

**Official Transcript of Proceedings**  
**NUCLEAR REGULATORY COMMISSION**

Title: Advisory Committee on Reactor Safeguards  
Regulatory Policies and Procedures

Docket Number: (n/a)

Location: Rockville, Maryland

Date: Wednesday, April 25, 2012

Work Order No.: NRC-1567

Pages 1-398

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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REGULATORY POLICIES AND PROCEDURES SUBCOMMITTEE

+ + + + +

WEDNESDAY

APRIL 25, 2012

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B1, 11545 Rockville Pike, at 8:30 a.m., William Shack, Chairman, presiding.

SUBCOMMITTEE MEMBERS PRESENT:

WILLIAM J. SHACK, Chairman

SAID ABDEL-KHALIK

J. SAM ARMIJO

DENNIS C. BLEY

CHARLES H. BROWN, JR.

MICHAEL CORRADINI (via telephone)

HAROLD B. RAY

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1 JOY REMPE  
2 MICHAEL T. RYAN  
3 STEPHEN P. SCHULTZ  
4 GORDON R. SKILLMAN  
5 JOHN W. STETKAR

6 CONSULTANTS TO THE SUBCOMMITTEE PRESENT:

7 THOMAS S. KRESS  
8 GRAHAM B. WALLIS

9 NRC STAFF PRESENT:

10 HOSSEIN NOURBAKSH, Designated Federal  
11 Official

12 KATHY H. GIBSON  
13 RICHARD CHANG  
14 JASON SCHAPEROW  
15 RANDY SULLIVAN  
16 TINA GHOSH  
17 PATRICIA SANTIAGO  
18 MARTY STUTZKE

19 ALSO PRESENT:

20 MARK LEONARD  
21 RANDY GAUNTT  
22 JEFF GABOR  
23 PATRICK MATTIE  
24 NATE BIXLER  
25 ED LYMAN

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24  
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CONTENTS

Opening Remarks . . . . . 4

Overview and Objectives . . . . . 9

Updated Peachbottom Analysis . . . . . 25

Updated Surry Analysis . . . . . 129

Fukushima vs SOARCA . . . . . 187

Peer Review Comments . . . . . 211

Public Comments . . . . . 238

Uncertainty Analysis . . . . . 258

Adjourn

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

8:29 a.m.

1  
2  
3 CHAIR SHACK: The meeting will now come to  
4 order. This is the meeting of the ACRS Subcommittee  
5 on Regulatory Policies and Practices. I'm Bill Shack,  
6 chairman of this Subcommittee. Members in attendance  
7 are Said Abdel-Khalik, Sam Armijo, Dennis Bley,  
8 Charlie Brown, who will be here in a few minutes; he's  
9 been delayed somewhat, Harold Ray, Joy Rempe, Mike  
10 Ryan, Steve Schultz, Dick Skillman and John Stetkar.

11 Mike Carradini is also participating  
12 through the bridge line, and hopefully it will work  
13 better. We apparently have a new phone, so we'll see  
14 if that cuts down the noise. Also in attendance are  
15 ACRS consultants Tom Kress and Graham Wallis.

16 The purpose of this meeting is to discuss  
17 the state of the art reactor consequence analysis  
18 SOARCA project. The Subcommittee will gather  
19 information, analyze relevant issues and facts, and  
20 formulate proposed positions and actions as  
21 appropriate for deliberation by the full committee.  
22 Dr. Hossein Nourbaksh is the designated federal  
23 official for this meeting.

24 The rules for participation in today's  
25 meeting have been announced as part of a notice of

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1 this meeting previously published in the *Federal*  
2 *Register* on March 28, 2012. A transcript of the  
3 meeting is being kept and will be made available as  
4 stated in the *Federal Register* notice.

5 It is requested that speakers first  
6 identify themselves, use one of the microphones, and  
7 speak with sufficient clarity and volume so that they  
8 can be readily heard. We have received no written  
9 comments or request for time to make oral statements  
10 from members of the public regarding today's meeting.

11 This happens to be the second consequences  
12 analysis that we've been discussing in the thing. We  
13 did spent fuel pool last time, and reactor  
14 consequences, severe accident consequences, not for  
15 the reactor. I just sort of want to reiterate, John  
16 Stetkar's motive.

17 It is what it is. So we're looking at the  
18 consequences of some selected sequences. We do want  
19 to look at the way those sequences were selected, that  
20 choice of scenarios, and again, I think another  
21 interesting conflict is what we mean by best estimate,  
22 in terms of something that has very large  
23 uncertainties, and hopefully we'll get some insight  
24 from that today.

25 We have a lot of material to get through

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1 today, so I'm going to just keep these remarks short  
2 and what the staff did. Kathy Gibson at the Office of  
3 Nuclear Reactor Research, I think, wants to provide an  
4 opening statement.

5 MS. GIBSON: Hi. I'm Kathy Gibson. I'm  
6 the Division Director for the Division of Systems  
7 Analysis and Research, and my division was the lead  
8 for this project, although we've had many people from  
9 the NRC and also our colleagues at Sandia, Dycoda and  
10 other offices within Research that helped us with it.

11 Today, we plan to present work to you that  
12 has been done on SOARCA since we last met with you in  
13 June of 2010, and I think we've met with you, I don't  
14 know, about a handful of times over the course of this  
15 project. So we intend to cover what we've done since  
16 we last met with you.

17 Since that time, we completed a peer  
18 review, and we've published a variety of NUREGS  
19 documenting the SOARCA work for public comment. We  
20 recently conducted public meetings at the two plant  
21 sites, in Pennsylvania and Virginia, the Peach Bottom  
22 and Surry plants.

23 Over the past year, we've completed  
24 reanalysis based on input from the peer reviewers and  
25 also from the licensee. We interacted with our

1 external peer review committee and we incorporated NRC  
2 staff comments from throughout the NRC on the  
3 documentation.

4 Additionally, substantial work has been  
5 performed on the SOARCA uncertainty analysis, and I  
6 know you have great interest in that topic. In that  
7 one of the plants that we analyzed in SOARCA, the  
8 Peach Bottom plant, is similar in design to Fukushima,  
9 there's been a lot of interest in comparisons between  
10 what we predicted in SOARCA for Peach Bottom station  
11 blackout and the Fukushima site.

12 So we have done some comparisons there,  
13 and our analysis and Fukushima shows that severe  
14 reactor accidents, even when unmitigated, they proceed  
15 more slowly, and radiological releases are smaller  
16 than what we previously thought.

17 So there's more time for evacuation, and  
18 as a result, there were no early fatalities predicted  
19 in SOARCA or at Fukushima. SOARCA predicted the  
20 individual risk of latent cancer fatalities to be  
21 millions of times lower than the general U.S. cancer  
22 fatality risk, and well within the Commission's safety  
23 goals, and only time will tell, of course, with  
24 Fukushima.

25 Finally, SOARCA analysis shows that

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1 successful mitigation will prevent core damage, or  
2 delay or reduce radiological releases. You will hear  
3 details about these activities today from NRC staff,  
4 our colleagues at Sandia and Dycoda, and a  
5 representative from the external peer review  
6 committee, and we look forward to your questions and  
7 comments.

8 I'll turn the floor over to Richard Chang,  
9 who's our project manager for this --

10 CHAIR SHACK: Richard, just before you  
11 start, Mike can you hear us? Can we hear you?

12 MEMBER CORRADINI: Are you talking to me,  
13 Bill?

14 CHAIR SHACK: Yes, talking to you. Okay,  
15 we hear you.

16 MEMBER CORRADINI: Yes, I can hear you,  
17 yes. There's a lot of paper shuffling, but that's  
18 pretty normal.

19 CHAIR SHACK: Okay. Well, you're not  
20 making a whole lot of noise so --

21 MALE PARTICIPANT: Yes, it's a big  
22 improvement.

23 CHAIR SHACK: Well, you told me to be  
24 quiet, so I'm trying to do my best.

25 (Laughter.)

1 MR. CHANG: Thank you. Hello. I'm  
2 Richard Chang. I'm the project manager for the SOARCA  
3 project, and one of the folks working as a program  
4 manager for it. I'll be providing an overview of some  
5 of the previous SOARCA briefings to the ACRS.

6 I will also be discussing the SOARCA  
7 conclusions for Peach Bottom and Surry, as well as  
8 providing an update on the project status from when we  
9 briefed you last, in the summer of 2010.

10 In 2006, NRC briefed the ACRS on the  
11 objective of SOARCA, which is to develop a body of  
12 knowledge on the realistic outcomes of severe reactor  
13 accidents.

14 We also briefed the ACRS on our approach,  
15 which was to use detailed integrated modeling of  
16 accident progression within MELCOR, and the modeling  
17 of off-site consequences within MACCS, to predict the  
18 likely outcomes for a significant but still remote  
19 core melt accidents.

20 In the 2007 time frame, NRC staff briefed  
21 the ACRS on scenario selection, MELCOR and MACCS  
22 improvements as part of SOARCA, SOARCA insights, as  
23 well as mitigative measures, and then began the  
24 process of the peer review in the late 2008 and 2009  
25 time frame.

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1                   In June 2010, NRC staff updated the ACRS  
2                   on the status of the peer review committee  
3                   interactions, as well as the status of the licensee  
4                   fact checks and NRC staff comment resolutions.

5                   I guess with the first bullet, SOARCA  
6                   demonstrates the potential benefits of employing 10  
7                   C.F.R. 5054 mitigation for the scenarios analyzed.  
8                   When successful mitigation is assumed, major core  
9                   damage is averted for all scenarios, but the Surry  
10                  short-term station blackout and its variant, the  
11                  short-term station blackout with thermally induced  
12                  steam generator and tube rupture.

13                  For the mitigated short-term station  
14                  blackout at Surry, containment failure is delayed by  
15                  an additional 41 hours, and for the mitigated  
16                  thermally-induced steam generator tube rupture at  
17                  Surry, containment failure is delayed by an additional  
18                  46 hours.

19                  However, since this is a bypass scenario,  
20                  you have small releases beginning at approximately 3-  
21                  1/2 hours. In addition, the SOARCA analyses indicate  
22                  that all modeled accident scenarios, even if operators  
23                  are unsuccessful in mitigating the accident, progress  
24                  more slowly and release much smaller amounts of  
25                  radioactive material than early studies.

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1           The earlier study that I'm referencing is  
2           the Sandia siting study, mainly Sandia siting study  
3           Source Term 1. As a result, public health  
4           consequences from severe nuclear plant accidents are  
5           smaller than previously calculated.

6           CONSULTANT KRESS: Is this primarily due  
7           to the change in the rate that things get released, or  
8           is there some difference in the source term other than  
9           being slowed down?

10          MR. CHANG: Sure, and part of it is  
11          because, and I'll go into it in the next slide, if  
12          you'll allow me. Sorry. I guess ultimately, to  
13          answer the question, SST-1, the release begins at  
14          approximately an hour and a half, whereas aside from  
15          the thermally-induced steam generator tube rupture,  
16          which begins at around 3-1/2 hours, you have the Peach  
17          Bottom short-term station blackout, and just to define  
18          what SOARCA defines as short-term station blackout as,  
19          it's the loss after the seismic initiator. It's the  
20          immediate loss of AC and DC.

21          The next quickest one would be Peach  
22          Bottom short-term station blackout, and the release  
23          begins at approximately eight hours.

24          CONSULTANT KRESS: So there's a difference  
25          in timing and the amount in the source term?

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1 MR. CHANG: Yes, yes, and just to get into  
2 it a little bit, for the unmitigated long-term station  
3 blackout at Peach Bottom and Surry, core damage begins  
4 at 9 to 16 hours respectively, and releases begin at  
5 20 hours for Peach Bottom and 45 hours for Surry.

6 Now for the unmitigated short-term station  
7 blackout, which is immediate loss of AC and DC,  
8 releases begin at eight hours for Peach Bottom and 25  
9 hours for Surry. The ISLOCA releases, which is also  
10 a bypass scenario, for the unmitigated scenario, the  
11 release begins at approximately 13 hours. Like I  
12 stated before, SST-1 begins at one and a half hours.

13 Now in terms of magnitude, for SST-1  
14 iodine is approximately 45 percent and cesium is  
15 approximately 67 percent, whereas for the SOARCA  
16 scenarios, it's a maximum of 15 percent for the ISLOCA  
17 scenario, ten percent for I have -- for the short-term  
18 station blackout for Peach Bottom, and around two  
19 percent for the other scenarios, or it may be less.

20 Now for cesium, they're all approximately  
21 two percent or less for the SOARCA unmitigated  
22 scenarios. Related to that, the delayed release is  
23 calculated, as Kathy said before, to provide more time  
24 for emergency response actions, such as evacuating or  
25 sheltering in place.

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1           Due to this, latent cancer fatality risk  
2 is generally dominated by the return criteria, which  
3 is, I guess, the long-term latent cancer fatality  
4 risk.

5           MEMBER CORRADINI: Can you repeat? I'm  
6 sorry. You said the latent cancers are dominated by  
7 what again? I'm sorry.

8           MR. CHANG: By the return criterion or the  
9 habitability criterion.

10          MEMBER CORRADINI: And you'll go back into  
11 that later, I assume?

12          MR. CHANG: Well, I can touch on it right  
13 now. What the return criterion, it's set by the state,  
14 and hopefully Joe will correct me if I'm wrong.

15                 It's set by the state, and it's a state  
16 limit for when folks, after hypothetical severe  
17 accident, when folks can return to live on the land,  
18 or use it for its original purposes.

19          MEMBER CORRADINI: So if I -- just let me  
20 push the point. So you're saying in Virginia, there's  
21 one policy and in Pennsylvania there's another policy?

22          MR. CHANG: There are actually two  
23 separate -- I believe Virginia follows EPA guidelines,  
24 which is two rems per year for the first year, and  
25 then after that, 500 millirem per year thereafter,

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1           okay, and Pennsylvania has a policy of 500 millirem  
2           per year throughout.

3                         MEMBER CORRADINI:   Okay, thank you.

4                         CONSULTANT KRESS:   Is this associated with  
5           the linear no threshold assumption also, in the sense  
6           that you're going to calculate the consequences of  
7           them being there forever after they come back?

8                         MR. CHANG:   I believe so, but hopefully  
9           someone else can step in to answer more clearly.

10                        MEMBER SCHULTZ:   To ask it differently --

11                        MR. CHANG:   Sure.

12                        MEMBER SCHULTZ:   You're presenting some  
13           conclusions in general qualitative terms?

14                        MR. CHANG:   Yes.

15                        MEMBER SCHULTZ:   Are those conclusions  
16           based on a linear no threshold model, or are they  
17           assuming a threshold?

18                        MR. CHANG:   They're based on LNT.   But we  
19           also have a couple of threshold calculations as well  
20           within SOARCA.

21                        MEMBER SCHULTZ:   And I understand we'll  
22           see those later?

23                        MR. CHANG:   I believe so, but I could talk  
24           through them a little bit now.   Sure.

25                        MR.   SCHAPEROW:   We don't have any

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1 presentation material on that today. We did show that  
2 at the last ACRS meeting. The off site consequences  
3 are a lot smaller with a threshold model, as  
4 expected, up to a factor of 100 smaller, especially  
5 because, you know, the threshold model in some cases  
6 is above 500 millirem per year.

7 MR. SULLIVAN: The return criteria, I  
8 believe you asked a question -- Randy Sullivan, part  
9 of the SOARCA team. You asked about the return  
10 criteria. Perhaps there's a nexus to linear no  
11 threshold.

12 I think the state just took a conservative  
13 view or what they considered to be a conservative  
14 view, and reduced the habitability criteria from the  
15 EPA recommendation of two rem in the first year, 500  
16 millirem thereafter, to 500 millirem every year.  
17 That's not a decision we were involved in. It just  
18 simply is what's written into the state plan.

19 I suppose there is a nexus too LNT in  
20 there somewhere, but it had little to do with SOARCA.  
21 We just followed the state plan.

22 CONSULTANT WALLIS: Can I ask you  
23 something about the scenario selection?

24 MR. CHANG: Sure.

25 CONSULTANT WALLIS: Earthquakes look

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1 pretty bad. The stuff now on the Internet about huge  
2 solar flare-ups, which supposedly can knock out the  
3 grid, damage may be to electrical systems in the  
4 plant, and maybe worse, knock out all communications  
5 and damage electronics on vehicles so people can't  
6 evacuate.

7 Is this a fantastic scenario, or have you  
8 somehow evaluated it?

9 MR. CHANG: As far as I'm aware, I don't  
10 think we evaluated solar flares. But for that one, I  
11 might have to defer to Marty Stutzke for scenario  
12 selection.

13 MR. SULLIVAN: This is sort of odd. Randy  
14 Sullivan, and I happen to be working on a task force  
15 at NRC regarding solar flares. We have a petition for  
16 rulemaking regarding what to do about solar flares.

17 The technical evaluations of solar flares  
18 are not conclusive as far as we're concerned. We see  
19 some agencies saying it's a "oh never mind," and  
20 others thinking it's a total disaster.

21 What we are fairly sure of, and we prefer  
22 to have deeper technical work to our standards before  
23 we made our mind up totally, is that emergency diesel  
24 generators survive through this event, no matter what.

25 The issue comes down to is their fuel

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1 supplies in a societal degradation, in a state of  
2 societal degradation. So we're focusing on, you know,  
3 most plants have seven days' worth of fuel supplies  
4 and probably more. We're focusing on how to make sure  
5 the generators run as long as they need to run, should  
6 there be a sustained outage.

7 CONSULTANT WALLIS: That's very good for  
8 the plant, but how about the people? I mean can they  
9 learn about it and can they evacuate?

10 MR. SULLIVAN: They don't have to evacuate  
11 if the generators are running.

12 CONSULTANT WALLIS: No, that's right. But  
13 if there are releases --

14 MR. SULLIVAN: But there's no releases if  
15 you have electricity or batteries, for that matter.  
16 So that's what we're focusing on, is plant safety.

17 CONSULTANT WALLIS: But you're looking at  
18 it. That's very good, and perhaps it will be an  
19 appendix to the SOARCA or something?

20 MR. SULLIVAN: No, it will not. It's a  
21 separate issue.

22 CONSULTANT WALLIS: It will not? A  
23 separate issue.

24 MR. SULLIVAN: Under a petition for  
25 rulemaking, and I don't know if that comes before you

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1 or not. I haven't got that far.

2 CONSULTANT WALLIS: Well, I can tell  
3 people who work, who ask me about this, that you're  
4 working on it.

5 MR. SULLIVAN: We are working on it, and  
6 from at least a staff perspective, we consider this to  
7 be a potential natural disaster, not as serious as a  
8 tsunami, but something that could affect society at  
9 large, and we want to make sure that our licensees are  
10 prepared.

11 CONSULTANT WALLIS: Thank you.

12 MEMBER CORRADINI: I had a question, if I  
13 could just go back to Slide No. 5.

14 MR. CHANG: Sure.

15 MEMBER CORRADINI: So you in Slide 5, you  
16 compare it to SST-1. I'm curious. There are other  
17 release categories in the '82 report. So from a  
18 comparison standpoint, what do these releases compare  
19 to, because clearly they don't compare to the SST-1.  
20 They're much lower.

21 MR. SCHAPEROW: This is Jason Schaperow on  
22 the NRC staff. The SST-1 source term in the siting  
23 study is a release from a reactor accident where  
24 there's no mitigation. It is an accident which  
25 basically injection is lost; the core melts and the

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1 release happens.

2 The other source terms in the siting study  
3 have mitigation. They have, for example, the SST-2  
4 has containment sprays. So what we're trying to do is  
5 we're trying to compare our calculations without  
6 mitigation to what's in the siting study. So that's  
7 why we chose SST-1.

8 MEMBER CORRADINI: And so just to be  
9 clear, without mitigation, implying still some sort of  
10 containment failure and physical processes are the  
11 only thing that make the difference, or are there also  
12 -- I thought embedded in the green and the red lines  
13 and the orange lines are operator actions?

14 MR. SCHAPEROW: Yes. There are operator  
15 actions in there. These are actions that the  
16 operators would take in accordance with their  
17 procedures. But these are actions that they would  
18 take regardless of what kind of accident it was, but  
19 these are not actions that would prevent the release.

20 These are just actions that they would  
21 take under any circumstances. So if we had an  
22 accident -- if we were back in 1982 doing this  
23 analysis, and we did it in a more detailed fashion, we  
24 would include those operator actions as well, I  
25 believe.

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1 MR. CHANG: Those are not the --

2 MEMBER CORRADINI: Okay. I'm just trying  
3 to compare apples to apples, and I just want to  
4 understand why you chose this as the comparison.

5 MR. SCHAPEROW: Yeah, and actually as an  
6 example, when I get into the ISLOCA discussion a  
7 little later this morning, I'll try to make that very  
8 clear, as to what we mean by mitigated and  
9 unmitigated.

10 MEMBER CORRADINI: All right, thank you.

11 CONSULTANT KRESS: That's surprising me,  
12 the 1982 reference, because I thought those mitigating  
13 features were a result of what you would do in case an  
14 airplane crashed into the --

15 MR. SCHAPEROW: Yes. Some of the  
16 mitigating features are just operators, like the  
17 pressure of taking the steam generators and using them  
18 to start cooling down the plant. Now that's not going  
19 to prevent the release, but in the old days, we didn't  
20 necessarily take all that stuff into account. So our  
21 earlier realistic analysis of a release didn't include  
22 those actions.

23 CONSULTANT KRESS: Mitigating versus  
24 unmitigating has to do with the standards that you  
25 develop --

1 MR. SCHAPEROW: Has to do with the --  
2 that's right. Has to do with new stuff, B.5.b, the  
3 new accident management guidelines, not the existing  
4 procedures from before.

5 CONSULTANT KRESS: Okay, thank you.

6 MR. SCHAPEROW: Anyway, I hope to clarify  
7 again a little bit more when we talk about the ISLOCA.

8 MR. CHANG: And related to that,  
9 individual early fatality risk is essentially zero for  
10 all SOARCA scenarios, and just on this slide, we're on  
11 Slide 6, SOARCA's absolute, individual latent cancer  
12 fatality risks are millions of times lower than the  
13 U.S. average annual cancer fatality risk, from all  
14 causes, which is approximately 2 times 10 to the minus  
15 3. The safety goal is shown to provide context for  
16 the SOARCA scenarios.

17 Now I just wanted to provide an overview  
18 of a status update from the last time we briefed you,  
19 and since the last time we briefed, we have new or  
20 revised analyses, based on input from the plant fact  
21 check comments, as well as the external peer review  
22 committee comments.

23 We've reanalyzed the short-term station  
24 blackout, but at Peach Bottom we've reanalyzed the  
25 short-term station blackout, with RCIC blackstart,

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1 assuming blackstart at one hour instead of ten minutes  
2 previously.

3 The licensees came back to us as part of  
4 their plant fact checks and said they didn't think ten  
5 minutes was a realistic time estimate. Mark Leonard  
6 will discuss our additional analyses on SRV failure  
7 criteria, based on comments from the peer review  
8 committee, as well as traversing in-core probe  
9 systems at Peach Bottom.

10 Randy Gauntt will discuss the distribution  
11 of risk to barium and cerium in the short-term station  
12 blackout versus long-term station blackout scenarios  
13 at Peach Bottom. At Surry, as Jason mentioned before,  
14 we reanalyzed the Surry ISLOCA scenario, based on a  
15 licensee fact check comment, and Jason Schaperow will  
16 discuss this in more detail.

17 We also adjusted the core pump flow rates  
18 in the mitigated long-term station blackout, but  
19 ultimately the results for SOARCA do not change.  
20 There's no core damage, and that was based on a  
21 licensee plant fact check comment.

22 We also added an appendix, which compares  
23 SOARCA to Fukushima on a couple of specific areas,  
24 which Randy Gauntt will discuss in more detail this  
25 afternoon. We also completed our peer review

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1 committee interactions. Jeff Gabor, who's a peer  
2 review committee member, will provide a peer review  
3 committee perspective.

4 We have begun work on the uncertainty  
5 analysis, which Tina Ghosh will discuss later today,  
6 and Pat Santiago will discuss the public comments  
7 we've received on SOARCA, as well as the proposed  
8 future SECY paper for the SOARCA project, and I think  
9 that was my last slide.

10 MALE PARTICIPANT: Sorry.

11 MEMBER REMPE: That's okay. Rather than  
12 pick on the people who did the plant-specific analysis  
13 presentation, when I was going through the material,  
14 those two reports had been issued as, I guess, final  
15 documents, whereas the other documents we were given  
16 were draft versions.

17 But when I was going through those  
18 documents, there were a lot of things in them that are  
19 detracting from the quality of the report. References  
20 that are cited but not listed; axes, legends that  
21 imply the external vessel temperatures higher than the  
22 internal vessel temperature.

23 There was something about condescending  
24 steam, I believe, in one.

25 (Laughter.)

1                   MEMBER REMPE: But I guess I would like to  
2 inquire whether the staff would be willing or consider  
3 reissuing those reports and having some cleanup.

4                   MR. CHANG: In regards to Volumes 1 and 2  
5 of the SOARCA reports?

6                   MEMBER REMPE: The Peach Bottom and the  
7 Surry-specific analysis.

8                   MR. CHANG: Yes. What we have done,  
9 related to that, we got a number of comments from one  
10 of the peer review committee members, as well as Karen  
11 Vierow. She actually might be listed on this goal, on  
12 specific editorial and comments with regard to axes,  
13 graphs, as well as things spellcheck didn't catch,  
14 that the staff may have missed in its review.

15                   So we've been incorporating those  
16 comments, and we do plan on having a Rev 1. So yes.

17                   MEMBER REMPE: I'll make sure the staff  
18 gets the same comments to you, some nitpicks that they  
19 still --

20                   MR. CHANG: They're important, and we're  
21 aware of that, and we have received some comments from  
22 the peer review committee members and various members  
23 of the public, that we're addressing those comments.  
24 So thank you.

25                   MEMBER REMPE: Good.

1                   MEMBER ARMIJO: Once you've done that,  
2 will you reissue chapters of the SOARCA report?

3                   MR. CHANG: The intention is what we'll do  
4 is, and I think Pat will send it out, but I think the  
5 intention is is to be able to issue a Rev. 1 in the  
6 near future, at the same time that NUREG-1935 is  
7 finalized. So that's the intention.

8                   MR. CHANG: And we've, Mark Leonard and I  
9 will run the slides.

10                  MR. LEONARD: My name is Mark Leonard.  
11 I've been responsible for the Peach Bottom MELCOR  
12 analysis for SOARCA. I'm a contractor for Sandia.

13                  So what I'm going to discuss this morning,  
14 if you go to the first slide please, are not the  
15 comprehensive front to back analyses or details of the  
16 individual calculations, but really focus on three  
17 particular items that came up in the last couple of  
18 years, as a product of the peer review committee's  
19 comments on the work that we have done.

20                  Three areas that they focused on several  
21 times actually, that permitted us to reexamine some of  
22 the assumptions that went into the development of the  
23 MELCOR model itself, the scenario description, and  
24 those are itemized here.

25                  I'll talk about the work that we've done

1 since the peer review comments were received, and what  
2 effects they had on the baseline analyses.

3 The first is the effects of safety relief  
4 valve seizure, and when I use that word, I mean  
5 sticking in the open position. We will not be talking  
6 about failure in the closed position today, primarily  
7 because if the lead SRV, the one that has been cycling  
8 for most of the early portion of the accident, and for  
9 some reason randomly or by other mechanism it closes  
10 or refuses to open on a demand, then simply the next  
11 relief valve, and the next one and the next one.

12 There are 13 in total in Peach Bottom. So  
13 the closed failure is not one that we've been  
14 particularly concerned about. Opening, though, does  
15 have an important impact on accident progression and  
16 the criteria that we used for deciding when a valve  
17 would stick in the open position has been among the  
18 comments that the peer review committee provided. So  
19 I'll talk about how we've reexamined that.

20 The second is an item that Bob Henry in  
21 particular had mentioned in the peer review comments,  
22 which was some observations he had made early on his  
23 analysis of TMI, as well as early, I won't necessarily  
24 call it an analysis. It's somewhat speculation, but  
25 there's also some evidence in terms of activity that's

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1       been measured in various parts of the reactor building  
2       at Fukushima, that would suggest that there might have  
3       been a containment bypass mechanism that leaked at  
4       least some activity to the building prior to the  
5       leakage to the environment.

6               The question is what pathway might that  
7       have been. He had a suggestion for that, especially  
8       in a BWR where there are -- there's one particular  
9       system that is a in-core instrument tube penetration  
10      system that I'll talk about, and we've looked at the  
11      potential for leakage through that system and changing  
12      the results that we've calculated so far in terms of  
13      the source term.

14             The third item is the effect of barium and  
15      cerium as particular species that contribute to the  
16      offsite releasive activity. Historically, those two  
17      species are not major contributors to offsite dose,  
18      primarily because their quantities released to the  
19      environment have been so small.

20             They are not the dominant contributor, but  
21      they are contributors to dose in the SOARCA  
22      calculations. So in particular, their release differs  
23      between the short-term and long-term blackout, and  
24      because they have a contribution to dose, they have  
25      raised some interest in terms of why those releases

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1 appear to be now significant when they've not been in  
2 the past. So we'll talk about that as well.

3 CHAIR SHACK: Let me just ask a question  
4 on essentially the verification of the MELCOR model,  
5 since all this kind of depends on MELCOR calculations.

6 When I look at the best practices book and  
7 then that report in the 1935, everything was  
8 referenced -- a lot of these release things are  
9 referenced to PHEBUS-type results, especially FPT1.

10 Again, these are all PWR kinds of things.  
11 I mean, you know, it's PWR control logs. Apparently  
12 the control log chemistry seems to have a strong  
13 effect on some of the releases. I see very little  
14 reference to the FPT3, which has the boron carbide,  
15 you know, the PWR-type thing.

16 What is the assumption that all these  
17 release values that we get from the PHEBUS PWR  
18 calculations are really relevant to Peach Bottom?

19 MR. LEONARD: I think I'd defer to Randy  
20 Gauntt for that, who did most of the assessment for  
21 the release models.

22 MR. GAUNTT: I guess in addition -- this  
23 is Randy Gauntt. In addition to -- we do lean heavily  
24 on the PHEBUS test for integral verification of the  
25 melt progression modeling and the source term. We

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1 also lean on the -- we go back to the Oak Ridge HI/VI  
2 test, and as well as the VERCOR tests.

3 These are small pellet tests, where the  
4 measure the release of different --

5 CHAIR SHACK: Well, let me just -- the  
6 daily report I defined on the FPT3 test indicated a  
7 rather quite striking change in the release of gaseous  
8 iodine. So I mean there was a marked change.

9 MR. GAUNTT: I mean that's a good, you  
10 raised a good issue, and I'd say FPT3 is, that's the  
11 latest of the PHEBUS test. I would describe it as  
12 being kind of on the research edge. The belief is  
13 that the boron that's released is somehow tying up  
14 with cesium, and resulting in less iodine being tied  
15 up with cesium.

16 So at least during the core damage phase,  
17 as this iodine's coming out, they were seeing, you  
18 know, some larger tens of percents, perhaps, of iodine  
19 coming out in gaseous form. I believe we may touch on  
20 that a little bit in the uncertainty.

21 CHAIR SHACK: Yeah. Like I said, now is  
22 that addressed in the uncertainty analysis?

23 MR. GAUNTT: I want to say yes, but I'm  
24 not sure I'm recalling that precisely.

25 MS. GHOSH: Yeah. This is Tina Ghosh. We

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1 did take more of the PHEBUS test into account and  
2 coming up with -- we have five separate bins for the  
3 chemical forms of iodine and cesium, and we are  
4 sampling larger fractions of gaseous iodine, which we  
5 didn't in the best estimate. So we're looking at the  
6 potential effects of taking that into account.

7 CHAIR SHACK: And do we have enough  
8 results from that series to know that that's the only  
9 effect that we have to be concerned with, the FPT3  
10 analysis?

11 MR. GAUNTT: FPT3?

12 CHAIR SHACK: Yeah. I could only find a  
13 brief summary report. I don't know what the status  
14 actually is.

15 MR. GAUNTT: My recall on FPT3 is the big  
16 outlier there is the behavior of that gaseous iodine,  
17 and it seems to me something that is slightly  
18 transient, in that as this iodine goes into the  
19 containment, yeah they are seeing initially 10, 15, 20  
20 percent gaseous iodine.

21 But in time, that gaseous iodine seems to  
22 fall away and approach a kind of steady state level.  
23 The belief is there's some chemistry going on within  
24 the containment, that is attempting to, you know,  
25 produce a more or less steady state in the airborne

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1 iodine.

2 So that's where the research front is  
3 right now, and we do not have models that currently  
4 capture that chemistry.

5 MEMBER ARMIJO: Are you pretty certain  
6 about the initial state of iodine at the initial  
7 melting?

8 MR. GAUNTT: From PHEBUS?

9 MEMBER ARMIJO: Yeah.

10 MR. GAUNTT: You're probing my memory  
11 here, because somebody may -- if somebody knows this  
12 better, speak up. But of the airborne iodine, there  
13 is elemental, and I think what's coming out is  
14 elemental. There also is a hyper-fine particulate of  
15 --

16 MEMBER ARMIJO: Aerosol type.

17 MR. GAUNTT: --of iodine or something  
18 that's hard to differentiate from gases, because it is  
19 so small, and then there's the organic.

20 MEMBER ARMIJO: Are we going to talk at  
21 some later point in more detail on that?

22 MR. GAUNTT: I think in the uncertainty  
23 study, we don't differentiate between elemental and  
24 organic. But we do, you know, differentiate between  
25 particulate and gaseous.

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1                   MEMBER REMPE: But in general, the  
2 database for BWR melt progression phenomena is  
3 considerably less than PWR. It's not just for  
4 protecting fission products, but just how the fuel  
5 assembly will degrade, how it's held up in the core  
6 plate, interactions on the lower head, the drain line  
7 as well as instrument tube failures.

8                   So I think that's important to keep in  
9 mind. There's a lot more uncertainties. Is it like  
10 less than ten BWR-specific test, as opposed to over 40  
11 for BWRs?

12                   MR. GAUNTT: You may have surveyed that  
13 number. I know I did one or two myself decades ago.  
14 The Germans did a couple of them as well. But we have  
15 been pretty PWR centric in our model development.  
16 That said, I feel that we have had opportunity to be  
17 studying Fukushima. I'll try to say a little bit  
18 about Fukushima a little bit later on, and I'm, you  
19 know, not at all discouraged with what, you know, how  
20 this compares to what we think we know about the --

21                   MEMBER ARMIJO: The reason I brought up  
22 the question is, you know, I'm not a severe accident  
23 person, but I did quite a bit work on fuel, and what  
24 we found in a lot of hot cell examinations of BWR fuel  
25 is that the iodine is, with rare exception, totally

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1 consumed as, tied up as cesium iodide.

2 I don't know if it decomposes when you go  
3 through a melting. I don't know any of that stuff.  
4 But it seems like if you weren't seeing it in the form  
5 of an iodide, how did it get out?

6 MR. GAUNTT: Our assumption in MELCOR  
7 generally is that the iodine will tie up with the  
8 cesium, and that's our predominant view of things.

9 This business in FPT3, you know, is -- I  
10 don't know where the chemistries is happening, whether  
11 it's happening right at the release site or after it's  
12 released from the fuel and sort of mixing up with  
13 vapors from the control blade, the boron carbide  
14 products.

15 But the theory is, that's been put forward  
16 is that the cesium is preferring to tie up with boron,  
17 and therefore leaving iodine without a dance partner,  
18 so to speak.

19 CONSULTANT KRESS: There's not that much  
20 boron in there, compared to --

21 MEMBER ARMIJO: BWR has got a lot of boron  
22 carbide. I don't know if that decomposes to --

23 CONSULTANT KRESS: Didn't VERCOR's  
24 program, aren't they looking at this? Did you check  
25 that?

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1 MR. GAUNTT: There's a follow-on from  
2 VERCOR called VERDON, and you know, it's moving  
3 forward. I don't know what's been done there yet.  
4 In MPT-3, they were examining the rod-type form of the  
5 boron carbon. So it's a little different from the  
6 blade and the boiler.

7 I think it probably encourages more  
8 oxidation of boron carbide and evolution of boric  
9 acids or whatever it is --

10 CONSULTANT KRESS: Part of an increased  
11 surface area.

12 MR. GAUNTT: Yeah, and they are -- in the  
13 boiler, the boron carbide mixes very intimately with  
14 the steel, and it principally, you know, becomes an  
15 iron boron liquefied thing that runs away.

16 Whereas in the PWR, it's actually a pellet  
17 stack inside a tubing, and so I think there's  
18 potential for that to stand up longer and have  
19 protracted exposure to steam, whereby you can get more  
20 gaseous forms evolving off. That's my understanding.  
21 I don't think the models for this are, you know, are  
22 very well developed at this point.

23 CHAIR SHACK: Just pursuing Joy's question  
24 a little bit, again the lower head models are all  
25 PWRs, and these lower heads look a little different.

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1 Is that accounted for in the uncertainty analysis?

2 MR. LEONARD: Not directly. Lower head  
3 failure mechanisms are not one of the parameters that  
4 we're currently examining in the uncertainty study.

5 MEMBER CORRADINI: Is there -- may I just  
6 ask a question to follow-on? Is there any work that  
7 the staff sees necessary to examine that, because the  
8 other thing that came out in previous discussions was  
9 timing of lower head failure, and whether it be a BWR  
10 or a PWR, the timing relative to any sort of  
11 mitigative actions can have a large effect.

12 So does the staff feel that this is an  
13 avenue that's worth pursuing, or just too uncertain to  
14 even begin, and you're taking a conservative approach?

15 MR. LEONARD: I would say one of the  
16 limitations is an availability of an analytical model.  
17 The tool that's available in MELCOR at the moment,  
18 excuse me, for representing the mechanism for a  
19 penetration of any type failure is entirely  
20 parametric.

21 It does not represent the meaningful heat  
22 transfer and material movement processes that we  
23 suspect are dominant mechanisms for tube ejection or  
24 any of other mechanisms that have been looked at in  
25 the past. It's a very parametric model.

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1           So from an uncertainty perspective, it  
2 certainly could be examined, but we would be looking  
3 at very general global parameters, not varying input  
4 parameters at the same level of fidelity that all the  
5 other parameters are being buried.

6           And to some extent that would be  
7 speculative, that would not be based on other even  
8 external detailed analyses. So it's an area that --

9           MEMBER CORRADINI: Just to follow up,  
10 Mark, if I might. So what you're really -- if I could  
11 say it differently, you're saying there no data to  
12 hang your hat on, so you install the parametric model,  
13 in which you dial in a result and then made  
14 sensitivity calculations on that result?

15           MR. LEONARD: That's what's currently  
16 done, that's correct, and we rely in many respects on  
17 the limited available experimental information, as  
18 well as some of the analytical work that Joy had been  
19 involved with in the past, as a basis for making some  
20 judgments about what reasonable values for those  
21 parameters might be, and trying to provide some  
22 informed judgment about whether global creep rupture  
23 would --

24           If we represent lower head failure by  
25 calculating global creep rupture in a reasonably

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1 detailed way, that that's adequate, that we would not  
2 be far off in a time of debris relocation to the  
3 drywell floor.

4 MEMBER REMPE: Let's talk about your  
5 vessel failure prediction. Did you predict an area,  
6 so you have a bottom, a hole in the bottom? Did you  
7 predict a tear like saw at the Sandia test, that  
8 depressurizes?

9 I never found an area in this report, and  
10 was that area based on an amount of vessel steel that  
11 was heated up in the relocating debris, or did you  
12 just have a default value, this is the area that they  
13 altered?

14 MR. LEONARD: There is a default value.

15 MEMBER REMPE: But it's not really based  
16 on data or analysis.

17 MR. LEONARD: Well, you're right in the  
18 sense that it is the area that is used is not  
19 intimately connected to the calculated temperature  
20 distribution. So those two things are disconnected,  
21 that's right.

22 The area is based on the geometric  
23 distance between neighboring control rod drive  
24 assemblies. I mean it has a physical interpretation,  
25 but it is not explicitly connected to the temperature

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1 distribution that the code calculates for creep  
2 rupture. That's true.

3 MEMBER ARMIJO: Not the bottom drain line?

4 MR. LEONARD: And the drain line is not  
5 represented at all.

6 MEMBER REMPE: At all.

7 MEMBER ARMIJO: Probably the quickest  
8 thing to melt down.

9 MEMBER REMPE: I think someone said that  
10 in the previous reports.

11 CHAIR SHACK: It seems strange to have it  
12 disconnected from the temperature distribution.

13 MR. LEONARD: The temperature  
14 distribution, make sure I say this correctly, the  
15 temperature distribution is the basis for calculating  
16 the global creep of the hemispherical head.

17 But the initial area that is created is  
18 not proportional, for example, to some prescribed  
19 temperature profile. The area is specified as part of  
20 the model definition, up front.

21 MEMBER CORRADINI: So if I could just --  
22 I'm sure we're beating up on this, and you've already  
23 told us you're not going to do any of the uncertainty.  
24 But let me just ask a thought question. If it were in  
25 the uncertainty, and you then considered a smaller

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1 hole, let's take for Peach Bottom the drain line, what  
2 would you expect to be the qualitative result of that?

3 In other words, does that change the  
4 result significantly? Does it create a larger  
5 release, a smaller release, a later release? Where do  
6 you go qualitatively with knowing that you've got  
7 potential holes that are small and may fail early?

8 MR. LEONARD: It affects the initial drain  
9 rate of debris out of the lower head into the  
10 containment floor. The drain rate is proportional to  
11 the whole size, but the whole size of blades becomes  
12 larger as the molten material pours through it.

13 Previous parametric work, sensitivity  
14 studies have been quite a while ago though, as many as  
15 ten years ago, I think, had tried to look at that, in  
16 terms of was the, if you will, the time frame from  
17 debris relocation from the lower head to the floor  
18 substantially changed if you used a small initial area  
19 that a blade, rather than a larger area initially.

20 And the outcome of that parametric study  
21 was that the difference was not significant in terms  
22 of the amount of time it took, especially for a BWR  
23 Mark I, with liner melt-through being the dominant  
24 containment failure mechanism.

25 Did it affect the time at which, or if you

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1 will, the time difference between lower head failure  
2 and liner melt-through failure, containment and the  
3 beginning of a release to the environment? The  
4 conclusion of that early work was that the difference  
5 was not significant.

6 MEMBER REMPE: And they considered  
7 material solidifying when it hit the liner and  
8 remelting and all that type of phenomenon?

9 MR. LEONARD: The answer is no, that it's  
10 time, perhaps, to revisit that parametric work,  
11 because the way in which we represent both the in-  
12 vessel material distribution, the debris bed itself in  
13 the lower head prior to failure, that material  
14 distribution is different now than it was in the way  
15 we represent it, even within MELCOR say ten years ago.

16 And in particular, the method used to  
17 calculate lateral debris movement across the drywell  
18 floor is very different. It's much more mechanistic  
19 now than it was at the time. So it's probably, I  
20 wouldn't disagree that it's time to revisit that  
21 parametric and see if that's something that we --

22 CONSULTANT WALLIS: Well falling out on  
23 the floor, you do have an analysis. Is there any  
24 data, when you talk about liquidus and solidus of  
25 concrete, and I'm not sure that's relevant. When

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1 fluid flows along the top of the concrete, does it  
2 care what the solid is? I mean I'm not -- is that  
3 based on data, on some sort of assumptions that may or  
4 may not be appropriate?

5 MR. LEONARD: This is in terms of the --

6 CONSULTANT WALLIS: The stuff flowing  
7 along the floor and getting to the liner.

8 MR. LEONARD: Right.

9 MEMBER CORRADINI: There's data, Graham.  
10 There's data from -- the Europeans have done a number  
11 of experiments. I can't remember the name of the test  
12 series.

13 They've done a number of experiments in  
14 terms of looking at various super heats of melt  
15 flowing across a concrete floor, because they were  
16 concerned of a similar fashion.

17 And also in the EPR, they've actually  
18 designed it to encourage spreading. So I can't  
19 remember the name of the test series. Joy may  
20 remember.

21 MEMBER REMPE: But I would almost think  
22 that it would be a direct hit on the liner actually.  
23 So I'm a little puzzled. Isn't that what usually they  
24 assumed, was that it came out of the vessel and it did  
25 attack the liner directly? So it's hitting that --

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1 it's carbon steel, right, the liner?

2 MR. LEONARD: It is, but the liner is  
3 several meters away. You have to --

4 MEMBER REMPE: It's if you have a bottom  
5 hole, and it has to go out --

6 (Simultaneous speaking.)

7 MR. LEONARD: No, within the -- for the  
8 BWR, the reactor vessel is supported by a cylindrical  
9 concrete pedestal that has a doorway in it. So the  
10 debris has to accumulate within the pedestal to a  
11 depth that now can flow laterally out the doorway,  
12 across the floor and then touch the drywell liner.

13 Under the baseline assumptions that we're  
14 using in terms of the criteria for movement, I mean  
15 that happens within a matter of minutes, 15 minutes  
16 perhaps. That's an average value for us. So it is  
17 fairly quick.

18 MEMBER CORRADINI: I guess, just since I  
19 started this digression, if you have a logic that  
20 makes sense to you guys, that while you don't want to  
21 do this within the uncertainty analysis, it would seem  
22 to me, at least in the uncertainty document, you ought  
23 to have a discussion that says this is not included  
24 and this is why it's not included, and leave it at  
25 that.

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1           The reason I brought it up in this regard  
2           is I can understand there's many things that you want  
3           to do in the uncertainty analysis, and this may be  
4           lower priority. But there ought to be at least a  
5           short discussion explaining why you think it is, based  
6           on either experimental or past parametric analyses.

7           MR. LEONARD: That's a good suggestion,  
8           and repeating what I said earlier, that one of the  
9           motivations for not representing it is because we  
10          don't have the analytical model foundation for that  
11          process, to the same level of fidelity that we have  
12          for the other ones that we're representing in the  
13          uncertainty study.

14          So it was difficult to decide how exactly  
15          you would define the parameters to vary.

16          CHAIR SHACK: I mean but that's one of the  
17          problems I have, is that you seem to fit the analysis  
18          on what you can do, and you know, then you know, okay.

19          I look at this scenario. I can't do a  
20          best estimate analysis of it, so I forget about it and  
21          I do this one over here that I can analyze.

22          Well that doesn't seem much of a criteria for  
23          selection.

24          MR. LEONARD: I don't want to defer, in  
25          terms of ejecting this comment away from me, but it

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1 would be helpful --

2 (Laughter.)

3 CHAIR SHACK: Oh yes, you do.

4 MR. LEONARD: When Tina comes up later  
5 today, she's going to talk a little bit about the  
6 parameter selection process. How did we go about  
7 selecting what could and couldn't be done, what should  
8 and shouldn't be done. If we can revisit that then,  
9 that would probably be helpful, because my guess is  
10 that the lower head failure mechanism is not the only  
11 one that we could offer. There's other issues that  
12 could/should be --

13 CHAIR SHACK: Well I mean, it is a larger  
14 question of how you address model uncertainties, and  
15 sometimes you can address model uncertainties in these  
16 parametric kind of calculations that you seem to be  
17 doing. Other times, you can't, but I want to make  
18 sure the uncertainty report doesn't just analyze the  
19 uncertainties that I can analyze.

20 At least if you can't analyze the other  
21 uncertainties, you ought to recognize that they're  
22 there, and they can in fact be perhaps at least as  
23 important as the ones that you are analyzing.

24 CHAIR SHACK: The only reason I bring up  
25 the model or the limitations of the model is that it

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1 was one of the, one of the criteria that was used to  
2 decide which parameters could and should be  
3 represented, so you didn't unfairly bias the effects  
4 of the uncertainty in one parameter against the  
5 effects of another.

6 The only reason why one might appear to be  
7 more important is because you're treating one  
8 extremely simplistic, with a very wide range of  
9 uncertainty, as opposed to one that you have a very  
10 detailed mechanistic model for, and you know the  
11 variance of that particular input parameter.

12 That was a concern, especially when it  
13 came to models like penetration failure, where the  
14 mechanistic model is very, very simple. It's almost  
15 --

16 CHAIR SHACK: I think we can understand  
17 that, but in the uncertainty analysis, we ought not  
18 give the impression that we've covered all of the  
19 things that are important if we haven't, and in fact  
20 we ought to at least catalogue them and give some  
21 judgments --

22 MR. LEONARD: And that's a fair summary.

23 CHAIR SHACK: --about where it could  
24 extend.

25 MR. LEONARD: And I think Tina will talk

1 about others, that in the process of running the  
2 initial spectrum of calculations, we discovered  
3 several things that were surprises, things that turned  
4 out to be more important than we would have expected.

5 So some refined analysis will probably  
6 fall out of that as well. So yes, it's been a  
7 learning process, that's for sure.

8 MEMBER REMPE: And claiming that the  
9 vessel failure is a higher fidelity, when the  
10 temperature distribution is not connected to the whole  
11 size doesn't quite jibe with me.

12 MR. LEONARD: Yeah. Okay. So if I've  
13 successfully deferred any more questions on  
14 uncertainty until later this afternoon, and we'll come  
15 back to it. It's a good discussion.

16 The next slide, please. The first of the  
17 three topics that I mentioned earlier is the outcome  
18 of the peer review process. It had to do with the  
19 criteria for the cycling safety relief valve to stick  
20 in the open position.

21 This failure mechanism, at least in terms  
22 of the detailed calculation of axiom progression in a  
23 MELCOR context, is something that's been done for  
24 quite a while, in terms of the history of NRC analyses  
25 of -- especially station blackout, long-term station

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1 blackout and accident progression.

2 But the criteria for defining when the  
3 valve sticks has always been a little soft. It's not  
4 clear even what the mechanism should be that could be  
5 represented, and how do you mathematically model them  
6 within the code. That's been evolving, and it was a  
7 good discussion with the peer review, in the sense  
8 that we were able to discuss the two primary  
9 mechanisms that are currently represented in these  
10 calculations.

11 The first referred to is the stochastic  
12 failure model, and that's one in which we simply use  
13 a specified failure rate, a random failure rate that  
14 comes from classic PRA databases. In the best  
15 estimate analysis, we take that failure rate, invert  
16 it to define the expected value for the cycle, the  
17 average cycle at which the SRV might stick in the open  
18 position, and we simply define that number as a number  
19 of cycles, cumulative number of cycles at which the  
20 SRV would stick.

21 CONSULTANT WALLIS: Doesn't it depend on  
22 for how long it's open, because that determines the  
23 heat transfer.

24 MR. LEONARD: That's the second mechanism.

25 CONSULTANT WALLIS: Yeah, but I mean

1 number one, it's not just number of cycles. It's  
2 something to do also with the characteristic of the  
3 cycle. If it's open/shut, open/shut, it's very  
4 different from staying open for a minute and shutting.

5 MR. LEONARD: That's right. Again, when  
6 we talk about the uncertainty, this parameter in  
7 particular is one of the major uncertain variables,  
8 that when we hear the initial results of the  
9 uncertainty analysis, you'll learn how the effects of  
10 uncertainty in the failure rate have had a very, very  
11 important effect on the outcome.

12 MEMBER BLEY: Mark, I don't remember  
13 details, but back 20 years or more ago, industry did  
14 some extensive testing, I thought. Now I don't know  
15 if they were done at temperature. I thought they  
16 were, and did you guys go back and revisit that data?

17 MR. LEONARD: There are two databases that  
18 we reviewed. One is the NUREG/CR that's the -- Marty  
19 Stutzke might remember the number. I don't recall off  
20 the top of my head, but it's the generic database for  
21 all the components, one of which are the SRVs, and it  
22 has the average failure rate for failure to open,  
23 failure to close.

24 We reviewed that, and in fact that is the  
25 primary basis for the distribution that's put into the

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1 uncertainty analysis. Another one is a study that was  
2 done, that reviewed in more detail than just the  
3 global failure rate, which is just -- which doesn't  
4 take into account at which cycle did the observed  
5 failures actually occur.

6 Did it fail on the first time, the second  
7 time, the 300th time, and it tried to decompose  
8 failure rate or correlate failure rate to the cycle at  
9 which it failed. Is the failure rate higher or lower  
10 as it begins to cycle, or does failure accumulate with  
11 time? It attempted to examine that.

12 The difficulty is that the observations of  
13 valve failure, although there are large numbers of  
14 them, not many of the LERs actually document at which  
15 cycle did the valve fail, so that the available  
16 information helps us decompose that failure rate as a  
17 function of number cycles is not particularly good.

18 Although this one study that I believe  
19 Idaho did, provided a recommendation for failure rate  
20 on the first cycle, the first few cycles, and then a  
21 different failure rate when you get into the hundreds.  
22 In our case, for the best estimate calculation, we had  
23 to choose a failure rate.

24 So we used a nominal value that came from  
25 the plant-specific PRA, and are using that for the

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1 best estimate single calculation. The uncertainty  
2 study considers that number to be a very wide  
3 distribution. So a full spectrum was considered.

4 But getting back to the question of  
5 temperature, that gets to our second criterion, both  
6 of which operate in parallel. So both mechanisms are  
7 always available, depending on which one would occur  
8 first.

9 The random failure or stochastic failure  
10 is always operative, and in parallel to that, we're  
11 calculating the temperature of a representative  
12 internal component to the valve. It's primarily the  
13 valve stem, the most exposed component, moving  
14 component within the valve, and we specify a  
15 temperature at which that component would reach, where  
16 the thermal expansion of the valve stem relative to  
17 the sleeve in which it has to slide is large enough  
18 that the gaps close.

19 The basis for that temperature is a -- go  
20 to the next slide, please.

21 CONSULTANT WALLIS: Isn't it a temperature  
22 difference of some sort?

23 MR. LEONARD: It is, in the sense that  
24 what we're looking at on the left, you'll see just a  
25 cross-section, a representative cross-section of the

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1 type of valves we're looking at. This is a, this  
2 happens to be a two-stage, and Peach Bottom uses  
3 three-stage valves.

4 The only difference in those has to do  
5 with components that are far-removed from the central  
6 portion of the valve, so we don't need to be concerned  
7 about that.

8 But the main valve stem that you can see  
9 in the center, slides left and right here in this  
10 picture through a sleeve, and the question is, is the  
11 temperature difference in combination with the  
12 material property differences, the valve stem is  
13 stainless. The sleeve and the valve body are carbon.  
14 There are some in-canal components internal to the  
15 valve.

16 So the combination of thermal expansion  
17 material properties, temperature differences, do all  
18 of those lead to a condition where the valve stem, in  
19 combination with the sleeve, the gap closes, the  
20 closure -- the clearance between --

21 CONSULTANT WALLIS: Probably all those  
22 things.

23 (Simultaneous speaking.)

24 MR. LEONARD: We're talking about all that  
25 stuff. When we began the SOARCA calculations,

1 whatever it's been, five, six years ago, we did some  
2 very simple hand calculations for this, because  
3 there's no analysis for this that we were able to find  
4 anywhere.

5 So we did some very simple 1(d) hand  
6 calculations, to try to understand how much time would  
7 it take, over what temperature history, for these  
8 components to reach temperatures at which material  
9 deformation. For example, if this valve, the valve  
10 stem is moving back and forth in a cyclic manner and  
11 very abruptly for the Target Rock relief valves.

12 They're not sliding valves. They slam  
13 full open, slam full closed, that that mechanical  
14 effect, with degradation of material strength, might  
15 lead to deformation, thermal expansion.

16 MEMBER RAY: Does it matter whether it's  
17 relieving steam or solid water or flashing or is that  
18 a variable in any of this?

19 MR. LEONARD: The fluid variables in this  
20 case are steam and hydrogen, that when we -- again,  
21 getting back to temperature.

22 MEMBER RAY: Not flashing in the valve  
23 body itself.

24 MR. LEONARD: Or for this condition at  
25 least, there's no water that would be moved. The

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1 safety relief valves in the boiler are on the steam  
2 line at a very low elevation, but the reactor, you  
3 have to enter the steam line. You have to go to the  
4 very top of the reactor vessel out the nozzle and  
5 down, which is --

6 MEMBER RAY: The most common cause of one  
7 of these failures, in my experience is vibration due  
8 to flashing in the valve body. It's not the  
9 temperature, that stem galling on the guide because of  
10 expansion. Anyway, I just wanted to know if there was  
11 what you assumed about the --

12 MR. LEONARD: Mechanical effects of  
13 flashing we have not taken into account.

14 MEMBER RAY: Well that's usually why a  
15 valve sticks open, is it's passing a flashing fluid,  
16 and it just causes the stem to vibrate enough to gall  
17 in the guide.

18 MR. LEONARD: If that occurred during some  
19 of the early cycles, when there was still plenty of  
20 water within the reactor vessel, in principle that  
21 would contribute to the database that leads to the  
22 stochastic failure probability.

23 So I can argue, perhaps, that that effect,  
24 if it's the dominant mechanism for observed valve  
25 failures, would be captured in the database that we're

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1 using for identifying the failure rate.

2 The thermal mechanism is something  
3 different, where unlike the early cycles, where the  
4 valve is operating at its rated temperature, that is  
5 the steam flow through the valve is within the domain  
6 of the rate of values for the valve, once the water  
7 level in the reactor vessel decreases below the top of  
8 the core, oxidation begins; the temperature of gases  
9 emerging from the top of the core exceed, by a large  
10 margin, the rated value, the rated temperature of the  
11 valve; and the fluid that's being passed is not just  
12 steam but also high temperature hydrogen.

13 The heat transfer to the valve changes  
14 considerably, and the valve temperatures increase at  
15 a much faster rate. So what we have done to try to --

16 MEMBER RAY: It would seem like there  
17 would be a huge difference between the failure rate of  
18 a two-stage valve and a three-stage valve, inasmuch as  
19 the pilot for a three-stage valve is a fairly tiny  
20 thing, and it would be significantly impacted by the  
21 severe transience.

22 Have you looked at the difference between  
23 two-stage and three-stage?

24 MR. LEONARD: In a minute, let's get to  
25 that, because it's a good -- it is one of the

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1       uncertainties in heat transfer through these detailed  
2       components, and I'll show you how we've been able to  
3       treat that so far. But it's a very good question.

4               Let's go to the next slide, because the --  
5       what I show there on the right is the 3D finite  
6       element model that was built for the valve body and  
7       the internal components, retaining material properties  
8       of both the cast body as well as the stainless shaft  
9       and other internal components.

10              What's shown here on slide are the  
11       boundary conditions to that three-dimensional model.  
12       On the left is the time-dependent temperature history  
13       of the fluid that has passed through the valve.

14              It's obtained straight from the MELCOR  
15       calculation for the long-term blackout, and on the  
16       right is a representative plot of the velocity or flow  
17       through the valve, which is really meant to remind us  
18       that it is not continuous flow.

19              It's cyclic flow. The valve is open for  
20       a few seconds, and then it's closed for 45 seconds or  
21       a minute, and then reopens again. The period is about  
22       45 seconds on average during the time frame that we're  
23       concerned about.

24              These are boundary conditions to that  
25       three-dimensional model, in terms of heat transfer

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1 within the central core of the model itself.

2 Next one. On the upper right is just a  
3 sample illustration of the graphical display of the  
4 temperature distribution in the valve, approximately  
5 at the time that failure is predicted. Failure in  
6 this case is when the gap between the moving valve  
7 stem and the sleeve that allows it to slide closes to  
8 zero.

9 Red in this case gives you an idea that  
10 really it is the valve stem and the components  
11 directly connected to it that are primarily absorbing  
12 most of the energy, that the thermal inertia of the  
13 body is so much larger that it takes a lag time, if  
14 you will, for temperature to penetrate most of the  
15 valve body.

16 CONSULTANT WALLIS: Well, symmetrical,  
17 cylindrical growth. It touches in one area  
18 presumably, doesn't it?

19 MR. LEONARD: Several actually, yeah.

20 CONSULTANT WALLIS: Several. But it does  
21 not assume any symmetry? You're actually in 3D --

22 MR. LEONARD: No. There's actually, if I  
23 can point to this, there's a sleeve here, which is one  
24 sliding component, but behind it is the piston that is  
25 the actual surface area that causes the force that

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1 moves that valve stem back and forth.

2 When it comes to the two versus three  
3 stage, among the things that had to be buried, and  
4 that's what's represented here by this 5, 10, 20  
5 percent flow, is the amount of flow that would  
6 initially come into the valve, but passes through  
7 these small ports to the drive mechanism in the back.

8 Those ports are open. In fact, that's the  
9 mechanism by which the piston allows the valve to move  
10 back and forth. The amount or fraction of flow, if  
11 you will, through the valve that is diverted through  
12 those ports is not known.

13 We don't know what fraction of the total  
14 flow that is discharged through the valve during the  
15 cycle actually is passed through the small ports,  
16 enters into that back stage, that portion where the  
17 piston is located, and then returns through a return  
18 line that was shown in your previous diagram out here.

19 The ports enter on one side, change the  
20 pressure on the outside of the piston, and then return  
21 through another port. The fraction of flow that's  
22 diverted in that direction rather than passing  
23 straight through the valve is not known. When we  
24 spoke to the valve --

25 MEMBER ADBEL-KHALIK: Well, you do know

1 the geometry.

2 MR. LEONARD: I'm sorry?

3 MEMBER ADBEL-KHALIK: Well, you do know  
4 the geometry?

5 MR. LEONARD: That's right.

6 Unfortunately, you know, in terms of a material  
7 response model, though, the material response model  
8 has to be provided at boundary condition -- the fluid  
9 flow, if you will, is not part of the finite element  
10 model of the valve material response. So we had to  
11 provide that as a boundary condition.

12 MEMBER CORRADINI: Can I just ask a  
13 question? I think I know where Said's going with  
14 this, and I guess I'd agree with him. If this is a  
15 major uncertainty, if it is, if it is, it seems to me  
16 that you could do a combined analysis, because --

17 And maybe it's just that the 5, 10 and 20  
18 onset. But such analysis has been done, is done in  
19 other circumstances. So I guess I'm curious. The 5,  
20 10 and 20 in your minds bound these various designs,  
21 in terms of what you call the bypass flow?

22 MR. LEONARD: We don't have a basis to  
23 judge whether it is bounding or not. So the next step  
24 would be to perform a calculation that would try to  
25 estimate the diversion flow, compared to the total

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1 value discharge flow. That's not known.

2 MEMBER CORRADINI: But okay. So but let  
3 me ask a different question. If you went to the valve  
4 manufacturer, they don't have any indication, under at  
5 least normal operating conditions, what the flow  
6 splits are?

7 MR. LEONARD: We asked that question, and  
8 did not get a response that was very helpful. It  
9 didn't mean that they didn't know; it's just it could  
10 be that we weren't able to get through to the people  
11 who might know.

12 MEMBER CORRADINI: Okay, right. I mean --

13 MEMBER ADBEL-KHALIK: Do you know many  
14 plants use two-stage versus three-stage?

15 MR. LEONARD: We do. We have an inventory  
16 of that. My recollection is the majority are three-  
17 stage. So the two variables you see in this case are  
18 trying to capture the parametric uncertainties that  
19 went into the analysis, and that's the fraction of  
20 flow that's diverted to the inner stage. That's the  
21 5, 10 and 20 percent diversion flow.

22 The other is the initial gap between the  
23 sleeve and the valve stem itself. That is proprietary  
24 information to the valve manufacturer. We weren't  
25 aware of it, but we know what typical clearance

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1 capacities are. They're typically rated, and these  
2 terms are very loose, versus a free or a close-running  
3 fit. It depends primarily on whether it's an internal  
4 sliding mechanism or an external mechanism.

5 And so we looked at all three, to see the  
6 extent that the initial gap had an effect on the time  
7 or conditions for seizure. So the two variables, flow  
8 diversion plus the initial gap size, and what's shown  
9 on the left are two representative temperature  
10 histories for the dimension of the gap from its  
11 initial condition, during valve heating, down to the  
12 point where the gap closes to zero.

13 So approximately 42, 45 hundred seconds in  
14 this case. Now this is seconds after initial heating  
15 begins, would be the time at which the closure, the  
16 gap width closes to zero.

17 We take that value of time, correlate it  
18 back to the temperature of the gas or the temperature  
19 of the valve stem itself at which closure occurred,  
20 and that becomes the criterion that we use in the  
21 MELCOR model for defining when the valve would seize  
22 by a thermal mechanism.

23 MEMBER ADBEL-KHALIK: So there is no way,  
24 for example, the bellows in the pilot to deform, that  
25 would cause the valve to permanently open?

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1 MR. LEONARD: In the pilot? That's  
2 certainly possible. Other mechanisms are being  
3 proposed --

4 MEMBER ADBEL-KHALIK: Higher probability  
5 than what you're assuming here?

6 MR. LEONARD: Even fatigue of the spring  
7 is possible if the spring itself is weakened, that it  
8 no longer has the strength to be able to drive the  
9 valve closed. I mean there are a number of other  
10 conceivable mechanisms that we've considered. This  
11 one was the one that we can analyze directly.

12 MR. SCHAPEROW: Also, our sensitivity  
13 analyses showed that if the valve stuck open a bit  
14 earlier during the core heat-up, it wouldn't make a  
15 big difference in the source term and the rest of the  
16 accident progression. So we looked at, I think we  
17 got, I don't know, maybe a dozen or so cases we ran  
18 for --

19 MR. LEONARD: Let's go to the next slide.

20 MEMBER ARMIJO: Before you leave that, you  
21 didn't analyze the close-running fit. I mean I'm just  
22 assuming maybe nobody uses, builds valves that way.  
23 So that would cut the time down quite a bit.

24 MR. LEONARD: We actually ran, I only just  
25 for the sake of not pressing your eyes to be able to

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1 see three curves on one page, I only used two  
2 representative ones. We did all three.

3 MEMBER ARMIJO: Okay, because that's a big  
4 change from 135 millimeters, .135 millimeters to .09  
5 is a pretty small change. But from .09 to .0275,  
6 that's a pretty big change.

7 MR. LEONARD: That's right.

8 MEMBER ARMIJO: I just wanted to know  
9 what, how much --

10 MR. LEONARD: Our understanding is that  
11 the free-running fit is the most representative of  
12 these types of components, that the close-running  
13 would be very finely machined components that wouldn't  
14 be subjected to the kinds of loads that a big SRV --

15 MEMBER ARMIJO: This would not be a  
16 typical for these valves?

17 MR. LEONARD: The close-running, the free-  
18 running fit, the curve at the bottom is the one that  
19 we've been advised is probably the most representative  
20 for this type of component.

21 So we used the criterion that was  
22 developed from this analysis, to define the thermal  
23 failure criteria for the valve, which operates in  
24 parallel to the stochastic criteria, and then we ran  
25 the best estimate case, which is represented here in

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1 this shaded color, with the valve stem temperature of  
2 about 900 K would be the criterion for thermal  
3 seizure.

4 CONSULTANT WALLIS: Now this stochastic,  
5 this five percent to 90 percent is based on some kind  
6 of a distribution?

7 MR. LEONARD: That's right.

8 CONSULTANT WALLIS: Where does that come  
9 from?

10 MR. LEONARD: The distribution that is,  
11 corresponds to the failure rate that we used --

12 CONSULTANT WALLIS: That's really an  
13 uncertain distribution, when you're looking at the  
14 tails, like five percent, isn't it?

15 MR. LEONARD: It's a wide distribution,  
16 that's true, and the values of stochastic here are the  
17 cumulative failure probabilities. So the expected  
18 value that we used corresponds to a cumulative failure  
19 probability of about 63 percent.

20 But what we looked at in addition to the  
21 base case, which uses the best estimate value of the  
22 valve stem failure temperature or closure criterion if  
23 you will, gap closure, the stochastic value that  
24 represents the expected value for valve sticking in a  
25 random context.

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1           We varied both of those parameters over  
2           some reasonable range, both lower and higher  
3           temperatures, earlier and later stochastic failure  
4           mechanisms, to see the extent to which uncertainty in  
5           these parameters really affected the results, and  
6           that's what I want to try to summarize here.

7           Several cases that are worth looking at is  
8           this is an interest. First, as you can see, and I'll  
9           focus primarily on the long-term blackout. For the  
10          base case, the stochastic failure mechanism occurred  
11          first in the base case for long term. But in the  
12          short term blackout, you can see that the thermal  
13          mechanism occurred first.

14          So difference in terms of the total number  
15          of cycles that preceded the challenge, in terms of  
16          core uncovering. We focused on the long-term blackout.  
17          If you push the stochastic failure criterion all the  
18          way out to say its 90 percent cumulative failure  
19          probability, that is, you're trying to force the  
20          thermal mechanism, the number of cycles increases  
21          considerably from the base case 270 up to 470.

22          The amount of time that it takes for the  
23          valve to seize obviously moves out considerably. That  
24          change in the failure criterion moves the seizure time  
25          out about three hours. What I've shown you in this

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1 column is the creep damage index for the main steam  
2 line, which I'll get to in a minute.

3 This is a series of numbers that tries to  
4 represent the time at which the source term to the  
5 environment becomes significant, and what I mean by  
6 that is when the iodine released to the environment is  
7 greater than one percent, that's the threshold that we  
8 begin to be concerned about changes in the source  
9 term.

10 This time changes about ten percent over  
11 that range. The magnitude, that is, it moves a little  
12 bit earlier. The magnitude of the release of iodine  
13 and cesium to the environment increases by about a  
14 factor of two.

15 If we vary another factor in the  
16 criterion, which is not only that the valve sticks in  
17 the open position, but what do we mean by open? Full  
18 open, some partial open position?

19 The idea was this valve is moving through  
20 a sliding valve stem. In principle, it could seize at  
21 any distance along that valve stem, even though the  
22 motion is full open/full close.

23 If seizure, collapse of the gap is the  
24 failure mechanism, then in principle it could seize at  
25 any open position. So we looked at some variants of

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1 that. Only a one-tenth open area versus a one-half.  
2 These are all full open areas.

3 And the interesting thing that we observed  
4 there is if we used the thermal failure mechanism at  
5 a smaller seizure area, that's when we begin to see  
6 other aspects of the model begin to pick up its  
7 participation. But with only a one-tenth open area,  
8 the depressurization rate of the reactor vessel was  
9 significantly reduced.

10 High pressures are sustained for a longer  
11 period of time into the process of core damage. The  
12 energy that would normally be discharged through that  
13 valve to the suppression is now a fuel bottled up  
14 inside the reactor vessel.

15 That energy is transferred in part to the  
16 main steam line, main steam line nozzle. Because of  
17 the high pressure in combination with high  
18 temperature, one here means this is the creep damage  
19 index that we calculate for the main steam line  
20 piping. The main steam line creep rupture would occur  
21 in that case.

22 It changes the release pathway to the  
23 environment, to the containment in a completely  
24 different way. Instead of discharge from the reactor  
25 vessel through the SRV to the pool to the torus, you

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1 now have a direct and large discharge directly to the  
2 drywell, and a load, a mechanical load, a pressure  
3 load to the drywell that would not be observed  
4 otherwise. The effect of that --

5 MEMBER RAY: Is the stochastic database  
6 just from the nuclear data? For example, look at  
7 super-critical fossil plant relief valve performance.  
8 Is that part of this database?

9 MR. LEONARD: When I mentioned the two  
10 studies that we reviewed, one of them is nuclear only;  
11 the other is more comprehensive than that. It  
12 includes fossil-fired plants as well.

13 MEMBER RAY: Yeah, because those would be  
14 more representative, I would think, for the kind of  
15 fluid that you're passing here. Man oh man, they sure  
16 stick a lot more than that --

17 (Simultaneous speaking.)

18 MR. LEONARD: If steam line creep rupture  
19 fails, you can see that has a significant effect on  
20 the environmental release. Instead of it only being  
21 a factor of two or so, you're talking about almost a  
22 factor of eight or ten increase in the release to the  
23 environment.

24 MEMBER CORRADINI: And Mark, I guess I  
25 didn't appreciate. If I had the creep rupture

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1 failure, it enters drywell, but then it goes through  
2 the bellows or through the piping, still back into the  
3 wet well, does it not?

4 MR. LEONARD: It does, but several things  
5 to take into account. One is that the pathway for  
6 that gas and the aerosol content that's in it to the  
7 suppression pool goes through the downcomers into the  
8 pool, which are a much larger diameter than the T-  
9 quencher small holes that are the discharge point for  
10 the SRVs.

11 So the scrubbing efficiency and the non-  
12 condensable gas content is very high, which reduces  
13 condensation as an aerosol capture mechanism. The  
14 very large flow rate, as well as the large diameter of  
15 the bubbles that are created in the pool by the  
16 discharge through the bellows is not nearly as  
17 effective a scrubbing process as you would get at the  
18 SRV tail pipe.

19 MEMBER CORRADINI: Right. So captured it  
20 based on the models, relative to the downcomer versus  
21 the actual SRV piping?

22 MR. LEONARD: And those effects are  
23 integral to the MELCOR model. It recognizes those  
24 dimensions and the difference in the flow pathways as  
25 part of the model. So the scrubbing mechanism is

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1 connected to the flow pathways, and the representative  
2 bubble size.

3 MEMBER CORRADINI: Okay, all right, and  
4 then one last thing. I guess I'm reading your table.  
5 You assume the creep rupture failure whole size?  
6 Where does that fit in here? I missed it.

7 MR. LEONARD: I didn't mention it. These  
8 calculations all assume that if creep rupture occurs,  
9 that it's a full diameter break. It is a variable we  
10 looked at elsewhere.

11 MEMBER CORRADINI: Okay, so and that's  
12 clearly conservative, but is it the basis is what? I  
13 guess I don't appreciate what the basis is.

14 MR. LEONARD: There's a paper I'd have to  
15 -- that we -- and we dug it up as part of the  
16 uncertainty, because this is a variable in the  
17 uncertainty analysis, is when the -- if the main steam  
18 line fails by creep, how large is the opening?

19 It's a variable that is included in the  
20 uncertainty analysis, and we've been struggling to  
21 define the distribution for that area, and we're given  
22 a reference for mainly a PWR study for hot leg creep  
23 rupture, which tended to show that when creep  
24 occurred, there's a very strong bias towards large  
25 opening areas. It either opened with a big hole or it

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1 didn't open. So that's the lower head.

2 MEMBER CORRADINI: Okay. That helps me.  
3 Then one last quick thing. If I go back to Slide 6,  
4 where, I mean maybe you could just point on the pretty  
5 color cartoon. Where is the creep rupture likely to  
6 occur on the outlet of the flanged area, on the inlet  
7 or not even near the valve body?

8 MR. LEONARD: It wouldn't be anywhere near  
9 the SRV. It would be up at the steam nozzle that's  
10 attached to the reactor vessel, because that would be  
11 the point -- or I should say that main steamline  
12 piping that is immediately downstream of the nozzle  
13 safe end, because that's the thinnest wall at the  
14 highest temperature.

15 MEMBER CORRADINI: Okay, and so that's  
16 upstream of where we're looking in the cartoon?

17 MR. LEONARD: Quite a bit upstream, yes.

18 MEMBER CORRADINI: Okay, all right. So  
19 almost like the T section coming out of the main steam  
20 line?

21 MR. LEONARD: No. In fact, this is a  
22 valve that's connected to the main steam line, tens of  
23 meters downstream from where the creep rupture  
24 location would occur. So when creep occurs, the SRV  
25 is taken completely out of the picture. It's not

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1 longer participating.

2 MEMBER CORRADINI: Okay, okay. Let me ask  
3 one last -- I'm sorry.

4 MR. LEONARD: Go ahead, Mike.

5 MEMBER CORRADINI: So let me jump to  
6 Fukushima. Is there some way, and I guess I have to  
7 get at this.

8 Is there some way going and saying if I  
9 wanted to investigate an observation, because there  
10 was a depressurization in all of these units, is there  
11 some observable that one would want to look at if one  
12 could, to determine a stuck open SRV versus a creep  
13 rupture failure upstream of that point, and if so,  
14 what would that be?

15 MR. LEONARD: Containment pressure.

16 MEMBER CORRADINI: Well, but in both  
17 cases, containment pressure. But in all cases, I  
18 guess Randy knows this better than anybody, I'm not  
19 sure if there was any sort of measurement of pressure.

20 Is there any sort of observable, other  
21 than pressure, or I should say the frequency of  
22 pressure measurements, maybe Joy knows this, was not  
23 at that time scale, that you could actually catch the  
24 difference?

25 MR. GAUNTT: Mike, this is Randy. Let me

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1 just say what I know about it or what I think I know  
2 about it.

3 MEMBER CORRADINI: I guess Randy, the  
4 reason I'm asking this is I'm looking at a way to  
5 essentially delineate between the two, and the only  
6 thing I can come up with is actually the recent  
7 events.

8 MR. GAUNTT: Yeah, and so let me tell you  
9 what we've done, in the context of our MELCOR  
10 Fukushima Unit 1 analyses. So we exercised the SOARCA  
11 approach in Fukushima, and lo and behold, we failed  
12 the -- we'd actually run it several ways. But we fail  
13 the steam line in the Fukushima analysis.

14 But we don't know that for sure. It's a  
15 bit of a horse race between whether the SRV would  
16 stick open. So we ran that case alternatively. In  
17 the case of the SRV seizing open instead of the steam  
18 line failing, the vessel blowdown is through the  
19 suppression pool. So the steam, the steam energy is  
20 deposited in the suppression pool.

21 Alternatively, if you fail the steam line,  
22 the blowdown is into the drywell environment. In both  
23 cases, there's a lot of hydrogen, not condensables.  
24 So in the case where we vent the steam into the  
25 drywell, we see a higher residual drywell pressure

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1 following blowdown than the case where it blows down  
2 into the suppression pool, because the heat sink is  
3 there.

4 Just based on those two scenarios that  
5 we've run, we get a better match with the long-term  
6 drywell pressure that's measured, the technical data  
7 for the steam line rupture than we do for the venting  
8 into the wet well.

9 So we kind of put our odds, we put 70  
10 percent of our chips on we think the steam line  
11 ruptured, and we're going to put 30 percent on well,  
12 on the other hand, it could have seized open the SRV.  
13 But we get a better match to the residual drywell  
14 pressure in Fukushima, when we rupture the steam line.

15 MEMBER REMPE: Are you talking Unit 1?

16 MR. GAUNTT: Unit 1, yeah.

17 MEMBER REMPE: Okay.

18 MEMBER ADBEL-KHALIK: On Slide 6.

19 MR. LEONARD: Okay.

20 MEMBER ADBEL-KHALIK: I understand that  
21 you don't know exactly, or the manufacturer did not  
22 give you the information as to how much flow would go  
23 to the pilot in the second stage, versus the main  
24 flow. But have you done the analysis to see even  
25 within these assumed "bypass flows" to the pilot and

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1 second stage, how long would it take for the pilot to  
2 reach these limiting temperatures?

3 MR. LEONARD: Only in the context that  
4 I've shown here, which is for those assumed --

5 MEMBER ADBEL-KHALIK: For the pilot, not  
6 for the main disk.

7 MR. LEONARD: No. The pilot itself has  
8 not been included in the model. It sits on top of  
9 here.

10 MEMBER ADBEL-KHALIK: Do you know how  
11 small the pilot is?

12 MR. LEONARD: The pilot is very small in  
13 comparison to this.

14 MEMBER ADBEL-KHALIK: Right. So at the  
15 five percent flow, do you think how long it would take  
16 for the pilot to reach these limiting temperatures?

17 MR. LEONARD: Well, the pilot is  
18 physically removed, even from the back stage of the  
19 main valve. That is, the pilot itself sits on top  
20 here, and it's, there's an additional flow diversion  
21 from this chamber up into the pilot and back.

22 So it would be a yet smaller fraction of  
23 the total flow that goes through this stage of the  
24 valve. The flow rate through here is designed to make  
25 sure that the pressure on the back side of the piston

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1 is sufficient to drive the valve closed, whereas the  
2 pilot only needs, it has a secondary shaft that moves  
3 back and forth, only to make sure of the pressure  
4 difference across the piston face itself.

5 MEMBER ADBEL-KHALIK: You're talking about  
6 a pilot for a two-stage, or a pilot for a three-stage  
7 valve?

8 MR. LEONARD: For the three-stage.

9 MEMBER ADBEL-KHALIK: For the three-stage?

10 MR. LEONARD: Yes.

11 MEMBER ADBEL-KHALIK: And you think that  
12 that pilot wouldn't reach these limiting temperatures  
13 --

14 MR. LEONARD: You raise a good question.

15 MEMBER ADBEL-KHALIK: Allow it to deform  
16 --

17 MR. LEONARD: Our judgment, if you will,  
18 was that because of the physical separation of the  
19 two portions of the valve, the pilot from the back  
20 stage of the main valve that we're showing here with  
21 the piston.

22 The fact that the flow rate into that  
23 section of the valve was smaller than we've already  
24 diverted to the piston and the spring area, meant that  
25 its response was going to be slower than what we see

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1 in direct contact with valve stream. That may not be  
2 correct, but that was our judgment when the model  
3 itself was built.

4 MEMBER ABDEL-KHALIK: Have you looked at  
5 temperature histories of leaking three-stage valves  
6 for both the pilot and the second stage?

7 MR. LEONARD: No.

8 MEMBER ADBEL-KHALIK: Okay. You would  
9 probably see that the temperature of the pilot is  
10 higher than the temperature of the second stage.

11 MR. LEONARD: During a cycle?

12 MEMBER ADBEL-KHALIK: Correct.

13 MR. LEONARD: Yeah. Are you aware of data  
14 that is available or are available for that?

15 MEMBER ADBEL-KHALIK: I couldn't give you  
16 the data.

17 MR. LEONARD: I'm interested in -- I'm not  
18 aware of any temperature distribution data. There are  
19 temperature measurements on the valve itself, but not  
20 numerous ones that would provide us with temperature  
21 distribution information. But if you're aware of  
22 some, that would be very helpful.

23 We have nothing to benchmark this  
24 calculation. Let's put it that way. If there is any  
25 information out there, we'd be very appreciative to

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1 learn of it.

2 MEMBER ADBEL-KHALIK: But if this is such  
3 an important calculation, with huge sort of  
4 uncertainty, and if there is even the possibility that  
5 under these conditions, that this valve would cycle  
6 for only once or twice, have you looked at the  
7 possibility of what happens if the number of cycles  
8 after which this valve was seized is only limited to  
9 a few, two?

10 MR. LEONARD: Go to the next slide again.  
11 You can see that in the short-term blackout case,  
12 where --

13 MEMBER ADBEL-KHALIK: It's 15 still.

14 MR. LEONARD: In this case, where instead  
15 of moving upward, moving the stochastic model out, you  
16 pull it back and say what if it fails in just the  
17 first few cycles? How does that affect things?

18 That's also been examined in the cases  
19 that are part of the uncertainty assessment the team  
20 will talk about later, where as I said, rather than a  
21 fixed number of cycles as the stochastic criterion,  
22 the full distribution of failure rate was considered,  
23 which is used then to calculate a smaller and larger  
24 number of cycles to failure.

25 In general, if it fails open, in a very

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1 few number of cycles, these results over here are much  
2 improved. Much lower releases on average than you see  
3 for the reverse, which is if the reactor vessel  
4 remains at high pressure longer, the valve continues  
5 to cycle as designed, and you reach a thermal failure  
6 criterion.

7 If you go that far out in time, the  
8 releases tend to get much larger, especially if you  
9 can move the thermal distribution in the system out to  
10 a point where main steam line creep rupture now  
11 becomes possible. That's a threshold over which the  
12 answer changes quite a bit.

13 MEMBER ADBEL-KHALIK: Great, thank you.

14 MR. LEONARD: Well thank you for the  
15 comments. I think, especially in terms of flow  
16 distribution, that's something we should look into.

17 MEMBER STETKAR: Mark, I hate to ask, and  
18 we're trying to do things real time here, so I'm only  
19 partially listening. The stochastic distribution that  
20 you did use for the failure rate, where was that  
21 derived from finally?

22 MR. LEONARD: The value that is used in  
23 these calculations came directly from the Peach Bottom  
24 IPE.

25 MEMBER STETKAR: That's what I've read.

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1 Where did they get their value?

2 MR. LEONARD: I don't know the answer to  
3 that.

4 MEMBER STETKAR: Because I know where  
5 NUREG/CR whatever the number is, the 6928. I know  
6 where that came from.

7 MR. LEONARD: What you will find is that,  
8 and in fact it's part of the document that we put  
9 together for Peach Bottom, is that a failure rate, or  
10 I should say the number of cycles, the expected value  
11 for failure --

12 MEMBER STETKAR: One over lambda.

13 MR. LEONARD: One over lambda, if you use  
14 the IPe failure rate, corresponds to roughly the 90th  
15 percentile of the value for the generic database.

16 MEMBER STETKAR: The generic database is  
17 dominated very strongly by a subjective, non-informed  
18 prior probability distribution, because there's only  
19 two failures in that generic database.

20 MEMBER RAY: John, aren't you back on the  
21 question, at least it sounds like you're trying to ask  
22 it --

23 MEMBER STETKAR: Well, to some extent. I  
24 just want to make sure that since we're going to --  
25 Mark has cleverly deflected the uncertainty to Tina,

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1 I just want to make sure of the uncertainty we're  
2 talking about, since he's a valve guy.

3 MEMBER RAY: Well, let me ask the  
4 question, though. Wasn't the answer then that it's  
5 not the fossil plant database where valves stick open  
6 all the time?

7 MR. LEONARD: That's correct.

8 MEMBER RAY: Okay.

9 MR. LEONARD: As far as I know, unless  
10 Peach Bottom somehow used that database to estimate  
11 whatever their estimate was derived from.

12 MEMBER STETKAR: Going to the report, it  
13 says that Peach Bottom has changed that value to that.

14 MR. LEONARD: That's correct. Our  
15 understanding is that they've moved to the NUREG/CR  
16 value, that's correct.

17 MEMBER STETKAR: Well, because it's a  
18 factor of, you know, four times lower.

19 MR. LEONARD: Again, we're kind of jumping  
20 ahead to what -- I hate to steal Tina's thunder, but  
21 there are a couple of problems with simply using the  
22 numbers out of that book, or the other book that goes  
23 with it.

24 One of them is that the data are -- the  
25 failure, the observed failures are all cases that a

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1 valve failed in one, two, three cycles. We're talking  
2 one, two, three hundred cycles.

3 MEMBER STETKAR: And when you say "all  
4 cases," you mean both?

5 MR. LEONARD: Both of them. And so the  
6 question remains what, how does the valve stochastic  
7 failure probability change as you move from one to  
8 tens to hundreds of cycles? There's no data. There  
9 are no data for that.

10 MEMBER STETKAR: But I think what Dennis  
11 was asking about, you know, quite a while ago, didn't  
12 -- wasn't there quite a bit of work done on the Target  
13 Rock valves back three or four years ago --

14 (Simultaneous speaking.)

15 MEMBER BLEY: --when this issue came up  
16 after TMI.

17 MR. LEONARD: The other document, not  
18 6928, if I have the right number, but there's another  
19 more recent document, 70-something, did look at not  
20 only the observed industry failures, but also the test  
21 data.

22 MEMBER BLEY: Including the industry test  
23 data.

24 MR. LEONARD: Including the industry test  
25 data, which did move, cycle the Target Rock valve

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1 several hundred times. If you look at the failure  
2 rate that the test data reports, it is virtually  
3 identical to the industry-observed data. It's 10 to  
4 the minus 4 or something.

5 MEMBER BLEY: And that was, they did --  
6 well, they didn't do high temperatures like you're  
7 talking about.

8 MR. LEONARD: We've intentionally tried to  
9 separate the thermal expansion in the high temperature  
10 condition from the stochastic failure.

11 We're always assuming here that the  
12 stochastic failure is applied primarily to thermal  
13 conditions within the design range of the valve, so  
14 that at least the thermal component is somewhat  
15 removed in comparison to all the other mechanical just  
16 corrosion and a variety of other effects, the  
17 vibration as well. I mean a number of other  
18 mechanisms that would be truly stochastic.

19 CONSULTANT WALLIS: But since the  
20 knowledgeable observer is going to be suspicious of  
21 the stochastic approach, couldn't you provide more  
22 data or some basis for it in your report?

23 MR. LEONARD: The basis right now that's  
24 documented, we could describe the details of the  
25 database --

1                   CONSULTANT WALLIS: But if it's based on  
2                   how many points or something, or something, so that  
3                   there's a -- it gives the reader more confidence.  
4                   Otherwise, it looks pretty iffy.

5                   MR. LEONARD: For the moment, we've  
6                   provided the references for that information.

7                   CONSULTANT WALLIS: That doesn't help.

8                   MEMBER STETKAR: Well, the report, there  
9                   are three paragraphs, and the report indeed does  
10                  parrot what Mark said, that they used the failure rate  
11                  from the Peach Bottom IPE study, period. It does note  
12                  that that's higher than, you know, this other --

13                  MR. LEONARD: About a decade higher than  
14                  the generic database would suggest, and I can say  
15                  there was considerable debate as to whether we should  
16                  keep the IPE value or move to the generic database,  
17                  and among the decisions for keeping -- among the  
18                  reasons for keeping the higher IPE value was the, I'll  
19                  say qualitative expectation that the failure rate  
20                  would increase as the number of cycles increased.

21                  There will be more and more likely for  
22                  failure to occur as you move from ones to tens to  
23                  hundreds of cycles. Quantitatively, we can't capture  
24                  that with --

25                  MEMBER BLEY: I don't know why. What were

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1 the arguments for that? I mean when we see, just pick  
2 something simple like check valves in a compressed air  
3 system that operate a lot, they fail a lot less than  
4 check valves that operate very rarely.

5 So I'm not sure what kind of argument you  
6 were basing that idea on, that increasing numbers of  
7 operations would increase the failure rate.

8 MR. LEONARD: I mean the proposed  
9 mechanisms were things related to the accumulation of  
10 corrosion products --

11 MEMBER BLEY: But operation tends to clean  
12 that stuff off. That's why we exercise.

13 MEMBER STETKAR: But in some sense, I mean  
14 if you think about the way the data are developed,  
15 this is not -- in some sense I think they're being  
16 misused a bit.

17 This is not a failure rate per demand in  
18 terms of number of cycles; it's sampling of  
19 population. One out of 270 valves will stick open.

20 MEMBER BLEY: Right.

21 MEMBER STETKAR: The first time it's  
22 demanded. That's different than saying it's going to  
23 run for 270, a valve will run for 270 times, you know,  
24 on average, before it fails.

25 MEMBER BLEY: It is. But it's typically

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1 used both ways because you don't have enough knowledge  
2 to discriminate what you're talking about.

3 MR. LEONARD: In fairness to the other  
4 speakers, I mean we are going to come back to this  
5 topic. So I want you to hold these thoughts, because  
6 your advice is going to be very helpful to know how to  
7 guide the uncertainty assessment of this issue.

8 MEMBER STETKAR: Just out of curiosity,  
9 because you and I have similar blocks in terms of  
10 remembering NUREG numbers, and Marty Stutzke doesn't.  
11 You got as far as NUREG-70, and I don't have that.

12 (Laughter.)

13 MEMBER STETKAR: Are there a couple of  
14 other digits on the NUREG, because I don't have it.

15 MEMBER BLEY: 7037.

16 MEMBER STETKAR: Okay. If we could get  
17 it. Just keep the thing going. If I could get it  
18 during the break --

19 MR. LEONARD: I have it with me. I have  
20 it down here, so when I'm finished, I'd be happy to  
21 give that information to you.

22 MEMBER BLEY: Before we leave this, I just  
23 wanted to toss one thing on the table, and it probably  
24 comes up in the uncertainty analysis. When you were  
25 describing your analysis of the temperature changes,

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1 you argued that gee, when there's temperature changes,  
2 that could seize us anywhere between 0 and 100  
3 percent. Ten percent is likely as anywhere else.

4 It doesn't sound physically reasonable to  
5 me. If you run a pump without cooling and the wave  
6 lengths begin to expand, keep it running and it keeps  
7 running, and you turn it off and it won't start again.  
8 I mean if you can get it moving, the chance that it  
9 stops at ten percent seems pretty unlikely.

10 MR. LEONARD: And I think that's -- we  
11 have learned the same way, that the initial  
12 distribution that the measurement presented, in terms  
13 of the seizure location, represented effectively  
14 complete uncertainty between full open/full close.

15 MEMBER BLEY: Like equally likely.

16 MR. LEONARD: Equally likely. What I  
17 think we're beginning to move to is one that is far  
18 more likely to simply stay open and not move. So  
19 there would be a strong bias toward a full open  
20 position.

21 MR. SCHAPEROW: Another argument in that  
22 regard is that the thing doesn't have, the stem  
23 doesn't have to move too far before you're now at the  
24 full open area, and once -- it keeps moving even after  
25 that. But it just isn't -- so you're in that zone

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1 very -- the ten percent opens on a very small amount  
2 of time as the thing's traveling out. It's just --

3 CONSULTANT WALLIS: And also, the stem is  
4 hotter at one end than the other. So the bit that  
5 sticks is the bit when it's full open, isn't it?

6 MR. LEONARD: That's right. So it's  
7 something we've learned along the way, where total  
8 uncertainty about an issue that we had no idea what  
9 impact we have.

10 MEMBER BLEY: It's a place to start.

11 MR. LEONARD: We've now learned that it  
12 has a very strong influence on the results, so we have  
13 to be more careful.

14 MEMBER BLEY: I'll just follow up on what  
15 Graham said earlier. I can understand brief  
16 references to failure rates and that sort of thing in  
17 the whole study. But when you've narrowed down on  
18 something important, providing more of the details,  
19 where that data comes from is really key.

20 MR. LEONARD: This is the feedback of the  
21 uncertainty assessment, in the sense that I don't  
22 think we fully appreciated how important the  
23 uncertainty about that was, until the uncertainty  
24 assessment was done, which now is following the  
25 original work.

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1           So we've documented what we've done, and  
2           are now discovering new information after that. So if  
3           I can, the final conclusions that we've come to, at  
4           least in terms of variance in the SRV failure  
5           criteria, is that reasonable variations in the failure  
6           criteria have a significant effect on in-vessel  
7           thermodynamic signatures.

8           What I mean is that things related to the  
9           time at which reactor vessel depressurization occurs,  
10          and to a small extent the time at which lower head  
11          failure occurs. The effects of those things, although  
12          the signature's changed, the cumulative effects in  
13          terms of the release to the environment, the time at  
14          which release begins is reasonably small, factors of  
15          two, not factors of ten.

16          Provided -- this is a very key, underlined  
17          word -- provided that creep rupture of the main steam  
18          line is not the outcome of the variance in the SRV  
19          failure criteria. When that happens, if that happens,  
20          then there's a significant threshold.

21          It's not a small increment. It's a  
22          significant increment in the radiological release to  
23          the environment. So that particular issue is  
24          receiving a lot of attention in the uncertainty  
25          analysis, okay.

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1           A total shift of ideas. That was the  
2 summary of our work on SRVs, and as I said, we'll come  
3 back to some of that. The second item that was raised  
4 during the peer review was the potential for a  
5 containment bypass pathway, that can be generated if  
6 a particular system, the traversing in-core probe TIP  
7 system in a BWR, is operating at the time the accident  
8 happens to occur.

9           So I'll quickly describe for you, for  
10 those of you not familiar with TIP, a very brief  
11 description of what the mechanical configuration of  
12 that system is, what it means in terms of a potential  
13 leak pathway, and what the operating practices of the  
14 system are, so we have an idea of what is the time  
15 window over which this possible leak pathway might  
16 occur.

17           The in-core probe system is used for  
18 reactor engineering calibration, power management --

19           MEMBER STETKAR: Mark, just make sure you  
20 stay pretty close to a microphone, so that you're on  
21 -- a lot of times it's easier if you use the mouse, if  
22 you have a mouse.

23           MR. LEONARD: The in-core system, the  
24 drive mechanism if you will, most of the machinery is  
25 in a room. Actually, here's a cross-section of this

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1 floor of the reactor building. It's in a room  
2 immediately adjacent to the containment outer wall.

3 That room contains, if you will, little  
4 motors that drive a cable that has a probe at the end  
5 of the cable that is driven into the core, and  
6 traverses the full axial length of the core to do flux  
7 measurements and a variety of other things that  
8 reactor engineering means for their work.

9 Cable runs through a tube that follows a  
10 path roughly shown here. It enters the reactor,  
11 enters a drywell through a penetration in the wall  
12 about mid-height in the spherical region. Enters  
13 through a hole through an upper region of the  
14 pedestal, and then vertically into the lower head to  
15 the core.

16 So the idea would be that if somehow this  
17 tube were open to the reactor building at the time the  
18 accident would occur, the difficulty would be that  
19 during the process of core damage, what would normally  
20 be the sealed end of the tube would now be melted and  
21 possibly open.

22 If the open area of the tube were exposed  
23 all the way out to the reactor building, this, the  
24 machinery out here is not designed to be leak-tight,  
25 at least not leak-tight against the pressure that

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1 would be at reactor vessel pressures. It's designed  
2 to be leak-tight at much, much lower atmospheric  
3 pressures than that.

4 So that could be the containment bypass  
5 leak pathway that was raised as a question of whether  
6 that would significantly impact our results if the  
7 system were operating at the time the accident  
8 occurred.

9 To give you an idea of the system  
10 configuration, on the left I've shown the reactor  
11 vessel would be on the left side, the drive units in  
12 the reactor building on the far right. There is a  
13 shield wall within the reactor building that separates  
14 the chamber where the probe itself is stored during  
15 normal operation.

16 This drive unit out of the reactor  
17 building through a cable pushes the probe out of its  
18 shield chamber, through the drywell wall, into a  
19 device that's referred to as an indexing unit, and the  
20 best basically to think about that is it's sort of a  
21 random selector or a design selector to allow only  
22 three drive mechanisms to be able to penetrate the  
23 core in many, many more locations.

24 So you have three drive mechanisms, any  
25 one of which can, through this indexing unit, be moved

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1 to a different radial location in the core, to be able  
2 to do measurements across the entire core radius.

3 Among the other reasons the indexing unit  
4 is important is that within it is a relief valve that  
5 would lift at relatively low pressures, that's  
6 designed primarily to protect the tubing system from  
7 the nitrogen purge system that provides a full  
8 nitrogen purge within the tube during normal  
9 operation.

10 If for some reason that system were to go  
11 haywire and to over-pressurize the tube, the relief  
12 valves would open. The relief valves are not designed  
13 to relieve, in terms of reactor vessel pressure.  
14 That's not the configuration that would be expected.

15 So the question is if within the reactor  
16 vessel you fail these tubes and expose this leak  
17 pathway, leakage through the index or the drive units  
18 out in the reactor building would provide a  
19 containment bypass mechanism. It's important to also  
20 recognize there are isolation valves in this system,  
21 a ball valve as well as what's referred to as a sheer  
22 valve.

23 The ball valve is the primary isolation  
24 mechanism, that when the probe is fully withdrawn it  
25 is in the shield, which is most of the operating

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1 period of the reactor. This valve is closed, and the  
2 system is completely isolated from the outside world.

3 MEMBER ARMIJO: Even if the guide tube  
4 failed, those valves would stop the pressure? It goes  
5 through -- the probe goes through a guide tube, right?

6 MR. LEONARD: In this case, the guide tube  
7 goes through the center of these valves. So for  
8 example, that's why the sheer valve is here, that if  
9 the probe is inserted at the time an isolation signal  
10 were to occur, and the probe cannot, for some reason,  
11 be removed, if the drive units fail, for example, if  
12 the ball valve cannot close because there's a cable  
13 through the middle of it.

14 That's the purpose of the sheer valve,  
15 that they're explosive valves that would drive a  
16 knife, if you will, through the cable and sheer the  
17 opening to the point where it causes isolation. Both  
18 of these valves require electric power. The ball  
19 valve is AC; the sheer valve explosive mechanism is  
20 discharged by a DC signal.

21 So in our case, for a full station  
22 blackout during core damage, where neither AC nor dc  
23 power would be available, if the system were in  
24 operation, there's a potential leak pathway through  
25 the open tube back to the drive mechanism. The

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1 numbers to keep in mind --

2 MEMBER STETKAR: And Mark, it's been a  
3 while since I looked at these things. Back the  
4 previous slide. You briefly mentioned the relief  
5 valves on the indexer. You're presuming that the  
6 drive mechanism will blow out at a lower pressure than  
7 those relief valves will lift, or have you looked at  
8 that? Am I stealing your story?

9 MR. LEONARD: We've bounded the leakage,  
10 because the leakage at the drive mechanism through  
11 what are effectively mechanical seals that at high  
12 temperatures would fail anyway.

13 MEMBER STETKAR: Okay.

14 MR. LEONARD: What that leak area would be  
15 is not --

16 MEMBER STETKAR: No. But I mean you told  
17 me what I was asking. You presumed that those seals  
18 will fail at a lower temperature pressure threshold  
19 than the relief valve would. The relief valve's  
20 probably --

21 MR. LEONARD: Because they're designed to  
22 be sealed against roughly maybe two bar. I mean a  
23 very low pressure relative to what we're talking  
24 about.

25 MEMBER STETKAR: And it's a probably 100

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1 and some odd pound relief valve?

2 MR. LEONARD: That's right.

3 MEMBER STETKAR: Okay.

4 MR. LEONARD: And they're certainly not  
5 capable of taking high temperature.

6 MEMBER STETKAR: Okay, thank you.

7 MR. LEONARD: Okay. The system's only in  
8 operation for about an hour every four months. That's  
9 the frequency that the probe measurements are taken,  
10 which from an action and frequency point of view  
11 represents somewhere in the neighborhood of 4 to the  
12 minus 4 per year. You have that on top of an accident  
13 sequence of  $1E$  minus 6.

14 The total frequency of the accident  
15 occurring at the time the tip is operating is very,  
16 very small. Nevertheless, we wanted to quantitatively  
17 measure the effect of the system if that condition  
18 happened to occur, and because of uncertainties, as I  
19 mentioned earlier in terms of leak areas, we first  
20 began by looking at a bounding case.

21 That is that the normal condition is that  
22 all three tubes in fact would be operating  
23 simultaneously. All three drives would be working at  
24 the same time, and the main reason for that is to get  
25 all the measurements done as quickly as possible, to

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1 reduce total exposure.

2 MEMBER ADBEL-KHALIK: I thought it takes  
3 a shift to do this, rather than an hour.

4 MR. LEONARD: We were informed that it  
5 takes an hour to do the total test cycle. This was  
6 among the information that we pulled from the fact  
7 check, I think, with the licensee.

8 MR. CHANG: We had a conference call with  
9 the TIP system manager over at Peach Bottom, and  
10 that's what they told us.

11 CONSULTANT WALLIS: It seems very quick.

12 MR. LEONARD: They're able to do -- by  
13 running all three tubes for an hour, they can do all  
14 the measurement locations fairly quickly, and it's  
15 part of their effort to reduce personnel exposure  
16 because, you know, this is one of the more active  
17 systems, from an activity point of view and an  
18 exposure point of view, one of the systems they have  
19 to be careful with.

20 I've already mentioned that the isolation  
21 valves require electric power to operate, and at the  
22 moment there are no formal provisions. What I mean by  
23 that is written procedures to close the valves in the  
24 absence of electric power. I think as part of the  
25 discussion we've had through this program, that's an

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1 insight that the licensee has considered.

2 Next. Because of the variables and some  
3 uncertainty in the leak area, we first approached a  
4 bounding case, which is all three lines are in  
5 operation. The isolation valves are full open, and  
6 all three probes are fully withdrawn.

7 What that means is the maximum leak area,  
8 full diameter of all three tubes. Now when I say  
9 that, that only corresponds to three times about a  
10 quarter-inch ID tube. These are very, very small  
11 tubes. The cable that drives the probe in is an  
12 aircraft cable of roughly a quarter in in diameter.

13 A much more realistic case would be that  
14 all three tubes are in operation, that with the probes  
15 inserted, the cable diameter is, as I mentioned there,  
16 .258 out of a 2-8 diameter. The gap around that is  
17 extremely small. So again, we're looking at the  
18 bounding case.

19 We built a model for the tubes. That is,  
20 the tubes themselves are considered the control  
21 volume. The leak through those tubes to the reactor  
22 building is incorporated into our integral calculation  
23 of action and progression, fission product release and  
24 transport.

25 What I've shown here is an overlay of the

1 baseline results, the best estimate results that are  
2 presented in the report, against a sensitivity that  
3 includes the maximum bounding leakage through the TIP  
4 tube.

5 On the left is the main bounding case.  
6 This is one where the iodine release, in comparison to  
7 the base case cesium, compared to the base case and  
8 molybdenum, as well noble gas, you can see that the  
9 difference is very small, certainly within the  
10 uncertainty of the accident signatures that we're  
11 generating in the first place.

12 MEMBER BLEY: Two quick questions, because  
13 it's been a long time since I looked at the TIP  
14 system. Is that tube typically is not open to the  
15 RCS, is it? So it would have to fail, and you're  
16 assuming that it fails?

17 MR. LEONARD: That's right. You're  
18 assuming that --

19 MEMBER BLEY: Because of the core damage.

20 MR. LEONARD: In this case the tube is  
21 assumed closed until the extent of damage in the core  
22 reaches approximately midcore height, and when fuel  
23 cladding or approximately mid-height of the core  
24 fails, based on the all the failure criteria that are  
25 normally represented as part of the material

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1 relocation models --, we open this tube. The idea is  
2 that you open --

3 MEMBER BLEY: This calculation doesn't  
4 have any frequency in it?

5 MR. LEONARD: What do you mean?

6 MEMBER BLEY: In the 10 to the minus 4,  
7 the chance that you're in this condition?

8 MR. LEONARD: This represents a case where  
9 that tube is full open. So you are effectively  
10 operating during that 10 to the minus 4th period.

11 MEMBER BLEY: But this is just a  
12 consequence. So it doesn't have that 10 to the minus  
13 4?

14 MR. LEONARD: That's correct. So that the  
15 --

16 MEMBER BLEY: But even so, it's not a big  
17 --

18 MR. LEONARD: This is fraction of  
19 inventory released to the environment, and the main  
20 curves that you see here are the baseline results that  
21 do not take into account this leakage pathway. The  
22 lines that are somewhat shorter, and it's only because  
23 it takes -- these calculations are very time-consuming  
24 because of the small dimensions that the tube  
25 represents.

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1                   We've been able to show that during the  
2 key portion of the release period, the release  
3 increases slightly, but not in a substantial enough  
4 way --

5                   MEMBER BLEY: This is going to matter. I  
6 always kind of question the 10 to the minus 4 because  
7 I don't know why you couldn't have accidentally left  
8 one of these ball valves open.

9                   MR. LEONARD: That's right.

10                  MEMBER BLEY: It might give you a higher  
11 exposure than the 10 to the minus 4.

12                  MEMBER ARMIJO: That's a stainless steel  
13 tube?

14                  MR. LEONARD: That's correct.

15                  MEMBER ARMIJO: And it not pressurized  
16 against reactor pressure?

17                  MR. LEONARD: That's correct.

18                  MEMBER ARMIJO: So when this, this thing's  
19 at high pressure and the fuel's getting very, very  
20 hot, the stainless steel is getting into creep  
21 rupture, creep collapse. But one of the mechanisms of  
22 failure is actually just flattened and squeezing these  
23 tubes down?

24                  MR. LEONARD: That's right.

25                  MEMBER ARMIJO: Did you take that into

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1 account, or you just left them geometrically?

2 MR. LEONARD: It's a good lead-in. Thank  
3 you for the question, because the curves you see on  
4 the left are --

5 MEMBER ARMIJO: But that's what will  
6 happen.

7 MR. LEONARD: --are the results if the  
8 tube remains fully intact, and there are no adverse  
9 effects on the tubes.

10 To the right, we actually calculate the  
11 wall temperature of the tube, and at temperature and  
12 pressures that would lead themselves to creep, we  
13 assume that the tube ruptures in a full open position,  
14 full open area to the drywell, because of the majority  
15 of the tube run is through the containment, not  
16 outside the building.

17 The isolation valves are only a few inches  
18 from the containment wall, for example. What you can  
19 see is rather than the release increasing slightly, it  
20 actually decreases slightly, and that's primarily  
21 because the leakage is now through the tube to the  
22 drywell, which provides additional scrubbing through  
23 the suppression pool.

24 CONSULTANT WALLIS: But not for the  
25 iodine. The iodine looks the same in the two cases.

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1 MR. LEONARD: That's right.

2 CONSULTANT WALLIS: Is that a misprint or  
3 is that --

4 MR. LEONARD: No. They're basically --  
5 you don't see nearly as strong an effect for the  
6 iodine as you do for either of the other two species  
7 shown here.

8 MEMBER STETKAR: Mark, the analyses you  
9 did on the creep rupture assumes pristine tubes,  
10 because there's been experience in these things of,  
11 you know, reasonably substantial wall thinning at  
12 several plants.

13 MR. LEONARD: Uh-huh. In this case, we  
14 used the design value of the tube wall thickness, but  
15 used the standard creep model in terms of stress  
16 required for the tube to fail.

17 MEMBER STETKAR: But I mean you -- thanks.

18 MEMBER REMPE: Where did you place this  
19 tube? In the center of the core, at the peak  
20 temperature of the core, wherever that is, and so it  
21 was a movable tube to hide the peak cladding  
22 temperature?

23 MR. LEONARD: The only thing that is tied  
24 to the core itself, in this case, is the criterion  
25 that's used to define when the tube opens, and in that

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1 case, we monitor the clad integrity in the radial  
2 center of the core.

3 I'd have to check to be sure on this, but  
4 either at the core midplane or slightly higher, one of  
5 the two. Certainly in the upper half of the core, but  
6 certainly also core, the center radius.

7 MEMBER REMPE: So it's at the center of  
8 the core? I mean you could tie it to just peak by  
9 temperature wherever it is?

10 MR. LEONARD: We could tie it to anywhere.  
11 We had to choose a location.

12 MEMBER REMPE: You picked a location.

13 MR. LEONARD: We picked the hottest  
14 location. That was the intent.

15 MEMBER REMPE: So it's a movable tube  
16 that's at the hot location, somewhere in the core?

17 MR. LEONARD: It would depend -- in this  
18 case, reality would depend on the indexing unit. If  
19 at the time this occurred, the indexing unit had moved  
20 the probes to some outer location, then the tube  
21 that's in operation would not be in the center.

22 But the guide tubes would still exist on  
23 all other core locations, and they would all go back  
24 -- they all go back to that indexing unit. So the  
25 connection, the flow connection between the core and

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1 the indexing unit for all radial locations is always  
2 open.

3 It's only from the indexing unit through  
4 the machinery, through the drywell wall to the reactor  
5 building, that's where you -- everything condenses  
6 down to only those three lines.

7 So in this case, we're assuming that even  
8 if the probe was not operating in the center, that the  
9 open tube from the center to the indexing unit is  
10 still open, and that it would somehow be connected  
11 through the tube to the outside world.

12 So it's bounding in a couple of contexts.

13 MEMBER REMPE: And then I missed somehow  
14 or other. I understand what the creep rupture TIP to  
15 this is. Tell me again of the continuous cases? Is  
16 that -- what does this say?

17 MR. LEONARD: The tube remains intact for  
18 the entire accident scenario, that the tube is always  
19 open and is not -- tube integrity is not in any way  
20 compromised by creep or any other mechanism.

21 MEMBER STETKAR: You blow out the seals in  
22 the --

23 MR. LEONARD: Blow the seals out in the  
24 drive mechanism. It's a continuous flow path to the  
25 reactor building. Maybe that's a better way to think

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1 of it.

2 CONSULTANT KRESS: Now this is a flow  
3 driven by steam pressure going through this tube,  
4 carrying the fission products with it?

5 MR. LEONARD: That's right.

6 CONSULTANT KRESS: So you have to know  
7 what the fission product concentration in the steam  
8 line is and in the core.

9 MR. LEONARD: That's right.

10 CONSULTANT KRESS: And how that gets  
11 driven into the entrance to the tube, and the pressure  
12 drop through there gives you the flow rate, and that  
13 ends up giving you that curve?

14 MR. LEONARD: That's exactly right. So  
15 whatever the local fission product concentration is in  
16 the core, at the location where the tube fails --

17 (Simultaneous speaking.)

18 CONSULTANT KRESS: It's probably about the  
19 same -- probably about the same anywhere in the core.

20 MR. LEONARD: That's right.

21 CONSULTANT KRESS: Yeah, okay.

22 MR. LEONARD: Okay. So the conclusions  
23 that we came to from this sensitivity were that first  
24 of all, the frequency of the situation is very low.  
25 Certainly, the combination of the conditional

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1 probability that the system is operating, coupled with  
2 the accident sequence frequency is well below the  
3 truncation limit that the program was designed for.

4 CONSULTANT WALLIS: Mark, if I may go  
5 back? Why does it blow out? I mean these things that  
6 are inserted. Because it's not pressurized, because  
7 it's sealed at the end. That's okay.

8 MR. LEONARD: I don't recall the design  
9 pressure for the system, but it's very low.

10 CONSULTANT WALLIS: So can this blow out  
11 the wire?

12 MR. LEONARD: Which water? I'm sorry.

13 MEMBER ARMIJO: The wire.

14 CONSULTANT WALLIS: The wire.

15 MR. LEONARD: The wire.

16 CONSULTANT WALLIS: The wire can be blown  
17 out by the pressure difference on it. So it's not so  
18 unreasonable to assume that the wire is gone.

19 MEMBER ARMIJO: It's a very long wire. It  
20 would probably just jam in there.

21 MR. LEONARD: It would probably bind up,  
22 because the wire is 20 or 30 meters long in the center  
23 of the tube, with a very small --

24 CONSULTANT WALLIS: I know it goes in  
25 pretty smoothly, so it comes out pretty smoothly.

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1 MR. LEONARD: But it would also have to be  
2 completely open at the drive end for that --

3 CONSULTANT WALLIS: Well, whatever the  
4 mechanism is there, it's not pressure. It doesn't  
5 take those pressures.

6 MR. LEONARD: But it's still connected to  
7 the drive mechanism at the other end. That's right.  
8 So the frequency of this event that we're looking at  
9 is very small.

10 CONSULTANT WALLIS: Test it.

11 MR. LEONARD: There will be another test  
12 you could do. The leak area is very small. We've  
13 examined a bounding one, at roughly eight times what  
14 would probably be the more likely area, if the cable  
15 were in place.

16 The possibility of creep was examined,  
17 because the tube temperatures would be very high, and  
18 the effect in terms of the fission product release to  
19 the environment for the offsite consequence  
20 calculation was small enough that it did not  
21 significantly disrupt the baseline accident sequence.  
22 We're very grateful for looking at it.

23 CONSULTANT KRESS: Did you by any chance  
24 go back to TMI and see if these calculations agreed  
25 with the kind of iodine you saw?

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1 MR. LEONARD: We have not.

2 CONSULTANT KRESS: No?

3 MR. LEONARD: Although we were provided,  
4 by the peer review committee, with some information  
5 about some activity measurements in the same area,  
6 same floor of the building at Fukushima. So it would  
7 be interesting down the road to see if this idea could  
8 be connected there.

9 CONSULTANT KRESS: They have these same  
10 probes there?

11 MR. LEONARD: Yes.

12 MEMBER SKILLMAN: TMI had 52. All were  
13 exposed to the complete chemistry and radionuclide  
14 inventory. But all are sealed at a seal table in the  
15 containment. So there was no backflow of consequence  
16 at TMI-2.

17 CONSULTANT KRESS: This was Henry's reason  
18 for --

19 MR. LEONARD: That was the initial  
20 motivation, yeah, that's right. For the last topic,  
21 I will pass off to Randy Gauntt, who examined barium  
22 and cerium behavior.

23 MR. GAUNTT: I have like ten slides here  
24 explaining some observed, some observations that were  
25 made relative to barium, but it seems not quite

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1 commensurate with the whole body of work that was done  
2 in SOARCA. But from time to time, MELCOR delivers an  
3 unusual result, and then I'll get called in to  
4 explain. Is there a bug in the code, or is this a  
5 good answer or what-not?

6 This is one of those instances here. In  
7 the case of the short-term station blackout in Peach  
8 Bottom, we observed that the barium and cerium were  
9 dominating the emergency phase dose, and what we knew  
10 was we were releasing to the environment ten percent,  
11 in the short term ten percent of barium in the short-  
12 term station blackout, and only one percent in the  
13 long-term station blackout.

14 This is at the end of the road. MELCOR  
15 delivers you the answer, and now it's a bit of an  
16 archaeological dig to find out now why did it release  
17 ten percent?

18 What I'm going to tell you, the sum story  
19 is right here on one slide, but I have -- the  
20 subsequent slides are basically the body of evidence,  
21 if you will, kind of circumstantial evidence that  
22 leads us to why we think we're seeing additional  
23 barium in the short-term station blackout.

24 What we do know is it's coming out during the  
25 ex-vessel, the core concrete interaction stage. We

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1 can tell that clearly, and that means it's being  
2 driven by the CORECON, that's the core concrete  
3 interaction, in concert with VANESSA.

4 VANESSA is Dr. Powers' code for doing the  
5 chemical equilibrium on the fission products  
6 speciation in the ex-vessel. So unfortunately,  
7 VANESSA does not reveal itself very well to the user.  
8 We see what's released at the end of the day.

9 So after digging into this quite a bit,  
10 short story is these enhanced releases are due to  
11 chemically reducing environment, that is a short  
12 period of time during the ex-vessel phase, when there  
13 is zirconium mixing with the core concrete.

14 The zirconium's quickly consumed, and then  
15 lesser reactive metals sequentially get consumed. But  
16 the zirconium is the strongest reducing agent.

17 MEMBER ARMIJO: But hold it. The  
18 zirconium's already been reacted with water to form  
19 hydrogen, and it's an oxide. So how can it be a  
20 reducing agent?

21 MR. GAUNTT: Because you don't oxidize all  
22 of it in the in-vessel stage. You drop a lot of  
23 zirconium with steel as well, unoxidized.

24 MEMBER ARMIJO: So you've apportioned the  
25 amount of zirconium that is just unreacted?

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1 MR. GAUNTT: Yeah.

2 MEMBER ARMIJO: And somehow that molten  
3 zirconium will reduce barium oxide, cerium oxide?

4 MR. GAUNTT: I'll step you through, you  
5 know, to show you what happens here. I kind of summed  
6 it all up here. It's chemically reducing. That  
7 favors the higher, the more volatile reduced form of  
8 barium.

9 I'll show you a little bit about that. It  
10 is temperature-dependent. We see that in the short-  
11 term blackout, there's higher temperature in the MCCI.

12 That seems to have an effect on the  
13 equilibrium, and there's also strung mass transfer due  
14 to all of this gas that's percolating through the core  
15 concrete. That tends to transport the barium out. So  
16 all these things act together, and I'd just note that  
17 BWRs have a lot more zirconium in them than PWRs.

18 So we tend to see this phenomena in our  
19 BWR calculations. It's come up in the past. Jocelyn  
20 Mitchell used to note from time to time man, I'm  
21 seeing a lot of barium in this calculation. I wonder  
22 why that is? And we finally dug into it here.

23 Let's go to the next slide. This kind of  
24 shows some of the circumstantial evidence here. I put  
25 a lot on this. You'd probably see it better on your

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1 slide. What I've indicated here is the barium  
2 release, along with MCCI temperature for the short-  
3 term station blackout and for the long-term station  
4 blackout.

5 It's a bit noisy. I apologize, but this  
6 is kind of how you have to root through this. What  
7 I've shown here, the red curve here is a fuel release.  
8 That's probably easiest to follow. Fuel release of  
9 barium prior to the ex-vessel. This is in-vessel  
10 release down here, around two percent.

11 Then at eight hours when the head fails,  
12 all this material, including unreacted zirconium,  
13 falls to the concrete and begins to react. The  
14 zirconium reacts quickly. What I've shown in the  
15 green shade there is the presence, the time period  
16 during which there is unoxidized zirconium.

17 Outside of this green bar, the zirconium  
18 has been consumed. It's all oxide, and so what you  
19 see is you see this big burst of release of barium  
20 during the time period that unoxidized zirconium is  
21 there. When the zirconium goes away, the release  
22 stops and the curve kind of goes over here.

23 We see in the long term blackout a similar  
24 period of time here, where there is unreacted  
25 zirconium, but a much smaller bump, and so here's some

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1 of the circumstantial evidence. We have higher MCCI  
2 temperature. That's this blue line here.

3 For reference, I'm showing here the  
4 boiling point of pure barium metal right here, and you  
5 can see that you have lower temperatures here in the  
6 long-term station blackout than in the short-term  
7 station blackout. So far, this is kind of all  
8 circumstantial. This is the trends we're seeing.

9 Next slide. So why the hotter  
10 temperature? I plot here in the top curve the decay  
11 heat. So it's earlier in time, and so the short-term  
12 station blackout has a higher decay heat that's with  
13 the fuel material on that. So there's more power from  
14 decay relative to the short term.

15 This kind of translates over to higher  
16 chemical energy in the core concrete interaction. You  
17 have more power from the generator than in the core  
18 concrete mix in the short term than in the long term.

19 CONSULTANT WALLIS: So when you do the  
20 uncertainty analysis of this temperature, it will be  
21 like a switch?

22 MR. GAUNTT: Right.

23 CONSULTANT WALLIS: For some scenarios, it  
24 doesn't reach the boiling point of barium and for some  
25 it does. It would be like a switch.

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1 MR. GAUNTT: I should think we might see  
2 that. I mean it does seem to be just right at that  
3 transition point.

4 MEMBER CORRADINI: Hey Randy?

5 MR. GAUNTT: Yeah.

6 MEMBER CORRADINI: Randy, can I ask a  
7 question? I just want to kind of follow on Graham's  
8 point. Is it really a switch, because you've got a  
9 partial pressure that's always --, or is there some  
10 chemical reaction that until you get it, until you  
11 actually get to a boiling point where you're  
12 generating essentially its own vapor, that you change  
13 the phenomena.

14 I would just think barium's always going  
15 to be outguessed at some partial pressure through the  
16 gas bubbles in your MCCI modeling, or am I  
17 misunderstanding?

18 MR. GAUNTT: Let's go to the next slide.  
19 I think it's tied in with the Gibbs energy. Now I  
20 don't know if there's any chemists here. If Dana was  
21 here, he would tell us all about this. Advance it.

22 MEMBER CORRADINI: I'm sure he would.

23 MR. GAUNTT: Yeah. The next slide, I  
24 guess this is more circumstantial evidence here. We  
25 have in the short-term station blackout -- here, I'm

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1 showing gas generation. There's a lot more gas  
2 percolating through the MCCI in the short term  
3 compared to the long term.

4 Now let's go to the next slide and try to  
5 put all this together. So it's not, Mike, actually as  
6 simple as calculating a vapor pressure. I show here  
7 on the chart vapor pressure of barium metal over pure  
8 barium, and the pressure of barium oxide over pure  
9 barium oxide.

10 Now that's not what's happening in the  
11 complex system. I just kind of show this for  
12 reference. But you can see that the barium metal is  
13 more volatile than the barium oxide, and you know, the  
14 difference here is just a few hundred degrees Kelvin  
15 that separates these two. So that shows you that it's  
16 real sensitive to temperature.

17 Now what actually happens in VANESSA, it's  
18 chemical equilibrium code, and it calculates  
19 equilibrium of a multi-component system. A lot of  
20 equations are being solved within VANESSA, and  
21 basically it's an approach that involves minimizing  
22 Gibbs energy, and Gibbs energy is temperature-  
23 dependent.

24 MEMBER CORRADINI: So Randy, Randy if I  
25 might just ask a question, and again maybe you guys

1 are all going to cleverly pass this off to the  
2 uncertainty person.

3 (Laughter.)

4 MR. GAUNTT: And I'll be catching a flight  
5 while you're doing that.

6 MEMBER CORRADINI: As I said, you're very  
7 clever. So I guess my point is if you want to  
8 unscramble this, can't you not just interdict into the  
9 calculation and just tell MELCOR that there's less  
10 zirconium?

11 In other words, if you think it's a  
12 combination of decay heat and zirconium content, and  
13 essentially the sparging rate that's affiliated with  
14 gas release on the concrete, one could unravel this by  
15 strictly changing one of these things from a  
16 sensitivity standpoint, reducing zirconium but keeping  
17 the higher decay.

18 So you can actually take what you're  
19 saying and see if by some qualitative hypothesis, that  
20 this essentially reduces it significantly. Do you see  
21 where I'm going?

22 MR. GAUNTT: Oh yeah, yeah. I should have  
23 talked to you sooner. You know, that's something we  
24 could definitely -- that's definitely doable.

25 MEMBER SCHULTZ: But that would address

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1 one of the variables, but there's also --

2 MR. GAUNTT: It would in temperature as  
3 well. It would confirm our circumstantial case here.

4 MEMBER ARMIJO: You know, I don't know  
5 what you've input into the VANESSA code, and I don't  
6 know the code either, but there's so many components  
7 that are involved here. You've got stainless steel.  
8 You've got zirconium in an oxide form and perhaps in  
9 a metallic form.

10 You've got stainless steel in a molten  
11 form. At some point in here you've got some concrete.  
12 You've got so many variables that go into this thing.  
13 It seems to me like you're -- it's oversimplistic to  
14 just pick out zirconium plus barium oxide. Oh by the  
15 way, you've got --

16 MR. GAUNTT: Well VANESSA, of course, is  
17 handling the full system, and I picked out a couple of  
18 the operative reactions, to just illustrate what's  
19 going on.

20 MEMBER ARMIJO: So you input all of these  
21 elements into the VANESSA?

22 MR. GAUNTT: They are in the VANESSA  
23 database, and we don't input anything. They're all  
24 there. Now MELCOR delivers to VANESSA so many  
25 kilograms of zirconium metal, so many kilograms of

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1 zirconium oxide, UO<sub>2</sub>, stainless steel, and all this  
2 mix drops down onto the floor, and then that's when  
3 VANESSA takes it on.

4 MEMBER CORRADINI: I think though Sam, I  
5 guess I'm somewhat sympathetic to Randy kind of  
6 unraveling it, because I do think, at least in old  
7 calculations that I remember, the presence of a lot of  
8 zirconium totally changes how the chemistry behaves,  
9 because it's stealing oxygen from everything, and it's  
10 keeping the temperature very high.

11 If you add that to the fact that you're  
12 early in time with the decay heat, I'm just looking  
13 for ways to very simply unravel it. That's the only  
14 reason I asked a question about this, because in some  
15 sense I think I see where Randy's going with this.

16 MR. GAUNTT: So the equations that I  
17 pulled out here, they're of course reversible. But  
18 here we see zirconium reducing barium oxide. Barium  
19 oxide would be the, you know, the preferred form  
20 otherwise. But zirconium is reactive enough to reduce  
21 the barium oxide and produce this more volatile barium  
22 metal form.

23 Additionally, there's hydrogen present in  
24 the MCCI because of the zirconium reacting with water.  
25 So this presence of hydrogen down here in the third

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1 equation, that's another strong reducing component  
2 that's pushing the equation over to produce barium  
3 metal.

4 It is temperature-dependent. You have to  
5 have the zirconium there. Without zirconium, you  
6 don't see this reduction in the barium, and then  
7 lastly, this strong gas sparging is, drives a mass  
8 transfer.

9 So what it does is it takes these volatile  
10 forms and sweeps them out, and sort of keeps the  
11 equations constantly in disequilibrium, and then  
12 VANESSA tries to put it back into equilibrium. So  
13 these equations are constantly pushing to the right-  
14 hand side, because of the mass transfer.

15 MEMBER REMPE: When you're relocated and  
16 you're doing the MCCI, how much unoxidized zirconium  
17 is there roughly? I'm sure it varies by scenario and  
18 time, but is it 40 percent, 20 percent, 10 percent?

19 MR. GAUNTT: Oh my gosh. Mark, do you  
20 recall?

21 MR. LEONARD: Twenty to thirty percent.

22 MR. GAUNTT: Twenty to thirty percent.

23 MEMBER ARMIJO: Is that mostly channel  
24 material? Is that where it's coming from?

25 MEMBER STETKAR: Mark, you've got to come

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1 up to the microphone.

2 MR. LEONARD: I think representative for  
3 these cases would be residual unoxidized zirconium in  
4 the neighborhood of 30 percent. When it arrives in  
5 the lower head, you don't know what, where it  
6 originated from. All you know is it's zirconium.  
7 Whether it came from unoxidized channel box or a clad,  
8 it's debris in a big pile. Where it originated from,  
9 you don't know.

10 MEMBER ARMIJO: And there wasn't enough  
11 steam or water to react with it?

12 MR. GAUNTT: In vessel? It's reacting in  
13 the core, and then it's incomplete, and then it runs  
14 through its melting point, and the metallic part of it  
15 runs down and freezes up. So you always end up with  
16 some fraction of unoxidized zirconium, both from the  
17 cladding and the channel boxes as well.

18 MEMBER SCHULTZ: Randy, the last bullet,  
19 strong gas sparging, again drives the mass transfer  
20 here. So that has a, as you described it, a dramatic  
21 effect on the result. Is that an element that's an  
22 assumption in the model, or is it well-based upon  
23 experimental evidence, the strong gas sparging in the  
24 MCCI?

25 MR. GAUNTT: I think it's well-based in

1 experimental observation. It's inescapable that  
2 you're producing a lot of carbon, in this case carbon  
3 monoxide and carbon dioxide, as well as hydrogen.  
4 Those are the principle gases that are coming off of  
5 the concrete.

6 MEMBER SCHULTZ: So then it does drive  
7 back to what Mike was describing, the content or the  
8 amount of zirconium that is in the area at this time  
9 in the evaluation?

10 MR. GAUNTT: Yeah. The principle role of  
11 the zirconium is to produce a reducing, sufficiently  
12 reducing environment that allows that barium to form  
13 in the first place. All of the carbon monoxide and  
14 carbon dioxide that's coming out of the concrete, it's  
15 just bubbling through this like a witches brew, right.

16 So it's constantly sweeping the gaseous  
17 products out, including the volatile barium, and that  
18 keeps the equations sort of unbalanced.

19 MEMBER SCHULTZ: And it drives the  
20 temperature, the zirconium.

21 MR. GAUNTT: And the zirconium drives the  
22 temperature up. So those things are all -- it would  
23 be interesting, you know, to carry out Mike's  
24 exercise, to see if we could, you know, physically  
25 turn some of those knobs and confirm that. That did

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1 not occur.

2 MEMBER REMPE: Of the assumptions about  
3 the unoxidized zirc are again assumptions based on  
4 limited data, especially with light phase progression  
5 and some of this occurring; correct? Or how strong  
6 are the databases to support some of this?

7 MR. GAUNTT: Yeah. Any of the assumptions  
8 you're talking about, they're deeply embedded in the  
9 melt progression models, and there are no assumptions  
10 that we're --

11 MEMBER REMPE: Right, I know that. But  
12 the models themselves are based on limited data is the  
13 point I just wanted to bring up again.

14 MR. GAUNTT: They're based on the  
15 experiment set we have, and we leaned heavily on the  
16 PHEBUS test. That's true.

17 MEMBER ARMIJO: I just wanted to ask you  
18 a question. If hydrogen is such an effective reducing  
19 agent, assume you reacted all of the zirconium and  
20 just made a lot more hydrogen, would this effect still  
21 occur?

22 MR. GAUNTT: If there was no zirconium and  
23 if you back up, yeah. As soon as the zirconium goes  
24 away, well this doesn't show it. It's one of the  
25 other slides, that one.

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1           As soon as the zirconium is consumed, and  
2 I was watching this, and this is one thing I can tell.  
3 As soon as the zirconium disappears, the barium  
4 release shuts off. So it's really tied in with the  
5 reducing properties of the zirconium.

6           MEMBER ARMIJO: So hydrogen alone won't do  
7 it.

8           MR. GAUNTT: So really it's the same --  
9 it's kind of the same story with cerium, cerium and to  
10 a lesser extent lanthanum, show these similar trends.

11           The next slide, I think, shows I just  
12 replicated this for the cerium release, and you can  
13 see prior to the in-vessel release of cerium was  
14 vanishingly small, but again, when it went ex-vessel,  
15 and for the period of time that zirconium is  
16 unoxidized, you see that bump of cerium here.

17           A much smaller bump over here for the long  
18 term blackout, and again, we think that's temperature  
19 dependence of the equilibrium. And finally -- okay,  
20 so with cerium, the operative reaction appears to be  
21 this one here, where cerium oxide is, goes to the  
22 gaseous form.

23           So it's essentially the same story, and  
24 like I said it is circumstantial. I checked this with  
25 Dana, and he says this is solid. That's what, this is

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1 what VANESSA should be doing. I think that's all I've  
2 got on cerium.

3 MEMBER ARMIJO: Well, I've got to ask the  
4 question, you know. From what you heard, have you  
5 gotten anything out of Fukushima that provides any  
6 data of barium and cerium bursts?

7 MR. GAUNTT: You know, I spent a month  
8 over there, and I was asking people do you see barium,  
9 and you know, they do report -- there are some reports  
10 where they show some barium.

11 But I don't see any smoking gun, in terms  
12 of this. I don't have -- I haven't picked up on  
13 anything on Fukushima, as far as barium, you know,  
14 heightened barium release, although I'm pretty sure  
15 Unit 1 went ex-vessel.

16 MEMBER ARMIJO: That's what most people  
17 think, but maybe more than one unit went ex-vessel.

18 MR. GAUNTT: And maybe Unit 3.

19 CONSULTANT KRESS: As far as I know --  
20 sorry, Mike. As far as I know, VANESSA has no  
21 experimental validation.

22 MR. GAUNTT: Tom, I don't know where it  
23 is. If it's there, I have not seen it.

24 CONSULTANT KRESS: I haven't seen any. It  
25 may be. That's why I'm asking is there any.

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1 MR. GAUNTT: I do not know where it is.  
2 If there is a basis, I think it's VANESSA was put  
3 together strictly on a chemical basis, and that was  
4 some years ago.

5 CONSULTANT KRESS: My chemistry's little  
6 rusty, but I was assuming Gibbs-free energy was  
7 applicable only in the gas phase, not the liquid  
8 phase. Somebody who's a better chemist than I, maybe  
9 they could --

10 MEMBER ARMIJO: It works. You know first  
11 of all, it's hard to think that this is an equilibrium  
12 situation here, you know, and you've got --

13 MR. GAUNTT: I do know that the VANESSA  
14 assumption is it takes, it calculates the equilibrium,  
15 and assumes it --

16 MEMBER ARMIJO: Yeah. That's the only way  
17 you can use it.

18 MR. GAUNTT: I don't think there's any  
19 rate associated with that. The rate step seems to be  
20 the mass transfer from the gas sparging. So there you  
21 have it, barium.

22 CHAIR SHACK: Just before you go, I had  
23 one question just on a curious footnote in the Peach  
24 Bottom report, and that is that their procedures for  
25 using their B.5.b to vent the containment, they set it

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1 up so they vent the drywell rather than the wet well.

2 That doesn't seem like the greatest idea  
3 in the world. Is there some reason they did that?  
4 When you talked to the people, I mean it seems a  
5 little curious.

6 MR. CHANG: Well, I guess ultimately, are  
7 you talking about the 18 inch line or --

8 CHAIR SHACK: Well, apparently they're not  
9 using the B.5.b to open that line. They just open the  
10 drywell. That's what the footnote says.

11 MR. CHANG: Sure. I guess ultimately, the  
12 B.5.b procedures, when we had discussions with them  
13 early on the SOARCA project, it was decided that a 16  
14 inch line would be the preferred pathway, to avoid any  
15 sort of concerns about habitability within the reactor  
16 building itself.

17 I guess Mark looks like he's got some  
18 input into that. Well never mind. So ultimately,  
19 what we did, I was just there with Bob Prato this past  
20 November, talking to the licensees, walking through  
21 procedures and assumptions within SOARCA.

22 We discussed with them the potential  
23 ability to use the B.5.b equipment, the two pony  
24 bottles, to be able to open up the 16 inch hardened  
25 vent line. They said yes, it is possible to use that.

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1 The one thing to note, though, is that containment  
2 venting, at least within SOARCA, I don't think it's  
3 needed until about 20 hours into the scenario, at  
4 least for the long-term station blackout.

5 So the intention was, rather than to put  
6 a weight towards mitigated and unmitigated, without  
7 having it done in HRA, what we did was we analyzed two  
8 scenarios. One scenario, which assumes that  
9 mitigative actions occur, and included in that, use of  
10 a 16 inch hardened vent line, and one where --

11 CHAIR SHACK: That sorts of contradicts  
12 the statement that you only used the things that were  
13 in their procedures now.

14 MR. CHANG: Sure, and I guess --

15 MR. SCHAPEROW: That's the mitigating  
16 case.

17 CHAIR SHACK: Yeah. But he said in the  
18 mitigated case, they used the 16 inch line, but their  
19 current procedure said you don't use the 16 inch line.  
20 You use the drywell line.

21 MR. LEONARD: This is Mark Leonard. It  
22 depends on when you say "this procedure," which  
23 procedure you actually mean. There are several  
24 procedures that govern the opening and actuation of  
25 containment vent lines, and there is a selection

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1 process of which vent pathway to take.

2 CHAIR SHACK: Well I mean again, I'm only  
3 reading the footnote.

4 MR. LEONARD: The implementation of B.5.b  
5 is that it existed at the time that we were doing the  
6 review for containment venting. The B.5.b equipment  
7 was incorporated into the vent procedure for the main  
8 drywell and I believe the wet well vent, the larger  
9 vents, but it had not yet been incorporated into the  
10 16 inch hardened pipe vent pathway.

11 The fact that the B.5.b specific features  
12 had not yet been implemented into that procedure,  
13 didn't obviate the selection procedure, which would  
14 tend to prefer the hardened vent for reasons that are  
15 mentioned in that procedure, that talk about  
16 contamination or difficulties in the reactor building  
17 of steam filling if that vent path were to be  
18 compromised somehow.

19 So that mixture of input is what led us to  
20 choose one, in spite of the fact that strictly  
21 speaking, the B.5.b portion of the implementation  
22 procedure is not yet incorporated into the hardened  
23 pipe vent procedure itself. I hope that helps.

24 MR. CHANG: And the one thing to note,  
25 just we did a couple of back of the envelope

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1 calculations, and we might not have necessarily  
2 included it in the report. But the four other vent  
3 lines, I think we also looked at a six inch vent line  
4 as well, and whether or not that would be sufficient  
5 to keep RCIC running and lower containment pressures,  
6 and really that was sufficient as well.

7 So I guess the point for is there are a  
8 number of vent pathways available for the licensee.

9 CHAIR SHACK: Any further questions? I  
10 think it's time for a break. Thank you very much for  
11 a very interesting presentation. We'll be back in 15  
12 minutes, 11:10.

13 (Whereupon, a short recess was taken.)

14 CHAIR SHACK: We will come back into  
15 session. Now we got lucky on the first two  
16 presentations, where one ran short and the other one  
17 ran long. But we may not be so fortunate for the rest  
18 of the day, so we might have to try to worry a little  
19 bit more about schedule.

20 MS. GIBSON: We'd be happy to come back a  
21 second day if it lasts long.

22 CHAIR SHACK: No. We have St. Lucie fun  
23 tomorrow. We're ready for the updated Surry analysis.

24 MR. SCHAPEROW: My name is Jason  
25 Schaperow. I'm with the Office of Nuclear Regulatory

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1 Research, and I'm going to talk today about the update  
2 Surry analysis that we've done since we met with you  
3 last in 2010.

4 This updated analysis came out of what was  
5 going on in 2010, which was we were in the middle of  
6 a peer review, and we also gave a copy of the Peach  
7 Bottom and Surry reports that we had drafted to the  
8 two licensees. We said here, take a look at this, and  
9 let us know if there's any factual errors, what's  
10 called fact check.

11 Sure enough, Surry came back with one and  
12 it was a doozy. So it required us to completely go  
13 back and completely revise the ISLOCA analysis, and we  
14 actually started on this kind of in earnest in the  
15 beginning of 2011. We were banging away at it, and in  
16 March, the big accident happened over in Japan, and we  
17 got yanked off it again.

18 So I'd like to think we would have  
19 finished -- this took us about a year to go through  
20 this reevaluation of the ISLOCA, but we lost a few  
21 months because of the Fukushima accident. We were  
22 busy in the ops center and on call all kinds of crazy  
23 hours.

24 Anyway, as I said, we did have -- we  
25 revised the analysis. The licensee identified that an

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1 important pathway in our model, that is between the  
2 Safeguards buildings and the ops building, was not  
3 open, as we had assumed it was.

4 It was a pipe tunnel and they had filled  
5 it previously a number of years back with penetration  
6 sealant.

7 CONSULTANT KRESS: Is that typical of  
8 other PWRs though?

9 MR. SCHAPEROW: I can't really -- I don't  
10 have an answer for you on that as far as.

11 CONSULTANT KRESS: They'll probably want  
12 to look --

13 MR. SCHAPEROW: There's other buildings,  
14 and they're all connected by pipe tunnels.

15 CONSULTANT KRESS: Yeah. Probably wanted  
16 to look for typical PWRs. I might have assumed that  
17 they weren't all filled that way.

18 MR. SCHAPEROW: Yeah. They said the  
19 reason they filled this with penetration sealants is  
20 because they had a contamination issue, as far as  
21 surface contamination. One area, they didn't want  
22 contamination in one area to end up in another area.  
23 It was supposed to be a radiation barrier.

24 MEMBER BLEY: And this was a whole tunnel?

25 MR. SCHAPEROW: Well, the tunnels got --

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1 you know, these pipes going through -- it's kind of an  
2 opening maybe about twice as big as the pipes, and  
3 what they did is they'd sprayed, they had sprayed  
4 penetration sealants to kind of fill up the open area,  
5 so that air would not flow between the two buildings.

6 MEMBER SKILLMAN: But in many cases, those  
7 gaps were filled for fire protection. A lot of that  
8 was --

9 MR. SCHAPEROW: Yeah. We talked about  
10 this, and they said it was for radiation.

11 MEMBER SKILLMAN: So I think it's probably  
12 safe to assume that this is typical and not atypical.

13 CONSULTANT KRESS: That's good to know,  
14 yeah.

15 MR. SCHAPEROW: Actually, when all was  
16 said and done, it turned out not to be an issue.  
17 There actually is other ways for these two buildings  
18 to communicate. The water would flood up in this area  
19 and push the sealant out. So it's not a structural  
20 thing. It can't take a lot of pressure.

21 But it turned out that in the final  
22 analysis, excuse the pun, it was not a factor. But  
23 what it did do is it caused us to go back and re-look  
24 at our entire ISLOCA model that we had built. So the  
25 original model did depend heavily on deposition in the

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1 aux building. It was where we had most of the  
2 deposition going on.

3 We thought we would lose that in this new  
4 model. We think that we'd better take another look at  
5 this. The other thing that was, we had gotten from  
6 the licensee and the IPE early on was that the lower  
7 head safety injection pumps could flood as a result of  
8 the ISLOCA, and so when we did the reanalysis, we  
9 found out that that might not be the case.

10 So we went back to the site, again about  
11 a year ago. We went, we visited the site. We talked  
12 mitigation. We did a walk-down of all these buildings  
13 that were just outside of containment where the ISLOCA  
14 was happening or would happen.

15 We developed a detailed model, a  
16 nodalization of these areas, the Safeguards area, the  
17 containment spray pump area and the main steam valve  
18 house. We also developed a nodalization for the  
19 ventilation system for this area, and finally, we  
20 developed a detailed model of the piping between the  
21 cold leg and this building. We didn't have that  
22 before.

23 So we added this new detailed piping model  
24 between the cold leg and the Safeguards area, and the  
25 reason we did was because we thought that we were

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1 going to see a lot of deposition in this piping, about  
2 180 feet of piping with a five-inch diameter. So it's  
3 a relatively modest-sized pipe, very long. We've got  
4 aerosols going down it, so we thought that this would  
5 be important.

6 So we added new aerosol models to MELCOR  
7 to treat turbulent deposition in straight pipes. We  
8 also have quite a number of elbows and other flow  
9 regulators in this piping, and we added models for  
10 that as well. Then we validated these models against  
11 the LACE test, the LACE bypass test in particular, and  
12 we also benchmarked it against the VICTORIA models.

13 MEMBER CORRADINI: So can I ask a question  
14 at this point? So you did a hand calculation that  
15 indicated that this would be an important effect, and  
16 this allows you to essentially improve MELCOR in the  
17 process, or what was the motivation for this last one?

18 MR. SCHAPEROW: Well, actually one of the  
19 peer reviewers had asked us why aren't you treating  
20 turbulent deposition in the low head safety injection  
21 piping? And we responded well, we have a lot of  
22 deposition in the Safeguards area, in the aux  
23 building. So when we went back to redo the analysis,  
24 we took another look at it, based in part on the  
25 comment of the peer reviewer, that it might be

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1 important.

2 Also, I went back and looked at the LACE  
3 test, and those tests were specifically run for this  
4 scenario, in an attempt to be prototypical, and they  
5 found a lot of deposition. The most prototypical LACE  
6 test, LA-1, 98 percent deposition in the pipe.

7 MEMBER CORRADINI: These are the tests at  
8 HEDL?

9 MR. SCHAPEROW: Yes.

10 MEMBER CORRADINI: At Hanford? Okay.

11 MR. SCHAPEROW: That's correct. Actually,  
12 I think it was greater than 98 percent. That was  
13 within the limit of their measurements. I don't think  
14 -- their pipe was a little small. I think it was  
15 about 2-1/2 inch diameter. I think it was roughly, I  
16 don't know, 80 feet long.

17 But it was enough to make us think that we  
18 really should be treating this. If we're going to  
19 claim realistic best estimate, or I should say more  
20 realistic, you know, best estimate that we can do, we  
21 felt that we needed this modeling.

22 So we took the time. It took us a few  
23 months to get it in and get it debugged. It was a  
24 heroic effort by the folks at Sandia, but it was well  
25 worth it, as you'll see in the analysis that I'm going

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1 to present.

2 MEMBER REMPE: In general, like in the  
3 documents, let's MELCOR 1.8.6 was used, but now this  
4 is one example where you've added new models.

5 How different were the versions of MELCOR  
6 used for Surry versus Peach Bottom, and you refer to  
7 it as MELCOR 1.8.6 Star or something, since you have  
8 -- there were other examples one can cite where model  
9 changes were made in the study?

10 MR. SCHAPEROW: Yes, yes. No, that's  
11 true. The project took place over six years, so I  
12 think I'd like to characterize model changes made  
13 during that time as bug fixes. This is perhaps the  
14 one exception, where we actually added a model to the  
15 code.

16 But I don't -- there was no -- the way the  
17 project was conceived actually in the very beginning,  
18 we knew we were going to have a long campaign of  
19 several years between the calculations and eventually  
20 we had the peer review.

21 So the way the project was conceived, we  
22 actually had at the very first year, in 2006, we sat  
23 with some experts and went through the MELCOR models,  
24 to see what, how the code was. Was it up to par? Was  
25 it ready for this campaign we were going to do?

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1           So I'd like to think that the code is  
2 basically the same as back in 2006. This one --

3           MEMBER REMPE: Well take this bottom hot  
4 leg model as an example that was added.

5           MR. SCHAPEROW: That's a result of the  
6 2006 review.

7           MEMBER REMPE: Right.

8           MR. SCHAPEROW: Actually, the ERIN expert,  
9 Jeff Gabor, says you really need to think about the  
10 potential for SML creep rupture. So we added modeling  
11 to treat that.

12           MEMBER REMPE: But generally speaking,  
13 except for this turbulent deposition, whatever version  
14 of MELCOR was used was used for both --

15           MR. SCHAPEROW: Yes, that's correct. And  
16 the reason this wasn't identified in 2006 is because  
17 the ISLOCA wasn't one of our original sequences.

18           We had other sequences for Surry, but this  
19 one didn't come up until we went on our first site  
20 visit, and we compared PRAs, our SPAR models pointed  
21 to your PRA say, and then out came the ISLOCA. So we  
22 didn't have the benefit of that earlier review.

23           But we did have the benefit of the peer  
24 review, and when we met with the peer reviewers, they  
25 said well, why aren't you doing turbulent deposition

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1 in the piping, and we got into resuspension and all  
2 that stuff. But they were right. We did need it. It  
3 would certainly improve the realism of our analysis.

4 So the new analysis came out with regard  
5 to start time at core damage. About the same as  
6 before. We're now at 13 hours; before we had nine  
7 hours.

8 The reason for this result is the  
9 operators do it by procedure. They would stop and  
10 isolate both of the low head safety injection pumps,  
11 and two of the three high head safety injection pumps.  
12 And with regard --

13 MEMBER STETKAR: Why would they do that?  
14 Do they meet the DoD criteria for shutting, resetting  
15 safety injection for some of those pump slots, and why  
16 do they need them?

17 MR. SCHAPEROW: The way we did the  
18 mitigation evaluation was we met with the operators.  
19 We asked them to go through their procedures, and tell  
20 us, for this scenario, how they would -- what they  
21 would do to mitigate. What actions would they take?  
22 They said well, we have procedures for this.

23 MEMBER STETKAR: Everybody has procedures  
24 for everything. I want to understand in this  
25 particular scenario, why they would get to the

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1 conditions where their procedures would absolutely  
2 instruct them to reset safety injection, and shut off  
3 those pumps?

4 MR. CHANG: Well, in regards to -- this is  
5 from memory, but in regards to the high head safety  
6 injection pumps, I think it's a specific step as they  
7 walk through it.

8 MEMBER STETKAR: Only when you reset  
9 safety injection is my recollection, unless people  
10 have really changed the philosophy of their  
11 procedures, and to reset safety injection, you can't  
12 turn those pumps off, in most plants anyway, unless  
13 you reset the Safeguards actuation signal.

14 You can't procedurally reset the  
15 Safeguards actuation signal until you meet criteria  
16 about pressure, level, subcooling margin, which you  
17 would not necessarily meet, I don't think, in these  
18 scenarios. So that's why I'm curious.

19 MR. CHANG: And from my understanding,  
20 which is somewhat limited, I understand that the  
21 licensee has developed procedures specifically for  
22 ISLOCA events, I think, and I need to dig them up to  
23 look at them.

24 MEMBER STETKAR: Different than the  
25 fundamental EOPs that the operators are trained on?

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1 MALE PARTICIPANT: And how would they get  
2 to them? How would they know?

3 MEMBER STETKAR: Philosophically  
4 fundamentally different.

5 MALE PARTICIPANT: Yeah.

6 MR. CHANG: And I'd have to get back to  
7 them, just to look through them. We have a copy. I  
8 have a copy at my desk, but --

9 MEMBER STETKAR: In some sense, it doesn't  
10 make too much difference, because there is an  
11 unmitigated, I guess, scenario that you look at. But  
12 the curiosities that I have here that --

13 MR. SCHAPEROW: Well but again, the reason  
14 we put these in here was because we were attempting to  
15 be realistic, you know, what would happen.

16 And based on our tabletop exercise and  
17 discussions, and actually in one case they actually  
18 went into the simulator with the procedure and walked  
19 through the procedures too, and when they got to these  
20 steps, they marked down the time they would get to  
21 these steps. That was what our modeling was based on.

22 MEMBER STETKAR: For a large interfacing  
23 system LOCA.

24 MR. SCHAPEROW: For a rupture, for a LOCA  
25 outside containment, correct.

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1 MEMBER STETKAR: A fairly large LOCA  
2 outside containment, six inch line.

3 MR. SCHAPEROW: Yes.

4 MEMBER STETKAR: That's surprising. Okay.  
5 That's surprising.

6 MR. SCHAPEROW: So with regard to the  
7 releases, the environmental releases, we calculated  
8 iodine, environmental release of 16 percent offsite,  
9 and a cesium release of two percent. Our earlier  
10 analysis was a nine percent for both cesium and  
11 iodine.

12 We had calculated significant deposition  
13 in the reactor core system, and in the low head safety  
14 injection piping. We also saw some iodine  
15 revaporization as the low head safety injection piping  
16 heated up. Iodine is more involved; so is cesium.

17 But the iodine did subsequently deposit in  
18 the Safeguards area, and also in the filtration  
19 system, which was operating. This is not a station  
20 blackout; the filtration system would be operating.

21 MEMBER STETKAR: Actually Richard, if you  
22 could just make a note. I'd really be interested in  
23 seeing those procedures that you used.

24 MR. CHANG: Sure.

25 MEMBER STETKAR: Because you know, this is

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1 something that he needs to check.

2 CONSULTANT KRESS: Is this cesium iodide  
3 that's revaporizing?

4 MR. SCHAPEROW: That's correct, cesium  
5 iodide. We used that vapor pressure in the model.  
6 Finally, we used this analysis to identify  
7 conservatisms in the PRA model, and additional  
8 mitigation measures that are practical.

9 We noted that about two hours and 40  
10 minutes into this event, the pressure and other  
11 parameters are low enough that they could start RHR  
12 and terminate the event. This is something that was  
13 not part of the PRA model that was our starting point.

14 MEMBER STETKAR: At, at --

15 MR. SCHAPEROW: At two hours and 40  
16 minutes.

17 MEMBER STETKAR: Surry RHR is separate  
18 from LHSI?

19 MR. SCHAPEROW: Correct.

20 MEMBER STETKAR: Separate pumps?

21 MR. SCHAPEROW: Separate systems.

22 MEMBER STETKAR: Good. Not typical of a  
23 lot of PWRs.

24 MEMBER SCHULTZ: Jason, you noted that  
25 that could be done, but did not take credit for it --

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1 MR. SCHAPEROW: Yeah. It wasn't taken  
2 credit for in the underlying PRA. We said well, why  
3 are you going to core damage? Well, you know, we  
4 didn't take credit for it. We just assumed that we  
5 had this hole. The refueling water storage tank was  
6 not refilled, core damage.

7 So again, that's kind of trying to show  
8 the benefits of this more detailed approach using  
9 MELCOR, is that once you try to -- when you put  
10 everything together in an integrated model like this,  
11 these things start becoming obvious. Like wow, you  
12 know. They could have used RHR. There's other things  
13 they could have done as well to mitigate, you know.  
14 I'll get into that later.

15 MEMBER SCHULTZ: This is fine. Thank you.

16 MR. SCHAPEROW: Just so to take a step  
17 back, I want to talk a little bit about the  
18 reanalysis, how we did it. We developed a new full  
19 plant model for MELCOR, to do an integrated analysis  
20 of ISLOCA. This new model includes detailed modeling  
21 of the adjacent buildings.

22 It includes the Safeguards area, the  
23 containment spray pump area, main steam valve house,  
24 and the ventilation system for these areas. The one  
25 area where we're not fully integrated is the low head

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1 safety injection piping deposition.

2 The full plant model uses a separate model  
3 we built, a smaller model just for the piping, to  
4 calculate how much stuff deposits in the piping, and  
5 this other model, which is run separately, we take the  
6 result from that and we put it into the full plant and  
7 we re-run the full plant case.

8 The new separate effects model includes  
9 the new deposition models, turbine deposition,  
10 inertial deposition. So what I'm going to do is I'm  
11 going to go first through the full plant model, and  
12 then I'll just backtrack a little bit, just show you  
13 how we came up with the DFs for the piping.

14 MEMBER STETKAR: Just out of curiosity,  
15 because I haven't really studied a lot about all of  
16 the nuances here. I think identifying prototypicality  
17 issues may be important. Do you have any sense of how  
18 the results might change if Surry didn't have the RHR  
19 system separate?

20 MR. SCHAPEROW: For our unmitigated case,  
21 we did not credit the RHR system.

22 MEMBER STETKAR: Okay. Thanks.

23 MR. SCHAPEROW: So you'll see this --  
24 you'll see basically unmitigated cases. I'll get into  
25 it. It only credits the operator reactions involving

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1 basically shutting the pumps off, and one other one.

2 MEMBER STETKAR: But it does credit that?

3 MR. SCHAPEROW: Yes, it does, it does.

4 MEMBER STETKAR: Thanks.

5 MR. SCHAPEROW: Okay. So the full plant  
6 model, I just want to show you a piece of it. This is  
7 the piece of -- this is an important piece, because  
8 this is where the break is. The pipe break is in  
9 these buildings adjacent to containment.

10 If you look all the way at the left, all  
11 the way on the bottom, you'll see a volume labeled A-  
12 54. That's the bottom floor of the Safeguards area.  
13 That's where the pipe break is. That's the thinnest  
14 wall piping, and if you look a little bit more over to  
15 the right, you'll see the right half is an elevation  
16 view of the buildings.

17 Again, A-54 is shown there in the bottom  
18 of the Safeguards area. The Safeguards area is  
19 connected to the pump spray area right next to it, and  
20 then next to that it's the valve house, the main steam  
21 valve house. Next to that, which is not shown here,  
22 is the aux building.

23 That tunnel that I was talking about,  
24 that's now filled with penetration sealant, is all the  
25 way at the bottom right-hand of this sketch.

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1 MEMBER BLEY: I'm sorry. These numbers --

2 MR. SCHAPEROW: Oh, I'm sorry.

3 MALE PARTICIPANT: Where is that?

4 MALE PARTICIPANT: It's over here.

5 MR. SCHAPEROW: Right here, right tunnel  
6 of the aux building.

7 MEMBER BLEY: Oh, okay.

8 MR. SCHAPEROW: So this is what  
9 originally, was the original flow path. The fission  
10 products would come in at A-54, move across through  
11 this area, and into the aux building.

12 That was our original thinking a few years  
13 back. But again, we did it. We went back to the  
14 site. We got better information. We have good  
15 information now, and we've got a better model now.

16 Also, I just wanted to mention briefly  
17 that we have the ventilation system model. We have  
18 both the supply and the exhaust of the ventilation  
19 system now, and of course this ventilation system  
20 includes the HEPA filters and the charcoal filters,  
21 all the stuff that's in place for accidents.

22 The next chart is a timing of events  
23 table, something we typically put together for these  
24 accident calculations. It shows not only the  
25 different actions that would be taken as well, but it

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1 also shows just when things happen phenomenologically.

2 Again, the ISLOCA scenario is a LOCA  
3 outside containment, with no refill of the refueling  
4 water storage tank. That's the base scenario.

5 But within that scenario, we wanted to see  
6 well, what would take place? What actions would  
7 happen? So as I said, to repeat myself, we went to  
8 the licensee. We said okay, what would you guys  
9 during this type of an event?

10 They said, well we would secure these  
11 pumps, and we'd begin a cool-down with the steam  
12 generators. That's what our procedures would direct  
13 us to do.

14 MEMBER BLEY: I hate to ask an almost  
15 insulting question, but I am. When you go to the  
16 utility and ask them how you do this, who were the  
17 people you actually asked?

18 MR. SCHAPEROW: We met with senior reactor  
19 operators. I think that was the main -- we had PRA  
20 staff there as well, both PRA staff and senior reactor  
21 operators.

22 MEMBER BLEY: And this was directed at the  
23 operators and not the PRA staff?

24 MR. SCHAPEROW: Yes.

25 MEMBER BLEY: Okay.

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1 MR. SCHAPEROW: I'm struggling --

2 MEMBER BLEY: Sometimes you get really  
3 different answers, because the PRA staff tells you all  
4 the things I could do, where the operators tell you  
5 how they really do use their procedures.

6 MR. SCHAPEROW: Yeah. I'm struggling a  
7 little bit about this because the person who was the  
8 lead in this area is no longer with us. He passed  
9 away a few months ago, Bob Prato. Richard's picked  
10 that up, you know. Remember, you weren't part of the  
11 ISLOCA stuff too much.

12 MR. CHANG: A little bit, but --

13 MR. SCHAPEROW: But yeah. We had, they  
14 were all involved in the conversation, because  
15 sometimes the PRA staff can help the senior reactor  
16 operators understand the event a little bit.

17 MEMBER BLEY: Most often we find that the  
18 operators can help the PRA staff to understand how the  
19 plant works.

20 MR. SCHAPEROW: There's a little back and  
21 forth. It's done in a group environment. We're all  
22 in the room together.

23 MEMBER ADBEL-KHALIK: Did you ever want  
24 this scenario in a simulator?

25 MR. CHANG: The licensees offered to run

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1 the at least beginning portion of operator actions  
2 early on, to see I guess ultimately what the timing  
3 would be.

4 So they walked through their procedures,  
5 at least for the first, I guess, maybe 20 or so  
6 minutes, first couple of steps about securing pumps  
7 and things like that, and provided us the timing. We  
8 actually did not observe them run the simulator.

9 MR. SCHAPEROW: Actually, we talked to  
10 them about that, and we got into the part where we  
11 said -- they asked how important is this to you?  
12 Should we take time out? Should we put the operators  
13 in the simulator and go through this?

14 So we actually took a few weeks or a  
15 month, and we ran some MELCOR calculations, and we  
16 came back to them and said look, we really need to  
17 know this well. They said okay, fine. We'll go into  
18 the simulator. We'll put the operators in the  
19 simulator and we'll do it.

20 That's kind of how it evolved, which was  
21 back in the, like July time frame maybe, a couple of  
22 months after Fukushima.

23 MEMBER BLEY: Just a skeptical point of  
24 view, because I've worked a lot doing the same kind of  
25 thing.

1           If you lay out the scenario ahead of time  
2           and what you're worried about, and then ask them what  
3           they'll do, you sometimes get an answer different from  
4           setting up the situation, maybe the simulator, with no  
5           preconceived idea of what's coming, and seeing what  
6           they really respond to it.

7           So it can give you very optimistic results  
8           sometimes. Go ahead, but that's a place I'd be  
9           skeptical a bit about.

10           MEMBER STETKAR: I'd say especially given  
11           some of the times that they've violated.

12           MR. SCHAPEROW: Yes. Results of the  
13           calculation. It's a LOCA, and sure enough, you know,  
14           when the accident happens, pressure comes down. This  
15           just shows just pressure dropping off in the first  
16           couple of hours. A little further out on the time  
17           line, down around 14, 15 hours, you'll see a couple of  
18           pressure bumps there.

19           This is core damage going on around here.  
20           So we have molten core debris falling down into the  
21           lower plenum where there's still some water. So we're  
22           seeing some pressure rises during that time.

23           With respect to water level in the vessel,  
24           the water level is maintained. They are shutting  
25           pumps off, but even one high head safety injection

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1 pump, which they are running, is plenty. They get to  
2 around six hours and the refueling water storage tank  
3 runs out of water. So then you see the fall off in  
4 the water level.

5 Moving to refueling water storage tank  
6 inventory, again this plot shows that the tank is  
7 empty at six hours. You'll see a couple of bends in  
8 the curve. This is where they're shutting pumps off.  
9 So when they shut the first pump off now, the flow  
10 rate out of this pipe is a little less and a little  
11 less.

12 With regard to fission products, this next  
13 plot shows where the iodine goes. Again, as Tom Kress  
14 pointed out, MELCOR models iodine vapor pressure as  
15 being cesium iodide. The iodine does end up in many  
16 places. Some of it ends up in the very beginning --  
17 when it releases from the core, it ends up in the RCS.  
18 Some ends up a little further downstream in the low  
19 head safety injection piping.

20 Then further downstream, some ends up in  
21 the Safeguards area, and then some of that is sucked  
22 into the filtration system. The net results was a  
23 fission product release of roughly 16 percent.  
24 That's the red line.

25 Moving to cesium, cesium is a lower

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1 volatility than iodine, so more of the cesium ends up  
2 closer to the core. So you'll see here the main two  
3 places where the cesium ends up. It ends up in the  
4 RCS and the low head safety injection piping, and  
5 relatively small amounts of it end up further  
6 downstream in the Safeguards area and the filters.

7 Okay. Just turning now to the separate  
8 effects model that we used, to come up with aerosol  
9 deposition to put in, aerosol deposition in the piping  
10 put into the full plant model, this shows our  
11 nodalization. About in the middle of this is a dashed  
12 line, showing the containment boundary.

13 We have seven nodes inside the containment  
14 for this piping, and then one node outside the  
15 containment. Then the pipe break is in the thin wall  
16 pipe just past this flow element. This is an orifice.  
17 It's a seven inch orifice in the line.

18 Turning to aerosol deposition, MELCOR does  
19 have a range of aerosol deposition models in it. It's  
20 got what we have typically used over the years for  
21 these analyses. It's got settling, it's got  
22 thermophoresis, diffusiophoresis. But in the past,  
23 when we did the steam generator tube analysis back in  
24 the late 90's, we used VICTORIA for the really  
25 detailed modeling of the tubes and the Venturis and

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1 the restrictions and the things that would go with  
2 that.

3 So we didn't have that in MELCOR at this  
4 stage. So we decided that we really needed to put it  
5 in. So we did add new modeling to MELCOR for  
6 turbulent flow conditions.

7 CHAIR SHACK: Remind me. How well did the  
8 VICTORIA model compare with the ARTIST experiments  
9 that were done later? Were you over-predicting the  
10 contamination? You don't remember?

11 MR. SCHAPEROW: Well, I'm not actually  
12 sure we ran VICTORIA for the ARTIST test. I don't  
13 know if anybody else here at Sandia, any of our Sandia  
14 staff, you know.

15 MEMBER CORRADINI: Can you give us, just  
16 to remind us of the history? We should remember this,  
17 but I don't. VICTORIA was disconnected, simply  
18 because it was not an integral part of MELCOR  
19 analysis. It was run separately? I didn't understand  
20 --

21 MR. SCHAPEROW: Well, the initial work  
22 that was done, I guess a lot of this goes back to the  
23 80's. The NRC was developing a set of detailed severe  
24 accident models. First and foremost was SCDAP/RELAP5,  
25 which treated the core, all the in-vessel stuff, the

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1 RCS. But it didn't do the containment and it didn't  
2 do fission product chemistry and aerosol deposition.

3 So in addition to SCDAP/RELAP5, we had the  
4 contain code for the containment part of the analysis,  
5 and we also had VICTORIA. VICTORIA was a detailed  
6 fission product chemistry and aerosol model. But in  
7 parallel with that, we were also developing MELCOR,  
8 which is supposed to kind of be integrated. It had  
9 everything in it, soup to nuts.

10 But of course we couldn't have the same  
11 level of details we had in SCDAP/RELAP5, or VICTORIA.  
12 So back in the 90's, when we were doing the steam  
13 generator tube rupture analysis, we ran SCDAP/RELAP5,  
14 and then we took the heat transfer fluid flow  
15 conditions from that and imported that into VICTORIA,  
16 and ran VICTORIA with all of its detailed aerosol  
17 models, to figure out what the deposition would be in  
18 the steam generator.

19 MEMBER CORRADINI: Okay. All right, thank  
20 you.

21 CONSULTANT WALLIS: These things deposit.  
22 Why do they stick?

23 MR. SCHAPEROW: They are -- these aerosols  
24 are partially molten. They're coming off the core.  
25 They've got multi-components. There's a lot of

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1 different --

2 CONSULTANT WALLIS: They solidify?

3 MR. SCHAPEROW: Pardon?

4 CONSULTANT WALLIS: They solidify?

5 MR. SCHAPEROW: Most of them, the aerosol  
6 material, it's got, it's made up of a whole world of  
7 chemicals.

8 CONSULTANT WALLIS: What does it do? Does  
9 it produce sort of a fuzzy deposit or smooth deposit,  
10 or what does it look like? Is it hairy, sort of  
11 things that stick out and --

12 MR. SCHAPEROW: Yeah. Well --

13 CONSULTANT WALLIS: I'm just wondering how  
14 much you can deposit without getting it reentrained?

15 MR. SCHAPEROW: Yeah. Well, actually we  
16 thought about the reentrainment issue. We talked to  
17 the peer review committee about it. I mean I don't  
18 mind it getting reentrained as far -- I mean as far as  
19 the MELCOR, the question is where does it end up, you  
20 know.

21 CONSULTANT WALLIS: What's it look like?  
22 Does it get reentrained? Why does it stick, all kinds  
23 of questions?

24 MR. SCHAPEROW: Sure. There's a lot of  
25 issues there. For me, kind of the bottom line issue

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1 was does it become a micron-sized aerosol again? It  
2 certainly -- actually, I saw some analysis that was  
3 done by industry.

4 I think it was a Polestar, Applied  
5 Technology. They did some analysis for ISLOCAs a few  
6 years back, and they concluded that it would kind of  
7 spread out and be all along the whole piping length,  
8 because it's kind of liquidy, kind of sloshy.

9 But other people might believe that it  
10 tends to be kind of solid. So it's kind of all get  
11 stuck up in the initial part of the piping, and not go  
12 anywhere. So it is going to get kind of dragged along  
13 the pipe? The flow rates are very high.

14 CONSULTANT WALLIS: And how thick is it?  
15 How thick?

16 MR. SCHAPEROW: Well, if you take the view  
17 that it stays where it eventually deposits, it will  
18 plug the pipe.

19 CONSULTANT KRESS: The cesium iodide and  
20 the cesium borate solids at these temperatures. So if  
21 you're talking about those two, they're not liquid.

22 CONSULTANT WALLIS: So it looks something  
23 like the exhaust pipe from your domestic dryer? It  
24 gets all fuzzy with lint and stuff like that? Is that  
25 what it looks like?

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1                   CONSULTANT KRESS: Those aerosols do look  
2 like that, right, the ones I've seen. They  
3 agglomerate into chains.

4                   CONSULTANT WALLIS: Not just that, but  
5 there must be some capacity to this thing, and maybe  
6 there's a limiting thickness or something. No. I'm  
7 just asking.

8                   MR. SCHAPEROW: No. Well, as I said, we  
9 thought about the issue about, you know, the major  
10 issue was would it reentrain. For us, the big issue  
11 was would it reentrain back into the aerosol-sized,  
12 the micron-sized particles, which is of interest for  
13 offsite consequences.

14                   But the other question about where would  
15 it end up was kind of important for the point of view  
16 of this issue we had with iodine revaporization. If  
17 all the aerosols deposited in one spot, like in the  
18 beginning of the piping, now you've got a lot of decay  
19 heat load concentrated in one area, and that would  
20 suggest that you would get iodine revaporization, and  
21 that's where our modeling came down.

22                   We actually revaporized a lot of it.  
23 You'll see in these slides I'm going to show you.  
24 You're going to see the first segment of piping all  
25 the iodine deposits, and then it revaporizes.

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1                   CONSULTANT WALLIS: And it doesn't  
2 redeposit.

3                   MR. SCHAPEROW: No. We're actually not  
4 predicting much redeposition. The place where we're  
5 seeing most of our deposition, as I'll get into, is  
6 down all the way at the very end, in the Safeguards  
7 area, where the piping is under water. So the piping  
8 is roughly, you know, 300 K. It's cold, and --

9                   MEMBER REMPE: So you do allow lift off?

10                  MR. SCHAPEROW: Well --

11                  MEMBER REMPE: Revaporization.

12                  MR. SCHAPEROW: We're predicting  
13 revaporization, because we're having such a  
14 concentration of radioactive decay in one area in the  
15 piping.

16                  MEMBER REMPE: That's the denature  
17 resuspension type of action?

18                  MR. SCHAPEROW: Yeah. This is the first  
19 time in my experience with severe accident analysis  
20 that we've seen enough fission products deposited in  
21 one area, where it heated it up enough to revaporize.  
22 When I worked on steam generator tube integrity, we  
23 saw that with the steam generator tube bundles, a lot  
24 of service area and the fission products tend to  
25 deposit throughout the bundle.

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1           So the main thing driving the fission  
2 product revaporization in that case is just the hot  
3 steam and the hydrogen coming off the core. The  
4 fission products themselves are so distributed across  
5 the tube bundle they're not really contributing much  
6 to the tube heating.

7           But here's a case where we've managed to  
8 concentrate so much radioactive material that we're  
9 actually reheating and revaporizing.

10           MEMBER ARMIJO: What's the chemical form  
11 that revaporizes?

12           MR. SCHAPEROW: Again, we used the vapor  
13 pressure for cesium iodide as the vapor pressure for  
14 iodine throughout the calculation, so -- and under  
15 these conditions, it's relatively volatile.

16           I want to take you through the results of  
17 the separate effects calculation. I'd like to focus  
18 here on the time period of roughly 14 to 16 hours.  
19 This is the time when we're seeing the core heat up  
20 and degradation and fission product release from the  
21 core.

22           The very first node in the separate  
23 effects piping is the lowest one here. It's the red  
24 curve, and so the flow rates in that area are in the  
25 area of 80 to 100 meters per second. And then a

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1 little higher up, the green line is --

2 CONSULTANT WALLIS: I was going to ask,  
3 what's the long-term prospect for this plane?  
4 Presumably, there's a long-term cooling that's  
5 actually effective eventually?

6 MR. SCHAPEROW: The pipe is uninsulated in  
7 the containment building.

8 CONSULTANT WALLIS: It's open. You just  
9 don't attempt to close it. It's a long pipe which is  
10 open to the environment.

11 MR. SCHAPEROW: Correct.

12 CONSULTANT WALLIS: What's the long-term  
13 prospect for this thing? I mean is there still stuff  
14 flowing through it at a late date?

15 MR. SCHAPEROW: Our analysis has the whole  
16 release, the release largely happening over a couple  
17 of hours.

18 CONSULTANT WALLIS: What's the long-term  
19 prospect for this pipe full of this stuff? Does it  
20 have flow through it over a long period of time later?

21 MR. SCHAPEROW: There is a little flow  
22 over the long term. Actually, you can see some of  
23 that down here at 22/24 hours. We've got, you know,  
24 flow in the 20 meters per second range down here.

25 CONSULTANT WALLIS: Vapor flow in a cold

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1 pipe it condenses, it washes this stuff out, or what  
2 does it do?

3 MR. SCHAPEROW: You're talking about long-  
4 term revaporization of what's stuck in the pipe?

5 CONSULTANT WALLIS: If you have this fuzzy  
6 stuff on the pipe wall, and you have steam flowing  
7 there for a long period of time, condensing, then  
8 presumably you have water that comes out eventually,  
9 presumably carrying (phone rings)?

10 MEMBER REMPE: That's Mike.

11 CHAIR SHACK: Are you there, Mike?

12 (Off record comments.)

13 CONSULTANT WALLIS: It all happened when  
14 Charlie came in, so --

15 MEMBER BROWN: I'm sorry, guys.

16 MR. SCHAPEROW: Basically, the piping in  
17 the reactor building, the low head safety injection  
18 piping actually comes off the cold leg. It goes down  
19 pretty much to the floor. But now you can kind of see  
20 in the sketch here. It goes down about 30 feet, 29-  
21 1/2 feet, and then it goes back up again. So with  
22 regard to water getting out of the piping, I don't  
23 think --

24 CONSULTANT WALLIS: Well, I just wondered  
25 what in the long term, there is steam flow through

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1 this pipe for a long time?

2 MR. SCHAPEROW: Yeah.

3 CONSULTANT WALLIS: There is?

4 MR. SCHAPEROW: Steam, hydrogen.

5 CONSULTANT WALLIS: So it will condense in  
6 the pipe, and presumably will wash --

7 MR. SCHAPEROW: Yeah. I'd have to get  
8 back to you.

9 CONSULTANT WALLIS: Wash stuff off the  
10 wall. Well, I mean this isn't where it goes.

11 MR. SCHAPEROW: Well --

12 CONSULTANT WALLIS: And you're going to  
13 get back to me.

14 MR. SCHAPEROW: I have to look at  
15 elevation, more elevation views of this to see,  
16 because this --

17 CONSULTANT WALLIS: Eventually it will  
18 fill up the bottom elbows with water, doesn't it?

19 MR. SCHAPEROW: That's correct.

20 CONSULTANT WALLIS: So you're going to get  
21 back to me on this one?

22 MR. SCHAPEROW: Yeah, okay.

23 CONSULTANT KRESS: It looks like (paper  
24 shuffling) in those parts, well above the steam  
25 condensation pressure.

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1 CONSULTANT WALLIS: Not forever.

2 CONSULTANT KRESS: Even after 24 hours.

3 MR. SCHAPEROW: Well, you know, eventually  
4 they're going to flood the containment I mean, if they  
5 want to stop this accident. So all this would be  
6 under water eventually. But as far as a  
7 revaporization release, it would have to get really  
8 hot to have revaporization really. Do you want to  
9 wait a minute or do you want to keep going?

10 CHAIR SHACK: Give him a second.

11 (Off record comments.)

12 CHAIR SHACK: Mike?

13 MEMBER CORRADINI: Yep.

14 CHAIR SHACK: Okay.

15 MR. SCHAPEROW: So this slide also lists,  
16 it lists the length of the piping in the system, 184  
17 feet. 23 elbows, a lot of places for fission products  
18 to get trapped. The piping system has a Venturi.

19 The reason I've got four written here is  
20 because we also use the Venturi deposition model to  
21 model the two stuck open relief valves in the system,  
22 and also the flat-plate orifice that is just inside of  
23 the Safeguards area.

24 Finally, we modeled the necking down from  
25 the cold leg into this piping as a sudden contraction.

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1 We validated this against the LACE bypass test and  
2 benchmarked it against our VICTORIA modeling. Well,  
3 we covered this. Okay. Sorry about that.

4 So anyway, a time frame of 14 to 16 hours.  
5 This is where most of the action is. The fission  
6 products -- the core is melting, the fission products  
7 are being released. We've got high flow rates in the  
8 system.

9 The next slide looks at temperatures in  
10 the system. Again, looking at 14 to 16 hours, you'll  
11 see there's a bunch of colored curves up near the top,  
12 and then there's a blue one at the bottom. The blue  
13 one at the bottom is the piping in the Safeguards area  
14 that's under water.

15 With regard to the colored curves above,  
16 the highest one is the --

17 CONSULTANT WALLIS: Well, how is it heated  
18 in the remote, in the far, far distance, the furthest  
19 from the vessel? How is it heated the furthest from  
20 the primary? How will it be heated, with steam?

21 MR. SCHAPEROW: There are three sources.  
22 One source is -- well, two. Decay heat from the core  
23 is coming and going through the piping, and so that --

24 CONSULTANT WALLIS: No, the heat doesn't.  
25 The steam goes through.

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1 MR. SCHAPEROW: Well, super-heated steam  
2 and hydrogen are coming out of the core and going  
3 through the piping. That heats it, plus there are  
4 some fission products deposited down there.

5 CONSULTANT WALLIS: It stays hot all the  
6 way to the end? It doesn't condense?

7 MR. SCHAPEROW: No, no. These  
8 temperatures are -- we're at 900 K. It superheated.

9 CONSULTANT WALLIS: So it stays hot all  
10 the way to the end of the piping?

11 MR. SCHAPEROW: Sure, yes. The uppermost  
12 curve, the red curve is the very first volume off of  
13 the cold leg. It gets quite hot. It gets up to 1,200  
14 K, and the reason is is this is where we're depositing  
15 most of the fission products.

16 We actually ran this model turning off  
17 decay power in the system, and we found that these  
18 curves, (cough) kind of collapse a bit. We don't have  
19 this big spike at 1,200 K for the red curve. These  
20 different colored curves kind of -- not completely on  
21 top of each other, but you don't see this big spread,  
22 and actually --

23 MEMBER CORRADINI: So can you just repeat  
24 that Jason? So you basically turned off -- I was  
25 going to ask about this. You turned off decay heat.

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1 MR. SCHAPEROW: In the piping. Not in the  
2 core; in the piping.

3 MEMBER CORRADINI: Yeah, I understand.

4 MR. SCHAPEROW: We've turned off decay  
5 heat in the piping, and these --

6 CONSULTANT WALLIS: Decay heat in the  
7 piping, because there are radioactivities occurring in  
8 the piping?

9 MR. SCHAPEROW: That's correct. We have  
10 decay in the piping, because for me, a big issue, for  
11 us a big issue was are we going to get revaporization  
12 of iodine and what's driving it?

13 Is it the decay heat from the core going,  
14 superheating the steam? Is that what's making the  
15 stuff come off the wall, or is it the fission products  
16 themselves stuck to the wall? Are they heating up the  
17 piping?

18 So we shut off the fission products  
19 themselves heating up the piping, and lo and behold,  
20 we didn't get the iodine revaporization.

21 MEMBER CORRADINI: Okay, thank you.

22 CONSULTANT WALLIS: But doesn't it help if  
23 you get vaporization when you -- why did you shut it  
24 off? Doesn't the heat help the vaporization?

25 MR. SCHAPEROW: Yeah, that's right. So if

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1 we shut off the decay heating in the piping, we did  
2 not get iodine revaporization. It stayed where it  
3 ended up.

4 CONSULTANT WALLIS: So you're showing that  
5 that was the cause of the vaporization?

6 MR. SCHAPEROW: That's correct.

7 MEMBER ARMIJO: How much cooler was the  
8 piping when you did that?

9 MR. SCHAPEROW: It was, they all, it all  
10 fell down a bit below 1,000 K. In the 900 K, roughly  
11 900 to 1,000 K was about our highest temperature in  
12 the piping.

13 MEMBER ARMIJO: From this 1,200 K level?

14 MR. SCHAPEROW: Yes, yes. We weren't  
15 anywhere near 1,200. We were way down.

16 MEMBER SKILLMAN: How well do you  
17 understand the fission product transport, such that  
18 there would be sufficient fission product isotope to  
19 give th at quantity of heating? What I think you're  
20 saying is the deposition on the pipe has sufficient  
21 fission product to give that temperature over (phone  
22 ringing) degrees K, over 1,000 degrees K.

23 MR. SCHAPEROW: Yeah. Well again, these  
24 models are -- you know, these are theoretical models  
25 that are widely used. I think it's called the Wood

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1 model, I believe, is the name of it, and they were  
2 validated against the LACE test.

3 So the other analysis that I had seen that  
4 was done by industry was where they also used similar  
5 modeling, but they spread out the fission products  
6 along the entire length of the piping.

7 So they did not predict revaporization of  
8 the iodine, because they had more -- the heat transfer  
9 favored it staying put, because they had spread it out  
10 along the whole length.

11 MEMBER SKILLMAN: Non-mechanistically, or  
12 that's what their model put out?

13 MR. SCHAPEROW: Well, they suggested that  
14 because of the liquid nature or the more liquid nature  
15 of the deposits that they would spread out as a result  
16 of these high flow rates.

17 MEMBER SKILLMAN: They would flow along  
18 and drag.

19 CONSULTANT WALLIS: They'd flow along,  
20 they'd come out the end?

21 MR. SCHAPEROW: They would kind of, yeah,  
22 dribble out into the Safeguards area.

23 CONSULTANT WALLIS: Or something --

24 MR. SCHAPEROW: Yeah, onto the floor or  
25 the water. I guess there was probably water there at

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1 the time.

2 CONSULTANT WALLIS: And they heat  
3 themselves and evaporate again.

4 MR. SCHAPEROW: If they were concentrated,  
5 if it was concentrated enough. Okay. So --

6 CONSULTANT WALLIS: This liquid film  
7 transport, was that modeled?

8 MR. SCHAPEROW: No, not for fission  
9 products.

10 CONSULTANT WALLIS: There is a liquid  
11 film, and if there is a high velocity of steam, it  
12 will flow along the wall, and eventually it will all  
13 come out.

14 MR. SCHAPEROW: Correct.

15 CONSULTANT WALLIS: What happens to it  
16 then?

17 MR. SCHAPEROW: That's right. It's on the  
18 floor of the Safeguards building.

19 CONSULTANT WALLIS: Will it do something  
20 now? Nothing good to the environment.

21 MR. SCHAPEROW: Well, it would have to  
22 make it through the Safeguards building and pass the  
23 filters.

24 CONSULTANT WALLIS: Maybe it's worthwhile  
25 calculating the rate at which that film would flow.

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1 MEMBER ADBEL-KHALIK: If you look at the  
2 previous slide, please, 17. When you get a result  
3 that looks like this, what is your reaction?

4 MR. SCHAPEROW: I did not believe that  
5 there would be significant fission products in one  
6 area to cause it to revaporize the iodine. But you  
7 know, we spent a lot of time at this. We spent, I  
8 don't know, a couple of months on this.

9 We really, we turned over a lot of rocks,  
10 to use a colloquialism. We tried it with insulation,  
11 without insulation. We tried it with radiated heat  
12 transfer. We spent a lot of time looking at this  
13 issue, and so this is our best shot.

14 CONSULTANT WALLIS: But somewhere in your  
15 calculation, you calculate how much iodine comes out  
16 of this pipe?

17 MR. SCHAPEROW: Yes. That's the Slide 18.

18 CONSULTANT WALLIS: Come out as a vapor.  
19 There's not a liquid film coming out or anything like  
20 that.

21 MR. SCHAPEROW: That's right, a vapor.  
22 Well, some of it might be small aerosol particles as  
23 well, very small, like the kind that condensed from  
24 vapor. Slide 18 has kind of the bottom line, result  
25 of the separate effects calculation. The top curves

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1 are the cesium and the bottom curves represent the  
2 iodine.

3 For the cesium, the dotted blue line is  
4 how much cesium came off of this cold leg and went  
5 into the piping, the low head safety injection piping.  
6 The bottom blue line is how much was retained in the  
7 piping. So you can see just about all of it was  
8 retained in the piping.

9 We started to see a similar trend for  
10 iodine back around 14 hours, but as the piping started  
11 to heat up, we saw that about half of the iodine would  
12 revaporize in that calculation. We took the DFs from  
13 this calculation, basically that the end points of  
14 these curves, we put them into the full plant model.

15 One thing we did not put into the full  
16 plant model was the time-dependent nature of the  
17 revaporization of the cesium iodide. If we did, we  
18 may have seen perhaps some additional deposition in  
19 the Safeguards area, because the release would have  
20 kind of been later, kind of after the big core  
21 degradation that's going on.

22 Maybe it would be a little quiescent in  
23 the Safeguards area, see a little more deposition.  
24 The other thing it would have delayed the release some  
25 more, providing more time for evacuation and offsite

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1 protection measures.

2 CONSULTANT WALLIS: So you have 200  
3 kilograms in a pipe, which is how long? How long is  
4 it?

5 MR. SCHAPEROW: 184 feet.

6 CONSULTANT WALLIS: And what's its  
7 diameter?

8 MR. SCHAPEROW: Internal diameter is 5.2,  
9 5.4.

10 CONSULTANT WALLIS: Approximately five  
11 inches?

12 MR. SCHAPEROW: It's below 5-1/2 and more  
13 than 5. I forget the exact number. We did these  
14 analyses a while ago, back in October. We finished up  
15 back in October. Actually, there's a lot more than  
16 this.

17 This is just cesium and iodine. We have,  
18 you know, we have tin from the cladding. We've got  
19 all the other isotopes. We've got -- later in the  
20 accident, we're actually going to get concrete  
21 aerosols in here from the CPI. This pipe has got a  
22 lot of aerosols in it.

23 CONSULTANT WALLIS: Well, I'm interested  
24 in how molten the stuff is on the wall.

25 MR. SCHAPEROW: Actually, it might vary as

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1 a function of time, as the different things come out  
2 of the --

3 CONSULTANT WALLIS: That's right. I'm  
4 just surprised you haven't calculated it.

5 MR. SCHAPEROW: Actually, this is an issue  
6 that we looked at a bit with VICTORIA, again back when  
7 we were doing steam pipe tube integrity, where because  
8 of VICTORIA's additional capability of doing fission  
9 product chemistry, we had or represented,  
10 theoretically at least, the chemical reactions that  
11 you could have in the RCS.

12 So we predicted how much of each chemical  
13 compound you would have, and we went back and we  
14 looked at well, what was the temperature in the steam  
15 generator, and what were the compounds that were going  
16 through it, and how much -- so what was liquid and  
17 what was solid. We actually calculated how many grams  
18 liquid, how many grams solid we had.

19 Actually, Nate Bixler did that work many  
20 years ago. So but yeah. Certainly it's an important  
21 issue.

22 Finally, my final chart here is again,  
23 more on the cesium iodide in the piping. This chart  
24 shows how much cesium iodide is deposited in each of  
25 the volumes in the piping, and one thing it shows, if

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1 you look at the red curve, that's the very first  
2 volume.

3 So we see a lot of deposition in the first  
4 volume, but then we see it revaporizing. We see  
5 similar behavior in all the volumes, except for the  
6 very last one, which is CV-301, the blue line. In  
7 that one, we don't see revaporization because it's in  
8 a much colder area, under water.

9 A recap of the results, our best estimate  
10 calculation now predicts 13 hours to start of core  
11 damage, and the reason there is this time lag between  
12 the initiator and the start of core damage is that we  
13 do model the operator actions that we believe will  
14 occur by procedure.

15 The iodine cesium release is again, we  
16 have a much bigger iodine release than a cesium  
17 release, again because of this revaporization of  
18 iodine.

19 I'd like to talk for a few minutes now  
20 about mitigation. Going back to the scenario  
21 definition, the unmitigated interfacing systems LOCA  
22 is a failure of the two check valves on the pipe, and  
23 no refill of the refueling water storage tank that  
24 gets you to core damage.

25 In our MELCOR calculation, we calculate

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1 that RWST will be empty in six hours, and core damage  
2 several hours later. So when we looked at it, we said  
3 well, maybe there is enough time to refill the  
4 refueling water storage tank. I don't know exactly  
5 what assumptions went into the earlier PRAs that we  
6 started with here, the earlier PRA like the SPAR  
7 model, but six hours is certainly quite a bit of time.

8 Also, going back to the pumps and the  
9 operation of the ejection pumps, we went back to the  
10 site in October, just this past October, and we talked  
11 to them about this final pump. They said they would  
12 keep one pump running, and we said well, you know,  
13 what do you mean keep this pump running?

14 Would you keep it running at its rate of  
15 low or would you throttle it? They said oh, "Well, we  
16 throttle it. Our procedures would have us throttling  
17 the thing."

18 So we did a calculation where they  
19 throttled the pump, just enough to keep the water  
20 level above the core kind of thing, and sure enough  
21 the water lasted --- the refueling water storage tank  
22 lasted an additional 24 hours, because decay power is  
23 going down, down, down, and you don't need the flow  
24 rate of that pump, 600 gpm, certainly not 24 hours  
25 into the event. You only need 100 gpm.

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1 MEMBER BLEY: Is that their practice, or  
2 is that actually in their procedures?

3 MR. SCHAPEROW: Well, they've --

4 MEMBER BLEY: The ones I've looked at,  
5 it's not in the procedure.

6 MEMBER STETKAR: If it's their procedure,  
7 we ought to see what their procedure is.

8 (Simultaneous speaking.)

9 MEMBER STETKAR: As Bill said, it is what  
10 it is.

11 MEMBER ARMIJO: Would there be a reason  
12 not to put it in procedures?

13 CONSULTANT WALLIS: Could I go back to  
14 this --

15 MEMBER STETKAR: We discussed that with  
16 various folks and --

17 CONSULTANT WALLIS: -- I'm sorry. You  
18 said you've got 180 feet of pipe, and you've got 200  
19 kilograms of only CSI, and you've got some other stuff  
20 as well. So roughly you've got about a kilogram per  
21 foot of this stuff, plus other stuff.

22 So I calculate you've got something like  
23 a centimeter of stuff all over the wall. If that's a  
24 liquid film, it's going to go pretty darn fast with  
25 the steam roaring by, and it will all get slushed out.

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1                   What happens to 200 kilograms when it  
2                   dumps out on the floor in the building?

3                   MR. GAUNTT: So Graham, this is Randy  
4                   Gauntt. We asked all these questions that you're  
5                   asking right now when we were looking at this, and  
6                   yeah, the depositions are thick. They're very cakey,  
7                   as you would calculate them. They do look a lot like  
8                   what the photos from LACE, where they cut into the  
9                   pipes and they show extremely thick depositions.

10                  Now we worried about a number of things.  
11                  We worried about being so much decay heat we could  
12                  melt the pipe. We looked at that, where we  
13                  rationalized that if we built up this cake and it was  
14                  molten, what would happen, because our models -- we  
15                  don't have a reentrainment treatment.

16                  CONSULTANT WALLIS: Or flow.

17                  MR. GAUNTT: So we said okay, it's going  
18                  to sluff off and go downstream and maybe hang up in  
19                  the pipe somewhere else, or ultimately maybe it just  
20                  dribbles out the end of the pipe. In any case, and  
21                  Jason, help me remember this right.

22                  In any case, we argued to ourselves that  
23                  this would not be a resuspension of a very, you know,  
24                  transportable aerosol. It would be big chunks and  
25                  blocks and mist, you know. It could be mist, it could

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1 be a puddle, and would not represent a transportable  
2 source term offsite.

3 Now what to do with it, you know, as it's  
4 falling out of the -- when it falls out of the pipe,  
5 yes. What happens then, yes.

6 (Simultaneous speaking.)

7 CONSULTANT WALLIS: Okay, so you have  
8 looked at this?

9 MR. GAUNTT: We worried about it, and you  
10 know, this is pushing the front on our ability to  
11 model this. We realized from the LACE experiments  
12 that we were neglecting turbulent deposition.

13 CONSULTANT WALLIS: Well, I think a story  
14 which simply says it deposits in the pipe, is not the  
15 end. I think the story should be continued along the  
16 way that they're describing here, because it is a  
17 thick deposit. You're saying it's hot enough to  
18 revaporize, which means it's probably hot enough to  
19 melt.

20 MEMBER ARMIJO: Well, what is the melting  
21 point of cesium iodide?

22 MR. SCHAPEROW: Just the cesium iodide  
23 revaporizes.

24 CONSULTANT WALLIS: But anyway, I think it  
25 would be good to continue the story in the report,

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1 because the intelligent reader maybe is going to have  
2 questions.

3 MR. GAUNTT: Would ask that question,  
4 right.

5 CHAIR SHACK: We're running a bit behind.  
6 So if we can finish up in about ten minutes.

7 MR. SCHAPEROW: Sure. I'm about done. I  
8 only have two or three more slides. The other point  
9 that I kind of raised earlier was that we noted that  
10 core damage could have in fact been averted by  
11 starting RHR. You know, the system is a separate  
12 system from the low head safety injection system.

13 They do have power. This is not a station  
14 blackout event, and they have to refueling water  
15 storage tank until six hours. So they have a few  
16 hours to get this started.

17 Finally, we also looked at what might be  
18 done to limit how much radiation is released offsite,  
19 basically through the system. We said well, if we're  
20 having a bypass event where we've got a hole in this,  
21 we've got this pipe bleeding out into the Safeguards  
22 building and subsequently went out this pipe, maybe we  
23 can open something else up inside containment and have  
24 the release going in the containment instead.

25 So we did a little looking. One potential

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1 thing was the PORVs on the pressurizer. So if they  
2 open the PORVs up, they could divert some of the  
3 release into the containment.

4 MEMBER ADBEL-KHALIK: Is that part of  
5 their EOPs, in response to this event?

6 MR. SCHAPEROW: I don't know. This is  
7 something that we thought up ourselves.

8 MEMBER ADBEL-KHALIK: It's not.

9 MR. SCHAPEROW: This is NRC research. So  
10 what have we learned from this detailed integrated  
11 analysis? What we learned is it would be really nice  
12 if we could do all these calculations and say hey, you  
13 know, we think that by changing the procedures thus  
14 and such, we'd be better able to mitigate severe  
15 accidents. I mean that's one of the ultimate goals of  
16 having a big model like this.

17 MEMBER ADBEL-KHALIK: I didn't think they  
18 had manual ways to open up those PORVs.

19 MR. SCHAPEROW: Ahh, but most of the  
20 accidents in SOARCA are station blackouts. This one  
21 is not. This one is the lights are on, so to speak.

22 MEMBER ADBEL-KHALIK: I didn't think you  
23 could do it with power.

24 MR. SCHAPEROW: Oh. Opening the PORVs is  
25 not sufficient, because the PORVs dead end in the

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1 pressurizer relief tank. But there are certain points  
2 in the accident where the pressure is high enough,  
3 that the pressurizer relief tank will open up into the  
4 containment. I'm sorry, I'm sorry.

5 MEMBER ADBEL-KHALIK: I see. That's what  
6 you used.

7 MR. SCHAPEROW: So we actually did two  
8 cases, one where they opened the PORVs early, like  
9 within the first hour or so of the initiator, and one  
10 where they opened the PORVs like around the start of  
11 core damage, because we wanted to see --

12 If they just opened the PORVs at some  
13 time, if the pressure doesn't go high enough, you're  
14 not going to create that release path through the  
15 pressurizer relief tank in the containment.

16 MEMBER STETKAR: My suspicion is if they  
17 open them up early, they're not going to be shutting  
18 pumps off.

19 MR. SCHAPEROW: Yeah. It may be more  
20 likely that they'd do that closer to -- you know, when  
21 they get into core damage, that may be when they start  
22 thinking we better start opening some of these valves  
23 up.

24 MEMBER STETKAR: Particularly the guidance  
25 to depressurize is for high pressure melt scenarios,

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1 and this wouldn't be at that time. So it's not -- I  
2 mean you could think of anything that you might want  
3 them to do.

4 MR. SCHAPEROW: But the thought is is  
5 that, you know, how do you stop a bypass accident?  
6 Well, make an opening somewhere else in the RCS. I  
7 think this has been thought about, and we saw this in  
8 spades in the steam generator tube integrity work, you  
9 know.

10 If you fail the hot leg either before or  
11 after tube rupture, that's a good thing, because then  
12 you're going to be directing (cough) into the  
13 containment and where they'll deposit, as opposed to  
14 in the steam generator, where they could revaporize  
15 later if it gets hot enough.

16 Oh, just a word on scenario frequency. We  
17 went into this. Our SPAR model scenario frequency was  
18 3 times 10 to the minus 8 per year. This why we  
19 didn't talk to the people at the site about this  
20 during our initial site visit. But when we went  
21 there, they said oh no, 7 times 10 to the minus 7 is  
22 what we have for our frequency for this event.

23 So we initially did include it in SOARCA.  
24 Subsequently, and Richard was involved in some of this  
25 in the last year or so, we talked to them again and

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1 they said no, no. We didn't mean it was 10 to the  
2 minus 7. We thought when it was 10 to the minus 7 if  
3 we had one check valve failure plus leakage of the  
4 second check valve.

5 But if you fail both check valves, then  
6 it's 10 to the minus 8. I'm like okay, fine. So we  
7 explained this, and therefore this is actually a lower  
8 frequency event than we had originally expected. We  
9 did keep it in the analysis.

10 MEMBER STETKAR: Since you want to talk  
11 about numbers, did they look at the chance that that  
12 second check valve didn't close? Do they have  
13 positive procedures to know that they were both  
14 closed? I mean if you want to talk about numbers. So  
15 you didn't investigate that.

16 MR. CHANG: I'm not sure about that. But  
17 at least for the first scenario, with catastrophic  
18 failure one check valve and leak by a second check  
19 valve, what they have is an MOV at the end, and in  
20 theory, it should be able to close off the line in  
21 ISLOCA.

22 MR. SCHAPEROW: At least that's the  
23 likelihood.

24 MR. CHANG: Oh yes, sorry.

25 MR. SCHAPEROW: Just to kind of wrap up on

1 bypass accident, since we had another bypass accident  
2 and tube rupture, I just wanted to kind of tie that  
3 together with the ISLOCA.

4 I think to sum it up, our analysis of both  
5 of these events, we used lowered detailed modeling  
6 than we had in the past, both in the area of operator  
7 actions as well as, of course, our phenomenological  
8 modeling has advanced quite considerably over the  
9 years.

10 Our releases from bypass accidents are  
11 smaller and more delayed than earlier studies, and do  
12 not result in large early releases. We also have some  
13 insights into mitigation as a result of our analysis.  
14 That concludes our Surry update.

15 CHAIR SHACK: Pretty good. Any further  
16 questions from the group? Joy.

17 MEMBER REMPE: Not on what you presented,  
18 but in going through the report, several times it  
19 talks about hot debris quickly heating the lower head  
20 above the melting temperature of stainless steel,  
21 1,700 on the inner surface.

22 I'm aware there's cladding that's  
23 stainless in the inner surface, but the vessel's  
24 carbon steel. So I'm always puzzled why one would  
25 reference that, and I just wanted to verify, did you

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1 use carbon steel for the vessel material?

2 MR. SCHAPEROW: I'd like to say yes, but  
3 I might not be the most authoritative person on that.

4 MEMBER REMPE: It's something we're  
5 thinking about, because I just --

6 MR. SCHAPEROW: It may just be a  
7 documentation thing --

8 MEMBER REMPE: Several times throughout  
9 the document, and I was just think it's something that  
10 ought to be verified. Also, there's again maybe it's  
11 a typo or I don't know what, but there's a Figure 5.4,  
12 and they have vessel failure at 2100 hours, and the  
13 inner surface is like 2,000 K; the outer surface is  
14 about --

15 MALE PARTICIPANT: I'm sorry. Can you say  
16 that again? I'm sorry.

17 MEMBER REMPE: It's Figure 5.4.

18 MALE PARTICIPANT: I don't have that.

19 MEMBER REMPE: And the inner surface is  
20 2,000 K; the outer surface of the vessel is about  
21 1,800 K, and you would have melted the vessel through  
22 if it was carbon steel. So I would have thought  
23 vessel failure would have been earlier.

24 So maybe it's just the put the line at the  
25 wrong place. But I just am kind of wondering about

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1 some of the results I saw in some of the plots, and I  
2 think some careful review is needed.

3 (Off record comments.)

4 CHAIR SHACK: We're going to recess for  
5 lunch, come back at one o'clock.

6 (Whereupon, at 12:15 p.m., a luncheon  
7 recess was taken.)

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1 A F T E R N O O N S E S S I O N

2 1:04 p.m.

3 CHAIR SHACK: We're back in session now,  
4 Mike.

5 MEMBER CORRADINI: Okay, great.

6 CHAIR SHACK: You're on the record.  
7 You're on the record. Don't say anything  
8 inappropriate, like I just did. Randy, are you going  
9 to start?

10 MR. GAUNTT: Okay, I'll go ahead and  
11 start. So Fukushima came along before we were able to  
12 get this project closed out, and it raised, I guess,  
13 a lot of obvious questions about how our SOARCA  
14 calculations were comparing to what happened at  
15 Fukushima.

16 I'll digress briefly and say I was able to  
17 spend a month in the embassy in Tokyo shortly after  
18 the accident, to kind of follow along. I was slightly  
19 embedded with the NRC team who was there in force, and  
20 I was sent by Department of Energy.

21 I have to tell you, I brought along my  
22 SOARCA calculation results for Peach Bottom, and one  
23 of the first things we did was pull out the SOARCA  
24 station blackout charts, and overlaid them on top of  
25 the emerging information that was coming out of the

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1 TEPCO database.

2 We adjusted the time base a little bit,  
3 and the comparison of that pressure signature and the  
4 response of the reactor was just stunning. So those  
5 results were very useful, in terms of having the  
6 discussion in Japan on what was happening in these  
7 reactors and so forth.

8 We were sort of warned not to say we had  
9 ever calculated Fukushima before, but in my mind we  
10 calculated Fukushima before it happened. So anyway,  
11 some of the questions that -- go ahead and advance the  
12 slide there.

13 Some of the obvious discussion points or  
14 questions about how SOARCA compared was obviously with  
15 the RCIC operation. We'll show a slide here that  
16 shows extraordinary long operation of RCIC. I'm not  
17 sure I understand how it ran so long in Unit 3, I  
18 think it was, Unit 2 I think it was. So we'll  
19 contrast that a little bit.

20 I'm hoping to just open the discussion,  
21 because I don't have total clarity on all of these  
22 issues. So we can maybe just discuss those as we go,  
23 and then the impressive hydrogen explosions that  
24 everyone's seen on TV. Do we get that in SOARCA, and  
25 yeah, we do get hydrogen explosions in SOARCA.

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1           Then there's the issue of our 48 hour  
2 truncation in the scope of response to SOARCA,  
3 compared to obviously these accidents proceeded for  
4 days and day, and may not actually have been over for  
5 months, when you think about it that day. And they  
6 were multi-units, three reactors simultaneously. So  
7 there's a question about multi-unit risk. I think  
8 you're going to touch on that.

9           Oh, there was hysteria over spent fuel  
10 pool No. 4. The word was it had uncovered and had  
11 caught on fire. We were asking where's the cesium?  
12 There would have been cesium release of biblical  
13 proportions, if that's a perfect term. Anyway, there  
14 is a spent fuel pool study going on right now, I  
15 think, and maybe you'll say something like that.

16           MEMBER ARMIJO: Randy you might, as you  
17 look further, you might look at the effectiveness of  
18 the mitigation work at the Daini site, 20 kilometers  
19 down the road. They weren't unaffected by the  
20 tsunami, but they did heroic efforts and a lot of very  
21 good application of their EOPs, their severe accident  
22 management and great leadership. It would be worth  
23 the staff to take a look at that.

24           MR. GAUNTT: Oh, I think you're right, and  
25 in the Fukushima units, we won't have time to talk

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1 about it. But the EOPs let them down. They just got  
2 into so much trouble with saturated suppression pools.

3 MEMBER ARMIJO: Yeah.

4 MR. GAUNTT: Anyway, the next slide, this  
5 is don't -- this is -- there may be some errors on  
6 this slide. I've been putting this together, because  
7 I love time lines, and this was to just sort of lay  
8 out this multi-unit accident, in terms of what was  
9 happening when.

10 The Unit 1 accident was virtually al  
11 hands-off short term station blackout, as it  
12 developed. Originally, folks thought the isolation  
13 condensers were running more than they were running.  
14 They did virtually no good, and after the tsunami they  
15 lost instrumentation.

16 That proceeded to core damage pretty  
17 quickly. I show on the time line there some events  
18 that, you know, anything in blue kind of represents  
19 their somehow managing heat sink, getting water into  
20 the reactor, or running RCIC or HPCI.

21 In the case of Unit 1, it's a mystery how  
22 the reactor depressurized. When they regained  
23 instrumentation, they could see that oh my gosh, the  
24 reactor has, it's depressurized. How did that happen?

25 We think in our analysis they ruptured a

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1 steam line, but there's a lot of -- there are a lot of  
2 different possibilities that happened. It seems  
3 pretty clear it went ex-vessel in Unit 1. Unit 3 may  
4 have gone ex-vessel as well. Unit 3 and Unit 2 both  
5 had the operation of RCIC, and Unit 3 had RCIC and  
6 HPCI. Unit 2 was running on RCIC for a very long  
7 time.

8 I show then some of the periods of time  
9 where they had core damage. At Unit 3, it looked like  
10 they almost recovered it and then they lost coolant  
11 injection and it's a kind of similar story for Unit 2.  
12 So that's kind of time line overview of the multi-unit  
13 nature of Fukushima.

14 Go ahead to the next slide. So in terms  
15 of operating of RCIC, Units 2 and 3 were operating  
16 heroically for a day to days, and I'm not real sure  
17 how they were able to run Unit 2 so long with likely  
18 saturated suppression pool. Elevated containment  
19 pressure probably helped them to raise the boiling  
20 point of the water.

21 So in contrast, you know, I think before  
22 Fukushima, we were probably ringing our hands on how  
23 long should we credit battery life and extended  
24 operation of the RCIC system. So this just shows you  
25 a comparison, where we're certainly far less heroic in

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1 the operation.

2 Our RCIC operation is basically limited by  
3 the battery life time, and of course in Fukushima,  
4 they went out to the parking lot to get batteries.

5 MEMBER ARMIJO: More batteries, yeah.

6 MR. GAUNTT: And work the system. So that  
7 --

8 MEMBER ADBEL-KHALIK: How do you think  
9 RCIC operated for 70 hours?

10 MR. GAUNTT: How did it?

11 MEMBER ADBEL-KHALIK: Yeah.

12 MR. GAUNTT: Like I say, elevated  
13 containment pressure, I think, kept the water from  
14 flashing. I don't have an analysis that explains how  
15 the pump was able to suck near-saturated water and not  
16 cavitate, and maybe it was cavitating to some extent.

17 MEMBER STETKAR: They tend to be -- well,  
18 I don't know. This was RCIC, so it's a little more  
19 complicated. It's a pretty simple plot.

20 MEMBER BLEY: That's a Terry, Terry  
21 turbine.

22 MEMBER STETKAR: You know, but I mean it's  
23 a centrifugal pump.

24 MR. GAUNTT: So you know, I don't know how  
25 effectively they were running. They did finally give

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1 out, and that's about all I have to say about RCIC,  
2 unless there's more discussion that you want to have  
3 on the topic.

4 MEMBER ADBEL-KHALIK: Is it at all  
5 reasonable to assume that the pumps would operate  
6 beyond the life of the battery? I mean are you trying  
7 to draw a lesson from this table?

8 MR. GAUNTT: Trying to draw a lesson from  
9 --

10 MEMBER ADBEL-KHALIK: From this table?

11 MR. GAUNTT: From this table. I guess  
12 we're just contrasting how we credit RCIC to what was  
13 done under more or less heroic measures at Fukushima.

14 MR. LEONARD: Randy, this is Mark again.  
15 We actually do credit RCIC operation beyond the end of  
16 batteries. In the long-term blackout, when the  
17 batteries die as we're simulating it, the reactor  
18 vessel pressure is already very low.

19 We had previously opened the SRV to  
20 depressurize, and we've been told by the system  
21 engineer with the licensee for us that under those  
22 conditions, if dc power goes away, the governor valve,  
23 which actually controls steam inlet flow to the  
24 turbine, wouldn't change its position. It would  
25 simply remain as it is, because the reactor vessel is

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1 already at low pressure.

2           If dc power stopped prior to  
3 depressurization, then that would not be the case.  
4 The governor valve position would change. The valve  
5 would go full open. Steam would enter the turbine at  
6 a much higher rate, and the system would trip on a  
7 turbine overspeed.

8           For our station blackout scenario, because  
9 of the prior depressurization of the vessel, that  
10 condition doesn't happen. The overspeed condition  
11 cannot occur because the reactor vessel's already  
12 depressurized. So in our case we do run the turbine,  
13 the pump for a while after dc power, but there's no  
14 instrumentation available to guide operators on level  
15 control.

16           So the question is well what flow rate  
17 would they attempt to manually manage the system, to  
18 "maintain level." The assumption in the SOARCA  
19 analysis is that in the absence of instrumentation,  
20 they simply let the pump run at the flow rate it had  
21 when the batteries died, just keep things as they are.

22           Unfortunately, what that does, because the  
23 loss of dc power also closes the SRV that was open,  
24 the leak rate, if you will, the loss of coolant from  
25 the reactor vessel to the pool is now terminated. So

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1 you no longer have a loss of coolant but you've got a  
2 constant flow of RCIC injection into the reactor  
3 vessel.

4 The vessel level continues to rise to the  
5 point where you spill over into the steam lines and  
6 the system kills itself, if you will. That's the RCIC  
7 scenario in a long-term blackout. So it's useful here  
8 in the sense that not only is it a matter of  
9 batteries; it's manual management of system flow and  
10 the absence of instrumentation or whatever else.

11 As Randy said, somehow they were able to  
12 do that, perhaps because of the electric power through  
13 auto batteries they brought into the control room, to  
14 be able to more accurately or have some indication of  
15 reactor vessel water level.

16 In our simulation for the long-term  
17 blackout, we have no instrumentation, no indication of  
18 reactor water level. That's the primary problem.

19 MEMBER ADBEL-KHALIK: But do we know the  
20 operator actions that led to the extended operation of  
21 RCIC?

22 MR. GAUNTT: I don't. I have looked at  
23 the TEPCO reports, and that's just not coming through,  
24 on precisely what were they doing.

25 MEMBER CORRADINI: Randy, may I ask, isn't

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1 there going to be follow-on report from the Japanese  
2 that will get more indepth about some of the operator  
3 actions, or is that -- or am I remembering wrong? I  
4 thought something was going to be coming out in the  
5 July or June time frame?

6 MR. GAUNTT: I don't know, Mike. The  
7 latest thing I have is dated December 2nd from TEPCO.

8 MEMBER CORRADINI: Okay, fine.

9 MR. GAUNTT: So that's RCIC. Next slide.  
10 The hydrogen explosions were --

11 CHAIR SHACK: Oh just on the RCIC, suppose  
12 you had the batteries. How long would you be able to  
13 run it without, before the suppression pool heated up?  
14 What would your calculation say for that?

15 MR. GAUNTT: I don't know if I've got that  
16 on the top of my head.

17 MEMBER CORRADINI: I was going to ask a  
18 different question. I am sorry. I'll wait for you to  
19 finish with Bill. I'm sorry.

20 MR. GAUNTT: Okay. So I don't know.  
21 Mark, do you --

22 MR. LEONARD: I don't recall the specific  
23 number either, but it's on the order of 24 hours. I  
24 mean it's day-ish, inside 24 hours.

25 MR. GAUNTT: Yes, it's a day-ish.

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1 MR. LEONARD: It's not 70 certainly.

2 MR. GAUNTT: Okay. So on the -- Mike, did  
3 you have a question?

4 MEMBER CORRADINI: Yeah. I guess just  
5 again on RCIC, I was talking to some system engineers.  
6 Let me ask you a question. It's a bit kind of out of  
7 the blue.

8 If one were to put essentially on the RCIC  
9 system I'll call it an alternator, that essentially  
10 recharged the batteries, so that RCIC not only  
11 provides cooling, but also is a way to, for an ongoing  
12 long-term station blackout, recharge the batteries.

13 Has that been considered at some sort of  
14 I'll call it alternative thinking about long-term  
15 station blackout and the ability to cope with it,  
16 because where I guess I'm coming from is this whole  
17 discussion you guys were having about how could the  
18 RCIC run without the batteries.

19 My thought is that if one can connect the  
20 two systems, such that you're draining the batteries  
21 by essentially doing all this control stuff, but if  
22 you use this small turbine pump combination to  
23 actually have some sort of way to charge back the  
24 batteries, now you have essentially a system that can  
25 provide long-term cooling for much longer term. You

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1 see my thinking?

2 MR. GAUNTT: Sounds like a good  
3 suggestion. I guess you're ultimately up against the  
4 -- but in this case, they're isolated from their heat  
5 sink.

6 MEMBER CORRADINI: Well, I think you're  
7 right. Given what we're talking about, now we've lost  
8 the heat sink. So we're ultimately going to get, hit  
9 the wall by a loss of heat sink or we'll do the  
10 saturation in the pumps, etcetera.

11 But I guess I'm trying to connect it such  
12 that if one has this system, which at least on an  
13 empirical basis for Units 2 and 3 had shown to be  
14 pretty doggone reliable in the face of a pretty  
15 dramatic event, what was one of their Achilles heel  
16 was there was a disconnect between recharging the  
17 batteries and potentially through actually the  
18 operation of RCIC.

19 CHAIR SHACK: That's actually looked at in  
20 a number of SAMA analyses for license renewal, but  
21 it's always rejected as not cost effective.

22 MEMBER CORRADINI: Was that Bill that said  
23 that?

24 CHAIR SHACK: Yes.

25 MEMBER CORRADINI: So maybe we just have

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1 to think about cross-benefit again.

2 MR. GAUNTT: Good discussion. Okay. On  
3 to hydrogen. We've been telling people for years and  
4 years nuclear power plants can't blow up, and then we  
5 see three, we see three nuclear buildings blown up.  
6 So do we predict that in SOARCA? Yes, we do predict  
7 hydrogen, significant hydrogen burns.

8 We don't specifically have a detonation  
9 model in MELCOR. The hydrogen burns, according to  
10 that turn area flammability chart, depending on steam  
11 partial pressure and hydrogen oxygen availability.

12 One difference, I think, between what  
13 happened at least in Fukushima Unit 1 versus our  
14 SOARCA analyses, is I am reasonably sure in Unit 1  
15 that they did not fail the drywell liner, at least not  
16 early on.

17 I believe that because of the protracted  
18 high containment pressure that was observed. In  
19 SOARCA, when we fail the lower head, in Peach Bottom  
20 we pretty much always fail the liner, which will then  
21 depressurize the system.

22 Instead in Fukushima, it appears, and I  
23 have to qualify everything I say, it's what I believe,  
24 that the hydrogen that got into the refueling bay in  
25 Fukushima Unit 1 was by virtue of the head flange

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1 leakage at the top of the system, and you can see that  
2 the Fukushima drywell pressure comes up to around 110  
3 psi and sits there for like ten hours, almost like  
4 it's pressure-regulated at 110 psi.

5 Our SOARCA model has that leakage mode,  
6 and we would predict, then, this constant source of  
7 hydrogen and steam going into the refueling bay.  
8 Interestingly, our analysis says it was the protracted  
9 hydrogen steam going into the refueling bay that kept  
10 it from exploding.

11 It wasn't until they depressurized the  
12 containment, that sort of cut off the steam flow, and  
13 then in the reactor building, steam began to condense  
14 and they approached flammability from that direction.

15 That's what MELCOR says, and there's other  
16 analyses out there. But in the cases where you fail  
17 the drywell liner, the hydrogen escape path is now low  
18 in the building where the liner rupture is. So that  
19 kind of changes the nature of the hydrogen burns. In  
20 the Peach Bottom analyses, we would have those burns  
21 down in the lower parts of the building, and Mark,  
22 were there ever any cases where we burned in the  
23 refueling bay?

24 MR. LEONARD: I think all of the cases  
25 eventually burn in the refueling bay, but they begin

1 down low.

2 MR. GAUNTT: They begin down low, whereas  
3 in Fukushima 1, it looks like it all went up in the  
4 refueling bay. Not so clear for Unit 3. The nature  
5 of the explosion looks like it could have involved  
6 some of the lower floors of the building.

7 MEMBER ARMIJO: What happens with the  
8 nitrogen from the inerted containment during this  
9 scenario? Is it purged? Is it purged at least out of  
10 the refueling bay building?

11 MR. GAUNTT: Yeah. It's just purged out  
12 into the --

13 MEMBER ARMIJO: Why didn't the hydrogen  
14 leak out also?

15 MR. GAUNTT: What our calculations tell  
16 us, I have to qualify that, is we probably leaked into  
17 the refueling bay upwards of a 1,000 kilograms of  
18 hydrogen. But if you look at the instantaneous  
19 concentration in there, there's only ever about two or  
20 three hundred kilograms resident.

21 So gas is coming in. It's displacing air,  
22 and some of it's leaking out of the building. That  
23 said, I think analysis of or understanding of hydrogen  
24 behavior under these circumstances is something we're  
25 probably going to need to study some more.

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1           MEMBER REMPE: And as part of that study,  
2           are there any subcompartments? I assume your  
3           nodalization diagram for the reactor building  
4           indicates the refueling bay is one big volume, right?

5           MR. GAUNTT: Yes, it is.

6           MEMBER REMPE: So are there some -- I'm  
7           not as familiar with the building up there. There are  
8           some subcompartments where hydrogen, it should be  
9           monitored in smaller regions?

10          MR. GAUNTT: Yeah. There's  
11          subcompartments in the floors below, and in fact  
12          hydrogen that goes into the refueling bay can work its  
13          way down, you know, as it --

14          MEMBER REMPE: And you monitored each of  
15          the volumes shown in this report, but are there -- is  
16          a way to break up the refueling bay that should be  
17          considered too?

18          MR. GAUNTT: You know, I think this topic  
19          is probably needs to be addressed through some CFD  
20          kind of studies. We represent this in MELCOR with one  
21          big control volume. You've got all the issues of high  
22          diffusivity of hydrogen, light gas stratification,  
23          thermal stratification and condensation of steam, you  
24          know, all ongoing. So it's --

25          I wouldn't say that we have necessarily

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1 the definitive analysis of that refueling bay, and  
2 that's something we ought to be studying. The  
3 hydrogen burns in SOARCA were sufficiently large to  
4 blow out panels, as we saw in Fukushima.

5 MEMBER ARMIJO: And that's only two to  
6 three hundred kilograms emission to do that?

7 MR. GAUNTT: Oh, it's interesting. In  
8 Fukushima, it was so delayed before they got to  
9 flammable conditions. But I think in our Peach  
10 Bottom, because it's coming in from lower floors, that  
11 you will reach flammability conditions sooner. Am I  
12 capturing that right, Mark?

13 MR. LEONARD: With the diagram you see on  
14 the slide, the release pathway in the SOARCA  
15 calculations would be roughly at the location of the  
16 vent pipes, of course. That's where the debris would  
17 contact the liner outside the pedestal. So the leak  
18 pathways is into the basement of the reactor building.

19 That volume is relatively confined,  
20 certainly small in comparison to the refueling bay.  
21 And depending on the other gases that are being  
22 discharged with it, steam nitrogen, that volume in  
23 fact may remain inert for a while. It may not be  
24 instantaneously flammable in the release.

25 But when the gas begins to move upward in

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1 the building and it encounters more and more air, then  
2 it reaches a flammable mixture fairly quickly,  
3 certainly by that first level above the torus itself.

4 And in each of those floors, as well as  
5 well as the rooms and the stairwells, are all  
6 represented as separate compartments. So the spatial  
7 distribution is represented in a fairly detailed way  
8 below the refueling bay.

9 So the flame, as it begins down low,  
10 propagates up high, provided the flammable mixture is  
11 available at upper elevations. But in all cases, the  
12 initial burn produces an overpressure that's large  
13 enough not only to open the blowout panels at the top  
14 of the building, but mainly the other doorways that  
15 are in the building itself.

16 MR. GAUNTT: So I think that's it on  
17 hydrogen. The 48-hour truncation. So that's -- it  
18 was so clear from Fukushima the accident's not over in  
19 48 hours, but the consensus view amongst the SOARCA  
20 team and the state and regional people, were that  
21 within 24 hours, equipment can be brought to the site,  
22 if needed, and response launched and by 48 hours, be  
23 able to get on top of the situation, and anyone else  
24 is welcome to add to that, who's been involved with  
25 the decision.

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1                   But that's our story and we're sticking to  
2 it. Randy, was there anything you can add to that?

3                   MR. SULLIVAN: We looked at this in some  
4 detail, but if you have no questions and wish to  
5 accept it, perhaps we don't have to go into it. But  
6 we were doing site-specific analyses, right. There  
7 are two heavy airlift wings within 150 miles of this  
8 site.

9                   We explored the kind of capacity that they  
10 have to lift heavy equipment into the site. It is  
11 substantial. We explored how much of his heavy lift  
12 equipment, helicopters I'm talking about, military,  
13 National Guard units in Pennsylvania and Virginia, not  
14 to mention the Naval air base or whatever that is at  
15 Norfolk.

16                   This stuff can lift 22,000 pounds.  
17 There's electrical generators and pumps all over the  
18 East Coast. So we put that together as being able to  
19 get stuff into the site. Now in the case of Peach  
20 Bottom, the roads are available, you know. In Surry,  
21 the earthquake is a little more, you know, has more  
22 substantial damage to roads, we believe.

23                   So if the roads are available, then you  
24 know, you've got an eight or 12 hour response time if  
25 you want it. So then we looked at pumping curves and

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1       how much water you have to move and could you flood  
2       the torus room to the level of the drywell penetration  
3       that's caused by the corium, and the answer to all  
4       that was yes.

5               The PWR is a little more complicated,  
6       because you're working against pressure, and that's  
7       the kind of analysis we did, you know. So that's  
8       where we came down, that there would be a national  
9       level response, including people in this building by  
10      the way, all looking for assets to help this plant  
11      out.

12             MR. GAUNTT: Multi-unit risk. Clearly, it  
13      was a multi-unit accident in Fukushima. We  
14      specifically did not collect to look at multi-unit  
15      issues in the SOARCA project, but this will be, I  
16      understand, addressed in the soon to be underway Level  
17      3 study.

18             Finally, spent fuel pool risks and the  
19      consequences. So we did not include spent fuel pools  
20      in the SOARCA analysis either, and again, I think  
21      maybe you're going to speak more about this.

22             MS. SANTIAGO: Just basically to say that  
23      there's two ongoing agency projects that you've heard  
24      about already, and I think there was a two weeks ago  
25      discussion with the subcommittee for the spent fuel

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1 pool scoping study, and of course, a Level 3 PRA.  
2 We've been talking about it for a number of months  
3 now.

4 CONSULTANT WALLIS: Shutdown risk is out  
5 because of frequency?

6 MR. CHANG: I think in the beginning  
7 chapters of the main report, I guess low power and  
8 shutdown risk, it's one of those things we acknowledge  
9 is not -- us not examining.

10 CONSULTANT WALLIS: But the consequences  
11 are not trivial.

12 MS. GIBSON: And that's also going to be  
13 covered in the Level 3 PRA.

14 MS. SANTIAGO: Correct, and I'll go  
15 through a whole list of comments and questions that  
16 we've gotten from the public, from the peer reviewers,  
17 from other stakeholders, that touch on many of these  
18 items that we're talking about, that will be looked at  
19 closer in other projects.

20 We had to stay with the scope, SOARCA,  
21 because in the last year, as you've listened this  
22 morning, we've done a lot in the reanalysis of the  
23 SRVs and the ISLOCA. You'll hear from the peer  
24 reviewers.

25 When Fukushima sadly happened, we diverted

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1 some attention to looking at questions for that. So  
2 we just had to limit, by direction in part, what we  
3 looked at for SOARCA.

4 But it didn't mean that we didn't hear  
5 those different issues. We just put them on a table  
6 and said okay, we're going to look at these and other  
7 projects, and I'll go through that a little bit later.

8 MR. GAUNTT: So sorry for the brevity of  
9 that, but that's our discussion on Fukushima.

10 MEMBER ARMIJO: I just want to ask you, do  
11 you have any kind of arrangement with the Japanese,  
12 when they start getting data on the product released  
13 in the environment, to check the barium/cerium issue?  
14 Is the staff going to get that information?

15 MR. GAUNTT: I don't know that we're in  
16 specific negotiations on that. But there is a  
17 developing relationship with NEA, OECD, the Japanese,  
18 NRC, Department of Energy and so forth that will be  
19 kind of looking down the road at some of these things.

20 We have a good idea right now if what  
21 cesium is on the ground, and that should be useful to  
22 us in terms of validating our atmospheric transport  
23 and deposition.

24 Most of the release went offshore, so  
25 there's a big lack of closure on, you know, how much

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1 actually got out. When we run the analysis on these,  
2 we predict something like one percent release, with a  
3 lot of capture in the suppression pool.

4 I think that we will be plugged into this  
5 for some time, and we're going to get very useful  
6 information out of the decommissioning process, that  
7 will kind of further help us validate this page. But  
8 on the whole, I'm fairly encouraged with how our codes  
9 have compared to what we think we know about Fukushima  
10 at this point.

11 MEMBER BLEY: Before we go ahead, I have  
12 a question that probably was sort of asked this  
13 morning, and I heard some things that address it, but  
14 only partially.

15 When I look through the report, it seems  
16 or it states that some human action, some operator  
17 actions are included in the unmitigated analysis, and  
18 some normal operator actions and EOPs are relegated to  
19 the mitigated, on a case-by-case basis.

20 I didn't see any clear criteria on how you  
21 decided which ones to put in which category. Can you  
22 tell us about that?

23 MR. SCHAPEROW: This is Jason Schaperow of  
24 the staff. The mitigated case was intended to include  
25 everything.

1 MEMBER BLEY: Okay. It doesn't say that  
2 --

3 MR. SCHAPEROW: The whole nine yards,  
4 whatever we thought the licensees were going to do,  
5 what they told us they would do, when we looked at the  
6 procedures.

7 The unmitigated cases were intended to be  
8 without the B.5.b equipment and procedures, because  
9 one of our primary objectives was what are the  
10 benefits of B.5.b. So we're trying to -- the reason  
11 we had two cases, we were trying to distinguish that.

12 MEMBER BLEY: Okay. Well, maybe I'll find  
13 out when you talk about it, because there are places  
14 in the report where it says only some of the non-B.5.b  
15 operator actions, and some were reserved for the  
16 mitigated case, and it gives a few examples and were  
17 scattered in the report.

18 MR. SCHAPEROW: Our philosophy was that  
19 again, the mitigated case should be the whole,  
20 whatever exists, whatever's existing. The unmitigated  
21 cases --

22 (Simultaneous speaking.)

23 MEMBER BLEY: It's easy to say that, but  
24 that's not what it says --

25 MR. SCHAPEROW: That was our overall high

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1 level philosophy.

2 (Simultaneous speaking.)

3 MEMBER ARMIJO: The mitigated, they threw  
4 everything at you.

5 MEMBER BLEY: Yeah, but in the end --

6 MEMBER ARMIJO: That's where the problem  
7 is, right?

8 MEMBER BLEY: That's where what I hear  
9 here and I heard earlier this morning doesn't match  
10 what I read in the report. I'll try to find a couple  
11 of those examples.

12 MR. GABOR: All right. Good afternoon.  
13 My name is Jeff Gabor. I work for ERIN Engineering.  
14 I'm one of 11 members of the SOARCA external peer  
15 review committee.

16 Next slide. The presentation I've got  
17 today is going to discuss the objectives of the peer  
18 review. We're going to highlight some of the  
19 individual peer review team members and their areas of  
20 expertise, provide an overview of the review process,  
21 and then finally get into the individual comments from  
22 each of the reviewers.

23 The main objective for the peer review  
24 process was to provide an independent review by each  
25 of the review team, of the technical work conducted

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1 within the entire SOARCA project. Our goal was to  
2 ensure that the SOARCA provided technically accurate  
3 information.

4 In addition to that, the peer group also  
5 offered some feedback on specific issues related to  
6 how this material would be presented to the general  
7 public, and I'll mention a couple of things there.

8 The list here shows the committee was made  
9 up of a variety of technical experts from industry,  
10 with identified areas of expertise from Level 1, 2, 3  
11 PRA, external hazards, emergency planning and health  
12 effects.

13 The peer review committee included the  
14 list you see here: Ken Canavan from EPRI; Bernard  
15 Clement from IRSN; myself; Bob Henry from Fauske and  
16 Associates; Roger Kowieski from Natural and Technical  
17 Hazards Management; Dave Leaver from Polestar; Bruce  
18 Mrowca from ISL; Kevin O'Kula from URS Safety  
19 Management Solutions; John Stevenson from Stevenson  
20 Consulting; Karen Vierow from Texas A&M, Karen was our  
21 chairperson; and Jacquelyn Yanch from MIT.

22 Next. The documents that our groups  
23 reviewed included the draft SOARCA NUREG documents.  
24 It also included the presentation material that was  
25 provided to us.

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1           We had a peer review comment resolution  
2 document that we worked on, where we would provide  
3 some questions, and then the staff and the contractors  
4 would get back to us on specific items.

5           Then anything that we would specifically  
6 ask for in terms of supporting information was also  
7 included.

8           The review process benefitted from many  
9 active discussions with the staff and their  
10 contractors. We had a total of five meetings between  
11 July '09 and December 2011; in addition, two  
12 teleconferences as well.

13           Some items that weren't specifically  
14 included in our scope of work were the final  
15 uncertainty review and the final uncertainty  
16 quantification and sensitivity analysis. We're eager  
17 to hear the presentation by Tina today, as well as  
18 everyone else.

19           We didn't specifically in our scope  
20 attempt to fix the document, editorial review of the  
21 document, although I understand that some of the peer  
22 review team did provide some comments on editorial  
23 things. The proposed uncertainty analysis methodology  
24 was presented to our team in October of 2010, and  
25 there was a peer review guidance memo that we issued

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1 at the time, providing some feedback on that plan.

2 The parameters and their associated  
3 distributions that were going to be used in the  
4 uncertainty analysis, they were presented to us in  
5 January of this year, and again, there was  
6 considerable feedback between the peer review team and  
7 the staff.

8 MEMBER STETKAR: So Jeff, although you  
9 said you didn't -- if I understand, you didn't review  
10 the uncertainty quantification because it's not done  
11 yet, I guess.

12 MR. GABOR: Correct.

13 MEMBER STETKAR: But you did review the  
14 input?

15 MR. GABOR: We did, the parameter  
16 selection and the distributions. Next. So as far as  
17 the coverage of the various SOARCA topics, I think we  
18 felt that the team included the right people to  
19 address all the major areas. You can see from the  
20 list in front of you accident sequence selection,  
21 mostly looked at by Ken Canavan and Bruce Mrowca.  
22 Accident progression, also Ken, Bernard from ISRN,  
23 myself and Bob Henry. Myself, Bob Henry and Bruce  
24 Mrowca also focused in on the mitigative measures.

25 We had several people looking at the

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1 radiological release results. In addition, Roger  
2 Kowieski and Dave Leaver focused a lot of their  
3 attention on the offsite emergency planning and  
4 response part of the calculation. Offsite  
5 radiological consequences, a similar group, including  
6 Kevin O'Kula and Jacquelyn Yanch.

7 Then finally, John Stevenson provided peer  
8 review of seismic issues and structural issues;  
9 overall PRA application, Ken Canavan and Mrowca, and  
10 then specific to severe accident modeling, mostly  
11 myself, Bob Henry and Karen Vierow.

12 MEMBER STETKAR: Jeff, maybe it's here,  
13 but was there any specific examination of what I call,  
14 you know, putting the pieces together, the integration  
15 of kind of the Level 1-2-3 --

16 MR. GABOR: It probably fits under the PRA  
17 application part. I would think Ken Canavan and Bruce  
18 Mrowca were mostly looking at that.

19 MEMBER STETKAR: Did they?

20 MR. GABOR: I think they have some  
21 comments. We'll get to their specific comments.  
22 Hopefully that will hit on a couple of those topics.  
23 Okay. At this point, I'd like to move into the  
24 individual assessments and provide a brief summary of  
25 each members' comments.

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1           The summaries of assessments included in  
2           the following slides are the final summaries. During  
3           the whole process, each reviewer provided comments on  
4           the review process, many of which were addressed by  
5           the SOARCA team, and I'm not going to present those  
6           things here.

7           The SOARCA analyses were reviewed based on  
8           -- were revised based on the comments from the review  
9           team, and basically this presentation doesn't identify  
10          all of the contributions that the review team made.

11          I think as stated on this slide, there was  
12          no attempt to pursue any kind of a consensus opinion,  
13          and as such, the individual comments from each of the  
14          team members were not altered by the chairperson, and  
15          represent those individual inputs.

16                 MEMBER CORRADINI: Can I ask you a  
17          question at this point?

18                 MR. GABOR: Sure.

19                 MEMBER CORRADINI: So was that a going-in  
20          part of the scope, that the committee would just  
21          provide individual comments and not come up with  
22          consensus comments, or was that a decision by the  
23          committee?

24                 MR. GABOR: It was a going-in, I believe.  
25          It was stated going in that there was no -- the staff

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1 didn't have an interest in pursuing that.

2           There were a couple of places where the  
3 group issued memos, where it wasn't necessarily  
4 consensus, but one opinion would be shared by multiple  
5 reviewers, and those were documented in a couple of  
6 memos that were transmitted.

7           MEMBER CORRADINI: Okay, thank you.

8           MEMBER ADBEL-KHALIK: So members did not  
9 benefit from the reviews that the specific subgroups  
10 focused on in specific areas?

11           MR. GABOR: They did. We all shared our  
12 own individual reviews as they were drafted up, and of  
13 course, we all participated jointly in all of the five  
14 meetings and the two telephone conferences.

15           MS. SANTIAGO: And we went through each of  
16 the reviewers' questions and the staff responses at  
17 those meetings. Some of these meetings were three-day  
18 meetings to go through all the comments.

19           MEMBER ADBEL-KHALIK: But the reports that  
20 were prepared as a result of those subreviews were not  
21 modified in any way as a result of those discussions.  
22 They were just information briefings for you?

23           MR. GABOR: Maybe I don't understand the  
24 question. I mean the final reports that the review  
25 team issued were there, were the opinions at the end

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1 of the project. So if there were issues that were  
2 raised and resolved, they may not appear in the final  
3 document, if they were satisfactory.

4 That's not quite -- I don't think that was  
5 true in each case. I think a lot of the -- we  
6 drafted, our initial draft came out quite a bit before  
7 the end of the project. So a lot -- and with a lot of  
8 us, I know me personally, I tried to keep the original  
9 comment, but then capture any resolution from the  
10 SOARCA team in my report.

11 Okay, so onto some specifics, and all I've  
12 tried to do is to highlight some of the key issues  
13 that each of the reviewers brought up during the  
14 process. Ken Canavan from EPRI, he felt that overall,  
15 that the SOARCA study met its objectives.

16 He noted that because SOARCA, since SOARCA  
17 was mostly a consequence evaluation, and didn't  
18 represent a full-scope PRA, that there could be a  
19 chance that some low frequency high consequences  
20 events would be missed, might not have been  
21 considered.

22 Next. In addition to that, Canavan noted  
23 that some of the SOARCA conclusions could be plant-  
24 specific and wouldn't apply to other plants. So that  
25 was a theme that you'll read in a lot of the peer

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1 review comments.

2 Specific to the review of the sequence  
3 selection process, Canavan noted that a plant-specific  
4 analysis could produce unique sequences, and sequences  
5 that weren't necessarily represented by the more  
6 generic process that the SOARCA, what was represented  
7 by the SOARCA methodology.

8 Canavan also commented that changes in key  
9 phenomenological assumptions could also influence the  
10 final results, and I think we heard some of that this  
11 morning in the presentations.

12 Bernard Clement from ISRN agreed that  
13 SOARCA overall met its objectives for updating the  
14 quantification of offsite consequences. He identified  
15 some specific phenomena associated with RPV failure.  
16 Again, we talked about that this morning, treatment of  
17 iodine release that might influence the overall  
18 results.

19 He also supported the proposed uncertainty  
20 analysis, and felt it would increase the confidence in  
21 the overall results.

22 And then specific recommendations that  
23 were made by Bernard included (1), to revise the  
24 SOARCA study based on any new PRA results or insights;  
25 (2), to expand the SOARCA study to address other

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1 plants, again the same theme that came through on many  
2 of the reviews.

3 A third item for Bernard is he commented  
4 that benchmarking SOARCA with future MELCOR versions  
5 would be recommended, and then specifically he  
6 indicated, he felt that there should be a reassessment  
7 of the thermally-induced tube rupture analysis with  
8 any updated flaw data or material data that might  
9 become available in the future.

10 For my review, I felt that SOARCA  
11 represented a major advancement in our understanding  
12 of severe accident progression and radionuclide  
13 release. Again, since the study was primarily focused  
14 in a deterministic evaluation, I cautioned and I felt  
15 that there was care needed in communicating these  
16 results in the context of a true risk assessment.

17 Next. My comments also identified some  
18 limitations in the deterministic approach taken, and  
19 highlighted some differences with a more complete  
20 probabilistic approach. Some of the technical areas,  
21 specific technical areas of most interest to me were  
22 treatment of the SRVs due to high RC primary system  
23 temperatures, and the impact that that had on actually  
24 reducing the source term.

25 It turns out opening the SRV, transporting

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1 all the fission products into the pool will overall  
2 reduce the amount that could be released once the  
3 containment was impaired or failed. I commented that  
4 there was, you know, clearly a competition between the  
5 seizure of the SRV and the potential for a main steam  
6 line rupture. We heard a lot about that earlier  
7 today, and that topic did become, as you can tell, a  
8 pretty major focus for additional work that was done,  
9 the finite element analysis and the additional work  
10 that the SOARCA team did.

11 I made notes while I guess Mark was  
12 talking this morning. I had also identified that I  
13 felt that they needed to look at lower head  
14 penetration failures. In analyses that we have done,  
15 we have found -- with industry tools, we have found  
16 that a limited penetration, welds might be vulnerable  
17 to a local penetration failure.

18 I also agree with Mark's comment earlier  
19 today. It may not make a big difference in the end  
20 result, because a smaller penetration failure is going  
21 to tend to grow into something larger anyhow.

22 CONSULTANT WALLIS: Did the staff respond  
23 to that? I mean I picked up that too. Did they  
24 respond to that issue of the low penetration?

25 MR. GABOR: The response that we got, well

1 the first response was it just wasn't a model  
2 currently in MELCOR. The other response was because  
3 the scenarios that the SOARCA team had looked at were  
4 low pressure scenarios, that ejection of an instrument  
5 tube or a CRD tube would be less likely at the lower  
6 pressure, which I tend to agree with. But there are  
7 high pressure scenarios to deal with as well.

8 The last point I thought I'd make was that  
9 I also, in looking and addressing the SRV seizure open  
10 scenario, that there could potentially be a release  
11 pathway, not unlike the steam line that came as a  
12 result of SRV tailpipe failure. The piping downstream  
13 of the SRV is thinner-walled piping. It's going to be  
14 exposed to pretty high temperatures.

15 If it would rupture, it would potentially  
16 be in the drywell air space, and again, probably much  
17 like the scenario that the NRC analyzed with the main  
18 steam line creep rupture, saying more about myself, I  
19 guess, than anything.

20 MEMBER REMPE: Just quickly, in your first  
21 slide you talk about you really ought to be careful in  
22 presenting results of this study against, for example,  
23 the safety goal, which you see in several of these  
24 documents. Do you think they ought to just take that  
25 safety goal line off? Are the caveats they have --

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1           how strongly do you think they ought to be careful  
2           about how they present it?

3                       MR. GABOR: I think, and I think they  
4           heard a lot of our comments, that the peer review team  
5           made, that you have to put it in the right context,  
6           that it's a consequence study. It's not a PRA, it's  
7           not a Level 3. We've got that coming, and I think the  
8           Level 3 project will address a lot of our concerns  
9           about doing more of a full-scope, you know, risk  
10          analysis instead of a more, I'll call a focused  
11          consequence study.

12                      MEMBER REMPE: So they should take that  
13          safety goal line off, or I didn't hear the answer to  
14          the question.

15                      MR. GABOR: I'm not sure I know the  
16          specific safety goal statement you're talking about.

17                      MEMBER REMPE: It was in the presentation  
18          chart.

19                      MS. SANTIAGO: The chart that Richard  
20          showed at the very beginning, and --

21                               (Simultaneous speaking.)

22                      MEMBER REMPE: They are presenting the  
23          results with the safety goal.

24                      MS. GIBSON: Actually, we added that line  
25          as a result of a comment from the peer review

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1 committee.

2 MEMBER REMPE: The peer review was happy  
3 about that.

4 (Laughter.)

5 MS. GIBSON: You probably noticed that we  
6 caveated that.

7 (Simultaneous speaking.)

8 MR. GABOR: I guess to answer to your  
9 question directly, I don't think it's incorrect to put  
10 the results up against the safety result in that  
11 context. It's more in terms of, you know, in  
12 portraying this as a full Level 3 PRA or as a PRA,  
13 they may have.

14 MEMBER REMPE: And they have a lot of  
15 caveats in the report. Okay. Just wondering.

16 MS. GIBSON: And specifically because of  
17 that. We had that large discussion at the peer review  
18 committee meeting in December about how to present  
19 that, and so --

20 MEMBER RAY: In that regard, let me just  
21 add, I don't quibble with the conclusion that it's a  
22 major advancement in our knowledge. It can well be,  
23 but then the problem is how do you keep that from  
24 implying that it's 75 percent of the answer that one  
25 would need to have? How do you put a major

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1 advancement in the context that you just talked about,  
2 and that's what I'm debating in my mind right now.

3 MR. GABOR: Specific to my definition of  
4 a major advancement, it's really focused on our  
5 ability to analyze the severe accident response.

6 It's not in sequence selection or -- and  
7 even personally, it's not, I didn't really focus th at  
8 much attention on the offsite consequences. The  
9 others that did also agreed that the modeling did  
10 represent state of the art techniques.

11 But I do think specific to MELCOR and  
12 MACCS-2, and the efforts that went in to upgrading the  
13 models, and how they were exercised in SOARCA, is  
14 state of the art.

15 MEMBER RAY: Yeah, and I think that's a  
16 good answer. It's just that the danger is that people  
17 will over-interpret the outcomes as being more  
18 conclusive than you intend.

19 MR. GABOR: Given that the uncertainty  
20 analysis wasn't part of our original scope, I had  
21 originally made some recommendations to include that  
22 in the final analysis, and as we all know, that  
23 evolved with the project, and we'll hear -- we're  
24 going to hear a lot about it today, I'm sure.

25 One of the things we did talk about, and

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1 of particular interest to me again on uncertainty  
2 analysis related to core melt progress, Level 2 PRA,  
3 is it's really difficult, because of how all of these  
4 parameters and we had some pretty active discussions  
5 on this, but how Level 2 parameters are all correlated  
6 to each other.

7 It's a different beast than doing random  
8 sampling on valve failures and things like that,  
9 because hydrogen generation, vessel failure, all of  
10 those parameters all tend to feed back on themselves  
11 and again, finally, my recommendation, no surprise,  
12 was that I saw benefit in taking the tools that were  
13 created for SOARCA, and extending that into a more  
14 complete Level 3 PRA framework.

15 Okay. I've got to get back on the other  
16 folks. Bob Henry felt that the study advanced our  
17 knowledge of severe accident progression. Again, I  
18 think his comment was in line with mine, that with the  
19 advancements and the modeling work that had been done  
20 with MELCOR.

21 He felt that the focus on a station  
22 blackout and the containment bypass events was  
23 appropriate, and then he felt that Fukushima validated  
24 the decision to kind of focus in on those scenarios.

25 Bob Henry had also described the

1 importance of RCIC operation, and identified or  
2 commented that it was, he felt, that it was  
3 conservatively modeled in the SOARCA study,  
4 specifically in looking at what happened at Fukushima  
5 Unit 2.

6 Okay. Henry saw that the MELCOR  
7 benchmarking activity was a strength. We spent a good  
8 part of a meeting going through a lot of the  
9 benchmarks. Bob Henry is quite interested in these  
10 benchmarks, and I think felt that it added a lot to  
11 the value of the end product.

12 As identified earlier, he felt that the  
13 importance of looking at these release pathways from  
14 the reactor coolant system initially identified that  
15 those hadn't been explored in SOARCA, and in  
16 particular, the in-core instrumentation in the TIP  
17 system, and how it might create a flow path that  
18 could, you know, potentially result in hydrogen and  
19 high radiation outside of the reactor vessel.

20 I think it was mentioned earlier about  
21 relating that back to TMI. He's actually done that,  
22 and I think the release is, I don't remember the  
23 details that he studied. But I believe that he can  
24 actually account for hydrogen and radiation levels in  
25 containment by looking at that leak pathway in TMI as

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1 well.

2 Let's see. Again, this release pathway  
3 had originally not been included in the SOARCA study.  
4 The only comment I made, again this morning listening  
5 to the presentation, is that I believe, you know, Mark  
6 did a good job showing the sensitivity to having that  
7 release pathway or not.

8 But one thing to keep in mind, and I think  
9 Bob Henry had raised this at the end of our process,  
10 that there could be other scenarios, that that sneak  
11 path or that release path could be a little more  
12 significant. That was it.

13 Next slide. Early on his review, Henry  
14 had recommended that the MELCOR best practice document  
15 include a more thorough description of the code  
16 benchmarking that had been done, and actually how  
17 those results from the benchmarks made their way into  
18 the SOARCA evaluation.

19 Okay. The next reviewer, in the review of  
20 the emergency response analysis, Roger Kowieski felt  
21 that the parameters and the assumptions were  
22 reasonable and adequate. He also let that the  
23 response time lines were consistent with actual time  
24 lines that were used by, you know, a typical offsite  
25 organization.

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1 Dave Leaver felt that SOARCA represented  
2 a substantive high quality effort, and that it made a  
3 significant contribution to the understanding of  
4 nuclear plant risk. He saw that the project  
5 transparency was a strength, and he felt that the  
6 Level 1 PRA work utilized the latest information  
7 available.

8 Leaver did feel that the study of the  
9 large seismic event should be a focus of some future  
10 evaluations. On the matter of completeness, Leaver  
11 believed that the approach was technically sound, but  
12 he did some benefits in expanding the scope to address  
13 additional sequence, accident sequences.

14 He also felt that expanding the study to  
15 address other plant types would strengthen the  
16 completeness argument for the effort. Leaver felt  
17 that there was nothing forthcoming from Fukushima that  
18 would indicate that SOARCA's sequence selection  
19 process had overlooked any important scenarios.

20 Then on the topic of public risk, Leaver  
21 felt that SOARCA provided strong evidence that past  
22 risk characterization had been unrealistic and  
23 excessively conservative, his words. The 50-50 4HH or  
24 the so-called B.5.b measures were found to be  
25 important to risk, and he felt that they provided a

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1 margin for some of the uncertainties associated with  
2 sequence selection.

3 Leaver also stated that the SOARCA results  
4 demonstrated the importance of emergency response  
5 planning and accident management, to reduce overall  
6 risk.

7 Okay, for Bruce Mrowca. He commented that  
8 he felt that the objectives were only partially  
9 achieved. He stated that SOARCA demonstrated state of  
10 the art techniques on the phenomenological modeling,  
11 but not on sequence selection process, or modeling of  
12 the security-related mitigation improvements.

13 MEMBER RAY: On that last point, why?

14 MR. GABOR: I'm going to get there.

15 Mrowca found that the sequence selection process was  
16 limited.

17 He felt it lacked some transparency, and  
18 in his write-up he provided some examples of how the  
19 process could have been improved, and then I think to  
20 your point, relating to the mitigative measures and  
21 the associated operator actions, he felt that a more  
22 thorough, disciplined human reliability analysis of  
23 these key operator actions was needed.

24 He believed that lacking this HRA analysis  
25 really limited the credibility of the benefit that

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1 could be achieved from these actions, these additional  
2 actions.

3 MEMBER RAY: Okay. So it's based on the  
4 operator performance, not on the reliability, what do  
5 I want to call them, non-compliance-based features  
6 and equipment and so on.

7 MR. GABOR: Yeah. His comments were  
8 mostly directed towards the human reliability. Okay.  
9 Kevin O'Kula reviewed -- in his review, he stated that  
10 he felt the SOARCA study met its goal of applying  
11 state of the art techniques to accident phenomena, and  
12 more in line with one of this areas of expertise, he  
13 felt that it represented state of the art for offsite  
14 consequence analysis.

15 Kevin had recommended some additional work  
16 in the areas of straight-line Gaussian plume segment  
17 modeling, economic impact modeling, and assumptions  
18 that had been made on decontamination and clean-up  
19 costs.

20 MEMBER CORRADINI: Can I just get a  
21 clarification? For the economic consequence modeling  
22 with older data, meaning the data was old in the sense  
23 of out of date in terms of economic values? If I  
24 remember correctly, that was his point?

25 MR. GABOR: I believe it's all of the

1 economic modeling, and it would include what you just  
2 mentioned. It might include underestimating the  
3 impact on society in terms of a cost. Others had, a  
4 couple of others, you'll see, had similar comments.

5 MEMBER CORRADINI: Okay.

6 CONSULTANT WALLIS: That's my comment on  
7 the whole SOARCA. I mean the message of the SOARCA  
8 seems to be nuclear power's okay, because nobody dies  
9 in an accident. That means that the other  
10 consequences become the determining factor, right?  
11 And it doesn't say much about that at all.

12 MR. GABOR: The land contamination and  
13 cost issues were not part of the SOARCA study.

14 MS. SANTIAGO: Correct.

15 MR. GABOR: That comment was raised by  
16 most of the peer reviewers.

17 CONSULTANT WALLIS: But then when you  
18 publish a document for the public, a glossy little  
19 thing which says it's okay because nobody died, people  
20 are going to pick on this, and they're going to say  
21 well, is that the only thing we worry about?

22 MEMBER CORRADINI: Can I ask Graham's  
23 question differently? It was not in the scope of the  
24 study to report out these measurables or these  
25 calculated values; is that correct?

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1 MS. SANTIAGO: That's correct. This is  
2 Pat Santiago. That is correct. It was originally  
3 part of the plan, and I'll talk about this again in a  
4 little bit. But in order not to delay the study more,  
5 that piece was carved out and it's being looked at  
6 under another project.

7 I think we're very, very clear on what  
8 SOARCA does look at, and it does indicate that it  
9 doesn't have a full HRA. It doesn't have the economic  
10 consequence and land contamination value. So Dr.  
11 Bixler and I see Randy Sullivan standing at the mic.

12 MR. SULLIVAN: You know, we were asked the  
13 same question by Commissioner Apostolakis, and there's  
14 nowhere in this study where it says we think it's okay  
15 that there's core damage. Our whole regulatory  
16 structure is such that we do not accept any of this.  
17 So I don't know how we get to this study saying it's  
18 okay, because nobody dies, that the plant melts down.

19 I mean it shows the effectiveness of  
20 emergency preparedness and saving lives. It has  
21 nothing to do with the NRC accepting these kinds of  
22 accidents as an okay thing.

23 MR. GABOR: Okay. I'll proceed. O'Kula  
24 found --

25 CONSULTANT WALLIS: Be careful you don't

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1 give the impression. I mean I agree with what you're  
2 saying, but you've got to be careful when you do  
3 something for the public that they don't think that's  
4 what you're saying.

5 MR. GABOR: O'Kula found that the approach  
6 taken for the offsite consequence was comprehensive  
7 and sufficiently best estimate. He also found value  
8 in finalizing the uncertainty analysis, which of  
9 course we hadn't be able to see the results of, to  
10 determine where the best estimate values would lie  
11 relative to the other statistical measures, and we're  
12 going to hear more about that.

13 John Stevenson provided comments related  
14 to seismic risk. Early on, he had raised a concern  
15 that for the seismic event, the magnitude that it was  
16 assuming for Surry, the liquefaction of the soil could  
17 lead to displacement of structures and potentially  
18 cause containment penetrations to rupture, creating a  
19 release pathway.

20 We heard that comment from John at every  
21 peer review meeting. He was very consistent.  
22 Stevenson, he had also raised questions regarding the  
23 build up of hydrogen and a possible need for  
24 procedures and hardware to avoid the potential for  
25 deflagration and detonation transition.

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1 His overall impression was that SOARCA  
2 made a significant contribution to the understanding  
3 of U.S. commercial reactor risk.

4 MEMBER STETKAR: Jeff, did John comment  
5 much on the seismic hazard or not?

6 MR. GABOR: Usually, he focused more on  
7 the liquefaction of the soil. He might have, in his  
8 individual comment. I don't remember.

9 MEMBER STETKAR: I mean I remember -- I  
10 wrote some notes to myself. Back in June, kind of we  
11 questioned for Surry that if you look at the USGS  
12 seismic risk map, you might infer that the frequency  
13 of the accelerations that were used could be, you  
14 know, a factor of 10 to 100 higher than what was used  
15 in the SOARCA project.

16 I was just curious. I know he's not a  
17 seismic hazard guy; that was just since he was your  
18 seismic name on the --

19 MR. GABOR: I don't recall that. If he  
20 did, he put it in his report. Okay. Next for Karen  
21 Vierow, Karen overall agreed that the approach for  
22 modeling severe accident phenomena was valid, and that  
23 SOARCA did represent the state of the art regarding  
24 severe accident modeling, again a comment similar to  
25 others.

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1           Vierow found that benchmarking of melt  
2           core was a strength, and that additional sensitivity  
3           on certainty analysis would be essential to the  
4           overall credibility of the project. Vierow also found  
5           useful insights in the study, but cautioned against  
6           extrapolating the results to other reactor types,  
7           again a pretty common theme.

8           Then finally, Vierow commented that the  
9           current evaluations still retain some conservatisms in  
10          the analysis, and that a decision or discussion,  
11          excuse me, a discussion of those conservatisms would  
12          be helpful, again to enhance the overall credibility  
13          of the study.

14          Then Jacquelyn Yanch looked at the  
15          consequence analysis and the associated health  
16          effects. She noted that the SOARCA did not consider  
17          socioeconomic impacts, kind of my word, but I'm pretty  
18          sure that's where she was going, and felt that it was  
19          a significant omission in the study.

20          In addition, Yanch noted that due to the  
21          extended accident times, that the public would have a  
22          significant amount of time to leave the area, and  
23          therefore incur very little dose, which we see in the  
24          results.

25          Most of the dose -- also we see that most

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1 of the dose calculated was incurred when the public  
2 returned back home, which was based on the state-  
3 established limits that we talked about this morning.

4 Then Yanch noted that the health effects  
5 approach that she felt reflected state of the art, and  
6 that it was consistent with approaches that had been  
7 taken by the scientific field in general, in those  
8 areas.

9 Then finally to wrap up, the peer review  
10 committee provided comments and written documents  
11 throughout the process. Specific memos were  
12 transmitted to the SOARCA team on key issues, and on  
13 the proposed uncertainty quantification and  
14 sensitivity analysis project.

15 Our final report was issued in January of  
16 this year, and that's all I have. Thanks for letting  
17 me summarize our findings, and I'd be happy to answer  
18 any other questions.

19 MEMBER BLEY: Something you said in the  
20 very beginning surprised me. I mean looking at some  
21 of the documents we got with the peer review comments,  
22 we see the comments from each of you, and a  
23 resolution. From what you said, that resolution was  
24 your resolution or I thought it was what the staff was  
25 saying they've done in response to the comments?

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1 MS. SANTIAGO: The resolution that you saw  
2 was what the staff --

3 MEMBER BLEY: That was the staff's  
4 response. Okay, thanks.

5 MS. SANTIAGO: And in fact, that's what we  
6 went through in December at a fairly lengthy meeting,  
7 and then we received the final peer review letter in  
8 January of this year, as staff said.

9 So I'm going -- my name is Pat Santiago.  
10 I'm the chief of the Accident Analysis Branch in the  
11 Division of Systems Analysis in the Office of  
12 Research. I'm going to talk a little bit now about  
13 the public comments on Commission documents that we  
14 are planning.

15 (Paper shuffling.)

16 Slide 2, go to the Commission documents.  
17 The first will be a Commission memo. I will provide  
18 the SOARCA NUREG that 1935 is the name for, and then  
19 we'll have the specific analyses for Surry and Peach  
20 Bottom, as well as we'll provide the public  
21 information brochure that was developed.

22 The second document that we'll provide to  
23 the Commission will be a description of the projects  
24 and issues that we've identified throughout the  
25 process, that call for follow-on research, and then

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1 we'll sum what the Commission had asked us to do  
2 originally, which was to develop a body of knowledge  
3 and give them a recommendation on the original scope  
4 of the project, which was to do 104 reactors, which  
5 was reduced over a period of time in scoping the  
6 project. So we'll talk a little bit more about that.

7 Slide 3 identifies the public meetings  
8 that we held. After we issued these NUREGs in January  
9 31st of this year, we set out to provide two public  
10 meetings at each or near each location. One was held  
11 at Surry, Virginia on February 21st, and the other one  
12 was held in Delta, Pennsylvania, which was near the  
13 Peach Bottom site.

14 We provided basically an overview of the  
15 project, and we discussed various aspects of scenario  
16 selection, offsite consequences, just as you see in  
17 the outline of the main report, as well as the public  
18 information brochure, and we responded to many  
19 questions. Mike.

20 We had a number of comments that we  
21 received, approximately 75 comments. We had many  
22 attendees at the Peach Bottom public meeting, which we  
23 expected, and we're still going through some of those  
24 comments. We're bidding them, and I'll talk a little  
25 bit more about that in a second.

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1 MEMBER ARMIJO: Excuse me. Those 75  
2 comments, were they written comments or are they --

3 MS. SANTIAGO: Correct. They were  
4 submitted through the Office of Administration.

5 (Off record comments.)

6 MEMBER SKILLMAN: On your Slide 3 please,  
7 how well attended were those public meetings please?

8 MS. SANTIAGO: The public meeting at Surry  
9 had a number of state representatives, a number of  
10 licensee representatives. We had a few members of the  
11 public, a student, I think, that attended. At the  
12 Peach Bottom public meeting, we had three groups,  
13 public interest groups. One was TMI Alert.

14 MEMBER SKILLMAN: Beyond Nuclear.

15 MS. SANTIAGO: Beyond Nuclear, and they  
16 actually provided comments at the meeting, and then  
17 they also, in addition, submitted them through the  
18 public website that we had established here at NRC,  
19 for receiving comments on the main report.

20 We had the representatives from the state  
21 of Maryland. We had Dr. Dave Allard from the state of  
22 Pennsylvania and his emergency preparedness director.  
23 We had several people from the licensee there as well.  
24 So that was more well-attended.

25 CONSULTANT WALLIS: Since they're going to

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1 be the audience, the people that are going to read  
2 this, the people it's addressed to, are the public,  
3 aren't they, and they're not the internal people like  
4 us?

5 MS. SANTIAGO: Correct.

6 CONSULTANT WALLIS: Is SOARCA supposed to  
7 go out there and influence millions of people?

8 MS. SANTIAGO: It's to inform and discuss  
9 a research project. That was done.

10 CONSULTANT WALLIS: It's important to get  
11 feedback from the people you're trying to influence,  
12 and eight people seems a pretty diminutive sample of  
13 that.

14 MS. SANTIAGO: We did the best with  
15 advertising. We attend University --

16 CONSULTANT WALLIS: I think you need to do  
17 a better job. Otherwise, you're going to get a report  
18 which is written for people like us, which I think it  
19 is.

20 MS. SANTIAGO: We have a variety of  
21 reports. We have a highly technical report that Tina  
22 writes, which documents this --

23 CONSULTANT WALLIS: The glossy one too.

24 MS. SANTIAGO: Yeah, the glossy one was  
25 for the public mainly, and we held a conference also

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1 at the -- well, a session at the Regulatory  
2 Information Conference in March. We had probably 125  
3 attendees there, several university professors,  
4 obviously a lot of folks from the industry.

5 MR. CHANG: We held a press conference  
6 with a number of --

7 MS. SANTIAGO: Yes. We held a press  
8 conference on February 1st, directly after we had the  
9 --

10 MR. CHANG: I'm going to send you the  
11 comment of my wife.

12 MS. SANTIAGO: Okay, on the glossy one?  
13 And so we've dealt with those or we're dealing with  
14 those comments still, and I'll talk a little bit more  
15 about those in a minute. So I guess the Regulatory  
16 Information Conference was the last public meeting  
17 that we had, and so on Slide 4, I want to just talk  
18 very briefly about the different types of public  
19 comments that we received.

20 The staff is currently finalizing the  
21 summary of all those comments, and then we're  
22 finalizing the responses to those public comments. We  
23 right now have binned those 75 comments into five  
24 general categories dealing with the scope of the  
25 analysis, scenario selection, accident progression,

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1 emergency preparedness and consequence analysis.

2 On this slide, I talk a little bit of what  
3 some of the comments have been. The common one has  
4 been, as you heard earlier, that we did not analyze  
5 the spent fuel pool, or we didn't consider multi-  
6 units. That wasn't in the scope of the plan, and I'll  
7 talk again in a few minutes about where we believe the  
8 agency will look at those particular issues.

9 Other comments noted again that SOARCA did  
10 not do a full HRA for operator actions, and we talk  
11 about the use of mitigated and unmitigated cases. We  
12 did, as Jason spoke of earlier, perform tabletop  
13 exercises and walkdowns at the sites, and we used that  
14 information for this study.

15 We tried to make sure it was very clear  
16 and detailed in the specific site analyses, and we had  
17 a summary in the main report of what we did. Another  
18 question involved how we reported offsite  
19 consequences, and we talk about early fatality risk  
20 and the latent cancer fatality risk. This is what we  
21 used in part to compare to the NRC safety goal and the  
22 1982 siting study.

23 Other comments noted that we should have  
24 looked at cancer incidence rates, as well as  
25 environmental contamination and economic consequences,

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1 and again, I'll talk about those particular issues in  
2 a minute.

3 Many comments came after the unfortunate  
4 event at Fukushima, and that stopped us for a little  
5 bit, so that we could look at what did we have in our  
6 study that we could touch on, at least, to compare.

7 So we included an appendix in the main  
8 report, and Dr. Gauntt went through the five topics  
9 that we selected on RCIC, 48-hour truncation, multi-  
10 units, that we talked about in very general terms.

11 MEMBER ARMIJO: In that session, was there  
12 a lot of concern about the spent fuel pools draining,  
13 burning? You know, was there disinformation still  
14 floating out there that there was a catastrophe out  
15 there?

16 MR. CHANG: At the RIC?

17 MEMBER ARMIJO: No, at your public  
18 meeting.

19 MS. SANTIAGO: Public meetings didn't ask  
20 very specific questions, I don't believe, about  
21 Fukushima. But we did note what we did include in the  
22 main report with regard to that. But we didn't get  
23 many questions on that. We got more questions  
24 actually on emergency preparedness, and Dr. Allard was  
25 ideal to have at the Peach Bottom public meeting.

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1           He was very supportive of how the study  
2 was done, and he actually explained what the state  
3 procedures were. Then as we go into a discussion on  
4 spent fuel pool, and you've heard it, I think the same  
5 group heard the discussion a few weeks ago, it talked  
6 more about the specifics and the consequences for  
7 that, and that study is really going to look into that  
8 more deeply than we could ever do in this particular  
9 time period.

10           There were also comments, many comments,  
11 in fact, about the codes that we used, the MELCOR code  
12 in particular. So we were very methodical about  
13 developing a validation and benchmark table for the  
14 MELCOR code, so that we could demonstrate how and what  
15 studies and what physical tests were done that could,  
16 that looked at the different sections of that code.

17           Another question talked about battery  
18 duration assumptions and station blackouts, and again,  
19 there were questions about the MACCS code and what the  
20 MACCS code does. So we're answering all these  
21 questions. Some of them I think we got even during  
22 the peer review discussions. So we'll be wrapping  
23 that up in the next week or two.

24           We did try to have that completed for this  
25 meeting, but we were focused more on edits to the

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1 NUREGs and also to making sure we had the second  
2 appendix that will be included in the main report,  
3 which was for the peer review.

4 Slide 5 talks about the memorandum that I  
5 mentioned that we will provide to the Commission, that  
6 provides all these NUREG documents, and as I noted,  
7 they'll be three appendices included in the main  
8 report. It will be the Appendix A, which was on that  
9 Fukushima comparison.

10 Another appendix will be on the peer  
11 review comments and its final letter, and that was  
12 all provided to the subcommittee two to three weeks  
13 ago.

14 What we'll do there is basically bundle it  
15 with a cover sheet that summarizes what was done, and  
16 the meetings that were held, and attach the final peer  
17 review report as well as that comment resolution  
18 document that you received from the staff.

19 MEMBER REMPE: When is the memorandum  
20 supposed to go out?

21 MS. SANTIAGO: Okay. The memorandum and  
22 the Commission paper are due in mid-June, and so we  
23 scheduled this meeting and also a full committee  
24 meeting in -- well, the full committee is May 10th, so  
25 that we could ask for a letter.

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1                   MEMBER REMPE: Will you have updated  
2 versions of the Volume 1 and 2 for Peach Bottom and  
3 Surry by that time?

4                   MS. SANTIAGO: We're hoping to have the  
5 updated versions by the end of next week, and so edits  
6 received any time now.

7                   MR. CHANG: And we've received some edits,  
8 editorial comments from Dave Leaver. But we've been  
9 incorporating in, and like I said before, (cough) as  
10 well. So yeah.

11                   MS. SANTIAGO: And so we have another  
12 person that's also focused on completing the summary  
13 of the public comments, binning them and providing  
14 responses.

15                   In fact, had a draft available and we're  
16 working through the final answers. So by hopefully  
17 the end of next week, we'll have that available, the  
18 other third appendix.

19                   And then we'll also talk in the memorandum  
20 to the Commission about the uncertainty analysis study  
21 and the status of it, and primarily identify the plan  
22 and the parameters that we're looking at. We expect  
23 to complete the uncertainty analysis at the end of  
24 November and Tina will talk more about that and the  
25 status and where we are.

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1                   On page or Slide 6, this is the  
2                   compilation of many, many comments that we've received  
3                   from various groups, the peer review, and these are  
4                   the lists of issues that I've mentioned, some in  
5                   passing, that we've identified, and where we think  
6                   other agency projects will look at them.

7                   As you see, the spent fuel pool issues and  
8                   the multi-unit and site risk will be looked at under  
9                   the Level 3 PRA, as well as the HRA and the low power  
10                  shutdown and other modes that we discussed earlier.  
11                  There also will be a comparison to NUREG 1150. People  
12                  have asked us about comparing that. That will be done  
13                  under the Level 3 PRA.

14                  On the economic consequence/land  
15                  contamination issue, there's currently an Office of  
16                  Research Commission paper that's under development,  
17                  plus we have other upgrades that we're looking at as  
18                  far as economic consequence modeling for MACCS. That  
19                  will be done in the next six months to a year.

20                  As far as cancer incidence rates, we took  
21                  the comment and we felt that that cancer risk study  
22                  would look at that aspect as well. Additional  
23                  comparisons Fukushima, we have a DOE/NRC group  
24                  completing a forensic analysis. I don't know that  
25                  they have identified other issues as yet to look at,

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1 but the five that we chose we felt were the top five  
2 that we could at least talk about very quickly, as to  
3 why they weren't included and how they will be dealt  
4 with under other agency projects, to answer questions  
5 on that.

6 And then in one of the very first  
7 Commission papers that we prepared, we talked about  
8 developing an integrated predictive computer-based  
9 tool. But in Research we currently have various  
10 activities that are looking at that. Large seismic  
11 events and soil liquefaction, as Dr. Stevenson raised  
12 a number of times, will be looked at under the seismic  
13 research plan.

14 Then that brings us back to other plant  
15 and containment types, like the ice condenser, the  
16 Mark II's, the Mark III's, the CE and B&W.

17 CONSULTANT WALLIS: Now on this integrated  
18 predictive computer-based tool, is that something that  
19 we can foresee being electronically available to  
20 students and universities?

21 MS. SANTIAGO: Yeah.

22 CONSULTANT WALLIS: So we can ask the  
23 class to look at various accidents and pursue them  
24 when you have comments on them, and maybe you'd like  
25 what they think?

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1 MS. GIBSON: That was something, as Pat  
2 said, that we had proposed to the Commission in the  
3 very first SECY that went up, to get approval to do  
4 the SOARCA project, and that was supposed to be part  
5 of the project.

6 As I understand it, the idea was that we  
7 would have a, what they call a faster than real-time  
8 tool, that the Operations Center and Reactor Safety  
9 Team could use to predict how an accident was going to  
10 progress.

11 What we decided over the years is that  
12 that alone would have cost as much as the SOARCA  
13 project, and probably taken as long. It was  
14 prioritized low and cut from the budget.

15 So we never did that, and what we're going  
16 to say in the SECY paper to the Commission is that  
17 based on the Fukushima experience, we don't think we  
18 need to do anything more on this, because we were able  
19 to use, with computers as fast as they are, and with  
20 MELCOR and MACCS.

21 We were able, and how long the accidents  
22 take place, as SOARCA showed and Fukushima, there's  
23 plenty of time to use the existing MELCOR and MACCS  
24 tools to do any predictive calculations that we want  
25 to do, and we did in fact do that during Fukushima.

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1 So that's a long answer to your question.

2 CONSULTANT WALLIS: That's wasn't quite  
3 what I asked.

4 MS. GIBSON: Well, you asked if it was  
5 going to be available for students and universities,  
6 and the answer is no.

7 CONSULTANT WALLIS: So much of this stuff  
8 is within a very tight community like us.

9 MS. SANTIAGO: Well MACCS --

10 CONSULTANT WALLIS: No one outside it can  
11 sort of play with it, and investigate and think about  
12 it. They're very good if the educational --

13 MS. SANTIAGO: MACCS is actually used at  
14 various universities, and I don't know MELCOR.

15 MS. GIBSON: So is MELCOR.

16 MS. SANTIAGO: But I can tell you from  
17 distributing MACCS, in my particular group we do it  
18 often, and so it is well-known.

19 CONSULTANT WALLIS: There is a potential.

20 MS. GIBSON: And we had a user group, and  
21 all you have to do is join the user group, and you get  
22 MELCOR, and the only thing we ask in return is that if  
23 you find any problems with it, you let us know so we  
24 can fix it.

25 MEMBER REMPE: In light of some the

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1 results you've gotten, even though they're clearly not  
2 comprehensive, wouldn't a new advanced or revised  
3 source term be something that could be -- with more  
4 work obviously, and maybe after the Level 3 PRA is  
5 done.

6 But it just seems like the source terms  
7 are so much lower. Your state of the art has improved  
8 so much that it seems like that would be something  
9 that would be a natural progression out of something  
10 like this, or it might confuse this, or something that  
11 nobody wants to do that for any reason.

12 MS. GIBSON: There is source term work out  
13 of it. It's not as a result of SOARCA. It's a result  
14 of the latest PHEBUS test.

15 MEMBER REMPE: Yeah. It just seems like  
16 --

17 MS. GIBSON: So eventually there will be  
18 another source term, but we haven't --

19 MEMBER REMPE: Aren't we supposed to do an  
20 advanced source term every decade or something like  
21 that, to stay updated, so that the utility --

22 MS. GIBSON: And that's in the works.

23 MEMBER REMPE: It's been quite a few  
24 decades since the last one.

25 MS. GIBSON: Well, with this PHEBUS test,

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1 the final meeting and results are coming out, I think,  
2 next month.

3 MEMBER REMPE: So then at some point in  
4 the future, that would be on the docket or the agenda  
5 to do. So I don't see it in this list. So it might  
6 be something that ought to be added.

7 MR. GAUNTT: A lot of the, Joy, a lot of  
8 the ground work for revising the regulatory source  
9 term, if that's what you're talking about, has been  
10 underway for several years.

11 We've been looking at MOX fuel, high  
12 burnup fuel, and in the process kind of learned that  
13 the, you know, regular source term for non-MOX, non-  
14 high burnup is different than the, you know, last  
15 installment of NUREG 1465.

16 I don't know what the schedule is or, you  
17 know, drive or doing a rev to that, but a lot of the  
18 ground work's been done.

19 MEMBER REMPE: Just I thought I would  
20 discuss it, and I thought I'd bring it up.

21 MEMBER ARMIJO: Is there any work on your  
22 list, maybe it's buried in one of these categories on  
23 tsunami, probabilistic tsunami hazard analysis?

24 MS. GIBSON: I'm going to look at Marty  
25 and say is anything going to be done on Level 3 PRA

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1 with regard to tsunamis? I mean we generally had  
2 gotten questions from groups on --

3 (Simultaneous speaking.)

4 MEMBER ARMIJO: Yeah, we did.

5 MR. STUTZKE: I'm Marty Stutzke from the  
6 Division of Risk Analysis in the Office of Research.  
7 As far as the site Level 3 project, we will look at  
8 all the external events that screen in for the site,  
9 according to the standard, ASME standard for that.  
10 Now whether that specifically includes tsunamis or  
11 not, I think that remains to be seen.

12 MEMBER STETKAR: If you were betting,  
13 given the site they've selected --

14 MR. STUTZKE: Probably not.

15 (Laughter; simultaneous speaking.)

16 MR. STUTZKE: Now the site that's been  
17 selected is Vogtle Units 1 and 2.

18 MALE PARTICIPANT: It's a --.

19 MR. STUTZKE: It is on the river. I tried  
20 to screen it out yesterday, and my boss told me no.  
21 It's still on the table like this. But that would  
22 also include, we're going to look at upstream dam  
23 failures at the site, to see whether that's  
24 worthwhile.

25 We'll look at just large precipitation

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1 events, things like that. Of course, hurricane risk  
2 like that; probably aircraft crash, things like that.

3 MEMBER ARMIJO: But not low elevation,  
4 coastal sites?

5 MR. STUTZKE: Well, not yet.

6 (Simultaneous speaking.)

7 MR. STUTZKE: The other thing is that  
8 within the Division of Engineering over in Research,  
9 they do have a tsunami research effort underway. But  
10 I don't know. I can't tell you the standard. That's  
11 what Annie Kammerer does.

12 CHAIR SHACK: Okay.

13 MS. SANTIAGO: Thank you. On Slide 7, I'm  
14 just going to talk a little bit more about the second  
15 document, the Commission paper, which will be a  
16 notation vote. That will be going up again in mid-  
17 June as well, and that paper will describe again the  
18 objectives, and that the staff believes that the  
19 SOARCA project objectives have generally been met, and  
20 that we don't believe a SOARCA-type analysis of all  
21 eight plant types or 104, as originally was described  
22 in the original paper, and now 108 licensed reactors,  
23 is needed.

24 We believe that the SOARCA project, as we  
25 present today, provides a large body of knowledge

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1 updating the understanding of severe accident  
2 progression, mitigation and method and consequences,  
3 rather. We updated and improved the models that we  
4 use, MELCOR and MACCS.

5 MEMBER BLEY: Can I back you up to this  
6 one, not that I'm arguing for a --. But maybe  
7 somewhere, as part of the uncertainty analysis, some  
8 addressing of things that might be quite different if  
9 you were looking at different types or plants, might  
10 be real helpful for the sites.

11 MS. SANTIAGO: Okay, and one of the things  
12 that we want to conclude is the follow-on research  
13 that we'll still recommend to the Commission after  
14 this SOARCA project when we send it out, and that's  
15 Slide A. We believe that we could benefit by doing  
16 the analysis of an ice condenser.

17 That's a unique containment design. We  
18 did begin Sequoyah when we first started this project,  
19 so we believe we could gain some cost savings in time,  
20 because we did begin the decks for that particular --

21 MEMBER BLEY: I forget. How many are  
22 there, five, four?

23 MS. SANTIAGO: Ice condensers?

24 MEMBER BLEY: Yeah.

25 MS. SANTIAGO: Yeah. I think there's

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1 about --

2 MR. CHANG: No, I'm not sure -- it's under  
3 ten, I think.

4 MS. SANTIAGO: Yeah, we have a list.  
5 Yeah, it's under ten, definitely under ten.

6 MEMBER BLEY: Well, it's about to get a  
7 Part 50 license hearing. Well, not about to, but is  
8 still in the queue to get one, Watts Bar II.

9 MS. SANTIAGO: And whether we'll argue  
10 that there's still a good need to look at it because  
11 of potential hydrogen vulnerabilities during station  
12 blackouts, and we believe if we limit it to just  
13 looking at the station blackouts, that we could do it  
14 in a relatively short time frame, a year, year and a  
15 half.

16 So we also think that in some of the NTTF  
17 recommendations and discussions that we've had, that  
18 they could inform some of those recommendations and  
19 results. So that's what the staff is drafting at this  
20 point in time, to prepare.

21 I have been talking to Hossein, because we  
22 did indicate to the Committee that we would provide  
23 drafts of these documents for your review. We just  
24 need some more additional management review and  
25 possible steering committee review before we present

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1 it to you.

2 But generally we've given our steering  
3 committee and our management these recommendations.  
4 So with that --

5 MEMBER BLEY: But when you spoke of it as  
6 documents, is it like a project planned for each of  
7 these, something like that or --

8 MS. SANTIAGO: At this point in time, we  
9 would just indicate to, in this Commission paper,  
10 correct, what the recommendation is, what the resource  
11 needs would be, time lengths, and that would be  
12 basically it. And again, it would be very focused  
13 with the station blackout. With that, I think we'll  
14 turn it over to Tina, since we've -- or do we get a  
15 break? We get a break.

16 CHAIR SHACK: Thank you very much. We  
17 will break until three o'clock.

18 (Whereupon, a short recess was taken.)

19 CHAIR SHACK: Now we can come back into  
20 session. Now the moment we've all been waiting for,  
21 the uncertainty analysis.

22 (Simultaneous speaking.)

23 MS. GHOSH: Yes. My name is Tina Ghosh.  
24 I'm; with the Office of Research. This is Patrick  
25 Mattie from Sandia National Lab, who is the lead on

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1 the Sandia side, and I asked Mark to come sit with us  
2 too, because he deferred a number of issues to this  
3 session.

4 (Laughter.)

5 MS. GHOSH: We have a fourth hot seat  
6 here, so what -- I'll get into who the team members  
7 are later, but I think as is obvious to everybody,  
8 SOARCA's a very multidisciplinary project, and  
9 certainly the uncertainty analysis, we're looking at  
10 a lot of different subject matters. So we have a  
11 fairly large group of core team members who are  
12 contributing to this effort.

13 So depending on how the discussion and  
14 questions go, we may direct, you know, questions to  
15 other team members who are with us today in the  
16 audience, and also a couple on the phone bridge, in  
17 case we need them.

18 So we can go to the next slide. This is  
19 the first time we're talking to the members of the  
20 ACRS about the uncertainty analysis in particular. We  
21 are in the middle of it right now, so we don't have  
22 final results and we certainly have quite a lot more  
23 work to do.

24 But we thought it's a good time to come  
25 talk to you, because at this point, we have a set plan

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1 in terms of the approach that we're talking, the  
2 parameters that we're looking at, initial  
3 distributions that we assign, and we've gotten some  
4 very interesting preliminary insights on what kind of  
5 phenomenology is driving results in different regions.

6 We thought we could talk a little bit  
7 about that with you today. We would like to come back  
8 to you after we're further along with results, and  
9 I'll talk a little bit about that at the end. So this  
10 is kind of going to be more of a broad overview of  
11 what we're doing in the uncertainty analysis, and we  
12 certainly welcome your feedback.

13 I think you got a preview of a couple of  
14 the issues we are struggling with. One of them has to  
15 do -- a couple have to do with SRV failures, what  
16 we've assigned in terms of distributions and what  
17 we're looking at.

18 If you have insights that could help us in  
19 progressing our understanding of what we should be  
20 doing, that would be very helpful, and we'll get more  
21 specifically to that, again further in the discussion.  
22 Next slide, please.

23 MEMBER STETKAR: Tina, before you start  
24 getting into it, I was trying to read ahead here, but  
25 and I didn't see it. So I guess I'd just like to get

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1 it on the table first. Could you define for me what  
2 the term "best estimate" means?

3 MS. GHOSH: In terms of the uncertainty  
4 analysis, the best estimate is what everybody else has  
5 done, who have spoken before me. So it's what is  
6 documented in the SOARCA main report, and the detailed  
7 analysis for Peach Bottom and Surry.

8 So that was kind of the team's, you know,  
9 best effort at providing a single estimate of, you  
10 know, consequences for the scenarios that were  
11 analyzed.

12 MEMBER STETKAR: Could you define for me  
13 what that means in the context of a real uncertainty  
14 analysis? What's the mode?

15 MEMBER BLEY: Maybe I could ask it in a  
16 little simpler way. I mean many people we talk with  
17 from SAP (ph), when they come here, when they speak of  
18 best estimate analysis, it's including uncertainty.

19 This is a point estimate, and is it  
20 supposed to be something like a mean? Is it supposed  
21 to be the most likely? Is it supposed to be the thing  
22 that would happen most often? What do people think  
23 about it when they claim they were doing best  
24 estimate?

25 MS. GHOSH: Yeah, and I'll let my team

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1 members jump in after I give an initial answer, but I  
2 believe that something like the mode or the most  
3 likely outcome is what was the aim of the best  
4 estimate, and you know, certainly while the best  
5 estimate was a point estimate, there were a number of  
6 sensitivity analyses that were done for specific  
7 issues.

8 But you're right, that this is the first  
9 integrated uncertainty analysis that we're looking at.  
10 But the best estimate was an attempt to create the  
11 most likely, and if anybody else wants to --

12 CONSULTANT WALLIS: Well, in some of your  
13 graphs, you show a probabilistic, probability  
14 distribution, and the best estimate is at one end or  
15 the other. So it's clear it's not the mode.

16 MS. GHOSH: Well theoretically --

17 CONSULTANT WALLIS: What you mean is what  
18 was assumed in SOARCA. It's not the usual definition.

19 MEMBER STETKAR: And that's actually the  
20 reason for my question, because SOARCA is a public  
21 document, and the public understands the term "best  
22 estimate" as this is as good as we can do, and we  
23 would bet our lives on this. That's the way the  
24 public understands that term.

25 MEMBER ARMIJO: It's a big public, John.

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1 (Simultaneous speaking.)

2 MEMBER STETKAR: It's a big public, but I  
3 would estimate that if a bunch of technical experts  
4 came out with a document that said this is our best  
5 estimate of what will happen, the average member of  
6 the public would say they're willing to bet their  
7 lives on this.

8 MEMBER SCHULTZ: We've heard of experts  
9 from the peer review that have said some, many. The  
10 models are conservative in these areas, but which may  
11 not be the best estimate.

12 MEMBER STETKAR: That's correct.

13 MEMBER REMPE: And in fact, Karen Vierow  
14 said I think you ought to emphasize more realistic  
15 instead of best estimate, and I'm guessing she's even  
16 more familiar with it than any of us are, and so maybe  
17 she's got a point --

18 CHAIR SHACK: Yeah, you know, but I think  
19 it's more than John said. It's the context of best  
20 estimate in something where you've got very broad  
21 uncertainties. It becomes, you know, a somewhat less  
22 meaningful thing. You know, if the uncertainty was  
23 very narrow when you say "best estimate," you really  
24 do have something in mind that may represent an  
25 expert's best opinion.

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1           When you have distributions as broad as  
2 this, I don't know about any public that John knows,  
3 but you know, I doubt that very many experts would say  
4 that this is really what's going to be. But I'm a  
5 little surprised that the mode is the word that you  
6 would pick.

7           I mean every time the NRC picks a metric  
8 or something, it's almost always the mean. I could  
9 understand the median, but the mode seems the least  
10 likely of all those parameters that I'd pick.

11           MR. LEONARD: In some sense it depends on  
12 whether we're talking about a statistical reliability  
13 parameter, SRV failure rates, stochastic failure rate.  
14 Then we could argue whether mean, mode, median is  
15 appropriate. In many cases, though, we're looking at  
16 phenomenological modeling uncertainties, not really  
17 parameter uncertainty.

18           Then what mean, median, mode, how you  
19 would properly interpret that becomes a little more  
20 difficult, more challenging. When I say mode, I  
21 would say we would say it's the most likely. It means  
22 it's based on the evidence we have from available  
23 experimental data, and availability of alternative  
24 ways to model the integrated processes.

25           What's the most likely, best combination

1 of the mathematical models we have, that seems to  
2 reproduce the signatures that we've observed in the  
3 experimental data. MELCOR as a code as a whole  
4 represents that style of thinking.

5 The other alternatives are available.  
6 Users can pursue the effects of other modeling  
7 approaches. But the "best practice" principles tend  
8 to use the selected combination of models and their  
9 input parameters, that provide the best match against  
10 the experimental data we have available. In that  
11 context most likely is what we're trying to represent.

12 MEMBER STETKAR: How do you answer the  
13 possibility that we heard from the previous  
14 presentation, that the uncertainty analysis report is  
15 kind of targeted for let's say, you know, late fall of  
16 this year, that quantitative estimates that come out  
17 of that uncertainty analysis, whether they're  
18 characterized as a median or a mean or something,  
19 could be substantially different than the quantitative  
20 best estimate that comes out of something that's  
21 published now in January-February-March?

22 How would the NRC staff answer that  
23 discrepancy, let's call it, or perhaps perceived  
24 discrepancy?

25 MS. GHOSH: Okay. So I think what I can

1 tell is we've done preliminary analyses, which we'll  
2 talk about. Today, we're only going to talk  
3 qualitatively about the results. But I think we have  
4 seen enough of a range of results to know kind of  
5 where the answers are likely to come out when we do  
6 the final set of runs that are going to be documented  
7 in the fall, and I think what we can say is that we  
8 haven't seen anything that invalidates what was done  
9 in the best estimate study.

10 In terms of the general conclusions, such  
11 as, you know, the source term and the health effect  
12 results being much, much, much lower than the Sandia  
13 siting study, I mean those continue to hold true in a  
14 very wide range of conditions that we're looking at.

15 MR. MATTIE: But I just want to add  
16 something here, and I think it's important, because  
17 internally we have this discussion almost daily, and  
18 it's almost a philosophical discussion of what are you  
19 more competent in?

20 Are you more competent in a mean value  
21 that can be heavily skewed by a very high outlier  
22 result, or are you more confident in a best estimate  
23 result, and a best estimate which in part operator,  
24 experience, you know, most likely occurrences, belief  
25 on a broad range of uncertainty, of possibilities,

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1 physical possibilities, that the belief, based on  
2 operator experience or other intuitive or basis on the  
3 phenomenology, that this is the most likely event?

4 I think you actually put more value in  
5 your best estimate, regardless of where it falls in  
6 the distribution, because when you do a probabilistic  
7 analysis, most of the time what you're saying is your  
8 probability of exceeding a certain value. That's more  
9 a quantitative measure than the mean, in my opinion.

10 MEMBER BLEY: But look, most likely  
11 nothing's going to happen, okay. But something may  
12 happen, and that's what we're interested in. So that,  
13 you know, if there's something that has a ten percent  
14 chance of happening, and it's nowhere near the most  
15 likely, given that you've got an accident going on,  
16 but the consequences are much more severe, that could  
17 really be where the answer is for the risk.

18 Now Tina is saying that you haven't seen  
19 anything like that yet in the cases you're looking at,  
20 but I find that a little surprising from what other  
21 people have said about DFs and things like this going  
22 on in various scenarios.

23 MS. GHOSH: Yeah. I think when we get a  
24 little bit further into the presentation, that we show  
25 -- I'll tell you the three cases that we've run so far

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1 from MELCOR, and I'll give you examples of the results  
2 of that we're seeing.

3 So it will give you some idea of the  
4 difference in results, and these are not statistical  
5 results. We picked out a couple of individual  
6 possibilities that kind of demonstrate when different  
7 phenomena dominate. The biggest one is main steam  
8 line creep rupture versus having the early stochastic  
9 SRV failure, which prevents that.

10 So you'll get a sense for, you know, the  
11 range of results we're seeing. You know, I think the  
12 challenge with this uncertainty analysis is that, you  
13 know, unlike something like a Level 1 PRA, where we  
14 have a lot of data on component failures, we're really  
15 looking at a range of phenomena in this uncertainty.

16 Some of them we have some idea of what the  
17 possibilities could be. Other ones, we don't have as  
18 much data and information on. So I think, you know,  
19 what Pat, again what Patrick was kind of going back to  
20 is do you put more -- I think what we, one of the  
21 values of doing the study is to see what are the most  
22 influential parameters, you know. What are kind of  
23 the ranges of parameter combinations that we would  
24 worry about, in terms of giving a very different  
25 result.

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1           But in terms of putting a lot of stock on  
2 the exact results, I mean that's harder to do, just  
3 because there's so much uncertainty about even  
4 characterizing the uncertainty in some of the  
5 phenomenology that we're looking at.

6           CONSULTANT WALLIS: Like the vessel  
7 failure. I mean this morning, I thought we heard  
8 there was no analysis and no data. So how can there  
9 be epistemic uncertainty?

10          MEMBER SCHULTZ: It sounds as if you're  
11 not doing an uncertainty analysis, as I would see it.  
12 You're doing an investigation into uncertainty.

13          MS. GHOSH: I think that's fair to say.  
14 For some of the things we're looking at, I think  
15 that's fair to say. You know, it's part of this  
16 iterative process. I think for some of the  
17 parameters, initially that was it, you know. We were  
18 just looking at what effect could this parameter have,  
19 looking at a certain thing.

20          You could almost look at it as a combined  
21 sensitivity analysis. So whereas before we were  
22 perhaps looking at one issue at a time, now we're  
23 taking the great computational power that we have and  
24 looking at many, many parameters, many, many different  
25 combinations at a time.

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1           So it is almost like an investigation of  
2           the effects of the possible uncertainties, and we'll  
3           go a little bit more into that. So it's very much an  
4           iterative process. Once you figure out which are the  
5           ones that are giving you the largest effects on  
6           results, you try to go back and scrutinize what you  
7           know about that parameter more and so on.

8           CONSULTANT WALLIS: We heard about the  
9           VANESSA code, right. I'm not sure that it's possible  
10          to determine the uncertainties in the code, because  
11          I'm not sure that there's a way to do that, because  
12          you can't untangle what's in the code.

13          Also, VANESSA's an equilibrium code. So  
14          the basic uncertainty is more than the parameters that  
15          it predicts or to go into it. It's in whether it's  
16          relevant, because great phenomena may be more  
17          important. So the epistemic uncertainty is not just  
18          determined easily by parameters.

19          You may have a code like VANESSA, where  
20          you can't really figure out what determines the  
21          uncertainty in its output, and you may also have a  
22          code like VANESSA which may not be the right, modeling  
23          the right phenomena.

24          MS. GHOSH: Yeah, actually and that brings  
25          us to, I guess, what the scope and the goals of the

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1 uncertainty analysis were, which is this slide, and  
2 you know, it's carefully worded.

3 The goal of this uncertainty analysis, and  
4 I certainly hope it's not the last uncertainty  
5 analysis we ever do, because it's a very interesting  
6 area, and we still have a lot left to learn. But we  
7 wanted to --

8 MEMBER STETKAR: Excuse me, Tina. You're  
9 not going to get out of it quite this quickly yet.  
10 This is a question for the whole project.

11 MS. GHOSH: I haven't gotten out of  
12 anything.

13 (Laughter.)

14 MEMBER STETKAR: Right. You're trying to  
15 get through the things on the slide. Obviously, it's  
16 a question for the whole project. It's not just the  
17 uncertainty analysis.

18 There is a lot of benefit to doing some  
19 amount of uncertainty analysis, especially considering  
20 the fact this is a public, focused toward public  
21 information, to illustrate a level of confidence, in  
22 terms of the margins that are available.

23 In other words, we have reasonably high  
24 confidence in a lot of the stuff that we've seen.  
25 We're not going to characterize anything by a best

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1 estimate, by a number. There's uncertainties; we've  
2 examined the uncertainties.

3 We don't have enough quantitative  
4 information to be able to characterize a number with  
5 1, 2 or 12 significant figures as a mean or a median  
6 or a mode or whatever you want to call it, of a  
7 distribution.

8 But we've done a lot of -- we've looked a  
9 lot at the uncertainties, to characterize the fact  
10 that we still have confidence in the margins,  
11 confidence in the fact that what we've done gives us  
12 information to say that a lot of the earlier studies  
13 did have a lot of conservatisms in them for the  
14 following reasons.

15 I think that's a very worthwhile exercise.  
16 I think it's a very powerful communications tool, if  
17 you cast it that way. On the other hand, developing  
18 that story ten months after something that comes out  
19 with numbers on it, that are called best estimates,  
20 could be a bit of a problem, follow me.

21 So it's not necessarily a discussion  
22 specifically about what's being done or will be done  
23 in the uncertainty analysis. It's a way that the  
24 whole project characterizes the results, and what  
25 people will understand as those best estimates.

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1                   MEMBER BLEY: Can I say one more thing on  
2 this? Well, I guess am belaboring it. But I don't  
3 see anywhere in your reports where this concept is  
4 really described.

5                   I see best estimate this, best estimate  
6 that, better best estimate this, and proved best  
7 estimate that. But nothing about what that really  
8 means. I think you're very vague about it.

9                   MR. MATTIE: I've got a -- in my head, you  
10 know.

11                  MEMBER BLEY: We all know what it means,  
12 but it might be very different to all of us.

13                  MR. MATTIE: I came here with a speech,  
14 and I remember very little of it. But I will say --

15                                 (Laughter.)

16                  MR. MATTIE: --going back to the goals, I  
17 mean realistically maybe we should never compare the  
18 uncertainty study with the best estimate, because what  
19 the uncertainty study, at least in this first  
20 iteration is, what is believed to be important  
21 parameters. They've been selected.

22                                 It's not a parametric study of everything  
23 in the consequence analysis or in the Level 3. It's  
24 what we believe, based on our experience in the SOARCA  
25 best estimate, what we believe are the most

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1 influential parameters.

2 We've taken the best available data to  
3 populate those distributions. We've run it through  
4 the mill and we come and we go wow, maybe we were  
5 wrong. This doesn't really affect it, or it affects  
6 what we thought it would, or it in fact has a greater  
7 effect.

8 When we revisit those results, we then  
9 take a closer look at the data that went into it, and  
10 what's our confidence on those extreme values, if  
11 that's in fact what's driving some of the unexpected  
12 behavior or surprises, and then we look at the model  
13 assumptions and how they relate to those ranges of  
14 inputs, and then we look in fact at the ability of the  
15 code to calculate over those ranges and model  
16 assumptions, and that iterates a few times.

17 I mean we honestly would have to do that  
18 extensively, before you could come back and say  
19 exactly where your best estimate fits within that  
20 distribution. In this first iteration, all we're  
21 really getting is an indicator of how much we know  
22 about what's driving our system uncertainty.

23 That's what we're getting in this first  
24 iteration of the uncertainty, and maybe that should be  
25 explicitly stated in the uncertainty analysis, rather

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1 than a comparison or a validation of the best  
2 estimate, because it's not.

3 CONSULTANT WALLIS: How about operator  
4 actions? I mean there are quite a few operator  
5 activities involved in this scenario. Are you going  
6 to subject them to uncertainty analysis?

7 MS. GHOSH: Yeah, we know. We talked  
8 about this actually with the peer review committee,  
9 you know. Several of the members brought up the fact,  
10 and this came up earlier. So we're looking at the  
11 Peach Bottom unmitigated long-term station blackout  
12 scenario. In that unmitigated scenario, there are a  
13 handful of operator actions that are credited.

14 Yeah, so there's two -- well, a third one  
15 that had -- okay. So there's two that we are planning  
16 to look at in a separate sensitivity analysis, and the  
17 primary reason for that is that we did not have an  
18 HRA, as you know, in the SOARCA best estimate.

19 We still don't have -- we don't really  
20 have an HRA team for the uncertainty analysis either,  
21 and anyway, we want to keep with what the SOARCA best  
22 estimate did. Those two actions are manual  
23 depressurization at one hour, and taking manual  
24 control of RCIC at two hours.

25 There's -- so we want to do is a

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1 sensitivity analysis that looks at what if those two  
2 actions were taken at a different time than what is --

3 CONSULTANT WALLIS: For actions you  
4 anticipate them taking.

5 MS. GHOSH: Yes.

6 CONSULTANT WALLIS: At Chernobyl and TMI,  
7 there were some things the operators did, which were  
8 not anticipated they would do.

9 MS. GHOSH: Errors of commission, so to  
10 say, yeah.

11 CONSULTANT WALLIS: Commission. I don't  
12 know what you do about something like that.

13 MS. GHOSH: Yeah. You know, I think for  
14 the scenario that we're looking at, you know, the  
15 station blackout, there's not a whole lot working.

16 You know, the ones that are credited, we  
17 felt had pretty high reliability, because they're  
18 described very specifically in EOPs and they're  
19 practiced regularly in the training that the operators  
20 have.

21 So we felt pretty confident that those  
22 would be taken. What we thought was uncertain was the  
23 timing, the precise timing at which those actions  
24 would be taken. There is a third action, to block  
25 open the doors, I think, to prevent overheating.

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1 MR. LEONARD: Well, there's a general  
2 series of actions that sheds loads on emergency buses  
3 to extend the battery lifetime. So we're not  
4 explicitly representing the actions, but we're  
5 representing the effect of the action, in terms of a  
6 distribution of the net battery lifetime. So that set  
7 of actions, if you will, is captured indirectly, but  
8 the other two are not.

9 MS. GHOSH: Yeah. So those will be dealt  
10 with separately, rather than the integrated  
11 uncertainty analysis.

12 MEMBER SCHULTZ: And what you've described  
13 is an uncertainty study or sensitivity study to  
14 elements that are different than what's been assumed  
15 in the analysis that's being published now.

16 MS. GHOSH: Right, right. Right now  
17 there's this --

18 MEMBER SCHULTZ: And I wouldn't call that  
19 an uncertainty analysis. I hate to back up to the  
20 beginning, but --

21 MS. GHOSH: Sure, sure. This is -- all I  
22 mean to say is we didn't include those as parameters  
23 in the integrated uncertainty analysis, but we're  
24 treating those separately. In a sensitivity analysis,  
25 that will be documented in the uncertainty --.

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1 MR. LEONARD: In a sense, the best  
2 estimate characterization suffers from the absence of  
3 an uncertainty analysis ahead of time. Had the, if we  
4 did the analysis in the reverse order, then this  
5 discussion wouldn't be taking place.

6 But the prescription was to reproduce a  
7 single best estimate characterization of accident  
8 progression offsite consequences for the scenarios  
9 that survive the screening criterion. The uncertainty  
10 analysis was an effort to try to characterize the  
11 uncertainty about that best estimate after the fact.

12 That puts us in a language problem,  
13 statistically in a language problem, but as Mr.  
14 Stetkar is fond of saying, it is what it is, and  
15 that's where we are.

16 MEMBER STETKAR: Well, but when you  
17 characterize what it is, again if it were only the  
18 group of us sitting around this table, I think we  
19 pretty well understand technically what was done.

20 MR. LEONARD: That's right, yep. But you  
21 asked the question would it change?

22 MEMBER STETKAR: Huh?

23 MR. LEONARD: You asked the question would  
24 the "best estimate" change. Now that you are in the  
25 position that in an idea context you would have been

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1 in the first place. We don't know the answer to that  
2 right now.

3 MEMBER STETKAR: And therefore, as Dennis  
4 mentioned, some discussion in today's report, not the  
5 November uncertainty report, but the SOARCA report on  
6 what is meant or how to interpret those best estimates  
7 or how to try to understand what they might mean, in  
8 the context of a yet to be published uncertainty  
9 study, and I agree with Steve; it's a study of  
10 uncertainties.

11 MEMBER REMPE: And I think that discussion  
12 should talk about phenomena especially, because it is  
13 difficult to say a best estimate --

14 MR. LEONARD: It isn't, because they're  
15 not only complex in the sense I mentioned earlier, but  
16 many of them are non-linear and cumulative and  
17 dependent.

18 So it's very difficult *a priori* to decide  
19 which direction the trajectory of any of these  
20 signatures we've talked about so far today, which way  
21 they will go when you start combining uncertain  
22 parameters. That's the purpose, really, of the  
23 uncertainty assessment, is to determine that.

24 MEMBER BLEY: I guess you're right, and  
25 the thing you said earlier is really important. Our

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1 letter four years ago kind of said you ought to be  
2 looking at uncertainties from the beginning, because  
3 that puts it in the context.

4 As I looked through the two reports you  
5 have, there's a lot of discussion of uncertainty in  
6 the earlier work, and that there's been research done  
7 to address that. There's almost now words addressing  
8 the fact that there's uncertainty in the scenario  
9 selection, in all of the steps that led to the results  
10 of the SOARCA analysis.

11 Now that's the thing, I guess, that  
12 bothers me most. Eventually, I don't think that's  
13 fixed, and that's where we're headed. But enough said  
14 on that.

15 CONSULTANT WALLIS: Can I give you an  
16 example that's puzzled me, and you may want to explain  
17 something here. You're talking about thread and  
18 collar friction, the tightening up the bolts on the  
19 head, and there's a statement that says "The friction  
20 factor varies between .12 and .2." Okay. So we  
21 expect a distribution or something.

22 Then it says "The best estimate value is  
23 .09." Now does that mean the best estimate value is  
24 the value that was use din the SOARCA, or how does it  
25 get to be outside the range of possible values? How

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1 do I interpret a statement like that?

2 MR. MATTIE: That one parameter, I guess  
3 -- which one is that?

4 CONSULTANT WALLIS: It's on page 429,  
5 drywell head flange tightening, where they tighten the  
6 bolts.

7 MR. LEONARD: Everyone's pointing at me.

8 (Laughter.)

9 MR. MATTIE: In response to your question,  
10 number one is in the report, "best estimate" indicates  
11 in the uncertainty draft report that you received,  
12 when it says "indicates a best estimate value," that  
13 was the value that was used in the best estimate  
14 calculation. That's correct.

15 CONSULTANT WALLIS: I'm thinking it would  
16 be much clearer to me if you said that the data shows  
17 it goes between .12 and .2. But SOARCA used .09.

18 MR. MATTIE: Yeah, the SOARCA estimate.

19 CONSULTANT WALLIS: Because when you say  
20 "the best estimate value" --

21 (Simultaneous speaking.)

22 MS. GHOSH: Okay, thank you. Yeah.

23 CONSULTANT WALLIS: I think you have to  
24 say "the SOARCA estimate." Then we'd know what you're  
25 talking about.

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1 MR. GAUNTT: I wonder if I might just make  
2 one comment. I don't know if it will help. This is  
3 Randy Gauntt, and I've been struggling with this  
4 uncertainty phase and what does the best estimate mean  
5 myself.

6 One thing I know the best estimate means  
7 we've evolved this code and invested knowledge in it  
8 for like 30 years, and we run it on TMI and we run it  
9 on PHEBUS experiments, and we try not to set up  
10 anything unique that's only good for this best.

11 So in a way, our best practices document  
12 is our cumulative notes on how we think is the best  
13 way to run this code, given the sum total of all the  
14 assessment work that we've done. That's what really  
15 brought us to the SOARCA study, is that after 30 years  
16 of work and assessment, is our best estimate.

17 And now we're challenged here with putting  
18 uncertainty distributions on this, and wondering well  
19 what should our cumulative knowledge that led us to  
20 this SOARCA platform, is that going to land on the  
21 mode or the median, or what does it mean in terms of  
22 the distribution?

23 So I guess I just wanted to make the point  
24 that we came up with best estimate based on 30 years  
25 of cumulative knowledge invested in the code, and now

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1 at this point we're struggling with what is  
2 uncertainty. I don't know if that helps but --

3 MR. LEONARD: Well it does, in the sense  
4 that I think the issues or the examples that Tina will  
5 eventually get to, you'll see that the topics that we  
6 tend to see as controlling are ones where the  
7 parameters are being varied are boundary conditions  
8 from outside the code, not parameters that reflect  
9 models inside the code.

10 CONSULTANT WALLIS: Change the term "best  
11 estimate" to "SOARCA estimate." Then we'd know what  
12 you're talking about, because it's very disconcerting  
13 to see a best estimate which is outside the allowable  
14 distribution. If you say "SOARCA estimate," then we  
15 could say "Aha. They wanted to be conservative, so  
16 they overestimated or something."

17 MEMBER BLEY: And Randy's comments are  
18 very reasonable, but you picked a term that means many  
19 things in the outside world. Generally, it's not  
20 that.

21 CHAIR SHACK: Tina.

22 MS. GHOSH: Okay. Getting back the goals  
23 of this uncertainty analysis, we wanted to develop  
24 insight into the overall sensitivity of the SOARCA  
25 results to uncertainty and inputs, in the existing

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1 SOARCA model. So I want to say that up front. We  
2 wanted to use the existing SOARCA models; we weren't  
3 looking at alternate models.

4 So using the existing models, we wanted to  
5 see well, what are the most influential input  
6 parameters for both the releases and consequences.  
7 And because we expect that we're going to be doing a  
8 lot more of this type of uncertainty analysis in the  
9 future on severe accidents, we wanted to demonstrate,  
10 you know, how one could go about doing an uncertainty  
11 analysis.

12 If we go to the next slide, as I mentioned  
13 the focus is on parameter uncertainty. There was a  
14 lot of discussion this morning on issues surrounding  
15 model uncertainty, which is an issue that's very near  
16 and dear to my heart. I spent some time developing a  
17 doctoral thesis, and as an intern with ACNW back when  
18 Mike was on the ACNW looking into that.

19 But for this uncertainty analysis, the  
20 extent to which we address model uncertainty, as Mark  
21 mentioned, is really where that is captured in the  
22 parameters, in the existing model parameters for  
23 MELCOR, and beyond that, we're not looking at  
24 alternate models for different phenomena.

25 And as we already mentioned, we're using

1 the Peach Bottom unmitigated long-term station  
2 blackout kind of as a first step, because we had to  
3 scope this uncertainty analysis. Fukushima happened,  
4 you know, after we had already -- after we were well  
5 into the SOARCA project, and after we had started the  
6 uncertainty analysis.

7 We did not change our scenario definition  
8 based on Fukushima, and I think Randy already talked  
9 a lot about that, like the RCIC run time and so on.  
10 So we kept it to our existing Peach Bottom long-term  
11 station blackout.

12 What we're planning in the uncertainty  
13 report is a separate qualitative discussion that talks  
14 about comparison with Fukushima. But we didn't change  
15 our scenarios to reflect what we saw at Fukushima.

16 MEMBER BLEY: Don't go on yet. Your  
17 second bullet is one that I was kind of hanging on as  
18 I tried to read the report, and I've been through it,  
19 but not in detail enough to feel comfortable. Model  
20 uncertainty is addressed only to the extent that some  
21 parameters, that's the thing that hit me.

22 Everything in here fiddling with  
23 parameters and what they could change, and you know,  
24 when we have a presentation on a new experiment that  
25 sometimes give us surprising results, there's

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1 different chemical processes than people expected.

2 Are you picking up -- it wasn't clear to  
3 me, because that's not what I do much of. Are you  
4 able to pick up those different possibilities and  
5 processes that might be going on strictly through the  
6 parameter uncertainty range? It would seem they have  
7 to be groups of parameters that would affect a whole  
8 process --

9 MR. LEONARD: Let me give one example,  
10 perhaps, to make it more concrete.

11 MEMBER BLEY: Yes.

12 MR. LEONARD: It was mentioned earlier  
13 about the speciation of either iodine or cesium or  
14 both. Certainly since siting study work was done,  
15 even early calculations with MELCOR, the insights from  
16 PHEBUS have caused us to change our understanding of  
17 the dominant form of the aerosol that cesium is  
18 transported.

19 In the past MELCOR, and before that  
20 earlier code calculations represented it as a  
21 hydroxide. The PHEBUS work now suggests that it forms  
22 a molybdate as the dominant transport form. That's  
23 not absolutely certain. The integrated effects of the  
24 PHEBUS experiments suggests that's the trend.

25 But if you do the small individual pellet

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1 release experiments, hydroxide still is, meaning  
2 evidence from other experiments. We can't completely  
3 eliminate the possibility that it could be an  
4 alternate form.

5 The competition between the two is a  
6 detailed chemical process that is not represented in  
7 either a deterministic way within MELCOR, but it is a  
8 true modeling uncertainty, in terms of what are the  
9 governing phenomenon that determine the proper  
10 speciation of both cesium and iodine.

11 MEMBER BLEY: And this change --

12 (Simultaneous speaking.)

13 MR. LEONARD: So how do you address that  
14 global modeling issue? The way in which we've tried  
15 to capture it here is to simply pre-populate the  
16 chemical species that MELCOR releases from the fuel  
17 and transports downstream into different chemical  
18 groups, pre-reacted chemical groups. How much of it  
19 is released as hydroxide, how much of it is released  
20 as a molybdate or other forms?

21 And so we do that in a discrete form. We  
22 have five different species, combinations of primarily  
23 iodine and cesium that can be transported.

24 Each of them has a relative probability,  
25 and so the modeling uncertainty associated with the

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1 chemical reactions that create those is not properly  
2 captured as a model uncertainty, but we represent the  
3 effects as parameter.

4 That is, a pre-populated concentration of  
5 those individual groups, and we randomly select from  
6 those different groups.

7 MEMBER BLEY: That makes sense to me.  
8 When I read this, it wasn't clear that -- it wasn't  
9 clear to me that picking those different populations  
10 and distributions was accomplishing, was at least  
11 trying to be a substitute for doing --

12 MR. LEONARD: A more comprehensive  
13 modeling.

14 MEMBER BLEY: The modeling. What we're  
15 really after here is a model uncertainty, and we're  
16 reflecting that through these selections. Does it say  
17 that in here? I might have --

18 MR. LEONARD: It might not say it as  
19 clearly as it should.

20 MEMBER BLEY: It wasn't clear to me. So  
21 I was saying gee, I haven't picked up any of the  
22 process stuff that's important, but I saw the  
23 possibility that you were doing that. I just couldn't  
24 tell.

25 MR. LEONARD: Yes.

1 MS. GHOSH: Right. Yeah, I appreciate the  
2 comment. We're still working on improving the  
3 documentation. You know, we're frantically both doing  
4 analyses and working on the documentation, and what we  
5 gave you is a snapshot in time, and we're certainly  
6 working on improving that as we continue our analyses  
7 and parallels.

8 So we'll revisit that, and make sure that  
9 we've captured some of that --

10 CONSULTANT WALLIS: Well, you can do that  
11 if you have data for the population, how you populate  
12 these various things. You have to use PHEBUS or  
13 something.

14 MR. LEONARD: Yes.

15 CONSULTANT WALLIS: And in the case when  
16 you used VANESSA, you don't have that. It's all model  
17 uncertainty.

18 MR. LEONARD: And the ex-vessel releases  
19 at the moment are not on the list. I'm trying to  
20 think. I have to check to be sure, but I don't  
21 believe that we're varying anything in terms of the  
22 ex-vessel contribution of the source term is not part  
23 of the list of uncertain parameters.

24 MS. GHOSH: Okay. So the focus of the  
25 uncertainty analysis is the state of knowledge

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1 uncertainty, the epistemic uncertainty and input  
2 parameters. We just want to point out the aleatory  
3 uncertainty due to weather will continue to be handled  
4 in the same way that it was for the SOARCA best  
5 estimate study.

6           Whether uncertainty is modeled in the best  
7 estimate, that's the one uncertainty that explicitly  
8 is modeled, and we continue to handle it in the same  
9 way in the uncertainty analysis. So as you know, we  
10 have the MELCOR portion, the MELCOR code to model the  
11 releases, and MACCS to take it to the final  
12 consequences, and we're looking at the uncertainty and  
13 the key model inputs for both of those codes.

14           MEMBER BLEY: I mean this one does it  
15 again. The focus is on uncertainty and input  
16 parameters, but it's not really what drove you. It  
17 was, I don't think. I think it was trying to pick up  
18 some of these modeling uncertainties and using that as  
19 a surrogate for it. I hope I'm right. If I'm not,  
20 then --

21           (Simultaneous speaking.)

22           MR. LEONARD: Randy can probably speak to  
23 this better, but in some ways that's natural to  
24 MELCOR. You know, the nature of MELCOR trying to  
25 calculate everything under the sun means that

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1 compromises have to be made to model detail, and some  
2 of the models are more parametric than others, and  
3 those parameters represent a combination of governing  
4 phenomena that lie behind them. So there's a range  
5 that is probably reasonable to pursue.

6 That's the connection between modeling and  
7 parametric uncertainty. Rather than, for example,  
8 what is the SRV stochastic failure rate as a number.  
9 I mean that's not what we're talking about.

10 MEMBER BLEY: I think your analysis would  
11 be more convincing if it told that story.

12 MR. LEONARD: Okay.

13 MEMBER SCHULTZ: And if you describe those  
14 things, and if you also describe in the description of  
15 what is being done, what is not being done, because  
16 you've described it nicely here. But that needs to be  
17 documented.

18 It has to be documented, so that the  
19 reader understands right from the first section of the  
20 documentation, this is what we are doing, this is what  
21 we are not doing, and why we're doing the first part  
22 and why we're not doing the second.

23 MS. GHOSH: Okay.

24 MEMBER REMPE: So phenomenological  
25 uncertainties that you're not capturing should be

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1 identified.

2 MR. LEONARD: That's right, and I mean Dr.  
3 Wallace has already pointed out since we've heard the  
4 ex-vessel contributions have some effect, I mean it's  
5 a model within MELCOR that we do not have parameters  
6 to vary. I mean it's a deeply-seated model within the  
7 code, that there's not a tool that we can use to  
8 manipulate it that looks at these phenomenological  
9 uncertainties. So it's not on the list.

10 CONSULTANT WALLIS: Do you look for  
11 strange numbers? I mean on Figure 4.1.1, there's a  
12 SRV closure estimate of 10 to the 7th demands before  
13 failure? Does that sound reasonable?

14 MR. LEONARD: No.

15 CONSULTANT WALLIS: 10 to the 7th, or  
16 maybe I misread the figure. Ten million demands for  
17 -- I would cut this probability thing off somewhere.

18 MR. MATTIE: Well let's -- we can address  
19 that. I mean but that directly comes out of the  
20 NUREG/CR information that we have, the distribution  
21 that we use, right. And I know many of you are  
22 familiar with that distribution and it's some form of  
23 Bayesian update and you fill in the gaps, you know.

24 So it's very sparse data. The idea is  
25 that you'll never get there, because the thermal

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1 failure happens well before that. So it wasn't a  
2 concern at that point.

3 CONSULTANT WALLIS: It doesn't matter.

4 MR. MATTIE: And I just -- there was  
5 something that was said earlier, and I apologize if  
6 maybe I'm out of order here, but I don't want to get  
7 in a situation where we promise something we don't  
8 deliver, because if you try to document everything you  
9 don't include, it could be an extensive documentation.

10 I'd rather say that we'll make a point of  
11 documenting that the analysis, the effects can only  
12 measure what we did include in the uncertainty. You  
13 can't measure a parameter you didn't make uncertain in  
14 the uncertainty analysis. It's constant. You know,  
15 you don't see any effect of it because it's constant  
16 value.

17 MEMBER BLEY: Even if you can't model it,  
18 if there's something that you know could be important,  
19 leaving that out, just leaving it out, I think,  
20 creates a misimpression.

21 MR. MATTIE: Where we could identify, and  
22 I think we have made in the past, especially in the  
23 conversations in the peer review, we tried to identify  
24 areas that we felt, we believe could be important, but  
25 we just had no basis for any distribution or to, you

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1 know, data to make it uncertain.

2 MEMBER BLEY: That's not everything.  
3 That's something you thought could be important. It  
4 deserves a spot, even if you can't quantify it.

5 MEMBER STETKAR: That's what I was getting  
6 to.

7 MR. MATTIE: But otherwise, we did try to  
8 include everywhere at the first cut we thought was  
9 important, based on subject matter expert input, and  
10 in some cases use uniform distributions, because we  
11 just don't know, to see if it actually has an effect  
12 in the analysis.

13 You know, I should get into the analysis  
14 results. That comes out. But I just want to make  
15 sure that --

16 MEMBER SCHULTZ: I've been really meaning  
17 to say that you want your documentation to be such  
18 that you don't leave the reader with the expectation  
19 that you've done everything, and then they can poke  
20 holes in the documentation or in the study, because  
21 you didn't describe why the entire spectrum wasn't  
22 included.

23 MEMBER REMPE: For example, you have in  
24 your main report, you concluded improved  
25 phenomenological modeling for things such as reactor

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1 pressure, vessel failure and molten core concrete  
2 interactions. Yet different failure modes weren't  
3 considered in the uncertainty analysis, ex-vessel  
4 phenomena uncertainties weren't considered, right?

5 MR. LEONARD: Ex-vessel fission product  
6 release was not considered uncertain, but lateral  
7 debris mobility was. It is treated as an uncertainty.

8 MEMBER REMPE: And that's the only or the  
9 key driving uncertainty you think with respect to ex-  
10 vessel phenomena, such as molten core-concrete  
11 interaction? There's not other types of phenomena  
12 that you might be wanting to consider?

13 MR. LEONARD: The comment's well-taken, in  
14 terms of how we would provide some, the reader some  
15 caution, that this is not necessarily comprehensive.  
16 That's fair. We'll find someone to do that.

17 MS. GHOSH: You're talking about -- you're  
18 talking about the main report?

19 MEMBER REMPE: Well, it's giving the  
20 reader one perspective, and then if they read the  
21 uncertainty analysis, they may think well they have  
22 taken -- and everyone has limitations to their work.  
23 I'm not trying to be too picky here, but I just think  
24 some acknowledgment of it is needed.

25 CONSULTANT WALLIS: It's very good to try

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1 to study the uncertainties you can characterize, and  
2 it's very valuable. But you have to say that there's  
3 some that you didn't characterize.

4 MR. LEONARD: In agreement.

5 MS. GHOSH: Okay. So this slide starts to  
6 describe basically how are we going about the  
7 uncertainty analysis. We've identified key uncertain  
8 input parameters. Not all uncertain input parameters,  
9 because you know as we've been discussing, certainly  
10 there are a lot of possibilities. But in expert  
11 judgment, what were considered to be the key ones in  
12 the model.

13 Then we propagate the uncertainty in two  
14 steps using Monte Carlo technique, get us to a set of  
15 source terms from the MELCOR code, and then we feed  
16 those in the MACCS code, and the MACCS code uses those  
17 source terms, along with the uncertain samples for the  
18 MACCS parameters to spit out, in this case up to 300  
19 code runs, which we call realizations.

20 So if I say "realization," it's  
21 essentially, you know, one code run, the output of one  
22 code run, and we're looking for basically what is the  
23 influence on the outcome. If we go to the next slide.

24 MEMBER REMPE: Out of curiosity, like how  
25 long does a typical uncertainty analysis take speaking

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1 in time, versus a single MELCOR for a similar case?

2 I mean is it --

3 MR. MATTIE: The same amount of time.

4 MEMBER REMPE: You can do the analysis in  
5 the same amount of the time as the point estimate?

6 MS. GHOSH: We have Sandia's resources.

7 MR. MATTIE: Roughly. We have about 300  
8 computers available, and that's what we do.

9 MEMBER REMPE: Okay.

10 (Laughter.)

11 MR. MATTIE: I will say, though, that --  
12 and again, I apologize for maybe being out of order  
13 here, but the machine time is the least of your time  
14 on these types of analyses. It's the actual close --  
15 you know, you're processing, you're evaluating.

16 You run your statistical measures, and  
17 we'll get into it in this presentation, on  
18 systematically, you know, going through the volume of  
19 data.

20 MS. GHOSH: Yeah, but we're essentially  
21 people-limited, in terms of how many people and how  
22 much time, rather than computational resources.

23 MEMBER REMPE: Okay.

24 MEMBER SCHULTZ: It's not out of order and  
25 it's not different.

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1 MS. GHOSH: The results we're planning to  
2 include in the final report are the cesium and iodine  
3 releases over time, the distribution of latent cancer  
4 fatality risk, and using the three dose threshold  
5 models, the LNT and the other two threshold models  
6 that were used in the main SOARCA study.

7 Really the crux of this is we want to be  
8 able to identify, out of the parameters that we've  
9 looked at, what are the most influential parameters to  
10 the outcomes and kind of why. So get at the  
11 phenomenological insights and what are the most  
12 important things that we can drive the results in  
13 different directions.

14 The tools we use are standard statistical  
15 regression-based methods, as well as scatter plots and  
16 looking at individual utilizations of interest to get  
17 phenomenological insights.

18 I think Jeff mentioned we -- as Jeff Gabor  
19 mentioned, we did solicit guidance from the SOARCA  
20 peer reviewers. The uncertainty analysis was outside  
21 of the scope of the SOARCA peer review committee, but  
22 we did present the initial approach and plan, and  
23 requested a guidance document from them.

24 We were lucky enough to be able to go back  
25 to them with an updated plan of the parameter choices

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1 and distributions, and kind of had a teleconference  
2 with them on how we had addressed their comments on  
3 what they had seen so far.

4 MR. MATTIE: They provided an extensive  
5 list of comments that we addressed, and quite frankly  
6 improved the analysis because of it.

7 MS. GHOSH: Yeah, and in the final report,  
8 we'll have an appendix that has the peer review  
9 reports, as well as the staff on responses to the --

10 CONSULTANT WALLIS: Your final conclusion,  
11 what will it look like? I mean SOARCA now says the  
12 very low, let's say it says no one will die. Let's  
13 say it says that. It seems to say that, but so what?

14 Your final report, because of all these  
15 broad distributions, is going to come out with a  
16 distribution that, you know, so much probability of  
17 100 people dying, all of this stuff, and it's going to  
18 look very different in terms of public impact, isn't  
19 it?

20 MS. GHOSH: You know, based on our  
21 preliminary insights, while we are going to get a  
22 distribution, we're still not getting anywhere close  
23 to, for example, essentially zero early fatality risk.

24 Even if the latent cancer risks are higher  
25 for cases like main steam line creep rupture, they're

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1 higher and, you know, in quantitative terms, could be  
2 quite a bit higher. But in absolute terms, we're  
3 still talking very low risk.

4 CONSULTANT WALLIS: But it doesn't change  
5 the conclusions?

6 MS. GHOSH: No, absolutely not.

7 MEMBER RYAN: Tina, could you just back up  
8 one second to the other slide. You mentioned the  
9 three dose threshold miles. Could you talk a bit more  
10 about that?

11 MS. GHOSH: Yeah. I believe maybe on June  
12 2010, the committee was briefed on this. We're doing  
13 LNT of course, because that is our regulatory basis,  
14 and then the other two we call, for short we call U.S.  
15 background, which is actually the average background  
16 and medical dose, which is set at 600 and some  
17 millirems per year.

18 So anything under 620 we disregard until  
19 you get above that threshold, and then the third model  
20 we call for short the Health Physics Society model,  
21 which is if you get five rem in any one year or ten  
22 rem over a lifetime, if you don't get anything above  
23 that, then we disregard those doses. We only  
24 calculate the risk once you get past that threshold.

25 MEMBER RYAN: What risk models are you

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1 using? Are you using linear, sublinear, threshold,  
2 for the cancer part of risk?

3 MS. GHOSH: Yeah. So we're going to  
4 eventually exercise all three of those models for our  
5 results. To date, we only have LNT results for one of  
6 the cases so far.

7 MEMBER RYAN: Right. But you are? That's  
8 kind of a future step?

9 MS. GHOSH: Yes, yes.

10 MEMBER RYAN: Thank you.

11 MS. GHOSH: And you know, we had some  
12 debate about whether to combine that health dose model  
13 uncertainty -- not uncertainty, but choice with the  
14 integrated uncertainty analysis, and the decision was  
15 that that's really mixing apples with oranges. So  
16 we're keeping that separate from the integrated  
17 uncertainty analysis.

18 MEMBER RYAN: You're talking about almost  
19 a deterministic decision to put it this way or that  
20 way.

21 MS. GHOSH: Yeah.

22 MEMBER RYAN: So it's probably good that  
23 you separated it.

24 MR. MATTIE: Initially, we had it  
25 included. That was a peer review input that we

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1 decided to go with, because we agreed.

2 MS. GHOSH: Yeah, it doesn't make -- yeah.  
3 So we took that out.

4 MEMBER RYAN: Thank you.

5 MS. GHOSH: Okay. So this is just a  
6 conceptual, a cartoon really of what kind of results  
7 are we getting. On the left side you have what was  
8 done for the best estimate.

9 You can see that for the MACCS portion,  
10 the weather was included as part of -- the weather  
11 uncertainty was included as part of the calculations,  
12 and what we report is in essence the mean consequence  
13 from, you know, all of the different possibilities  
14 from the weather bins. What we're adding --

15 MEMBER BLEY: Can I ask even about that.  
16 I mean (cough) in the consequence assessment was  
17 really the weather over the data set we got, which is  
18 not all that big over the range of what might possibly  
19 happen. How many years are in that data set?

20 MS. GHOSH: Oh, the weather, yeah.

21 MEMBER BLEY: Twenty years, thirty years,  
22 something like that?

23 MS. GHOSH: No. This issue comes up a  
24 lot.

25 MEMBER BLEY: It does, but if you're going

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1 to do uncertainty, maybe you ought to consider that we  
2 could be outside that range. Every year, we get some  
3 new weather that's outside the range. So if one looks  
4 more broadly, you don't have the data, but at least  
5 you can, from anecdotal reports and records, see  
6 where, whether weather's done in the past and at least  
7 make comments on how it might.

8 MS. GHOSH: Yeah. What's typical in MACCS  
9 applications, you use a full year of weather data.

10 MEMBER BLEY: It's one year.

11 MS. GHOSH: One year, and you make enough  
12 weather bins --

13 MEMBER BLEY: I forgot. I thought it was  
14 more than that.

15 MS. GHOSH: No, one year, and you make  
16 enough weather bins to have a statistically  
17 significant representation of all the different  
18 combinations of, you know, of what you could see, and  
19 Nate can elaborate.

20 But based on past studies, if you choose  
21 one year versus another, and you know, from the early  
22 SAMA analyses that were submitted for license  
23 renewal, the staff had asked them, had requests for  
24 additional information, asking, you know, what's the  
25 difference if you use one year versus another?

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1                   And it turns out that it doesn't make a  
2 huge difference whether you use -- which year of data  
3 you use, as long as you use a complete data set that  
4 has all the seasons and so on.

5                   MEMBER STETKAR: Tina, suppose you use 50  
6 years and looked at the variability over that 50-year  
7 data set, not Year 1 versus Year 2?

8                   CONSULTANT WALLIS: That's right. That  
9 varies a lot.

10                  MR. BIXLER: I would say -- this is Nate  
11 Bixler from Sandia Labs and the PI for WINMACCS,  
12 MACCS-2 development. Statistically, how many years of  
13 weather data you would want or need depends on what  
14 kind of statistic you're looking at out of the  
15 results.

16                  If you're looking at mean results, what we  
17 found is that they depend about ten percent above or  
18 ten percent below a typical value, depending on which  
19 year of data you use. So a range of plus or minus ten  
20 percent. If you were looking at a 95th or 99th  
21 percentile result, then of course it's going to matter  
22 more which year's worth of data you're looking at.

23                  So since we in the SOARCA analysis we  
24 focused on mean results, it wasn't particularly result  
25 which result we were -- which year of data we were

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1 looking at.

2 MS. GHOSH: So the graphs on the right now  
3 show the contribution of the uncertainty analysis.  
4 Now you get a family of curves rather than one curve,  
5 and the spread of curves gives you some indication of  
6 the contribution of the epistemic uncertainty to the  
7 problem.

8 So we go to the next slide. I just wanted  
9 to quickly list who we have on the team, because I'm  
10 next going to go into kind of our process for choosing  
11 the uncertain parameters and the distributions, and we  
12 relied a lot on expert judgment.

13 So just so you know who those experts were  
14 on the team, one of them is sitting right next to me.  
15 We had several people who have a lot of experience  
16 with MELCOR, and just on severe accidents in general.  
17 I won't read all the names. Randy Gauntt you already  
18 heard from this morning. Mark Leonard, sitting next  
19 to me and there are others from Sandia.

20 Ed Fuller, who more recently joined us,  
21 our group here at the NRC. Similarly for MACCS, we  
22 have folks who have been working with the MACCS code  
23 and consequence analysis for many, many years. You  
24 have uncertainty analysis methodology folks like  
25 Patrick and myself, and for the health effects

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1 modeling portion, and in particular the latent health  
2 effects, because that is what drives the risk.

3 As I said, even with all our variations,  
4 we haven't seen any early fatalities. We had some  
5 help from Keith Eckerman at Oak Ridge National  
6 Laboratory, who had co-authored Federal Guidance  
7 Report 13, which has an uncertainty approach for  
8 health effects modeling in there, which he helped us  
9 implement for the SOARCA, both for the SOARCA main  
10 study as well as for the uncertainty analysis.

11 So the next slide. As I said, we relied  
12 heavily on our experts to come up with what should be  
13 these key input parameters that we're looking at, and  
14 to come up with distributions for them.

15 Our approach was based on a formalized  
16 process, but we didn't actually employ a formal FERC  
17 process, and you know, the experts were informed not  
18 just by their general knowledge of all the  
19 experimental data that's out there and their years of  
20 working with MELCOR and MACCS, but also a lot of the  
21 work that had been done specifically for SOARCA.

22 So for example, we had preliminary  
23 insights from the sensitivity studies, looking at  
24 single issue for SOARCA and so on. So all of this  
25 knowledge was brought to bear on coming up with kind

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1 of a list of parameters.

2 Then we also shared that list with  
3 certainly our SOARCA peer review committee, but also  
4 with other folks at Sandia and NRC outside of the  
5 project, who have expertise in these areas. So to get  
6 kind of a check on are we capturing important things.  
7 And if we go to the next slide --

8 MEMBER STETKAR: Tina, before you leave  
9 this, the last bullet says it's based on the  
10 formalized PIRT process, but you said you didn't  
11 really do that.

12 MS. GHOSH: Yeah.

13 MEMBER STETKAR: What you're doing is an  
14 expert elicitation process, and indeed the agency has  
15 written, you know, a reasonable amount of guidance on  
16 how to do that. I'm curious why you didn't follow  
17 that approach. It's a little bit different than PIRT.

18 MEMBER BLEY: Or at least some of the  
19 structured part, to control biases and make sure  
20 you're getting all the information on the table. Now  
21 maybe you did some of that, but when you just say it  
22 was informal and what you just said. Again, you're  
23 not doing that.

24 There's a lot of sources of bias, even  
25 with the best experts, that if you don't control that

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1 and force people to think beyond the place they start,  
2 you lose a lot of confidence in what comes out of such  
3 a thing. So if you can tell us any more about what  
4 you did and how you did it, it would be helpful.

5 MS. GHOSH: Yeah. I think, you know, to  
6 some extent, the uncertainty experts worked hand in  
7 hand with the subject matter experts, to kind of draw  
8 out those issues, to kind of refine, in particular you  
9 know, the distributions.

10 But because a lot of this we're doing for  
11 the first time, in terms of the scope of what we're  
12 looking at, and you know, recognizing that our scope  
13 doesn't include everything, but it actually includes  
14 quite a lot that we're looking at, and we'll get to  
15 that a little bit later, about 23 independent MELCOR  
16 parameters, the first iteration is almost an  
17 investigation into, you know, what could be the  
18 possible effects of the uncertainties and the precise  
19 distributions.

20 For a lot of them, we didn't have a lot of  
21 data to go on. So at this stage, you know, so I say  
22 it's an informal PIRT process. You could call it also  
23 informal expert elicitation. I think the types of  
24 things that are prescribed to do in a formal process  
25 we did, but much more informally, and perhaps not

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1 documented in a way that you would for a formal  
2 process.

3 But I think the kinds of thought processes  
4 you're thinking of, I mean we tried to get at. So for  
5 example, after Fukushima happened, you know, we  
6 certainly revisited what we were looking at, and even  
7 though we weren't changing our scenario based on  
8 Fukushima, you know, just trying to come up with  
9 hazardous accident provided insights that we should  
10 now be looking at other things.

11 In fact, we added the head flange  
12 parameters after the Fukushima accident. So we had  
13 some group discussions to go through these, you know,  
14 thought processes. But it wasn't formal. It was more  
15 informal.

16 MR. MATTIE: I just want to say two things  
17 to that, and one is that there's a lot in that bullet,  
18 you know. On one hand we say we didn't follow a  
19 formalized PIRT, and it goes back an earlier question  
20 about we didn't include everything. We know we  
21 didn't.

22 And then the second part is, I don't want  
23 to under-value the effort that we actually did put  
24 into the parameter selection and distributions. In  
25 terms of at least the uncertainty team, the entire

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1 uncertainty team has been through an expert  
2 elicitation in a formalized PIRT process many, you  
3 know, several times at least before most of us.

4 So we used that process, although not  
5 documented. That's the key here. We didn't document  
6 the process, which is what you would really do in a  
7 PIRT, you know. Part of it is the transparency and  
8 the confidence-building and the distributions and the  
9 full evaluation.

10 Many in most, if not all, though I can't  
11 speak for all of them, the subject matter experts have  
12 also been through formal expert elicitation and PIRT  
13 processes, and they employed those techniques when  
14 choosing what they believed to be most important  
15 parameters and their distributions and technical  
16 basis.

17 And thirdly, we socialized this, and  
18 that's a slight understatement, with the peer review  
19 panel, and got extensive comments back, which we then,  
20 to our best ability, addressed and I believe we  
21 addressed them all to their satisfaction. We had a  
22 resolution meeting in January of this year, in terms  
23 of those parameters.

24 And I said thirdly and lastly, but in  
25 reality there's one more item. The last item is that

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1 the consequence analysis in WINMACCS especially and  
2 MACCS-2 was developed as a probabilistic code to  
3 handle uncertainty, and has quite an extensive  
4 technical basis for the distributions that we're using  
5 in that analysis.

6 So the majority of our expert elicitation  
7 processes focused on the MELCOR side more than the  
8 MACCS side. So there's a fairly robust, although not  
9 extensive treatment of uncertainty, not a complete  
10 treatment. That's what the PIRT-like process but not  
11 a PIRT involves.

12 MS. GHOSH: And if we go to the next  
13 slide, you know, we tried to focus on confirming that  
14 the parameters representations we came up with  
15 appropriately reflect the key sources of uncertainty,  
16 and that we have a reasonable and defensible technical  
17 basis for them.

18 So in that Chapter 4, the draft Chapter 4  
19 that we shared with the Committee before this meeting,  
20 is our attempt to capture all the thinking that went  
21 into, you know, why we think the parameter is  
22 important, and you know, basis for the distribution  
23 with references and so on.

24 So that's kind of where we tried to  
25 summarize and capture, you know, the thinking that

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1 went into the parameters. If you go to the next  
2 slide, and just an overall philosophical point.  
3 Again, there are many more parameters than the ones  
4 that we included in this uncertainty study.

5 But the attempt was to obtain contribution  
6 from uncertainty across the spectrum of phenomena if  
7 you look at different stages of accident progression,  
8 and get kind of balanced depth and breadth of  
9 coverage, rather than digging very deeply into one  
10 area and neglecting another area.

11 And same as the second bullet. Yeah,  
12 that's okay. We can go ahead to the next slide.

13 MEMBER ADBEL-KHALIK: With regard to the  
14 sequence issue, the SRV stochastic failure rate, do  
15 you plan to or have you looked at the opposite problem  
16 of set point drift? It is certainly not unheard-of  
17 for plants to send their SRVs for as-found testing  
18 after each outage, and most, if not all SRVs would  
19 fail the plus or minus three percent acceptance  
20 criteria.

21 If you look at the opposite problem, I  
22 assume that the consequences would be more severe.

23 MR. LEONARD: For example, if the drift  
24 were upward.

25 MEMBER ADBEL-KHALIK: It's always upward

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1 when I mean that failing the same point.

2 MR. LEONARD: It moves -- first of all,  
3 the absolute value at which, the pressure at which the  
4 valve lifts is not the issue. It's whether it opens  
5 and stays open or not.

6 So if it drifts upward a few, even a few  
7 tens of psi by the time it opens, then it's not going  
8 to affect the accident progression. And if the lead  
9 SRV is the one that drifts --

10 MEMBER ADBEL-KHALIK: If you know that for  
11 sure.

12 MR. LEONARD: Yes, in the sense that we  
13 see the effect of --

14 MEMBER ADBEL-KHALIK: That a ten percent  
15 set point drift.

16 (Simultaneous speaking.)

17 MR. LEONARD: I can say yes in the sense  
18 that as you see the effect of drift in representative,  
19 even in long-term station blackout calculations, where  
20 because the delta P that is the basis for whether the  
21 valve opens is reactor system pressure to drywell, not  
22 to the environment, over a long-term blackout the  
23 drywell containment pressure begins to slowly  
24 increase.

25 That increase in the base pressure can be

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1 observed at the set point, the absolute value of the  
2 reactor vessel pressure at which the relief valve  
3 actually lifts.

4 So if you were to watch the cycles in  
5 pressure, over time they actually begin to drift  
6 upward. Not because of anything in the set point  
7 drift, but because the base pressure is affected.

8 MEMBER ADBEL-KHALIK: Right. But my  
9 concern is the actual set point drift due to corrosion  
10 bonding of the valves.

11 MR. LEONARD: If the lead SRV set point  
12 were to drift upward beyond the set point for the next  
13 SRV, the other one simply picks up and moves.

14 MEMBER ADBEL-KHALIK: But if all of them  
15 drift high, have you looked at the LERs for plants  
16 that send their SRVs for testing?

17 MR. LEONARD: The effect of drifting all  
18 the SRVs upward no, has not been examined.

19 MEMBER ADBEL-KHALIK: Actually, I've  
20 looked at the LER database.

21 MR. LEONARD: I'm just struggling to  
22 understand how even a few tens of psi upward drift  
23 would affect the accident progression itself.  
24 Certainly, it would affect the signature, in the sense  
25 that the absolute value of pressure at which the lift

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1 would occur changes.

2 But if it's still going to cycle  
3 approximately at the same range, and if the rest of  
4 the events in terms of the controlling phenomena are  
5 unaffected, I'm just trying to think what effect would  
6 a -- instead of increasing it from 2250 it goes to  
7 2270.

8 MEMBER ADBEL-KHALIK: It would likely be  
9 a lot higher than 1270. We're talking about a BWR  
10 SRV.

11 MR. MATTIE: It could be a qualitative  
12 answer to that if you know what your, you know, a ten  
13 percent of 20 percent set point drift and you look at  
14 the pressure curve on, let's say, an SRV stochastic  
15 failure that has, you know, not occurred.

16 I mean what kind of temperatures would we  
17 have to get before we get something else occur, like  
18 a thermal failure or a creep failure. You could  
19 qualitatively say at what point does the drift not  
20 matter?

21 MR. LEONARD: Well, except for the first  
22 few minutes, only one valve cycles anyway. So you  
23 would have to drift all 13 for it to significantly  
24 adversely affect the pressure history. Eventually, it  
25 would get to whatever the lowest one would be.

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1 MEMBER ADBEL-KHALIK: I mean it is not  
2 unheard-of that most, if not all SRVs --

3 MR. LEONARD: Would drift upwards.

4 MEMBER ADBEL-KHALIK: For a plant would  
5 drift up beyond the plus three percent acceptance  
6 criteria.

7 MR. LEONARD: Okay.

8 MS. GHOSH: I guess we'll look into that  
9 further. This slide lists the MELCOR zirc parameters.  
10 I want to point out that some of the bullets actually  
11 contain multiple parameters. I think we're looking at  
12 23 independent parameters all together, and the  
13 italicized headings are sort of the categories or the  
14 phase of the accident progression that we're  
15 considering.

16 So we have sequence issue, the battery  
17 duration, the SRV stochastic failure rate, and when  
18 stochastic failure happens, whether when it happens,  
19 may or may not bring into play if SRVs is going to  
20 thermally seize open instead. If the SRV thermally  
21 seizes open, then we also sample an open area fraction  
22 for the SRV.

23 We have in-vessel accident progression  
24 parameters. I don't need to read all of them. We  
25 list them here. There's ex-vessel accident

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1 progression parameters and that's the debris lateral  
2 relocation time constants. Then we have some  
3 containment and building behavior parameters.

4 CONSULTANT WALLIS: Where does vessel  
5 failure fit into this?

6 MS. GHOSH: Sorry?

7 CONSULTANT WALLIS: Where does the failure  
8 of the vessel fit into this? I see things happening  
9 inside and outside, but I don't see a vessel failure  
10 somewhere in here.

11 MR. MATTIE: Well, I would say Randy could  
12 probably better answer that. But the fuel failure  
13 criterion, the zircaloy melt breakout temperature, you  
14 know, anything in-vessel, is effectively going to  
15 control the timing the timing that the core drops into  
16 the lower head.

17 CONSULTANT WALLIS: It takes some time to  
18 fill the vessel.

19 MR. MATTIE: It does take some time, yes.

20 CONSULTANT WALLIS: So how do you  
21 represent that?

22 MS. GHOSH: That's modeled.

23 MALE PARTICIPANT: How do you represent --

24 CONSULTANT WALLIS: Well, that's not in  
25 the list here.

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1 MR. LEONARD: As you mentioned earlier,  
2 that you know, we've had several comments in the past  
3 about the absence of either penetration failure.  
4 Right now we're representing global creep rupture of  
5 the lower head as the failure mechanism. That's  
6 what's calculated, and either the initial opening size  
7 that Joy had mentioned earlier, or the possibility of  
8 penetration failure --

9 CONSULTANT WALLIS: What do you use for  
10 your uncertain parameter in terms of this creep  
11 failure? What's your uncertain parameter that you're  
12 going to put in your code, to characterize how long it  
13 takes to fail?

14 MR. LEONARD: The Larson-Miller parameter  
15 is the parameter in this case, but it is not on the  
16 list of the uncertain variables that we're sampling.

17 CONSULTANT WALLIS: How do you put it into  
18 your analysis? How do you put vessel failure into the  
19 uncertainty analysis?

20 MR. LEONARD: The criteria for lower head  
21 failure as a particular phenomenon is not sampled as  
22 an uncertainty.

23 CONSULTANT WALLIS: It has to happen in  
24 order for this whole thing to --

25 MR. LEONARD: We could sample from a

1 distribution of the Larson-Miller parameter, and have  
2 chosen not to, and the rationale for it --

3 MEMBER REMPE: Or the temperatures,  
4 because you've got to have a life fraction rule.  
5 There's a lot of things that go into it.

6 MR. LEONARD: That's right. We considered  
7 it in the early selection list, and it fell to the  
8 second tier, primarily because when we watched the  
9 behavior of the creep model, we raised from a damage  
10 index of zero to a damage index of one so quickly that  
11 --

12 CONSULTANT WALLIS: In the vessel.

13 MR. LEONARD: On the lower head.

14 MEMBER REMPE: That's due to other things  
15 associated with the melt core progression, that you  
16 wait until the dryout has occurred before you start to  
17 heat up.

18 MR. LEONARD: Exactly right. So but given  
19 that as a generic boundary condition, a  
20 phenomenological boundary condition to the way the  
21 accident progression takes place, that the thermal  
22 challenge to the lower head does not occur until all  
23 the water is evaporated, and the debris begins to  
24 slowly heat up, with that signature as part of the  
25 damage progression.

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1 CONSULTANT WALLIS: Will slowly heat up?

2 MR. LEONARD: Yes.

3 CONSULTANT WALLIS: So how hot does it  
4 have to get before it does anything?

5 MR. LEONARD: That's where roughly the  
6 melting point of stainless steel comes in. The debris  
7 temperature reaches approximately 1,700 K at the time  
8 we typically see creep rupture occur in the vessel at  
9 low pressure.

10 MEMBER REMPE: You could, I mean you said  
11 you have a stated area that you're assuming, and you  
12 could take that area and bury it to accommodate a  
13 penetration failure up to whatever that area is,  
14 something like that.

15 MR. LEONARD: That's right.

16 MEMBER REMPE: But there's some things  
17 that could be done. Timing if it was a penetration  
18 would occur a lot earlier probably than what you're  
19 doing with vessel failure. Again, with the expert  
20 elicitation theme that wasn't important. I guess it  
21 doesn't matter, but I guess I'm not sure I would have  
22 come to the same conclusion.

23 It seems like some of your peer reviewers  
24 did say that it was important parameter.

25 MR. LEONARD: Yeah. We had comments

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1 several times about penetration, and there are a  
2 couple of ways, at least two ways that could be  
3 accommodated. They're in the area as a distribution,  
4 but using the creep criterion is the trigger for  
5 actually invoking failure.

6 I mean we could put those two things  
7 together and perhaps come up with a way that at least  
8 influenced the debris drain rate to the containment,  
9 and right now there's nothing that influences that.  
10 That's true.

11 CONSULTANT WALLIS: So it happens very  
12 quickly. It's sudden, an all or nothing thing? I  
13 mean I just think TMI got a blister in its vessel, but  
14 it didn't fail.

15 MR. LEONARD: Right.

16 CONSULTANT WALLIS: So something stopped  
17 it from failing.

18 MR. LEONARD: Right.

19 CONSULTANT WALLIS: And you don't seem to  
20 have anything in here like that. It has to get hot  
21 enough for long enough for something to happen.

22 MR. GAUNTT: Maybe I can add a few words  
23 to that. Randy Gauntt, and I guess our understanding  
24 of TMI, we don't have a mechanistic explanation for  
25 why the head didn't fail, but there was always water

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1 down in the head. However it happened, it was  
2 coolable.

3 When we take that forward to modeling in  
4 the BWR, we have found the 1(d) dryout criteria for  
5 debris to be unrealistically aggressive, and kind of  
6 taking our cue from TMI, there was water in the lower  
7 head of TMI. That was coolable. We steer the code  
8 such that you essentially have to dry out the lower  
9 head before it begins to really threaten the lower  
10 head.

11 I think also in this calculation, it's  
12 going to be at low pressure by the time you get to  
13 relocation. So in fact it's not even a creep  
14 analysis. What you'll see is node by node, starting  
15 from the inside. You're basically melting your way  
16 through the vessel until there's no strength left. So  
17 it's not really a --

18 CONSULTANT WALLIS: That sounds good. So  
19 why don't you -- can't you model that and figure out  
20 how long it takes and put some uncertainty on it?

21 MR. GAUNTT: We would do that. We would  
22 --

23 CONSULTANT WALLIS: It seems to me an  
24 important phenomenon in this whole scenario.

25 MR. LEONARD: What Randy just described is

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1 modeled and is calculated. That's the baseline  
2 approach to the model.

3 CONSULTANT WALLIS: It should be some line  
4 here which says something about progression of failure  
5 of lower vessel or something.

6 MR. LEONARD: What we're saying, though,  
7 is the reason it's not on this list is the parameters  
8 that govern that model are not treated as uncertain  
9 variables.

10 CONSULTANT WALLIS: Just use a number.  
11 You don't vary it at all. There's no uncertainty  
12 about when the vessel fails.

13 MR. LEONARD: In this case, there's no  
14 uncertainty about the parameters that calculate when  
15 the lower head fails, that's true.

16 MR. GAUNTT: Our knob on that, were we to  
17 put it in, I think would be some kind of heat transfer  
18 coefficient from the debris to the head.

19 MEMBER REMPE: Like a gap.

20 MR. GAUNTT: Would be --

21 MEMBER REMPE: That's been observed in  
22 some of the --

23 (Simultaneous speaking.)

24 MR. GAUNTT: Gap resistance or something,  
25 and I'm not sure, but don't we just fail a whole ring

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1 when we --

2 MR. LEONARD: It fails on a ring by ring  
3 basis.

4 MR. GAUNTT: Fails on a ring by ring  
5 basis. So the area turns out to be the --

6 MR. LEONARD: Effective area of the ring.

7 MR. GAUNTT: Area of the ring, yeah.

8 MR. LEONARD: It's reasonably a good  
9 start.

10 MR. GAUNTT: It's a big failure.

11 MR. LEONARD: It's noted. I mean both the  
12 comment from the peer review as well as what we've  
13 heard today, that some means of capturing the effect  
14 of smaller, slower drain -- smaller hold, slower drain  
15 rates --

16 MEMBER REMPE: The earlier --

17 (Simultaneous speaking.)

18 MR. LEONARD: We'll have to consider how  
19 we'll do that. This surface coefficient between  
20 debris in the lower head is already a parameter that  
21 we have some control over. It's the way in which we  
22 ensure that the lower head dries out before you begin  
23 to thermally attack the vessel. I mean that's one of  
24 the parameters that controls that. Okay.

25 MS. GHOSH: Okay, and then we have fission

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1 product release transfer and deposition parameters.  
2 So go to the next slide. There are about 20  
3 independent uncertain parameters in the MACCS portion,  
4 but there's actually hundreds of individual  
5 parameters, because a lot of these are large groups of  
6 parameters. For example, a lot of the latent health  
7 effects parameters, there's a lot of them. They're  
8 radionuclide-specific.

9 But here again, we tried to look at all of  
10 the different areas that MACCS models. So the  
11 atmospheric transfer and deposition, the emergency  
12 planning and response, as well as the health effects.

13 MEMBER RYAN: Just a quick question, Tina,  
14 on the cancer mortality risk coefficient. Are you  
15 correcting for cancers cured versus cancers developed?  
16 What is the cancer mortality risk coefficient telling  
17 me?

18 MS. GHOSH: Yes. What is it telling you?

19 MEMBER RYAN: Yeah. What does it do? How  
20 do you define it?

21 MR. MATTIE: Defer that one to Nate.

22 MS. GHOSH: How deadly?

23 MR. BIXLER: The cancer risk coefficient  
24 is just giving a dose to an organ, which the risk of  
25 getting a fatal cancer from that dose to the organ.

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1 MEMBER RYAN: Oh, I see, and it's one of  
2 the several things you kind of --

3 (Simultaneous speaking.)

4 MEMBER RYAN: Sorry. I misunderstood the  
5 topic. Thank you.

6 MS. GHOSH: I am going to actually skip  
7 the next couple of slides, because Mark talked  
8 extensively about SRVs, and we're going to come back  
9 to some, you know, initial insights that we're seeing.

10 We can go to Slide 17. We don't need to  
11 spend a lot of time on this either. This is more just  
12 a cartoon of the phenomenology that the parameters  
13 that we're varying is meant to capture.

14 In essence, they're time at temperature  
15 models for different phenomena, and you know, the  
16 parameters are uncertain. But they're meant to  
17 capture the uncertainties in the melt progression  
18 stages.

19 So if we go now to Slide 18, okay. This  
20 is another example. Mark talked a little bit about  
21 this before. Based on the PHEBUS program findings,  
22 you know, cesium, there's a lot of cesium molybdate  
23 was observed, whereas traditionally cesium hydroxide  
24 is the species that was assumed in past analyses.

25 So we've created five bins, which we show

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1 on the next slide, and the reason they're important is  
2 for example, the vapor pressure varies, depending on  
3 which species that the cesium is in.

4 So we're looking at alternate speciation  
5 for both iodine and cesium, and we based the fractions  
6 for the bins that you'll see on the next slide on the  
7 different PHEBUS tests that are now available, that  
8 weren't all available at the time the main SOARCA  
9 study was completed.

10 So if we go to the next slide, you see  
11 what our combinations are. I know the writing is kind  
12 of small, but I believe you have hard copies in front  
13 of you. Combination 5 is what we are taking as most  
14 likely -- of all of the cesium and cesium molybdate,  
15 and a small fraction of gaseous iodine. But most of  
16 the iodine is still in the cesium iodide form.

17 And for the other bins, we have alternate  
18 samplings for cesium hydroxide in different fractions  
19 of gaseous iodine, though still small. So the  
20 cesium, I think in essence it's less than ten percent  
21 as cesium iodide. So the mass balance is retained,  
22 and what's left over, over 90 percent of the cesium is  
23 split according to these fractions into either all  
24 cesium hydroxide, all cesium molybdate or a portion of  
25 both.

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1                   CONSULTANT WALLIS: You have extraordinary  
2 precision in combinations under 3.

3                   MALE PARTICIPANT: Four and five.

4                   MS. GHOSH: Yes. These were based on the  
5 PHEBUS experiments. But you're right, that we  
6 shouldn't convey false precision, because of course  
7 there's a lot of uncertainty around these fractions.  
8 That's our interpretation of what PHEBUS is telling us  
9 about --

10                   (Simultaneous speaking.)

11                   MS. GHOSH: Yeah, right. Okay. All  
12 right, next slide. You know, before I get into  
13 discussing the preliminary analyses we've done and  
14 what we're seeing, I want to stress again, and we said  
15 this a couple of times, that uncertainty analysis is  
16 an iterative process.

17                   You know, we've learned some things with  
18 the first couple of iterations, and you know, we're  
19 revisiting the things that you see in the bottom box,  
20 which says "iterate." We want to make sure that we're  
21 within the range of validity of what MELCOR is  
22 modeling, that the analysis stable.

23                   And then one of the early issues we  
24 identified is that we think we're actually looking at  
25 two different scenarios, which is whether or not MSL

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1 creep rupture happens, and that really changes, you  
2 know, the outcome. And then just checking, you know,  
3 whether we've uncovered any bugs or modeling errors.

4 So we're in the midst of this iterative  
5 process, and what I'm going to go through is just give  
6 you a status of, you know, what we've done so far and  
7 give you some examples of interesting insights that  
8 we're getting, and then kind of end with where we're  
9 going.

10 So the next slide. The preliminary MELCOR  
11 analyses we've done so far, we've done three cases.  
12 So the first case, which we'll call the combined  
13 scenario, uses all of the distributions as they're  
14 laid out in Chapter 4 of what we gave you from our  
15 draft report.

16 And what we found with that is that, you  
17 know, both SRV stochastic and SRV thermal failure  
18 parameters were varied, and Mark mentioned that, you  
19 know, the stochastic failure rate database is perhaps  
20 modeling a different situation than we are expecting  
21 to occur in the long-term station blackout scenario,  
22 and that that stochastic failure rate, actually most  
23 of it lies to the left of, you know, the SOARCA best  
24 estimate value that was used.

25 In that first case that we did, we ended

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1 seeing that an SRV thermal failure actually happens  
2 most of the time, and as we were sampling that thermal  
3 failure open area as a first cut, we said okay, it's  
4 just uniform from zero to one.

5 But we ended up observing a lot of main  
6 steam line creep failures when we have mostly SRV  
7 thermal failures happening, and we're varying that  
8 open area anywhere from almost fully closed all the  
9 way to fully open.

10 So as a second -- and then we thought, you  
11 know, we're really modeling two scenarios here. The  
12 best estimate scenario was that we have a relatively  
13 early stochastic SRV failure. In this UA case now,  
14 we're modeling main steam line creep rupture. It's  
15 really a different scenario than what we did for the  
16 best estimate.

17 So the second case we did, kind of as a  
18 sensitivity, we had the thought well let's keep the  
19 SRV thermal seizure open area fixed at one, which is  
20 fully open, to see what -- we're not going to get as  
21 much main steam line creep rupture, to see what we get  
22 there.

23 Then the third case, we fixed the SRV  
24 stochastic failure rate to be the same as we had in  
25 the SOARCA main study, to kind of look at the

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1           uncertainty around, you know, what may be closest to  
2           the SOARCA main study.

3                       Then a quick note. We haven't done as  
4           much analyses with the MACCS so far. But what we did  
5           so far is we used the source terms from that first  
6           case, from the combined scenario case using the LNT  
7           model, and treating both the aleatory and epistemic  
8           uncertainty, as I mentioned before.

9                       So if we go to the next slide. This is a  
10          very high level broad-brush kind of qualitative  
11          description of summarizing, you know, what we've seen  
12          so far. So the cesium release timings are very  
13          similar to the SOARCA --

14                      CONSULTANT WALLIS: Excuse me. These are  
15          based on some kind of Monte Carlo sampling, are they?

16                      MS. GHOSH: Yes.

17                      CONSULTANT WALLIS: So how many runs did  
18          you do?

19                      MS. GHOSH: For each one, we attempted  
20          300.

21                      CONSULTANT WALLIS: 300 runs.

22                      MS. GHOSH: Yeah. So we had three cases  
23          of 300 each. In every case, we had a handful of  
24          either failed runs or MELCOR runs that were going to  
25          take so long that we didn't want to wait for them.

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1 But there are quite a few runs that we've done at this  
2 point.

3 So the time, the cesium release timing is  
4 important, and the reason I'm concentrating on cesium  
5 is because that is the dominant radionuclide for long-  
6 term health effects, which is pretty much the only  
7 health effects that we're seeing. So we focused a lot  
8 on cesium.

9 The magnitude of release at 48 hours is  
10 generally slightly higher than we saw in the best  
11 estimate, and again, this is because we were seeing a  
12 lot more main steam line creep rupture cases. But  
13 it's still far, far, far below the siting study  
14 results, just to give you some context.

15 CONSULTANT WALLIS: You say the magnitude.  
16 You mean the mean release, or what do you mean by  
17 that, magnitude of the release?

18 MS. GHOSH: Yeah. Well, you can pick your  
19 figure of merit in any of them. Mean, median, 95th  
20 percentile.

21 CONSULTANT WALLIS: All of them. All the  
22 choices are generally higher than the SOARCA estimate.

23 MS. GHOSH: Right, right.

24 MR. LEONARD: If you remember back to the  
25 table that I presented this morning on the SRV topic,

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1 where we had one case that went to main steam line  
2 creep rupture, if you look at the release fractions at  
3 48 hours for that case, it was a factor of eight or  
4 ten higher.

5 That's what we're really referring to  
6 here, is that number. So it's consistent with the  
7 early sensitivities in that sense.

8 MR. MATTIE: In that case, there's the  
9 distribution results, many of which look like the one  
10 that Mark just described, the main steam line creep  
11 rupture that was presented in that SOARCA best  
12 estimate as an alternative sensitivity. Many that  
13 look like thermal SRV, and a handful that look like  
14 stochastic SRV.

15 MS. GHOSH: For the MACCS results, again,  
16 we only did the first combined case so far, but  
17 essentially the distribution of risk results for  
18 latent cancer fatality risk looks similar to the best  
19 estimate, and the early fatality risk is still  
20 essentially zero.

21 So if we go to the next slide, we are  
22 getting interesting phenomenological insights from  
23 now, you know, kind of looking at all the results and  
24 kind of unraveling what's driving what, when and so  
25 on, and we can confirm a lot of the phenomenology that

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1 we had already seen in the SOARCA, the main SOARCA  
2 study.

3 And as I mentioned before, nothing that  
4 invalidates what was done in the SOARCA main study.  
5 In particular, there's a strong dependence between the  
6 number of SRV cycles before failure to reclose, and  
7 the probability of thermal SRV failure and/or main  
8 steam line creep rupture.

9 And you know, Mark had already shown this  
10 with the sensitivity analyses that he had done, that's  
11 documented in the Peach Bottom report. We see that  
12 there's a dependence between the area fraction of the  
13 SRV thermal failure and the current MSL creep rupture,  
14 again something that we had already seen in the  
15 sensitivity analyses, and then the chimney effect when  
16 the railroad doors fail open is also observed.

17 CONSULTANT WALLIS: This is where you had  
18 to modify MELCOR to put in another halfway or  
19 something? Because the chimney effect isn't modeled  
20 in MELCOR.

21 MR. LEONARD: This is, the chimney effect  
22 is referring to a flow path through the reactor  
23 building after the containment fails. In this case,  
24 the railroad doors are the main equipment access doors  
25 at grade level in the building, which I don't believe

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1 is on the diagram we showed earlier today.

2 But because the release path from  
3 containment enters the building at a low elevation,  
4 the residence time and attenuation of any released  
5 aerosol within the building depends a lot upon the  
6 extent to which there's an air flow through the  
7 building.

8 So if the building remains bottled up and  
9 only opens by the blowout panels at the top of the  
10 building, there's still enough circulation and  
11 residence time in the building that attenuation is  
12 reasonably good. I mean a DF of two or three is  
13 better than zero, better than one.

14 What we find more often, though, is that  
15 the hydrogen deflagrations that occur early create a  
16 differential pressure that blow those doors open. The  
17 question is when that happens, and they're enormous  
18 doors, because they're double-hinged doors designed to  
19 allow a railroad car to enter the building.

20 So the question is when they fail, what  
21 kind of effective area do you have, and there are two  
22 doors in parallel, with a chamber between them. So  
23 this parameter is trying to take into account  
24 uncertainty on the effective flow area through those  
25 doors to the environment, which creates the inlet air

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1 flow that drives that chimney flow up to the upper  
2 elevation of the building, and completely destroys the  
3 residence time.

4 So a large area in principle shortens the  
5 residence time in aerosols --

6 CONSULTANT WALLIS: The chimney is modeled  
7 without modifying MELCOR?

8 MR. LEONARD: That's right. I mean the  
9 buoyancy from the low elevation to the top is part of  
10 the natural calculation. That's right.

11 MEMBER ARMIJO: Wouldn't that be an easy  
12 thing to spot from the Fukushima events, whether the  
13 doors were blown open or not? They're accessible.

14 MR. LEONARD: Again, the damaging hydrogen  
15 combustion at Fukushima was high, not low, and so the  
16 destruction of the building is primarily you see at  
17 the top.

18 MEMBER ARMIJO: But not in Unit 4. The  
19 bottom of that building was blown out.

20 MR. LEONARD: That's right, that's right,  
21 that's right. So the effects, the qualitative of the  
22 effects are similar to what we see in these cases,  
23 where the building walls remain intact because they're  
24 concrete at that lower elevation, and the doors open.

25 I mean doors to everything. The railroad

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1 doors, the doors to the stairwells, all of those, and  
2 each one of those doorways in the building is  
3 explicitly modeled in the MELCOR model, with a known  
4 differential pressure that has to be generated for  
5 them to open.

6 So it changes the flow paths, plural,  
7 through the building when that happens. The most  
8 important one is whether you get this inflow of air at  
9 grade level that allows you to create the chimney  
10 effect through the equipment hatch that passes through  
11 all elevations of the building.

12 That's why it seems to show up. It's a  
13 little surprising that it was as important as it is,  
14 but there's an explanation for it.

15 MR. MATTIE: That bullet doesn't rank its  
16 importance. It's just it was noted as important.

17 MS. GHOSH: So the next slide, Slide 25,  
18 this is just a quick snapshot, again, of analyses in  
19 progress, of what our step-wise rank regression is  
20 showing as important for both the iodine and cesium  
21 releases at 48 hours.

22 The step, the rank correlation coefficient  
23 is just a very rough, rough, rough measure of how much  
24 of the variation in output can be explained by  
25 different input parameters that we're varying.

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1           The SRV open area fraction for thermal  
2 seizure, not surprisingly, shows up as very important,  
3 because that is a controlling feature of whether or  
4 not you have MSL creep rupture.

5           CONSULTANT WALLIS: Well isn't it likely  
6 to be fully open?

7           MS. GHOSH: Yeah, and we need -- this is  
8 one of the issues that we are revisiting now, and  
9 actually we want to have some discussion with the  
10 Committee on, because we are coming back to that. In  
11 fact, we talked a little bit already about it earlier  
12 today.

13          MR. MATTIE: In this particular analysis,  
14 it's uniform between zero and one.

15          CONSULTANT WALLIS: That's not likely.

16          MS. GHOSH: And that's why it's an  
17 iterative process. As our first cut, we had assigned  
18 a uniform distribution, but now that we're seeing so  
19 much main steam line creep rupture, we are revisiting  
20 what that distribution should truly be.

21          MEMBER STETKAR: Tina, way back when we  
22 were talking about, you know, expert elicitation or a  
23 PIRT process, was that uniform distribution the result  
24 of your polling experts on how valves work?

25          MS. GHOSH: You know, for some of the

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1 parameters, again because we knew this was going to be  
2 an iterative process of the first cut, we assigned  
3 uniform distributions, you know, between the bounds  
4 that we thought were likely and you know, with the  
5 thought that depending on --

6 MEMBER STETKAR: Well, let me stop you  
7 there. Did you do that for everything?

8 MR. MATTIE: Can I answer this?

9 MEMBER STETKAR: As sort of the baseline  
10 state of knowledge?

11 MR. MATTIE: We did not have an expert  
12 elicitation for this particular parameter. We used  
13 the subject matter experts in MELCOR modeling, and  
14 because we didn't have an expert elicitation, we could  
15 only go from zero to one, because we didn't have any  
16 basis for doing something different.

17 MEMBER STETKAR: Well, let me then go.  
18 Does that mean that except for the MELCOR modeling,  
19 everything else is characterized by a uniform  
20 distribution between zero and one?

21 MS. GHOSH: To answer your question, no.  
22 So there are two issues. There's one, you know, what  
23 the bound should be and then what should the shape be  
24 within those bounds. So for some of the parameters,  
25 it was felt that we had enough information that we

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1 thought there was some likely value.

2 So we, for example, a triangular  
3 distribution is what we used, kind of I think for  
4 several of the parameters, because we felt that  
5 there's more confidence that we knew what would be a  
6 more likely value, and that while we recognize that  
7 there's uncertainty around that value, we think that  
8 it's more likely.

9 So we picked a mode and then have a  
10 triangular distribution around it. For some of the  
11 parameters, as a first cut, we assigned the uniform  
12 distributions for, you know, the bounds that came up.  
13 And another example we'll talk about a little bit  
14 later. So this is one of them, the open area fraction  
15 for the thermal seizure area was one of them.

16 Another one was the drywell liner failure  
17 area. Just as a first cut, we assigned a uniform  
18 distribution. We initially did not think it would be  
19 that important. So just to, you know, to throw it  
20 into the mix in the combined uncertainty analysis,  
21 initially we assigned a uniform distribution, to see,  
22 you know, whether it makes a difference and under what  
23 conditions and so on.

24 MR. MATTIE: I want to kind of go back to  
25 that. We first started with the subject matter

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1 experts in the different models, MELCOR and MACCS, and  
2 they identified the parameters and the modeling areas  
3 they thought were important.

4 The next step was to go in and take the  
5 available technical basis of the data that was  
6 available, that was at least available to the best of  
7 their knowledge, and define distributions.

8 In some cases, it was well-defined. In  
9 many cases for MACCS, there was extensive expert  
10 elicitation that had been done previously. There was  
11 a number of studies --

12 CHAIR SHACK: That's probably Corradini.

13 MR. MATTIE: Is that cutting me off?

14 (Phone ringing.)

15 CHAIR SHACK: Mike, is that you?

16 MEMBER ARMIJO: I guess not.

17 MEMBER CORRADINI: Yes, this is me.

18 CHAIR SHACK: Oh. It's a little slow in  
19 the take-up.

20 MEMBER CORRADINI: Sorry.

21 MR. MATTIE: Okay. We're on the  
22 uncertainty analysis.

23 MEMBER CORRADINI: That's okay.

24 MR. MATTIE: Slide 25. Okay, just to  
25 finish that comment, though, and then where we didn't

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1 have or knowledge of the sufficient technical basis,  
2 we proposed distribution values to evaluate.

3 At that point, we went through the peer  
4 review, which greatly improved many of them, and in  
5 other areas, we agreed that we didn't know or didn't  
6 have a technical basis to do anything different, and  
7 evaluated at that point whether we believed that it  
8 was sufficient for the first iteration or the  
9 iteration of this uncertainty study.

10 One of the parameters that demonstrates  
11 that is the open area fraction on thermal-failed SRV.

12 CONSULTANT WALLIS: So the railroad door  
13 open area is a uniform distribution?

14 MR. MATTIE: Again, yes.

15 CONSULTANT WALLIS: It is?

16 MR. MATTIE: Yes. Another area which we  
17 looked --

18 MS. GHOSH: Yeah. There's two, and in  
19 fact --

20 CONSULTANT WALLIS: It's likely that  
21 they'll blow open a crack.

22 MR. MATTIE: Well, what's interesting is  
23 that --

24 (Laughter.)

25 MALE PARTICIPANT: It's got bad hinges or

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1 something.

2 MS. GHOSH: We don't go zero to one,  
3 though. The bounds are not zero to one. They're less  
4 than that, and also we're sampling the inner door area  
5 as well as the outer door area, and there's a set of--

6 MR. MATTIE: There's two doors, but  
7 there's -- I don't want to steal all of the Tina's  
8 thunder, but we were working on this for several  
9 months, and it's always exciting to share your  
10 results. But for instance in that parameter, we found  
11 that it wasn't actually the open area fraction that  
12 was important. It was whether they're open or closed.

13 Just the fact that you have that chimney  
14 effect is the dominant effect. It doesn't really  
15 matter how big the opening is, as long as you get some  
16 positive flow through there. In this case, the  
17 distributions sufficiently tell us what we need to  
18 know.

19 But for SRV open area fraction when we  
20 have a thermal failure SRV, we find that it is  
21 extremely sensitive. Tina will get to that, and we  
22 need to revisit that because of its importance, that  
23 you know, the basis for that distribution is probably  
24 not sufficient.

25 MEMBER BLEY: It's not a throttle valve.

1 It's like a gate valve. When it's ten percent open,  
2 there's still flow. So it's not surprising that you  
3 found that.

4 MR. MATTIE: Fair enough.

5 MEMBER BLEY: I'm not very surprised.

6 MR. MATTIE: Fair enough.

7 MS. GHOSH: So the chemical form I'll talk  
8 about too. SRV stochastic failure rate we already  
9 discussed, and then it turns out the dynamic  
10 agglomeration and shape factors also shows up as  
11 important. We talk a little bit about that later.

12 So Slide 26. Now here we have a scatter  
13 plot to show what is the influence of essentially the  
14 SRV stochastic failure rate, you know, as the  
15 distributions that are laid out in the Chapter 4 that  
16 you all have, on whether or not SRV thermal failure  
17 happens, and then SRV thermal failure with main steam  
18 line creep rupture.

19 I think, as you can see from this case,  
20 almost all of the time in this first case, you're  
21 getting SRV thermal failure. It's only for the very  
22 high sample values of the stochastic failure rate,  
23 where you have SRV stochastic failure.

24 CONSULTANT WALLIS: I don't understand the  
25 axis here. It says "influence of number of cycles,"

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1 and I see 10 to the minus 4. That's not a cycle.

2 MS. GHOSH: Oh yeah. The cycle, right.  
3 It's a one over. So the number of cycles is one over  
4 the failure rate.

5 MR. LEONARD: This is failure rate.

6 CONSULTANT WALLIS: So you're talking  
7 about a million cycles at the bottom end?

8 MS. GHOSH: At the bottom end?

9 MR. MATTIE: Yes.

10 MS. GHOSH: Yes. At the very lower end,  
11 yes.

12 MR. MATTIE: That's what that means.

13 MS. GHOSH: Right. So 270 was the best  
14 estimate value, and as you can see, right now we're  
15 taking this lambda distribution from the NUREG/CR  
16 report that Mark mentioned, and the best estimate  
17 value is fairly high on this distribution of failure  
18 rate.

19 It's one of the issues we're struggling  
20 with, that you know, we have this sense that this  
21 failure rate distribution isn't completely  
22 representative of the situation that we're modeling in  
23 the long-term station blackout, but then what else do  
24 we use to come up with a distribution for this?

25 CONSULTANT WALLIS: So this tail is

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1 extrapolated in some way. We shouldn't take the tail  
2 seriously, should we, down in the bottom left-hand  
3 corner?

4 MR. LEONARD: This is a beta distribution.

5 MEMBER STETKAR: It's a beta distribution.

6 CONSULTANT WALLIS: Extrapolated to  
7 infinity.

8 MR. LEONARD: Well, it's a beta -- there's  
9 a non-informative prior, and then they updated it with  
10 two failures --

11 (Simultaneous speaking.)

12 MR. LEONARD: Tina made the right comment  
13 here though. You can see that any failure rate less  
14 than 10 to the minus 3 certainly always leads to  
15 thermal failure first. So the precise number is not  
16 important. It doesn't matter. Where we were in the  
17 baseline SOARCA analysis, you can see with that  
18 triangle is up in the range where stochastic failures  
19 happen to occur first.

20 You don't have to move very away from  
21 that, where the thermal mechanism takes over. I mean  
22 that's really the lesson learned here, I think.

23 MS. GHOSH: Right, and then once the  
24 thermal mechanism takes over, we're sampling an open  
25 area right now, and we're seeing a lot of main steam

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1 line creep failures, since we're sampling the whole  
2 range from zero to one, and okay.

3 So the next graph on Slide 27 now shows  
4 what is the dependence of whether or not you get main  
5 steam line creep rupture on that sample value of the  
6 SRV thermally failed open area, and as you can see, as  
7 you have lower open area fractions, you're much more  
8 likely to have MSL creep rupture.

9 The black line is essentially a cumulative  
10 exceedance probability for how likely is it that  
11 you'll have MSL creep rupture, if you have a value or  
12 exceedance probably if you have that value or less.  
13 So as you have larger open area fractions, you're  
14 becoming less likely to have MSL creep rupture. Right  
15 now, we are sampling uniformly from zero to one.

16 Mike, did you have a question or comment?

17 MEMBER STETKAR: He's not shy. He'll  
18 chime in.

19 MS. GHOSH: Okay, and for rather large  
20 open areas, there's much less chance of having an MSL  
21 creep rupture. If we go now to Slide 28, this is  
22 actually --

23 (Phone ringing.)

24 MS. GHOSH: I think we lost him. This is  
25 just an illustration of the chimney effect. I guess

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1 the question earlier of the railroad doors. The  
2 refueling bay panels always open, and then depending  
3 on whether or not the railroad doors open, you either  
4 have or don't have a chimney effect, and the actual  
5 open area is not as important as whether or not the  
6 railroad doors are open at all, and this is already  
7 noted in the best estimate.

8 MEMBER ARMIJO: There's no effect of  
9 rubble in the building reducing the flow? It's you  
10 don't consider that, or you just assume everything  
11 geometrically is okay?

12 MR. LEONARD: In this case, the equipment  
13 hatch is really big, so unless you somehow totally  
14 block, and when I mean really big, I mean it's ten  
15 meters square. Unless that's totally blocked somehow,  
16 this chimney effect would not be impeded. I mean it's  
17 conceivable, but --

18 MEMBER ARMIJO: But even if this was  
19 cracked open, like leaking through the doors. Are you  
20 actually -- I misunderstood you. I thought you said  
21 if they were just slightly opened.

22 MR. LEONARD: You're talking about rubble  
23 against the railroad doors?

24 MEMBER ARMIJO: Rubble within the  
25 building, and you know, all the flow paths are

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1 blocked.

2 MR. LEONARD: Again, because the height of  
3 the railroad doors is very tall, I mean I don't know  
4 the precise number, but they're 20 or 30 feet tall,  
5 and the dimension of the equipment hatch that rises  
6 from the grade level up to the top of the building is  
7 ten meters square, I mean it's big. It would take a  
8 lot of debris of any type to somehow impede that flow.  
9 So no, it's neglected.

10 MS. GHOSH: Okay, Slide 29 now shows one  
11 of the new insights that has been quite interesting,  
12 and initially surprised us, and we couldn't have had  
13 this insight with the main SOARCA study, because it  
14 has to do with when we have cesium hydroxide as an  
15 option, as a chemical form of cesium, whereas in the  
16 main study it's all cesium molybdate.

17 We found in that first case that combined  
18 case that a lot of the cesium was actually getting  
19 held up by the stuff on top of the core, and it turns  
20 out that there's a lot of chemisorption that's  
21 happening, and this happens at high temperatures, and  
22 you end up losing a lot of the cesium hydroxide onto,  
23 you know, stuff getting stuck to the steam dryers and  
24 the upper reactor pressure vessel.

25 So this is a surprising result, I would

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1 say, because the conventional wisdom was that cesium  
2 hydroxide would lead to higher releases than cesium  
3 molybdate, but actually in this case, it turns out  
4 when you have high enough temperatures, it gets held  
5 up due to chemisorption.

6 We did talk to subject matter experts in  
7 this area, to confirm that this is a real phenomena  
8 that's backed up by data and so on. It turns out that  
9 it is. It's modeled in MELCOR and it's backed up by  
10 real data. So that was a surprising finding.

11 This scatter plot just shows that  
12 depending on what chem form you're sampling, how much  
13 of the fraction is getting chemisorbed. So the  
14 chemical bin 1 is where all of it is cesium hydroxide,  
15 and you see that you get a significant amount of  
16 chemisorption on all of the cesium hydroxide.

17 Chem form 2 and 4 is a half and half,  
18 cesium hydroxide and moly, and you get, you still get  
19 a significant chemisorption, less than where it's all  
20 -- and then you can see with the molybdate it's not  
21 getting held up. So anyway. So this was an  
22 interesting finding, and the -- yes.

23 MR. MATTIE: I just want to -- I only want  
24 to point out this, the population that we're plotting  
25 is only for the creep rupture cases.

1 MS. GHOSH: Thank you. If we go to the  
2 next slide, just to continue on that line, so as  
3 Patrick said, that plot was for the main steam line  
4 creep rupture conditions. But for other conditions,  
5 cesium hydroxide can lead to slight increase in  
6 releases, for I think the reasons that the  
7 conventional wisdom told us, has a lower vapor  
8 pressure rate.

9 So for the stochastic failure SRV  
10 scenario, the cesium hydroxide leads to higher  
11 releases. The MSL creep rupture scenario gets held up  
12 and because of the chemisorption, it leads to lower  
13 releases.

14 MR. MATTIE: I would say also this is one  
15 of the reasons that we devised the specific cases  
16 based on different scenarios, because unless you  
17 sample it frequently enough, you can't get these  
18 statistical correlations. They won't show up.

19 MS. GHOSH: Okay. The next slide, Slide  
20 31, I think comes to another surprising result I would  
21 say, in the analyses that we've done so far. This  
22 drywell liner open area, the distribution, and Mark  
23 can speak to this better than I can.

24 But you know, we initially set up bounds  
25 in the distribution to kind of see well, what is the

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1 potential effect, and we find that there is in fact  
2 quite an interesting effect that this drywell liner  
3 open area has.

4 What we're plotting here is whether or not  
5 there's water in the drywell coming from the wet well.  
6 So the green circles are that you have no water in the  
7 drywell coming in from the wet well, and all of the  
8 red circles, and you can see there's a lot of them, is  
9 where wet well water is getting drawn into the  
10 drywell.

11 This is certainly a surprising result, and  
12 it turns out that because of the way it's modeled in  
13 MELCOR, the open area -- the pressure differential  
14 that's created once you have the drywell liner open  
15 area is pretty large, and it's large enough that you  
16 draw water from the wet well into the drywell.

17 We didn't see this effect in the best  
18 estimate, the main SOARCA calculations. So this is  
19 kind of a new phenomena that we're looking at. We're  
20 still trying to track down now do we think it's  
21 physically realistic to be able to open up, for  
22 example, a one square meter hole in such a short time  
23 period, which is what is, you know, creating this  
24 effect.

25 So this is one of the things, and as part

1 of our iterative process now we're trying to track  
2 down, because it is showing up as more important than  
3 we initially had anticipated. I don't know if you  
4 want to add anything to that.

5 MR. LEONARD: This might be a good example  
6 where the insight of the initial uncertainty  
7 calculations have led us to question the model itself,  
8 not just the value of the parameter.

9 CONSULTANT WALLIS: Question whether or  
10 not there's wet well water in the drywell?

11 MR. LEONARD: No. When we say the liner  
12 open area, what this means is when debris contacts the  
13 liner, and the liner fails, creating some opening to  
14 the environment, the question is well how big is that  
15 opening, and in all previous analyses, that value is  
16 a number that is opened instantaneously as the  
17 effective open area for leakage out of the containment  
18 to the reactor building.

19 When we start looking at larger areas than  
20 we had normally considered in the past, what we did  
21 not consider is the impact of the assumption in this  
22 model, that the total area opens instantaneously, that  
23 it isn't equivalent to a leak before break, or a rip,  
24 if you will, that gradually grows, at least grows over  
25 a time constant that's compatible with the

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1 depressurization time of the containment.

2 In this case, because it's instantaneous,  
3 when you get to the upper ends of the uncertainty  
4 range, the drywell blows down very quickly. The wet  
5 well cannot keep up, because the passage of gas from  
6 the wet well back up into the drywell is blocked by  
7 definition by design with water.

8 It can't keep up, and the only way that  
9 differential pressure can equilibrate is to drywell  
10 the water, not all out, some of the water out of the  
11 wet well through the vent pipes up into the drywell,  
12 relieve that differential pressure, and then the water  
13 settles back down again.

14 So that short time frame differential  
15 pressure is what's causing this effect of the water,  
16 and the reason the water's important is because all of  
17 the early volatile fission products that were released  
18 from the core were deposited in the pool through the  
19 open SRV.

20 So when the water comes up and evaporates  
21 because there's now debris on the floor of the  
22 drywell, the activity associated with that water  
23 contributes to the source term. So the cesium iodide  
24 content in the water becomes part of the environmental  
25 release.

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1                   CONSULTANT WALLIS: Now what you're saying  
2 is if the hole is bigger than a certain amount, you'd  
3 get water in the drywell? That doesn't anything about  
4 verifying this curve. So the implication is that  
5 you're somehow verifying a probabilistic, a  
6 probability distribution.

7                   That has nothing to do with it. I don't  
8 know where the distribution comes from, but what  
9 you're really saying is that if it's bigger than a  
10 certain size hole you get water.

11                  MR. LEONARD: We do, under the assumption  
12 that the area opens instantaneously. I guess that's  
13 the comment that I'm trying to make is --

14                  CONSULTANT WALLIS: But it's sort of  
15 misleading to put it on the probabilistic diagram,  
16 because there's nothing about probability in your  
17 conclusion.

18                  MS. GHOSH: Yeah, I apologize. This is  
19 just a way to show that for the sampled values we  
20 have on the X axis of the runs that we do --

21                  CONSULTANT WALLIS: But you get a  
22 surprising result physically.

23                  MS. GHOSH: Yes.

24                  MR. LEONARD: The probabilities come in in  
25 that these results were based on a linear distribution

1 of an instantaneous open area between .1 and 1.

2 CONSULTANT WALLIS: That's a questionable  
3 conclusion.

4 MR. LEONARD: So well there's two  
5 questionable ones. You know there are some people who  
6 have commented that the upper bound may be too large.  
7 That's a fair comment. I think what this observation  
8 is teaching us more than that is that it isn't the  
9 area; it's how quickly does that area open, that the  
10 model itself may need to be manipulated before we make  
11 the final calculations.

12 So this has been an interesting insight,  
13 because it's not the number that matters; it's the way  
14 in which that number is applied to the calculation.

15 MR. MATTIE: It's just not one of your  
16 obvious, you know, value-added. For most people, when  
17 they think of an uncertainty study, this is not one of  
18 their primary conclusions that, you know, going into  
19 it that we're going to actually validate some of the  
20 modeling assumptions here.

21 We find that this one may break down. But  
22 I want to make that point, because you make an  
23 interesting one. This cumulative probability on this  
24 graph, it's just the sample value. So it's the  
25 distributions. So I'm plotting just the sample values

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1 over the distribution for this parameter, and then  
2 just color-coding when something occurs.

3 MS. GHOSH: Right. So the color-coding is  
4 what we're trying to convey, not the --

5 MR. MATTIE: Not the probability of  
6 whether that actually occurs.

7 CONSULTANT WALLIS: But shouldn't they lie  
8 exactly on the line?

9 MR. MATTIE: Well, the black line is the  
10 theoretical sample, and then the red dots are the  
11 Monte Carlo samples, as interpreted by me as the CDF.  
12 So my CDF approximation might be slightly off. So I  
13 would determine it to my CDF approximation.

14 MS. GHOSH: Okay. So the next slide, I  
15 guess, is just an introduction to the next two slides.  
16 We're now showing probabilistic results at this  
17 meeting. As I mentioned before, we would like to come  
18 back to the Committee with results when we're further  
19 along.

20 But we wanted to just give you some  
21 examples of the different behavior that we're seeing,  
22 the different profiles based on what we have done so  
23 far. So the first example is where we do have a main  
24 steam line creep rupture case, with this water influx  
25 to the drywell, and the second one will be

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1 chemisorption example.

2 So if we go to the next slide. For your  
3 reference, on Slide 35 are the profiles for the SOARCA  
4 best estimate, which I'm not going to talk about. But  
5 that's for your reference, you know, for comparison to  
6 what we are showing here.

7 So you can see here, and the legend, just  
8 for your information, the SRV OA frac, this yeah.  
9 This is down, great. The blue box on the lower left  
10 of the graph, that first parameter, we're telling you  
11 what the sample values are of some of the key  
12 parameters.

13 That's the open area fraction for thermal  
14 SRV failure. The second one is the chem form. In  
15 this case, it was all cesium molybdate. The third one  
16 is the drywell liner failure area, so in this case it  
17 was .73 meters squared. The DASF is the dynamic  
18 agglomeration shape factor, which was sampled as 1.17,  
19 and the railroad doors were open in this case, as they  
20 are in most cases actually.

21 So this graph is showing essentially where  
22 SRV thermal failure happens, which in this case around  
23 12 hours, and then when we have MS� creep rupture  
24 following with the cesium release to the drywell,  
25 which looks like it's roughly a little bit before 16

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1 hours.

2 Then the red arrows is just pointing to  
3 where we have, we observed this influx of water from  
4 the wet well into the drywell, and eventually the  
5 drywell failure and cesium released to the  
6 environment. There's a lot of data on this curve.  
7 I'm not going to go through all of it, each of the  
8 curves. But maybe for your information to look at.

9 MR. MATTIE: I chuckled a little bit when  
10 Randy's presentation, and he only had four or five  
11 curves on here. So --

12 (Off record comments.)

13 MS. GHOSH: Okay. The next one is an  
14 example where we see significant cesium chemisorption.  
15 This is from the first probabilistic case, and the  
16 dark kind of bluish-purple curve shows, you know, what  
17 is chemisorbed onto the steam dryers and deposited on  
18 the upper RPV head.

19 So this is from the same probabilistic  
20 case as the one on the previous slide, and you can see  
21 the cesium releases are significantly lower, because  
22 the cesium is trapped on the steam dryers in the upper  
23 RPV.

24 MEMBER ARMIJO: Some things are saying  
25 it's failed on here.

1 MS. GHOSH: Sorry?

2 MEMBER ARMIJO: This goes from -- one goes  
3 from zero to one; the other one zero to .5.

4 MR. MATTIE: They're on different scales.

5 MEMBER ARMIJO: You're just trying to  
6 calibrate.

7 MS. GHOSH: Yeah, thank you.

8 MEMBER BLEY: So Tina, I'm trying to  
9 calibrate myself. We're going through a lot of these  
10 and we're seeing very great changes to some of these.  
11 Your statements earlier that nothing invalidates the  
12 SOARCA calculation. I take it to mean that you find  
13 no cases that lead to higher consequences than were  
14 modeled in the original analysis; is that what it  
15 means, because we're seeing quite a bit of  
16 variability?

17 MS. GHOSH: Yeah. You know, I think part  
18 of it comes down to what is the explanation for the  
19 variability. I mean right now the variability is  
20 coming from what we put into the uncertainty analysis,  
21 and I think we pointed out there are several  
22 parameters that at this point, the team is  
23 uncomfortable with what we put into the analysis on  
24 the front end.

25 I think one is the SRV stochastic failure

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1 rate. We're struggling to come up with a better  
2 database, to represent a situation that we think is  
3 closer to what we're modeling in the long-term station  
4 blackout. I think a second example is the drywell  
5 liner failure area, and this issue of the  
6 instantaneous pressure differential --

7 MEMBER BLEY: That's a modeling problem.

8 MS. GHOSH: Right, that we're trying to  
9 figure out, you know, how should we make sure that  
10 we're not creating some unrealistic, you know,  
11 outcome. There's another one that we'll talk about  
12 later.

13 We're investigating some of the dynamic  
14 agglomeration shape factor and particle density, some  
15 of the related fission product parameters, to make  
16 sure that we have not ignored correlations, that we  
17 may be incorrectly independently sampling variable  
18 values that should really be correlated, and in fact  
19 not even just the two that I mentioned.

20 But there are other parameters in MELCOR  
21 that are probably correlated that we're not even  
22 sampling, and we're trying to be smarter about how we  
23 do that so again, we don't create physically  
24 unrealistic results. So with all of the exploration  
25 that we've done, we have seen, you know, significant

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1 variation in, for example, the release amounts.

2 Similar to what Mark showed, you know, is  
3 possible with the SRV sensitivity case studies done.  
4 So as we mentioned, maybe ten times higher a cesium  
5 release. But they're still way, way, way below the  
6 siting study results or say earlier studies or the  
7 safety rule or anything like that.

8 And it also comes down to do we think, you  
9 know, main steam line rupture case is more likely than  
10 the SRV stochastic case, and that's something we're  
11 really struggling with, you know, what to say about  
12 that. I think right now, you know, if we don't have  
13 any more information than we have today, we'll  
14 probably present two cases in the uncertainty report.

15 One for where we keep the SRV stochastic  
16 failure rate fixed, which will be more like the best  
17 estimate on the uncertainty around the best estimate,  
18 and then the second case where we do vary it, and if  
19 we don't have a better distribution than we have  
20 today, that's really going to be a main steam line  
21 creep rupture case.

22 And if there's no -- I don't think we have  
23 any indication that tells us that our best estimate or  
24 main SOARCA scenario should have been a main steam  
25 line creep rupture case, because that's really driven

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1 by factors of what we put into the inputs, that we're  
2 now questioning whether, what is the basis for those  
3 distributions.

4 The two key lines is the stochastic  
5 failure rate that we're struggling with, and also  
6 using a uniform distribution for that thermal seizure  
7 open area, which may not be appropriate.

8 MEMBER RAY: Remind me. The thermal  
9 failure is later than the stochastic?

10 MR. MATTIE: Yes.

11 MR. LEONARD: Always.

12 MEMBER RAY: Yeah, okay. Well, I'm glad  
13 you're still struggling with the stochastic failure.

14 MR. MATTIE: I think in the grand picture,  
15 you know, the variation on source term releases that  
16 we're looking at is explainable. In the  
17 phenomenology, we're discovering some insights that we  
18 had previously not seen before. We're still talking  
19 about very small fractions released ultimately to the  
20 environment, within a range like, as Mark discussed.

21 And then consequences that are as  
22 expected, based on what we saw in the best estimate.  
23 So you know, we have seen nothing from the results so  
24 far that could, that will, that have exceeded the  
25 threshold for the ability for emergency planning and

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1 evacuation to handle the event, such that we're not  
2 getting early fatalities and the long-term  
3 consequences are substantially like we've seen in the  
4 best estimate.

5 So you can split the hairs really fine,  
6 and want to validate the modeling assumptions and the  
7 phenomenology that we see. But we've seen nothing  
8 extreme, and going back to your original question,  
9 that would lead us to believe that something in the  
10 best estimate was done incorrectly or wasn't treated.

11 MS. GHOSH: Yeah, right. And getting back  
12 to your consequence piece, I think we can go ahead and  
13 skip ahead to Slide 36, which summarizes the MACCS  
14 results essentially, which right now we've only done  
15 for that first combined case, which is primarily main  
16 steam line creep rupture cases.

17 What we see here is that the health effect  
18 risk varies sublinearly with the source term. So even  
19 if you have a larger source term, in essence the  
20 habitability criterion, if you have enough time to  
21 evacuate and done the habitability criterion, is  
22 really a controlling feature of the consequences that  
23 you see, because people are not allowed to return back  
24 and in essence get dosed, until you've met that  
25 habitability criterion.

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1           So that kind of -- that's why the eventual  
2 consequence results vary very sublinearly with the  
3 source terms, even if the source term --

4           CONSULTANT WALLIS: They don't go up.  
5 They go up slower than linearly.

6           MS. GHOSH: Much slower, much, much  
7 slower, yeah.

8           CONSULTANT WALLIS: It's not the  
9 consequence for the people. I mean they're away from  
10 home for twice as long.

11          MS. GHOSH: Right, and yeah, I guess we  
12 talked about that earlier.

13          CONSULTANT WALLIS: I wouldn't be happy  
14 not to die, but to have to go away for all that time.

15          MS. GHOSH: Sure, sure.

16          MR. MATTIE: We haven't looked at that one  
17 yet.

18          MS. GHOSH: Yeah. We've limited the  
19 consequences that we look at to the same ones that are  
20 looking at in the SOARCA study, yes. And then, you  
21 know, cesium isotopes always dominate for the long-  
22 term risk, which is why we spent so much time looking  
23 at the cesium part of the source term.

24                 The barium, tellurium and cerium can  
25 dominate over iodine for short-term risk, but these

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1 are very, very, very small risks.

2 MEMBER RAY: Not too important.

3 MS. GHOSH: Yeah, I think that's all to  
4 say about that. We'll have more MACCS results later.  
5 I think at this point we've done more with the source  
6 term results. But next time we come talk to you,  
7 we'll have more phenomenological insights for that  
8 part of it.

9 Just to give you a very high level view,  
10 Slide 37 shows kind of the range of consequences that  
11 we're seeing out of MACCS, and the best estimate kind  
12 of lies, you know, within the range for the 0 to 10  
13 and 0 to 20 miles. Again, this is for the combined  
14 case and using LNT. We haven't done the alternate  
15 dose model calculations yet.

16 CHAIR SHACK: As soon as you bring the  
17 frequency in, you sort of raise John's question, of  
18 what the seismic frequency is. When I went through  
19 these, even if I use the old 1488 values, your values  
20 seem low to me, and they're only going to get lower  
21 compared to, you know, what we think are more modern  
22 estimates.

23 So just where did these frequencies come  
24 from? Are they based on 1488, or are they --

25 MS. GHOSH: The mean core damage

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1 frequency?

2 CHAIR SHACK: Yeah.

3 MS. GHOSH: Of 3E to the minus 6? I think  
4 Marty is coming to answer.

5 MR. STUTZKE: The answer is they're  
6 basically based on 1488, but you have to account for  
7 the seismic failure that gets you into core damage as  
8 well. 1488's merely the occurrence of the initiating  
9 event, okay.

10 CHAIR SHACK: Yeah, but sort of it would  
11 fail everything. I was kind of equating the two of  
12 them.

13 MR. STUTZKE: No, because components have  
14 seismic resonance fragility that's also included in  
15 there.

16 CHAIR SHACK: Okay. That was good enough.  
17 Fair enough, and it's still John's question, for the  
18 more substantial one.

19 MS. GHOSH: Okay, so the next slide. I  
20 guess based on what we have looked at with the MACCS  
21 analyses, and we did a preliminary habitability  
22 criterion, sensitivity analysis. By the way, we  
23 decided to treat the habitability criterion separately  
24 from the integrated uncertainty analysis, maybe partly  
25 for policy reasons.

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1           That criterion is set by the states, and  
2           from what I understand, if an actual accident were to  
3           happen, they might set a different criterion --

4           CONSULTANT WALLIS: The criterion is not  
5           age dependent? I would think that somebody who's in  
6           their 70's would be happy to go back, because by the  
7           time they die, they'd be 100 years old. But you don't  
8           want children to go back. That would make a big  
9           difference.

10          MS. GHOSH: Right, you know, and actually  
11          one of our peer reviewers, Jacquelyn Yanch, you know,  
12          brought up the issue of were a real accident to occur,  
13          you know, are people really going to be forbidden, and  
14          when would different groups be willing to go back.

15          But we have not explored, you know, these  
16          issues as part of SOARCA, and we're relying on the  
17          state guidance, what the state says that they would  
18          use should an accident occur.

19          However, if a real accident were to occur,  
20          the state is free to set a different criterion than  
21          what is on paper. So we wanted to look at the  
22          sensitivity, because certainly we know this is a  
23          controlling feature of the consequence analysis, and  
24          we wanted to see what is the effect.

25          But we kept it outside the integrated

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1 uncertainty analysis, because we didn't want to mix it  
2 up with -- mix essentially a policy decision up with  
3 the consequence modeling.

4 MEMBER RYAN: Tina, I'm guessing in answer  
5 to Dr. Wallace's question or proposition is that you  
6 really haven't dealt with voluntary or involuntary  
7 risks. I can go back into an area where I'm going to  
8 get a dose because I chose to, rather than -- I'm  
9 guessing that's outside the scope of what it does, is  
10 that right?

11 MS. GHOSH: Yeah. I would say that's  
12 correct.

13 MEMBER RYAN: Not that it's not a good  
14 question, but it's not -- I'm sensing it's not within  
15 your scope at this point.

16 MS. GHOSH: Right. It is outside the  
17 scope of what we've done, yeah. So not surprisingly,  
18 the health effect risk is nearly proportional to the  
19 habitability criterion, when you assume an LNT model.

20 If you then look at alternate dose models,  
21 and you're looking at alternate habitability  
22 criterion, well if the habitability criterion is lower  
23 than your dose truncation model, I mean your health  
24 effect drops very dramatically.

25 But again, that's not surprising. But

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1 we're doing the calculation just to document what the  
2 effects could be. Just in terms of, you know, a  
3 reality check, you know, as we keep mentioning,  
4 uncertainty analysis is an iterative process, and we  
5 want to make sure that we've put into it makes sense  
6 at the other end.

7 The preliminary MACCS results, we haven't  
8 uncovered anything that says that what we've put into  
9 the input parameter distributions are unreasonable.  
10 So we're not expecting to change anything on that at  
11 this point.

12 If you go to the next slide, so what do we  
13 have left to do? Clearly, we're still in the middle  
14 of the uncertainty analysis. We still need to finish  
15 our regression analyses using the various statistical  
16 measures to identify influential parameters.

17 We're going to continue investigation into  
18 single realizations, to confirm phenomena that we  
19 think is important, and also validation of results.  
20 We want to get some insights on other source or  
21 metrics of interest, such as hydrogen production and  
22 iodine, for examples.

23 We need to do the same analyses for the  
24 MACCS results, and we have to finish the separate  
25 sensitivity analyses that we have planned, the

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1 habitability criterion, which we've started but  
2 haven't finished, and also as we mentioned earlier,  
3 the timing of the two operator actions that are  
4 credited in the unmitigated long-term station  
5 blackout. We want to see the effect of varying the  
6 timing for those two actions.

7 On the next slide, we're planning an  
8 appendix with a discussion and qualitative comparison  
9 with Fukushima, very similar to what was done for the  
10 main study, and we are planning at this point to  
11 update some of the parameter distributions, and in the  
12 next few slides, I'll just talk a little bit about  
13 that.

14 Yeah, we can go to the next slide. The  
15 dynamic agglomeration and shape factors and particle  
16 density parameters that we have, they do turn out to  
17 be important, and when we went back and revisited the  
18 ranges that we were sampling, and the fact that we  
19 were sampling them independently, we suspect that we  
20 are not doing that properly.

21 So we're revisiting both the ranges that  
22 are feasible to sample, and also you know, to kind of  
23 think about the correlation effects that might be  
24 important. So that's an FYI. When we come back, we  
25 should have the updated information.

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1           The distribution for the drywell liner  
2 failure flow area, we talked about that already.

3 We're revisiting, you know, the mechanics of how the  
4 model is working, and whether it's realistic or not.

5           Then the third issue, the uniform  
6 distribution of that SRV thermally-failed open area,  
7 it very much drives the occurrence of main steam line  
8 creep rupture, and we are thinking at this point that  
9 a uniform distribution from zero to one is not the  
10 most realistic.

11           CONSULTANT WALLIS: For this failure flow  
12 area, it would really help if you had a mechanistic  
13 analysis, which could give you some sort of a bounding  
14 value, instead of just assuming ten times nominal or  
15 something.

16           If you could show that there is some  
17 bounding value from, I don't know, First Law of  
18 Thermal Dynamics or something, which says it's not  
19 going to fail bigger than so much in the worse  
20 possible case or something.

21           MR. LEONARD: In this case, it was done in  
22 the sense that the failure will occur at the contact  
23 surface between debris in the wall, and we know what,  
24 that the debris movement out of the pedestal to the  
25 wall is focused in the direction of the doorway. So

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1 there's going to be a natural, if you will, azimuthal  
2 spread, and that upper bound was well if it spreads to  
3 its full q quadrant dimensions and the rip is roughly  
4 that big, you know, a few centimeters big.

5 CONSULTANT WALLIS: It doesn't climb the  
6 wall. It just spreads along.

7 MR. LEONARD: It can't really climb the  
8 wall, at least openings. So that's what the bounding  
9 value was, is if that entire quadrant contacts  
10 instantaneously with an open area of approximately a  
11 few centimeters, what is that azimuthal dimension?  
12 What's that effective area? That's where the number  
13 came from.

14 I think the question now is not so much  
15 what that number is, but is it at all reasonable to  
16 open it, you know, in one instant, or should it  
17 somehow more gradually open from a smaller to a larger  
18 area?

19 CONSULTANT WALLIS: This one sounds  
20 incredible.

21 MR. LEONARD: Yeah, that's right. When  
22 it's small, it doesn't matter. But it's turning out  
23 to be important now, so we have to upgrade the model.

24 MR. MATTIE: We've discussed it, and I  
25 discussed it with Dana Powers, and he felt that, you

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1 know, it would happen quite quickly, but on the order  
2 of seconds, not instantaneously, and so it may be, you  
3 know, rather than --

4 CONSULTANT WALLIS: You mean it spreads  
5 all along instantly?

6 MR. MATTIE: Well no. He meant the  
7 penetration.

8 CONSULTANT WALLIS: Oh, the initial  
9 penetration.

10 MR. MATTIE: The initial contact.

11 CONSULTANT WALLIS: But that one meter  
12 square doesn't happen instantly.

13 MR. MATTIE: Exactly, exactly, yeah. Let  
14 me, in this particular analysis, it's probably more  
15 important in the fact that area, at some point the  
16 area isn't going to matter. But the rate clearly does  
17 matter, yeah.

18 MS. GHOSH: So we're working on that one,  
19 and then the next slide, I think this one we've talked  
20 about a lot about too. We're uncomfortable, and we  
21 don't know, we're not sure what else is out there to  
22 come up with a distribution for the SRV stochastic  
23 failure rate, but we do think the database we're  
24 relying on is not representative of the situation in  
25 our scenario. So we're struggling with that.

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1           If anybody knows of any other information  
2 sources, I think we would welcome that. So the  
3 schedule. I think as Pat Santiago mentioned, there's  
4 a Commission memorandum that's going to go up in June,  
5 that forwards the results of the SOARCA main study,  
6 and that memorandum will contain a very short  
7 discussion on where we are with regard to the  
8 uncertainty analysis, the schedule and what our  
9 interim conclusions are.

10           We hope to complete the analyses and  
11 documentation around September of this year, and we  
12 would like to come back to the ACRS and present the  
13 results and the final report, and we would like to get  
14 a letter from the ACRS, if you all were willing to do  
15 that, on the final uncertainty analysis.

16           And right now, we are planning to transmit  
17 the final uncertainty analysis to the Commission in  
18 November of this year. Any questions?

19           CONSULTANT WALLIS: Well, it seems to me,  
20 this isn't a question, it seems to me that this  
21 uncertainty and sensitivity study is every bit as  
22 important as the SOARCA report, because without it,  
23 there are all kinds of questions that remain from the  
24 SOARCA.

25           So I think it's a very important

1 supplement. Without it, the SOARCA report would be  
2 weaker significantly. That's just a personal opinion.  
3 But it's very important. I think you're doing a  
4 professional job.

5 MEMBER REMPE: What about doing something  
6 for Surry and not just Peach Bottom?

7 MS. GHOSH: We would love to do that. You  
8 know, I keep trying to sell this uncertainty analysis  
9 as a first step, you know. I think it's the first  
10 time we're really trying to tackle a problem of this  
11 magnitude, in terms of the integrated look at so many  
12 different parameters using the MELCOR code.

13 So this is kind of a first step. We're  
14 doing, you know, one of the scenarios for Peach  
15 Bottom. I think we would really like to do, as a next  
16 step, one of the Surry scenarios, and also because I  
17 think we'll be helping out with the Level 3 PRA  
18 project, which is for PWR.

19 So you know, in some sense to the extent  
20 that we can get insights for PWR, similar to what  
21 we're getting for Peach Bottom now, to help us be  
22 smarter about the uncertainty analysis when we get to  
23 Vogtle, I do think it would be valuable, and we're  
24 hoping to get that.

25 We don't have concrete plans at this

1 point, but I think that's a natural next step.

2 CHAIR SHACK: I think we could probably  
3 write a letter. I think we could do that.

4 (Simultaneous speaking.)

5 CHAIR SHACK: So I think that might well  
6 come up in a letter.

7 MEMBER STETKAR: You're going to discuss  
8 the uncertainty analysis when you come to the full  
9 Committee in a couple of weeks?

10 MS. GHOSH: Oh.

11 MEMBER STETKAR: The question is what do  
12 you present to the full Committee?

13 MS. GHOSH: Yeah. What would you like us  
14 to present?

15 MEMBER STETKAR: I would say the  
16 uncertainty analysis, but most of the committee is  
17 here. I'm not sure how many more -- well, Sanjoy.

18 CHAIR SHACK: Sanjoy will be here.

19 FEMALE PARTICIPANT: Dana.

20 MEMBER STETKAR: Dana. Oh, Dana has to  
21 recuse himself.

22 CHAIR SHACK: And Jack may not be back.  
23 That's about it.

24 (Simultaneous speaking.)

25 CHAIR SHACK: We'll have some time to

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1 think about it some more, and so I really, I think,  
2 you know, we've been through much of this before. I  
3 really think the uncertainty --

4 MEMBER STETKAR: Not much of that has  
5 changed.

6 CHAIR SHACK: And not much of that has  
7 changed. The uncertainty analysis is really -- I mean  
8 I'm sort of with Graham, that when you have a best  
9 estimate analysis, it doesn't make -- it's not  
10 complete until you've got the uncertainty analysis.

11 So I really think that uncertainty here is  
12 just absolutely necessary to complete this, and that's  
13 one reason we might write a letter recommending that  
14 Surry could be under an uncertainty. But let's plan  
15 on just doing the uncertainty analysis as the full  
16 Committee presentation.

17 MEMBER RAY: Well, if you say -- you know,  
18 I'm trying to get my mind around what, how do we use  
19 the results, who do we apply them to. One of the  
20 things that's been mentioned is to validate the  
21 viability of the emergency evacuation planning, for  
22 example. The time for the release is such that we can  
23 have confidence that evacuation can be used as a way  
24 of avoiding radiation exposure.

25 But embedded in the uncertainty analysis,

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1 of course, is at least one variable that has a heck of  
2 an effect on the timing, and that is what if that  
3 valve sticks open the first time it lifts? You've got  
4 -- and I realize these are safety valves, not PORVs.  
5 But you've got block valves on PORVs because they do  
6 stick open.

7 I've certainly seen safety valves stick  
8 open on fossil plants a lot. So if the question was  
9 is there a much earlier release scenario associated,  
10 now this is a beyond design basis accident. I  
11 understand that. It's long-term SBO.

12 So you know, I'm just struggling with  
13 well, is that even relevant to anything, because it is  
14 an accident that's beyond a design basis, and so how  
15 important is it to recognize that there's a much  
16 earlier, credible, in my mind anyway, release  
17 scenario?

18 All you have to do is have one of these  
19 valves stick open the first time it lifts, and you're  
20 on your way. And so the bottom line is --

21 MR. LEONARD: Let me comment on that,  
22 because our observations from the sensitivity and I  
23 think the uncertainty analysis is confirming it, that  
24 the earlier the SRV sticks, the better you are.

25 MEMBER STETKAR: The better it is.

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1 (Simultaneous speaking.)

2 MR. LEONARD: Time frames get down. It's  
3 when it sustains the cycling for a very long time,  
4 that's when most of these other phenomenological --

5 MEMBER RAY: I forgot. You did say that,  
6 but that's just part of the processing I've been doing  
7 through. I'm glad you reminded me of it.

8 CHAIR SHACK: When you lose cores, it's  
9 generally a good idea not to have valves stick open.  
10 Once they're gone --

11 (Simultaneous speaking.)

12 MALE PARTICIPANT: It depends on where the  
13 valves are, though.

14 MEMBER RAY: I guess I was thinking the  
15 valve sticks open, you lose your water inventory, the  
16 core fails and you have an earlier release, and that's  
17 sort of the simplistic way I was thinking about it.

18 In any event, like I said, that's at least  
19 one application that I can draw out of this, that it's  
20 where you use the results to say yes, our emergency  
21 planning provisions are adequately for even a beyond  
22 design event like this.

23 CHAIR SHACK: Can you hook up Mike again?

24 MEMBER RAY: All of that was just meant by  
25 way of saying I'm trying to grapple myself with how do

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1 you apply the uncertainty, because that presumes you  
2 have some vision for how to apply the results  
3 themselves.

4 MEMBER STETKAR: Well first I want to have  
5 some confidence in the results.

6 MEMBER ADBEL-KHALIK: I'm grappling with  
7 the same kind of question, and it just -- it is good  
8 that you're doing the uncertainty analysis. But my  
9 concern is that there are just so many parameters that  
10 it doesn't matter what kind of answer you get.

11 You will always be able to justify the  
12 result to yourself, because there are just so many  
13 interrelated parameters, and therefore ultimately, the  
14 credibility of this study will just depend on whether  
15 or not the result passes the smell test. To me, at  
16 this stage, it's still an open question.

17 MS. GHOSH: Sorry. I don't know if I  
18 understood what you were saying. You're saying  
19 there's so many parameters that could explain  
20 variation in results, or I'm sorry. Can you  
21 elaborate?

22 MEMBER ADBEL-KHALIK: There are so many  
23 variables that it doesn't matter what answer you get.  
24 You will always be able to sort of argue your way  
25 through the answer.

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1 MR. MATTIE: I don't know if I'd agree  
2 with that statement.

3 MS. GHOSH: Yeah. You know, the past-  
4 done, you know, I guess past uncertainty analyses show  
5 that even when you have a lot of uncertain parameters,  
6 it's usually just a handful that's driving the  
7 results.

8 (Phone ringing.)

9 MS. GHOSH: I think we're seeing the same  
10 thing here. We have 23 parameters we've put in, but  
11 we're really driving the results with a handful of  
12 them.

13 CHAIR SHACK: Hold on, because the -- no.  
14 The phone is interfering with the microphones. So  
15 until the phone stops, don't talk.

16 MS. GHOSH: Oh, okay.

17 (Off record comments.)

18 MEMBER RAY: But we haven't achieved  
19 perfection yet. It's better, but not --

20 MEMBER ARMIJO: It's a lot better.

21 MEMBER STETKAR: Apparently Mike doesn't  
22 have any final comments.

23 (Laughter.)

24 CHAIR SHACK: We can email him.

25 MS. GHOSH: I'll just repeat my last

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1 sentence for the record, because I think there was  
2 some interference. Past uncertainty analyses have  
3 generally shown that even when you have a lot of  
4 uncertain parameters that you, you know, put into your  
5 analysis, it's usually just a handful that are  
6 controlling the results.

7 I think we're finding something similar in  
8 this case. We've put in 23 parameters, but it really  
9 boils down to a handful that's really driving changes  
10 in the results.

11 MEMBER ADBEL-KHALIK: Assuming that you  
12 know what's going on in detail, and you understand all  
13 the phenomena, I would agree with you. But I don't  
14 think we do.

15 MR. MATTIE: You always have to consider  
16 your state of knowledge in these types of analyses.

17 MEMBER ADBEL-KHALIK: Yes, and that's why  
18 I say ultimately it will just depend on whether or not  
19 the final result passes the smell test.

20 MR. MATTIE: If you make a convincing case  
21 that you understand what's an important phenomena, and  
22 to that regards, of the 23 parameters that we put in,  
23 we only measure their importance of those 23  
24 parameters, and of those 23 parameters that we  
25 considered, only a handful of those parameters showed

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1 an important effect.

2 And when we say "important effect," what  
3 we're describing is the -- its contribution, that  
4 single parameter's contribution the variants or  
5 uncertainty in the expected outcome. So there are  
6 parameters that we didn't consider that could also be  
7 important.

8 If you did a parametric study exhaustive  
9 on every conceivable input of MELCOR, then you could  
10 also come back and say well, what about parameters  
11 that aren't in MELCOR? You could, right?

12 MEMBER ADBEL-KHALIK: Sure.

13 MR. MATTIE: So but at some point, you  
14 would have a level of confidence in your result. I  
15 think that's what we're doing, is we're contributing  
16 to that level of confidence in the ultimate result.

17 MEMBER STETKAR: And again, for the  
18 purposes of the study, I think you know, go back to it  
19 is what it is. It's not what it's not. But given the  
20 constraints of what it is, being able to still express  
21 some knowledge about, you know, I come back to  
22 margins.

23 I had this discussion with drawing a line  
24 with safety goals or whatever, but still having some  
25 degree of confidence that within the range of what

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1 we've been able to examine, and some expression over  
2 uncertainties over that range, we still have learned  
3 something, and we still have some confidence about  
4 what that margin is, and I think that's important.

5 (Dial tone.)

6 Anybody can always argue that you can look  
7 at other things, and indeed you can. And indeed,  
8 there's a possibility they might be important. But  
9 that's not what it is.

10 MEMBER BLEY: I guess what I like about  
11 this afternoon is seeing that you're finally  
12 addressing these issues. What I like is that you've--

13 MEMBER CORRADINI: I'm here.

14 MEMBER BLEY: --you've begun, you're  
15 trying to explain a variability in your results, and  
16 understand them in terms of what's modeled and what  
17 might not be in the model, and that side of it.

18 So this is for me a big step forward in  
19 this whole SOARCA exercise, and I look forward to  
20 seeing where you get to next. But I think you're on  
21 the right track, and that's the first time I've said  
22 that.

23 (Laughter.)

24 MEMBER SCHULTZ: I agree, and the reason  
25 I say or would stress the importance is that we heard

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1 an identification of how many downstream projects,  
2 analyses, programs are going to be affected, are going  
3 to leave -- the SOARCA analysis will lead toward or  
4 lead to follow-on analyses, and that makes this  
5 portion of the SOARCA analysis that much more  
6 important.

7 CHAIR SHACK: Around the table, Dick.

8 MEMBER SKILLMAN: No comments. But thank  
9 you for a very informative day. Thank you very much.

10 CHAIR SHACK: Dennis, anything additional?

11 MEMBER BLEY: No, except the thing I  
12 mentioned earlier, if what everybody told us earlier  
13 about what operator actions are where, is the way you  
14 said, then get rid of that statement in your report  
15 that says we looked at --

16 CHAIR SHACK: The procedures.

17 MEMBER BLEY: Others as well. In the  
18 mitigated cases, we looked at the actions associated  
19 with B.5.b and other modeled human actions separate  
20 from that. Just get rid of that; it's not true. If  
21 it is true, tell what they are. I think we'd better  
22 have Mike's comments before we lose him again.

23 CHAIR SHACK: Yeah. What's happening to  
24 Mike?

25 MEMBER CORRADINI: Are you making jokes

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1 about me again?

2 CHAIR SHACK: No. We wondered what --

3 MEMBER STETKAR: You keep disappearing.

4 MEMBER BLEY: We want to hear from you  
5 before you disappear.

6 MEMBER CORRADINI: Well, I lost, I  
7 basically lost service. I tried to call back and it  
8 was busy. So I kept on sending emails, so that's all  
9 right. So do you want my comments now?

10 CHAIR SHACK: Yes, before you get dropped  
11 again.

12 MEMBER CORRADINI: So first of all, I  
13 thank the staff. I followed it up through, but not  
14 including the uncertainty analysis. That's when I  
15 kind of went offline. I think the uncertainty  
16 analysis --

17 CHAIR SHACK: Well, you're going to hear  
18 it again at the full Committee.

19 MEMBER CORRADINI: I guess I would  
20 emphasize that in the uncertainty document, what  
21 things they cannot vary in a rigorous way or in the  
22 way in which they're choosing to do it. That doesn't  
23 mean they shouldn't identify that uncertainty.

24 I'll use the example when Randy was up,  
25 and I asked about his -- I asked about his comment

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1 that for short-term station blackout versus long-term  
2 station blackout, there was a factor of 10 difference  
3 in source term release.

4 He did a kind of a heuristic thinking  
5 process, that he thought it had something to do with  
6 early times, high temperatures and a lot of zirconium.  
7 So you may not be able to directly do the sort of  
8 analysis you're doing on some of the other variables,  
9 where you pick a high and a low and you do a  
10 distribution.

11 But that doesn't mean you ignore what  
12 you're uncertain about. So I would think the  
13 uncertainty analysis ought to be, in some sense, a  
14 relatively good listing of the things that you know  
15 you might be unsure about, but you may not have the  
16 tools to at least investigate it within the structure  
17 of how you're doing some of the other calculations.

18 That's one example. The other example is  
19 in relation to the scope. Scope did not cover land  
20 contamination. Clearly, we had discussed that, but  
21 there was a mention of another ongoing study that  
22 would do that.

23 I've come up with a number of things that  
24 popped in my head, but I think the uncertainty  
25 analysis at least ought to identify what you think are

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1 the key physical things, that even though you know  
2 they're uncertain, you're not able to analyze it in  
3 the way you're analyzing the others. But at least  
4 it's a place where you can go back to, and do further  
5 analysis.

6 Beyond that, I think in terms of specific  
7 accident sequences and melt progression, I actually  
8 think it's a very complete report in many ways. So I  
9 think that's good. Other than that, that's my major  
10 comment, is how I deal with physical processes that  
11 don't fit the mold of the uncertainty protocol.

12 CHAIR SHACK: Harold, anything else?

13 MEMBER RAY: I've said everything, Bill.  
14 Thank you.

15 CHAIR SHACK: Sam.

16 MEMBER ARMIJO: Yeah. I think, I mean I'm  
17 pretty impressed. I think you've taken on a big job  
18 and dealt with it as best anybody could. The thing I  
19 think you're still some conservatism in parts of your  
20 model, the barium and cerium behavior. I think some  
21 of the results you're getting on that may be an  
22 artifact resulting from the way you're using the  
23 VANESSA code.

24 It's a thermodynamic code with no kinetics  
25 in it. So I'm -- with a heterogeneous debris, with

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1 solid UO<sub>2</sub>, with barium and cerium buried inside the  
2 UO<sub>2</sub>, things melting. It's very complicated, and so I  
3 don't think you can use the thermodynamic reaction to  
4 assume that everything reacts, even though it's not in  
5 contact.

6 So but it may not matter. Like you  
7 mentioned, you have 20-some parameters and maybe this  
8 barium and cerium phenomena just really doesn't impact  
9 much. But I think I know someone in Albuquerque who  
10 will teach me something about VANESSA, and I'll maybe  
11 change my mind later. But that's what I got out of it  
12 today. That 's all.

13 CHAIR SHACK: Said?

14 MEMBER ADBEL-KHALIK: I have no other  
15 comments.

16 CHAIR SHACK: John.

17 MEMBER STETKAR: Nothing more, thanks.

18 CHAIR SHACK: Charlie.

19 MEMBER BROWN: Nothing else.

20 CHAIR SHACK: Joy.

21 MEMBER REMPE: Well, several times I've  
22 mentioned vessel failure and drain line, and I think  
23 I heard that that will be addressed. I was really  
24 glad to hear that they'll be a Rev. 1 of the two  
25 plant-specific reports, and again the uncertainty

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1 analysis of documenting what it can and cannot do or  
2 how things were applied to accommodate. I think that  
3 was important.

4 I know you can't document that you didn't  
5 consider meteor attacks or whatever, but some of the  
6 key things I think you can do that. So I think I  
7 heard that that would be done, so I was happy.

8 CHAIR SHACK: Tom.

9 CONSULTANT KRESS: Well again, I have a  
10 number of comments about the whole day, not  
11 particularly about the uncertainty.

12 CHAIR SHACK: Work on the whole day.

13 CONSULTANT KRESS: Well, in the first  
14 place, I do think this was a good study and was a good  
15 thing that you're doing. I think it's well  
16 worthwhile, and did a good job, and most of it is  
17 technically dependable for it is what it is.

18 Of course you would probably know, I was  
19 disappointed that there were no societal risks, or not  
20 risks, societal consequences included, but I  
21 understand why, and I'm kind of glad to hear that  
22 there's a program later on to look at that, and I'd be  
23 interested in following that.

24 But when I get to doing this, consequences  
25 and risk even, the societal effects, I think they're

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1 going to need another safety goal. They have to  
2 define what societal risk is acceptable to them from  
3 the standpoint of the safety code, and I think they  
4 need to give that a lot of thought.

5 I also thought that the mitigation versus  
6 non-mitigation needed to be better explained, in the  
7 sense of what was left out and what wasn't in those  
8 two. I thought it did show that the SAMDAs are really  
9 useful things. We probably should have had some of  
10 those SAMDAs in there much sooner than this. That's  
11 one of the lessons I took away from it.

12 It seems like the timing of the release is  
13 almost as important or moreso than the quantities, and  
14 I think there might be some, if I were to look at the  
15 uncertainties, that may be an area that I'd think  
16 about whether we have that right. I think it could  
17 involve things like that valve sticking.

18 You know, I understand that if it sticks  
19 earlier, you're better off. But maybe it sticks  
20 later, and I don't know where is the worse place for  
21 it to stick, to stick open. I like the comment made  
22 by some of the peer reviewers that most of the  
23 consequences result from the return criteria.

24 I think this brings to mind, I think for  
25 a long time, the linear no dose assumption has been a

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1 real issue that needs to be re-thought out,  
2 particularly if that's going to be the maximum  
3 consequence driver.

4 I guess I'm all right with choosing the  
5 accident sequences that has a cutoff frequency value  
6 to them, but I would -- at first thought, I was  
7 thinking that we'd be better off to select an accident  
8 sequence from a LERF value, rather than the CDF,  
9 because the LERF value gives you bigger consequences.

10 It's a measure of the fission product  
11 releases, and I think I would have chosen that as my  
12 criteria to choose a sequence. This was advertised as  
13 state of the art, but I worry about VANESSA in there,  
14 and basically for the same reasons Sam mentioned, that  
15 I don't think when you have a heterogeneous mixture of  
16 things that come out at different times, I don't think  
17 you could even do a Gibbs-free energy with those.

18 VANESSA, I'm sure, assumes equilibrium, a  
19 complete mixture of everything, and works it from that  
20 point. I don't know if it -- I don't think I've ever  
21 seen any validation of it, experimentally or  
22 otherwise. It's strictly an analytical model.

23 So I worry about that part, and I don't  
24 know how you would do an uncertainty analysis on that,  
25 because the way it's done, it actually maximizes the

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1 consequences, and maybe that's acceptable. So maybe  
2 I'm not so worried about it.

3 One question I had early on was I don't  
4 know how plant-typical Surry and Peach Bottom are, for  
5 all of the BWRs and PWRs. But and I worried about why  
6 aren't we looking at other plants, but we got an  
7 answer to those. So I lost, I just marked that one  
8 off my list.

9 I don't think the study in any way does  
10 away for the need for Level 3's for actually all the  
11 plants. It does provide some good input and some good  
12 things that the Level 3's can think about and be part  
13 of their study. So I was glad to see that.

14 One comment somebody made, I forgot here,  
15 and I agree we have to, and that is the documentation,  
16 I think, it would be nice if it's very clear that they  
17 tell what the reasons are for the consequences being  
18 so much different than previous studies. It would be  
19 nice to have that really made clear.

20 And I think if not so much related to this  
21 study, but when the Level 3's are done, I think  
22 there's a real need for us to revisit the consequence  
23 models that are in MACCS. I don't think we've ever  
24 taken a real serious look at them, and I think it's  
25 time that we did that. That's most of the comments I

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1 had.

2 CHAIR SHACK: Graham.

3 CONSULTANT WALLIS: Well, I won't add  
4 anything now. I'll send you a report with details.

5 CHAIR SHACK: Any additional comments or  
6 questions before we go to the public? Well again, I'd  
7 like to thank the staff for a very informative  
8 presentation. Any comments or questions from the  
9 audience?

10 MEMBER STETKAR: Public comment?

11 MR. LYMAN: Thank you. This is Ed Lyman  
12 from the Union of Concerned Scientists. I'd just like  
13 to characterize what I think this study, where we are  
14 today with this study. Despite six years of effort  
15 and God knows how much staff time and money, it has  
16 essentially confirmed the magnitude of the latent  
17 health consequences from the siting study in 1982.

18 All you have to do is look at Table 7-15,  
19 to see that the -- other than the consequences within  
20 ten miles, the short-term station blackout unmitigated  
21 is within a factor of two of what they got in the 1982  
22 safety study. That factor of two is essentially  
23 meaningless, in light of the uncertainty analysis that  
24 we've seen, where the fission product releases are at  
25 least are variant, at least by a factor of two, and

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1 even if it's sublinear, you can see that it certainly  
2 could wash out a lot of that difference.

3 So I think the study, rather than finding  
4 significantly smaller latent health consequences than  
5 the siting study, it's essentially confirmed it. Now  
6 with regard to early fatalities, it's a tautology.  
7 All the study has shown is if you evacuate the public  
8 within the emergency evacuation zone before there's a  
9 release, that you're not going to have any early  
10 fatalities.

11 Now I think the great insight is that the,  
12 at least for the scenarios evaluated, core damage  
13 occurs, releases are delayed, relative to the  
14 assumptions that were for the SST-1 source term and  
15 what are contained in the baseline assumptions for the  
16 setting of the emergency evacuation zone.

17 But again, this does not evaluate -- this  
18 was not intended to evaluate the scenario which could  
19 lead to the fastest early release. That might be a  
20 large break LOCA or a terrorist attack, where you  
21 could conceivably have releases which are faster than  
22 even the short-term station blackout. So it doesn't  
23 really address the issue of whether emergency planning  
24 evacuation times are adequate.

25 And certainly with regard to Peach Bottom

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1 and Surry, these plants are not representative with  
2 regard to the evacuation time estimates that are  
3 achieved, because they're in relatively rural areas.  
4 So they're not representative of large population  
5 plants that are in more densely populated areas, where  
6 evacuation time estimates may be longer than five or  
7 six hours.

8 So I don't think -- so I think the study's  
9 a lot better than when it started, that there are  
10 interesting technical insights that have come out of  
11 it.

12 But it should stop pretending that it's  
13 proving something which it isn't proving, namely that  
14 there's some significant, that older estimates were  
15 significantly more conservative, and that somehow  
16 nuclear power is much, much safer than people thought  
17 in the past.

18 I think it essentially has highlighted  
19 some interesting areas, but essentially confirmed  
20 those older studies. Thank you.

21 CHAIR SHACK: Okay. Any other comments?

22 (No response.)

23 CHAIR SHACK: Is there anybody on the  
24 bridge line? Is the bridge line open?

25 (No response.)

1 CHAIR SHACK: Then I think we can adjourn  
2 for the day.

3 (Whereupon, at 5:47 p.m., the meeting was  
4 concluded.)

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**U.S. NRC**

UNITED STATES NUCLEAR REGULATORY COMMISSION

*Protecting People and the Environment*

**State-of-the-Art Reactor Consequence  
Analyses (SOARCA)  
ACRS Subcommittee  
Meeting**

Richard Chang

April 25, 2012

- Previous ACRS Interactions
- Conclusions for SOARCA Pilot Plants
- Status Update

# Previous SOARCA Briefings to ACRS

- July 2006- Subcommittee
- September 2006- Full Committee
- December 2006- Full Committee
- July 2007- Subcommittee
- November 2007- ACNW
- November 2007- Subcommittee
- December 2007- Full Committee
- June 2010- Subcommittee

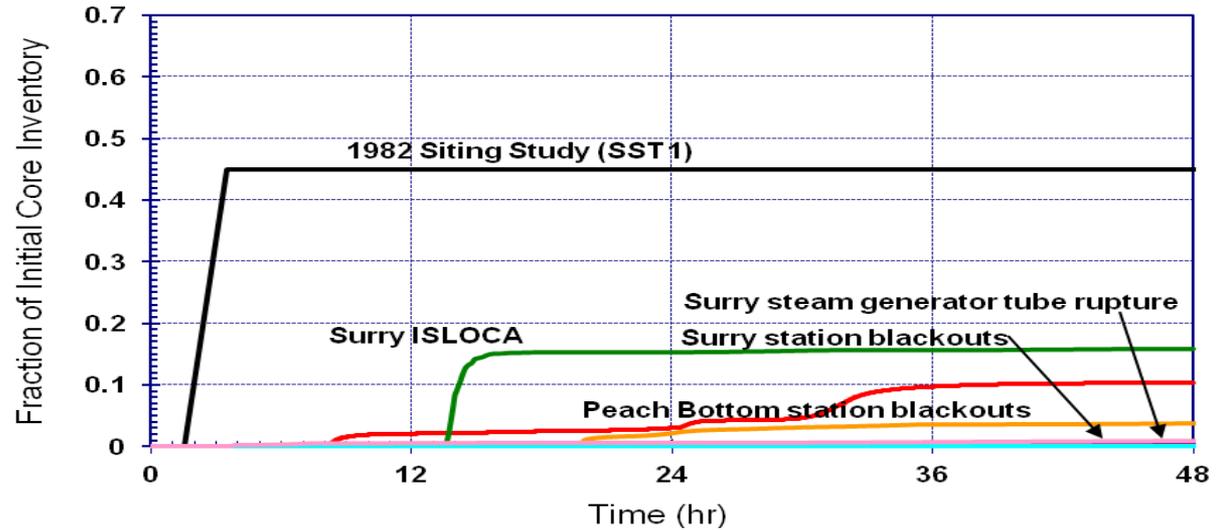
# Conclusions for SOARCA Pilot Plants

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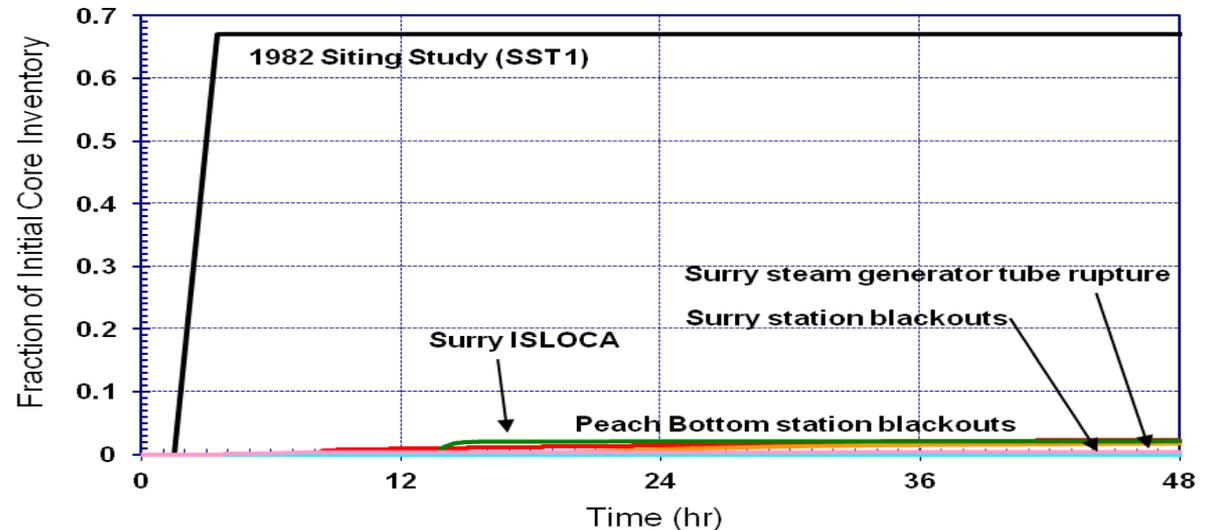
- When operators are successful in using available onsite equipment during the accidents analyzed in SOARCA, they can prevent the reactor from melting, or delay or reduce releases of radioactive material to the environment.
- SOARCA analyses indicate that all modeled accident scenarios, even if operators are unsuccessful in stopping the accident, progress more slowly and release much smaller amounts of radioactive material than calculated in earlier studies.

# Conclusions for SOARCA Pilot Plants (cont.)

Iodine Release

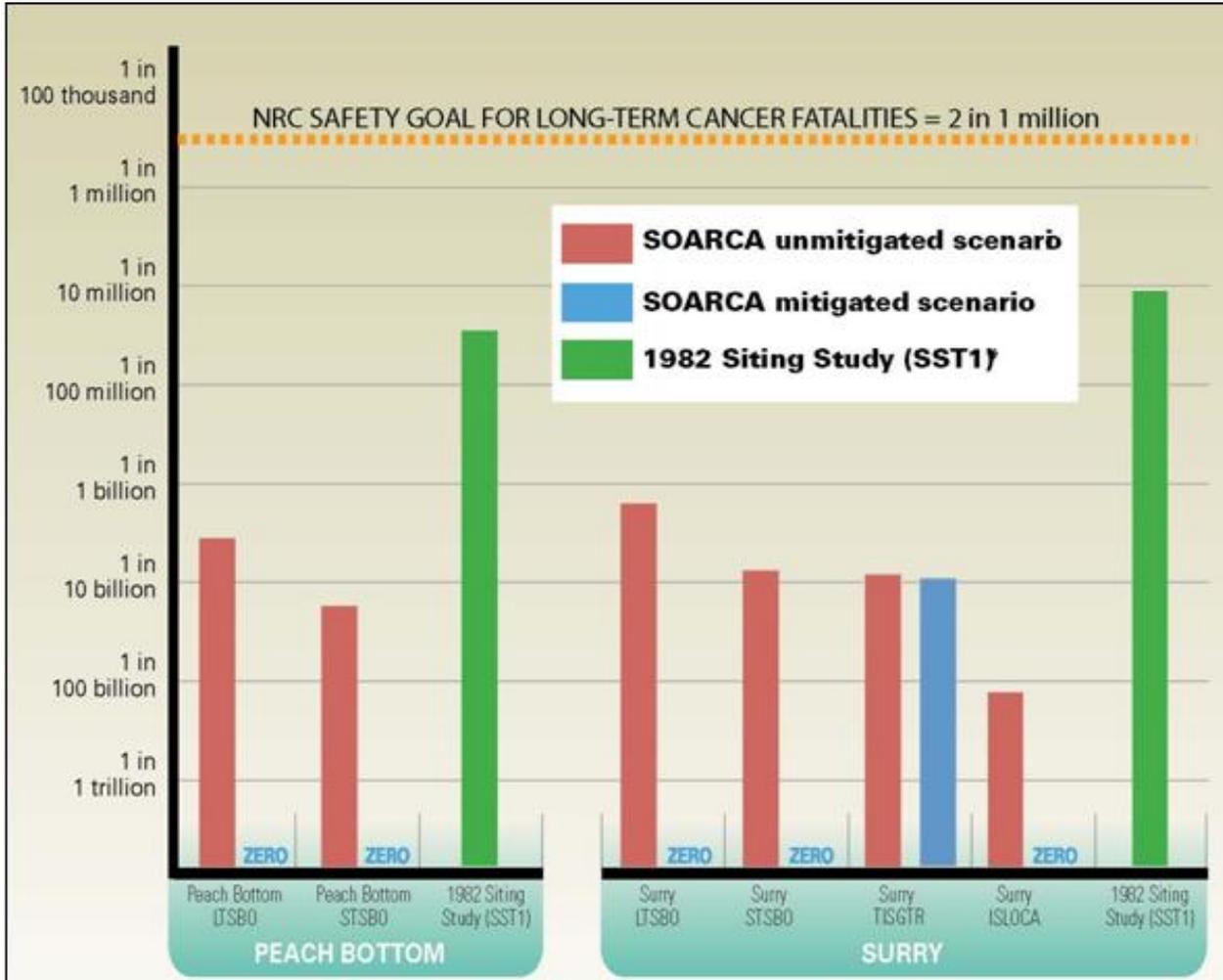


Cesium Release



# Conclusions for SOARCA Pilot Plants (cont.)

Scenario-Specific Risk of LCF for an individual within 10 miles assuming LNT (per reactor-year)



Note: Comparisons of SOARCA's calculated long-term cancer fatality risks to the NRC Safety Goal and the average annual U.S. cancer fatality risk from all causes are provided to give context. Relative to the safety goal comparison, the safety goal is intended to encompass all accident scenarios. SOARCA does not examine all scenarios typically considered in PRA. Additionally, estimated risks below  $1 \times 10^{-7}$  per reactor year should be viewed with caution because of the potential impact of events not studied in the analyses and the inherent uncertainty in very small calculated numbers.

\* The 1982 Siting Study did not calculate the risk of long-term cancer deaths. Therefore, to compare the 1982 Siting Study SST1 results to SOARCA's results for risk of long-term cancer death, the SST1 release was put into the MACCS2 code files for Peach Bottom and Surry unmitigated STSBO calculations.

- New/revised analyses based on plant fact checks/external peer review committee comments
  - PB RCIC start time for STSBO w/blackstart; SRV analyses; TIPS; and Ba/Ce
  - Surry ISLOCA reanalysis; and mitigated LTSBO
- Fukushima Appendix
- SOARCA Peer Review
- Public Comments and Commission Documents
- SOARCA Uncertainty Analysis



# **Resolution of Peer Review Issues on the Peach Bottom MELCOR Analysis**

**ACRS Briefing  
April 25, 2012**

**M.T. Leonard  
R.O. Gauntt**

**State-of-the-Art Reactor Consequence Analysis Program**



# Outline

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**Overview of three topics discussed at length with the SOARCA Peer Review panel:**

- Effects of SRV seizure (open) on accident progression and source terms**
- Potential for containment bypass and early fission product leakage from containment via failed in-core instrument tubes**
- Late environmental release of Barium and Cerium**

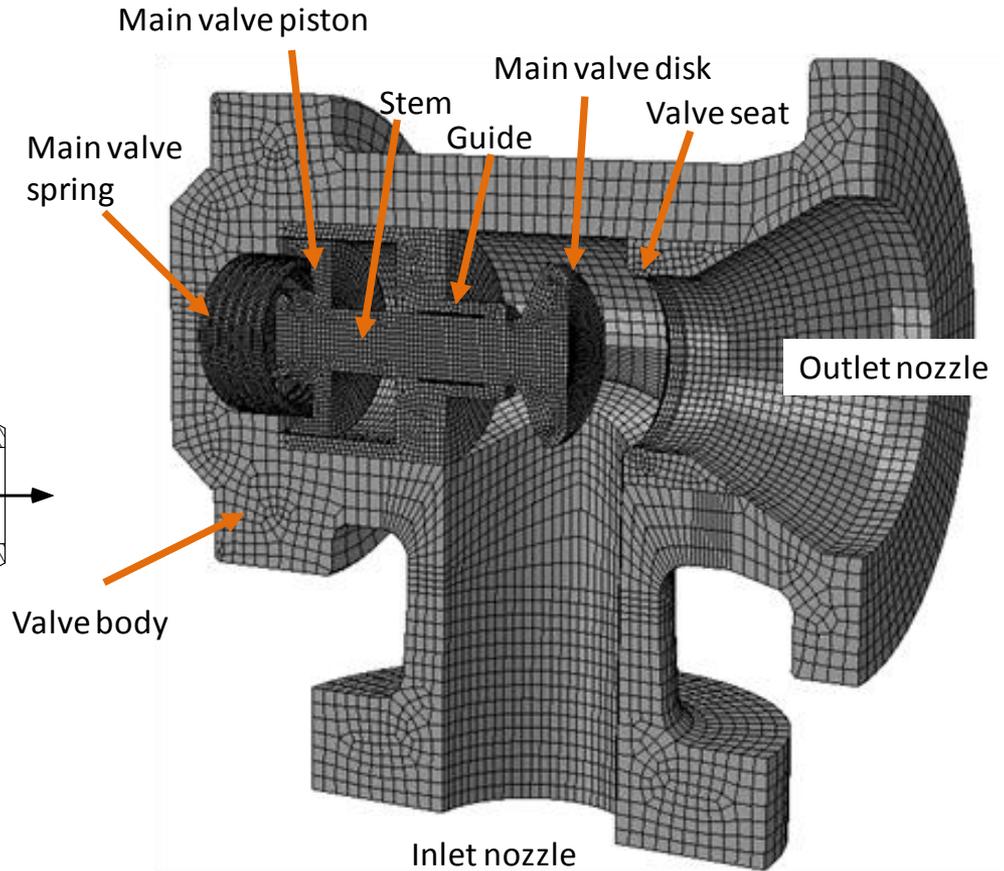
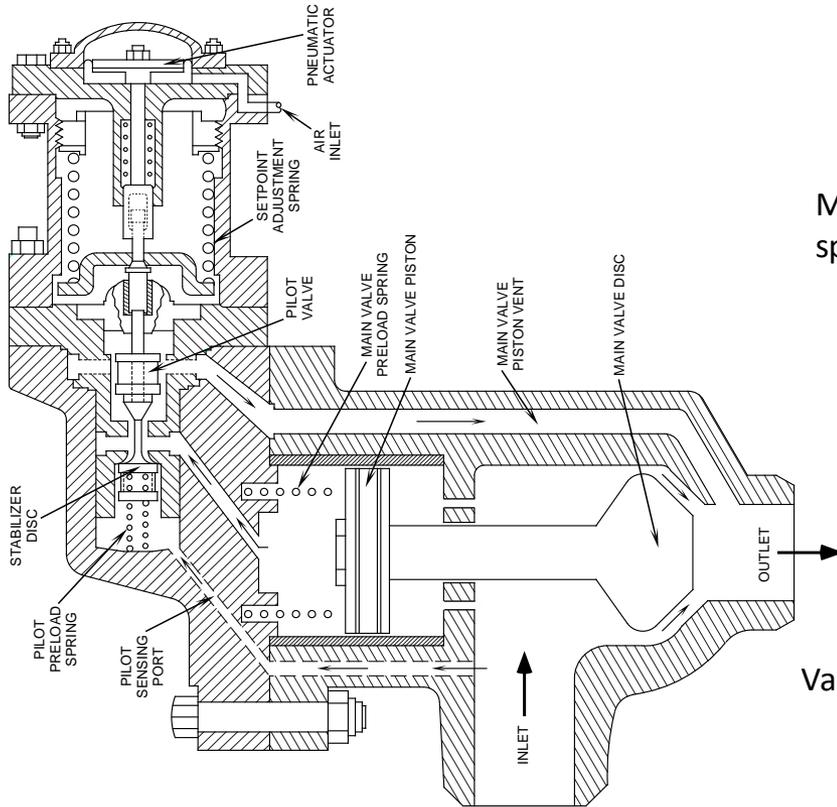


# (1) SRV Failure Mechanisms During LTSBO

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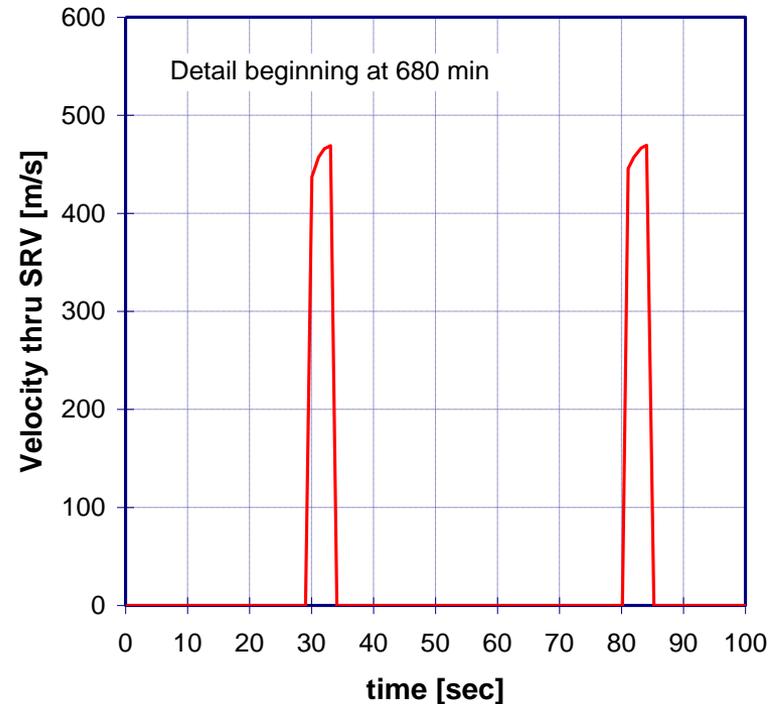
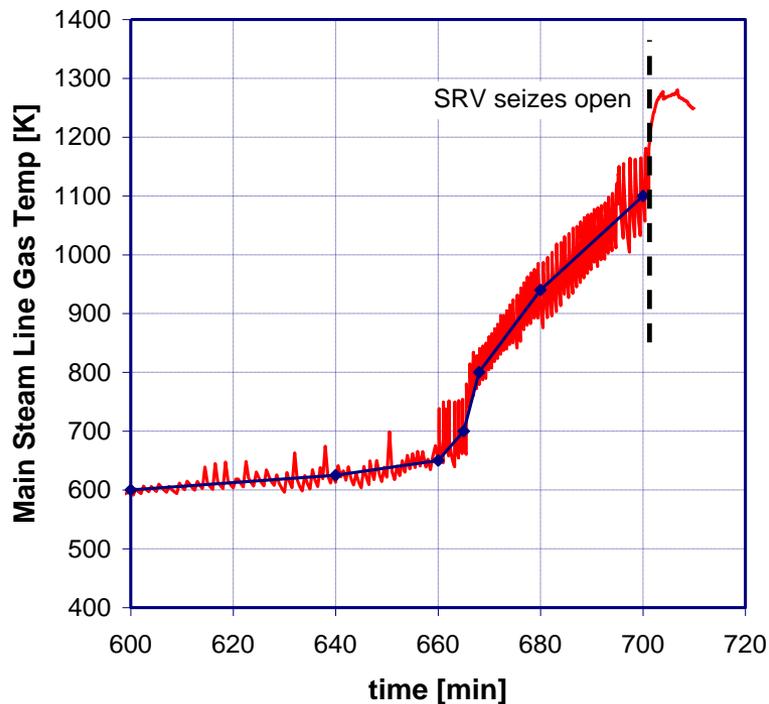
- **Stochastic failure to reclose**
  - Random failure of valve closure mechanism
  - High number of valve cycles
  - Addressed by applying SRV failure rate ( $\lambda$ ) from Level 1 PRA data base: expected value ( $1/\lambda$ ) for number of successful cycles before failure ~270.
- **Seizure in open position after onset of core damage due to heat transfer from high temperature gas**
  - Thermal expansion of internal valve components likely failure mechanism
  - Addressed by calculating thermal response of sample valve internal component and comparing to seizure criterion based on detailed finite element model of SRV

# Finite Element Model of Target Rock SRV

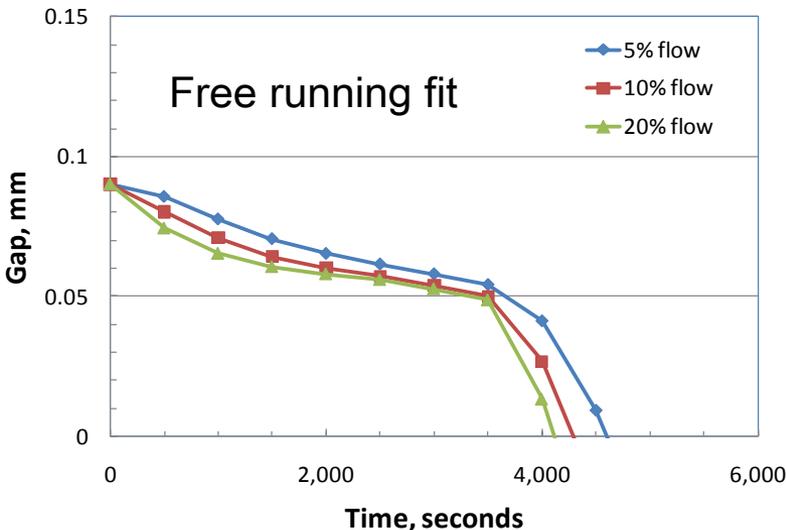
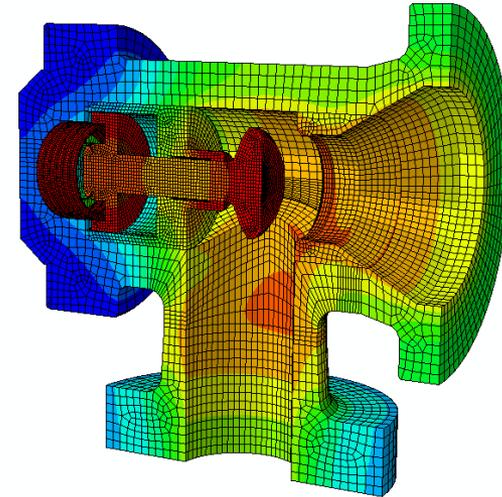
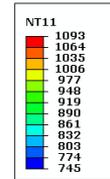
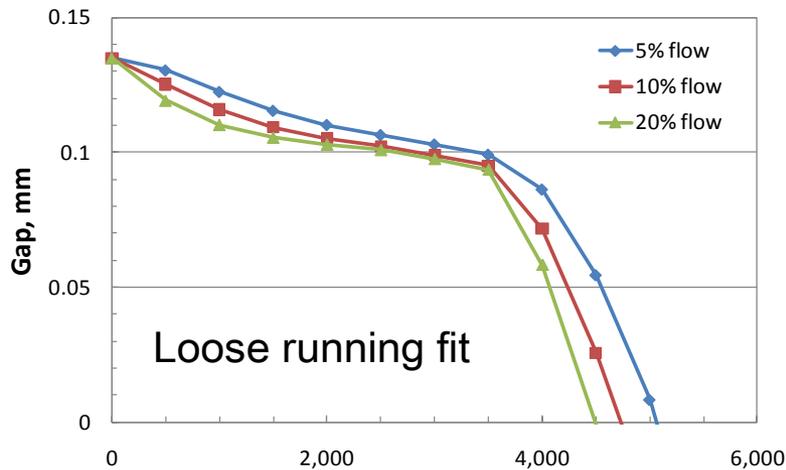


# Thermal Analysis of Target Rock SRV (2)

- **Boundary conditions: temperature and flow from MELCOR calculation of LTSBO**



# Reduction in Gap Clearance for Valve Stem



Clearance Fit Type	Minimum gap size, mm
Loose running fit	0.135
Free running fit	0.090
Close running fit	0.0275

Full closure of gap, when:  
 $800K < T_{gas} < 900K$

# Impact of Alternate SRV Failure Criteria on Environmental Release

SRV seizure criterion	SRV failure mode	Nr of cycles at Seizure	Time of SRV Seizure (hr)	Max MSL L-M Damage Index	Iodine Release to Env > 1% (hr)	Fraction of Inventory in Environment at 48 hrs		
						Iodine	Cesium	Ba
<b>LTSBO</b>								
Valve Stem > 900K; Stochastic 63%	S	270	8.2	5.4E-08	23.5	2.0%	0.5%	0.6%
Valve Stem > 811K; Stochastic 90%	T	465	11.2	1.2E-05	21.8	3.2%	3.2%	1.3%
Valve Stem > 900K; Stochastic 90%	T	475	11.4	7.0E-04	21.2	4.8%	1.8%	0.8%
Valve Stem > 900K; Stochastic 90% (1/10 open area)	T	475	11.4	1.0	12.8	17.8%	5.3%	1.5%
Valve Stem > 900K; Stochastic 90% (1/2 open area)	T	475	11.4	0.0290	20.6	3.3%	2.3%	0.8%
Valve Stem > 1100K; Stochastic 90%	T	497	11.7	0.53	21.0	3.5%	1.9%	1.5%
<b>STSBO</b>								
Valve Stem > 900K; Stochastic 5%	S	15	5.5 min	2.4E-06	12.1	1.7%	0.5%	4.3%
Valve Stem > 900K; Stochastic 50%	S	187	1.7	1.6E-05	9.2	11.4%	1.7%	6.3%
Valve Stem > 811K; Stochastic 90%	T	187	1.7	1.6E-05	9.2	11.4%	1.7%	6.3%
Valve Stem > 900K; Stochastic 63%	T	195	1.8	0.001	9.7	11.6%	1.7%	9.6%
Valve Stem > 900K; Stochastic 90% (1/10 open area)	T	195	1.8	1.0	5.5	18.4%	8.0%	4.7%
10 cycles with Gas Temp > 1000K; Stochastic 90%	T	211	2.1	0.133	8.8	11.1%	2.0%	8.4%

Indicates "Best Estimate" Case

S=stochastic  
T=Thermal

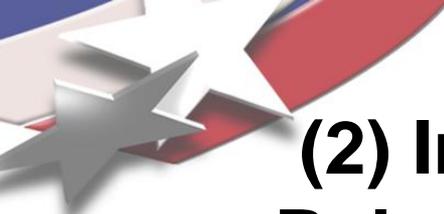
Grey indicates cases in which MSL creep rupture occurs.



# Conclusions of SRV Sensitivity Analysis

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- **Variations in SRV failure criteria have significant effect on in-vessel thermodynamic signatures, but small effect on:**
    - Time to lower head failure
    - Time environmental release begins
    - Cumulative release to environment
- ... provided creep rupture of the main steam line (MSL) is averted.**
- Conditions leading to MSL creep rupture to be investigated in detail in SOARCA Uncertainty Analysis**

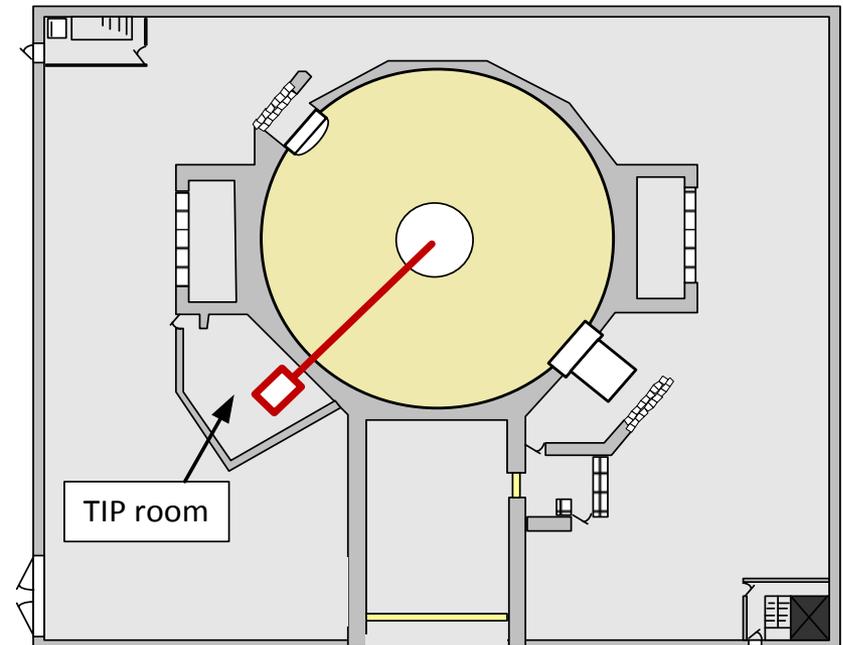
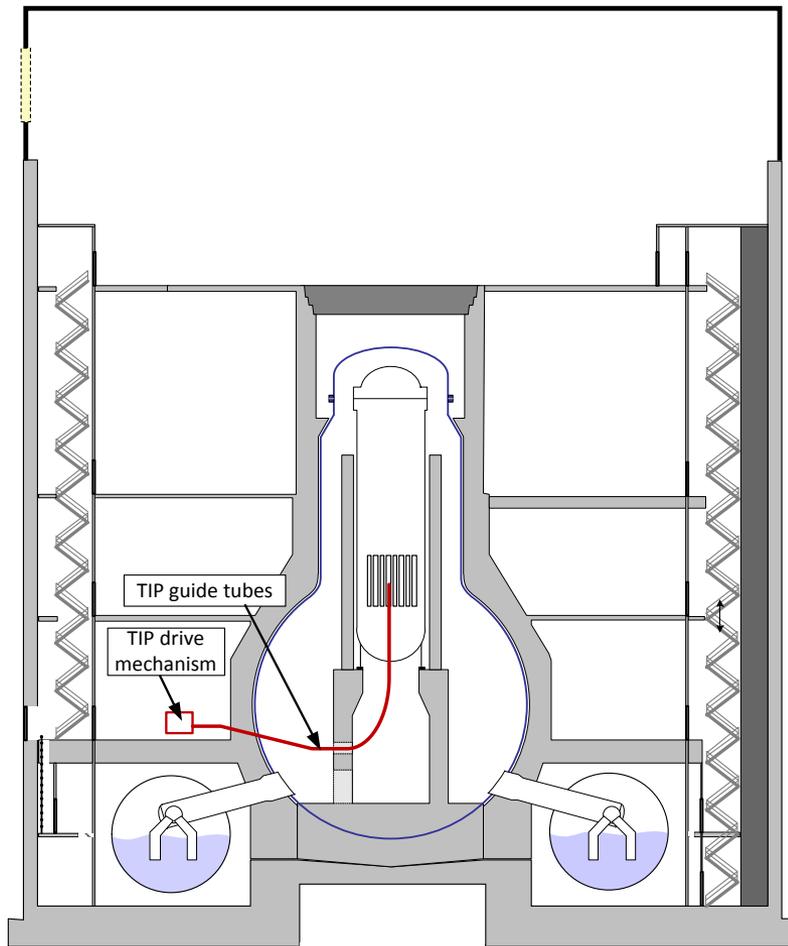


## **(2) Investigation of Early Fission Product Release through In-core Instrument Tubes**

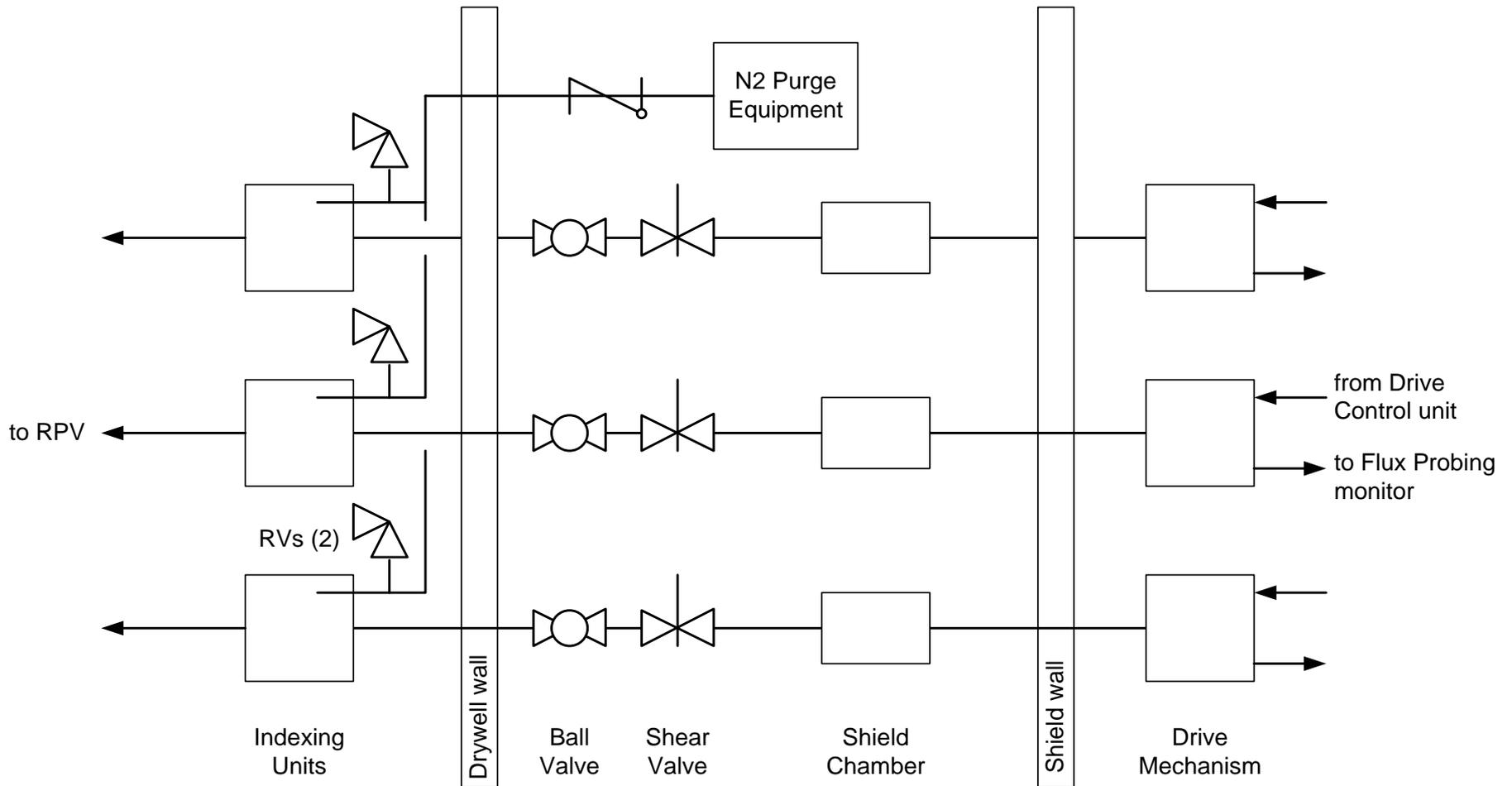
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- **Description of “Traversing In-core Probe” (TIP) system**
  - **Mechanical configuration**
  - **Potential leak pathway(s)**
  - **Operating practice (time windows for leakage)**
- **MELCOR model**
- **Calculated Results for LTSBO**

# Postulated Containment Bypass Leak Pathway via TIP tubes



# TIP Drive Configuration





# Operating Conditions

---

- **TIP system in operation (ave) 1-hr every 4 months**
  - Average conditional frequency =  $4.6E-4/yr$
- **All three tubes in operation simultaneously to minimize overall exposure time**
  - Probe inserted (tube cross-section occupied by drive cable) most of operating time period
  - All probes fully-withdrawn unlikely, but possible
- **Isolation valves require electric power to operate**
  - No formal provisions for actuation if power is unavailable

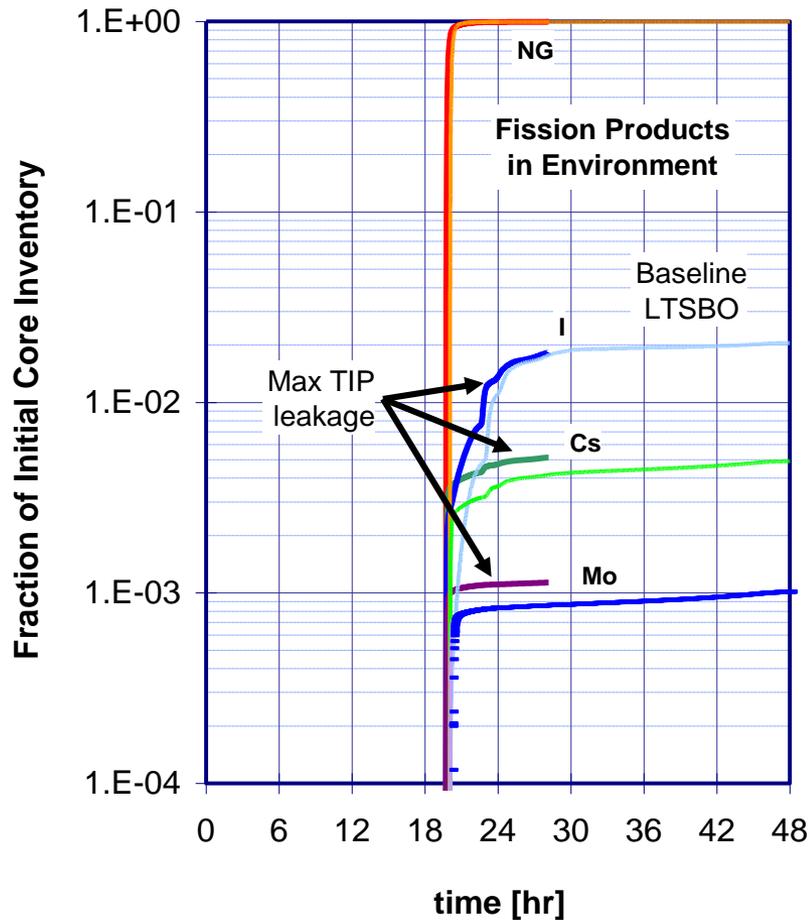


# Leakage Potential

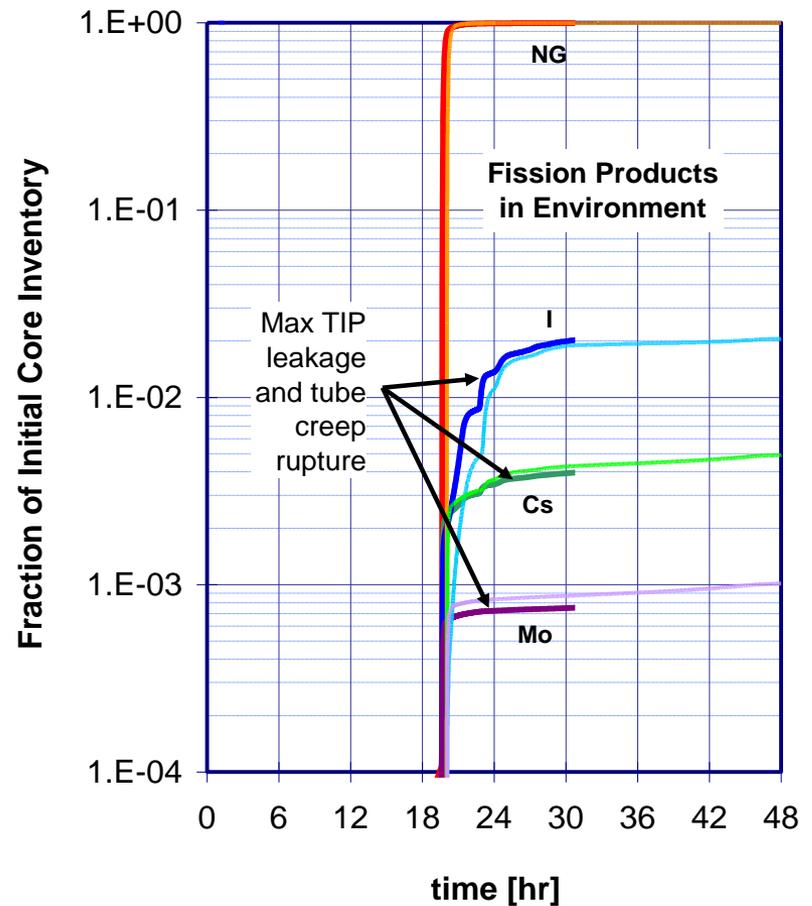
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- **Bounding case**
  - 3 lines in operation at a time (isolation valves open)
  - All 3 probes fully withdrawn to shield chamber
  - Area corresponding to 3 x 0.28-in (ID)
- **More realistic case**
  - 3 lines in operation (isolation valves open)
  - All probes inserted (tubes filled with 0.258-in cable)
- **In both cases limited area defined by tube cross-section (RVs and tube end-point areas larger)**

# Sensitivity Calculations with Bounding TIP Leakage – Source Term



Continuous TIP leakage



Creep Rupture of TIP tube



# Conclusions on Effects of TIP Leakage

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- **Frequency of accident sequence occurring at time TIP system in operation well below truncation threshold ( $\sim 10^{-9}$  to  $10^{-10}$ )**
- **Most likely leak area less than  $0.1 \text{ in}^2$** 
  - Bounding area  $\sim 0.8 \text{ in}^2$
- **Possibility of creep rupture of tube in drywell**
  - Eliminates direct containment bypass, but retains early containment (drywell) leakage
- **Effects on F.P. release are small for bounding (maximum) leak rate**



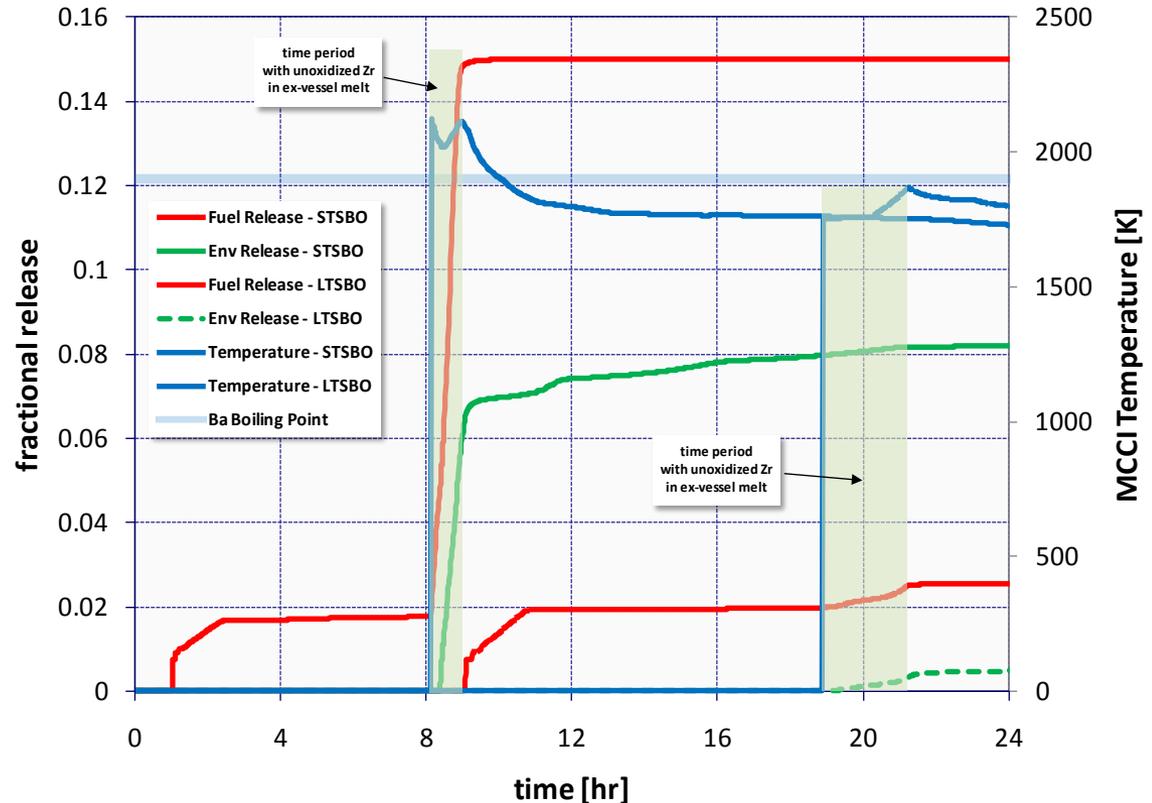
# Ba and Ce Behavior Background

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- **Ba and Ce predicted to dominate “emergency phase” doses for Peach Bottom STSBO**
  - ~10% in STSBO versus ~ 1% in LTSBO
- **Enhanced release occurs during the ex-vessel MCCI phase**
  - CORCON/VANESSA
- **Investigation show enhanced release attributable to**
  - Chemically reducing environment (*essential*)
  - MCCI temperature (*strong effect*)
  - Strong mass transfer from MCCI gas generation (maintains disequilibrium)
  - BWR’s have more Zr in core relative to PWR’s

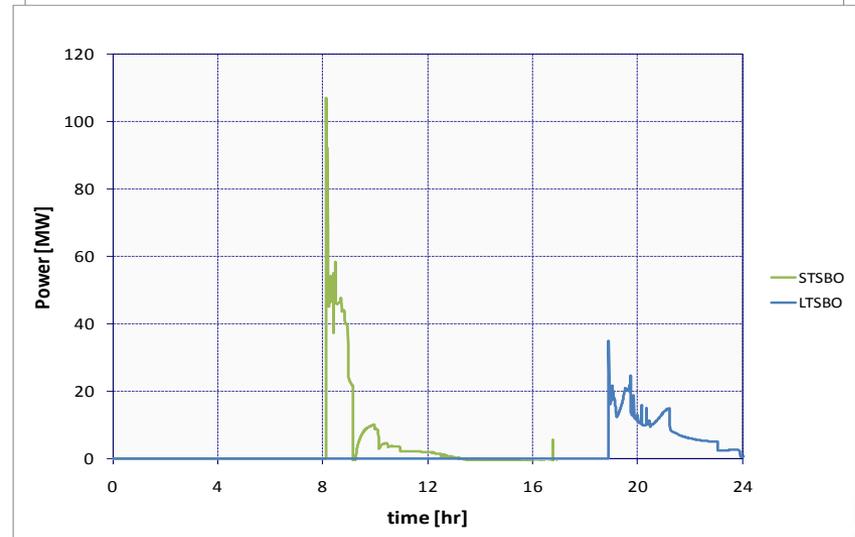
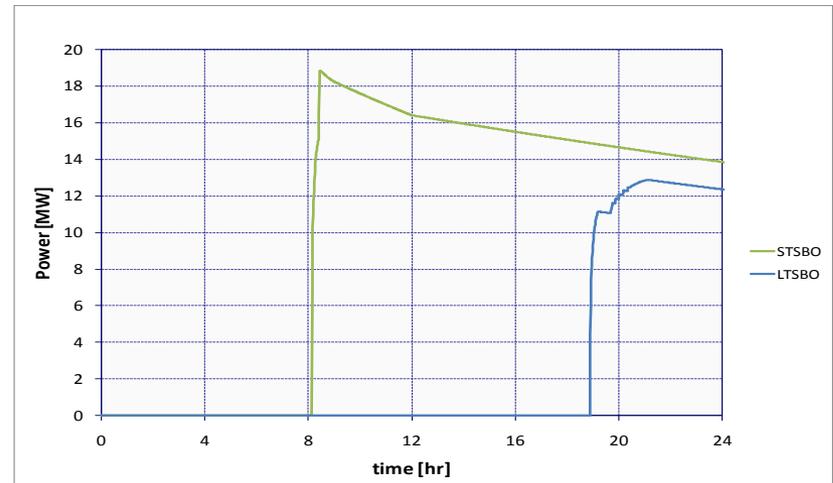
# Barium Release

- **Considerable variability was observed with respect to Barium releases**
  - General trend is that environmental releases for the STSBO are on the order of 8% to 10%
  - The LTSBO, on the order of 0.5% to 1%

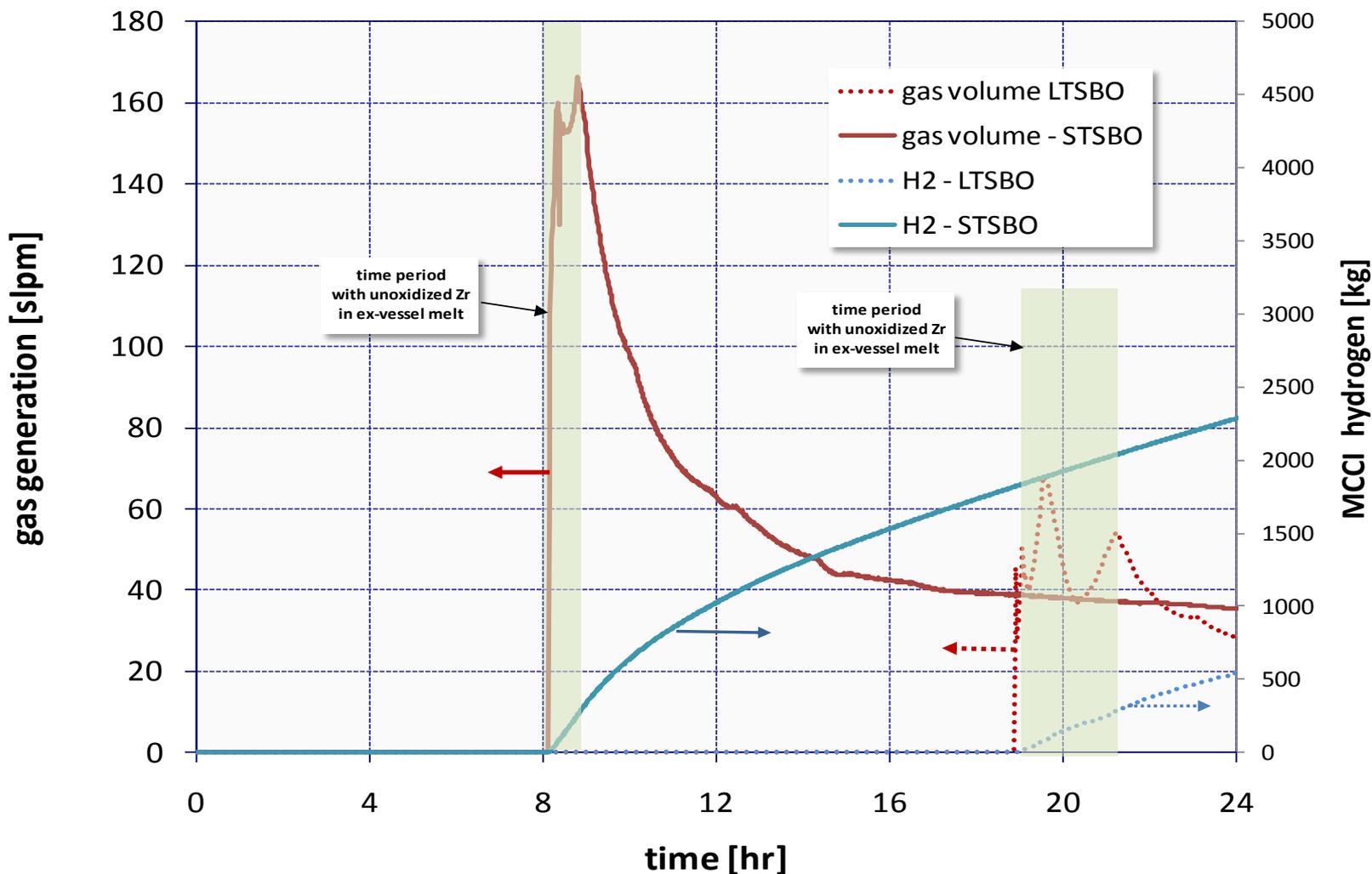


# Decay Heat and MCCI Chemical Power

- Decay heat is larger in STSBO
- Temperature is higher in STSBO
- MCCI Chemical heat is larger in STSBO
- Factors combine to maintain higher MCCI temperature
- Gibbs energy is sensitive to temperature
- Net effect is higher partial pressure of Ba and Ce



# Non-condensable gas and H<sub>2</sub> generation in MCCI stage of STSBO and LTSBO





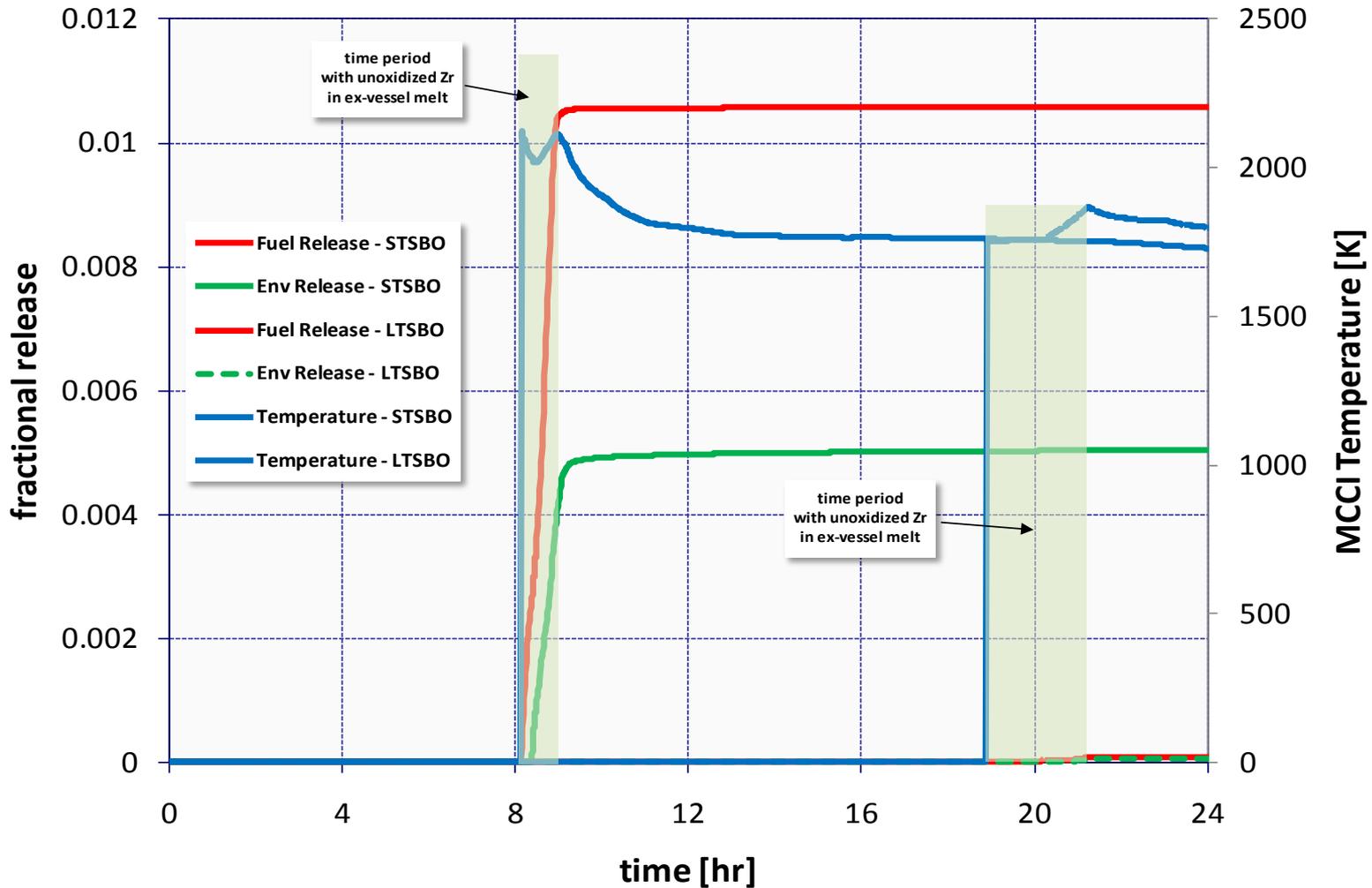


# Cerium Release

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- **Ce and to a lesser extent La show similar trends of enhanced release in the STSBO BWR analysis, again attributable to the intense but brief period of Zr driven chemical reduction in the ex-vessel MCCI release phase**
- **In the case of Cerium release, the fraction of the inventory that is released in-vessel is vanishingly small and for both STSBO and LTSBO, Ce release essentially occurs in the ex-vessel MCCI phase**

# Fractional release of Cerium in STSBO





# Cerium Chemical Reaction

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- The net reaction for release of Ce in the ex-vessel stage is:



- Where the metallic Zr ensures highly reducing conditions are maintained and the vigorous gas sparging through the MCCI melt ensures the equilibrium is shifted towards the right hand side of the equation



## Barium and Cerium Conclusions

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- While not readily apparent by MELCOR output, the partial pressure of hydrogen in the MCCI melt for the STSBO is much larger than in the LTSBO due to more rapid Zr oxidation and higher melt temperature, both effects responsible for the much larger predicted Ba and Ce release
- Again, as with the Ba release when the metallic zirconium becomes consumed the sparging rate of non-condensable gas decreases and the reduction potential is diminished considerably and the release of Ce falls off



# Conclusions on Barium / Cerium Release

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## Summary Discussion



**U.S. NRC**

UNITED STATES NUCLEAR REGULATORY COMMISSION

*Protecting People and the Environment*

**Updated Surry Analysis  
ISLOCA Reanalysis**

ACRS Subcommittee Meeting

April 25, 2012

# Overview

- ISLOCA analysis required complete revision
  - Licensee reviewed SOARCA Surry report in 2010
    - Licensee identified that the release pathway into Aux building which afforded significant deposition is filled with penetration sealant
    - Original ISLOCA analysis had significant deposition in Aux building
    - Original ISLOCA analysis had LHSI pumps flooding in 2 minutes
- Site visit and plant walkdown – January 2011
  - Developed new detailed model of Safeguards Area, Containment Spray Pump Area and Main Steam Valve House
  - Developed detailed ventilation system model
  - Developed LHSI piping model
  - Additional review of mitigation

# Overview

- Added new models to MELCOR
  - Turbulent deposition in straight pipes
  - Inertial deposition in elbows and other flow irregularities
  - Validated against LACE tests and benchmarked against VICTORIA
- Results
  - Core damage began in 13 hours (previously estimated 9 hours)
    - Operator actions (by procedure) to stop and isolate both LHSI pumps and to stop 2 of 3 HHSI pumps
    - Operators used Surry plant simulator to estimate times to stop and isolate LHSI pumps
  - Iodine and cesium releases of 16% and 2%, respectively. (previously estimated 9% for both iodine and cesium)
    - Significant deposition in RCS, LHSI piping
    - Iodine revaporization from LHSI piping with subsequent deposition in Safeguards Area and ESF Filtration which serves Safeguards Area

# Overview

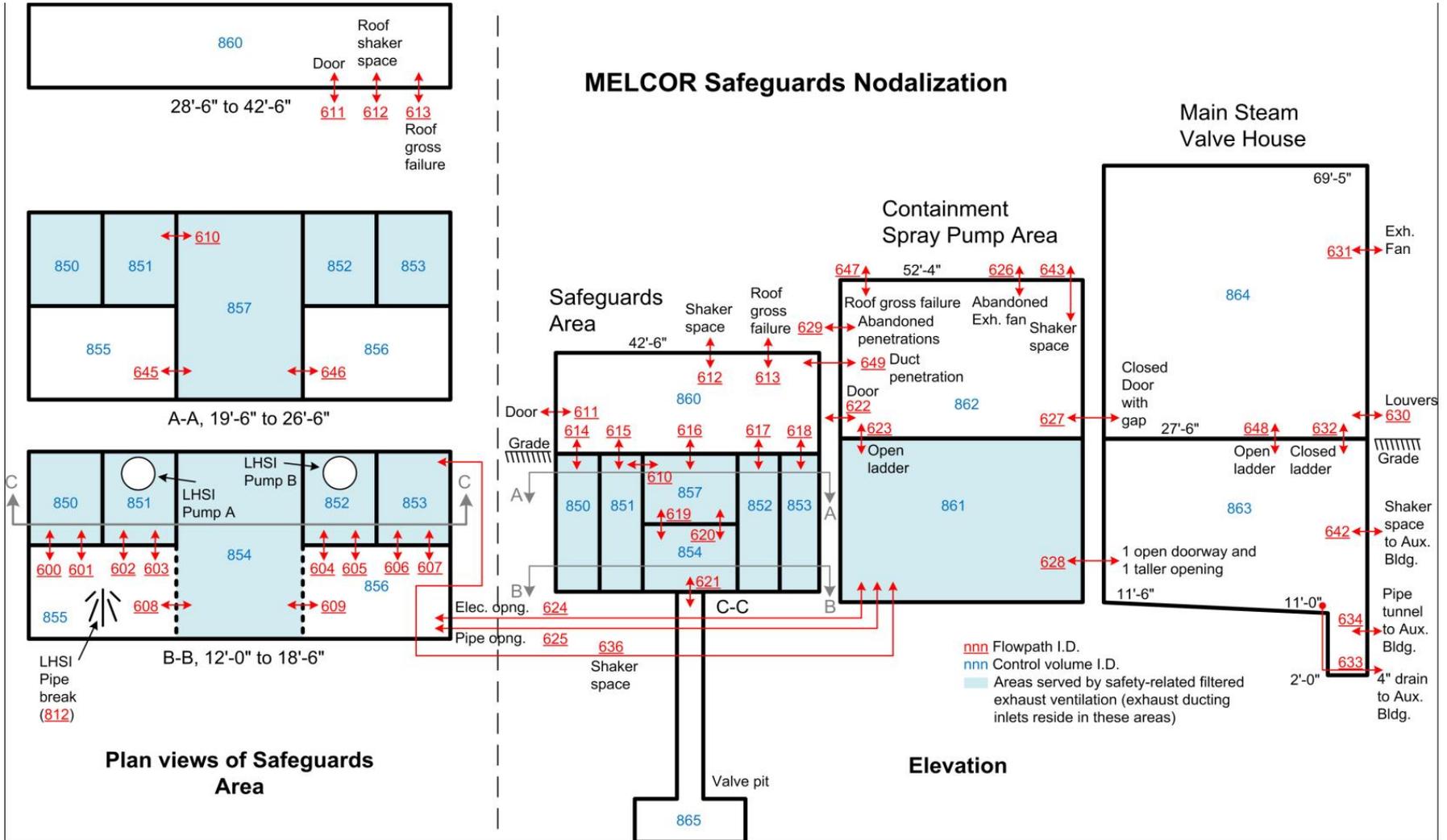
- Used MELCOR analysis to identify conservatisms in PRA model and additional mitigation measures that are practical (e.g., use of RHR prevents core damage)

# Approach to ISLOCA Reanalysis

- Developed new full plant MELCOR model for integrated analysis of ISLOCA
  - Includes detailed modeling of Safeguards Area, Containment Spray Pump Area, Main Steam Valve House and ventilation system
  - Uses DFs from separate effects MELCOR model for LHSI piping
    - separate effects model incorporates new deposition models
      - turbulent deposition in straight pipes and inertial deposition in elbows, venturis, sudden contractions

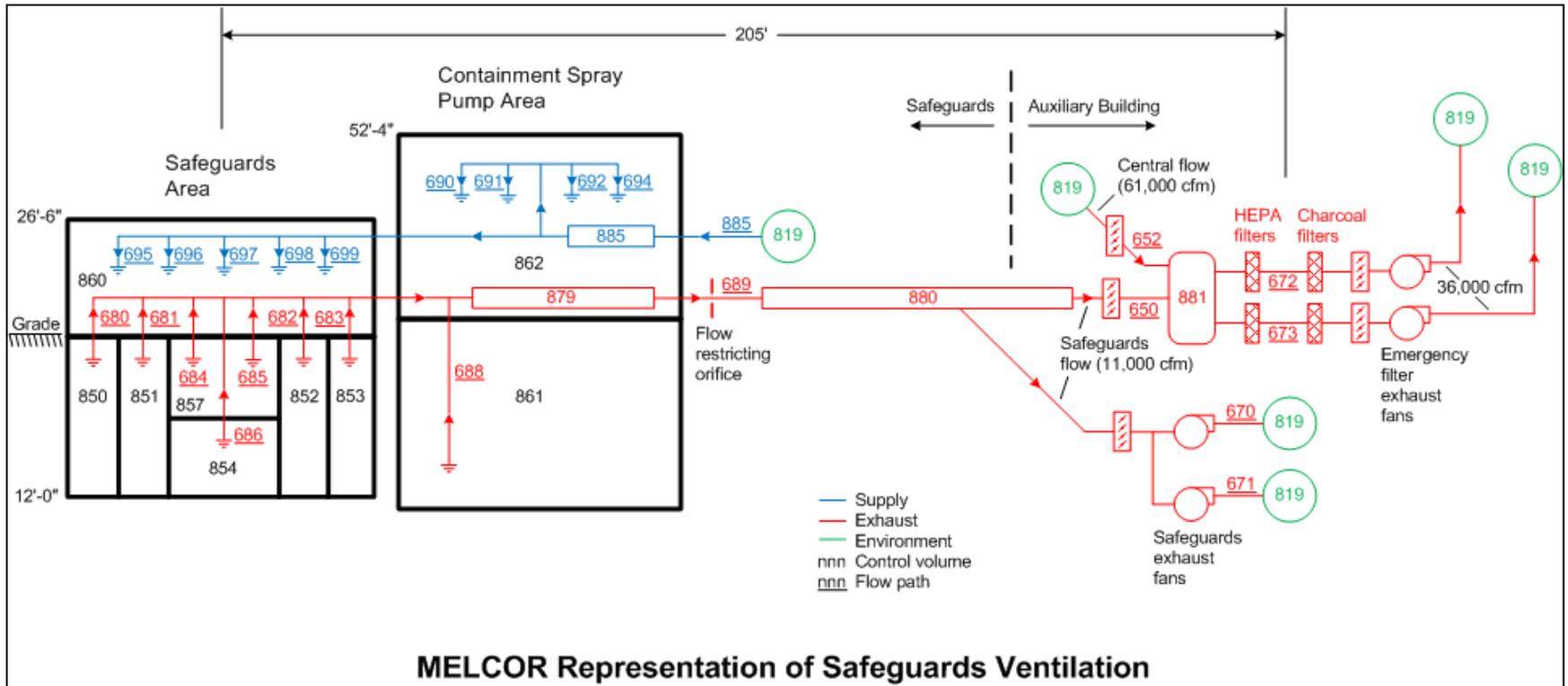
# Full Plant MELCOR Model

## Safeguards Area, Containment Spray Pump Area, Main Steam Valve House





# Full Plant MELCOR Model ESF Ventilation System

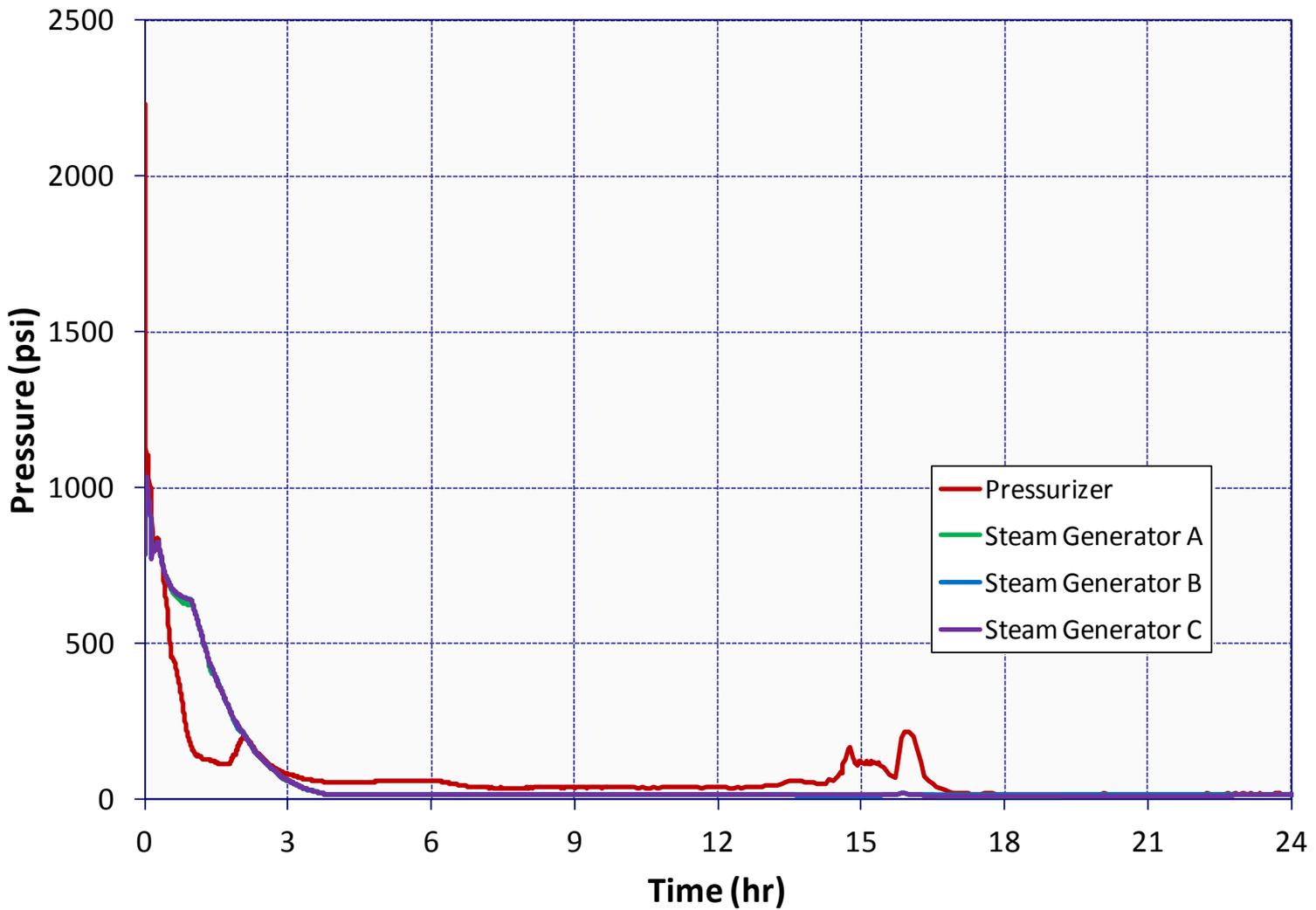


# Unmitigated ISLOCA – No RWST Refill

Event Description	Time (hh:mm:ss)
LHSI check valves fail	00:00:00
LHSI piping ruptures in Safeguards Area (outside Containment)	00:00:00+
Safeguards Area personnel door opens	00:00:16
SCRAM	00:00:22
ECCS initiates	00:00:26
Safeguards Area filtered exhaust ventilation system starts	00:00:26
Safeguards Area roof flashing tears	00:00:36
LHSI isolation valve MOV 1890C motor floods (valve inoperable)	00:02:41
MSVH/Aux. Bldg. pipe tunnel opens (penetration sealant dislodges)	00:04:13
Operators stop LHSI Pump A*	00:06:17
Operators secure 1 of 3 HHSI pumps	00:15:00
Operators stop LHSI Pump B*	00:15:44
Operators isolate LHSI pump suction*	00:16:18
Accumulators begin discharging	00:28:27
Operators begin cooldown	01:00:00
Accumulators exhausted	01:12:00
Operators secure 2 of 3 HHSI pumps	01:45:00
RWST exhausted, HHSI ends	06:12:00
Water level at TAF	10:15:00
First fuel rod gap release	12:49:00
First hydrogen burn	13:29:00
Release of 1% of core inventory of iodine to environment	13:39:00
Safeguards roof fails grossly (from hydrogen burn)	13:54:00
Reactor lower head fails	18:34:00

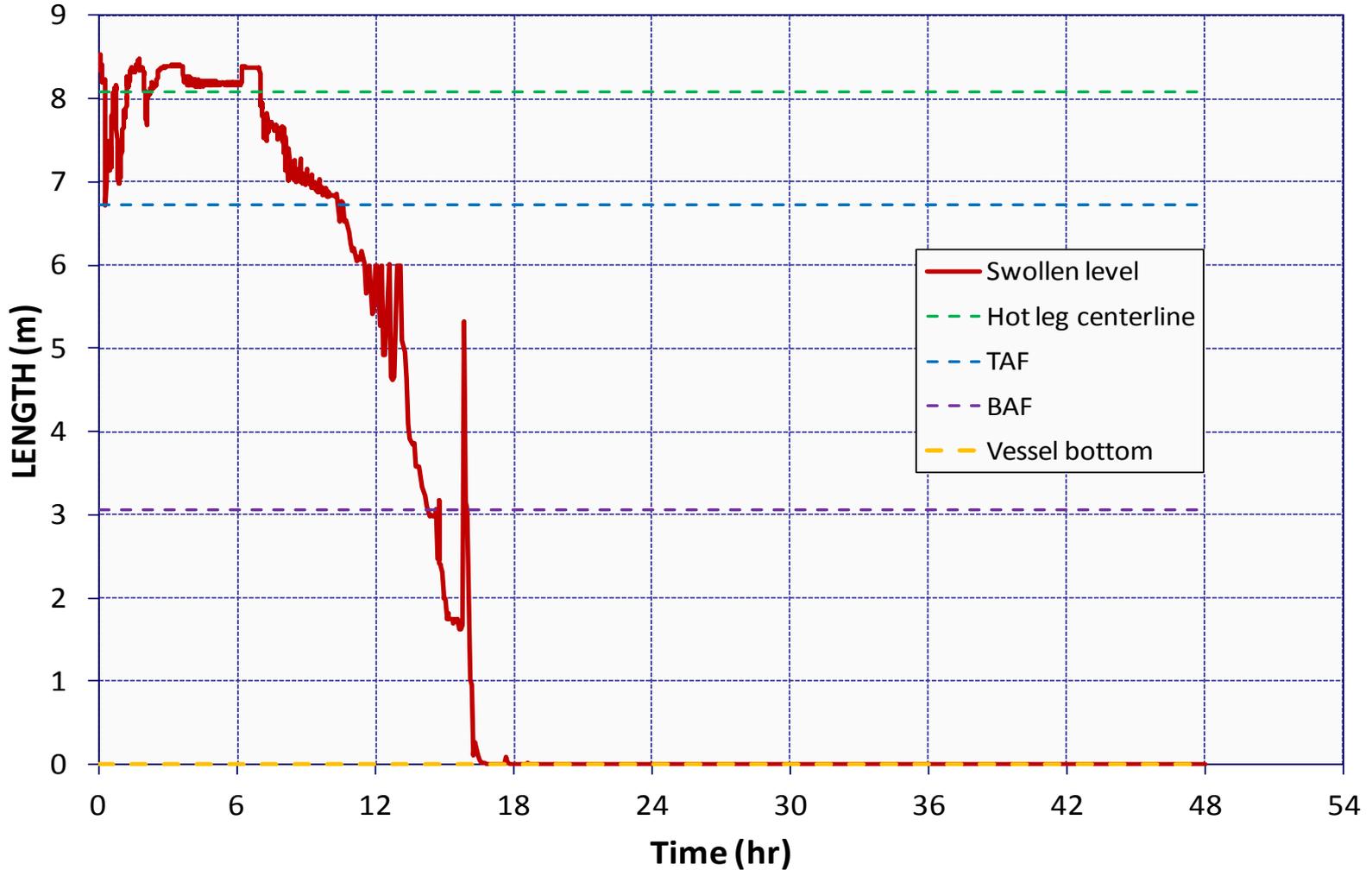
\*Operators used Surry plant simulator to estimate times to stop and isolate LHSI pumps.

# RCS Pressure



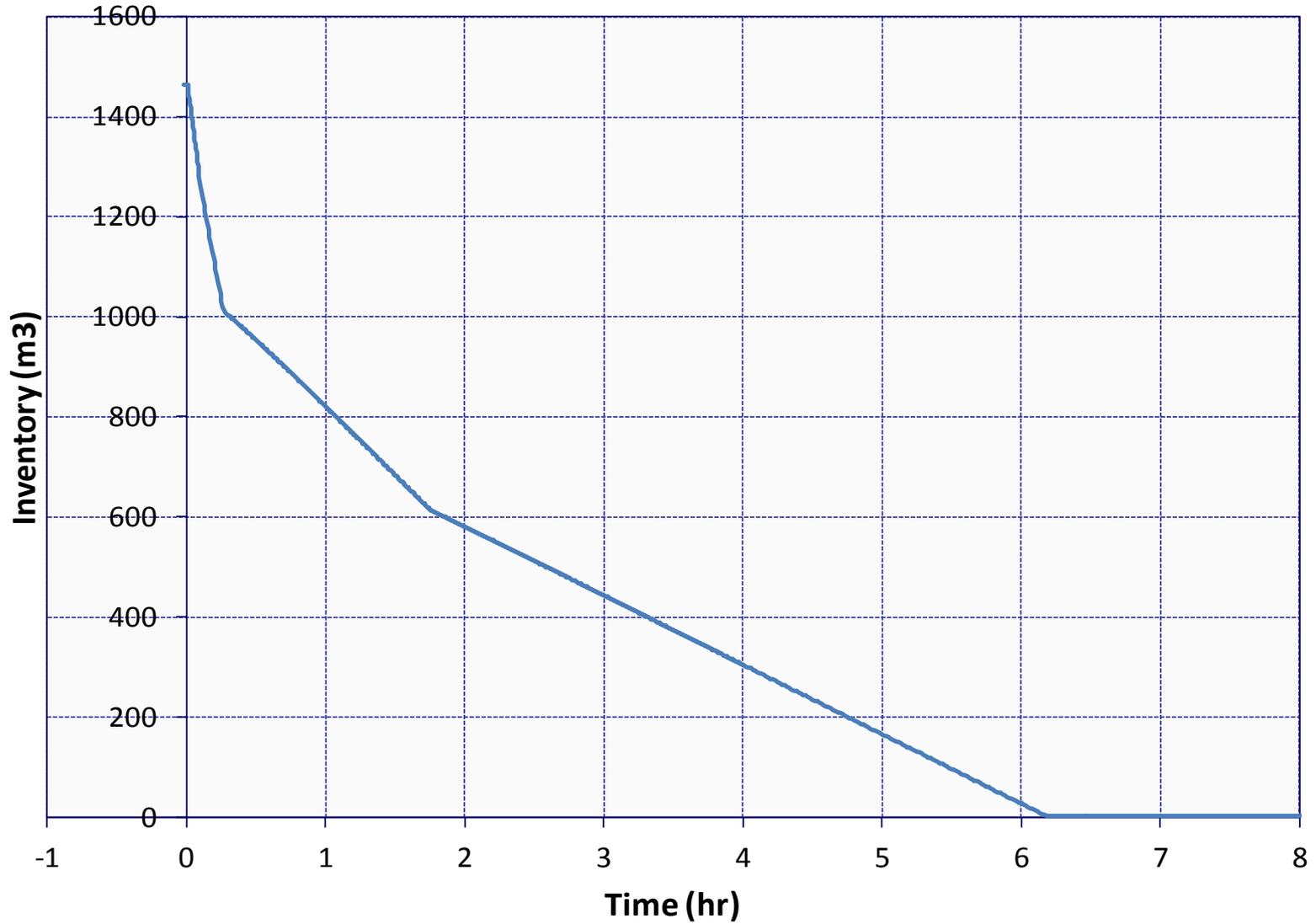


# Reactor Vessel Water Level

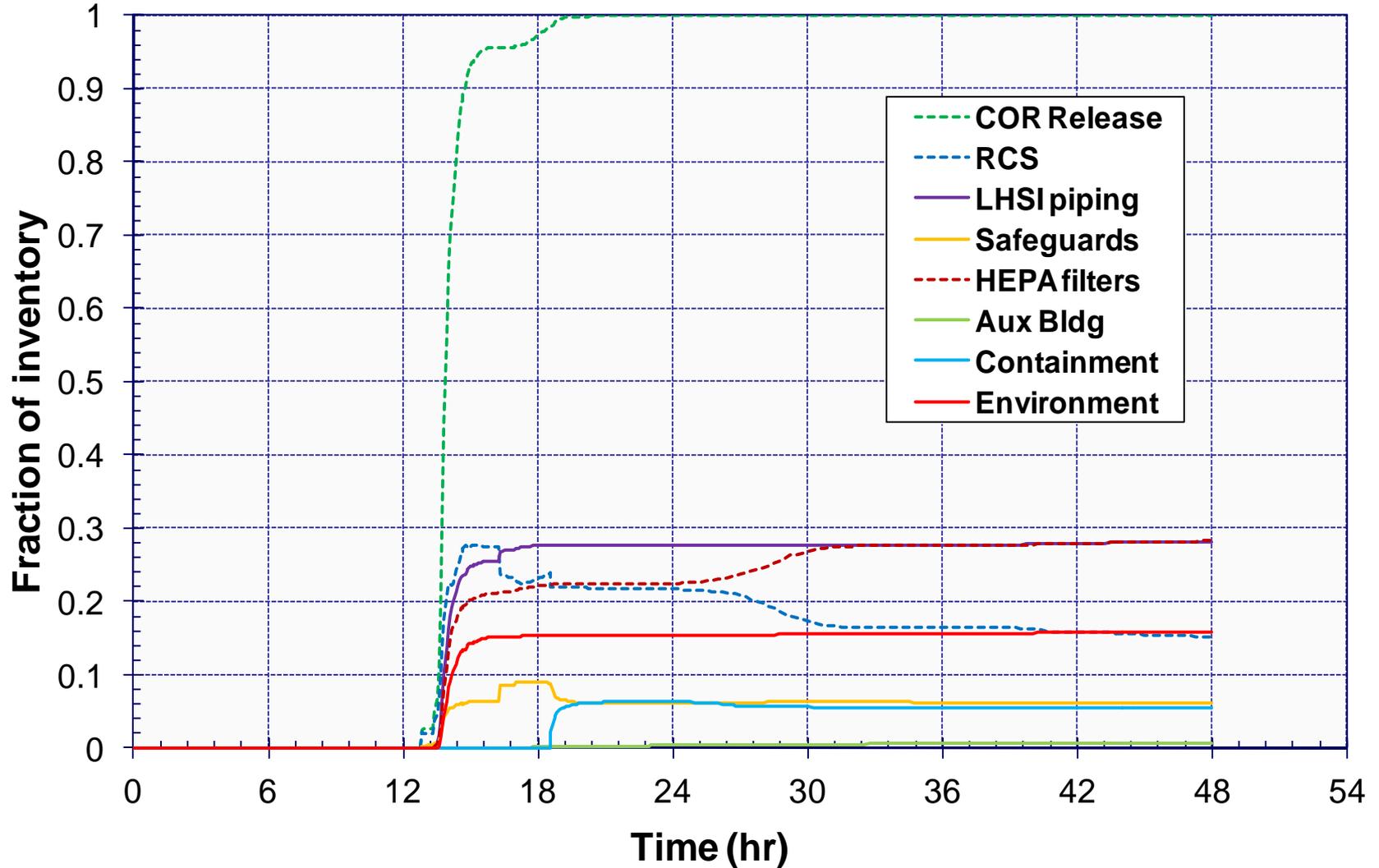




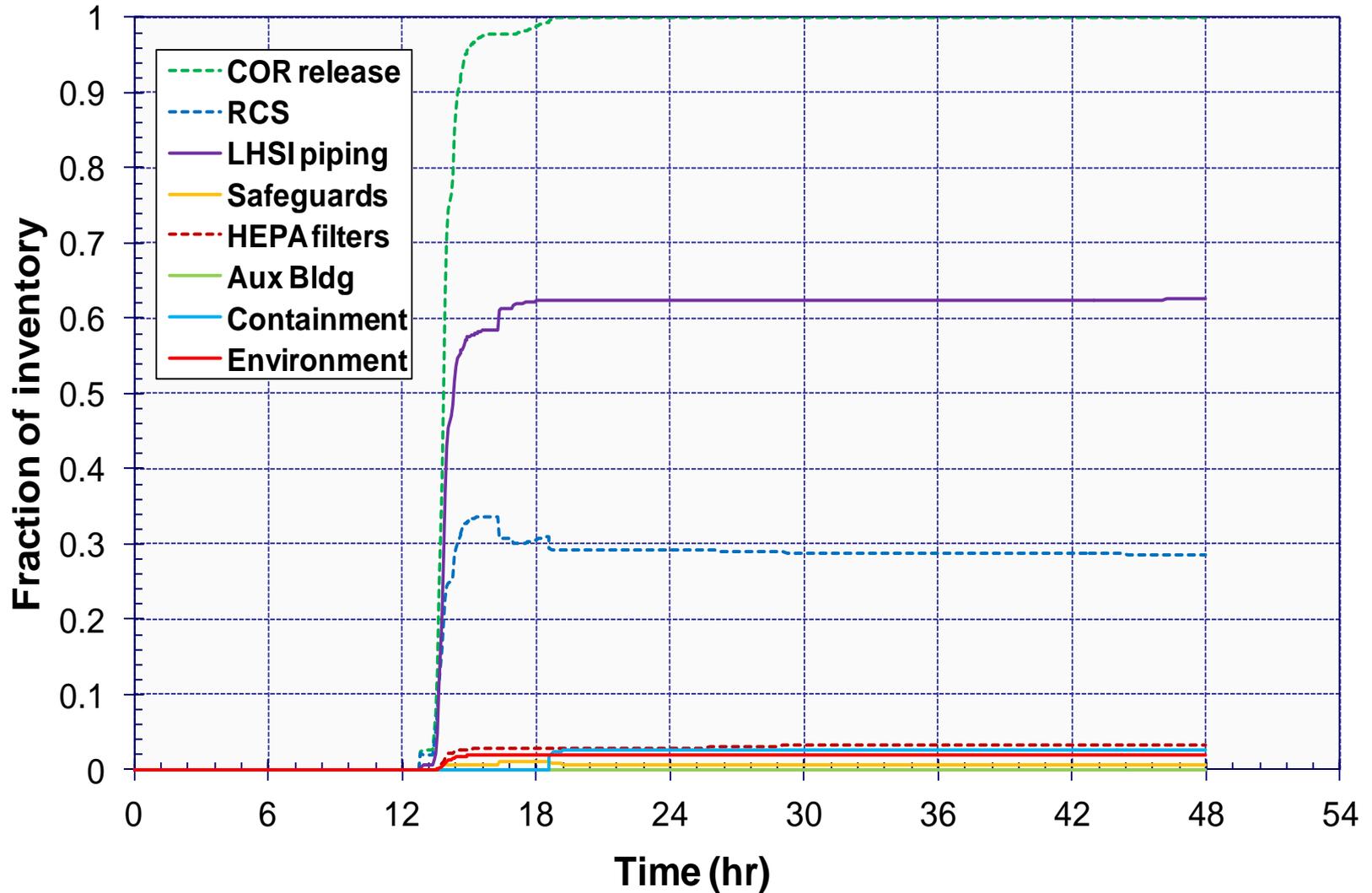
# RWST Inventory



# Iodine Distribution

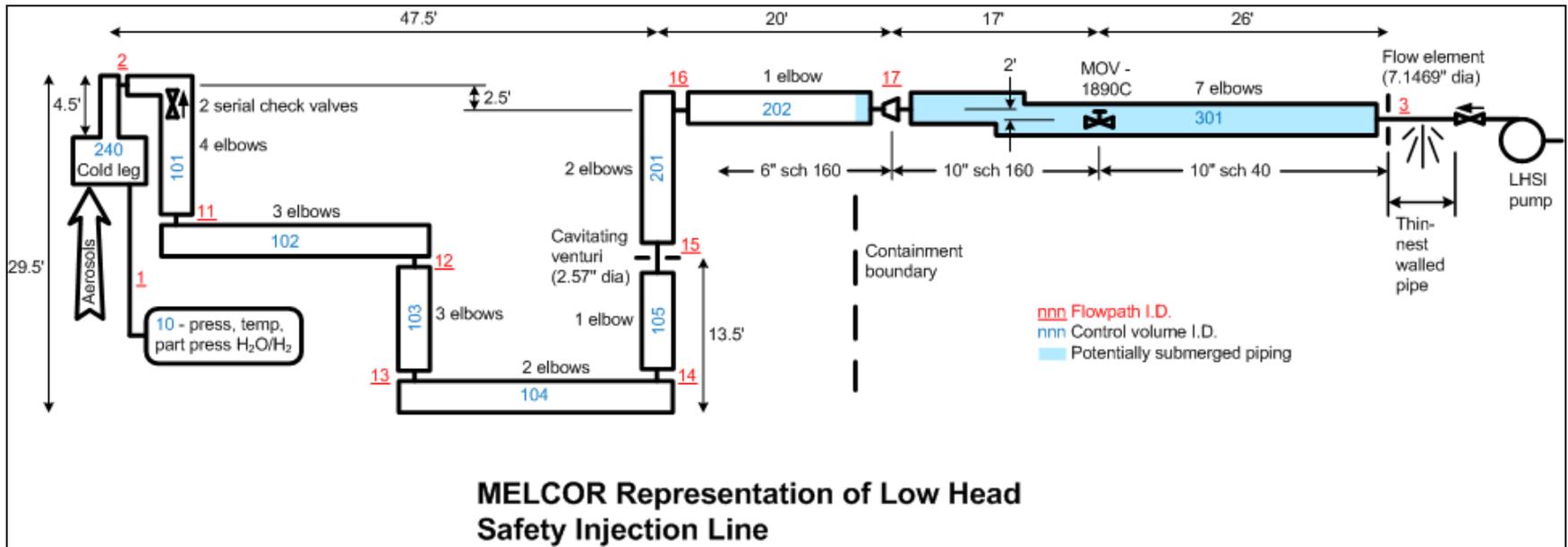


# Cesium Distribution



# Separate Effects MELCOR Model for LHSI piping

- Separate effects MELCOR model developed to estimate DFs in LHSI piping for full plant MELCOR model

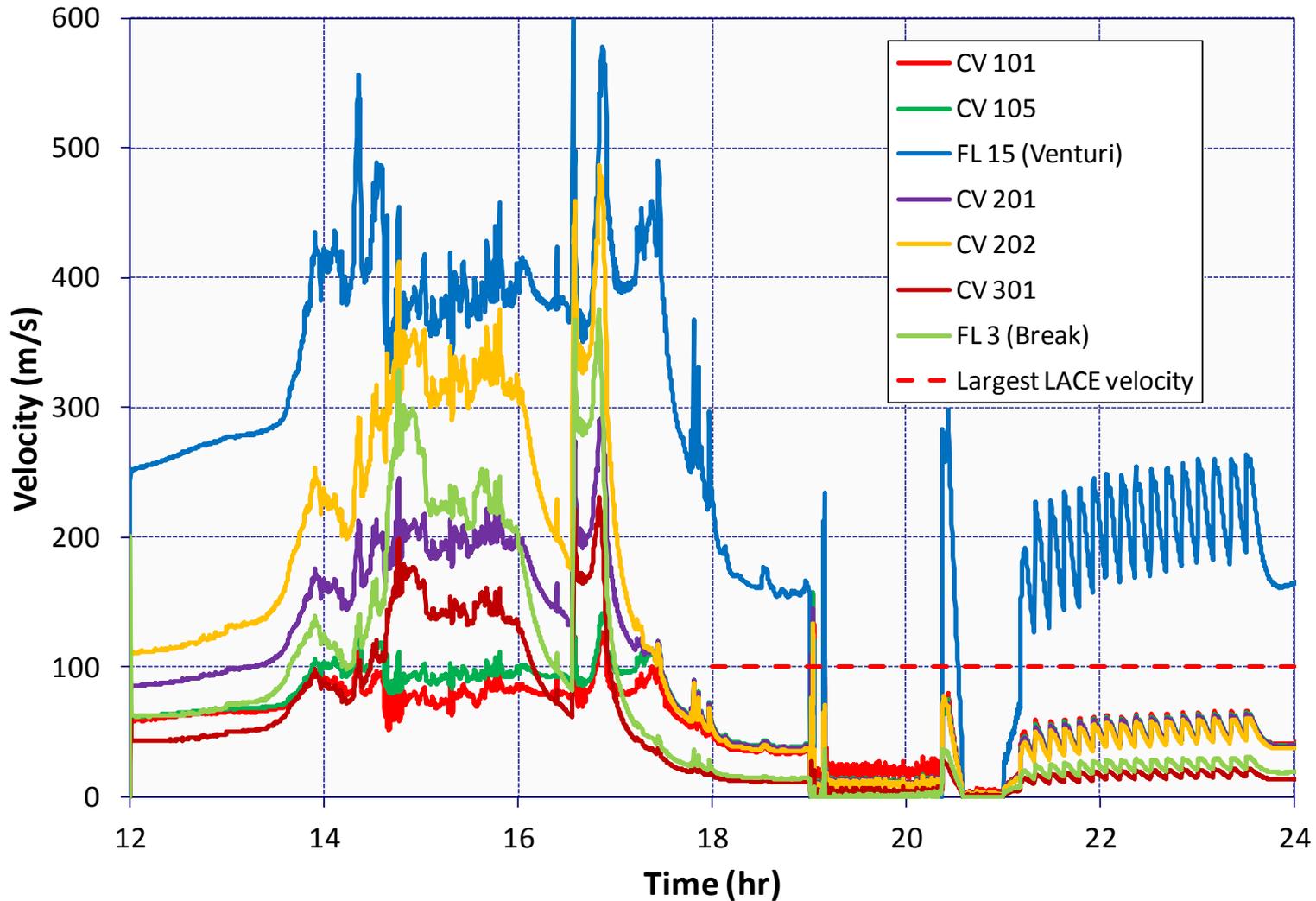


# Separate Effects MELCOR Model for LHSI piping

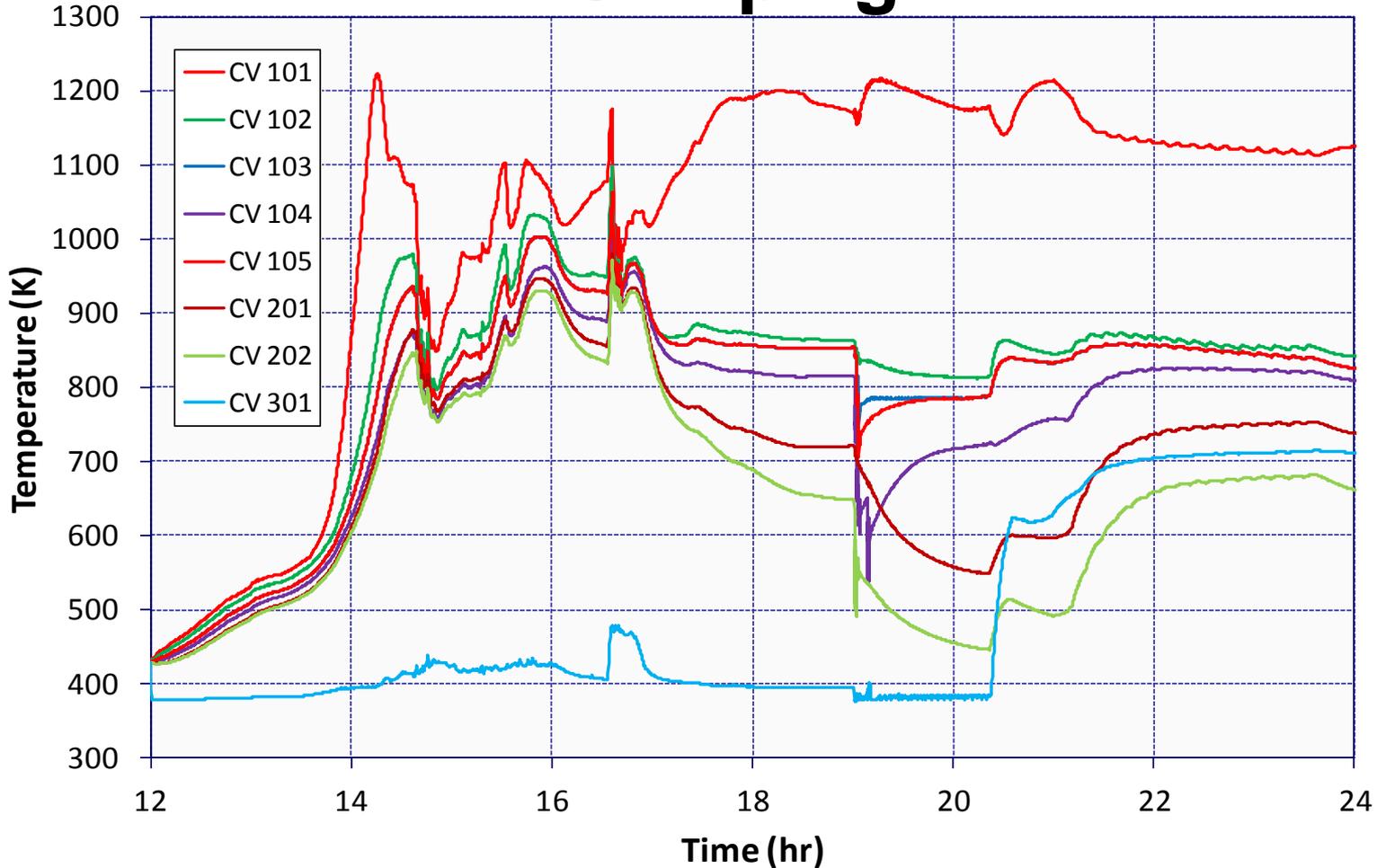
- MELCOR has traditionally modeled aerosol deposition under typical severe accident conditions (VICTORIA used for special conditions)
  - Settling, thermophoresis, diffusiophoresis
- Added new modeling to treat deposition under turbulent flow conditions
  - Turbulent deposition in straight pipes (184 feet)
  - Inertial deposition in elbows (23), venturi (4), sudden contraction (1)
- Validated against LACE test results and benchmarked against VICTORIA modeling



# Separate Effects Calculation Vapor Velocity in LHSI Piping

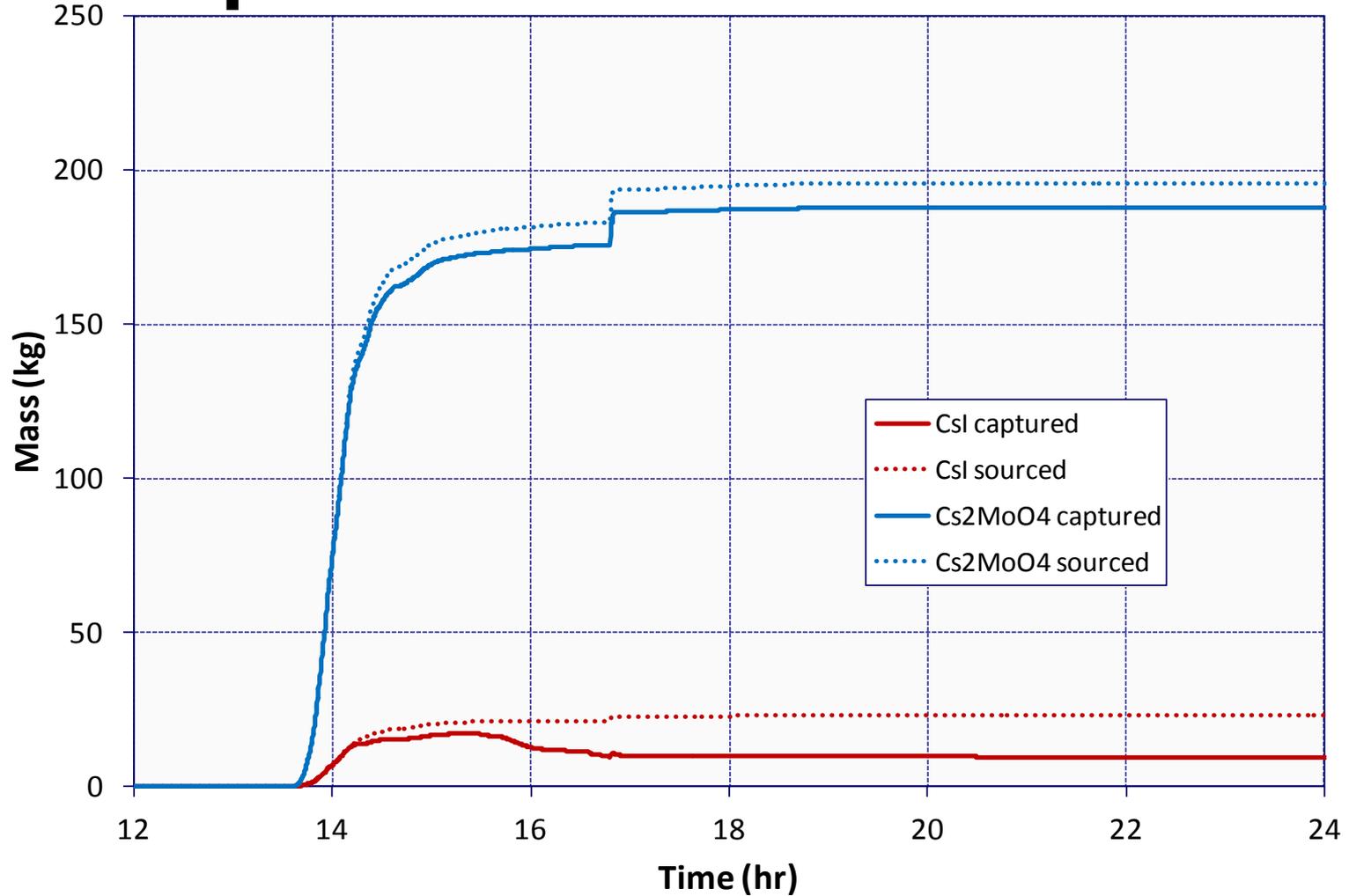


# Separate Effects Calculation Inner Wall Temperature in LHSI Piping

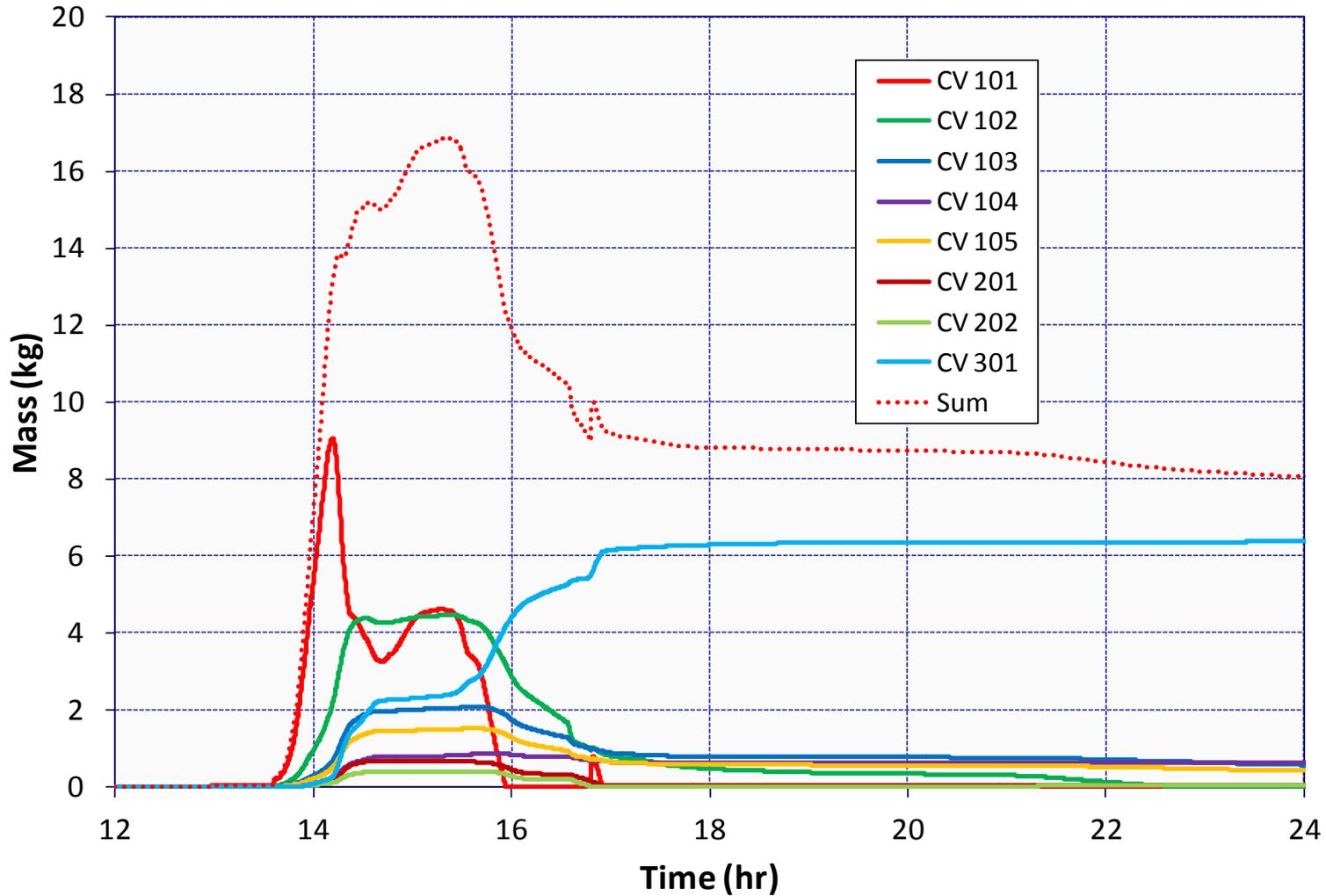




# Separate Effects Calculation



# Separate Effects Calculation CsI Deposition in LHSI Piping



# Unmitigated ISLOCA – No RWST

- **Results**

- Core damage began in 13 hours (previously estimated 9 hours)
  - Operator actions (by procedure) to stop and isolate both LHSI pumps and to stop 2 of 3 HHSI pumps
  - Operators used Surry plant simulator to estimate times to stop and isolate LHSI pumps
- Iodine and cesium releases of 16% and 2%, respectively. (previously estimated 9% for both iodine and cesium)
  - Significant deposition in RCS, LHSI piping
  - Iodine revaporization from LHSI piping with subsequent deposition in Safeguards Area and ESF Filtration which serves Safeguards Area

# Mitigation of ISLOCA

- Unmitigated ISLOCA – catastrophic failure of 2 check valves and no RWST refill or cross-connect
  - RWST empty at 6 hrs, core damage starts at 13 hrs – ample time to refill RWST
- Unmitigated ISLOCA calculation included operator action (by procedure) to stop and isolate both LHSI pumps and to stop 2 of 3 HHSI pumps
  - During October 2011 site visit, we learned that, by procedure, operators also would throttle the remaining HHSI pump
    - Delays emptying RWST and starting core damage by an additional 24 hours
      - HHSI flow at 6 hours (600 gpm without throttling, 150 gpm needed)
      - HHSI flow at 24 hours (100 gpm needed)

# Mitigation of ISLOCA

- Core damage could be averted by starting RHR
  - RHR entry conditions established by 2 hrs and 40 min
  - RWST not empty until 6 hrs (without throttling remaining HHSI pump)
- Opening pressurizer PORVs reduces the fission product release
  - Diverts some fission products to the containment
  - Other RCS-to-containment valves would perform similar function

# Frequency of ISLOCA

- SPAR model –  $3 \times 10^{-8}$ /ry
- Licensee PRA model – NRC originally understood to be  $7 \times 10^{-7}$ /ry
- During recent site visits, NRC learned that licensee PRA model had 2 ISLOCA scenarios:
  - Catastrophic failure of 1 check valve and up to 300 gpm leak-by of second check valve –  $7 \times 10^{-7}$ /ry
  - Catastrophic failure of 2 check valves –  $3 \times 10^{-8}$ /ry
- $3 \times 10^{-8}$  does not meet SOARCA screening criterion of  $10^{-7}$ 
  - NRC elected to retain scenario because it has been commonly identified as an important contributor in PRA

# Conclusions – Bypass Accidents

- SOARCA analysis of ISLOCA and SGTR used more detailed modeling of operator actions and plant systems and improved phenomenological modeling in MELCOR
- Fission Product Releases
  - Releases from bypass accidents are smaller and more delayed than in earlier studies. Bypass accidents do not result in large early releases.
- Accident Mitigation
  - SOARCA analysis provides insight into conservatisms in PRA model and leads to identification of additional mitigation measures that are practical (e.g., use of RHR prevents core damage)



**State-of-the-Art Reactor Consequence Analyses  
(SOARCA) Project**

***Comparing SOARCA with the  
Fukushima Accident***

**Presented to the  
Advisory Committee on Reactor Safeguards  
Washington, DC  
April 2011**

**Dr. Randall O. Gauntt, Sandia National Laboratories**

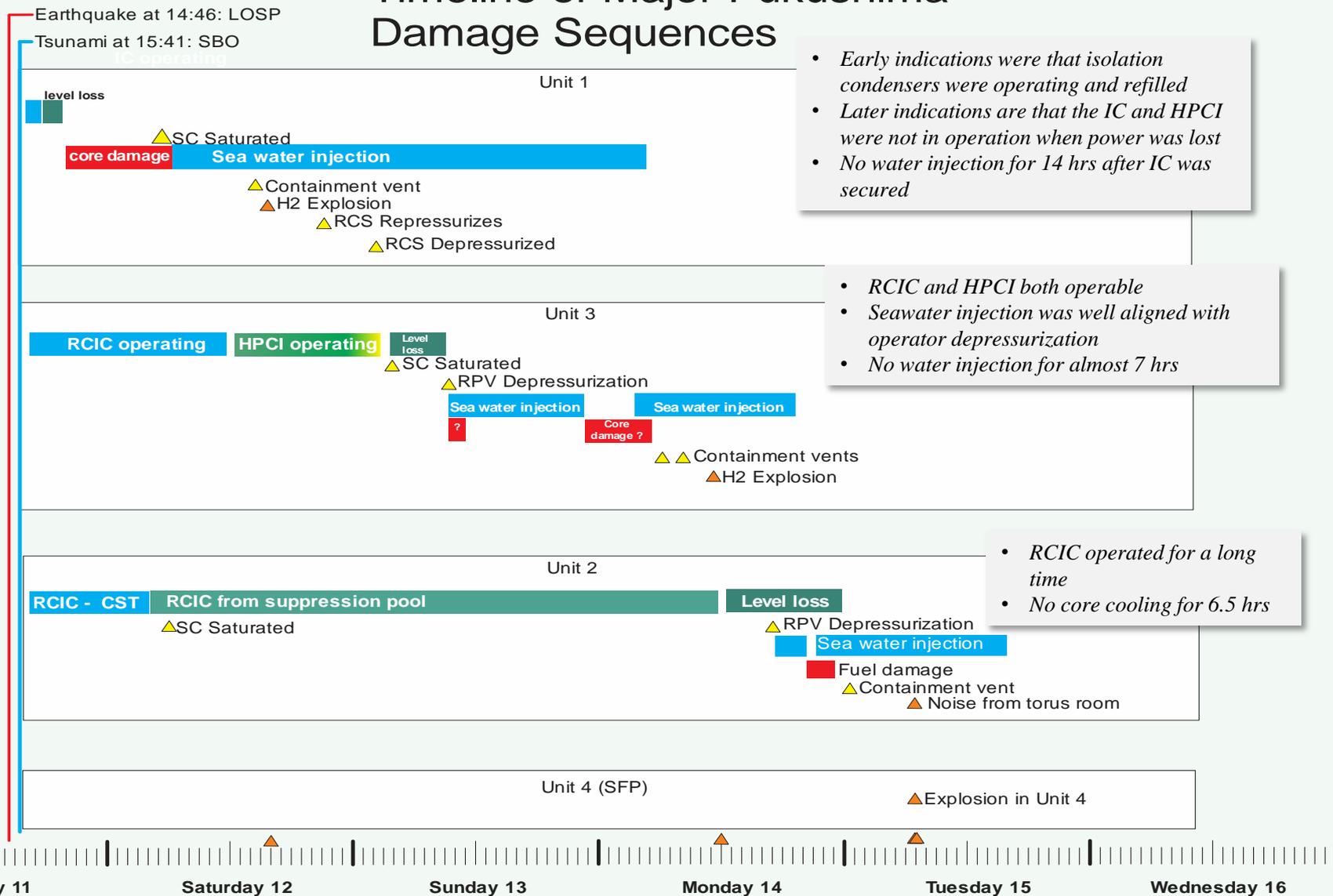
# Overview

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- RCIC operation
- Hydrogen release and combustion
- 48 hour truncation
- Multiunit risk
- Spent fuel pool risk/consequences

# Illustration of Major Fukushima Damage Sequences Developed for Discussion Only

## Timeline of Major Fukushima Damage Sequences



- Early indications were that isolation condensers were operating and refilled
- Later indications are that the IC and HPCI were not in operation when power was lost
- No water injection for 14 hrs after IC was secured

- RCIC and HPCI both operable
- Seawater injection was well aligned with operator depressurization
- No water injection for almost 7 hrs

- RCIC operated for a long time
- No core cooling for 6.5 hrs

# Operation of RCIC

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	Start of RCIC operation (hours)	End of RCIC operation (hours)	Duration of RCIC operation (hours)
Fukushima Unit 2	0	70	70
Fukushima Unit 3	0	21	21
Peach Bottom unmitigated LTSBO	0	5	5
Peach Bottom unmitigated STSBO with RCIC blackstart	1	3	2
Peach Bottom unmitigated STSBO without RCIC blackstart	Not modeled	Not modeled	N/A

# Hydrogen Release and Combustion



Photo modified from SAND2012-3221C

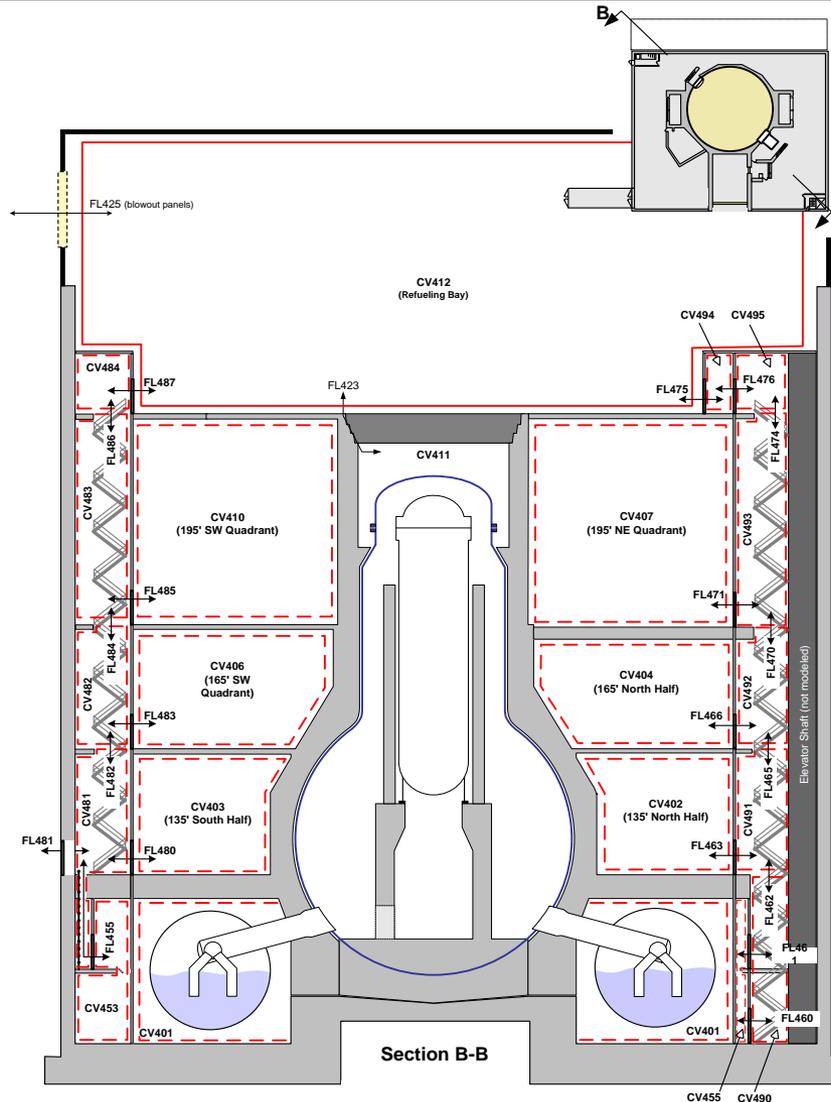
Unit 3

Unit 1

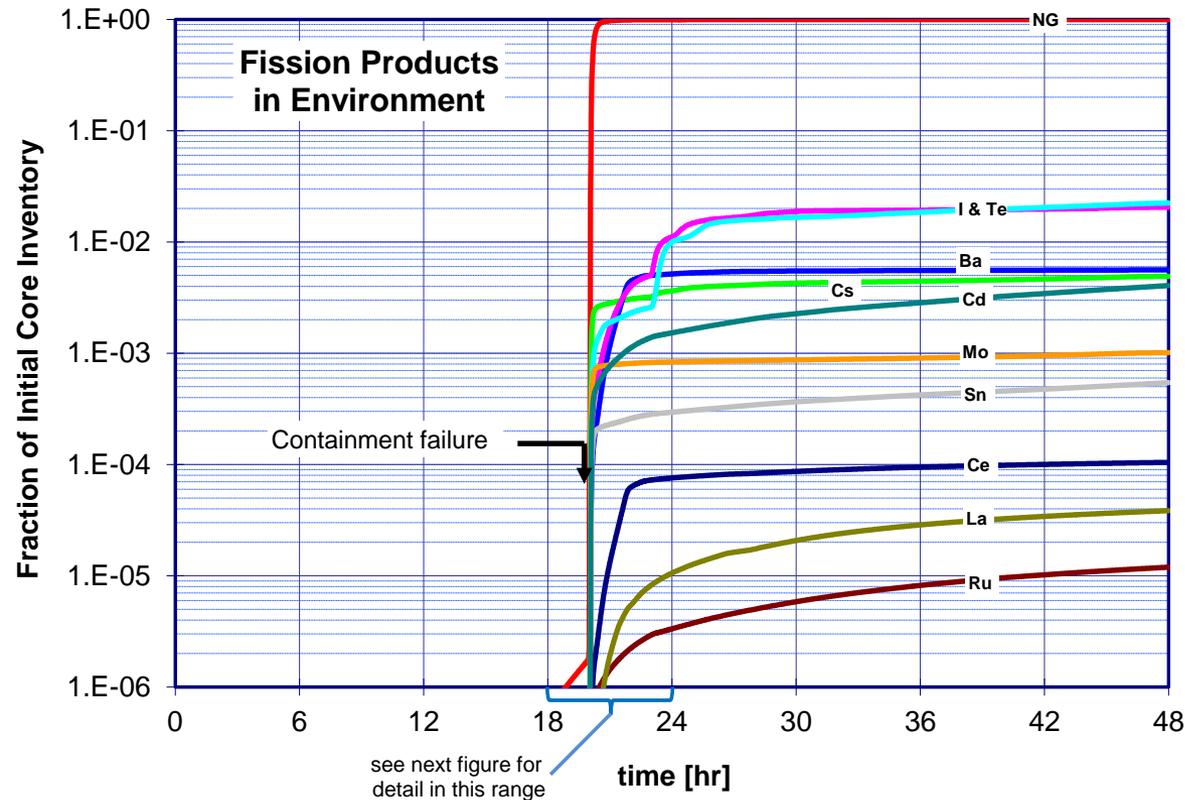
A Government of Japan report suggests the hydrogen release pathway was leakage through the drywell head flange

# Peach Bottom LTSBO Hydrogen Concentrations

SOARCA models leakage through the drywell head flange



# 48 hour Truncation for Releases



**Peach Bottom LTSBO**

The 48 hour truncation time for SOARCA was based on the availability of the many resources at the State, regional, and national level to mitigate the accident

- If all other options failed, the ability to flood the reactor containment could occur within 48 hours

# Multiunit Risk

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- Multiunit risk was an item considered for follow-on research.
- This will be included in the Level 3 PRA

# Spent Fuel Pool Risk/Consequences

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- Spent fuel pool risk was an item considered for follow-on research.
- This will be included in the Spent Fuel Pool Scoping Study and the Level 3 PRA.

**PEER REVIEW OF THE  
STATE-OF-THE-ART  
REACTOR CONSEQUENCE ANALYSIS (SOARCA)  
PROJECT**

Jeff Gabor  
ERIN Engineering & Research, Inc.

Presented to the Advisory Committee on Reactor Safeguards  
April 25, 2012

# Overview

- Peer Review Objectives
- Peer Review Committee Members
- Peer Review Process
  - Committee Charter
  - Review Scope
  - Coverage of SOARCA Topics by Committee Members
- Individual Assessments by Peer Reviewers
- Documentation Provided Throughout the Peer Review

# Peer Review Objectives

- The main objectives:
  - to provide independent reviews by each Committee member of the technical work conducted within the SOARCA project
  - to assure that the SOARCA study is technically accurate
- Guidance with respect to specific issues and comments on the effectiveness of presentation within the SOARCA NUREG documents to the public have also been offered.

# Peer Review Committee Members

- Ken Canavan, Electric Power Research Institute (EPRI)
- Bernard Clément, Institut de Radioprotection et de Sûreté Nucléaire
- Jeff R. Gabor, ERIN Engineering
- Robert E. Henry, Fauske and Associates
- Roger B. Kowieski, Natural and Technological Hazards Management Consulting, Inc. (NTHMC)
- David E. W. Leaver, WorleyParsons Polestar
- Bruce B. Mrowca, Information Systems Laboratories
- Kevin R. O’Kula, URS Safety Management Solutions
- John D. Stevenson, JD Stevenson Consulting Engineer Company
- Karen Vierow, Texas A&M University
- Jacquelyn C. Yanch, Massachusetts Institute of Technology

# Review Scope

- The documents reviewed included:
  - draft SOARCA NUREG documents
  - presentation materials provided at Peer Review Committee meetings
  - Peer Review comment resolution documents
  - Uncertainty Analysis Plan
  - Supporting documents that were supplied at the Committee's request.
- Latest draft SOARCA NUREG available to the Committee at the time of preparation of final deliverable:
  - Main Report (Dec. 23, 2011)
  - Volume 1 (Oct. 12, 2011)
  - Volume 2 (Nov. 17, 2011)

# Review Scope

- The scope of the review does not include:
  - the Uncertainty Quantification and Sensitivity Analysis
  - editorial review of the SOARCA documents
  - review of the public brochure

# Coverage of SOARCA Topics

- Accident sequence selection
  - Ken Canavan
  - Bruce Mrowca
- Accident progression
  - Ken Canavan
  - Bernard Clément
  - Jeff Gabor
  - Robert Henry
- Mitigation measures
  - Jeff Gabor
  - Robert Henry
  - Bruce Mrowca

# Coverage of SOARCA Topics

- Radiological release
  - Bernard Clément
  - Jeff Gabor
  - Robert Henry
  - David Leaver
- Off-site emergency planning and response
  - Roger Kowieski
  - David Leaver
- Off-site radiological consequences
  - David Leaver
  - Kevin O’Kula
  - Jacquelyn Yanch

# Coverage of SOARCA Topics

- Seismic issues
  - John Stevenson
- Structural issues
  - John Stevenson
- Probabilistic Risk Assessment applications
  - Ken Canavan
  - Bruce Mrowca
- Severe accident modeling
  - Jeff Gabor
  - Robert Henry
  - Karen Vierow

# Individual Assessments

- All of the written materials which were provided to the SOARCA team by the reviewers have been assembled by and coordinated through the Peer Review Committee chair.
- Each reviewer's assessment of SOARCA has been transmitted as received, without editing or other modification by the chair.
- A consensus opinion of the Committee has not been pursued during the review process.

# Individual Assessments – Canavan (1/2)

- The SOARCA study has largely met its objectives.
- Consequence Analysis:
  - While effort in SOARCA is expended to attempt to ensure that that the most significant sequences, in terms of both frequency of occurrence and related consequences are chosen, there are always questions as to the rigor of this process in any analyses of this type.
  - There is the possibility that certain accident sequences, while not dominant, may have higher risk than would be indicated by the frequency of the accident sequences due to an increased consequence.

# Individual Assessments – Canavan (2/2)

- Plant-specific nature of SOARCA
  - Because these plants do not encompass all of the design, maintenance and operation practices across the nuclear fleet, some conclusions are likely applicable to that site only and the results may not be typical.
- Individual Accident Sequences
  - As part of the SOARCA review, the accident sequences criteria used in the SOARCA study were applied generically to various accident sequences in previously published PRA studies. However, it should be noted that this review was informal and generic. Plant-specific application could produce different results.
  - Changes in assumptions or the state of knowledge of certain phenomena could influence the results of the analysis and further limit the usefulness of the final result.

# Individual Assessments – Clement (1/2)

- The SOARCA project succeeded in achieving the objectives of updating quantification of offsite consequences.
- Uncertainties exist concerning the first failure locations. This was not addressed for RPV failure.
- Due to a shortcoming in MELCOR's FP behavior treatment, a gaseous iodine source term was "superimposed" on MELCOR's source term. This might not give consistent results for sequences that were not studied in the SOARCA.
- Addressing the uncertainties issue will increase robustness of the results and confidence in the conclusions.

# Individual Assessments – Clement (2/2)

- Recommendations:
  - Revise SOARCA documentation according to new PRA results if their outcomes make it useful.
  - Address other pilot plants using the SOARCA methodology.
  - Benchmark SOARCA evaluations of selected sequences with future versions of MELCOR
  - The likelihood of TI-SGTR for Surry should be re-assessed using update flaw distributions and material changes when such data is available.

# Individual Assessments – Gabor (1/3)

- SOARCA represents a major advancement in our understanding of severe accident progression and radionuclide release.
- SOARCA successfully addressed the major objectives of the project related to severe accident progression.
  - However, due to the primarily deterministic approach taken, great care must be taken in communicating these results in a risk context to the public.

# Individual Assessments – Gabor (2/3)

- The focus on individual accident progression scenarios in a deterministic framework has limitations.
  - The consequences are a strong function of the path selected.
  - It is not sufficient to characterize the potential consequences of a severe accident scenario using a single accident progression analysis, even if it is the best estimate case.
  - The presentation of risks must be made in a fully probabilistic framework, rather than the SOARCA project's quasi-probabilistic framework.

# Individual Assessments – Gabor (3/3)

- The SOARCA project does not adequately address the uncertainty in severe accident phenomena.
  - A full appreciation of the results and uncertainties can only be accommodated in a fully probabilistic assessment addressing the applicable uncertainties.
  - This is being addressed in a separate program.
- It is important that the largely deterministic analytical techniques employed in the SOARCA project be extended into true risk frameworks in order to more completely characterize the results and communicate risks.

# Individual Assessments – Henry (1/3)

- The SOARCA activity is a major step forward in developing credible, integral analyses for severe accident sequences to be used in regulatory decision-making.
- Accident sequence selection:
  - The focus on the sequences of Station Blackouts and containment bypass is appropriate
  - The Fukushima accidents validate the selection of the SBO sequences for the SOARCA.
  - Equally important is the role of the RCIC system, that is conservatively modeled in the SOARCA accident response evaluations.

# Individual Assessments – Henry (2/3)

- MELCOR Modeling of the Severe Accident Sequences
  - The MELCOR results are reasonable and benchmarked with appropriate phenomenological experiments except for some aspects of the following:
    - Possible challenges to the integrity of the RCS pressure boundary
      - Flow paths along in-core instruments may lead directly to the containment atmosphere.
      - These flow paths were not modeled in the MELCOR analyses.

# Individual Assessments – Henry (3/3)

- A review of the MELCOR “best practices” document is an important component of the documentation that should be reviewed along with each MELCOR accident analysis that is used in specific regulatory decisions.
  - It is recommended that the MELCOR “best practices” include the insights developed from an individual benchmark such that these would be implemented in integral plant analyses going forward.
  - Without such a procedural step, it is not clear what is learned and what is used from the benchmarks.

# Individual Assessments – Kowieski (1/1)

- Regarding the off-site emergency response sections:
  - The parameters used and assumptions made in the emergency response modeling were reasonable and adequate.
  - The emergency response timelines used in the modeling are consistent with the actual response action timelines by the off-site response organizations.

# Individual Assessments – Leaver (1/3)

- The SOARCA is a substantive, high quality effort which makes a significant contribution to the understanding of US commercial reactor risk.
- The technical quality of the SOARCA is high and provides a major advancement in the state-of-the-art of characterization of integrated severe accident risk in Levels 2 and 3.
  - The transparency, which has been and continues to be a key objective, indirectly supports the quality of the SOARCA project.
  - The internal event Level 1 work utilized the latest information available.
  - The selection process for external event sequences was less clear. Large seismic events should be assessed as a part of a separate, future study integrated into the NRC seismic research program.

# Individual Assessments – Leaver (2/3)

- On the matter of completeness of scope, the SOARCA project has taken an approach that is technically sound.
  - Those classes of accident events not considered were identified within the SOARCA and are not likely to substantially alter the SOARCA findings on reactor risk.
  - There would be benefits to applying more detailed best estimate, SOARCA-like methods to some of these classes of events.
  - Extension of SOARCA to other LWR plant types would further strengthen the completeness of effort.
- On the matter of completeness of sequence selection, the Level 1 (CDF) screening process is reasonable from a technical standpoint.
- With respect to accident types and offsite health consequences, there is nothing forthcoming from the Fukushima accident that suggests that the SOARCA selection process overlooked important accident scenarios.

# Individual Assessments – Leaver (3/3)

- Observations on reactor safety and public health risks associated with US LWR operation based in light of SOARCA findings:
  - The SOARCA project provided very strong, convincing evidence that LWR risk characterization has been unrealistic and excessively conservative.
  - The 50.54(hh) mitigative measures are important not only because of the risk impact but also because of the provided margin for uncertainties in sequence selection and analysis, making the SOARCA risk predictions even more robust.
  - Perhaps the most significant finding from the SOARCA project is the importance of the role of emergency response and accident management in reducing risk.
    - It is now an appropriate time for the nuclear community to begin consideration of how SOARCA methods and results could be used to further improve LWR safety.

# Individual Assessments – Mrowca (1/3)

- The SOARCA project objectives stated in Section 1.2 of the Main Report were only partially achieved.
  - The innovative and state-of-the-art techniques used in the SOARCA analysis are focused on the phenomenological modeling and are not used for the identification of sequences to be modeled or for the application of security-related mitigation improvements.
- With regard to the objective of incorporating significant plant improvement and updates, the SOARCA project stated that the team attempted to accurately reflect plant conditions and use the latest Level 1 information concerning initiators derived from plant-specific models. The practice employed appears reasonable.

# Individual Assessments – Mrowca (2/3)

- Sequence Selection
  - The lack of a Level 3, internal and external events PRA resulted in the use of a sequence selection and screening process that does not guarantee completeness.
  - This reviewer found weaknesses in the defensibility and transparency of the process.
  - The case for using the selected screening process is not well made.
    - The analysis concludes that the benefits could most efficiently be demonstrated by applying the methods to a set of the more important severe accident sequences. However, the benefits of realistic analysis can be achieved by selecting any relevant set of sequences.
    - The other SOARCA objectives suggest that it is necessary to capture all or a significant portion of the risk. A more comprehensive approach would appear to be called for.

# Individual Assessments – Mrowca (3/3)

- Treatment of Mitigation Measures and Operator Actions
  - The failure probabilities for the additional security-related mitigation actions were not determined, preventing the determination of the mitigated sequence frequencies and the full assessment of their impact.
    - The lack of a human reliability assessment severely limits the credibility of the benefit of these additional actions.
    - It also results in incomplete frequency information.
  - The SOARCA Project did not demonstrate through state-of-the-art techniques that the mitigation improvements objective was achieved.

# Individual Assessments – O’Kula (1/2)

- Adequacy of the SOARCA Concept
  - The SOARCA study more than met its goal of applying state-of-art, and valid approaches for evaluating severe accident phenomena and ensuing subsequent offsite consequences.
  - However, some aspects of the offsite consequence analyses maintain older models or input data. These are acceptable for achieving the overall goals on the SOARCA project in most cases but merit some thinking in the direction of upgrades or replacement with other options for later work.
    - Straight-line Gaussian plume segment model
    - Economic consequence model with older data
    - Assumptions and input data associated with decontamination and cleanup of economic assets

# Individual Assessments – O’Kula (2/2)

- SOARCA Approach
  - The approach taken for the offsite consequence analysis was comprehensive and met expectations for contemporary standards and assumptions.
  - The SOARCA processes were sufficiently best-estimate with respect to the offsite consequence analysis performed.
  - It will be important to finalize the uncertainty analysis to understand parameter impacts and sensitivities, and where the best-estimate values lie relative to other statistical figures-of-merit.

# Individual Assessments – Stevenson (1/2)

- I agree from a natural phenomena hazard standpoint, the greatest threat to the loss of electrical power both from sources outside and inside the two NPP's studied resulting in station blackout is a very low probability of occurrence earthquake.
- The concern raised is that such a level of earthquake for the Surry NPP could lead to the soil liquification or consolidation leading to displacement that might cause containment penetrations to rupture and thereby lead to early containment failure which was identified in the SOARCA study.

# Individual Assessments – Stevenson (2/2)

- There is a need to assure that:
  - the severe accident management team is aware of the potential for hydrogen build-up in containment to detonation concentration levels.
  - and for them to develop administrative procedures or install hardware to preclude this detonation level build-up from occurring.
- My overall impression of the SOARCA project and associated documentation is that it is a realistic effort to validate the consequences of a complete loss of cooling to a large commercial BWR and PWR power reactor and as such makes a significant contribution to the understanding of U.S. commercial reactor risk.

# Individual Assessments – Vierow (1/3)

- Adequacy of the SOARCA Concept
  - The SOARCA approach for modeling severe accident phenomena is valid, in part, because it is a comprehensive and integrated analysis approach.
  - SOARCA is state-of-the-art for analysis of severe accident sequences in that the latest version of MELCOR severe accident modeling has been adopted.
    - Version 1.8.6 was used in SOARCA. The changes from 1.8.6 to 2.1 are for “modernization” to a newer FORTRAN version.
  - The SOARCA approach is adequate because code validation has been conducted in a systematic manner to test code capabilities for key SOARCA phenomena and their interactions.
    - Some analysis aspects remain that require additional sensitivity studies and uncertainty quantification. These studies are essential to the credibility of SOARCA.

# Individual Assessments – Vierow (2/3)

- Attainment of SOARCA Objectives
  - The objectives for severe accident analysis have been largely met.
    - Many insights have been gained.
    - However care should be taken in extrapolating results to other reactors as reactor-specific characteristics may exist.

# Individual Assessments – Vierow (3/3)

- Presentation of the SOARCA effort as “best-estimate”
  - The current evaluations retain some conservatisms,
  - Care should be taken by the SOARCA team to qualify the claim of best-estimate analyses.
    - “More best-estimate”, or “more realistic” than earlier analyses would be appropriate.
  - A compendium of conservatisms and their justifications would be useful.
    - Discussion of the conservatisms would enhance SOARCA’s credibility by illustrating to the public that the results were not adjusted in an optimistic manner.

# Individual Assessments – Yanch (1/2)

- No effects on the population other than radiation-induced health impact are evaluated in the SOARCA study and no attempt has been made to evaluate the consequences of environmental contamination and its impact on human suffering, human health, or the local and national economic consequences of a severe reactor accident.
  - This is a significant and important omission.
- For most of the scenarios addressed in the SOARCA study, the accident proceeds slowly enough that, should it be necessary to give the evacuation order, the public can leave in a timely way so that little to no radiation dose is incurred until the public is permitted to return home.
  - When to return home is determined by return-home dose limits set by individual states.

# Individual Assessments – Yanch (2/2)

- SOARCA approach to estimating health impact reflects the state-of-the-art.
  - The strategy for determining the impact of exposure to anthropogenic radiation is broadly consistent with the approach taken by the scientific field in general and by several national and international agencies and committees.
  - Approach: assume a threshold for acute effects, integrate the dose over a 50 year period, assume cancer is the only impact on long-term health, the use of a DDREF of 2.0, and the application of a common risk factor throughout the entire dose range.

# Documentation Provided Throughout the Peer Review

- Peer Review Comments following July 2009 Meeting
- Peer Review Comments following September 2009 Meeting
- Comments on SOARCA Document Description following March 2010 Meeting
- Memo Providing Guidance on SOARCA Issues
- Memo on Uncertainty Quantification and Sensitivity Analysis
- Memo Providing Guidance on Uncertainty Analysis Methodology
- Draft Committee report in May 2010
- Final Committee report in January 2012

# Backup slides

# Committee Meetings

- Rockville, MD, July 28-29, 2009.
  - A draft of the SOARCA NUREG document, dated July 2009, was received for review prior to the meeting.
  - The SOARCA team presented the project to the Committee members
  - Initial comments and questions were discussed verbally.
- Action items:
  - The Committee provided written comments on the SOARCA document and information presented at the two-day meeting

# Committee Meetings

- September 15-16, 2009 in Bethesda, MD.
  - Prior to this meeting, supplemental material including reports of MELCOR and MACCS external review committees, the 1982 Sandia Siting Study and a memo from Dana Powers on fission product retention in steam generator tubes were transmitted to the Committee members.
  - The SOARCA team presented the latest results to the Committee members.
- Action Items:
  - The Committee provided written comments on the SOARCA document and information presented at the two-day meeting

# Committee Meetings

- March 2-3, 2010 in Rockville, MD
  - A draft of the SOARCA NUREG document, dated February 14, 2010, was received for review prior to the meeting.
  - Presentations by the SOARCA team on the first day focused on comment resolution and plans for Uncertainty Quantification and Sensitivity Analysis.
  - The second day of meetings was primarily for discussions amongst the peer reviewers and small group meetings with members of the SOARCA team, as requested by the peer reviewers.

# Committee Meetings

- March 2-3, 2010 in Rockville, MD (cont.)
- Action items:
  - The Committee members were asked to provide written comments on the description of the SOARCA in the draft NUREG.
  - Issues arose for which the SOARCA team requested guidance on a time scale shorter than that for preparation of the Committee's final report. The Committee provided a memo.
  - The Committee members were asked for their insights into the Uncertainty Quantification and Sensitivity Analysis, an issue which several members were interested in but which was determined to be outside of the review scope. The Committee provided a memo.

# Committee Meetings

- October 26-27, 2010, Rockville, MD
  - The reviewers received a draft plan for the Uncertainty Analysis, dated Oct. 19, 2010, a draft NUREG/CR on uncertain input parameters for use in off-site consequence analysis codes and an ORNL report documenting an uncertainties in cancer risk coefficients.
  - The SOARCA team discussed the proposed Uncertainty Analysis technical approach and resolution of peer review comments from earlier meetings.
  - On the second day, the peer reviewers discussed completion of the Committee's final report.
- Action items:
  - prepare a list of unresolved review comments
  - draft a guidance memo on the Uncertainty Analysis
  - finalize the Committee's report.

# Committee Meetings

- Rockville, MD, Dec. 6-8, 2011
  - The reviewers received the draft SOARCA NUREG document dated Nov. 29, 2011 (Main Report), Oct. 12, 2011 (Volume 1) and Nov. 17, 2011 (Volume 2).
  - The SOARCA team presented changes in SOARCA analyses and results on the first two days.
  - On the third day, a description of the MELCOR code validation effort was provided.
- Action item:
  - Complete the Committee's report

# Committee Meetings

- Sept. 5, 2011 teleconference
  - The SOARCA team provided a written response to reviewer comments to date on July 29, 2011.
  - A teleconference between the SOARCA team and the peer reviewers was conducted to discuss the responses and clarify whether the reviewers had any remaining issues.
- Jan. 5, 2012 teleconference
  - A second teleconference was conducted to explain to the peer reviewers the selection of parameters being used in the Uncertainty Analysis and their distributions.
  - The reviewers had not seen the results or conclusions of the Uncertainty Analysis at the time of preparation of the final report.



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# **Public Comments and Commission Documents**

ACRS SOARCA Briefing

April 25, 2012

- Overview of Public Meetings/Comments
- Commission Memorandum
  - SOARCA Documents
- Commission Paper - Notation Vote
  - Issues Considered for Follow-on Research
  - Conclusions
  - Recommend Analysis of Ice Condenser Containment

# Overview of Public Meetings

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- NRC held 2 public meetings on SOARCA: 2/21-Surry; 2/22- Peach Bottom
- 30-day public comment period
  - ~75 comments received from 8 people
- RIC SOARCA session March 14

# Overview of Public Comments

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- Scope (battery duration; site-wide risk; need for HRA; low-power and shutdown modes; reporting alternate results)
- Fukushima comparisons (potential release of large amounts of contaminated water)
- Assumptions within MELCOR and MACCS2 (MELCOR validation; gaussian plume model; FGR-13 use; weather data; evacuation timing)

## SOARCA Deliverables

- NUREG-1935, SOARCA Report
- NUREG/CR-7110, Volume 1, Peach Bottom Integrated Analysis
- NUREG/CR-7110, Volume 2, Surry Integrated Analysis
- NUREG/BR-0359, Modeling Potential Reactor Accident Consequences

## Issues Considered for Follow-on Research

- Spent fuel pool issues (SFPSS, NTTF, Level 3 PRA)
- Multi unit and site risk (Level 3 PRA)
- Low power, shutdown, and other modes (Level 3 PRA)
- Human reliability analysis (Level 3 PRA)
- Comparison to NUREG-1150/historical studies (Level 3 PRA)
- Economic Consequences/Land contamination (RES SECY paper)
- Cancer incidence rates (Cancer Risk Study)
- Additional comparisons to Fukushima (DOE/NRC Forensic Analysis)
- Develop integrated, predictive computer-based tool (NSIR/RES activities)
- Large seismic event and soil liquefaction (seismic research plan)
- Other plant and containment types – eg, Ice condenser, Mark II, III, CE, B&W (open)

# Commission Paper- Notation Vote

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## Conclusions

- The staff believes that the SOARCA project objectives have generally been met
- Staff believes SOARCA-type analysis of all 8 plant types or 104 reactors as originally described (now 108 licensed reactors) is not necessary
  - Provided body of knowledge updating understanding of severe accident progression, mitigation, and consequences
  - Provided flexible and updated models and methods
  - Level 3 PRA will continue to add to this body of knowledge
- Staff recommends limited follow-on research

## Recommend Follow-on Research

- Analysis of Ice Condenser Containment during station blackouts
  - Ice condenser is a unique containment design
  - Behavior may be different than Mark I and Large Dry containments analyzed in SOARCA
  - Potential hydrogen vulnerabilities during SBO
  - Potentially different mitigation strategies and timing
  - Supports response to NTF recommendations and other agency projects and decisions



# **SOARCA Uncertainty Analysis**

Presented by: Tina Ghosh, PhD

ACRS Subcommittee Meeting  
April 25, 2012

# Outline

- Goals and approach
- Selected parameters and bases
- Preliminary analyses
- Phenomenological insights from MELCOR and MACCS2
- Status and schedule

# Goals of the Uncertainty Analysis

- Develop insight into overall sensitivity of SOARCA results to uncertainty in inputs
- Identify most influential input parameters for releases and consequences
- Demonstrate uncertainty analysis methodology

# Approach

- Focus is on parameter uncertainty
- Model uncertainty addressed only to the extent that some parameters represent or capture alternate model effects
- Peach Bottom, unmitigated, long-term station blackout scenario chosen
- Scenario definition not changed after Fukushima
  - A separate qualitative discussion planned for an appendix

# Approach (continued)

- Focus is on epistemic (state-of-knowledge) uncertainty in input parameters
- Aleatory (random) uncertainty due to weather is handled in the same way as the SOARCA best estimate
- Looking at uncertainty in key model inputs
  - MELCOR parameters
  - MACCS2 parameters

# Approach (continued)

- Key uncertain input parameters were identified
- Uncertainty in these parameters propagated in two steps using Monte Carlo and Latin Hypercube (LHS) sampling:
  - A set of source terms generated using MELCOR model
  - A distribution of consequence results generated using MACCS2 model
- An epistemic sample set of 300 generated to complete a corresponding number of individual code runs (Monte Carlo “realizations”) to evaluate the influence of the uncertainty on the estimated outcome

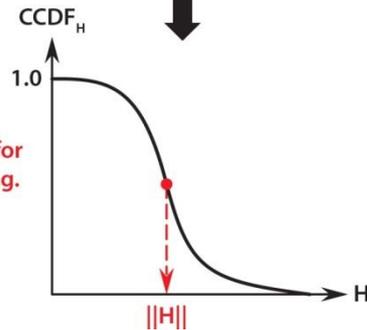
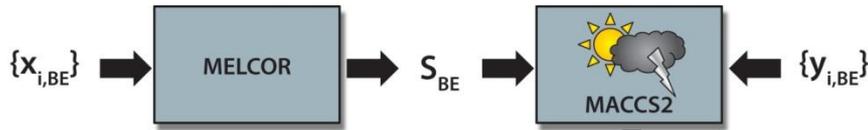
# Approach (continued)

- Results reported will include:
  - Analysis of source term releases including Cesium and Iodine release over time
  - Distribution of latent cancer fatality risk, with three dose threshold models
  - Description of most influential uncertain parameters in study
- Tools used to analyze results include statistical regression-based methods as well as scatter plots and phenomenological investigation of individual realizations of interest
- Guidance solicited from SOARCA peer reviewers on the uncertainty analysis plan documenting the approach, chosen parameters and distributions



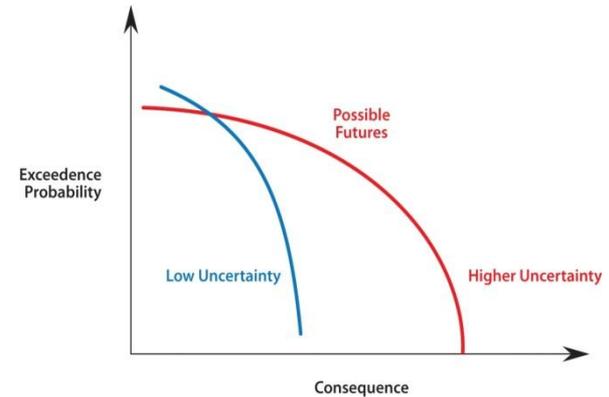
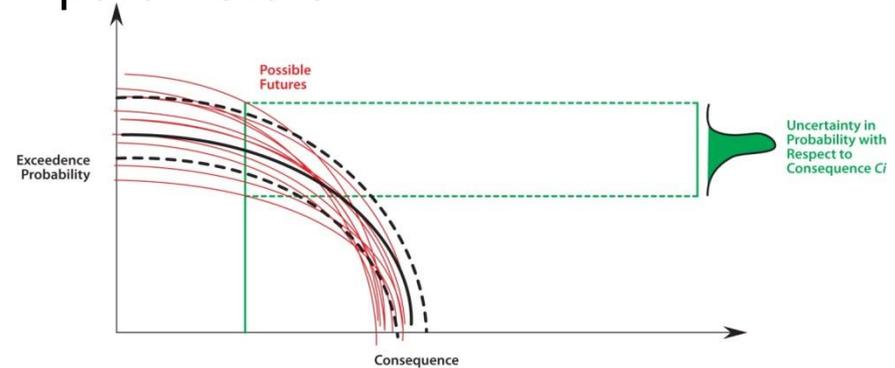
# SOARCA Uncertainty Analysis

Best estimate calculations include weather variability in the consequences



$||H||$  is the mean consequence for a specific accident sequence, e.g. latent cancer fatalities

Probabilistic UA includes both the weather variability and the uncertainty in the epistemic input parameters



# Core Team Members

- MELCOR and severe accident progression: Randy Gauntt, Kyle Ross, Doug Osborn, Don Kalinich (SNL); Mark Leonard (dycoda); Ed Fuller (NRC)
- MACCS2, consequence analysis and emergency response: Nate Bixler, Joe Jones, Doug Osborn (SNL)
- UA methodology: Patrick Mattie, Cedric Sallaberry, Jon Helton (SNL); Tina Ghosh (NRC)
- Consultants for MACCS2 latent health effects modeling: Keith Eckerman (ORNL); Tony Huffert (NRC)

# Process for Choosing Parameters and Distributions

- Core team of staff from SNL and NRC with expertise in probability and statistics, uncertainty analysis, and MELCOR and MACCS2 modeling for SOARCA
- Subject matter experts (SMEs) provided support in reviews of data and parameters
- Approach is based on a formalized PIRT (phenomena identification, and ranking table) process.

# Process (continued)

- Focus on:
  - confirming that the parameter representations appropriately reflect key sources of uncertainty, and
  - ensuring model parameter representations (i.e., probability distributions) are reasonable and have a defensible technical basis.

# Process (continued)

- Attempt to obtain contribution from uncertainty across the spectrum of phenomena operative in the analyses, through a balanced depth and breadth of coverage
- A subset of possible uncertain parameters is proposed that cover the range of phenomena across the stages of a severe accident.

## *Sequence Issues*

- Battery duration
- SRV stochastic failure rate, thermal seizure criteria, and open area fraction

## *In-Vessel Accident Progression*

- Main steam line (MSL) creep rupture open area fraction
- Zircaloy melt breakout temperature
- Molten clad drainage rate
- Fuel failure criterion
- Debris radial relocation time constants

## *Ex-vessel Accident Progression*

- Debris lateral relocation time constants

## *Containment & building behavior*

- Drywell liner failure flow area
- Drywell head flange leakage parameters
- Hydrogen ignition criteria (where flammable)
- Railroad doors open fraction

## *Fission Product release, transport, and deposition*

- Cesium and Iodine chemical forms
- Aerosol deposition parameters

## *Atmospheric Transport and Deposition*

- Wet deposition model linear coefficient
- Dry deposition velocities
- Dispersion parameters

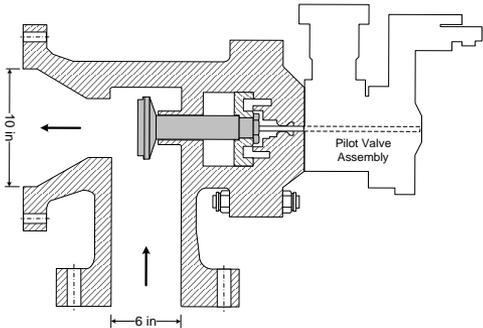
## *Emergency planning and response*

- Shielding factors
- Hotspot and normal relocation
- Evacuation delay and speed

## *Health Effects*

- Early health effects
- Latent health effects
  - Groundshine dose coefficients
  - Dose and dose rate effectiveness factors
  - Inhalation dose coefficients
  - Cancer mortality risk coefficients

# BWR SRV Seizure Modeling



## Modes of Valve Seizure

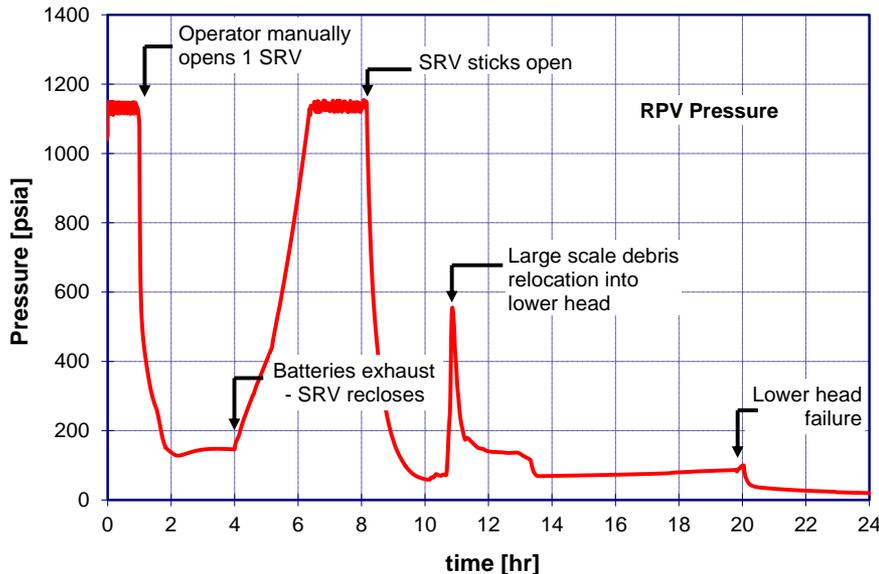
- Excessive cycling
- Differential thermal expansion
- Material deformation

In severe accident conditions, high temperature gases well exceed design conditions

$$T_{op} \sim 600K$$

$$T_{SA} > 800 \text{ to } 1100K$$

cycles for hours

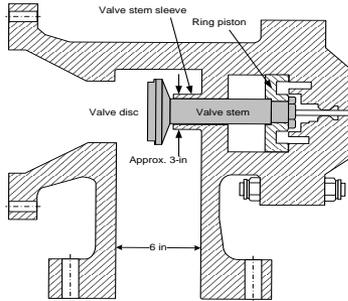


Seizure in stuck open eventually occurs

- excessive cycling
- thermal deformation
- partial or full open

Valve behavior important to accident progression

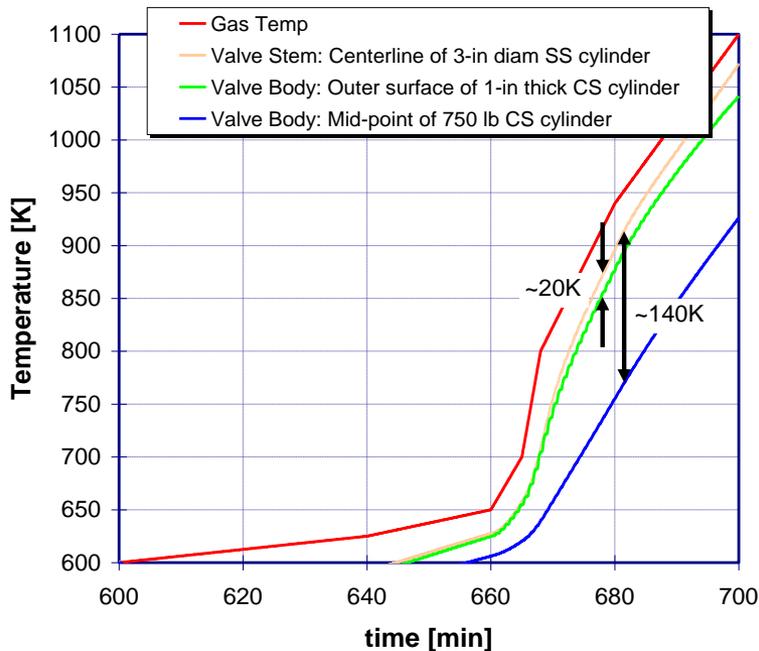
# SRV Thermal Failure



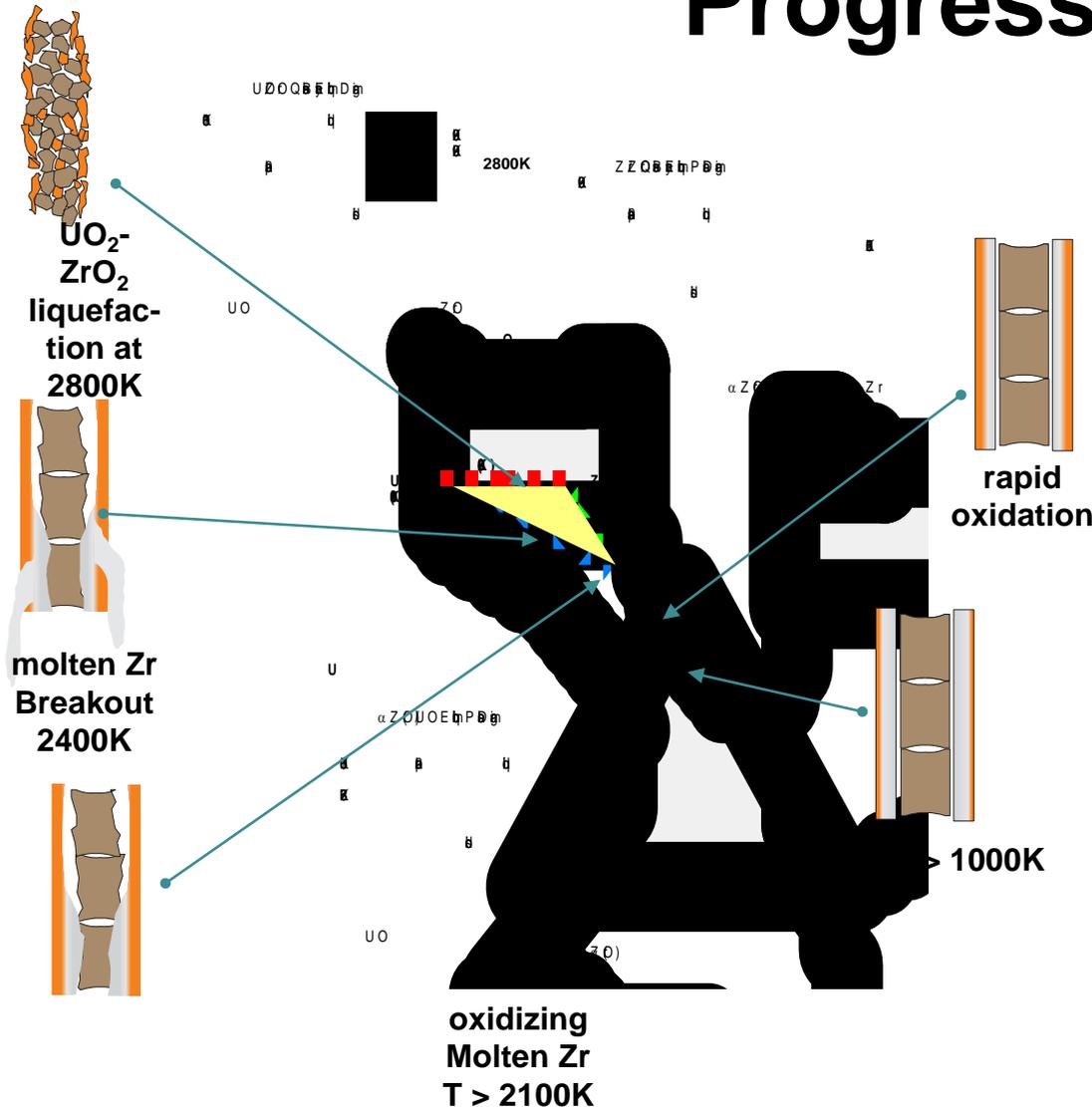
- In severe accident conditions, high temperature gases well exceed design conditions
  - $T_{op} \sim 600K$
  - $T_{SA} > 800$  to  $1100K$
  - cycles for hours

- **SOARCA Best Estimate Boundary Conditions:**

- Gas flow through the valve is based on a cycle period of 45 seconds with an open cycle duration of 5 seconds
- Gas velocity during an open cycle is constant during a single five second cycle, but increases from 420 m/s to 500 m/s as the gas temperature increases from 600 K to 1100 K
- Gas temperature as a function of time. Approximately 100 K temperature changes between the beginning and end of a cycle were neglected. The mid-point values were used
- The steam and hydrogen mole fractions were specified as a function time



# Modeling Melt Progression Stages



Zr metal melt at 2150K

UO<sub>2</sub> dissolution in Zr metal ~20%

Zr melt breakout ~2400K

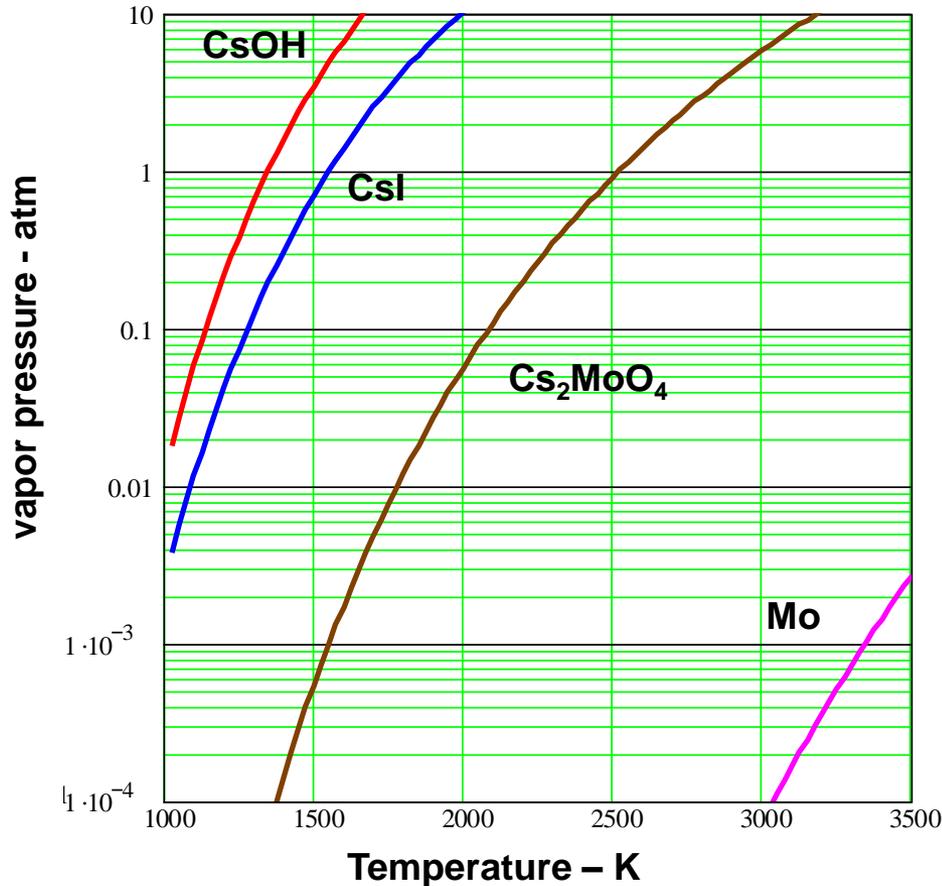
Loss of rod geometry ~2600K

UO<sub>2</sub>-ZrO<sub>2</sub> liquefaction ~2800K

Parameters uncertain



# Speciation of Cesium and Iodine



- Based on Phebus program findings
  - Iodine treated as CsI
  - Cs treated as CsI and Cs<sub>2</sub>MoO<sub>4</sub>
- Cs<sub>2</sub>MoO<sub>4</sub> considerably less volatile than CsOH or CsI
  - Affects retention in RCS and long term revaporization
- Uncertainty analysis exploring alternative balance of speciation
  - I<sub>2</sub>, CsOH, CsI and Cs<sub>2</sub>MoO<sub>4</sub>

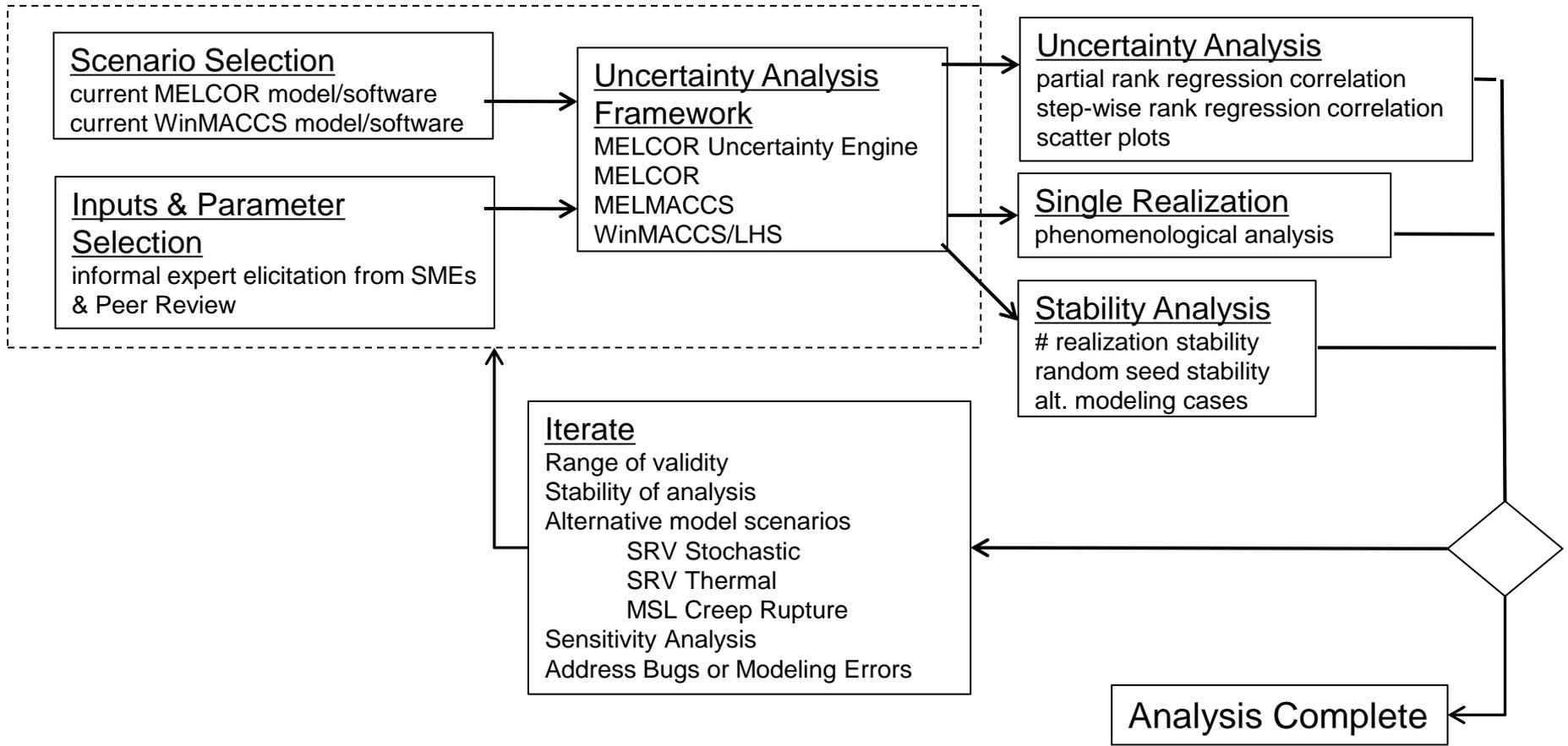
# MELCOR Parameters

## CHEMFORM

### *Chemical Forms of Iodine and Cesium*

Parameter		Distribution			
<b>CHEMFORM: Five alternative combinations of RN classes 2, 4, 16, and 17 (CsOH, I<sub>2</sub>, CsI, and Cs<sub>2</sub>MoO<sub>4</sub>)</b>		Discrete distribution			
		Combination #1 = 0.125			
		Combination #2 = 0.125			
		Combination #3 = 0.125			
		Combination #4 = 0.125			
		Combination #5 = 0.500			
Five Alternatives		Species (MELCOR RN Class)			
		CsOH (2)	I <sub>2</sub> (4)	CsI (16)	Cs <sub>2</sub> MoO <sub>4</sub> (17)
<b>Combination #1</b>	fraction iodine	--	0.03	0.97	--
	fraction cesium	1	--	--	0
<b>Combination #2</b>	fraction iodine	--	0.002	0.998	
	fraction cesium	0.5	--	--	0.5
<b>Combination #3</b>	fraction iodine	--	0.00298	0.99702	--
	fraction cesium	0	--	--	1
<b>Combination #4</b>	fraction iodine	--	0.0757	0.9243	--
	fraction cesium	0.5	--	--	0.5
<b>Combination #5</b>	fraction iodine	--	0.0277	0.9723	--
	fraction cesium	0	--	--	1
<b>Best estimate</b>	Fraction iodine	--	0.0	1.0	--
	Fraction cesium	0.0	--	--	1.0

# Probabilistic Uncertainty analysis is an iterative process



# **Preliminary Analyses**

## ***Source Term/MELCOR***

3 probabilistic cases:

- (1) Combined scenario probabilistic case using distributions as laid out in draft NUREG/CR, chapter 4, with SRV stochastic, SRV thermal, and MSLL creep failures occurring.
- (2) SRV Thermal scenario case keeping the SRV thermal seizure open area constant at 1
- (3) SRV stochastic scenario case keeping the SRV stochastic failure rate constant, at the SOARCA best estimate value



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# **Preliminary Analyses Consequence/MACCS2**

- Source terms from combined scenario case
- Using LNT model
- Aleatory & epistemic uncertainty

# **Preliminary Analyses**

## ***Summary Results***

- MELCOR: Cesium release timings are similar to SOARCA best estimate, magnitude of release at 48 hours generally slightly higher than best estimate (but still far below Siting Study SST1 results)
- MACCS2: distribution of risk results for latent cancer fatality risk similar to the best estimate, and early fatality risk essentially zero

# Phenomenological Insights

## *MELCOR Analyses*

- Confirmation of phenomenology seen in the SOARCA best estimate, and nothing that invalidates the SOARCA best estimate
  - In particular, strong dependence between number of SRV cycles before failure to re-close and probability of thermal SRV and/or MSL creep rupture, and
  - dependence between area fraction of SRV open when failed thermally and occurrences of MSL creep rupture
  - Chimney effect when rail road doors are failed open
- As well as additional new insights

# **Parameter Sensitivity**

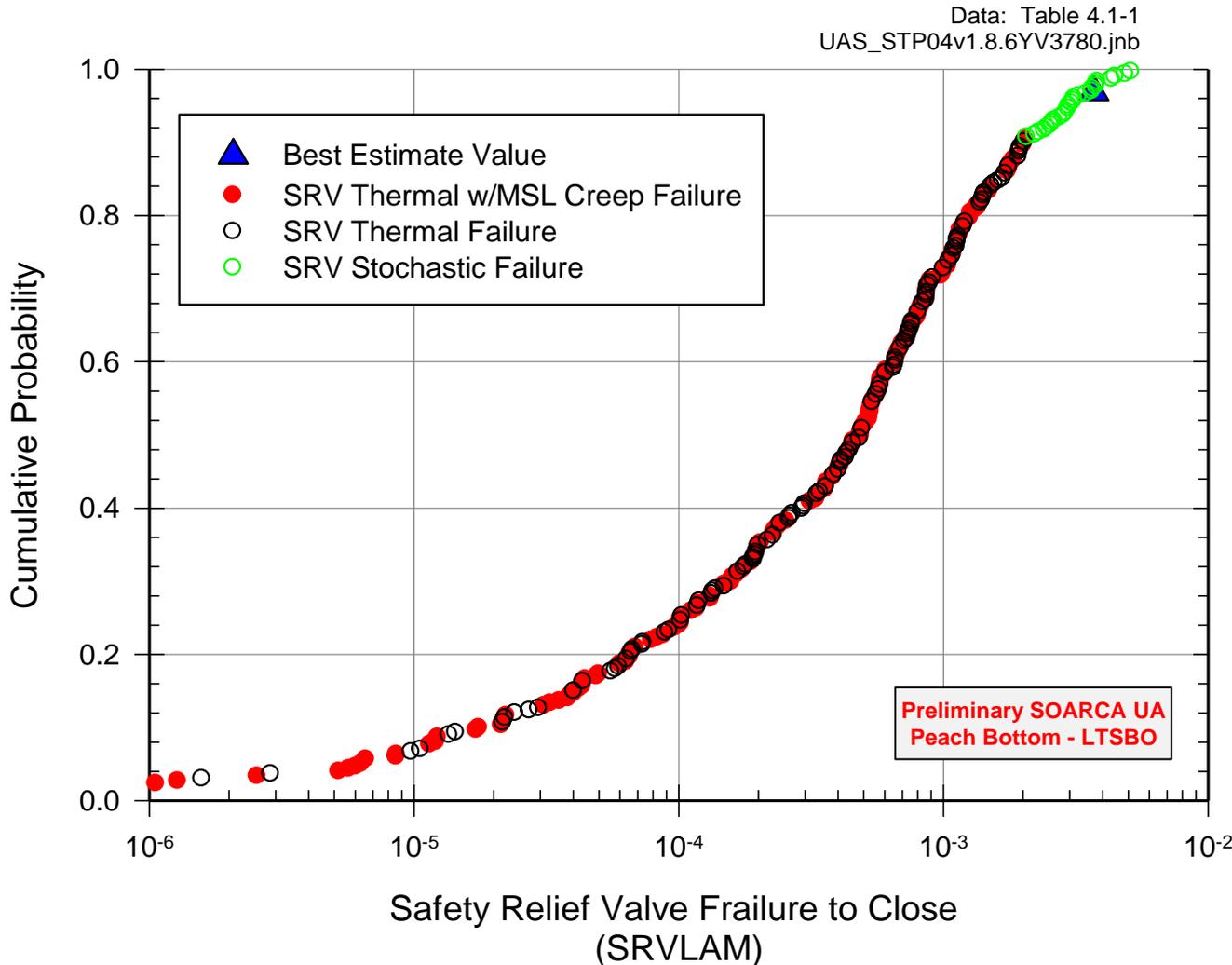
## ***Source Term SOARCA UA***

### ***Peach Bottom LTSBO***

Stepwise rank regression on the fractions of cesium and iodine release in 48 hours indicate the following parameters are important:

- SRV open area fraction for thermal seizure ( $R^2 = 0.29 - 0.30$ )
- Chemical form ( $R^2 = 0.06 - 0.09$ )
- SRV stochastic failure rate ( $R^2 = 0.04 - 0.06$ )
- Dynamic agglomeration and shape factors ( $R^2 = 0.02 - 0.05$ )
- Railroad door open area ( $R^2 = 0.03 - 0.04$ )

# Influence of Number of SRV Cycles before Failure to Re-Close



Distribution from  
 NUREG/CR-6928

$\lambda$  mean value =  $7.95 \times 10^{-4}$  per demand (1,258 cycles)

$\lambda$  best estimate value =  $3.7 \times 10^{-3}$  per demand (270 cycles)

Cited in Peach Bottom IPE

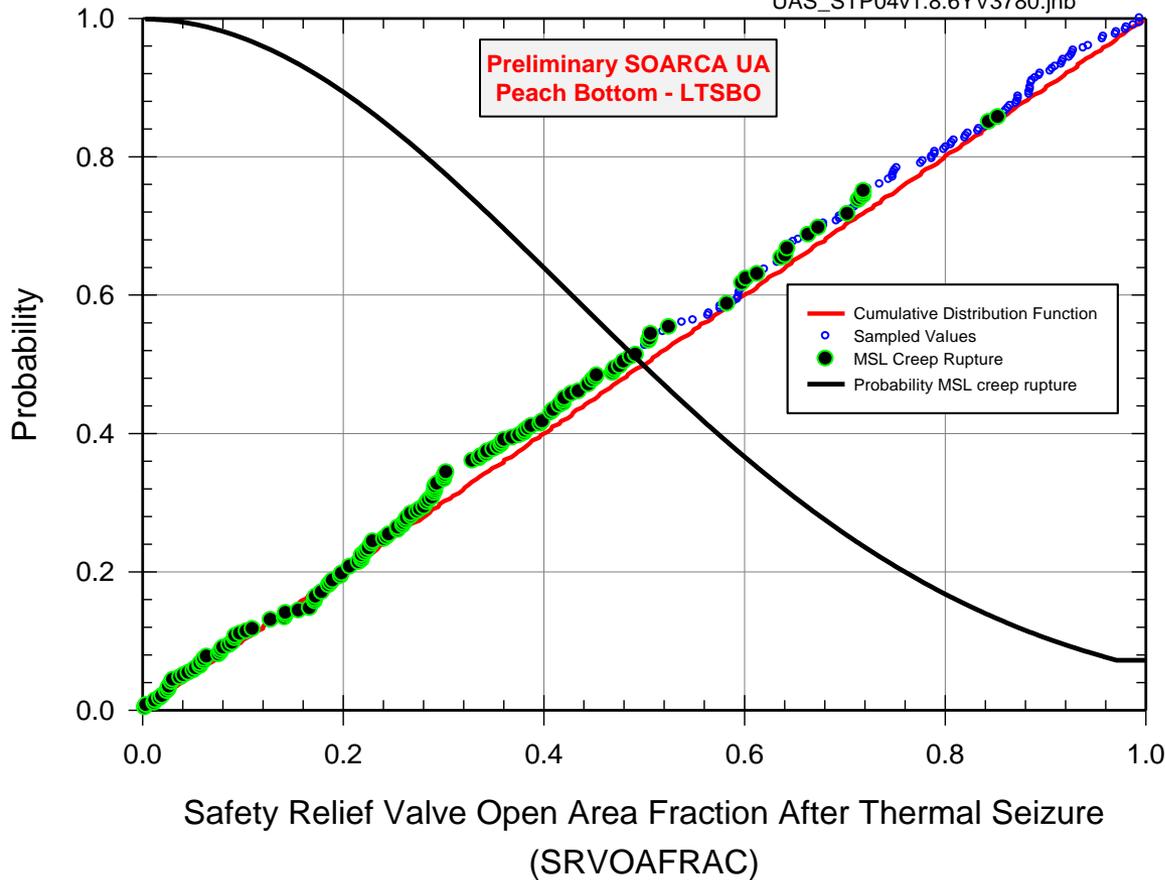
Timing of SRV failure is important

SRV will fail thermally

Potential for MSL creep failure controlled by SRVOAFRAC

# Influence of SRV Thermal Failure Open Area when SRV Thermal Failure Occurs

Data: NUREG/CR Table 4.1-3 & RizVarSamples.csv (1/7/2012)  
 UAS\_STP04v1.8.6YV3780.jnb



Uniform Distribution  
 [0,1], failed closed to  
 failed fully open

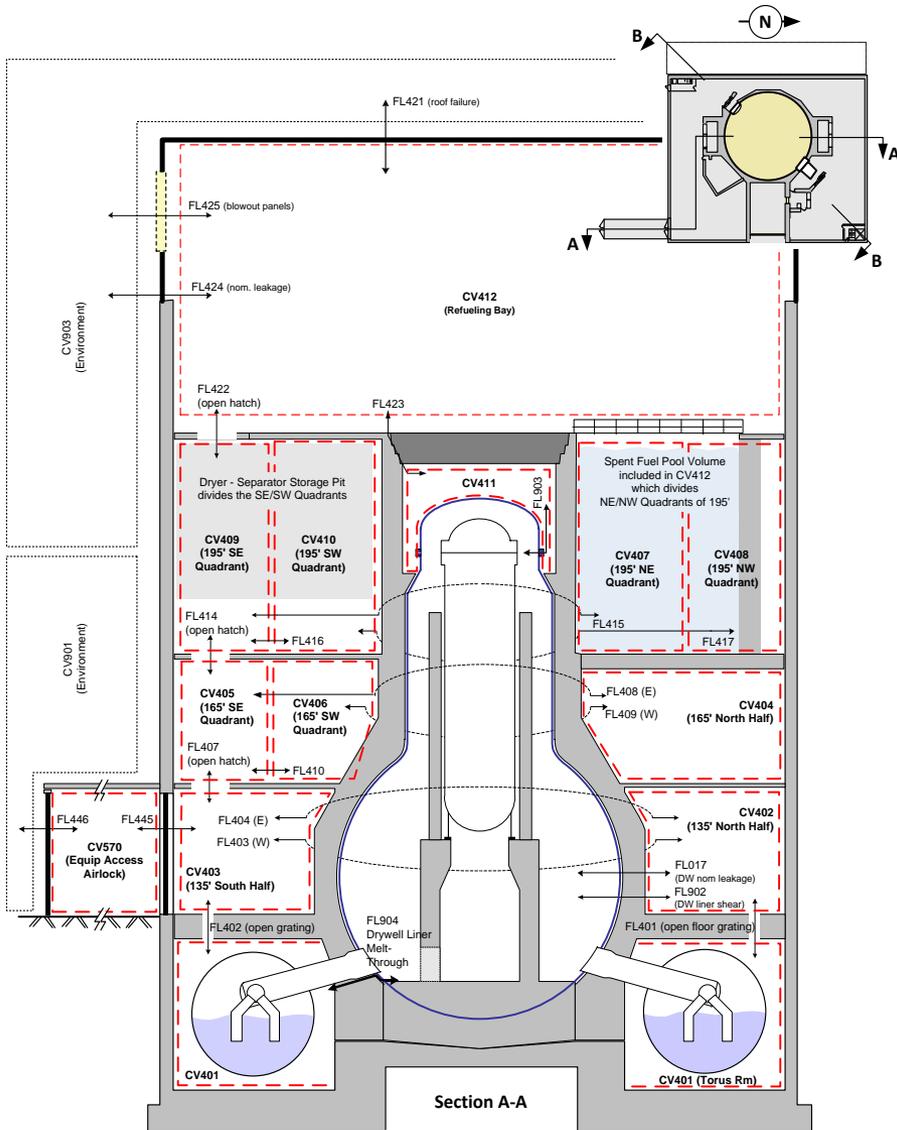
mean value = 0.5

Timing of SRV failure is  
 important

SRV will fail thermally  
 first in all cases

Potential for MSL creep  
 failure controlled by  
 SRVOAFRAC

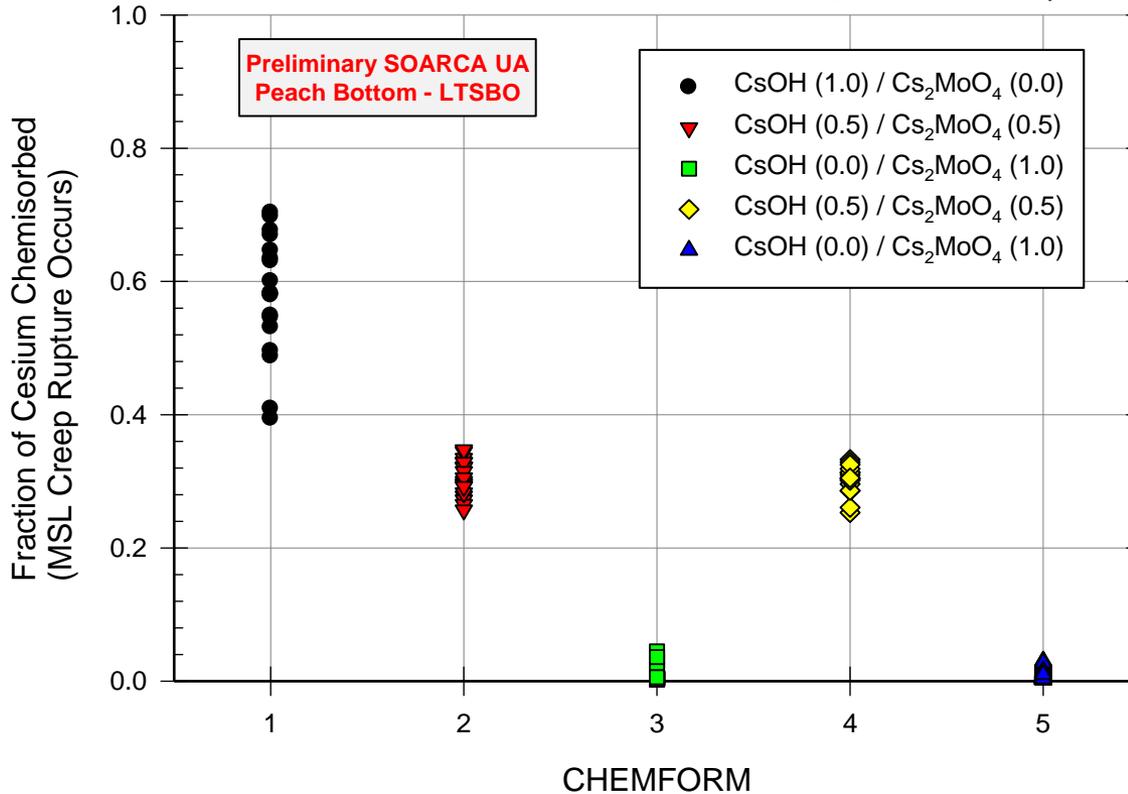
# Railroad Doors



- Railroad doors opening creates a chimney effect leading to increased releases to the environment; actual opening area is not as important as whether they are open or closed
- This effect was noted in the SOARCA best estimate and has been noted in previous MELCOR studies.

# Effect of CsOH on Fraction of Cesium Chemisorbed in MSL Creep Rupture Cases

Data: Table 4.1-1  
 UAS\_STP04v1.8.6YV3780.jnb



Discrete distribution  
 [0.125,0.125,0.125,0.125,0.5]

Chemisorption on the steam dryers and upper RPV

Limits the mass available for release

Occurs in higher temperature MSL creep rupture cases

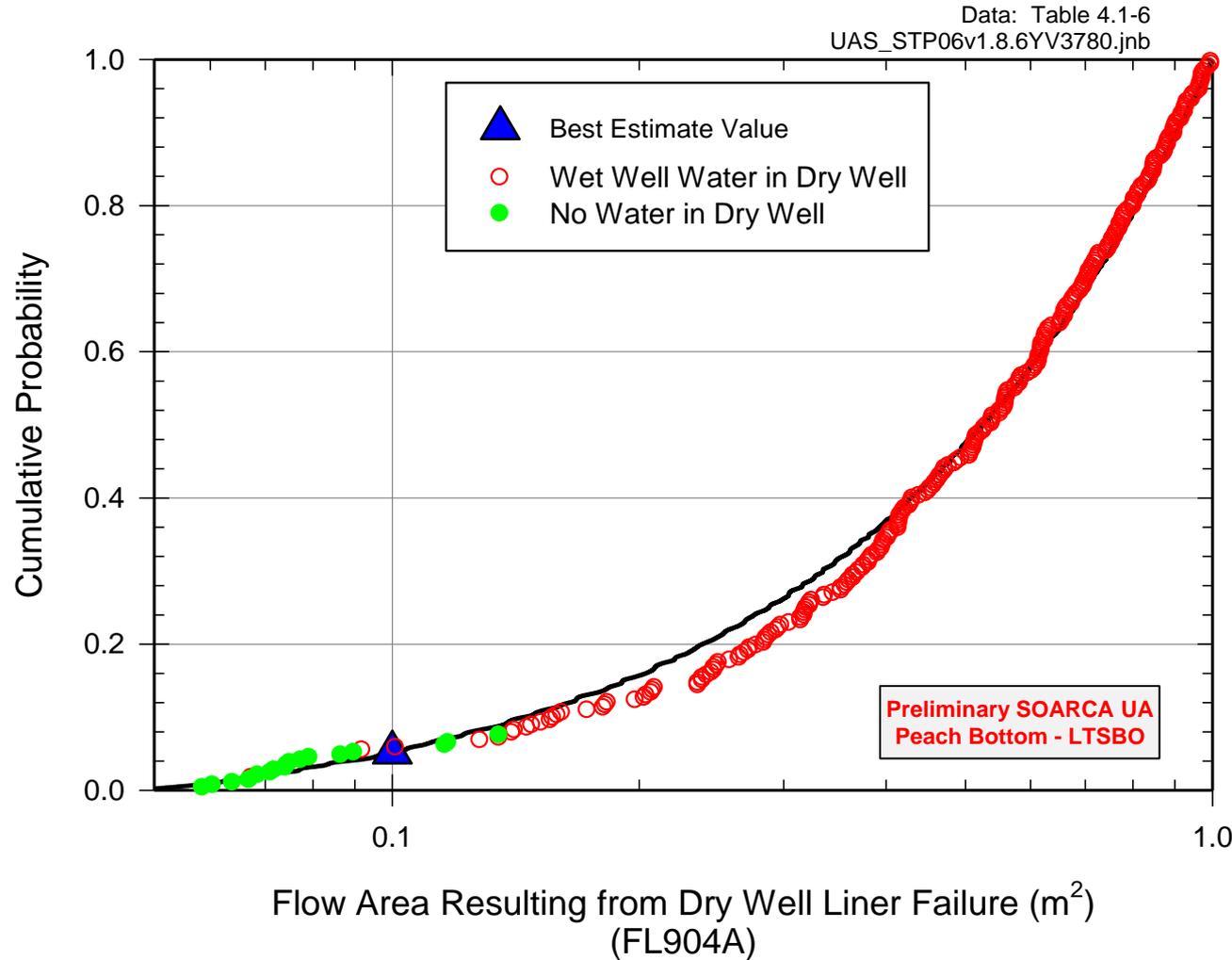
This effect not seen in best estimate calculation (no CsOH in best estimate)



# Chemical form of Cesium

- Chemical form of Cs as CsOH (present in bins 1, 2, and 4) can have an important effect limiting the mass available for release to the environment due to chemisorption for high temperature scenarios like MSL creep rupture conditions
- CsOH can slightly increase releases for lower temperature accident progression events like stochastic failure of SRV

# Drywell Liner Open Area



Uniform distribution selected from [0.05,1]

Vacuum breakers overwhelmed by pressure vented from dry well

Mass of RN relocated in water flashed into dry well

Mass is deposited on surfaces in dry well and can be slowly released to environment

Timing of opening area is important

This effect not seen in best estimate calculation.

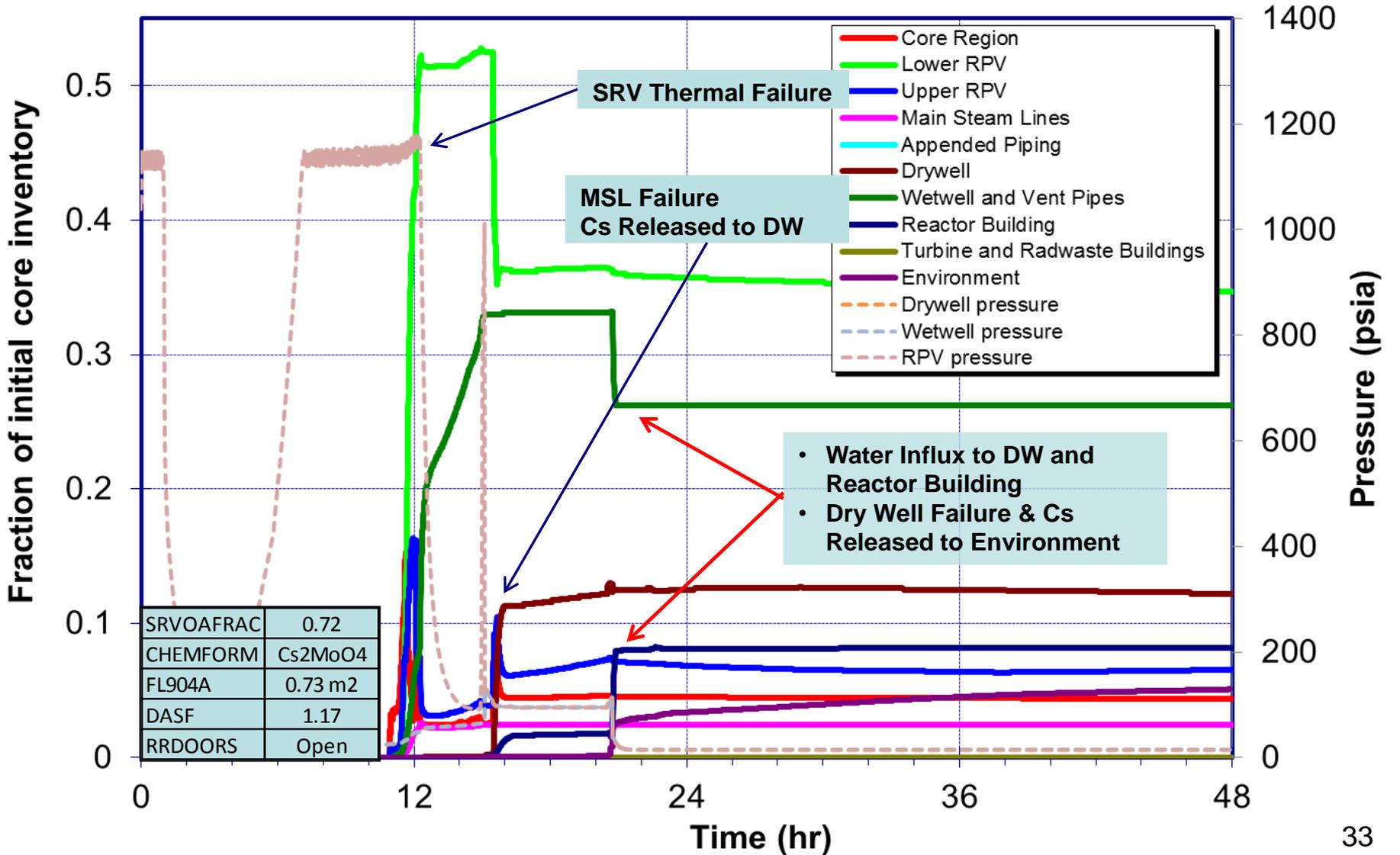
# Examples of Single Realizations from the UA Monte Carlo runs

- Examples from SOARCA UA Combined Case for Peach Bottom Unmitigated Long Term Station Blackout, Cesium distribution over time
  1. Main Steam Line Creep Rupture, water influx to drywell
  2. Chemisorption on steam dryers and upper RPV



# SOARCA UA Peach Bottom Unmitigated LTSBO - Main Steam Line Creep Rupture

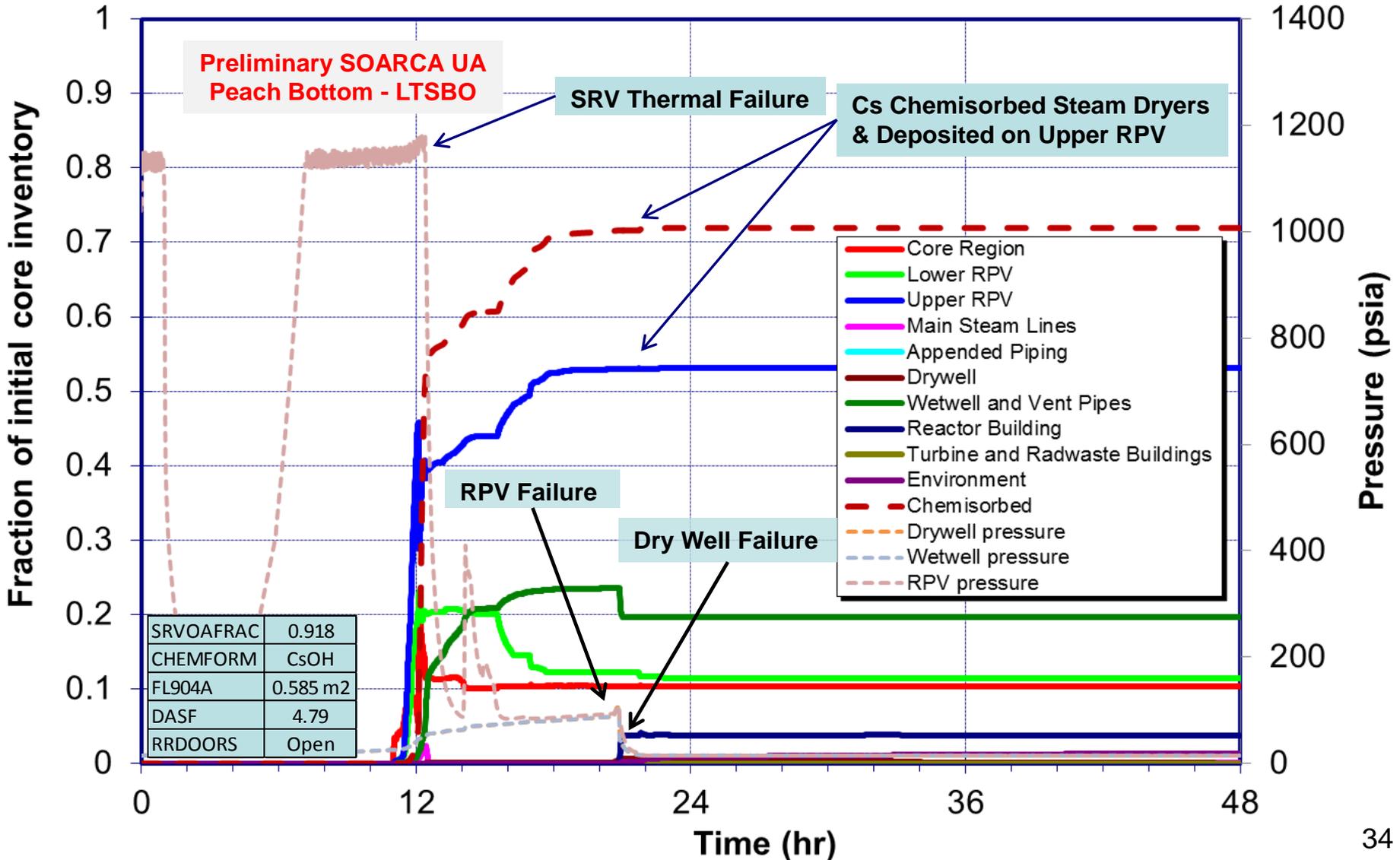
## Cs Distribution - P04R1z299 (MSL Rupture Case)

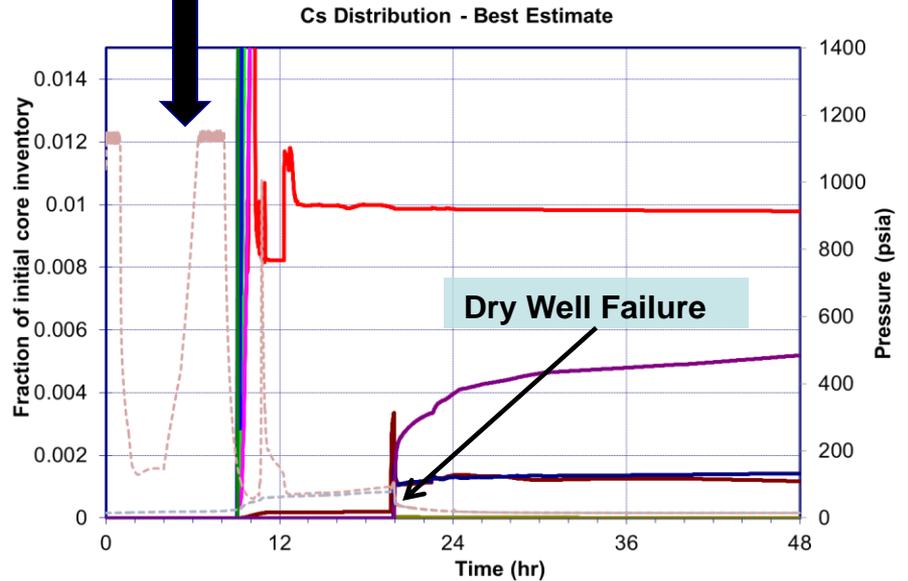
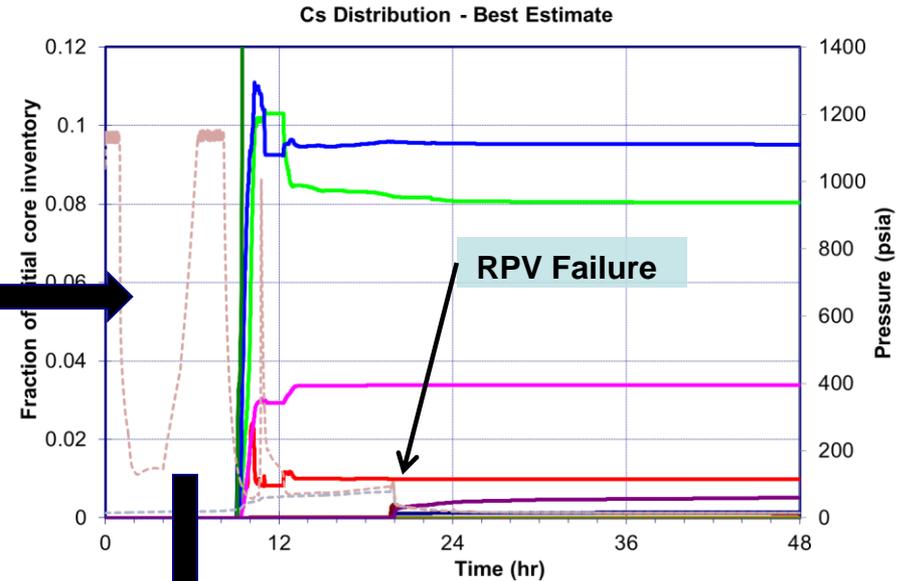
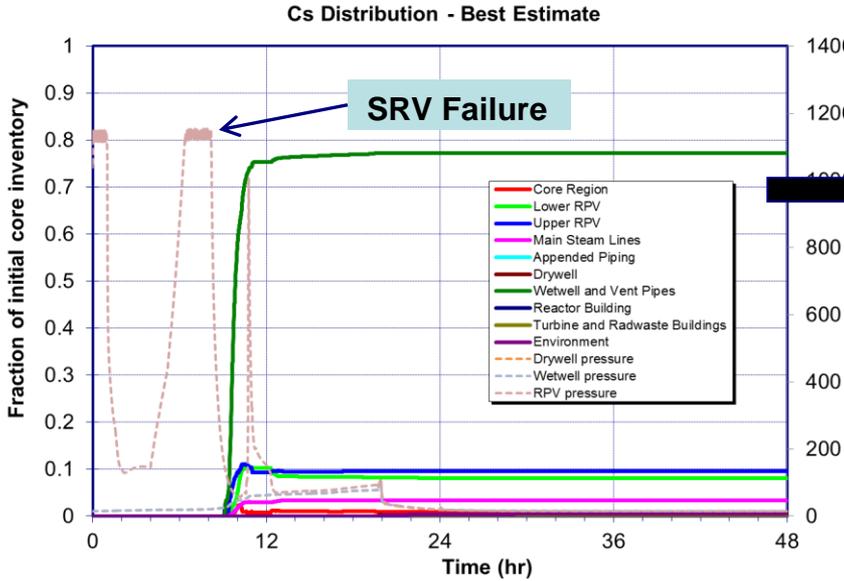




# SOARCA UA Peach Bottom Unmitigated LTSBO- SRV Thermal Failure w/CsOH

## Cs Distribution - P4R1z196 (CsOH Case)





SOARCA Best Estimate  
 Peach Bottom  
 Unmitigated Long Term  
 Station Blackout



# **Phenomenological Insights**

## ***MACCS2 Analyses***

### **UA Combined Scenario Case – Peach Bottom LTSBO**

- Unlike older studies, both SOARCA best estimate and preliminary UA results show that the long-term phase dominates health effect risks because emergency response is faster than progression to release
- Health-effect risks vary sublinearly with source term because more remediation is required for larger releases, i.e., people are not allowed to return to their homes until dose is below prescribed level regardless of initial level
- Cesium isotopes always dominate for long-term risks; barium, tellurium, and cerium can dominate over iodine for short-term risks

# Preliminary Analyses *consequence results using LNT*

- Individual latent cancer fatality (LCF) risk best estimate falls within the distribution of results from the UA combined case
- Early fatality risk is still essentially zero

<b>Individual Latent Cancer Fatality Conditional Risk (per event)            Peach Bottom Unmitigated LTSBO (Mean Core Damage            Frequency of 3E-6/reactor year), Combined Case Using LNT</b>		
	0-10 miles	0-20 miles
Minimum	2E-5	1E-5
Maximum	9E-4	6E-4
<i>SOARCA Best            Estimate</i>	9E-5	8E-5



# **Phenomenological Insights**

## ***MACCS2 Analyses***

### **UA Combined Scenario Case – Peach Bottom LTSBO**

- Based on preliminary habitability criterion sensitivity analysis:
  - Health effect risk is nearly proportional to habitability criterion assuming LNT (related to dominance of long-term phase)
  - Health effect risks drop dramatically if there is a threshold in dose response and habitability is chosen to be below the threshold.
- Preliminary results suggest that distributions of MACCS2 input parameters are reasonable

# UA Status

- Finish uncertain parameter sensitivity analyses
  - Regression analyses (e.g., stepwise rank correlation coefficients, scatter plots)
  - Continued investigation of single realizations to confirm physical phenomena and validation of results
- Phenomenological insights for other source term metrics (e.g., iodine, hydrogen production, barium, etc.)
- Additional MACCS2 results and analyses
- Separate sensitivity analyses:
  - Habitability criterion
  - Evaluation of the timing of two operator actions in the unmitigated LTSBO

## **UA Status (2)**

- An appendix with discussion and qualitative comparison with Fukushima
- Uncertainty analysis is an iterative process requiring feedback from the analyses to validate the robustness of models used to simulate the physical phenomena and the modeling assumptions over the sampled hypercube
- Identified MELCOR parameter distributions that are under consideration for revision
  - e.g., selection of uniform distributions in absence of strong technical basis

# Parameter Evaluation and Refinement

Ongoing examination of the technical basis and range of model validity to evaluate potentially non-physical regions of the sample hypercube:

- Dynamic and agglomeration shape factors (i.e., Chi/Gamma) and particle density improperly sampled independently
- Uniform distribution of drywell liner failure flow area (FL904A) up to a value of 10x its nominal value may not properly reflect SME state-of-knowledge and timing of dry well liner failure
- Uniform distribution of SRV open area fraction for SRV thermal failure events. Drives occurrence of MSL creep rupture.

# Parameter Evaluation and Refinement (2)

- SRV stochastic failure rate
  - Available database may not be representative of the situation in the SOARCA unmitigated LTSBO scenario, where the SRV fails after repeated cycling and in high-temperature conditions

# Schedule

- Commission memorandum forwarding results of the SOARCA pilot plant study will contain short discussion on status of UA and interim conclusions (June 2012)
- Complete analyses and documentation (September 2012)
- Present final results and updated insights to ACRS (Fall 2012)
  - Staff is seeking an ACRS letter on the final report
- Transmittal of final NUREG/CR report to Commission (November 2012)



**U.S.NRC**

UNITED STATES NUCLEAR REGULATORY COMMISSION

*Protecting People and the Environment*

**Questions?**

# Acronyms

BWR	Boiling water reactor
DW	Dry well
LCF	Latent cancer fatality
LHS	Latin Hypercube Sampling
LNT	Linear no threshold
LTSBO	Long-term station blackout
MSL	Main steam line
ORNL	Oak Ridge National Laboratory
PIRT	Phenomena Identification and Ranking Table
RN	Radionuclide
RPV	Reactor Pressure Vessel
SME	Subject matter expert
SNL	Sandia National Laboratories
SOARCA	State-of-the-Art Reactor Consequence Analyses
SRV	Safety relief valve
SST1	Siting study source term 1
UA	Uncertainty Analysis