be a combination
25 of mechanical of the excavation induced stresses,

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1 thermally induced stresses. On top of it you may have
2 some transitory migratory motion and then because of
3 that there are seismic stresses. Now, any one of
4 these stresses by itself can cause failure in the
5 rock. And in combination, definitely there is
6 potential for rock failure and I would like to loosely
7 define when I say failure we are talking about two
8 possibilities. One is we have something called a rock
9 strength where you take a small sample in the
10 laboratory and measure the strength of the rock and
11 assign that as the rock strength and that strength is
12 not necessarily representative of what happens in the
13 field so there is conversion from the lab to the field
14 behavior but there is what we call an all strength,
15 and if the rock strength is exceeded by any one of
16 these stresses or a combination of these stresses, we
17 term it as failure.

18 This does not necessarily mean that the
19 rock will come tumbling down. It means that the rock
20 has been heavily stressed. But that could also be
21 because the nature of the rock, the jointed nature of
22 the rock and discontinuities and so no and so forth
23 there could be excess of information in the placement
24 of the hole and then we can term that as failure
25 either due to the strength being exceeded or due to

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1 the mix of information. That's what we loosely call
2 a rock free nuclear. Now, let's go back to Slide 9.
3 What you see in the first figure there is a pictorial
4 representation of what could be an ideal condition.
5 The perforated ground support along with the rock
6 bores will keep the opening stable and then you have
7 the in place waste inside and covered by a drip shield
8 whose function is to prevent the rocks from falling
9 onto the waste package and damaging it and also from
10 the water dripping onto the waste package.

11 And with time, the roof support, the
12 ground support system, loses it's effectiveness and
13 then the stresses that I just explained, the
14 combinations of those stresses will create some kind
15 of effect, the strip condition which will start
16 failing the rocks. As I said, the rock failure could
17 be excessive deformation on individual rocks falling.
18 We'll come to that in a couple of minutes. But I've
19 shown two configurations there.

20 The middle one is what we call the
21 trapezoidal type of failure, deformed shape of the
22 emplacement drift and the last figure is like what we
23 referred to as the chimney shape where you have the
24 vertical elliptic final configuration at the
25 emplacement hole as a result of degradation.

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1 Now, the biggest thing here, we have to
2 admit is when does this happen, how long does it take
3 and what would be the extent of this degradation and
4 how -- what would be the rate of this rubble
5 accumulation around the value system. And now let's
6 go to number 11. Okay, I just wanted to bring in a
7 few terms here so that these are normally used in
8 different context but what we mean by rock fall is
9 basically individual pieces of rocks. They could be
10 small, they could be large. In fact, they could be as
11 small as an inch or two in size. They could be
12 several feet in length. It could be regular shape.
13 It could be irregular shape and it could be even
14 pointy. You know, you could have a very sharp edged
15 rock which has got the capability to punch into the
16 barrier system. And that's what we mean by rock fall.
17 We refer to the individual pieces falling in.

18 And when we talk about drift collapse,
19 we're talking about massive volumes of rock, several
20 linear feet of the emplacement cliff coming down,
21 bringing in tons and tons of material, which could
22 happen as a result of some very strong motions during
23 seismic events. And the third point there, we're
24 talking about the drift degradation which is normally
25 -- is referred to the gradual change that takes place

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1 as a result of accumulation of rubble over a period of
2 time, generally as a result of thermal stresses being
3 immediate layers which are exposed to heat can spall
4 in small layers and accumulate around and near the
5 barrier system and they could, of course, be made
6 worse by seismic checking and thermal dumping and on
7 and so forth.

8 But the most important message here is
9 that regardless of whether it is due to rock fall or
10 to drift collapse or drift degradation due to thermal
11 loading, we have rubble accumulation taking place on
12 a continuous basis until it is prevented from
13 happening somehow. Okay, now, let's come to Slide 12.
14 So what's significance now. So we need to look at
15 the significance of the drip regulation in general.
16 That would be from the pre-closure perspective as well
17 as for the post-closure perspective. We are going to
18 be, as I said, focusing only on post-closure today but
19 I just wanted to make sure that we also understand
20 that there could be some implications during pre-
21 closure but there are regulatory requirements both NRC
22 regulations as well as DOE's own regulations for safe
23 operations. So there would be ground support system
24 and we would know the design of the ground support
25 system as a part of the license application and the

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1 adequacy of the design itself would be determined in
2 the context of the pre-closure safety assessment and
3 the pre-closure performance objectives.

4 In any case, from the discussions that we
5 are talking about today, it is important to note that
6 DOE does not take any credit for the performance of
7 the ground support system in the post-closure period.
8 Slide 13, please. Now, Slide 13. All right, now, the
9 -- in Slide 9 we saw the conditions, the initial
10 condition and two possible conditions and we all know
11 that it is not possible to precisely calculate when a
12 shape would be in a particular form. So we have to
13 look at a range of possibilities. And all these
14 predictions are based on some analytical methods and
15 numerical models which all carry their own
16 assumptions. And the -- as a result of the rock
17 failure, there's going to be accumulation of rubble
18 and this accumulated rubble could actually behave like
19 a backfill around the engineered barrier system and
20 therefore, it could change the temperature conditions
21 and the near-field enlightenment and all that. So it
22 has, in fact, the -- the unit, if it does not fail,
23 the engineered barrier system, the system
24 mechanically, it has an impact as a result of the
25 changes in temperature and effluent chemistry but the

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1 more important one is if it has an impact, if it
2 structurally collapses the drip shield is what we are
3 discussing here today as the mechanical performance.
4 So our objective in this particular ISI at the -- when
5 we are looking at the mechanical disruption of the
6 engineered barrier system, that's in the context of
7 that we are looking at the process of drift
8 degradation our objective is to see what could be the
9 extent of the log as a result of this accumulation of
10 rubble and what might that do to the mechanical and
11 structural performance of the engineered barrier
12 system.

13 So it has an impact both in terms of the
14 effluent chemistry, the temperature and the
15 environment, what it might do to the corrosion
16 characteristics and so on and so forth and would there
17 be sustained loading which would impact on the creep
18 behavior, and, if course, the impact of individuals
19 rocks that might punch into the engineered barrier
20 system. So the -- that is the context and that's the
21 reason why we believe there is going to be a
22 significance of the drift degradation process in the
23 context of the overall performance of the engineered
24 barrier system.

25 So before we exclude or include it we will

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1 have to have a technical basis to understand the
2 process level so that we can transfer that into the
3 abstractions in the performance assessment. Okay, now
4 we're on Slide 14. What have we done as -- with all
5 this understanding? I'm just trying to touch upon
6 some of the activities.

7 As I mentioned earlier, we have had a long
8 history of interactions with the Department of Energy
9 and we have reviewed the reports that are available to
10 us. And we have done our own independent analysis as
11 I mentioned, to see if there is any specific aspects
12 of the facts that we would like to focus on in our
13 reviews. And the most important thing that we have
14 come up with is that there is even in the limited
15 analysis that we have done, you'll see that there is
16 potential uncertainty both in how we take the
17 information from the site characteristics and the data
18 that are available to us from reviewing the reports,
19 therefore, we have concluded that it's necessary to
20 look at the range of parameters when we do the
21 independent analysis and factor these into the
22 performance assessment.

23 And the last bullet there on this slide
24 talks about the topic that was discussed in the last
25 briefing to you by performance assessment team, so

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1 again, I'm not going to discuss in detail about that
2 today. All right, now let's look at Slides 15. Okay,
3 based on the reviews that we have conducted to date,
4 what we have seen is that the understanding
5 considerations of drift regulation in their analysis
6 suggests that the emplacement drifts would remain
7 stable for a long time under expected mechanical and
8 thermal conditions.

9 I explained to you the mechanical stresses
10 which would result -- which are excavation induced,
11 super-imposed on top of the existing central
12 conditions and then on top of it you have the thermal
13 stresses. This -- their analysis, what we have
14 reviewed, shows that there would be some degradation
15 but it is not significant but it would continue with
16 the -- the drifts would essentially continue to be
17 stable for a very long period of time under those
18 loads. And then the -- we also have learned that
19 their conclusions are that the drifts may collapse
20 under strong seismic events, so they have taken into
21 account several seismic e rings of different
22 magnitudes which would cause different degrees of
23 collapse of the emplacement drift as a function of
24 time.

25 And then the third blip, the drip shields

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1 can potentially withstand the impacts that are due to
2 the static loading. In other words, the accumulated
3 static loading by itself is not sufficient to failure
4 of the drip sheets. That's one of the things that we
5 are seeing. However, they do account for the thinning
6 of the material due to generalized corrosion as a
7 function of time. And in Number 18, and continuing to
8 summarize our understanding of DOE's conclusions, they
9 have analysis which suggested the drip shields may
10 collapse and mechanically interact with waste packages
11 under strong seismic events. However, their main
12 failure mechanism that they considered is from
13 interaction between these packages and a stable drip
14 shield condition. The drip shield has not collapsed.
15 There is space and the waste packages are free to move
16 around during strong motion, up and down, laterally
17 and hit against each other and also interact with the
18 supporting -- if we go back to the design picture that
19 -- can we go back to the -- no -- yeah, this one. You
20 can see the waste packages are resting on pedestals
21 and then the whole thing is resting on what we call
22 the inert and there could be banging of these packages
23 against each other and they could have an effect of
24 waste package jumping up and hitting against some of
25 the sharp objects of the supports. So they have

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1 looked at the potential damage under strong seismic
2 motion but it is under a condition where the drip
3 sheet is in tact.

4 So what do we understand from our own
5 alternate modeling scenarios? That's on Number 17.
6 As I said, we have employed numerical models and used
7 the DOE data and does some of our own independent
8 interpretations of the parameters, strength
9 parameters, analyze the strength stress characters so
10 on and so forth. And what we have concluded, you
11 know, in all independent studies is that the thermal
12 stresses could be strong enough over a period of time
13 to generate stresses and stress gradients in the
14 exposed layers of the rock. And those stresses could
15 be large enough to exceed the strength in which case
16 the thin layers of rocks could fail or spall and start
17 falling. And once that layer of rock fails and
18 spalls, the next layer of rock gets heated up. As
19 long as there is heat source, this process continues
20 and the thermal degradation continues and the
21 accumulation of rock rubble continues. And of course,
22 there is going to be an addition of degradation due to
23 intermittent seismic damage.

24 So you have this accumulated rock rubble
25 could generate sufficient static loading on the drip

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1 shield sufficient to fail the drip sheet as designed.
2 I have to emphasize the fact that we have looked at
3 the current design and as I said, the design is, you
4 know, subject to change. But the current design under
5 several distributions of loads, you have to understand
6 that the load distribution is pretty complex. It is
7 not just a particular load. A load could be
8 unsymmetrical, it could be on one side if the drip
9 shield, on both sides. It could be different in
10 different sections of emplacement drifts and it could
11 be different heights of rubble accumulated at
12 different parts. It's not going to be uniform because
13 there are four or five categories of rocks in the
14 repository and two major rock types like the
15 lithophysal rocks versus the non-lithophysal rocks.
16 The lithophysal rocks are characterized by cavities
17 and the non-lithophysal rocks are jointed rocks which
18 have -- are characterized by the fracture
19 characteristics or jointed characteristics.

20 So there's going to be a wide ranging
21 possibly some load conditions but we have looked at
22 several conditions under several loading conditions.
23 We believe that the drip shields could collapse as
24 designed and those drip shields could interact with
25 the waste package and there could be a load transfer.

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1 In other words, a large amount of static loading is
2 sitting on top of the drip shield, which is sitting on
3 top of the waste packing, transferring the load
4 through a lateral -- a sharp edge of one of those
5 members and has a potential effect of stress
6 concentration starting some kind of a damage process
7 of the waste package surface. Does it mean that it's
8 going to breach the waste package? No, I'm not saying
9 that but it could start the process of accelerated
10 corrosion and there could be surface damage as a
11 matter of -- as a function of time later on.

12 So we also have concluded in our limited
13 studies that we have potentials for waste package
14 surface damage due to strong motions as a result of
15 the entire assembly now moving up and down. Now you
16 have waste package sitting on top of a drip shield and
17 on top of it is accumulated static loading. So you
18 have to look at this entire thing, up and down or
19 laterally or whatever. Under those conditions there
20 could be some potential damage to the surface.

21 All right, Number 18, there are other
22 additional considerations in the second part of -- I
23 already covered the first dash. Under the second
24 dash, there is the sustained lower and the creep
25 effects and the -- also there is a generalized

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1 condition that is also taking place with time. And
2 the temperature impacts on the material properties
3 themselves with time could also have an impact. These
4 could be secondary considerations but some
5 considerations that need to be looked at. And there's
6 also the issue of the degradation of the pallet itself
7 on which the waste packages are supported. All
8 materials which are subjected to degradation as a
9 function of time.

10 So now, under Slide 19, based on the
11 review that we have conducted to date and based on the
12 independent analyses that we have conducted to develop
13 our own insights to this process and its potential
14 impact on the mechanical performance and eventually on
15 the performance of the DBS as a whole, we have started
16 developing a review approach and in this review
17 approach and in this review approach, basically what
18 we would like to do is we have not looked at the
19 entire story that the Department of Energy has put
20 together in support of its claims or conclusions.

21 We have seen it in bits and pieces and
22 hopefully in the license application we will see an
23 integrated story and when we do that, our approach
24 would be to check to see if DOE appropriately
25 considers the site characteristics. When I say this,

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1 we're talking about the joints, the fractures, the
2 voids, the material properties and how the laboratory
3 properties have been extrapolated to the field
4 conditions and how the strength parameters have been
5 interpreted so on and so forth for the rocks, of the
6 various types there.

7 This does not necessarily mean that we
8 expect that every joint will be discontinued to be
9 modeled, only to the extent that it has an impact on
10 the overall performance. That's what we would be
11 looking at. And we would also be looking at whether
12 appropriate models have been used by the lithophysal
13 and non-lithophysal type of rocks in coming up with
14 the relation process itself and appropriate models
15 have been used for the structural mechanics part of
16 the analysis of the drip shield and the waste package.
17 And whether they looked at alternate possibilities,
18 alternate concepts, not necessarily sticking to one
19 particular model but look at different types of models
20 and see whether we can come to the same conclusions
21 based on various analysis.

22 And of course, we are going to look at the
23 issue of calibration of these models that have been
24 used with the information that is available to us in
25 terms of the laboratory tests and as you know, there

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1 is a large scale heater test already done. So models
2 that are used for this purpose can be used to
3 calibrate the final events and also to validate the
4 models to some extent, but I'm going to be extremely
5 careful when I say validation because it's not going
6 to be possible to validate our predictions or analysis
7 for thousands of years. That's, you know,
8 unreasonable and unrealistic to expect that, but
9 having said that, we can do certain things with the
10 available test data both the large scale as well as
11 the lab scale to calibrate and we'll be checking to
12 see whether the models used are calibrated
13 appropriately and validated to the extent reasonable.

14 And we would also -- the most important
15 thing we would be looking at is whether the
16 uncertainty has been factored at various stages for
17 the parameters and for the characters fix. And when
18 we do that, I think we'll be in a fairly good position
19 to either support or question the conclusions made by
20 any analysis, like 20 years.

21 So what are some of the review
22 considerations now for the process level as well as
23 the TPA abstractions level? Based on our
24 understanding of -- I jotted down a few important
25 ones. At the process level, we know that there is

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1 potential for degradation both due to thermal loading
2 and due to seismic motion. And we know that as a
3 result of this there is going to be accumulation of
4 rubble with time and even though we may not be able to
5 exactly say what would be the height of load on that,
6 we do have some idea of the ranges of possible static
7 loading that can occur as a result of accumulation and
8 using that loading and the input from the seismic
9 hazard, we would be able to analyze the potential for
10 buckling of drip shields. That's a potential failure
11 mode of the drip shields because we have seen as
12 designed the drip shields have the potential for
13 buckle under static load and definitely under
14 combination of static and laboratory motion.

15 And since there is that potential for
16 buckling of the drip shield, we do know that the dip
17 shields in some cases may not function as intended and
18 the second thing we will know -- we also know is that
19 there could be interaction between the drip shield and
20 the waste package and as a result of that, there could
21 be surface damage to waste package. So we are going
22 to look at where these things have been analyzed and
23 they have been abstracted into the TPA in analyzing
24 the long term impact of the drip degradation.

25 The Department of Energy could exclude or

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1 include this and if the exclude, we expect them to
2 provide a technical basis for why it was excluded and
3 we would have a basis based on our own understanding
4 either to agree with their finding or to ask further
5 questions.

6 Now, let's look at Slide 21. In addition
7 to the primary considerations, there are some
8 secondary considerations. You have looked at these
9 and we have looked at these also. For example, could
10 the drip shields separate themselves and because of
11 that reason allow water to seep in and drip onto the
12 waste packages? That's one of the potential failure
13 modes due to either -- mostly due to seismic motion or
14 it could be due to unsymmetrical failures, one part of
15 the drip shield failing and the other on not failing
16 and separating the two off. And then the other
17 consideration is of individual rock blocks. In fact,
18 several years ago, we used to think that this was a
19 very major issue, huge rock blocks falling and
20 damaging the EBS. Over a period of time that concern
21 has reduced in comparison to what might happen as a
22 result of accumulated rubble over a period of time.
23 But still that is something that needs to be
24 considered because there could be some huge rocks
25 impacting on the EBS performance but that could be

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1 limited in extent. It could be here and there rather
2 than a continuous number of drip shields failing in
3 the individual rock blocks.

4 And there is the issue of the faulting.
5 It has been considered and considered as a very low
6 probability thing and even if it does happen, it is
7 supposed to be limited to that particular area where
8 the faulting takes place and so it's going to impact
9 a limited number of waste packages. But these are
10 secondary considerations and we'll be looking for
11 these in our reviews as well.

12 So I'd like to summarize my review
13 approach in Slide 22. It's an approach that has
14 resulted from a number of years of interactions
15 amongst ourselves, amongst various disciplines within
16 the staff here as well as in the Center. So we do
17 believe that there's going to be a rod degradation as
18 a result of problem loading and also it will be made
19 worse by intermittent seismic loading and there is
20 going to be some sort of rubble accumulation as a
21 result of this. And now, we have to have some
22 estimate of what sort of load distribution we might
23 have as a result of this rubble accumulation on top of
24 which there could be intermittent seismic load.

25 And then we look at the consequence of

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1 this rubble accumulation and potential damage to the
2 structural performance or the mechanical performance
3 of the drip shield which leads to the drip shield not
4 doing what it is supposed to do which is to protect
5 the waste package from rock fall as well as from water
6 dripping on. And then the potential load transfer, if
7 there is a failure, is that a potential load transfer
8 and how many cases and what might that do and is there
9 a consequence?

10 And that is the last step. I'm not going
11 to discuss that issue here because that's part of the
12 performance assessment discussions we already heard.
13 And as far as for that review approach and the plans
14 that we have, what kind of review capability do we
15 have within the staff as well as our Center support.
16 I believe that we have extensive knowledge and
17 experience, both field experience and analytical
18 knowledge both from modeling, not only analytical
19 modeling but also numerical modeling of continuous
20 and discontinuous media. We have expertise in
21 geologic engineering, mining engineering, structural
22 mechanics, and also we have a number of years of
23 combined experience in licensing reviews and hearings.
24 So I feel confident that we have a team that is well-
25 prepared and knowledgeable and experienced and has

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1 quite a bit of engineering judgment to apply to make
2 sure that this review is risk informed. And I'd like
3 to recap in Slide 24, this is basically the old saying
4 that you can tell them what you're going to tell them,
5 tell them, tell them what you told them.

6 I have some liquidity but you know, I went
7 into a log background of the history of this going
8 back to a couple of decades and how this issue has
9 been discussed as an isolated piece of rock mechanics
10 issue and then as an integrated sub-issue under the
11 mechanical disruption of the barrier system. And I
12 talked about the significance of drift degradation
13 both for pre-closure and post-closure and mentioned
14 that the particular aspects would be looked at in the
15 context of PCSA to the extent necessary. But the --
16 we have to remember that DOE has not taken any credit
17 for the performance of the ground support system in
18 its post-closure analysis and we discussed the
19 significance during post-closure as a result of the
20 accumulation of rubble and we summarized current
21 understanding of what DOE has done in its approach to
22 considering this in its PA and we also discussed some
23 of the highlights from our own independent analysis
24 and based on all this, I gave you a review approach
25 that the staff has developed so that when we do the

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1 receive the license application, we are in a good
2 position to approach this in a rational and risk
3 informed manner.

4 In summary, my last slide, we understand
5 DOE's approach. We believe based on what we have
6 seen, but that doesn't mean that we have seen
7 everything, there is new information coming in as we
8 speak and we haven't been able to review all that yet.
9 And hopefully between now and the license application
10 arrival we will have time to review those, especially
11 the latest information of the seismic consequence
12 analysis and the staff continues to perform
13 independent limited analysis because we have questions
14 of our own how important is this process to the
15 overall performance of the engineered barrier system
16 so we continue to sharpen our pencils and continue to
17 do more analysis as needed and we have the capability,
18 we have the modeling capability as well as the
19 analytical capability to continue that.

20 The most important thing I'd like to leave
21 as a message here is that we have a fairly flexible
22 review approach. So whatever the Department of Energy
23 presents, we are ready to review that with an open
24 mind. We have no positions why we have technical
25 basis for raising questions if there are significant

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1 differences between our understanding and the
2 understanding that will be submitted in the license
3 application. And with that, I think I'll conclude and
4 take any questions and I have a number of people here
5 to help me if I get into trouble.

6 DR. HINZE: Well, Dr. Nataraja, let me
7 congratulate you on a very clear and well-organized
8 presentation. I think your focus upon the staff
9 review approach is very helpful to the Committee,
10 while you also provided us with a lot of technical
11 details and all of that is extremely helpful. It's
12 an excellent presentation in my view.

13 With that, I will ask the Committee if
14 they have any questions for Raj. Allen?

15 VICE CHAIR CROFF: Yes, I've got maybe a
16 couple. If I understood what you said or at least
17 implied, your understanding of DOE's approach is that
18 you expect the drifts to remain intact under
19 mechanical and thermal conditions but seismic could
20 cause some difficulty; whereas, in your analysis, if
21 I understood the implication, the thermal stresses you
22 feel are more likely to cause degradation or collapse
23 of some kind. Can you elaborate? I mean, there's, I
24 guess, fairly apparent to me some difference in the
25 two analyses. Can you be more specific on where the

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1 differences are, I mean, in terms of models or
2 assumptions or whatever?

3 MR. NATARAJA: Well, our analysis is based
4 on a assumption that the rocks are going to behave in
5 a linear elastic fashion. It's a very simplified
6 model and we have a relationship between the strength
7 of the material and the elastic models. So this is
8 based on the laboratory testings that the Department
9 has performed. So we use that data to input the
10 elastic models in our analysis which basically
11 calculates the stresses as a function of thermal
12 input.

13 So it's a very simple and straightforward
14 analysis. You input thermal load and there's a stress
15 characteristic based on various information and based
16 on the models that we input to the various elements of
17 the rock within the vicinity of the placement drift,
18 the stresses are much higher than strength values.
19 This is a kind of factors in geotechnical engineering
20 and rock mechanics.

21 If the stress is higher than the strength,
22 we assume failure but where failure is vaguely used
23 many times, it may or may not mean that the rock will
24 break up when it starts falling. In some cases, it
25 does, in some cases may not, depending upon the joints

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1 and other things, you know, that may prevent. There
2 may be high stress -- small areas of high stresses but
3 there may be no score for the formation because of the
4 way it in which it is arranged and may prevent it from
5 happening. But there is no basis to quantify that
6 other than to say if the stresses are greater than the
7 strength, and if there is no support, the rock is
8 going to spall and we can see this. In fact, we used
9 to use this methodology in developing countries. In
10 India and China, they use it even today. You heat a
11 brittle rock with a lot of charcoal and wood or
12 something for several days, remove that and then full
13 cold because the thermal gradient develops quick. So
14 this is not imagination or something. If there is
15 sufficient gradient due to thermal stresses, but
16 that's a drastic example that I'm giving.

17 You're not having such a drastic gradient
18 here but you do have thermal gradient because you have
19 this high heat source that is giving up the first
20 layer of rock and it becomes smaller and smaller as it
21 goes inside. So that first layer of rock when it is
22 completely over-stressed and if the strength is
23 exceeded and there is no support, it's logical to
24 expect that the thermal spalling cannot go and that's
25 what we are calling failure here. It's a slow process

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1 but it's a continuous process that goes on as long as
2 there is a heat source which is the process of 1,000
3 years plus.

4 VICE CHAIR CROFF: Why doesn't DOE's
5 analysis show a similar effect?

6 MR. NATARAJA: DOE's model is slightly
7 different. What they have done is they described the
8 rock as made up of polygons of different shapes and
9 those polygons are connected by joints and they sort
10 of manipulate the properties of those joints using
11 some sort of a calibration process, comparing it with
12 laboratory testing to simulate what might happen in a
13 test and use that in the large scale.

14 Depending upon the properties that you
15 have for those joints, even though the stress might be
16 higher, it does not allow you to fail. In other
17 words, the individual blocks cannot separate and fall
18 down because of the assumptions they have made. So
19 it's a slightly different analytical technique about
20 which we have some questions about the validity of the
21 assumptions and the conditions and so on and so forth.
22 These are the questions that we have raised and it is
23 a topic that is of a continuing discussion.

24 So you can model it using different
25 approaches. They used this approach because they

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1 believe that they can represent the voids using these
2 different polygons you can represent the lithophyte
3 and then do a laboratory test and reproduce that
4 laboratory test with some assumed stress strength
5 characteristics of the joints and cohesion and
6 friction characteristics and then you reproduce, try
7 to reproduce the laboratory results and say it's now
8 representing what happens, but whether that happens in
9 reality or not is somewhat questionable.

10 Again, I'm not saying that any one
11 particular model gives you an accurate prediction of
12 what happens. We have to use a number of models and
13 we have to use our judgment to see what are the
14 various possibilities. If you use simply the
15 analytical techniques, you can see that trapezoidal
16 type of opening ending up with rock falling on either
17 side or you can have an elliptic shape and all that.
18 Again, you have to make assumptions and these are
19 theoretical calculations which cannot be verified
20 immediately. It will take place over a period of
21 time. And there is also the nature itself has got its
22 joints and characteristics in such a way which may
23 prevent some failures from occurring. So, they will
24 make some analysis and they will make some conclusions
25 and we have made some analysis and we have made some

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1 conclusions, but again, we are not going to say that
2 we are going to compare our results with their results
3 and then say that they're wrong, they're right or
4 anything like that. All we are going to say is, okay,
5 have we factored all the uncertainties of the
6 characteristics into the analysis and have we come up
7 with a conclusion which represents a range of
8 possibilities based on the range of possibilities of
9 characteristics and material properties and the
10 ultimate conceptual models.

11 VICE CHAIR CROFF: Okay, the second
12 question, a couple of slides you mentioned, I think
13 this is under DOE's approach, strong seismic events
14 can cause failure. How strong? I mean, it is --

15 MR. NATARAJA: 10^{-5} probably would be the
16 exceedance and beyond they have collapses. Definitely
17 10^{-6} it's total collapse. 10^{-5} it starts happening, so
18 they are pretty large acceleration values and large
19 velocity values.

20 VICE CHAIR CROFF: Okay, but fairly
21 improbable.

22 MR. NATARAJA: Well, I don't know how to
23 say improbable. We have a hazard curve the goes up to
24 10^{-8} and 10^{-4} and beyond is based on some extrapolation.
25 If I get into trouble here, I have friends here to

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1 help me out with that, but they looked at the
2 accelerations from the hazard curve and the velocities
3 corresponding to those accelerations from the hazard
4 code and did the -- they've done the analysis and 10^{-5}
5 and beyond they expect large collapses to occur but
6 they occur very infrequently but you know, that is
7 factored into the analysis.

8 VICE CHAIR CROFF: Okay, thank you.

9 DR. HINZE: Dr. Ryan?

10 CHAIRMAN RYAN: Raj, thanks for the
11 presentation. It's -- you know, I guess one question
12 on certainty analysis. I think about, you know, a PRA
13 where you've got a whole bunch of processes and you
14 treat them typically statistically or
15 probabilistically. Have you done that sort of
16 analysis or are you really relying on what I take away
17 from your talk as more deterministic and judgment
18 informed modules?

19 MR. NATARAJA: We would do parameter
20 studies but I don't know whether that would be the
21 same as what you're talking about but we --

22 CHAIRMAN RYAN: I'm talking about where
23 you have a bunch of inputs that you vary somehow with
24 a statistical model or some kind of a function that's
25 appropriate for those parameters and then do a -- you

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1 know, a multiple kind of analysis where you get a
2 range of results.

3 MR. NATARAJA: It's done more at the PA
4 level than at the process level. It's more the
5 abstraction of the parameters. There we have a range
6 of parameters and distributions which have input into
7 the Performance Assessment models.

8 CHAIRMAN RYAN: So at the end of the day
9 how likely is it a package fails? That's what I'm
10 reaching for.

11 MR. NATARAJA: Right, that is done in the
12 PA and I don't know if anybody wants to help me.

13 CHAIRMAN RYAN: Are all the parameters
14 from your modeling structure analyzed in the PA,
15 probabilistically? Is that right? Tim, can you help
16 me with that?

17 MR. McCARTIN: Well, you're correct that
18 there's a range of effects in the performance
19 assessment case in that -- I mean, are you getting at
20 are there a lot of realizations where you have seismic
21 induced failures of the waste package?

22 CHAIRMAN RYAN: Yeah, that's what I
23 meant.

24 MR. McCARTIN: And I think that
25 -- you know, and I'll say my memory is you know, if
you had an average, you're looking at around 10

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1 percent of the waste packages fail due to seismic
2 drift collapse scenario, on that order.

3 CHAIRMAN RYAN: And again, I'm way out of
4 my element technically but what I'm trying to get at
5 here is that your judgmental abstractions, which I
6 don't challenge on their merit at all, how do you get
7 from that kind of a professional judgment circumstance
8 to where you've got you know, sort of a probabilistic
9 treatment of that in the TPA?

10 MR. NATARAJA: That's where we have the
11 range of possibilities of the height of accumulated
12 rubble. So with the varying heights of accumulated
13 rubble possible and also different types of the
14 solutions has a different impact on the structural
15 mechanics and the structural collapse of the drip
16 shield. And if the drip shield fails, then there is
17 an interaction between the drip shield and the waste
18 package.

19 CHAIRMAN RYAN: Also that's one of the
20 possible outcomes.

21 MR. NATARAJA: Right.

22 CHAIRMAN RYAN: You're capturing all those
23 ranges of possibilities in the assessment.

24 MR. McCARTIN: Correct, the 10 percent is
25 due to in some cases you know, the extent of the

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1 collapses is smaller than other cases and when it
2 happens, et cetera. There's a lot of factors that
3 come into play.

4 MR. RUBINSTONE: One answer might be we're
5 not explicitly in the TPA modeling each drift
6 collapsing per se. What we're capturing, as Raj said,
7 by looking at ranges of possible rubble accumulation
8 and metric configurations of the tape.

9 CHAIRMAN RYAN: So when you do a TPA run,
10 you're capturing one version of that.

11 MR. RUBINSTONE: Right, so you have to
12 have a distribution of rubble to sample that in TPA.

13 CHAIRMAN RYAN: And that's what you're
14 doing?

15 MR. RUBINSTONE: I think that's fair to
16 say.

17 CHAIRMAN RYAN: Okay.

18 MR. McCARTIN: Yeah, and dependent also
19 obviously, a particular run would have certain seismic
20 events.

21 CHAIRMAN RYAN: Right and again, you're
22 going through many, many, many realizations and over
23 that hopefully sample the distributions appropriately
24 and check well, that what you do anyway and so forth.

25 MR. McCARTIN: Right, right.

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1 CHAIRMAN RYAN: So okay, thanks. But, you
2 know, again, the engineering aspects you're talking
3 about are fascinating to me but I just want to make
4 sure that we're not setting a deterministic result
5 from that module and then having that go in
6 deterministically in the TPA. It sounds like we are
7 not.

8 MR. McCARTIN: Correct, when I was saying
9 on the order of 10 percent was an average over all the
10 realizations, all the runs, what do you see.

11 CHAIRMAN RYAN: And that could range from
12 some --

13 MR. McCARTIN: Some are zero, some are
14 large -- you know, it's a spectrum.

15 CHAIRMAN RYAN: Fair enough. Thank you.
16 Thanks, that answers my question.

17 DR. HINZE: Dr. Weiner?

18 DR. WEINER: First of all, I also want to
19 thank you for a very thorough presentation and I want
20 to point out the obvious, I'm certainly not an expert
21 in this area. This is way outside of my expertise but
22 so you can consider my questions in that context. If
23 I ask you something dumb, just tell me.

24 Your Slide 19, you used the words
25 "appropriately considering site characteristics and

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1 reasonably calibrated back validated models".
2 Considering the fact that your model is completely
3 different from that of the Department of Energy, and
4 that the views that NRC staff and the Center have on
5 drift degradation are almost diametrically opposed to
6 those of the Department of Energy, what do you really
7 mean by the words "appropriately"? How are you going
8 to make that judgment?

9 MR. NATARAJA: Well, these words are
10 coming from basically our overall look. We have a
11 review approach so these are basically, I mean, we may
12 not have a precise definition of what appropriately is
13 but when a rock mechanic, a geological engineer or a
14 mining engineering depending upon the field, when he
15 or she looks at an analysis, will be able to determine
16 whether it is appropriate or not because we are all
17 equally knowledgeable in the state of the art and what
18 can be done, what cannot be done as far as the
19 modeling approach is concerned.

20 And then when I say appropriately, first
21 we go back to the level of site characterization
22 itself. It starts with dividing the entire block into
23 two major blocks which is one is the lithophysal, the
24 other one is the non-lithophysal. Lithophysal is
25 about 85 percent. Non-lithophysal is only about 15.

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1 So we would be more interested in the dominating 85
2 percent in terms of overall performance, not that we
3 are going to ignore the 15. And then the type of
4 characterization for the 85 percent is different
5 because it's the dikes that control the behavior of
6 the rocks. And then the jointed, the factor within is
7 a different kind of characterization, so we are going
8 to -- our experts look at the site characterization
9 and the results.

10 For example, all the mapping that was done
11 in the ESF and how that information was translated
12 into the models. Kevin Smart spent two weeks along
13 with us looking at this kind of information. So
14 that's where we determine whether the site
15 characteristics have been appropriately factored into
16 the models.

17 And then the laboratory tests and the
18 interpretations going from the small scale unconfined
19 compression to table-top to the in-situ inter-test.
20 How the data has been interpreted and used in stress
21 strength characteristics and parameters. The same
22 thing comes in the materials aspects. We have -- of
23 course we looked at the creep and corrosion aspects
24 and there were things which are factored into the
25 analysis. So at every stage, that's why I said, I

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1 gave the list of the disciplines involved and each
2 discipline has its own unique way and uncertainty and
3 that's what we do. We look at how this uncertainty
4 has been factored and once they use all the data, give
5 it sufficient weight and then use a representative
6 distribution, that's appropriate in my mind.

7 So I don't know that I can precisely say
8 with some criteria, saying that if I check one, two,
9 three, four inappropriately, I don't think it will be
10 possible. We need to look at the entire, the
11 integrated claim of the safety case that we make.
12 Supposing they have such a wonderful design for the
13 drip shield which never fails under any expected
14 conditions. We are worrying way too much about some
15 of the details. So that's -- the real why we're
16 varying is we did some independent analysis, how the
17 drip shields are potentially could collapse under some
18 conditions.

19 Supposing we found out at that point that
20 neither the seismic nor the static loading would do
21 anything to the drip shields, then we're done because
22 drip shields will do what they're supposed to do and
23 protect the waste packages and rock fall and water
24 dripping and so on and so forth. So the question of
25 the waste package damage becomes less and less

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1 critical.

2 But if that's not the case -- now, we have
3 to look at what happens as a result of the accumulated
4 rock, have they factored that into their near-field
5 chemistry and the water flow and temperature effects
6 and so on and so forth? I think by the combined
7 intelligence of the review team, they would be able to
8 make a determination whether it's appropriate or not.

9 DR. WEINER: Thanks. That's very helpful
10 that illumination. Are there any natural analogues
11 for the lithophysal drift degradation that you are --
12 that you're studying? I mean, there are caves all
13 over the place. Clearly you don't have any analogues
14 for drip shields and waste packages. But you do have
15 -- there are caves everywhere. What has been observed?

16 MR. NATARAJA: We don't have thermal load
17 is the problem. If it was just simply the integral
18 conditions and super-position of laboratory we do have
19 plenty of examples and in fact, there are studies
20 which document the cases where the case of the
21 underground facilities, tunnels, et cetera, failed
22 under certain (inaudible), but you know, you don't
23 have analogue for heat. So it's extremely difficult
24 to come up with an analogue that is really meaningful
25 and representative of what happens at the risk

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1 replacement form. The nearest example right now is
2 the in-situ heater test. That may or may not be in
3 the right one but at least it is in the tough
4 (phonetic) and it is heated and we have data to look
5 at. The least we can do is use those models to see
6 whether our models similarly -- what is happening in
7 the near -- the vicinity of the in-situ test. We have
8 that.

9 There's the heater which is the dummy for
10 the waste canisters and we have the emplacement head
11 and that's something that is not done yet. A real
12 composite of the model predictions to the extent of
13 degradation because unfortunately they have different
14 kinds of supports. It is not unsupported. We've got
15 steam, we've got all kinds of things and there
16 probably may be some locations without any support,
17 I'm not sure, with some mesh and you can see grass
18 coming down there.

19 So we have evidence to the fact that if
20 you heat up the rock it is going to spall but the
21 question is, how much? What is the extent of this
22 degradation and how long does it continue, what are
23 the final -- when does it stop and what will be the
24 height of the rubble? That is an extremely difficult
25 question to answer and I don't think any model will

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1 give you that, the correct answer and you shouldn't
2 expect it.

3 So we should definitely base our judgment
4 on possible means. Look at what happens and if that
5 doesn't have a major factor and consequence, then
6 you're okay. That's the approach we're taking.

7 DR. WEINER: But you certainly -- what I
8 take it from your response is that you will
9 incorporate the results that you have had from the
10 heater test because those heater tests have been going
11 on for some time.

12 MR. NATARAJA: Yeah, we've asked DOE this
13 question and --

14 MR. RUBINSTONE: One of the problems with
15 the heater test is they'd shut it off and they did an
16 initial entry into the tunnel, but then they've
17 suspended most of the site operations, so they're not
18 doing the full decommissioning of the heater test.
19 There's cameras in there now to observe it but they
20 haven't pulled out the heaters, they haven't taken
21 down the mesh and looked at how much material has
22 fallen.

23 MR. COLEMAN: You need to identify
24 yourself.

25 MR. RUBINSTONE: I'm sorry, Jim

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1 Rubinstone, NRC.

2 DR. WEINER: But what I understand from
3 what Raj is saying, you can observe a certain amount
4 of rock fall starting to take place.

5 MR. RUBINSTONE: Yeah, the fall is the
6 best you can do at this point because they haven't
7 done the full decommissioning of the tunnel there.

8 MR. NATARAJA: And that's only in a small
9 limited exposure. You know, you have that entire
10 thing to support it, so it's not exactly --

11 DR. WEINER: But I suppose --

12 MR. RUBINSTONE: It's the best we can get.

13 DR. WEINER: I suppose real data is always
14 better than just suppositions that you put in your
15 model. Could you go to your Slide 9, the one with the
16 figures with the rocks? Yeah, that one. Okay, let's
17 suppose one of these scenarios, one of these -- yeah,
18 the one with all the rocks falling and sparking
19 things.

20 Let's suppose that one of these two
21 scenarios on the right does take place. Since the end
22 product of all of this is the movement of
23 radionuclides to the accessible environment, if that
24 were to happen, wouldn't you get dust along with rock
25 fall of course. Wouldn't you get retardation of

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1 movement of radionuclides by a variety of mechanisms,
2 absorption onto rock surfaces and so absorption in the
3 dust and so on? Would that have any effect of
4 retarding the motion of radionuclides?

5 MR. NATARAJA: I think I'm going to ask
6 for help here. This is way beyond my comprehension,
7 but I'm pretty sure that if -- there is a way to
8 handle that in our analysis. Tim, do you want to --

9 MR. McCARTIN: I mean, well, certainly if
10 water and radionuclides are moving around rock, I
11 mean, there is a potential for some retardation. I
12 mean, if it's rubble and you're moving around the
13 rock, there wouldn't -- it would be more like a
14 fracture movement and there might not be as much
15 retardation. The dust, I guess there's a possibility
16 for some there. In our TPA code certainly, we do have
17 the invert properties and we do account for the
18 potential for retardation through the invert. One
19 could, you know, possibly enhance the retardation, the
20 invert, if one felt the properties of the rubble were
21 enough that it would be -- enhance that in a
22 significant way.

23 I mean, the biggest problem -- if it's
24 true like sort of a like a gravelly or rubblely thing,
25 it would be -- the water would most likely -- well,

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1 it's always hard to say but the potential would be for
2 it to move around the rock rather than through it and
3 more like a fracture flow than a porous media flow,
4 but you know, there's certainly -- it is a possibility
5 that there's some retardation.

6 DR. WEINER: But you're looking at
7 incorporation of this into any performance assessment
8 that is done. In other words, this has been -- is
9 being considered in performance assessment. You know,
10 volcanic tuff when it breaks up does produce a lot of
11 fairly fine large surface area particles.

12 MR. McCARTIN: Right, well, I don't want
13 to mislead you that it's -- I'm saying that we have an
14 ability to consider retardation in the invert if there
15 was a potential for a lot of retardation through the
16 rubble then I think, yes, we could incorporate in the
17 code, but I -- there really -- right now we've looked
18 at some of the potential for that rubble more to
19 effect how water might get to the package rather than
20 retardation of radionuclides away but there is a
21 recognition that, yes, if you have a collapse drip
22 there's rubble and how might that effect some of the
23 processes. So it's an interesting suggestion,
24 retardation that it's worth putting in the mix.

25 DR. WEINER: Thank you very much for that,

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1 Tim. I have one other question. To what extent have
2 you and to what extent can you determine that DOE has
3 included references from the peer reviewed literature
4 in the modeling of drift degradation? In other words,
5 the reference you refer to in your slides are Center
6 reports but has there been any general literature
7 search or general peer reviewed backup of your model,
8 of the DOE's model, as far as you know?

9 MR. NATARAJA: Yes, our models are
10 standard models which are used by all the people in
11 the field. It's not -- nothing is generated for this
12 purpose.

13 DR. WEINER: Thank you.

14 MR. NATARAJA: And Center staff who have
15 done the work have published numerous papers in
16 referred journals and so they are standard what we are
17 using as well as what DOE is using. They're all
18 standard models, state of the art and they have
19 experts in that field. In fact, the people who are
20 doing the modeling for DOE are the people who have
21 developed a number of models in this field, people
22 from ITASCA (phonetic) if you're familiar with that.

23 They're at the cutting edge of the
24 American modeling for rock mechanics and mining. So
25 they are being in use and they're continuously being

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1 tested. So I don't have any question about the model
2 itself but a model does what you tell the model to do,
3 depending upon what you import. You know, you might
4 get some crazy results some times. So you -- that's
5 where we have to be able to review them carefully.
6 I'm sure they have been internal experts reviewing
7 that. It's not like some information here is being
8 sent out with the actual review or anything like that.

9 DR. WEINER: Thank you. That's it.

10 DR. HINZE: Dr. Clarke?

11 DR. CLARKE: I do have one question and
12 it's a question that's probably better addressed to
13 the DOE but you're here and I'm interested in your
14 response. As I listen to the discussion on the
15 different kinds of failures that could result, in
16 inter-relationships between the two, I found myself
17 thinking about failure in general and also wondering
18 if there's a role for performance confirmation here.
19 And what I mean by that is organizing the analysis and
20 I don't know what's the best way to do it, event trees
21 or logic diagrams or some analytical framework where
22 you could possibly identify precursors to failure,
23 things that might suggest that they be monitored
24 during a time the repository is open.

25 MR. NATARAJA: I'm positive that

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1 performance confirmation has taken into account that
2 program. I don't remember all the details but --

3 DR. CLARKE: So this is being --

4 MR. NATARAJA: Drift stability is one of
5 the things there which comes in. But through the
6 precursor period this is continuously maintained, at
7 least that's the claim. Now we can have safe pre-
8 closure operations, the government support is
9 maintained for that period.

10 DR. CLARKE: I understand. Nevertheless,
11 things might be observed that could be useful to know.

12 MR. NATARAJA: I'm positive there will be
13 sections of the facility which will be dedicated to
14 observing the behavior of the underground -- you know,
15 holes.

16 MR. RUBINSTONE: I don't know if this will
17 make it in the DOE's final performance confirmation
18 plan but an earlier version did I believe call for
19 having one drip loaded early and little hotter than
20 average and have strain meters and such monitoring the
21 rock around it. That was in an early version. Like
22 I said, we'll see what we get with the LA in terms of
23 the PC plan, but I think they're thinking the same way
24 that you were with that comment.

25 DR. CLARKE: Very good, thank you.

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1 DR. HINZE: Thank you, Jim. John Pye?

2 MR. PYE: Yes, an excellent presentation,
3 Raj.

4 MR. NATARAJA: Thank you.

5 MR. PYE: Do you think several mechanical
6 models, numerical models capture all the processes
7 that lead to drift degradation?

8 MR. NATARAJA: When you say all the
9 processes, it's very difficult for me to say yes, but
10 if you would give me three or four of the bigger ones
11 then I'll say yes or no.

12 MR. PYE: Well, you threw out some
13 empirical terms, rubbing, spalling. There are other
14 terms we use in mining and geotechnical engineering
15 that do lead to different modes of drift degradation.
16 Do you think the models that DOE and the NRC are using
17 capture all those processes?

18 MR. NATARAJA: I would say there is a
19 serious attempt to capture all the processes. I mean,
20 the model doesn't distinguish between rubbing, you
21 know, displacing or breaking up and all that. The
22 only thing you can get in the model is you have a
23 stress/strength relationship and the value. You input
24 certain load which translates itself into stress and
25 the composite to whatever you assign as strength based

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1 on the stress/strength curve, and you define failure.
2 If you define failure as exceeding the strength,
3 that's serves our intent here. But in the DOE's case,
4 they have a slightly different arrangement where they
5 have these polygons which are attached to each other
6 and they are free to fall if they can detach
7 themselves from the main mass and that happens based
8 on the friction and the cohesion characteristics of
9 the joints, the interfacial connections between one
10 polygon and the other.

11 So again, that's another way of defining
12 the strength being exceeded. Not only the strength
13 instead of the main element, you know the strength of
14 the joint. So the strength of the joint is exceeded,
15 that polygon, if it's geometrically possible to detach
16 itself, it will detach itself. But that model chose
17 that. So if you can try various possible shapes and
18 sizes of these polygons, you can probably look at the
19 various things like the spalling, rubbling, et cetera,
20 et cetera.

21 MR. PYE: All right, you talk about
22 thermal hydrological process ultimately effecting the
23 end drift environment but you sort of separate thermal
24 mechanical and see thermal hydrological as a
25 consequence. If you put thermal hydrological and

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1 mechanical together, for example, the project asserts
2 that there's capillary diversion. Well, if there's
3 capillary diversion, there's going to be water close
4 to the drift profile. Do you see that as having an
5 impact on drift stability or drift degradation?

6 MR. NATARAJA: I probably -- I don't know
7 if I answered the question not having done an analysis
8 of that kind but I think it presents -- you're talking
9 about massive amounts of water flow or just some --

10 MR. PYE: Not massive, just joints that
11 are close to saturation.

12 MR. NATARAJA: Well, if the joints are
13 saturated with water, definitely it's going to reduce
14 the friction. So I expect under those conditions, it
15 would be easier for those different polygons to detach
16 themselves from the main body and fall off. But
17 again, I'm speculating here. I don't really -- it is
18 a very complicated problem. If you want a model,
19 thermal mechanical hydrological all together, it's
20 extremely difficult to.

21 MR. PYE: Okay, picking up some of the
22 earlier comments, it seems the conceptually that you
23 have quite a different model from DOE. You,
24 essentially, at this point using the same data sets
25 although you're going to re-investigate those. My

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1 question is, what value do parametric sensitivity
2 studies provide you with if you're going to compare
3 them with DOE if conceptually, you have different
4 models? When you talk about uncertainty, you're just
5 talking about parametric uncertainty.

6 MR. NATARAJA: Well, first of all, we have
7 to agree on whether the model itself is applicable to
8 the situation that is being analyzed. That's the
9 first question. Now, if you don't agree with the
10 model itself, then there's no point in looking at
11 uncertainty.

12 MR. PYE: Oh, I agree.

13 MR. NATARAJA: So I'm making the
14 assumption here that this model will be acceptable
15 because it is the state of the art model being
16 developed by experts in the field unless we find some
17 fundamental flaw in it. I haven't seen any such
18 thing. I'd probably leave it to the other experts in
19 the modeling area to make that comment, but having
20 said that, the -- there's always going to be questions
21 about the boundary conditions, the actual values that
22 you use for the parameter, such as the cohesion and
23 friction and the strength of the material itself.
24 Those things can be reviewed and questioned if we
25 don't agree with them.

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1 MR. PYE: Okay, you talked about your
2 staff's approach. It's a multi-discipline approach
3 and it needs to be integrated. You touched on thermal
4 hydrological issues in the context of these
5 environments may cause corrosion of the waste package
6 and drift shield. If I look at Slide 6, where will
7 the issue of in-drift environment be addressed? Which
8 discipline will address those conditions?

9 MR. NATARAJA: The material science people
10 will provide us the inputs for the thinning of the
11 metal with time.

12 MR. PYE: In corrosion issues there are
13 always two aspects. You ask the corrosion engineer
14 how long will the structure with this material, this
15 configuration, last and he will ask what's the
16 environment? So it's on that issue, who is going to
17 tell you what the environment is? You've got to
18 debris that. You're going to have a film of
19 conductivity. You're going to have conditions with
20 respect to heat transfer in those piles of debris.
21 Where will that information come from and how will it
22 be integrated?

23 MR. NATARAJA: We have one group who we
24 call Murphy (phonetic) chemistry people. That's the
25 group responsible for some of the things that you

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1 mentioned. And we also have a hydrology group which
2 -- thermal hydrology that are models at the Center
3 that have been used to calculate the very things that
4 you just mentioned. So we have integration between --
5 I didn't specifically mention thermal hydrology as a
6 separate group but there are activities going on
7 looking at just those kinds of things.

8 MR. PYE: All right, thank you.

9 DR. HINZE: That's it? Just a few
10 questions, Raj. The assumption that the ground
11 support, the stainless steel ground supports will
12 disappear at pre-closure, at end of pre-closure, how
13 conservative is this and is this possible to be
14 handled in a probabilistic manner in the assessment
15 rather than in a deterministic that's just gone?

16 MR. NATARAJA: Well, it is definitely
17 conservative to assume that it just vanishes at the
18 end of pre-closure period. It doesn't happen. It's
19 not like T equals 100, it just vanishes, but I don't
20 know wether we have a rational way of calculating the
21 effectiveness of -- this is meant to be a pre-closure
22 support system and it is designed with that life in
23 mind. It's not designed to withstand for hundreds and
24 hundreds of years. Probably 100 years is what they
25 would use as the base case, but I'm not sure.

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1 But it is conservative in the sense that
2 there is going to be some drift support in some parts.
3 But I think for your point of view, I think it is
4 reasonable to assume that it is not there. I mean, if
5 you use that, I don't think it is overly conservative
6 but I can't quantify --

7 DR. HINZE: Are there tests and evaluation
8 and laboratory work done to support this, the fact
9 that it will essentially for the end repository?

10 MR. NATARAJA: If you take credit for
11 that, then we will have a need to do that kind of
12 analysis. If they don't I don't see any -- I mean,
13 it's -- it is a conservative assumption but how
14 conservative it is and, you know, what does it do to
15 the overall performance, I don't think I can quantify
16 that.

17 MR. RUBINSTONE: This is DOE's choice to
18 not take credit for that ground support serving any
19 purpose after -- or during the post-closure analysis.
20 If they decide they want to take credit and they have
21 a basis for it, we'll evaluate it. It's not our
22 position to tell them to take credit for things that
23 they don't think they should take credit for.

24 DR. HINZE: And you have not evaluated it
25 at this point. Let me ask about setback distances. We

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1 all know that there are quite extensive fracture zones
2 associated with some portions of some faults. And as
3 I understand it, there is a certain setback distance
4 that DOE will assess to their -- to the repository.
5 Are you -- do you have any feeling for how large the
6 setback distances should be around any fault, around
7 any specific fault? How are you handling the analysis
8 of the setback distances?

9 MR. NATARAJA: I'll have to request some
10 help here but all I can say here is that if there is
11 a fault, they're going to avoid that. That's the
12 first thing they're going to do. You know, they're
13 not going to emplace waste knowing full well there is.

14 DR. HINZE: Right, but some of those
15 extend for meters.

16 MR. NATARAJA: Right, but they have a
17 criterion for these circumstances. If there is
18 somebody from geology or seismology that wants to
19 answer that question, there is a subtract distance
20 that they have assigned.

21 MR. IBRAHIM: Earlier we -- Marcus
22 Ibrahim. We have a setback 15 meters from the fault.
23 That's what we mentioned in one of the reports.

24 DR. HINZE: And that's regardless of what
25 fracturing might be found?

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1 MR. IBRAHIM: It depends what you call
2 fracture and what you call fault. So fracture is
3 completely different issue than faulting. And when we
4 talk about faulting that's a major displacement along
5 the fault which can cause an eruption to the waste
6 package.

7 DR. HINZE: Ten meters?

8 MR. IBRAHIM: Fifteen meters.

9 DR. HINZE: Fifteen? Going back to some
10 of the previous questions regarding analogues, the
11 drift scale heater test is potentially a very
12 important test to this entire problem of what -- of
13 which model is correct and which parameters are being
14 evaluated and I understand that you've not
15 incorporated that and I didn't understand that until
16 Jim explained that, that this is because of the fact
17 that it has not been totally decommissioned.

18 MR. NATARAJA: That's right.

19 DR. HINZE: You know, looking up there,
20 you see those slabs are pretty thin but we don't -- we
21 haven't looked at them all. What -- are we going to
22 have that information and if so, when are we going to
23 have that information and will you incorporate it to
24 test your models at that point?

25 MR. NATARAJA: I don't know that answer to

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1 when it is going to be available and if it is going to
2 be available but we have raised the issue of they have
3 calibrated their models using results of the field
4 test that they have collected. I don't think that we
5 are going to subject ourselves to that condition of --
6 it's DOE's responsibility to calibrate their models to
7 the extent they can with the available information.

8 And we have raised that question. As far
9 as our model is concerned, our model is a much
10 simplified model compared to theirs and our model
11 shows there's going to be spalling and whatever
12 leaking we can see there, we see spalling. To every
13 extent we have some calibration of our own model but
14 I'm not going to take credit for that and say that,
15 you know --

16 DR. HINZE: It would seem that validation
17 of the modeling that you're doing should be of pretty
18 high significance to the NRC.

19 MR. HILL: Britt Hill, NRC staff. I'd
20 like to provide a clarifying comment on this.

21 DR. HINZE: All right, Britt.

22 MR. HILL: There are some limitations to
23 the analogy from the heater test. First, the total
24 was mined for the heater test using Alpine mining
25 techniques, so it's not quite the same surface

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1 configuration, if you will, as what we would
2 potentially be seeing for the emplacement drifts at
3 Yucca Mountain. There also is a fairly large
4 stainless -- or a large support mesh sitting on the
5 roof of the heater test that is keeping any of the
6 spalling rock up in contact or very close to contact
7 with the ceiling itself. It's providing insulating
8 barrier and effecting the thermal gradient that you
9 would expect to see under a condition where all the
10 rock rubble was allowed to fall down.

11 So it does provide some useful insights on
12 the model or any potential model for drift
13 degradation, but it doesn't provide a good basis for
14 model validation. At best, we're getting some avenues
15 of support for some of the processes that were being
16 captured.

17 DR. HINZE: That's helpful, Britt. Let me
18 ask you then Britt, do we know that properties of the
19 added where the drift scale, the heater tests are
20 being conducted? Do we know those in detail so we can
21 relate to physical properties through the extent of
22 the spalling?

23 MR. NATARAJA: Yeah, I think that failure
24 has been entirely characterized and the properties so
25 that --

1 DR. HINZE: In detail so that that can be
2 related.

3 MR. HILL: But let's be clear though. The
4 models are not using a parameterization that
5 explicitly represents a specific set of rock
6 conditions. You're not looking at this exact fracture
7 density or fracture orientation. You're abstracting
8 that into a rock characteristic. So I don't want to
9 over-play the -- any individual segment of a drift may
10 behave very differently from the corresponding segment
11 because of these sorts of variations in rock
12 characteristic.

13 MR. RUBINSTONE: Another thing to remember
14 is that the models that the center has done and that
15 DOE has done are two-dimensional models on a cross-
16 section of a drift and in the repository drifts, those
17 will be bored out and will be relatively uniform with
18 slight variations in the rock height alone along the
19 strike of a drift. The drift scale heater test, I
20 think has much more heterogeneity in the types of
21 support that was put in and because of the tendency of
22 the outlying mine, so that the two-dimensional models
23 may be less representative of that alcove than they
24 would be of a drift.

25 DR. HINZE: Speaking about analogues, in

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1 terms of the effect of seismic, of ground motion on
2 drift degradation, as I recall I believe the 1992
3 Little Skull Mountain earthquake which was in the
4 upper crust was right underneath the X tunnel which
5 was cut into basalt, which of course, has not -- which
6 is more akin to the non-lithophysals rocks, but I
7 recall going into that and shortly after the
8 earthquake occurred, and could see no evidence of
9 degradation of the drift of the X tunnel from the
10 seismic activity.

11 Have you look at other analogues that
12 might be useful in terms of understanding the effect
13 of seismic ground motion?

14 MR. NATARAJA: We have not looked at the
15 particular analogue, of any other analogue other than
16 look at the potential review. In the literature we
17 have got, somebody took the trouble (inaudible)
18 somebody had not ventured a guess. Number one,
19 papers have come in after that. Basically, what
20 they've done is they've looked at number of mines,
21 number of tunnels, number of underground facilities.
22 They have documented what happened, did they fail,
23 what was the extent of failure, small amount of
24 failure, large amount of failure, intermediate, like
25 that. They have got a graph. I think it's Professor

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1 Downing and somebody else, Jude or someone.

2 Anyway, that is the compiled history of
3 number of facilities and number of different drop
4 types. That is what is generally used as an
5 indication of under what acceleration you might expect
6 failure. So there are some threshold values after
7 which you expect failure to take place, but then you
8 don't know the extent, how to take that average thing
9 that is based on number of rock types and number of
10 facilities, built using different techniques and all
11 that. When you use that, it gives you some idea but
12 you cannot exactly say, "This is what happens." But
13 I think we have some indication of damage, under a
14 given vibratory motion especially when it comes to
15 10^{-5} and beyond.

16 DR. HINZE: Let me ask -- our time is very
17 short here, but let me ask one final question and you
18 talked about your workshop at the Center where all of
19 the disciplines would get together to discuss their
20 impact upon the ISIs and so forth. Can you tell me
21 how the coupling of drift degradation with seepage and
22 with igneous activity were brought together and folded
23 in for information to be put into the total
24 performance assessment.

25 MR. NATARAJA: Seepage, yeah, definitely

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1 we had participation by people from thermal hydrology
2 group and in fact, they were represented in every one
3 of our discussions, not only in that workshop but also
4 in our interactions with DOE. So they've been
5 following -- I think what we're doing is first we are
6 looking at is there a potential for degradation and if
7 there is degradation, is there an impact on mechanical
8 performance? And is there an impact on the flow into
9 the drift.

10 DR. HINZE: How has that been incorporated
11 into the DPA? Have you given the parameters and so
12 forth, that will permit --

13 MR. NATARAJA: I think there is a section
14 which deals with the opening shapes and the in-flow.
15 I think Tim probably might be the better person to
16 answer that question.

17 MR. McCARTIN: In a fairly abstracted
18 manner, there are certain parameters to account for
19 how infiltration eventually ends up as seepage and
20 then ends up getting into the waste package and there
21 was some looking at say what seepage through rubble
22 piles might do in terms of getting into a waste
23 package. And so it just -- there's a -- there is some
24 flow parameters, yes.

25 DR. HINZE: How about the igneous

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1 activity?

2 MR. McCARTIN: Igneous activity, we
3 haven't done much with respect to altering
4 infiltration into say damaged waste packages for the
5 intrusion. The focus has primarily been in the
6 extrusive case where just because of the nature of the
7 probabilities and the releases, there's just -- in the
8 way it's modeled in TPA, the extrusive tends to be a
9 much more significant release.

10 DR. HINZE: But have you incorporated any
11 of the drift degradation into the intrusive scenarios?

12 MR. McCARTIN: Well, one can do it --
13 there's parameters to adjust that but have we done
14 explicit modeling to say okay, after a certain amount
15 of time, if intrusion occurred, and there was drift
16 collapse, it wouldn't occur, we haven't been -- we
17 haven't done the explicit modeling. It could be done,
18 though.

19 DR. HINZE: I think -- is the flexibility
20 built into the TPA to provide the because as I
21 understand it, you have --

22 MR. McCARTIN: For the smart user, I would
23 say. For the -- in that there isn't -- there isn't --

24 DR. HINZE: Excuse me, but the TPA is
25 being distributed to the world.

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1 MR. McCARTIN: Right, with a user's manual
2 that explains all the things you can and can't do.
3 There is -- there's not a direct coupling of say drift
4 collapse which -- and if you had an igneous intrusion,
5 and now the drift collapse would change the nature of
6 the intrusion, there is not an explicit coupling in
7 the TPA code for that. But you could do it with the
8 parameters that are in there for the intrusion case.
9 But you would have to look at the inputs and think
10 through the problem how you want to represent it and
11 you could represent it.

12 DR. HINZE: Dr. Hill would like to make a
13 comment.

14 DR. HILL: Thank you, Dr. Hinze, Britt
15 Hill, NRC staff. I just want to stress that the TPA
16 code is a review tool for staff and that we have a
17 range of alternative conceptual models that have to be
18 considered for igneous activity. As you've seen in
19 Raj's presentation, the information that our staff is
20 using would show that drift degradation may occur
21 early during the post-closure performance. In that
22 case, if you wanted to use the NRC's TPA tool, you
23 would adjust the parameter that's used for the igneous
24 scenario for intrusive to show a limited range of
25 waste package interactions with magma.

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1 However from what we've seen from the
2 available DOE information, their models would have the
3 drift staying open for potentially a very long period
4 of time. So we need that flexibility to have both an
5 adjusted parameter for limited interactions as well as
6 no interactions with a collapsed or partially
7 collapsed drifts.

8 DR. HINZE: Thank you very much. We -- it
9 is now one minute to 12:00 if I read that clock right.

10 CHAIRMAN RYAN: No, it's one minute after
11 12:00.

12 DR. HINZE: I read it the other way.

13 (Laughter)

14 DR. HINZE: Are there any other questions?
15 John?

16 MR. PYE: Empirical design methods, Cal
17 Carzigi (phonetic) in the 20s and 30s came up with
18 some empirical estimates of loosening load about
19 tunnel structures. Did you take those into account?
20 Did you compare them with your modeling estimates?

21 MR. NATARAJA: Yes, we did. Actually, in
22 calculating the static loading and estimating the
23 height of the rubble, and translating that into a
24 load, you might have seen in both the DOE's as well as
25 in our report, there are two curves, and there are a

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1 number of points from the analytical models. One of
2 those curves represents the design view. So we have
3 taken that into account in the empirical calculations.

4 MR. PYE: Well, in hard rock conditions as
5 opposed to non-cohesive material, near surface tunnel
6 structures, what are we looking at, 1.5 or 2B, the
7 width of the excavation in terms of extent or where
8 are your models putting the extent of loosening, 2B,
9 3B or --

10 MR. NATARAJA: I would have to request --
11 who would like to answer that question but I think
12 what we have looked at is the two cases of one
13 trapezoidal shape, other one is a chimney elliptic
14 shape and I think vertical elliptic shape, if you look
15 at the h-max here, I don't have the actual number of
16 it, it at least is -- if this is clear it is at least
17 three times the diameter or something but I'm not sure
18 whether it is to scale. Maybe Goodluck wants to
19 elaborate on that.

20 DR. HINZE: Can we make is extremely
21 brief?

22 MR. OFOEBU: Yes, Raj, the difference in
23 the shape of the collapsed (inaudible) you end up
24 making with the tunnel the largest laterally and
25 vertically and that is you try (inaudible). Then the

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1 other option of course, is a tunnel that grows like a
2 chimney but it (inaudible) and that's you know, we got
3 (inaudible).

4 DR. HINZE: Thank you very much. I think
5 we're going to have to cut it off at that point.
6 Since there are no other indications that there is a
7 burning question, I will pass it off to you, Dr. Ryan
8 and four minutes early?

9 CHAIRMAN RYAN: No, in geologic space
10 perhaps. Raj, thank you, it's been an interesting
11 discussion and presentation. So we really appreciate
12 your time this morning and thank you very much and
13 with that, we'll adjourn the morning session and
14 reconvene for our letter writing at 1:00 o'clock.

15 (Whereupon, at 12:04 p.m. the above-
16 entitled matter recessed, to reconvene at 1:00 p.m.
17 the same day.)

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CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on
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184th Meeting

Docket Number: n/a

Location: Rockville, MD

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.



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Drift Degradation and its Impacts on Engineered Barrier System Performance

Review Approach and Capability

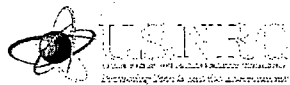
Briefing To ACNW&M

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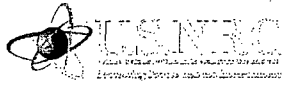
Contributors: Dr. Goodluck Ofoegbu and Dr. Luis Ibarra
(CNWRA)

November 13, 2007



Outline

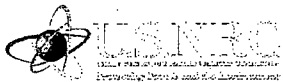
- Purpose
- Background
- Significance of Drift Degradation
- Related Staff Activity
- Current Understanding of DOE Approach
- Alternate Modeling Scenarios
- Staff Review Approach
- Staff Review Capability
- Recap
- Summary and Conclusions



Purpose

- Present Current Staff Understanding of Drift Degradation Process in the Context of Mechanical Disruption of Engineered Barrier System
- Describe Staff Approach and Capability to Review DOE's Analyses in a Potential License Application for a HLW Repository at Yucca Mountain

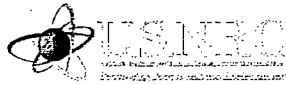
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Background

- Key Technical Issue (KTI) Agreements
- Drift Degradation Analysis Model Report (AMR)
- Detailed Staff Review of AMR
- Independent Analyses by Staff to Risk-Inform Understanding of Drift Degradation Process and its Potential Impacts on Engineered Barriers System (EBS) Performance

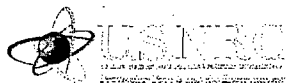
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Background – Recent Activities

- NRC-CNWRA Workshop (March 2006)
- Summary of Current Understanding of Drift Degradation and its Effects on Performance (Report, August 2006)
- Independent Analyses of Drift, Drip Shield and Waste Package Mechanical Performance
- Review Approach Development
- Development of Parameter Distributions for Abstractions in NRC TPA Code
- NRC-DOE Interaction (October 2007)

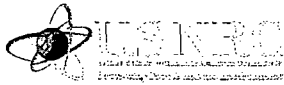
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Background – Disciplines Involved

- Geology
- Seismology
- Rock Mechanics and Mining Engineering
- Structural Mechanics and Earthquake Engineering
- Materials Science
- Performance Assessment

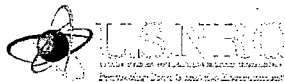
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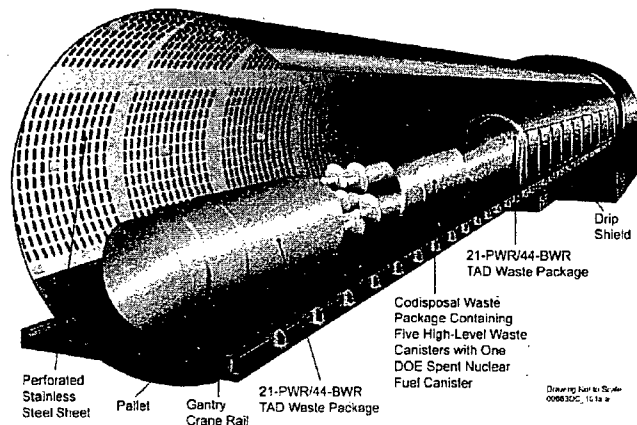
Background – DOE Design

- Excavation by Tunnel Boring Machine (TBM)
- Stainless Steel Bolts and Perforated Sheets Provide Ground Support During Pre-closure Period
- The Drip Shield Protects the Waste Package from Impacts of Falling Rock and Contact by Dripping Water During Post-closure Period
- Waste Package Consists of an Exterior Cylinder Made of Alloy 22 and an Internal Stainless Steel Cylinder
- The Waste Package Rests on a Pedestal (Pallet)
- The EBS is Supported on a Crushed Tuff Bed (Invert)

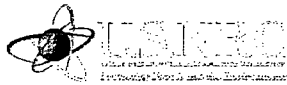
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Background – Waste Emplacement Drift

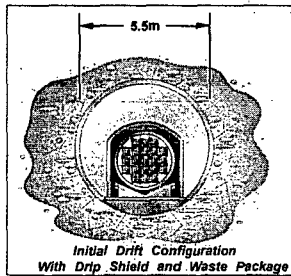


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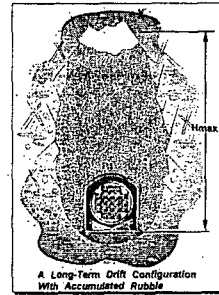
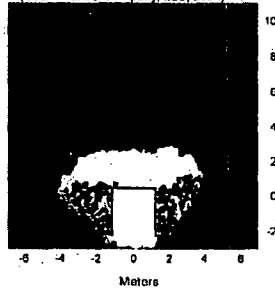


Background – Drift Configurations

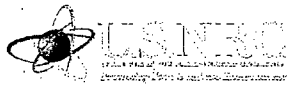
- Initial and Potential Long-Term Emplacement Drift Configurations



A Long-Term Drift Configuration With Accumulated Rubble from Figure 6-162(b), p. 6-212, Drift Degradation Analysis Rev 03 (Bechtel SAIC Company, LLC, 2004)



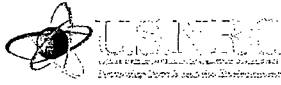
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Background – Causes of Failure of Underground Openings

- In-Situ Stress Conditions Change Because of:
 - Excavation (Mechanical Stresses)
 - Heat (Thermal Stresses)
 - Earthquakes (Seismic Stresses)
- Any one Stress by Itself or in Combination with Others may Cause Rock “Failure”
- Failure May be due to Strength being Exceeded or due to Excessive Deformation

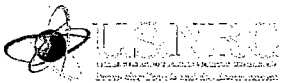
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Background – Terminology

- Rockfall (Individual Pieces of Rocks – Small and Large – Falling from Exposed Surfaces of Underground Excavation)
- Drift Collapse (Massive Failure of Large Volume of Rock Crashing Down)
- Drift Degradation (Gradual Change in Drift Configuration from Thermal Spalling and/or Seismic Shaking)
- All of the Above Result in Rubble Accumulation

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Significance of Drift Degradation Pre-closure period

- DOE Plans to Install Ground Support to Provide Stable Underground Openings During Pre-closure Operations
- Adequacy of Ground Support Design to be Determined in the Context of Pre-closure Performance Objectives
- DOE Takes No Credit for Ground Support Performance Beyond Pre-closure Period.

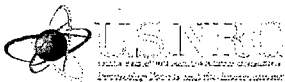
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Significance of Drift Degradation Post-closure Period

- Ground Support not Relied upon for Long-Term Stability
- Uncertainty in Predicting Long-Term Stability of Underground Openings Under Thermal and Seismic Conditions is High
- Rockfall, Drift Collapse and Drift Degradation Could Occur During the Long Regulatory Period and Impact the EBS Mechanical Performance
- Focused Staff Review may be Needed Because of the Potential Significance to Overall Performance

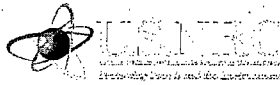
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Staff Activity Related to LA Review Preparation

- Pre-licensing Review of DOE Reports
- Limited Independent Analyses Focused on Areas of High Potential Importance and/or High Uncertainty
- Development of Stepwise Review Approach
- Development of Abstraction Models and Parameter Distributions for NRC TPA Code

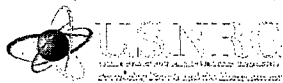
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Current Understanding of DOE Approach

- **Emplacement Drifts Remain Stable for a Long Time Under Expected Mechanical and Thermal Conditions**
- **Drifts May Collapse Under Strong Seismic Events**
- **Drip Shields can Withstand the Potential Rock Impacts and Accumulated Rubble (i.e., Static Loading) Under the Expected Thermal and Chemical Environment**
- **Generalized Corrosion Could Decrease Drip Shield Capacity**

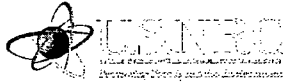
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Current Understanding – Cont.

- **Drip Shields May Collapse and Mechanically Interact With Waste Packages Due to Very Strong Seismic Events**
- **The Main Failure Mechanism Contributing to Waste Package Damage is Dynamic Interaction with Other Engineered Barriers During Seismic Events Under Stable Drip Shields**

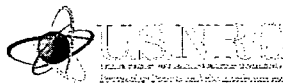
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Alternate Modeling Scenarios

- Independent Interpretation of Data and Alternate Conceptual Models Suggest:
 - Thermal Stresses Could Exceed Rock Strength and Result in Spalling of Thin Layers of Rock Around the Emplacement Drifts
 - Accumulated Rubble Load Could Lead to Structural Instability of Drip Shields
 - Demands During Seismic Events May be Several Times Larger Than the Drip Shield Capacity

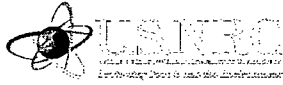
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Alternate Modeling Scenarios – Cont.

- Independent Interpretation of Data and Alternate Conceptual Models Suggest:
 - A Collapsed Drip Shield Leads to Drip Shield-Waste Package Mechanical Interaction and May Result in:
 - Localized Corrosion of Waste Packages
 - Waste Package Mechanical Damage Under Strong Seismic Events.
 - Creep, General Corrosion, Temperature Effects and Pallet/Invert Degradation May Further Adversely Impact EBS Mechanical Performance

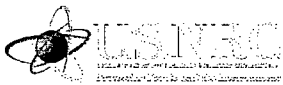
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Staff Review Approach

- Check if DOE:
 - Appropriately Considers Site Characteristics (Joints, Fractures, Voids), Material Properties (Stress-Strain Characteristics and Strength Parameters)
 - Considers Appropriate Conceptual Models and Failure Criteria
 - Employs Reasonably Calibrated/Validated Models
 - Considers Reasonable Ranges of Conditions and Parameter Distributions to Account for Uncertainty and Variability

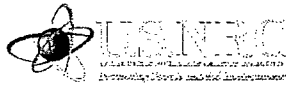
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Staff Review Approach – Consideration of Independent Analyses

- Process Level:
 - Potential for Buckling of Drip Shields Under Static Loads Due to Rubble Accumulation
 - Potential for Drip Shield-Waste Package Interaction
 - Potential for Waste Package Damage Under Seismic Events
- TPA Abstractions:
 - Potential Long-Term Impacts of Drift Degradation – Both Due to Thermal and Seismic Stresses – on EBS Performance

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Staff Review Approach – Secondary Considerations

- Separation of Intact Drip Shields as a Potential Failure Mode
- Individual Rockfall Impacts as a Potential Failure Mode for Drip shield
- Waste Package Damage due to Faulting Events

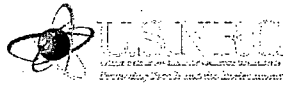
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Review Approach -- Summary

- Rock Degradation and Rubble Accumulation →
- Load Distribution From Rubble Accumulation →
- Drip Shield Structural Performance and Potential Drip Shield Failure →
- Potential Load Transfer to Waste Packages →
- Potential Waste Package Damage →
- Potential Consequences?

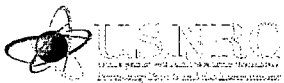
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Review Capability

- Between the NRC and CNWRA
- Extensive Knowledge and Experience in:
 - Analytical Methods and Numerical Modeling of Continuous and Discontinuous Media
 - Rock Mechanics and Mining Engineering
 - Structural Mechanics and Earthquake Engineering
 - Licensing Reviews and Hearings

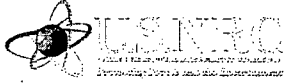
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Recap

- Provided Background
- Discussed Significance of Drift Degradation in the Context of EBS Performance
- Summarized Current Understanding of DOE Approach
- Discussed Highlights of Independent Analyses
- Presented Review Approach and Staff Capability

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Summary and Conclusion

- Staff Understands DOE Approach of Considering the Effects of Drift Degradation on EBS Mechanical Performance
- Staff Continues to Perform Limited Independent Analyses to Focus Review Efforts and Enhance Review Capability
- Staff Review Approach is Flexible and Considers Alternate Conceptual Models and a Range of Reasonable Conditions Both at the Process Level and at the Abstraction Level