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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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FUTURE PLANT DESIGNS SUBCOMMITTEE

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TUESDAY

APRIL 9, 2013

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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 10:00 a.m., Dennis C.  
Bley, Chairman, presiding.

COMMITTEE MEMBERS:

- DENNIS C. BLEY, Chairman
- MICHAEL L. CORRADINI, Member
- HAROLD B. RAY, Member
- JOY REMPE, Member
- GORDON R. SKILLMAN, Member
- JOHN W. STETKAR, Member

1 ACRS CONSULTANT:

2 THOMAS S. KRESS

3 NRC STAFF PRESENT:

4 MARK BANKS, Designated Federal Official

5 ALSO PRESENT:

6 CARL SINK, DOE

7 FRED SILADY, INL

8 DAVID PETTI, INL

9 DAVID ALBERSTEIN, INL

10 MARK HOLBROOK, INL

11 JIM KINSEY, INL

12 ANNA BRADFORD, NRO

13 DON CARLSON, NRO

14 TOM BOYLE, NRO

15 JONATHAN DEGANGE, NRO

16 JIM SHEA, NRO

17 ARLON COSTA, NRO

18 MIKE MAYFIELD, NRO

19 MICHELLE HART, NRO

20 MIKE KANIA\*

21

22

23

24 \*Present via telephone

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A G E N D A

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

10:00 a.m.

CHAIRMAN BLEY: The meeting will come to order. I'm Dennis Bley, chairman of the Future Plant Design Subcommittee.

We have with us today -- well, we don't. We have committee members Harold Ray, John Stetkar, Mike Corradini and Joy Rempe. We might have others joining us as the day goes on. There's another meeting that's drawing some of us there.

Dr. Tom Kress is here as our consultant. Good morning, Tom. Mr. Mark Banks is the -- of the ACRS staff is the designated federal official for this meeting.

The purpose of today's meeting is to receive a briefing from Idaho National Laboratory and the NRC staff on the NGNP project. Department of Energy, the official sponsor of NGNP is here too.

During the subcommittee meeting on January 17 we received an update from INL on the TRISO coded fuel research. INL also briefed us about the work they've been doing with the NRC staff on development of a licensing framework for NGNP.

Today we expect to hear from the NRC staff regarding their review of INL work on the licensing

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1 framework development in addition to hearing from INL  
2 this morning.

3 Member Mike Corradini, Joy Rempe, Harold  
4 Ray and Dana powers have some potential conflict of  
5 interest. Hence they may be limited in discussion  
6 regarding their own work.

7 The rules for participation in today's  
8 meeting were announced in the Federal Register on  
9 March 25 of 2013 for an open meeting. This meeting is  
10 open to the public.

11 We have a telephone bridge line for the  
12 public and stakeholders to hear the deliberations. To  
13 minimize disturbance the line will be kept in listen-  
14 in mode only until the end of the meeting when we will  
15 provide an opportunity for any member of the public  
16 attending this meeting in person or through the bridge  
17 line to make a statement or provide comments.

18 As a transcript of the meeting is being  
19 kept we request that participants in this meeting use  
20 the microphones located throughout the meeting room  
21 when addressing the subcommittee. Participants should  
22 first identify themselves and speak with sufficient  
23 clarity and volume so that they can be readily heard.

24 We will now proceed to the meeting and I  
25 call upon Mr. Carl Sink of the U.S. Department of

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1 Energy to begin his introduction of the NGNP project.  
2 Carl?

3 MR. SINK: Good morning. Thank you very  
4 much for having us here again today.

5 As an introduction I'd like to just  
6 briefly review how we got to where we are today.  
7 Starting back in 2008 the Department and the NRC  
8 jointly issued a NRC-DOE Licensing Strategy as called  
9 for in the Energy Policy Act of 2005.

10 As part of that it identified that there  
11 were four key licensing technical policy and  
12 programmatic issues that may need Commission  
13 resolution before moving forward with a licensing  
14 framework. These included the acceptable basis for  
15 mechanistic source term calculation, the approach for  
16 using the frequency and consequence curve for  
17 selecting licensing basis events, the allowable dose  
18 consequences for those events, and requirements and  
19 criteria for using a functional containment that was  
20 anticipated for the NGNP.

21 We have continued this work and after  
22 review by the Nuclear Energy Advisory Committee in  
23 2011 which recommended that we continue working with  
24 the NRC to develop a licensing framework Secretary Chu  
25 endorsed that with his letter forwarding the NEAC's

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1 report to Congress.

2 DOE appreciates the strong level of  
3 interaction that we've had with the NRC staff. We  
4 published, as I said before, the licensing strategy  
5 jointly. There was review and feedback on a large  
6 number of white papers covering various topics related  
7 to the NGNP. We've had about 18 public meetings over  
8 the last 3 years which were hosted by the NRC. Review  
9 of the NGNP responses to about 450 requests for  
10 additional information and feedback on that.

11 And then review of technology development  
12 plans specific to the NGNP project as well as approval  
13 of the NGNP quality assurance program description.  
14 And as we'll hear later on today they have given us  
15 feedback on the highest priority licensing issues that  
16 were described in a letter we sent them on July 6.

17 In that letter we specifically requested  
18 that those four key areas be highlighted again,  
19 licensing basis event selection, establishing  
20 mechanistic source terms, the functional containment  
21 performance requirements, and development of emergency  
22 planning, emergency planning zone distances.

23 So DOE has been focused and continues to  
24 be focused on resolution of key licensability issues  
25 to enable those applicants and the commercial sector

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1 to move forward under using a licensing framework.  
2 This framework which NGNP has proposed provides a  
3 process for assuring, along with the fuel  
4 qualification results which we talked about some last  
5 time, may touch again on today, that there is adequate  
6 protection for the public over a wide spectrum of  
7 internal and external events.

8 And we look forward to today's follow-on  
9 meeting following up on a couple of topics that where  
10 additional information was requested in our January  
11 meeting and also hearing the input from the NRC staff.

12 CHAIRMAN BLEY: Thank you.

13 MR. SINK: Thank you.

14 MR. SILADY: Good morning. My name is  
15 Fred Silady and my task here is to provide a summary  
16 --

17 MEMBER CORRADINI: Can I ask before we  
18 lose Carl, just so I understand. So, I guess I want  
19 to understand the path forward. I'm sorry. So, with  
20 the position paper -- or I don't know the proper  
21 terminology for what the staff has produced. That  
22 will then be used in what -- what's the next steps  
23 from DOE side given that the staff has responded some  
24 things with agreement, some with not so agreement,  
25 some with policy issues to Commission. What is the

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1 DOE going to do in response to that?

2 MR. SINK: From our reading of the actual  
3 papers that were presented to us there was a  
4 significant level of agreement with the positions we  
5 had put forward. And we need to make sure that there  
6 is clarity in that there's nothing left vague with  
7 those.

8 And our understanding is that the NRC  
9 staff based on the feedback they get from the ACRS may  
10 make modifications to those position papers and re-  
11 publish them later this year.

12 MEMBER CORRADINI: Okay. And then? I'm  
13 trying to figure out is that going to be the end of it  
14 from NRC's interaction with DOE on the NGNP at this  
15 point in time and everything will be put on hiatus?  
16 I mean I'll ask the staff the same question. I'm  
17 trying to understand from your perspective where is it  
18 going.

19 MR. SINK: At this point in time then that  
20 will be the end of our -- on this particular topic.  
21 The interaction on this licensing framework  
22 development. We are still going to be continuing to  
23 R&D and interaction with the NRC and the staff on the  
24 fuels development, on the modeling, the work we're  
25 doing on HTTF. Other topics that we're doing jointly

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1 with the NRC staff will continued.

2 But so far as these meetings on this  
3 framework it was jointly agreed that we've come about  
4 as far as we can come with these topics for right now  
5 until an applicant comes forward.

6 MEMBER CORRADINI: Okay, so, all right.  
7 So you actually got to the point I guess I want to  
8 understand which is until somebody applies with a  
9 specific design both NRC will stand -- staff will  
10 stand down in discussions with you and then this  
11 effort on the DOE side will essentially cease.

12 MR. SINK: That's my understanding, yes.

13 MEMBER CORRADINI: On the licensing  
14 framework.

15 MR. SINK: The licensing framework, right.

16 MEMBER CORRADINI: Okay. All right. Then  
17 let me ask one follow-up question. Back in some year,  
18 I don't know what year, a few years ago the Commission  
19 specifically pointed to the NGNP as an example of  
20 exercising the technology-neutral framework process.  
21 This is kind of more of a question for the staff but  
22 since you're there. Has -- and you've seen, I think  
23 it's 1860? 1260? I can't remember. Has this been  
24 exercised from your perspective? In other words, has  
25 the technology-neutral framework process been

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1 exercised with this as an example to the point that it  
2 actually has been advanced. Any progress?

3 MR. SINK: I think so far as NGNP  
4 specifically and the high-temperature gas reactor  
5 project is concerned it's not completed yet. But we  
6 are anticipating moving forward with other advanced  
7 reactor concepts, licensing framework efforts with the  
8 NRC staff. Discussions about that are standing up  
9 right now for how that would move forward on  
10 additional projects.

11 MEMBER CORRADINI: Can you remind me what  
12 those are?

13 MR. SINK: Such topics as a fluoride-  
14 cooled high-temperature reactor, fast reactor, sodium-  
15 cooled fast reactor. Topics such as that.

16 MEMBER CORRADINI: And your intention, the  
17 DOE's intention is to use an approach similar to what  
18 you'd use for NGNP since this has shown some -- or  
19 this has been shown to be amenable with staff.

20 MR. SINK: Definitely. A lot of the work  
21 that we've done already in these areas is going to  
22 roll into that effort.

23 MEMBER CORRADINI: All right. Thank you.  
24 Sorry.

25 CHAIRMAN BLEY: Let me fire that up just

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1 a little bit. I think I understood everything you  
2 said but is there a series of technical white papers  
3 and assessments of those papers -- what are your  
4 expectations? I mean we don't have an applicant, we  
5 don't have a design. Is there any agreement from your  
6 point of view that issues are settled at this point or  
7 how do you look on these white papers and the  
8 assessments of them by staff?

9 MR. SINK: I think that based on the  
10 feedback that we hear today and any additional  
11 feedback and questioning from the ACRS there's  
12 potential that these -- the four key issues could be  
13 settled.

14 CHAIRMAN BLEY: Okay, thank you.

15 MEMBER RAY: Well, Dennis, I think that  
16 that -- I had a similar question which is we've used  
17 the word "framework" here a great deal. I'm not sure  
18 we all know what that means which is implicit in the  
19 question you asked.

20 It really goes not I think to the good  
21 faith effort to provide responses but to how qualified  
22 the responses need to be, you know, how hedged given  
23 the limited information is available at this point in  
24 time.

25 So I think we shouldn't delay things here

1 now but I do think a better understanding of what is  
2 meant by the Commission itself in terms of a framework  
3 being established, what does that really translate  
4 into is what I'm searching for here. I mean we can  
5 all do our best effort to reflect an effort but it's  
6 limited in its --

7 MR. KINSEY: This is Jim Kinsey from the  
8 INL. Just maybe to offer a point of clarification  
9 that might help a little bit.

10 The other piece of the licensing strategy  
11 that Carl mentioned that pointed out the four primary  
12 issues was a conclusion by both DOE and the NRC staff  
13 members involved with that working group that the NGNP  
14 could be licensed by adapting for the most part  
15 existing light water reactor regulations.

16 So when we talk about this framework we're  
17 really talking about the processes that would be used  
18 to work through that adaptation process. So if that  
19 helps to clarify. And these four items are key  
20 cornerstones or key foundations of that adaptation.

21 MEMBER CORRADINI: So here's what my  
22 concern is. Maybe I'm the only one that's concerned.  
23 But everything we had, there's so many issues that pop  
24 up and then rise up and then fall, and rise up and  
25 fall. I'm worried that when this falls it'll fall

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1 apart.

2 So I want to make sure it's very clearly  
3 documented where there are things that are -- I won't  
4 use the word "settled," I guess nothing is completely  
5 settled, but where it looks apparently things are in  
6 concert and where they're not in concert, and what are  
7 the action items to move forward.

8 And to me that's very important. That's  
9 why I was asking the questions of Carl was that -- is  
10 that if things aren't settled and there's things that  
11 need to be further done in fuels like there was some  
12 discussion about length of time and temperature and  
13 such things, then that's clearly identified as  
14 something that needs to be worked on. And there are  
15 certain things that are -- people seem to be okay  
16 with. I got the impression that the way in which  
17 licensing basis events were identified or at least the  
18 process by which they are staff seemed comfortable  
19 with. Those are clearly done so that when this gets  
20 dropped or put on hiatus it doesn't have to reinvented  
21 6 months later, 6 years later, whatever it is.

22 MR. SINK: Yes. That's our intent as  
23 well.

24 MEMBER CORRADINI: Okay. And then my  
25 second concern is, and I'm sure the Commission did

1 this, I'm just not sure -- and I'm wanting to ask the  
2 staff this. I want to make sure the staff really has  
3 responded to the Commission's directive for 1860 which  
4 is this is an example case for technology-neutral  
5 framework application and what are their lessons  
6 learned so that when you do come up with whatever the  
7 things you said you're going to come up with next we  
8 don't start from scratch.

9 We actually can say, okay, we did this  
10 with the NGNP, it's on hiatus but the same process or  
11 at least we can pick up here so we don't have to start  
12 from a, I don't want to say ground zero, but less  
13 than an optimal point.

14 CHAIRMAN BLEY: Now I think we're ready.

15 MR. SILADY: Good. Let's go to the first  
16 slide. At our January 17th session with you we went  
17 into some detail on these five areas. And we have a  
18 couple of more items to talk about at this meeting  
19 this morning before the staff as before. And we just  
20 wanted a summary, a very brief summary of the summary  
21 if you will of the January 17th meeting.

22 And these areas are the safety approach  
23 and design basis, the licensing basis event selection  
24 process, the mechanistic source terms, the functional  
25 containment, the siting source terms and of course

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1 fuel qualification and radionuclide retention. So I'm  
2 going to briefly go through those in a number of short  
3 slides here. Next page.

4 One slide for the safety approach and  
5 design basis summary. The top objective is not to  
6 disturb the normal day-to-day activities of the public  
7 outside the exclusionary boundary. So our  
8 quantitative requirement which is a design target of  
9 the project is to meet the protective action  
10 guidelines at an exclusion area boundary of roughly  
11 400 meters. And that's for a very wide spectrum of  
12 events within and beyond the design basis.

13 We believe our safety approach and design  
14 basis summary is responsive to the advanced reactor  
15 policy. You can go back to the January 17 meeting for  
16 a tick by tick check-off of how we're responsive to  
17 it.

18 You obviously recall that we have a  
19 defense-in-depth system of barriers. They are -- many  
20 of them, they're concentric or one is completely  
21 inside of the other. At the level of the few  
22 elements, the helium pressure boundary and the reactor  
23 building they're independent. And these barriers  
24 collectively comprise the functional containment.

25 The emphasis has always been since the '85

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1 time frame after Three Mile Island when we shifted  
2 from large HTGRs down to the modular HTGR where we  
3 deterministically said hey, we're going to size and  
4 we're going to configure the reactor in a long,  
5 slender, annular core. It's been on retention within  
6 the -- at the source within the radionuclide particles  
7 and within the fuel element.

8 So to do that we need to do the following  
9 three sub-functions which we talked about, the passive  
10 heat removal, the control of heat generation and the  
11 control of chemical attack. Next page.

12 The licensing basis event selection  
13 summary is that we're going to determine when top-  
14 level regulatory criteria must be met. The top-level  
15 regulatory criteria are the quantitative direct --  
16 top-level regulatory criteria are -- have three  
17 things. We went through all the regulations, NRC, EPA  
18 and so on and we screened them so that we could figure  
19 out what we needed to design to.

20 And if they're quantitative so that you  
21 can design to them, they're direct measures of  
22 consequence, of risk to the public, and they're  
23 technology-neutral, they're generic. So we select  
24 then during the design and licensing process with the  
25 risk insights of a full-scope PRA that considers

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1       uncertainties we select these events.

2                   And they fall into categories.  Those that  
3       you expect during the life of the plant, those that  
4       you don't expect in a plant lifetime but which might  
5       occur if you had a fleet of plants, like several  
6       hundred, and those that aren't expected even in a  
7       large fleet of plants, the beyond design basis events,  
8       the events that you don't design for with conservative  
9       margins but which you have the capability to respond  
10      to and still meet our top requirements.

11                   And there's a fourth category.  This is  
12      the traditional Chapter 15 events.  And we derive  
13      those from the design basis events by assuming only  
14      safety-related SSCs respond successfully.

15                   So the DBEs and the AEs and the beyond  
16      design basis events, those we put on a frequency plot  
17      which is the next plot.  And those have the entire  
18      plant responding.  So we see the interplay between  
19      what is safety-related, not safety-related, and so on.

20                   MEMBER CORRADINI:  So, just to clarify.

21                   MR. SILADY:  Sure.

22                   MEMBER CORRADINI:  So for the DBAs, all  
23      the similar assumptions we're familiar with for light  
24      water reactors apply.

25                   MR. SILADY:  I wouldn't claim to know all

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1 those assumptions. But we --

2 CHAIRMAN BLEY: -- assume a single  
3 failure. The failure criterion is the one --

4 MR. SILADY: If the event had single  
5 failures in it, fine. If it had multiple failures in  
6 it, fine. That we get from the DBEs.

7 Then we just look at it with the safety-  
8 related SSC. So I think the answer is no with regards  
9 to that. Not that we wouldn't pick that up in the  
10 beyond design basis events, perhaps, but we take  
11 multiple failures within the design basis event  
12 region. And we're looking at more than one reactor as  
13 you'll see.

14 MEMBER STETKAR: I wasn't here in January  
15 so perhaps you covered some of this, but as I read  
16 through it I had some confusion about the notion that  
17 you just described. You said that the DBAs are  
18 derived from the DBEs, assuming that only safety-  
19 related systems are available. Is that correct?

20 MR. SILADY: Yes, that is correct.

21 MEMBER STETKAR: Okay. Suppose I have a  
22 beyond design basis event scenario whose frequency is  
23 in the beyond design basis event area. Because non-  
24 safety related systems have been included in that  
25 model. So for example, the frequency is, pick a

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1 number. One --

2 MR. SILADY:  $10^{-6}$ .

3 MEMBER STETKAR:  $10^{-6}$  and of that  $10^{-6}$   $10^{-3}$   
4 of that is because of non-safety related systems. If  
5 I didn't take credit for those systems the frequency  
6 would be  $10^{-3}$ . Is that scenario then a candidate for  
7 a design basis accident? Because it's not a design  
8 basis event in the general concept.

9 MR. SILADY: We're going off a little bit  
10 but I think it's a very crucial point so let me just  
11 try to summarize it succinctly.

12 MEMBER STETKAR: I'm not sure we're going  
13 off because I want to understand what a design basis  
14 accident is.

15 MR. SILADY: Right. But we talked about  
16 this in January. There are beyond design basis events  
17 that have high consequences that would not be able to  
18 meet the dose criteria for the design basis region,  
19 the 10 C.F.R. 50.34. Just as we want to make sure  
20 that the DBAs that mitigate and stay within the design  
21 basis region, 10 C.F.R. 50.34, we want to make sure  
22 that beyond design basis events with high consequences  
23 don't float up. And so we make things safety-related  
24 to have the requisite reliability to prevent those.

25 So that is how beyond design basis events

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1 can have requirements put on SSCs that then become  
2 safety-related. We had a nice little chart that had  
3 on the FC chart we had one area where we're mitigating  
4 DBAs and one area where we're preventing beyond design  
5 basis events.

6 So, because if the beyond design basis  
7 event doesn't have a consequence that's going to  
8 exceed 10 C.F.R. 50.34 what the fraction is of the  
9 plant that responded that was safety-related and what  
10 the fraction was non-safety related isn't as material  
11 as it is if it would violate 10 C.F.R. 50.34.

12 MEMBER STETKAR: I'll have to go back and  
13 read the transcript.

14 MEMBER CORRADINI: You're going to show  
15 that curve I assume.

16 MR. SILADY: We're going to show the curve  
17 but we're not going to -- we can pull up the backup if  
18 we need I believe.

19 MR. KINSEY: I think the backup will be a  
20 good idea.

21 MR. SILADY: Yes.

22 DR. KRESS: Let me ask you a question  
23 about that. When you look at an SSC in one of these  
24 events and look at the uncertainties associated with  
25 it to see if it might move you into another frequency

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1 or another consequence. You just look at one SSC?

2 MR. SILADY: We look at the sequence and  
3 we look at the function. And then in that sequence  
4 there are certain SSCs that are available and not  
5 available. And we look then at if the event straddles  
6 the design basis region let's say and the beyond  
7 design basis event we say well, our certainty is not  
8 sufficient to say it's in this region or in that  
9 region. We'll look at the consequences of it against  
10 both as if it first were in the design basis and  
11 secondly it's in the beyond design basis.

12 DR. KRESS: If it takes, say, two or more  
13 or three SSCs to move you in one direction or the  
14 other beyond this top-level criteria would all three  
15 of those or however many it took --

16 MR. SILADY: That would be a design choice  
17 as to one or more of them need something to be  
18 tightened up in order to meet the requirements.

19 DR. KRESS: And what criteria do you use  
20 for that choice?

21 MR. SILADY: Making sure that the event  
22 meets the dose criteria in the design basis region or  
23 the QHOs in the beyond design basis event region.

24 DR. KRESS: Yes, but suppose further or  
25 the probability of one failure, say three SSCs lose

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1 you and the two won't. Would you make all three of  
2 them safety-related or?

3 MR. SILADY: If -- you cannot make one  
4 system of a high consequence beyond design basis event  
5 keep you in that low-frequency range.

6 DR. KRESS: You're looking at one at a  
7 time SSC.

8 MR. SILADY: If you cannot make one --  
9 that would be the designer's preference, to put the  
10 reliability into that. Then you go to a second one,  
11 obviously.

12 DR. KRESS: But if it takes two of them to  
13 move you would you make both of those SSCs?

14 MR. SILADY: Yes.

15 DR. KRESS: You know one of them won't do  
16 it by itself.

17 MR. SILADY: That's right.

18 DR. KRESS: So you'd make two.

19 MR. SILADY: Yes.

20 DR. KRESS: Well, how about four of them?

21 MR. SILADY: I don't think for a given  
22 function we have four heat removal systems.

23 DR. KRESS: You probably don't for a given  
24 function but you may have three.

25 MR. SILADY: Yes, yes. And generally we

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1 find by using passive SSCs like the reactor cavity  
2 cooling system we can make it sufficiently reliable  
3 that we can say that one alone is sufficient.

4 In other functions such as control of heat  
5 generation we may need two reactivity systems. We  
6 find that generally we do for some rare events.

7 DR. KRESS: So you would make both of  
8 those.

9 MR. SILADY: Yes.

10 DR. KRESS: Even though one of them won't  
11 do it by itself.

12 MR. SILADY: They work in tandem to get  
13 you in the successful -- for some sequences only one's  
14 required. For other sequences maybe both are  
15 required. It's not that black and white. You have to  
16 look at each of the licensing basis events.

17 MEMBER REMPE: Fred, remind me because  
18 I've forgotten. Is the RCCS safety-related?

19 MR. SILADY: It is. For heat removal,  
20 yes. All right, well this is good. We didn't expect  
21 maybe that we'd be going back to January 17 but I'll  
22 be happy to answer the questions.

23 MEMBER CORRADINI: We still haven't moved  
24 off of the 17th. So let me repeat the question that  
25 Dennis and John asked just so I'm clear. So if it is

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1 safety-related and it is going to be used as part of  
2 the analysis for the DBA, the single failure criterion  
3 applies.

4 MR. SILADY: I don't think we've said  
5 that. We're always after getting the reliability.  
6 And we don't think in some cases single failure is  
7 sufficient. And that diversity may be better than  
8 redundancy.

9 MEMBER CORRADINI: So can I say your  
10 answer back to me a different way?

11 MR. SILADY: Yes.

12 MEMBER CORRADINI: If I have system X and  
13 I have one of system X, and I have system Y and I have  
14 one of system Y, your redundancy is that if X fails Y  
15 is there to perform the function.

16 MR. SILADY: If needed to stay in that  
17 region and meet that requirement.

18 MEMBER CORRADINI: So therefore X and Y  
19 must be safety-related.

20 MR. SILADY: Yes. Yes. We have that,  
21 let's say in the case of the control of heat  
22 generation. We have a control rod system and it has  
23 a lot of redundancy in it, banks of different rods and  
24 so on and in the I&C in the protection system there's  
25 redundancy. But parts of it are only single.

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1           And then we have a reserve shutdown system  
2           which is completely independent that also drops by  
3           gravity and so on. And it has different numbers of  
4           hoppers so it has redundancy. We didn't go in though  
5           and say thou shalt have redundancy and take the  
6           single-failure criteria. Usually those things are the  
7           first thing you do in terms of reliability. And  
8           they're built in for investment protection reasons and  
9           so on. So you have a full plant design that's looked  
10          at all your requirements for normal operation,  
11          investment protection, availability as well as safety.

12                   I think we'd be hard pressed to say that  
13          we found any sequences that violate the single failure  
14          criteria that we're not doing anything about. I mean  
15          that's -- we're --

16                   MEMBER CORRADINI: Well, that's kind of  
17          what I'm getting to.

18                   MR. SILADY: Yes. But to take it as a  
19          rule, thou shalt use the single failure criteria, is  
20          kind of why I'm pushing back a little bit.

21                   MEMBER CORRADINI: Okay.

22                   MR. SILADY: Okay. So we've gotten off a  
23          little bit into the fourth bullet. And we -- the  
24          safety classification system focuses on mitigation for  
25          a spectrum of DBAs to successfully perform required

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1 safety functions. But we were trying to keep it  
2 succinct and so we didn't add also to prevent high-  
3 consequence beyond design basis events which could  
4 have been on the slide as well. And I think I've  
5 summarized that. Let's go to the next page.

6 Now this is the top-level regulatory  
7 criteria which are in solid blue that we took out of  
8 the regulations. Placed on a frequency axis. And in  
9 some cases it's easier to do than in others.

10 And so this was the proposal that we've  
11 made. It was actually made in the eighties with the  
12 DOE-sponsored MHTGR program. And it has evolved a  
13 little bit in terms of terminology and so on. But  
14 basically there's a region that is the anticipated.  
15 And we decided to take it down to once in 100 years.  
16 There's another region that goes between the lower  
17 level of the anticipated event region. It goes down  
18 to the  $10^{-4}$  and so on.

19 Well, what are those numbers? What are  
20 those frequencies? They're the frequency of an entire  
21 event sequence, not just the initiating event. And  
22 they are for an entire plant of multiple modules.

23 DR. KRESS: Let me ask the question.

24 MR. SILADY: Yes.

25 DR. KRESS: To me that means, of course,

1 in order to see where things fit in that thing you  
2 have to specify ahead of time how many modules you're  
3 going to have.

4 MR. SILADY: Yes. You have a design.

5 DR. KRESS: You have a design, in other  
6 words.

7 MR. SILADY: Yes.

8 DR. KRESS: And you have so many modules.  
9 The tendency in my mind would be then, I'd want to  
10 select the number of modules so that I get just about  
11 as close as I want to to that top-level regulatory  
12 criteria without exceeding. Do you have a criteria on  
13 how close you're going to let it get by the number of  
14 modules?

15 MR. SILADY: We really don't do it the way  
16 you say. I mean we look at the other stakeholders in  
17 terms of the users and the operators and our  
18 requirements coming from them on how many modules make  
19 it economic, make the O&M optimum that provide the  
20 demand for the electricity, the steam nearby.

21 DR. KRESS: Even though you may end up  
22 pretty close to that line. Do you have a criteria for  
23 how close you're going to let it get depending on the  
24 uncertainties associated with the --

25 MR. SILADY: We don't have a quantity

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1 requirement at this stage prior to a full conceptual  
2 design. But in past projects we've seen like the  
3 MHTGR that were orders of magnitude anywhere to the  
4 left of the solid line and even the dashed line which  
5 of course as you can see is the design target which is  
6 more stringent. So we haven't had to say thou shalt  
7 be a factor of 20 or a factor of 5 or whatever.

8 And that tradeoff with modules -- I do  
9 have a backup that shows the MHTGR cases. Can we put  
10 that up at this point?

11 CHAIRMAN BLEY: Slide 30?

12 MR. SILADY: Yes. This was presented.

13 MEMBER CORRADINI: I remember that --

14 MR. SILADY: Yes.

15 MEMBER CORRADINI: I think we did see this  
16 one, yes.

17 MR. SILADY: And we had already started to  
18 talk a little bit about design basis accidents as well  
19 as design basis events and how the design basis  
20 accidents only have safety-related SSCs. Originally  
21 this plot was just of the first three categories of  
22 LBES. They were called anticipated operational  
23 occurrences. They were called design basis events as  
24 they are now. And they were called emergency planning  
25 basis events back then where now we're calling them

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1 beyond design basis events.

2 DR. KRESS: How many modules does it --

3 MR. SILADY: And it had four modules.

4 DR. KRESS: Four modules, okay.

5 MR. SILADY: And there have been HTGR  
6 designs that have had up to 10. But no more that I'm  
7 aware of. And so we saw where those events lied on  
8 the diagram. And we're using this for design as well  
9 as licensing. So the ones on the abscissa that have  
10 zero dose were very important to us because there was  
11 something keeping them inside the acceptable line that  
12 if it didn't work it might fly over to the right-hand  
13 side here. So we had to know which ones those were  
14 and specify their capability and reliability and so  
15 on.

16 The point with the green on this chart is  
17 that these DBAs when you deterministically start  
18 assuming from your DBEs that you don't have systems  
19 they're lower frequency. There are some over there on  
20 the abscissa that are pretty close to the same  
21 frequency and with the uncertainty bands they were  
22 DBEs.

23 But there were quite a few DBEs on the  
24 high-risk, the high-consequence events that were in  
25 the mud if you will, that were below that needed to

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1 meet the NRC safety goals, below 5 times  $10^{-7}$ . And  
2 there are some that don't even show up on this plot  
3 that goes down to  $10^{-8}$ .

4 So the DBAs are not -- don't come out of  
5 the frequency consequence plot. The DBEs do and then  
6 you use your deterministic approach that we use in  
7 Chapter 15 to make sure that the safety-related alone  
8 could help you meet 10 C.F.R. 50.34.

9 So these events that are way low that  
10 normally would be compared to the safety goals, the  
11 QHOs, the Q fatality safety goal there only have to  
12 meet the 10 C.F.R. 50.34 and your Chapter 15.

13 All right, thanks for that diversion. Are  
14 we good now maybe? Let's go back to my other plot and  
15 see if there are any points there that -- just wrap up  
16 with.

17 I wanted to make sure that you understood  
18 that it's the event sequence, that it is per plant  
19 year and it's going to have a full-scope PRA so it's  
20 not just going to be reactor, it's going to be other  
21 sources like spent fuel and so on. So you might have  
22 spent fuel shared or you might have it per reactor  
23 module. All that's in the mix here.

24 DR. KRESS: So you're going to specify up  
25 front though how many modules.

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1 MR. SILADY: Yes, yes.

2 DR. KRESS: You would let the person  
3 buying the plant say we want five modules for our  
4 side, and then you'll put --

5 MR. SILADY: I can't predict how the  
6 business arrangements might be. But we will have a  
7 design that probably mock 1 is four reactor modules.  
8 And then somebody comes in and say oh, I only want one  
9 now. And so then we'll say, okay, well we have to --  
10 will you have the interest in someday having four and  
11 they may say yes.

12 And so we'll build the shared things for  
13 the four and we will sequentially add them. But the  
14 PRA and the selection of the LBEs has to consider the  
15 four because someday you're going to build that out  
16 perhaps.

17 DR. KRESS: Well the way you do that is  
18 just find the consequences for the one module and just  
19 --

20 MR. SILADY: That's not --

21 DR. KRESS: -- multiply by the number of  
22 modules.

23 MR. SILADY: No, no, no.

24 DR. KRESS: No, you can't do it?

25 MR. SILADY: You can't do that because

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1 you're going to have some events that affect all four  
2 of them. That's the beauty of the approach.

3 DR. KRESS: How do you treat those?

4 MR. SILADY: You say, okay, I've got a  
5 seismic event, or I've got --

6 DR. KRESS: Station blackout.

7 MR. SILADY: -- station blackout and  
8 that's the initiating event. And then you look at  
9 what the chances are of it affecting one or more  
10 modules. And you work your way across the event tree.

11 DR. KRESS: Well, let's take seismic.

12 MR. SILADY: Yes.

13 DR. KRESS: You have to say yes, it's  
14 going to affect all four modules.

15 MR. SILADY: Right, but it may take out  
16 let's say the main heat transport system for all four.  
17 But it may not take out all the shutdown cooling  
18 systems for four.

19 MEMBER CORRADINI: How do you know -- I  
20 can almost guess Tom's next question is how do you  
21 know with any certainty that it isn't anything but a  
22 multiplicative on the one module effect. Is that  
23 where --

24 DR. KRESS: That's where I'm -- you could  
25 read my mind. But my conclusion was that since

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1 there's so many SSCs that are relatively independent  
2 of the initiating event that probably the way you  
3 treat the initiating events that affect all of the  
4 modules at the same time, you probably go ahead and  
5 calculate the consequences due to one module and just  
6 multiply the number of frequencies.

7 And just like you would do the internal  
8 events. It's the way I think you'd probably treat  
9 that.

10 MR. SILADY: If it was the example loss of  
11 offsite power. We have a lot of passive systems.

12 DR. KRESS: Yes, that's what I had in  
13 mind.

14 MR. SILADY: Yes. And so it might be  
15 bimodal in that case in the sense that all the passive  
16 systems had an independent failure because the same  
17 maintenance crew did the maintenance on all of them or  
18 the same manufacturer or whatever. Low-frequency  
19 albeit. But you could think of things that can get  
20 passive failures as well. And then you've got the  
21 loss of offsite power and the loss of onsite power and  
22 so on. And you end up with some failures in the low  
23 frequency range.

24 But there are shades. And we have found  
25 that there are events where it's like 30 or 40 percent

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1 of them are all reactors are taken out. And 20 or 30  
2 percent are just one.

3 DR. KRESS: So the consequences would be  
4 affected --

5 MR. SILADY: Yes.

6 DR. KRESS: -- rather than just a single  
7 --

8 MR. SILADY: Yes.

9 CHAIRMAN BLEY: I'm going to interrupt  
10 because we're repeating I think a lot of what we  
11 talked about last time. And you have some new stuff  
12 you're going to get to.

13 MR. SILADY: I want to.

14 CHAIRMAN BLEY: And all of you do. So I  
15 think we're going to have to reduce the amount of  
16 revisiting the old material and look for those  
17 responses aimed at -- probably that were aimed at  
18 questions --

19 MEMBER STETKAR: Can I ask one quick one?

20 CHAIRMAN BLEY: Sure.

21 MEMBER STETKAR: And you can turn me off  
22 if this was discussed in January also. I read quite  
23 a bit of the study so I don't want to hear high-level  
24 things, I want to hear details.

25 I understand how you're treating

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1 uncertainty on the Y axis. I understand how you're  
2 doing that.

3 I do not understand how you're treating  
4 uncertainty on the X axis. In particular, you state  
5 that in the AOO region you will compare only the mean  
6 value of the consequence with the high-level goal. In  
7 the DBE region, whatever that means, you said you're  
8 going to take the upper bound of the mean which I'm  
9 assuming you really mean the 95th percentile of the  
10 uncertainty because I don't know what the upper bound  
11 of the mean means. You're going to compare that with  
12 your goal.

13 In the beyond design basis event you will  
14 compare only the mean with the goal. I don't  
15 understand that rationale. Because if I take a beyond  
16 design basis event with an uncertainty bound in the X  
17 axis and I move it up then I don't know what I'm  
18 comparing on the consequence scale. And I'll just  
19 leave it there because maybe you discussed it in  
20 January. So I'd like to understand how you're  
21 treating those uncertainties in those ranges because  
22 all the high-level stuff you say sounds good until you  
23 look at how it's going to be done in practice.

24 MR. SILADY: For all the events.

25 MEMBER STETKAR: For all of the events.

1 MR. SILADY: For all the events, the AEs,  
2 the DBEs, the beyond design basis events we do a  
3 consequence uncertainty.

4 MEMBER STETKAR: Yes, you do.

5 MR. SILADY: And so we've got the full  
6 distribution everywhere.

7 MEMBER STETKAR: Yes, you do, and I'm not  
8 arguing with that. I'm saying that you're picking and  
9 choosing what parameters of that uncertainty  
10 distribution you want to compare with your goals.

11 MR. SILADY: We tried to follow industry  
12 practice in terms of --

13 MEMBER STETKAR: Picking and choosing what  
14 parameters of the uncertainty you're choosing with  
15 each area, period.

16 MR. SILADY: We are, yes.

17 MEMBER STETKAR: Okay. I don't know the  
18 rationale behind that.

19 MR. SILADY: Okay. It is discussed in the  
20 white papers.

21 MEMBER STETKAR: I read it and I didn't  
22 understand it. It just says other people have done it  
23 in the past.

24 MR. SILADY: Okay. I'm being told that  
25 maybe in a couple of slides.

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1                   MEMBER STETKAR: Okay, if you're going to  
2 address it then we'll get to it.

3                   DR. KRESS: One other issue I have with --  
4 just popped out of a regulatory criteria being stair  
5 step has bothered me all along.

6                   MR. SILADY: Yes.

7                   DR. KRESS: And I would have made straight  
8 line --

9                   MR. SILADY: ISO risk. Or maybe it was an  
10 adverse --

11                  DR. KRESS: Well, I mean it's maybe non-  
12 risk averse. But I would have made it a straight  
13 line. That way I know exactly how far away I am from  
14 the boundaries. But if you're pretty close with this  
15 stair step I'm never quite sure how close I am to the  
16 boundaries and how to -- because there's some  
17 arbitrariness to these stair step methods in terms of  
18 the slope.

19                  MR. SILADY: There is in more than -- in  
20 probably one case for sure.

21                  DR. KRESS: Yes. So I would have elected  
22 to have a little conservative straight line on the  
23 slow glove plot for my top-level criteria. Did you  
24 consider that?

25                  MR. SILADY: We took these from the

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1 regulations and the QHO ends up looking like a  
2 straight line. And so you're happy with it.

3 DR. KRESS: yes.

4 MR. SILADY: The 10 C.F.R. 50.34, we had  
5 it all of 25 rem and back in the eighties we said --  
6 the staff gave us feedback, oh, for a higher frequency  
7 DBEs we wouldn't want to come that close. Take 10  
8 percent of it. So we made that a slope based on that  
9 input.

10 The 10 C.F.R. 20, we believe we have it  
11 exactly the way the regulation says and we can't  
12 change the regulation. It's summed over all the  
13 events and you can't exceed that. So depending upon  
14 what the frequency is you can have an event that  
15 occurs twice a year so you only take half of it.

16 So it is what it is. We would love to  
17 have something come to us that says here's the NRC  
18 frequency consequence curve and here's the basis for  
19 each kind of like they did for the safety goals.  
20 Office of Policy Evaluation could come up with.

21 DR. KRESS: Well, you could have drawn a  
22 line between the bottom points on those stair steps  
23 and make a straight line through it. And it would be  
24 a little bit conservative but --

25 MR. SILADY: That's true.

1 DR. KRESS: -- it would take away all the  
2 -- any arbitrariness.

3 MR. SILADY: You're talking about going  
4 from 10 C.F.R. 50.34 out to 10 C.F.R. 20.

5 DR. KRESS: Yes.

6 MR. SILADY: This was a starting point  
7 that where it's not about the specifics, it's about  
8 the process. There are bigger questions than where  
9 the line is.

10 DR. KRESS: Yes. Well, you know, it  
11 depends on how close you get to that line as to how  
12 you're selecting SSCs as to whether you cross over or  
13 not. It would make a difference if you had a straight  
14 line as opposed to the stair step I think as to which  
15 ones might cross you over into the unacceptable  
16 region. That was one of my issues. I don't know, I  
17 just right now don't know how to deal with that.

18 MR. SILADY: Okay.

19 DR. KRESS: One way you can deal with it  
20 is be sure you don't get very close to the stair step.

21 MR. SILADY: That in essence is what we  
22 have found to this date, yes. Let me go on.

23 MEMBER REMPE: Actually, I have one quick  
24 clarification too. You're saying --

25 MR. SILADY: Dennis, I'm really trying to

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1 go on here.

2 MEMBER REMPE: I know. If you have 10  
3 versus 4 versus 2 modules you're almost implying that  
4 you might have different events, you might have  
5 different systems you designate as safety-related or  
6 you might move the boundary.

7 MR. SILADY: No. No.

8 MEMBER REMPE: What will you do?

9 MR. SILADY: A vendor in all likelihood is  
10 going to have a four-module design or X-module design.  
11 He's going to offer that.

12 MEMBER REMPE: And I know of other vendors  
13 who've come in and said even though we're way over the  
14 safety limits we're not changing the design because  
15 it's too expensive. And so what the design is is what  
16 it is, and they just delete the cost because it's too  
17 expensive to make modifications is why I'm asking the  
18 question.

19 MR. SILADY: Well, where I was going is as  
20 the market develops you might come out with a second  
21 package. Instead of four you see there's a need for  
22 a two-pack, or you see there's a need for a six-pack.  
23 And so you offer then a selection. Do you want the  
24 two or the four, you know, whichever two you select.

25 CHAIRMAN BLEY: I think Joy's point is the

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1 one that's been bothering me. You go down, it's no  
2 big deal I think. You go up to more units on the site  
3 you may have to really change the design and that  
4 seems, you kind of said that, it's a pretty unlikely  
5 thing to see happen.

6 MR. SILADY: Yes, yes. You --

7 CHAIRMAN BLEY: So from early on --

8 MR. SILADY: Early on --

9 CHAIRMAN BLEY: -- somebody's got to  
10 decide how you're going to design this thing.

11 MR. SILADY: Yes. Exactly.

12 CHAIRMAN BLEY: For the maximum number of  
13 --

14 MR. SILADY: Yes, that's right. And  
15 there's all these questions about what if you don't  
16 put it on greenfield and you put it where it has  
17 existing reactors. Is there any budget, is there any  
18 room for you to put yours on there and still overall  
19 site-wise meet the requirements. But we're not going  
20 there today, okay?

21 CHAIRMAN BLEY: Okay.

22 MR. SILADY: Next page. I did it.

23 (Laughter.)

24 MR. SILADY: We'll go back. Okay. Later.

25 The frequency took a lot of discussion but it's pretty

1 straightforward. You're going to use the same  
2 frequency in all cases, event sequence, mean and plant  
3 instead of a reactor. But now we're inheriting all  
4 these different requirements out of the regulations  
5 and some of them are at the EAB, some are at the LPZ,  
6 some are, you know, you can read the chart. And we  
7 talked about this in the earlier meeting.

8 And so just for ease of presentation we're  
9 plotting everything at the EAB. And almost all the  
10 regulations now have gone to the total effective dose  
11 equivalent.

12 So when it came time to do NRC safety  
13 goals even though we're plotting and showing where the  
14 points are relative to the -- at the EAB we would do  
15 it per the regulation. You know, the acute to -- as  
16 shown there to 1 mile, the latent at 10 miles. And it  
17 would be the complementary cumulative distribution  
18 function on all the accident rule set that that comes  
19 with that particular requirement.

20 DR. KRESS: If you meet your EAB criteria  
21 you're almost sure to meet those other two.

22 MR. SILADY: That's right. And that's why  
23 we did it this way.

24 DR. KRESS: Yes, but there's one missing  
25 there.

1 MR. SILADY: Okay.

2 DR. KRESS: That's the societal risk. The  
3 total cost of an accident. This goes up forever, or  
4 maybe 50 miles. But I'm not so sure you automatically  
5 meet that when you meet the EABs. But I don't see  
6 anywhere where you're looking at that. The PRA  
7 preliminarily looked at the total cost of an accident.  
8 And taking all the events including beyond design  
9 basis and everything. But I don't know where that  
10 fits into your system.

11 MR. SILADY: Well, if it comes from the  
12 NRC or --

13 DR. KRESS: There's no requirement yet  
14 from the NRC.

15 MR. SILADY: I know, that's the point. We  
16 screened the current regulations. But we have from  
17 our user, in the MHTGR days we had an investment  
18 protection. And it had an FC chart.

19 DR. KRESS: Oh, you have one.

20 MR. SILADY: And then the C --

21 DR. KRESS: It has dollars for the C?

22 MR. SILADY: Yes, exactly right.

23 DR. KRESS: Oh, wonderful. I love that.

24 MR. SILADY: We're off into another topic.

25 DR. KRESS: Okay.

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1 MR. SILADY: Okay. At  $10^{-3}$  you couldn't  
2 be down for 6 months. At  $10^{-5}$  you couldn't have plant  
3 write-off, et cetera.

4 DR. KRESS: Somewhere I'd like to see that  
5 eventually.

6 MR. SILADY: Okay. I can send it. Next  
7 page, please.

8 Now, we've touched on this already. We've  
9 got different requirements shown in the green across.  
10 We've got these categories in the column, first  
11 column. They come to us with different accident rule  
12 sets.

13 And so although we're doing our  
14 uncertainty distributions for all the top three  
15 categories we pick whatever value we need for whatever  
16 the requirement is. And our understanding is on this  
17 page, that for the 10 C.F.R. 20 we come the events and  
18 we look at it at the EAB for that 100 mrem.

19 And when it comes time for the DBEs or the  
20 10 C.F.R. 50.34 it's just the DBEs and we look at it  
21 upper bound, 95 percent. For the emergency planning  
22 you want to know what the real expected, the mean  
23 values are going to be to compare to your PAGs,  
24 whether you have to move or shelter people.

25 For the QHOs we know that that's pretty

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1 well spelled out. So once we've derived there's a  
2 space between the top three which can go on an FC  
3 chart very neatly and the DBAs that are scattered  
4 everywhere.

5 We use the upper bound against 10 C.F.R.  
6 50.34 again at the EAB even though there's an LPZ.  
7 And we do this typically for 30 days but we will look  
8 at 2 hours of course, the worst 2 hours.

9 And all the while you have to keep in mind  
10 that our design objective, what we're trying to do is  
11 have that EPZ be at the EAB. Next page, please.

12 MR. KINSEY: Excuse me, Fred. Before you  
13 move on. Does this help to answer the question about  
14 where we do consequence uncertainty and where the  
15 limits come from? And the method --

16 MEMBER STETKAR: It doesn't help to answer  
17 where the limits come from except that you feel that  
18 your interpretation is somebody else has told you to  
19 do it this way. So I'm going to ask the other people  
20 that you feel have told you to do it this way.

21 MR. SILADY: Well, it's not just telling  
22 us but we've looked at a lot of different sources,  
23 regulatory and submittals and so on, and this is what  
24 we believe is current.

25 MEMBER STETKAR: I'll ask the staff.

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1 MR. SILADY: Okay.

2 MEMBER STETKAR: See if they agree.

3 MR. SILADY: There is some disagreement on  
4 this as well, so this is a good thing to bring to  
5 mind.

6 MEMBER STETKAR: I didn't quite see that  
7 disagreement. I'll ask the staff.

8 MR. SILADY: Okay, very good.

9 MEMBER STETKAR: Keep you going.

10 MR. SILADY: Next page.

11 MEMBER CORRADINI: So your objective -- I  
12 just want to get to your objective.

13 MR. SILADY: Yes.

14 MEMBER CORRADINI: Your objective is to  
15 make the EAB the EPZ.

16 MR. SILADY: Correct.

17 MEMBER CORRADINI: And if necessary you'd  
18 have to grow the EAB to make that occur.

19 MR. SILADY: If necessary. But there's  
20 lots of other things we could do. We can change the  
21 design. We can do more research. We can sharpen the  
22 pencil. You do all the designer tricks in order to  
23 find a way to make your design such that you wouldn't  
24 have to shelter or evacuate anybody offsite.

25 MEMBER CORRADINI: Okay.

1 MR. SILADY: Next page. This is the  
2 discussion we've already had of how we get the design  
3 basis accidents from the DBEs. We don't get them out  
4 of the air. We get them from the DBEs. That gives  
5 them a firm, systematic, nothing's going to drop  
6 through the cracks because we're going to put all the  
7 focus on the PRA that gave us those DBEs.

8 The DBAs are not derived from the beyond  
9 design basis events. It's the events that are in that  
10 frequency range in the DBEs that go into Chapter 15  
11 that we're going to look at deterministically. This  
12 is one of the major assumptions that blends the  
13 probabilistic with the deterministic. Enough said on  
14 that, let's go to the next page.

15 MEMBER STETKAR: No, not enough said.  
16 That last bullet is the thing that I'm not  
17 understanding. Because if I do a risk assessment and  
18 I look at I'll call them sequences. I look at a  
19 sequence and I have a bunch of things that fail and a  
20 bunch of things that succeed. And a bunch of things  
21 that fail get me down to 1 times  $10^{-6}$ . And that's a  
22 BDBE.

23 MR. SILADY: Yes.

24 MEMBER STETKAR: And it has some  
25 consequence.

1 MR. SILADY: Yes.

2 MEMBER STETKAR: So I have uncertainty  
3 about that consequence. Now, if I look at the bunch  
4 of things that have failed and I say, well, half of  
5 that bunch is non-safety related. I'll call it non-  
6 safety related. Now, if I -- do I assume that that  
7 non-safety related stuff cannot work when I think  
8 about design basis accidents?

9 MR. SILADY: In our framework we think of  
10 design basis accidents in the DBE space. In the  
11 beyond design basis event space we only think of those  
12 that are high-consequence that would exceed 10 C.F.R.  
13 50.34 that we would then need to make things safety-  
14 related to keep them low-frequency.

15 So the only time in which the DBA or the  
16 safety-related comes into play is either from the DBEs  
17 to mitigate them, to meet the consequences, or from  
18 the high-consequence BDBEs that are -- if we looked on  
19 the chart they're over to the right that we don't want  
20 to have rise up because there --

21 MEMBER STETKAR: But they're still not  
22 considered DBAs but they might have -- you might  
23 define safety-related equipment because of that  
24 criterion.

25 MR. SILADY: Yes. And actually --

1 MEMBER STETKAR: I got it.

2 MR. SILADY: Okay.

3 MEMBER STETKAR: Next slide.

4 MR. SILADY: Thank you. Good, progress.  
5 Next slide, please.

6 Now the functional containment is a topic  
7 that we covered on the 17th as well. Our upper tier  
8 -- and I've already told you that it's all of those  
9 barriers that are for lack of a better word concentric  
10 or nested, and that there's independence and so on  
11 between the helium pressure boundary and reactor  
12 building and all the fuel.

13 What we do here is we set intentionally  
14 that we're going to have requirements on retaining  
15 radionuclides within the fuel. We really want to put  
16 the focus on retention at the source.

17 But we're going to look at what the other  
18 barriers do for us as well in terms of helping us have  
19 additional margin to our requirements. So, the  
20 standard that we're looking for performance here is  
21 characterized by during normal operation retention  
22 within the fuel so that we have a really relatively  
23 low inventory within the helium pressure boundary.

24 Then if you have a leak in the helium  
25 pressure boundary it won't exceed the requirements

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1 offsite. That's the idea.

2 And then secondly we're going to limit  
3 releases throughout the spectrum for the off-normal  
4 events. Whether it be an early release or an early  
5 and a delayed and so on.

6 Finally, our functional containment system  
7 has the capability to control leakage when you think  
8 of it in the full five barriers. Next page.

9 Our summary of where we are, and this is  
10 largely from the MHTGR and the PBMR and some of the  
11 other designs that have been before in the pre-  
12 application interactions over the decades is that we  
13 can release that which comes out during normal  
14 operation from the helium pressure boundary and meet  
15 10 C.F.R. 50.34.

16 Our limiting LBEs tend to be, the risk-  
17 significant ones, have an initial release from the  
18 helium pressure boundary. Because if you don't fail  
19 the helium pressure boundary you aren't getting  
20 anything out.

21 And there's a range of possibilities  
22 there. There's leak sizes and leak locations, and  
23 there's the possibility of the relief valve. And the  
24 high-risk events really are not the big breaks in the  
25 helium pressure boundary but it's that relief valve

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1 that goes off because the steam generator is at higher  
2 pressure. You can have a steam generator tube leak  
3 and that in certain sequences if the water keeps  
4 coming that relief valve lifts. So that's the initial  
5 release.

6 And then you have the larger delayed  
7 release from the fuel which takes as you know 2-3  
8 hours because of low power density and high heat  
9 capacity.

10 The next two statements are significant.  
11 We will meet 10 C.F.R. 50.34 without consideration of  
12 reactor building retention. We will meet the PAGs  
13 with the entire functional containment including the  
14 reactor building.

15 As you're going to hear later in the day  
16 the reactor building safety-related primarily for  
17 structural reasons. Next page.

18 The summary on the functional containment  
19 mechanistic source terms is that there's a blend.  
20 We're using retention at the source and the intrinsic  
21 properties and the passive features in order to meet  
22 the requirements. It's consistent with the advanced  
23 reactor policy. It's consistent with discussions of  
24 the containment function of mechanistic source terms  
25 in various SECY documents and with the approaches that

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1 have previously been reviewed dating back to the  
2 eighties. Two or three different times as we've done  
3 with NGNP, we did it with the MHTGR, with PBMR Exelon  
4 and with PBMR alone. Next page.

5 Here's the last page before I turn it over  
6 to Dave to talk about the fuel area. The siting  
7 source term is essentially -- our approach to it is  
8 essentially the same as what we did in the eighties  
9 and which the staff reviewed in NUREG-1338.

10 It's consistent with the discussions of  
11 containment function and mechanistic source terms in  
12 more recent SECY documents. It implements a modular  
13 HTGR-appropriate interpretation of that footnote that  
14 started off in 10 C.F.R. 100 and which is now in 50.34  
15 and 52.79 regarding siting.

16 Limiting DBAs are what we use to evaluate,  
17 to determine the SSTs. Remember our chart with the  
18 blue dots? We used the big ones that are way down in  
19 the mud as our -- source terms. Five times  $10^7$ , even  
20 some of them below that, but above  $10^8$ .

21 Back in the eighties the staff still  
22 wanted more what-ifs and deterministic flavor. So  
23 they said hey, go look at these other bounding event  
24 sequences is what they called them. And we had to  
25 look at cross-vessel failure, double-ended guillotine.

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1 We had to look at all the rods being pulled and we had  
2 to look at -- and we did it. And we intend to do that  
3 again.

4 And the reason we did it is to assure  
5 there were no cliff edge effects. That's how we used  
6 those what-ifs, so that we know the safety terrain,  
7 the topography of the land, that there's nothing  
8 lurking out there both in the weeds.

9 Well, I've had fun. I hope I've covered  
10 the ground. I've used way too much time and I  
11 apologize but I've left a little bit for Dave I  
12 believe.

13 CHAIRMAN BLEY: Not really, but it's only  
14 our lunch, so.

15 MR. PETTI: So last time you heard a lot  
16 about the fuel program, what we're doing to support  
17 the design. So just in summary that we do have a  
18 large fuel program providing data under NRC-accepted  
19 QA program to really understand fuel performance and  
20 fission product behavior for laying the technical  
21 foundation needed to qualify the fuel made to  
22 fabrication process and product specifications within  
23 an envelope of operating in accident conditions that  
24 we think will bound modular HTGRs.

25 The results to date that I talked about

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1 last time are consistent with the design assumptions  
2 about fuel performance and radionuclide retention that  
3 have been historically used by reactor designers. And  
4 we're getting data to support model development and  
5 validation.

6 And in one simple statement the results to  
7 date support the design basis that you heard about  
8 include the approach for functional containment and  
9 mechanistic source term.

10 In terms of what are our key results, we  
11 have a vastly improved understanding of TRISO fuel  
12 fabrication. We spent significant effort to improve  
13 our understanding over the historic German process.  
14 Much better fabrication and characterization by the  
15 fuel vendor largely because measurement science is  
16 just better than it was in 1978 and 1980. Our ability  
17 to do certain parts of the fabrication equipment is  
18 better. We're actually leveraging the computer  
19 industry and making chips, one of the key components  
20 in the fabrication of fuel is the same component.

21 We've had an outstanding irradiation  
22 performance. You have a large statistically  
23 significant population in TRISO fuel particles at high  
24 burnup and high temperature HTGR conditions. And we  
25 have confirmed the expected superior irradiation

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1 performance of uranium oxycarbide fuel at high burnup  
2 which has been a point in the fuel community for  
3 decades.

4 We're in the middle of wrapping up our  
5 post-irradiation examination of the first fuel AGR-1.  
6 And as many know silver tends to come out of this  
7 fuel. We got a lot of silver out of the fuel in AGR-  
8 1. Generally consistent with the model predictions to  
9 date but no cesium release from intact particles under  
10 irradiation. Any cesium we see in the fuel matrix  
11 after irradiation, it was a defective particle in that  
12 capsule.

13 There was no palladium attack or corrosion  
14 of silicon carbide despite large amounts of palladium  
15 outside the silicon carbide. Percent level of  
16 palladium went through the silicon carbide but the  
17 silicon carbide is fine as evidenced by the fact that  
18 there's no cesium outside the silicon carbide.

19 And we have done some safety testing. I  
20 think we just finished number 7. Hundreds of hours at  
21 16-, 17- and in red there is 1,800. We just completed  
22 an 1,800 degree C test demonstrating the robustness of  
23 the fuel. And we'll talk about it in the next slide.

24 So the accident safety testing is well  
25 under way. We simulate this core conduction cooldown

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1 that you see in the plot. And what we do is simple,  
2 right now, isothermal testing for hundreds of hours at  
3 16-, 17- and 1,800. We have done -- it says six  
4 tests. I was losing track -- have been completed.

5 We will actually try to do a test sometime  
6 this year, early next year that follows the purple  
7 line, the actual time/temperature results for the core  
8 to compare to the isothermal. And we are thinking  
9 about deconsolidating the particles and just heating  
10 up the particles and not the matrix because our  
11 releases look like it's just material that had  
12 diffused out into the matrix under irradiation and the  
13 particles were not releasing under these accident  
14 tests. We just want to be able to confirm that. But  
15 it does look like that that's the case.

16 MEMBER CORRADINI: So can I? I'm not a  
17 fuels person. I was hoping there would be somebody in  
18 the committee that knows the right question to ask but  
19 since -- so your last point, I guess I have a number  
20 of questions.

21 So your last point is that you think it  
22 got there from the fabrication event and during the  
23 irradiation testing, or it leaked out over long time  
24 spans during irradiation testing? That's what I  
25 wasn't clear on.

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1 MR. PETTI: During irradiation depends on  
2 the fission product. Some fission products will  
3 diffuse through the silicon carbide.

4 MEMBER CORRADINI: The metallics.

5 MR. PETTI: Some of the carbides besides  
6 silver which is not safety-significant. But europium  
7 and very low levels of strontium we see in the matrix,  
8  $10^{-3}$  to  $10^{-5}$  fractions, small levels.

9 Then we put a twin compact because that  
10 one we had to destroy to get that number. Then we  
11 take the one sitting right next to it and put it in  
12 the furnace and the release is about the same as when  
13 we dissolved it and said what's in the matrix.

14 The releases are flat over time. You put  
15 it in the furnace, you get to the temperature, they  
16 never increase which says it what sort of came out and  
17 then just slowly, slowly on a log plot.

18 MEMBER CORRADINI: You're just essentially  
19 cooking it out of the --

20 MR. PETTI: Cooking it out of the matrix,  
21 not out of the particles.

22 MEMBER CORRADINI: Okay.

23 MR. PETTI: So. So to absolutely confirm  
24 that it would be nice just to heat some particles and  
25 that's what I think we're planning to do.

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1                   MEMBER CORRADINI: All right. So the same  
2 question is the staff in reading their document were  
3 concerned about time and temperature. And are you  
4 going to address that somewhere in these slides?  
5 Because I want to get a feeling because I don't  
6 appreciate all of this.

7                   MR. PETTI: That had to do more with I  
8 believe irradiation testing. I think the accident  
9 testing time and temperature is well in excess.

10                   I showed a plot the last time that I was  
11 here that tried to capture because there's so many  
12 different transplants in the irradiation capsule. How  
13 much time, what fraction of the fuel spent at what  
14 temperature. And we've -- now that we have that all  
15 in place we'll do that for every capsule to show.

16                   But for instance, AGR-1, 5 percent of the  
17 fuel spent time above 1400 degrees C for 100 days. So  
18 there is a lot of fuel that got very hot. So we're  
19 trying to capture that metric because it's a hard  
20 metric to capture.

21                   CHAIRMAN BLEY: Your uncertainty  
22 calculations, and I've just started reading the  
23 reports on the temperature, thermocouple data analysis  
24 and the uncertainty. You came up with, I forget,  
25 something like 50 degrees.

1 MR. PETTI: Sixty degrees I think.

2 CHAIRMAN BLEY: Something like that, yes.  
3 But there's some odd stuff in there with some -- a  
4 large number I think of thermocouples failing and some  
5 other problems. Some tests that didn't come out quite  
6 the way you expected on the thermocouples. And it  
7 wasn't clear to me that your analysis included all of  
8 those kinds of problems. Did it? And can you point  
9 me to --

10 MR. PETTI: There's two ways to do the  
11 uncertainty analysis.

12 CHAIRMAN BLEY: Okay.

13 MR. PETTI: Let's say you could --

14 CHAIRMAN BLEY: How important is it, these  
15 results?

16 MR. PETTI: Right. So you could try to  
17 predict the thermocouple. The thermocouple is not in  
18 the fuel, it's near the fuel. And then say okay, if  
19 I hit that really well, let's say I miss it by 15  
20 degrees, then I just look at the uncertainty from the  
21 thermocouple to the fuel. And I add the 15 degrees as  
22 a bias maybe.

23 We did not do that. We instead calculated  
24 it completely from the outside of the capsule in,  
25 first principles. So the thermocouples are there to

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1 help us control the experiment but the uncertainty  
2 analysis is a complete propagation from the outside  
3 in, all the effects that we know --

4 CHAIRMAN BLEY: Based on the physics.

5 MR. PETTI: Based on the physics. Now,  
6 AGR-1 happens to be unique because we borated the  
7 graphite to an extent that our gaps closed, tried to  
8 close. That made it very, very complicated. AGR-2,  
9 we don't see that behavior. I can show you graphite  
10 capsules that are just as complicated, some may argue  
11 more complicated. We can predict within 30 to 40  
12 degrees.

13 So we're slowly building up. We've got,  
14 you know, I can show you a non-heat generating test  
15 graphite. I can take all the graphite irradiation  
16 effects, I can calculate that. Now with fuel I've got  
17 to add heat generation, I've got to add gamma heating  
18 of all the metals, all of that. That gets all folded  
19 in.

20 But given that there's still concern for  
21 the formal qualification we are going to do a mock-up,  
22 a heated mock-up. We also have three different ways  
23 to measure temperature now that we need to qualify in  
24 some way before we put them in the reactor.

25 We will basically put all of the different

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1 TCs we're going to use in this -- we've got an actual  
2 sound, sonar-based wireless system that we're going to  
3 try. And we will set it up in the lab. We will  
4 change the gas mix like you do in irradiation and run  
5 the finite element model to show sort of as a way to  
6 qualify it before the irradiation.

7 CHAIRMAN BLEY: And that's in the  
8 continuing work.

9 MR. PETTI: That's in the continuing work,  
10 right.

11 MEMBER CORRADINI: And that's part of AGR  
12 -- the end radiation one is AGR --

13 MR. PETTI: The next one will be 5, 6, 7  
14 altogether. So we're hoping to start that actually  
15 later this year.

16 CHAIRMAN BLEY: Okay. I'll try to study  
17 that. I'm a little vague on this stuff. I've been  
18 reading it, trying to --

19 MR. PETTI: AGR-1 has some oddities. I  
20 think when we do the results for AGR-2 it'll be  
21 better.

22 So in terms of the results in the high-  
23 temperature heating we have found that releases are  
24 very low and it's either fission products that diffuse  
25 in the matrix, a defective particle, and we have

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1 finally seen one or two particles fail at 17- and  
2 1,800. We're not absolutely convinced yet till we do  
3 the full PIE but the odds are it looks like the  
4 particle fail in the reactor.

5 Now, just to tell you about how important  
6 this is though for 1,800 degrees. If we had taken  
7 German UO2 fuel and put it in the furnace at 1,800  
8 degrees C we would start to see very rapid release  
9 after tens of hours. UCO TRISO, it just doesn't look  
10 like that. So while there are some failures the  
11 physics is definitely different. And we believe it  
12 has to do with oxycarbide fuel instead of UO2.

13 So that will all come out I think. We've  
14 got some UO2 in our second capsule. We plan to do  
15 some heating. But we're clearly beginning to see a  
16 difference between the two fuel --

17 MEMBER CORRADINI: So you intend to  
18 essentially do as you said, take the compact, go  
19 through the accident heating to show empirically what  
20 you would think is the root cause of what you get in  
21 terms of --

22 MR. PETTI: Right, right. Now we've got  
23 all this old German data that we can plot and show you  
24 the two different plots but we've got to go to the  
25 structural stuff.

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1                   MEMBER CORRADINI:  -- staff would rather  
2                   see.

3                   MR. PETTI:  Yes, we've got -- and it's not  
4                   so much the heating as much as it is we've got to go  
5                   in and do the detailed PIE which it requires some of  
6                   these advanced techniques we have.  I think I know  
7                   what the problem is but again I won't go too far out  
8                   on a limb.  We think we know what the problem is with  
9                   UO2.  But 2 more years we'll know that answer.

10                   So today you asked us based on last time  
11                   the role of the reactor building in defense-in-depth  
12                   and what's our approach to defense-in-depth.  So we  
13                   have presentations on those.

14                   MR. ALBERSTEIN:  Okay, my name's Dave  
15                   Alberstein.  I work for TechSource providing support  
16                   to INL on the NNGP project.

17                   And we decided to first talk about the  
18                   role of the reactor building in defense-in-depth and  
19                   reactor building design alternatives.  We had a lot of  
20                   questions in January regarding what if you do this to  
21                   the design of the reactor building, what if you do  
22                   that.  What -- would a containment constitute defense-  
23                   in-depth whereas other design alternatives you  
24                   wouldn't have defense-in-depth.

25                   So we decided that the best thing to do

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1 before we talked about the general approach to  
2 defense-in-depth which Mark Holbrook will talk about  
3 would be to give you a rundown on the role of the  
4 reactor building in defense-in-depth and what happens  
5 in regard to offsite doses if you choose other design  
6 alternatives for the reactor building.

7           The slide that's up there right now, slide  
8 number 2, gives a quick review of the safety  
9 attributes, key safety attributes for the modular  
10 HTGR. These are listed because they have an effect on  
11 the decisions one makes with regard to how to design  
12 the reactor building. The fuel coolant and moderator  
13 are all chemically compatible under all conditions  
14 that we're aware of.

15           The fuel has large temperature margins in  
16 normal operation and during accident conditions.  
17 Normal operating temperatures are significantly below  
18 the temperatures at which significant degradation of  
19 coated particle integrity could occur. And the same  
20 is true during accident conditions.

21           Safety is not dependent on maintaining  
22 helium coolant pressure. If you lose coolant pressure  
23 you're not going to transfer large amounts of energy  
24 into the reactor building the way you might with other  
25 reactor designs that you're familiar with.

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1           Post-accident heat removal, there's not a  
2 lot of heat that needs to be removed. In terms of the  
3 reactor building the RCCS removes the heat from the  
4 reactor system and does so passively. The response  
5 times of the reactor are long days as opposed to  
6 seconds or minutes as a result of the large amount of  
7 graphite in the core, its thermal capacity.

8           And lastly, there are multiple as we said  
9 concentric independent radionuclide barriers.  
10 Breaching the helium pressure boundary doesn't result  
11 in failure of the fuel or for that matter of the  
12 reactor building. So if we move to the next slide.

13           The role of the reactor building in safety  
14 design. The required safety function of the reactor  
15 building for the modular HTGR is to provide structural  
16 protection from both internal and external events and  
17 hazards for the passive heat removal of heat from the  
18 reactor vessel to the reactor cavity cooling system.

19           It needs to maintain the relative geometry  
20 between the vessel system and the helium pressure  
21 boundary and the RCCS. That's the safety-related role  
22 of the reactor building.

23           It does other things that are not required  
24 to meet the regulatory requirements for offsite dose.  
25 It does provide additional radionuclide retention.

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1 And as was noted in one of the viewgraphs Fred  
2 presented you have to have that retention taken into  
3 account to meet the EPA PAGs at the exclusion area  
4 boundary. However, we do not need credit and don't  
5 anticipate that we ever will need to take credit for  
6 the reactor building's radionuclide retention  
7 capabilities to meet the regulatory requirements of 10  
8 C.F.R. 50.34 for offsite dose at the exclusion area  
9 boundary.

10 The building also limits air available for  
11 ingress into the system after a helium pressure  
12 boundary depressurization. But this again is not  
13 needed to meet offsite dose requirements. Next slide.

14 MEMBER CORRADINI: You said a mouthful.

15 MR. ALBERSTEIN: Yes.

16 MEMBER CORRADINI: And so can we take the  
17 first bullet so I make sure I understand? So except  
18 for the fact that it keeps everything where it's  
19 supposed to be in the event of any sort of internal or  
20 external event you don't need the reactor building.

21 MR. ALBERSTEIN: To meet the regulatory  
22 requirements for offsite dose.

23 MEMBER CORRADINI: Okay, so I want to make  
24 sure I've got this right before we go on. So, I could  
25 have an open structure with just a bunch of steel

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1 girders to keep everything structurally in the same  
2 location and life would be fine.

3 MR. ALBERSTEIN: I have a slide on that in  
4 a little bit.

5 MEMBER CORRADINI: Okay.

6 MR. SILADY: The answer is yes.

7 MR. ALBERSTEIN: Yes.

8 MEMBER CORRADINI: Okay. The second  
9 bullet you said something, I think I should understand  
10 it but I'm a little bit confused. The EPA PAGs are  
11 essentially the limiting issue. So whether or not you  
12 meet 10 C.F.R. 50.34 is irrelevant because you want to  
13 meet the EPA PAGs to eliminate the need for  
14 evacuation.

15 MR. ALBERSTEIN: Yes.

16 MEMBER CORRADINI: But if you were not of  
17 so mind to do that and you were willing to come up  
18 with an emergency planning and evacuation scheme you  
19 wouldn't need the reactor building for that either.

20 MR. ALBERSTEIN: To meet the offsite dose  
21 requirements --

22 MEMBER CORRADINI: Of 50.34.

23 MR. ALBERSTEIN: -- 50.34, 52.79, that's  
24 correct.

25 MEMBER CORRADINI: I can't get all the

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1 numbers in my head.

2 MR. ALBERSTEIN: Yes.

3 MEMBER CORRADINI: Okay.

4 MR. ALBERSTEIN: Yes.

5 MEMBER CORRADINI: All right. Then the  
6 only thing standing in the way of not having a reactor  
7 building versus steel structure is defense-in-depth  
8 which is you're putting all your eggs in the fuel  
9 vessel.

10 MR. ALBERSTEIN: We still need the reactor  
11 building to protect the structures that are needed for  
12 passive heat removal.

13 MEMBER CORRADINI: Okay, but that's not  
14 for fission product retention, that's for structural  
15 support.

16 MR. ALBERSTEIN: Correct.

17 MEMBER CORRADINI: So I'm still back to my  
18 original question which is you're -- and now maybe I'm  
19 misinterpreting. You're claiming I don't need  
20 defense-in-depth. The fuel is robust enough. As long  
21 as I keep everything where it's supposed to be through  
22 all the accident initiators in terms of structural  
23 dimensionality, that I expect this to stay here and  
24 that to stay there so that all those functions are  
25 met, I don't need a reactor building.

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1 MR. ALBERSTEIN: To meet offsite dose  
2 requirements --

3 MEMBER CORRADINI: Right.

4 MR. ALBERSTEIN: -- I don't need a reactor  
5 building.

6 MEMBER CORRADINI: No. I wanted to make  
7 sure I got it right. Thank you.

8 MR. KINSEY: And again, to clarify, we'll  
9 talk further about the defense-in-depth aspects in a  
10 few minutes. We weren't covering that at the moment.

11 MR. ALBERSTEIN: Okay. Can we move on to  
12 the next slide? The reference design right now for  
13 the modular HTGR that was developed by General  
14 Atomics. And we're going to tend to talk in the  
15 context of that design. The next modular HTGR may be  
16 somewhat different. We can't speak for future  
17 designers.

18 But the reference design for that  
19 conceptual design was a vented reactor building. It  
20 addresses several specific design issues for modular  
21 HTGRs. Number one, it's compatible in terms of its  
22 volume with the fact that you have a non-condensing  
23 helium coolant that doesn't carry a lot of energy into  
24 the reactor building in the event of depressurization.

25 It's matched to the accident behavior of

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1 the modular HTGR. You vent it early in the transient  
2 when the radionuclides released from the helium  
3 pressure boundary are relatively low in terms of the  
4 activity. Later in these core heatup transients when  
5 the delayed releases take place the building is closed  
6 up where you can maintain some control over the rate  
7 at which those radionuclides could be later released.

8 And overall, providing this vented  
9 capability provides a more benign environment for the  
10 passive reactor cavity cooling system design, be it an  
11 air-cooled system or a water-cooled system. The  
12 vented building provides for lower heat pressure and  
13 structural loads on the RCCS all of which is  
14 advantageous in the design of the HTGR.

15 Next slide shows you a couple of things  
16 that are important. What this slide shows you are the  
17 vent paths that the helium would have to follow in the  
18 event of a helium pressure boundary breach to be  
19 released from the reactor building.

20 A couple of things to note. On the figure  
21 on the left at the top where it says "Operating floor  
22 elevation 6 inches," that's where grade is. So most  
23 of this reactor building is below grade.

24 Number two, note that the paths for  
25 depressurization and venting are somewhat tortuous.

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1 It's not a simple matter of releasing directly to the  
2 atmosphere without going through a number of cavities  
3 that can have an effect on the amount of radionuclides  
4 that actually get out of the building.

5 And lastly, note at the upper left the  
6 final release point is about 20 feet above grade. So  
7 the points here are that the paths for release are  
8 tortuous. Most of the activity with regard to  
9 depressurization takes place below grade. The release  
10 point is at about 20 feet.

11 And then after the venting has taken place  
12 and the louvers are closed back up again most of the  
13 building is below grade. It's not sitting out there  
14 with the wind blowing on it and all of that. It's a  
15 below-grade structure.

16 So now --

17 MEMBER CORRADINI: I'm sorry. So this is  
18 from the '86 or -- I can't remember the date.

19 MR. ALBERSTEIN: That's late eighties.

20 MEMBER CORRADINI: Okay. That's the --

21 MR. ALBERSTEIN: GA design.

22 MEMBER CORRADINI: Okay. And then there  
23 was an upper bound calculation as to what would be the  
24 radionuclide release with that approach. And that was  
25 well within the EPA PAGs.

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1 MR. ALBERSTEIN: I'm going to turn to Fred  
2 here since he did those --

3 MR. SILADY: Yes.

4 MEMBER CORRADINI: And staff issued a  
5 draft, a preliminary SER and concluded the same.

6 MR. SILADY: Generally. There were some  
7 asterisks --

8 MEMBER CORRADINI: What does generally  
9 mean?

10 MR. SILADY: There were some asterisks on  
11 the first NUREG-1338 that had to do with if the R&D  
12 was completed and so on. And I think the ACRS said it  
13 best in the wrap-up of that series of interactions is  
14 that neither the designers, the staff, nor themselves  
15 had found an event that exceeded the requirements.

16 MEMBER CORRADINI: And sorry. So to bring  
17 us back up to date now 25 years later or whatever it  
18 is, the concern about having dust reside in little  
19 nooks and crannies and that dust having radionuclides  
20 with it, does it change that conclusion? About dust  
21 transport during this. In other words, it's not just  
22 in the active -- it's not just in the pressurized  
23 helium but it's also in stuff that has eroded away  
24 from the graphite that's sitting in nooks and crannies  
25 that wouldn't have been cleaned up during the active

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1 cleanup during its circulation. That doesn't change  
2 the conclusion?

3 MR. ALBERSTEIN: The effects of dust need  
4 to be taken into account. And we believe that the  
5 extent to which dust effects can affect the offsite  
6 doses differs as a function of the design. In the  
7 case of the prismatics there's no historic evidence of  
8 dust buildup in prismatic HTGRs. In the case of  
9 pebble beds there is historical evidence of dust  
10 buildup and that would have to be taken into account.

11 MEMBER CORRADINI: Okay. The reason I'm  
12 asking the question is I've attended enough of the  
13 workshops that that answer tracks with what I've  
14 heard. But what I'm trying to get at is the  
15 uncertainty issue which is if I understand the system  
16 operation you're continually cleaning up the helium  
17 such that if God forbid you have an event like this  
18 there's not a lot of resident radionuclides.

19 Then the only place where you have a  
20 potential short circuit is these -- essentially an  
21 uptake of this and the dust is sitting somewhere  
22 within the system that you haven't cleaned up. It's  
23 not that I don't disagree with the logic, I want to  
24 understand how that affects the uncertainty in the  
25 estimate.

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1 MR. SILADY: I think Dave made the  
2 distinction between the reactor types. And so we'll  
3 take it into account, whichever one.

4 It's not just the helium purification  
5 system captures the radionuclides or it's on dust.  
6 There's plateout on metallic surfaces. And it's not  
7 just that there's a leak in the helium pressure  
8 boundary and the helium leaves and the dust goes with  
9 the helium. There are a lot of other effects in terms  
10 of --

11 MEMBER CORRADINI: That I'm well aware of  
12 from other dealings. I'm well aware of that. On the  
13 other hand, all of those pieces of physics are tough  
14 to estimate. So I'm trying to understand if I had to  
15 draw an uncertainty bound on this, a range, that all  
16 the things that was concluded back in '86 still  
17 maintain even with the uncertainty you might get from  
18 it. That's why I'm asking the question. With  
19 prismatic. Let's not go back to pebble for the  
20 moment.

21 MR. PETTI: I think it's fair to say that.

22 MEMBER CORRADINI: Okay.

23 MR. ALBERSTEIN: There are, you may recall  
24 from the mechanistic source terms white paper there  
25 are design margins on both circulating activity and on

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1 condensable radionuclides like cesium, strontium, and  
2 so on and so forth. Between the best estimate of what  
3 circulating activities, for example, would be and the  
4 upper bounds that are assumed as initial conditions  
5 when an accident takes place.

6 The factor of 4 on the noble gases, the  
7 factor of 10 on the condensable radionuclides, the  
8 condensable metallics like cesium and strontium. And  
9 those design margins are intended in part to account  
10 for these types of phenomena.

11 MEMBER CORRADINI: Okay. So last  
12 question, then I'll stop. Is there anything from a  
13 testing or periodic maintenance approach to this that  
14 one could check to see that you don't have a buildup.  
15 Because I'm still -- I have this worry about this.  
16 And so if I can't be sure, and I have an uncertainty,  
17 is there something in periodic testing or maintenance  
18 that one can check this out?

19 MEMBER REMPE: Couldn't the staff suggest  
20 that a license condition be included, whether the  
21 instrumentation at the startup?

22 MEMBER CORRADINI: I guess I want to know  
23 -- I'm looking for some sort of --

24 MR. KINSEY: That's an attribute of course  
25 that would be specific to the design and it's

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1 something that I would expect that the design --

2 MEMBER CORRADINI: This is an  
3 instrumentation guru who wants to solve everything in  
4 instrumentation.

5 MR. KINSEY: That's right.

6 MEMBER CORRADINI: I'm looking for  
7 something that I can test or surveil on some periodic  
8 basis that gives me confidence that the uncertainty  
9 band is not here but it's there.

10 MR. ALBERSTEIN: Circulating activity and  
11 plateout activity can be monitored during operation.  
12 It was done at Fort St. Vrain. Will be, yes.

13 You're asking specifically about  
14 monitoring for dust levels and I'm hesitating just a  
15 little bit here.

16 MEMBER CORRADINI: I'm trying to come up  
17 -- well, I've made my point. I'll stop. I'm just  
18 trying to -- it just seems to me that that to me is --  
19 this uncertainty is an important one relative to  
20 everything you're saying. Because if I buy what  
21 you're saying a lot of things naturally proceed from  
22 it. So I'm trying to find out what the uncertainty is  
23 on this.

24 DR. KRESS: I understand you have these  
25 measurements for the plateout and the circulating

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1 activity. My question is what are you going to do  
2 with them. Do you have some plans in mind, say, oh,  
3 well that's too much here, let's shut down the reactor  
4 and change out the fuel?

5 MR. ALBERSTEIN: At Fort St. Vrain, good  
6 example, there were actually tech spec limits on both  
7 circulating and some plateout activity levels. And if  
8 those limits were exceeded, yes, you'd have to shut  
9 the system down.

10 DR. KRESS: So you plan on doing the same  
11 sort of thing.

12 MR. ALBERSTEIN: I can't imagine not  
13 having tech spec limits on similar parameters.

14 DR. KRESS: I just never saw that anywhere  
15 in the white paper.

16 MR. ALBERSTEIN: Yes, and in fact we got  
17 an RAI early on from NRC on that subject. And we gave  
18 a lengthy response about what was done at Fort St.  
19 Vrain without making specific commitments for the guy  
20 that has to design and operate the next one. Because  
21 we just didn't feel given where we were with the  
22 design at that point in time and now that that would  
23 be appropriate for us to do. But historically the  
24 precedent is there.

25 DR. KRESS: It seems to me like in order

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1 to put a tech spec on that you need to know a lot of  
2 information about how the events would -- during  
3 release plated out fission products on the primary  
4 system. I haven't seen much data on that. There's an  
5 -- how I say this but there's going to be some --

6 MR. KINSEY: It's in the plan.

7 DR. KRESS: It's in the plan?

8 MR. KINSEY: There are data. There will  
9 be more data. There's some data that you may not be  
10 aware of.

11 MR. ALBERSTEIN: Okay, let's move onto the  
12 next slide. We had a lot of questions in January as  
13 I said about what if you did this to the reactor  
14 building design or that.

15 What we're going to show you here to wrap  
16 this up are summary results of two reactor building  
17 design alternative studies that were done, one by GA  
18 back in the late eighties and one by the folks at PBMR  
19 roughly 10 years ago I believe, Fred? Yes, 10 years  
20 ago.

21 The first slide is a summary of some  
22 reactor building design alternatives that were  
23 considered by GA back in the late nineteen eighties.  
24 You can see five cases here that were considered.

25 The reference case, the vented building

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1 with the moderate leakage rate of 100 percent per day.  
2 You can argue with the adjective "moderate" but that's  
3 what we used.

4 Other options that were looked at  
5 including putting filtration on the vents and still  
6 maintaining a 100 percent per day leak rate. Next, a  
7 filtered vent with a lower leak rate of 5 percent per  
8 day, that was option number three.

9 A couple of variations on option number  
10 four with a larger volume building to maintain  
11 relatively lower pressures during the depressurization  
12 event. And lower leakage, one variation was with an  
13 air-cooled RCCS, the other with a water-cooled reactor  
14 cavity cooling system.

15 Number five, two variations on another  
16 unvented, a larger volume so therefore lower-pressure  
17 design, one with a leakage rate of 5 percent per day  
18 and the other with a leakage rate of 1 percent per  
19 day. So these options looked at various combinations  
20 of filtration and building volume to assess what the  
21 effects on offsite dose would be of going with these  
22 containment design alternatives.

23 If you go to the next slide you see a  
24 summary of the results here. These are whole body  
25 doses at 30 days at the exclusion area boundary which

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1 was 450 --

2 MR. SILADY: Twenty-five.

3 MR. ALBERSTEIN: Four hundred twenty-five  
4 meters in this particular analysis against the  
5 frequency consequence curve that was in effect in the  
6 late eighties.

7 CHAIRMAN BLEY: I'm sorry, these dashed  
8 curves are --

9 MR. SILADY: -- cumulative distribution  
10 functions over all the events.

11 CHAIRMAN BLEY: And the 4A, 4B are  
12 different types of releases?

13 MR. SILADY: They're things on the  
14 previous page.

15 CHAIRMAN BLEY: Oh, the previous page.

16 MR. ALBERSTEIN: They're the alternatives.

17 CHAIRMAN BLEY: Okay, thank you.

18 MR. ALBERSTEIN: And you can see -- keep  
19 in mind number one, the number one there in the little  
20 square, the number one is the reference design well  
21 within the FC curve limits. And pretty much resulting  
22 in offsite doses that are equal to what was considered  
23 annual background back at the time this study was done  
24 which is a little bit higher today than it would have  
25 been back then.

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1           You can see that the alternatives where  
2 one adds filters to the vents really didn't make much  
3 of a change in terms of offsite dose.

4           MR. SILADY: Not for the whole body.

5           MR. ALBERSTEIN: For the whole body. For  
6 the alternatives that have lower leak rates and higher  
7 volumes to result in lower pressure you did gain quite  
8 a bit on dose but you're gaining it relative to a  
9 point at which you weren't going much over background  
10 doses to begin with. So that raises the questions of  
11 adequate protection versus perfect protection for the  
12 public and whether an investment of resources to go to  
13 design alternatives such as numbers four and five are  
14 really buying anything of substance in terms of  
15 protection of public health and safety.

16           CHAIRMAN BLEY: Let me ask a question  
17 that's more aimed at Fred I think. I didn't ask this  
18 before because you weren't talking about it. Is there  
19 any requirement in the licensing framework for how far  
20 away from the requirements curve the PRA result CCDF  
21 has to form?

22           MR. SILADY: That's Tom's question  
23 earlier. And I'm not aware of it.

24           CHAIRMAN BLEY: Okay.

25           DR. KRESS: So if somebody wanted to add

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1 two more modules --

2 CHAIRMAN BLEY: Okay, yes, it's a  
3 turnaround. Yes, it's a turnaround of the same  
4 question.

5 MEMBER CORRADINI: So I don't understand  
6 4A and B. What does the air -- or the water RCCS do  
7 that 4A and B is different than 5A and B? Maybe I'm  
8 confused. Is it just the air and the water RCCS  
9 change the pressure?

10 CHAIRMAN BLEY: 4A/B and 5A are about the  
11 same; 5B is a little different.

12 MR. SILADY: They looked at it just to see  
13 if there was a discriminator there. Because when you  
14 go to a leak-tight building of any kind you can't have  
15 the air RCCS chimneys and so on, communication, the  
16 same way. So there's a different design on the air.

17 MEMBER CORRADINI: Oh. You're saying the  
18 plumbing is different.

19 MR. SILADY: Yes.

20 MR. ALBERSTEIN: If you look carefully  
21 here you'll see that 4A, 4B and 5A --

22 MEMBER CORRADINI: They're all the same.

23 MR. ALBERSTEIN: -- all the same. And in  
24 fact if you look at the previous slide they're all the  
25 same leakage rate of 5 percent per day. It turns out

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1 that's what's driving it. And then 5B, a little bit  
2 lower in dose because that was a lower leakage.

3 MEMBER CORRADINI: Oh, that was my  
4 interpretation. So the only difference between 1, 2  
5 and 3. Well, wait a minute now. I wanted to finish  
6 that. So 3 is a different leakage but yet it is  
7 vented.

8 MR. SILADY: Filtered.

9 MEMBER CORRADINI: So that means what?  
10 I'm sorry that -- I'm looking at the same time to see  
11 if we have this 88.311 that I can look in detail. I'm  
12 sure we've got it somewhere.

13 MR. ALBERSTEIN: Filtration doesn't buy  
14 you very much for the whole body dose.

15 MEMBER CORRADINI: Okay. But -- okay.  
16 Yes, but the devil's in the details. What do you  
17 mean? You have the initial blowdown of the loss of  
18 pressure.

19 MR. SILADY: We don't filter it.

20 MEMBER CORRADINI: That's what I thought.

21 MR. SILADY: Yes. But you filter it after  
22 it closes.

23 MEMBER CORRADINI: So you've got some sort  
24 of dual valve. This thing blows down. The damper  
25 opens or whatever you call this thing, louver opens.

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1 You let all that stuff out. This closes and  
2 everything seals up against that pressure and you  
3 filter everything beyond. Everything and beyond --

4 MR. SILADY: There's a filter in the  
5 reactor building and it's competing with the leakage  
6 from the reactor building.

7 CHAIRMAN BLEY: Just for me the case  
8 without the filter you talked about the tortuous path.  
9 That somehow you assume some DF on the tortuous path?

10 MR. ALBERSTEIN: Yes. It depends on the  
11 sequence.

12 CHAIRMAN BLEY: Or if you had a filter.

13 MR. SILADY: Yes, there's sequences with  
14 water, sequences that are dry and so you've adjusted  
15 the DF.

16 CHAIRMAN BLEY: Okay.

17 MR. SILADY: The point of the 4A, 4B and  
18 5A were different designs of a leak-tight containment  
19 and we had to think about it broadly. What's it going  
20 to mean to our cost? What's it going to mean to our  
21 RCCS reliability? How is it going to work? And it  
22 ended up in looking at it only from the perspective of  
23 public safety it had the same curve. But looking at  
24 it from the perspective of cost or design margins and  
25 so on it had significant impact.

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1 MEMBER CORRADINI: But just so I'm reading  
2 the numbers right, assuming all the numbers are right,  
3 the difference between 1 and 5B is an order of  
4 magnitude at low frequency and high dose.

5 MR. SILADY: About everywhere. It's  
6 almost parallel.

7 MEMBER CORRADINI: Yes. And the  
8 difference between 1 and 3 is about a factor of 2.

9 MR. SILADY: Yes, depending upon where you  
10 are because of the log scale.

11 MEMBER CORRADINI: And -- okay.

12 MEMBER REMPE: How much do you get from  
13 the deposition in the tortuous path?

14 MR. SILADY: It's nuclide-specific as you  
15 well know.

16 MEMBER REMPE: Is it -- raised it up to  
17 where you start getting close to your limits?

18 MR. SILADY: If there was no building you  
19 mean?

20 MEMBER REMPE: Yes.

21 MR. SILADY: If it was a reactor on the  
22 ground.

23 MEMBER REMPE: Yes. If you just released  
24 it out. Have you ever done a calc to see? I mean  
25 because then suddenly you are relying on the tortuous

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1 path for some sort of retention.

2 MR. SILADY: There's no way it's going to  
3 go over towards -- past the PAG. I mean we've looked  
4 at, you know, there's margin there.

5 We need additional tests and it's in the  
6 plan for radionuclide retention mechanisms in the  
7 building for our mix of helium and nuclides at these  
8 very small levels. Then we've got a whole lot of  
9 combinations of different releases. But surface  
10 deposition and so on is important.

11 MEMBER CORRADINI: So this is I guess,  
12 again, more details. And Dr. Bley will tell us to be  
13 quiet.

14 CHAIRMAN BLEY: We've already eaten about  
15 15 minutes into lunch.

16 MEMBER CORRADINI: So is it already at the  
17 be quiet stage?

18 CHAIRMAN BLEY: It's pretty close, yes.

19 MEMBER CORRADINI: Okay, so one last  
20 question because staff brought this up. These are all  
21 blowdown and then long-term heatup where there is not  
22 a high point vent that I don't bring in air and  
23 continually heat up and oxidize. Is that correct?

24 MR. SILADY: These all -- all the ones  
25 that have a leak in the helium pressure boundary

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1 ultimately have some air that comes back into the  
2 reactor. Because it cools down. We're talking 30  
3 days here.

4 MEMBER CORRADINI: I understand.

5 MR. SILADY: Okay. So they all have some  
6 of that. But there were no -- in this frequency range  
7 there were no leaks.

8 MEMBER CORRADINI: Where I had a low point  
9 enter and a high point exit --

10 MR. SILADY: No.

11 MEMBER CORRADINI: -- such that I could  
12 feed and continually oxidize.

13 MR. ALBERSTEIN: That's a 10 to the minus  
14 double digit scenario.

15 MEMBER CORRADINI: Okay. Okay, fine.  
16 I'll stop. Thank you.

17 MR. ALBERSTEIN: Let's move onto the next  
18 slide. As I said, also there were studies done in the  
19 last 10 years or so by the folks at PBMR and  
20 Westinghouse on alternative reactor building  
21 configurations for the pebble bed.

22 You can see here the list of alternatives  
23 that were examined. Again, unfiltered, vented with  
24 moderate leakage as the reference case. Case 1B,  
25 adding blowout panels between components within the

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1 reactor building.

2 The next case, option number 2, partial  
3 filtering. Venting again with blowout panels and a  
4 moderate leak rate.

5 Then option 3A, a lower leak rate in the  
6 range of 25 to 50 percent a day, again filtered, fully  
7 filtered in this case with blowout panels again.

8 3B, adding an expansion volume for the gas  
9 to the building. And then options 4A and B, looking  
10 at a pressure-retaining system with internal blowout  
11 panels and very low leakages, less than 1 percent per  
12 day.

13 So again, a broad spectrum of alternative  
14 designs were considered and the next slide shows you  
15 the results. I said we had a slide on no reactor  
16 building.

17 What we have here is a comparison of  
18 thyroid dose at the exclusion area boundary against  
19 the EPA PAG limit on thyroid of 5 rem. And you can  
20 see in the case of alternatives 1A and 1B which is the  
21 second column from the left there was substantial  
22 margin relative to the PAG. So with alternatives 2 or  
23 3 did further reduce the dose and increase the margins  
24 relative to the PAGs.

25 CHAIRMAN BLEY: And according to our

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1 previous discussion these are mean values.

2 MR. SILADY: Yes. Yes.

3 MR. ALBERSTEIN: Yes. However, in some  
4 cases added features can fail. And if that happens  
5 late in a sequence when the delayed release is taking  
6 place the gains in margin relative to alternatives 1A  
7 and 1B are lost. And that's what you see in the  
8 crosshatch columns.

9 The pressure retaining design, 4A, also  
10 increased margin relative to the PAGs. But again if  
11 late in the sequence you have late failure due, for  
12 example, for a seismic aftershock you can actually get  
13 higher doses offsite for the thyroid than you would  
14 get from the base case alternative. And in fact  
15 higher doses than you would have received if you'd had  
16 no reactor building at all.

17 So the bottom line here is that one has to  
18 be careful when throwing around ideas with regard to  
19 reactor building design for modular HTGRs. You have  
20 to be careful to understand the accident behavior of  
21 the HTGR system. Bottling things up isn't necessarily  
22 going to buy you the reductions in offsite dose  
23 consequences that you would intuitively think you  
24 would get.

25 MEMBER CORRADINI: But to get back to

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1 Joy's question about the previous study, am I reading  
2 this right, that I have a DF of 20 if the reactor  
3 building is there?

4 MR. ALBERSTEIN: Which column are you  
5 looking at?

6 MEMBER CORRADINI: I was looking at the  
7 purple that's 10,000 and the next purple over which is  
8 500. That's a DF of 20.

9 MR. ALBERSTEIN: For iodine.

10 MR. SILADY: For this event with thyroid.

11 MEMBER CORRADINI: Which is the limiting  
12 -- based on something I thought you said earlier  
13 that's the limiting thing for the EPA PAGs, right?

14 MR. ALBERSTEIN: We think that's the  
15 harder one to meet from the whole body, yes.

16 MEMBER REMPE: So from what you're saying,  
17 earlier you said well, it's only safety-related for  
18 heat transfer. But then there's certain criteria  
19 associated with this building for decontamination and  
20 reduction and release that is relied upon. So it  
21 seems like --

22 MR. ALBERSTEIN: To meet the PAG.

23 MEMBER REMPE: Right.

24 MR. ALBERSTEIN: To meet the PAG but not  
25 to meet the 25 rem whole body requirement.

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1                   MEMBER REMPE: But since there's no  
2 evacuation planning associated with this approach it  
3 seems like there would need to be some sort of  
4 regulatory oversight in the design of the building to  
5 make sure that you don't need evacuation.

6                   MR. SILADY: There obviously would be a  
7 regulatory oversight on the entire plant.

8                   MEMBER REMPE: But there's to be some  
9 criteria like tech specs or something.

10                   MEMBER CORRADINI: But can I try her  
11 question differently? The building -- I mean I'll go  
12 back to the previous one where you said it's a factor  
13 of 2. So, let's say they're all the same within the  
14 uncertainty of all this sort of stuff. That means the  
15 building is a factor of 20, adding a filter is a  
16 factor of 2 so I've gone from a factor of 20 to a  
17 factor of 40 to 50 decontamination factor for the very  
18 fact of the presence of the building, it in itself is  
19 the filter. So you would have to have some sort of  
20 performance objective for the building to perform as  
21 a filter, otherwise you get -- you go beyond your  
22 limit.

23                   MR. SILADY: The reason that you see the  
24 difference between the two first two columns is no  
25 building, not even a tent, doesn't quite meet the PAG.

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1 We're getting tremendous radionuclide retention within  
2 the fuel to be even that close.

3 MEMBER CORRADINI: I'm not following.

4 MR. SILADY: So now you go to the second  
5 column and we say whoa, based on our best estimates of  
6 the DFs this is sizable. We need a little more data  
7 here to see if that 20 is real.

8 MR. ALBERSTEIN: And there's no denying  
9 that a building versus a tent helps.

10 MEMBER CORRADINI: I know, I know. But  
11 I'm just, I'm framing it this way because there were  
12 some bullets somewhere in one of these presentations  
13 that it's strictly structural. My point is this at  
14 least demonstrates by sensitivity it's not strictly  
15 structural. It in and of itself has to have a  
16 performance objective because it's performing as you  
17 call it a leak in containment, we'll call it a  
18 confinement, whatever you want to call it, that you  
19 now have to show performance on. Otherwise it doesn't  
20 meet your objective.

21 MR. SILADY: The objective we're talking  
22 about here is the design target.

23 MEMBER CORRADINI: Yes, I understand.

24 MR. SILADY: Okay.

25 MEMBER CORRADINI: I'm with you.

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1 MR. SILADY: So the structural -- and the  
2 reason to make it safety-related was for 10 C.F.R.  
3 50.34. That was where that statement was.

4 It's clear that -- we had it as a bullet.  
5 To meet the PAGs we need the building.

6 MEMBER CORRADINI: Okay. All right.

7 MEMBER REMPE: But it can't just be any  
8 building is what I'm --

9 MR. SILADY: Right.

10 MEMBER REMPE: It's got to be a certain.

11 MR. SILADY: Yes. And PBMR had a  
12 different looking building than the MHTGRs, much  
13 different. Largely above grade.

14 MR. ALBERSTEIN: And their building, a  
15 decontamination factor of 20 is a little bit higher  
16 than what the MHTGR folks assumed.

17 CHAIRMAN BLEY: I think we can move on and  
18 close this out as quickly as you can. Give Mark some  
19 time although he's got enough slides to go for an hour  
20 it looks like.

21 MR. ALBERSTEIN: I won't. In summary with  
22 regard to reactor building alternatives. We believe  
23 that the vented building, the reference design is the  
24 best match for the characteristics of the HTGR.

25 For the low-frequency events a high-

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1 pressure low-leakage LWR-type containment can actually  
2 increase radionuclide release relative to our  
3 reference case. You want to add filters or active  
4 HVAC systems you can get some small improvement in  
5 offsite dose. But under certain low-frequency event  
6 scenarios they may not be available and again provide  
7 you relatively little additional margin.

8 So these studies really have confirmed the  
9 decision in our design approach to place the emphasis  
10 on retention at the source within the fuel. There's  
11 a whole lot more detail on all of this in response to  
12 the RAI number FQ/MST-82 and all the references that  
13 were provided with it. That is all I have.

14 CHAIRMAN BLEY: Thank you. Mark, how long  
15 do you think it'll take to get through yours? The  
16 ones that -- there's some that are almost repetitive.

17 MR. HOLBROOK: Yes, exactly.

18 CHAIRMAN BLEY: So focus on the things  
19 that are new that you're trying to tell us from the  
20 last meeting.

21 MR. HOLBROOK: My name is Mark Holbrook.  
22 I work for the Idaho National Laboratory. Been  
23 involved with the NGNP project for some period of  
24 time.

25 And as was mentioned by the chairman we

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1 have several technical points in these series of  
2 slides that have been brought up before by both David  
3 Alberstein and by Fred Silady. And so we'll move  
4 through some of those technical points and try to  
5 focus more on the higher-level structure of how we  
6 want to evaluate defense-in-depth as an approach.

7 Slide number 2 provides an overview of  
8 where we're headed in this presentation. So we'll  
9 kind of move on. We're going to discuss very briefly  
10 on the next slides a few details and then we'll get  
11 into the bulk of the presentation which is in the  
12 center of this slide, plant capability, programmatic  
13 and risk-informed evaluation of defense-in-depth.  
14 Then we have some summary slides at the end.

15 The overall intent of the approach is to  
16 develop a structured system for evaluating defense-in-  
17 depth adequacy. So we want to be able to define how  
18 we're going to evaluate whether we have adequate  
19 levels of defense-in-depth in the overall design and  
20 the process that would be applied by a future  
21 applicant.

22 The elements involved in this evaluation  
23 process would be looking at the plant capability to  
24 provide defense-in-depth, to be able to look at the  
25 programmatic elements of defense-in-depth that would

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1 be applied by a future applicant and to look at the  
2 risk-informed evaluation process to be able to  
3 determine whether we've met all the principles that  
4 we've laid out in our white paper for defining  
5 defense-in-depth.

6 If you look in Chapter 2 of the white  
7 paper there's several discussion points and references  
8 from the regulations looking over a long period of  
9 time of how people have tried to define defense-in-  
10 depth in the past. That paper was written  
11 approximately 2 years ago so we thought it would be  
12 more useful maybe to look at something more recent  
13 such as this summary of NRC's defense-in-depth  
14 strategies you see at the bottom of the slide.

15 This comes out from last year's order for  
16 the containment fence that was issued on March 12 of  
17 2012. And you can see it on the screen there but it  
18 focuses on the definition of defense-in-depth in the  
19 context of prevention, mitigation and emergency  
20 planning. So at the end of these series of slides I'm  
21 presenting today I'm going to recast what our process  
22 looks like within that structure.

23 The next series of slides talks about  
24 those three principal elements, plant capability,  
25 programmatic and evaluation. On this first slide here

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1 we focus first on plant capability. In fact, the next  
2 series of slides draws in many of the physical points  
3 that have been made in the other presentations having  
4 to do with the attributes of the plant that provide  
5 defense-in-depth.

6 So you see there there's kind of a  
7 triangle chart or a graphic that you might look at  
8 that tries to pull together the concept. You see down  
9 in the lower lefthand corner plant capability,  
10 defense-in-depth, in the lower right programmatic and  
11 then risk-informed evaluation with a triangle in the  
12 center that talks about the PRA results and the  
13 deterministic analysis.

14 We're first focusing on that lower left  
15 triangle, plant capability, defense-in-depth, which  
16 reflects the decisions that are made by the designer  
17 to implement function structures and the SSC design  
18 and availabilities to ensure that we have defense-in-  
19 depth in the plant.

20 So a lot of the things that have been  
21 talked about in previous parts of today's  
22 presentation, the inherent reactor characteristics  
23 that we take advantage of. Event progression, time  
24 cost is provided by the graphite in the core. We're  
25 going to focus a little bit in the subsequent slides

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1 on the radionuclide barriers to prevent release of  
2 radioactive material. How the passive and active SSCs  
3 work together to provide us defense-in-depth. We also  
4 implement some of the discussion that we've had in  
5 previous meetings about SSC safety classification,  
6 design margins, conservative approaches. All these  
7 things are factored into what we would call plant  
8 capability defense-in-depth.

9 If you look at the reactor nuclide  
10 barriers we've mentioned in previous points in today's  
11 presentation that the barriers are concentric, they're  
12 independent, and that their performance emphasis is on  
13 the performance of the fuel barriers as we look at  
14 those.

15 Also as mentioned previously the reactor  
16 building provides defense-in-depth for meeting the  
17 top-level regulatory criteria at the EAB. However, as  
18 was previously noted we do need to rely on the  
19 building to meet the PAGs at the EAB.

20 Both active and passive SSCs are working  
21 in concert with these inherent design characteristics  
22 to reduce the frequency of challenges to the  
23 radionuclide barriers. And we'll talk about a series  
24 of challenges in the subsequent slides that Fred  
25 brought up in his presentation first thing this

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1 morning.

2 But our process is looking at a full  
3 spectrum of events, not just a few limiting or  
4 bounding events. So we're looking at all challenges  
5 to barrier integrity and independence. So we're  
6 looking at all the possible failures that could be  
7 within the frequency range domain that we've defined  
8 in our licensing basis event process and we're taking  
9 into consideration all of those things.

10 Safety margins and conservative design  
11 approaches will be used to address uncertainties in  
12 barrier and SSC performance. And this refers back a  
13 little bit to some of Tom's earlier questions about  
14 how we would consider the reliability and the  
15 availability of the SSCs as part of our event  
16 selection and our overall approach to defense-in-  
17 depth.

18 Fred mentioned this morning three key  
19 functions that we've got to maintain in the plant to  
20 be able to minimize the challenges that we make to our  
21 integrated set of barriers.

22 The first one is control of heat  
23 generation. We have a combination of inherent reactor  
24 characteristics which is a plant capability issue.  
25 And the available SSCs both passive and active

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1 available for our consideration when we look at  
2 control of heat generation.

3           So in this case as Fred mentioned earlier  
4 we have two independent and diverse systems for  
5 reactivity control. And they rely on gravity. So in  
6 a loss of power control rods will shut down the plant.  
7 We also have an independent system, the reserve  
8 shutdown system that Fred mentioned earlier. Each of  
9 these systems is available for maintaining reactor  
10 subcritical. Each of these systems available for cold  
11 shutdown during refueling. So that's one aspect of  
12 plant capability.

13           Another key function that we have to  
14 maintain is removal of core heat. In this case here  
15 we have a combination of both active and passive  
16 systems. Again these have been mentioned prior.

17           The normal mode of removing heat from the  
18 plant of course is to use a helium transport system to  
19 be able to remove that heat out of the plant under  
20 normal operation to the steam generator and finally to  
21 the ultimate heat sink.

22           But we also have alternate methods. We  
23 have a shutdown cooling system that is an active  
24 system. It's typically not -- we don't see it as  
25 being safety-related but that is available during

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1 shutdown periods and during planned maintenance to be  
2 able to remove the heat from the helium system.  
3 Again, this system that draws the helium through a  
4 heat exchanger which then has its own cooling water to  
5 be able to provide the ultimate heat sink.

6           However, we also have a passive system  
7 that's available for off-normal events, provides heat  
8 removal and investment protection. This is the  
9 reactor cavity cooling system, RCCS system. In that  
10 mode of operation we have the heat being radiated from  
11 the reactor vessel which is uninsulated to the panels  
12 that are surrounding the reactor. And then again we  
13 have either a passive air system or a water system  
14 available to remove the heat from the RCCS.

15           Any questions on that?

16           The third mode, third function, control of  
17 chemical attack that Fred mentioned this morning. In  
18 this case we have a combination of inherent reactor  
19 characteristics and design features that minimize the  
20 effects of chemical attack.

21           As far as inherent characteristics you can  
22 see on the list there we have non-reacting helium as  
23 a coolant. We have slow oxidation rates afforded by  
24 the graphite that we have in the core. And again, it  
25 was mentioned before, the water-graphite reaction is

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1 endothermic and we need to have very specific  
2 conditions to be able to even postulate the kind of  
3 sustainable reaction rate within the core.

4 From a design feature we have limited flow  
5 area through the core. It was mentioned we have a  
6 large L over D on this plant. There is a lot of flow  
7 resistance in the coolant channels.

8 Reactor building is embedded so that tends  
9 to minimize some of the effects of leakage from the  
10 building. We also have limited sources of water. We  
11 have moisture monitor, steam generator isolation and  
12 dump systems to try to minimize the injection of water  
13 into the plant. Again, these are all design features.

14 And then again when you look at the fuel  
15 itself within the particles, within the compact,  
16 within the matrix we have several layers that if we  
17 did have an oxidation event it takes a long period of  
18 time before you could postulate that you would be able  
19 to have a direct attack on the particles themselves  
20 from an oxidizing event. So these are all meant to  
21 address some of the plant capability aspects of  
22 defense-in-depth.

23 The second element, programmatic defense-  
24 in-depth, is all those processes and procedures that  
25 you would expect to be in place at any operating

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1 plant. Inspection programs, test programs, quality  
2 assurance programs, all those kind of things would be  
3 implemented at this facility. You see some examples  
4 there.

5 Special treatment requirements in  
6 particular. Some of the questions we had earlier  
7 about technical specifications. Yes, we understand  
8 there would be some design limit specifications on the  
9 fuel. Also, it's reasonable to expect that we'd have  
10 some circulating activity requirements that we need to  
11 implement through tech specs. All these kind of  
12 things would be implemented. And that would fall  
13 under programmatic defense-in-depth.

14 Now, the final part of the triangle is the  
15 risk-informed evaluation of defense-in-depth. This  
16 third element provided by the evaluation process that  
17 you see that's fed by information that's coming out of  
18 the PRA and also from deterministic safety evaluations  
19 that you would typically do in Chapter 15 for your  
20 plant provides a framework for performing these  
21 evaluations to determine how well your plant  
22 capability and programmatic strategies are being  
23 implemented.

24 So it provides accident prevention and  
25 mitigation insights, it provides input into your

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1 safety classification to -- when you have several sets  
2 of SSCs that are available to provide required safety  
3 function it allows you to choose wisely in the  
4 selection of those particular systems to provide the  
5 safety functions that are needed. And it also  
6 provides an opportunity to identify key sources of  
7 uncertainties.

8 So on the next slide we talked a little  
9 bit more about risk-informed evaluation. We want to  
10 identify credible failure modes and challenges to the  
11 barriers including dependencies and interactions along  
12 the barriers and other SSC failure modes. This is  
13 what I mentioned earlier is we want to challenge our  
14 design and make sure that our PRA is looking at all  
15 the possible spectrum of events and failure modes that  
16 need to be considered.

17 We also identified the roles of SSCs in  
18 this process in the prevention and mitigation. We  
19 wanted to make sure that we have a balance of  
20 prevention and mitigation in our design. We want to  
21 quantify the extent to which accidents are being  
22 prevented and mitigated. And we're using both the PRA  
23 and our safety evaluations to do that.

24 And finally, we want to establish that  
25 there are no events with significant frequency of

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1 occurrence that rely on a single element of the design  
2 or programmatic approach in protecting the public from  
3 a release.

4 So again, the whole purpose of the risk-  
5 informed evaluation is to be able to scrutinize the  
6 effectiveness of both the plant capability of defense-  
7 in-depth and the programmatic defense-in-depth.

8 In fact, this approach was called out in  
9 Appendix C of NUREG-2150 which is the Risk Management  
10 Task Force where they mentioned the fact that this  
11 particular process that the NGNP is proposing includes  
12 a concept for using risk assessment methods as a  
13 measurement of effectiveness. And they called that  
14 out as an paragraph that is very similar to the  
15 approach or the thinking of the task group.

16 MEMBER STETKAR: Mark, before you leave  
17 this, and I hate to do this because of time so I'll  
18 try to make it quick. You've heard a couple of  
19 questions already this morning about concerns in terms  
20 of evaluating the margin to the acceptance criteria.

21 And I'll just read something out of the  
22 defense-in-depth paper. It's in Section 3.3.2.2 if  
23 you want to look it up. It says, "If the 95th  
24 percentile of the frequency of the licensing basis  
25 event is above the break point for separating the AOOs

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1 from the DBEs, or the DBEs from the BDBEs the  
2 licensing basis event is assigned to the higher  
3 frequency category where more stringent dose criteria  
4 apply."

5 MR. HOLBROOK: Yes.

6 MEMBER STETKAR: Vertical scale. The 95th  
7 percentile from the consequence uncertainty  
8 distribution is required to be within the associated  
9 frequency consequence curve. That is a statement.  
10 That is a measurable metric from my risk assessment to  
11 give me confidence in the margins regardless of  
12 whether I'm doing a single unit or a multi-unit plant  
13 in consequences.

14 That's from a December 2009 paper. By the  
15 time we get to the licensing basis event selection and  
16 everything else we heard we've abandoned that notion  
17 of 95th percentile over the whole frequency  
18 consequence curve. So I'm curious about why it's  
19 morphed into that.

20 And I'll ask the staff more about that  
21 because you pointed that way. Because when I read the  
22 defense-in-depth paper I said geez, I understand how  
23 they're doing this. I understand now how I can  
24 quantify my confidence in those margins both  
25 vertically and horizontally, wherever I am on that

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1 surface. And now today I can't understand how I can  
2 quantify that confidence in the margins.

3 MR. HOLBROOK: It's certainly true within  
4 the DBE region. Okay. Your question really --

5 MEMBER STETKAR: It's over a whole  
6 surface. I'm interested in the whole surface.

7 MR. HOLBROOK: -- the AE region and the  
8 beyond design basis event region.

9 MEMBER STETKAR: And with that because of  
10 the time I'll let you finish.

11 CHAIRMAN BLEY: Kind of -- if I can  
12 rephrase. If that one makes sense to you then why  
13 aren't they all the same?

14 MEMBER STETKAR: Exactly. Yes. Because  
15 if they're all the same then I understand how I can  
16 measure my confidence in my margins. I might disagree  
17 in terms of how confident I should be, whether that  
18 should be 99th percentile or 90th percentile. But at  
19 least I can measure it.

20 DR. KRESS: That depends on how good you  
21 know these probabilities.

22 MEMBER STETKAR: That's okay.

23 CHAIRMAN BLEY: But all the rationales for  
24 all that discussion is in the licensing basis event.  
25 And Fred regurgitated that this morning.

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1                   MEMBER STETKAR: I understood the  
2 rationale -- I understood all of the rationales on the  
3 vertical axis. I didn't understand them on the  
4 horizontal.

5                   MR. HOLBROOK: This slide here is just to  
6 provide an integrated picture of some of the details  
7 that I presented on the previous slides. So it's kind  
8 of a takeaway slide if you want to look at this  
9 construct and refresh your memory on what pertains to  
10 what, and what insights are flowing in what direction  
11 and all of that.

12                   Is there any questions on that?

13                   CHAIRMAN BLEY: I'm trying to remember.  
14 At the last meeting your approach framework for  
15 defense-in-depth is very broad. Kind of, almost  
16 everything in the design is focused through defense-  
17 in-depth. I think some people objected to that and  
18 were asking you hard questions about it.

19                   MR. HOLBROOK: I would characterize it a  
20 little bit different. What you see in plant  
21 capability defense-in-depth and what you see in  
22 programmatic defense-in-depth are the kinds of things  
23 that you would expect to see when you try to define  
24 defense-in-depth for today's light water reactors.

25                   I think the thing in my opinion that is

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1 somewhat more new is to then use the probabilistic  
2 risk assessment process and the safety evaluation  
3 process for your accidents in Chapter 15 to go back  
4 and reassure yourself since we have the opportunity to  
5 do this during the design phase, to go back and  
6 convince yourself by going through additional steps  
7 that we haven't presented in these slides but are  
8 found in the defense-in-depth paper such as Figure 3-  
9 7.

10 To systematically go back and look through  
11 all the principles that we defined in that white paper  
12 to convince ourselves that the plant has adequate --  
13 the physical plant has adequate capabilities and we  
14 also have programmatic where needed and that there is  
15 a reasonable balance between the two.

16 Not to have an over-reliance on  
17 programmatic to cover up for some deficiency in the  
18 plant. We want to have a balance and we want to have  
19 a structured approach which is really what this is  
20 doing is a structured approach to go back and  
21 systematically convince ourselves that we have those  
22 elements that are traditionally found in light water  
23 reactors.

24 That's really what this process is all  
25 about and I think that's what they were trying to say

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1 in NUREG-2150, that we have -- the thing that's  
2 different here is (a) we're doing it up front, (b) we  
3 have a structured approach that uses risk and  
4 determinism to be able to evaluate whether we have  
5 adequate defense-in-depth before the plant is ever  
6 built. Does that help?

7 MEMBER STETKAR: That's good, thanks.

8 DR. KRESS: The light water reactors  
9 generally have diesel generators and batteries to  
10 guard against loss of offsite power. You don't have  
11 any of that here, right?

12 MR. HOLBROOK: Well, it depends -- well  
13 no, the answer is no because again it comes back to  
14 your plant design specifics about what is your  
15 reliance on 1A with AC distribution. If you have  
16 passive safety systems that don't rely on that then  
17 you don't need it. Okay? So it's design-specific.  
18 Okay?

19 In summary, what I wanted to do here,  
20 we've got this slide then we've got one final slide  
21 that kind of sums up everything that's gone on today.

22 What we wanted to do here is we wanted to  
23 just translate what I talked about, some of those  
24 characteristics within the context of prevention,  
25 mitigation and emergency planning such as the

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1 definition that you found on slide 3 I believe it was.

2 So again we're trying to evaluate the  
3 plant capability and programmatic elements with an  
4 integrated risk management approach. I just explained  
5 that.

6 Within the context of prevention,  
7 mitigation and emergency preparedness again there is  
8 several aspects and I didn't try to list them all here  
9 because I wanted to keep this down to one slide, but  
10 there's plant capability aspects that fall under  
11 prevention, there is certainly plant capability  
12 aspects that fall under mitigation, and then there's  
13 also administrative or programmatic I should say  
14 elements that fall under mitigation and also emergency  
15 preparedness.

16 All we tried to show is that we're looking  
17 at these things in a similar manner as the staff would  
18 look at things, looking for prevention, mitigation and  
19 emergency preparedness issues. But we're trying to do  
20 it in a structured, integrated, risk management  
21 approach. So, that's all I was trying to show. This  
22 slide, there's really no new technical information on  
23 that slide besides what we've already discussed.

24 Then finally, this is the last slide in  
25 our presentation this morning. Again we wanted to

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1 leave you with a takeaway looking at -- maybe at the  
2 10,000-foot level of some key attributes that we've  
3 discussed at several points this morning. Our design,  
4 our approach addresses the full spectrum of internal  
5 and external events on a per-plant year, not on a per-  
6 reactor basis.

7 We've mentioned several times it includes  
8 events that could affect multiple reactor modules to  
9 be able to assess an integrated plant risk. So we're  
10 looking across all of the plants and that -- or all  
11 the reactor modules that would constitute a plant to  
12 ensure that any events that would affect multiple  
13 units are taken into consideration and are included  
14 and would be displayed on a frequency consequence  
15 curve.

16 Again we mentioned we're using ceramic  
17 fuel. It doesn't melt when challenged by a full  
18 spectrum of internal and external events.

19 We are looking at cliff edge effects. We  
20 want to find that safety terrain, make sure it's  
21 adequately addressed. So we're looking at events  
22 below 5 times  $10^{-5}$  down into the  $10^{-8}$  range to be --  
23 make sure that we don't miss something that we need to  
24 assess in our process.

25 We assure that the safety is not wholly

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1 dependent on any single element. Again, this is part  
2 of our defense-in-depth that I've just gone through.  
3 We want to make sure that we don't have any single  
4 point kind of failure whether it's in the design,  
5 construction, maintenance, or operation of the  
6 facility.

7 We want to provide compensatory means to  
8 make sure that prevent accidents are less than the  
9 effects. In other words, a balance between prevention  
10 and mitigation if a malfunction occurs.

11 And finally, as we mentioned several times  
12 we have multiple, concentric, independent radioactive  
13 nuclide barriers that we want to protect. A breach  
14 into the helium pressure boundary does not result in  
15 failure of the fuel or the reactor building. In other  
16 words, we don't rely on the presence of helium to be  
17 inside the core to be able to get heat out of the core  
18 as we mentioned during some of the earlier slides in  
19 the presentation.

20 So with that our presentations are  
21 finished. We thank you very much for your  
22 consideration. We'd take any other questions that you  
23 may have.

24 CHAIRMAN BLEY: That's great. Thank you  
25 and thanks for doing that quickly and effectively.

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1 We'd like to mention on the record that Dick Skillman,  
2 member of the ACRS, has joined us during the morning.

3 We're going to take a break now for lunch.  
4 I'm sorry, we are going to come back at 1 or try to as  
5 close to that as we can because we have a full  
6 afternoon. We could have started earlier but we  
7 thought the agenda this morning would not take as long  
8 as it did. And we'll recess until 1 o'clock. Thank  
9 you all.

10 (Whereupon, the foregoing matter went off  
11 the record at 12:16 p.m. and went back on the record  
12 at 1:00 p.m.)

13 CHAIRMAN BLEY: The meeting is back in  
14 session. We expect we'll have some more members this  
15 afternoon as other meetings finish up but we have no  
16 one yet. In fact we're missing two. I think Joy is  
17 gone. Joy's gone, that's right. But Mike said he'll  
18 be back after the lunchtime meeting. Sam is also  
19 gone, same meeting. Sorry for the mumbling. I should  
20 have done that before I opened.

21 At this time we're looking forward to  
22 hearing from staff about their evaluation of these  
23 white papers we've been hearing about at our last two  
24 meetings. I will turn the meeting over to Anna  
25 Bradford at this time and we look forward to hearing

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1 from the staff.

2 MS. BRADFORD: Thank you. We appreciate  
3 being here today. My name's Anna Bradford. I'm the  
4 chief of the Small Modular Reactor Licensing Branch II  
5 in the Office of New Reactors. And we're here today  
6 to talk to you about some work we've been doing over  
7 the last few years for the Next Generation Nuclear  
8 Plant.

9 As you heard from DOE we've been focused  
10 on some very important issues such as mechanistic  
11 source term and event selection. And some of these  
12 issues are being addressed in a broader sense in other  
13 activities in the Agency such as Fukushima-related  
14 activities or the small modular light water reactor  
15 licensing activities. But I just want to point out  
16 that today we're here to specifically talk about the  
17 NGNP issues and that design-specific information and  
18 the current regulations as they apply to what we've  
19 been thinking about.

20 So we're meeting with you today. We're on  
21 the schedule to meet with the full committee in May.  
22 After that we're hoping to get a letter from the  
23 committee with comments that you may have on our  
24 assessments and then we'll finalize our assessments.  
25 And those will be sent to DOE and also made publicly

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1 available.

2 So we look forward to the interactions  
3 today and at this time I'll turn it over to our senior  
4 project manager Dr. Don Carlson.

5 CHAIRMAN BLEY: Thank you. Don?

6 DR. CARLSON: Good afternoon and thank you  
7 committee members for this chance to present our  
8 assessment findings, our results for the NGNP pre-  
9 application review activities on these key licensing  
10 issues.

11 Again, my name is Don Carlson. I'm the PM  
12 for NGNP and before the break this afternoon I will be  
13 joined by Tom Boyle and Jonathan DeGange. And after  
14 the break I'll be continue with help from Jim Shea and  
15 Arlon Costa.

16 We have -- my presentation is really just  
17 an overview, an introduction. So big questions about  
18 our findings really should come in the presentations  
19 that follow my overview. So then I will turn it over  
20 to in the second part of the agenda to my partners  
21 here at the table to talk licensing basis events and  
22 then Jim Shea on source terms. I will give the talk  
23 on functional containment performance and Arlon Costa  
24 on emergency preparedness. So you have our contact  
25 information there.

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1           We've had many contributors to this  
2 activity over the years. Sud Basu has been involved  
3 in these activities from the very beginning as have I.  
4 Mark Caruso, Michelle Hart. We have in the appendices  
5 of two of our documents a list of contributors to  
6 these activities. Stu Rubin who contributed early on  
7 to these activities and has come back as a member of  
8 the public after 1 and a half years of retirement,  
9 he's in the audience today.

10           CHAIRMAN BLEY: We'll look forward to  
11 hearing his comments.

12           DR. CARLSON: I also have on the phone  
13 today Mike Kania. Dr. Mike Kania is an expert  
14 consultant on TRISO fuel. He has been a major player  
15 in TRISO fuel R&D during his Oak Ridge career in the  
16 seventies, eighties and nineties and has collaborated  
17 extensively with the German TRISO fuel program over  
18 the decades. Now he is working through Brookhaven  
19 National Lab and has been a major contributor to our  
20 recent activities on fuel qualification for TRISO  
21 fuel. So I've asked him to listen in on the phone and  
22 stand by to help us discuss detailed questions that  
23 any members may have.

24           So as Anna mentioned we are requesting a  
25 letter and are on the full committee schedule in May

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1 to do that.

2 I'm going to give a little overview now of  
3 the project history. You're probably familiar with a  
4 lot of this but the NGNP project was established by  
5 the Energy Policy Act of 2005. DOE and INL were  
6 tasked to demonstrate by 2021 a prototype high-  
7 temperature gas-cooled reactor for co-generating  
8 electricity and process heat. The NRC has licensing  
9 authority for the prototype plant.

10 So as stipulated by the EPAct the DOE and  
11 NRC jointly issued a licensing strategy report to  
12 Congress in 2008 and selected -- jointly selected an  
13 option 2 where option one would be a traditional  
14 deterministic approach and option 4 would be a more --  
15 quite a risk-based approach. And so option 2 and  
16 option 3 would be those two extremes.

17 And so option 2 is described as a risk-  
18 informed and performance-based approach where you use  
19 deterministic engineering judgment and analysis  
20 complemented by PRA insights to establish the NGNP  
21 licensing basis and requirements.

22 So the other major activities we've been  
23 going through are what we are talking about today, a  
24 series of white paper submittals that we have been  
25 assessing since 2010. A year and a half ago DOE with

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1 -- based on a review by the Nuclear Energy Advisory  
2 Committee, some of whose members are here on the ACRS,  
3 decided in a letter to Congress that DOE will not  
4 proceed with the detailed design activities at this  
5 time and instead will continue to focus on high-  
6 temperature reactor research and development.

7 And the key item here, interactions with  
8 NRC to develop a licensing framework. And then  
9 establish a public-private partnership, and that was  
10 the part that has really been difficult for them to  
11 establish and go forward with the plan.

12 So the plan was, as you may recall, to  
13 meet the 2021 demonstration target to submit an  
14 application to us by 2013, this year. And we have not  
15 been on track to do that.

16 So we have been using DOE-reimbursable  
17 funds here in the NRC to engage within DOE on these  
18 four key -- using four key areas. And I'll discuss  
19 what those are in a minute.

20 So we issued our preliminary assessment  
21 reports to DOE in February of last year. And as was  
22 indicated today there was an extensive RAI process,  
23 request for additional information, hundreds of those.  
24 And I would like to acknowledge that DOE and INL did  
25 a very thorough and prompt job of responding to those

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1 RAIs.

2 I'd also like to say that the staff  
3 provided some very insightful questions and comments  
4 to go with those. Together all those RAIs and RAI  
5 responses are a substantial repository of what we've  
6 learned over the last few years.

7 And if you look at the page count they  
8 actually far outnumber the pages of the white paper  
9 we're reviewing. So I would urge future people  
10 engaging in follow-up activity of this kind to study  
11 all of those materials, not just what we're presenting  
12 today.

13 So the products that we issued last year  
14 were basically Rev zero of the initial assessments of  
15 the fuel qualification white paper and mechanistic  
16 source terms white paper, and then another report  
17 assessing the contents of what we called the set of  
18 white papers describing their risk-informed  
19 performance-based approach. And those were the  
20 defense-in-depth white paper, the LBE licensing basis  
21 event selection white paper, and the safety  
22 classification of SSCs white paper.

23 Then also in February NRC issued a letter  
24 to DOE agreeing to focus on four issues in these four  
25 key areas, licensing basis event selection, source

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1 terms, functional containment performance and  
2 emergency preparedness.

3 We started engaging and then in July of  
4 last year DOE provided a letter to us that clarifies  
5 their approaches to the issues and exactly what staff  
6 feedback they would like us to provide on those  
7 issues.

8 And so we engaged in a number of public  
9 meetings and conference calls through November of last  
10 year. And we also reviewed a number of supporting  
11 technical documents that DOE and INL submitted during  
12 that time that clarified some of these issues. Again,  
13 as you know in January DOE provided an information  
14 briefing.

15 And now let's talk about the three  
16 products. So again what we are asking the committee  
17 to look at and write a letter on ultimately is these  
18 three staff products.

19 Product one is what we call the issue  
20 summary report. Its formal title is "Summary Feedback  
21 on Four Key Licensing Issues." And those are the four  
22 key issues that we talked about just now.

23 And then Rev 1 of the two assessment  
24 reports. So an updated assessment report on fuel  
25 qualification and mechanistic source terms and an

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1 updated assessment report on the risk-informed  
2 performance-based white papers with additional  
3 insights from the PRA white paper that we reviewed  
4 during this time.

5 This update, the Rev 1, the things that  
6 we've been doing since February involved additional  
7 staff beyond the staff that were involved in the  
8 initial phase activities that gave us the Rev zero of  
9 these reports. And so we have different perspectives  
10 and high-level concurrence on the staff positions  
11 presented in these updated papers.

12 So let's talk a little bit about this  
13 issue summary report. Again, the four issues. These  
14 same four issues were highlighted in the joint DOE-NRC  
15 licensing strategy report to Congress in 2008.

16 The same kinds of issues were considered  
17 in NRC pre-application activities for modular HTGRs.  
18 They have been packaged in various ways but they  
19 always come down to these four major issues.

20 And as we noted there was a lot of  
21 engagement on these issues in the late eighties and  
22 early nineties with DOE and General Atomics for the  
23 MHTGR and in about 10 years ago on the pebble bed  
24 modular reactor. In fact, the approaches proposed by  
25 DOE and General Atomics back then for modular HTGR and

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1 for pebble bed modular reactor are very similar to  
2 what we now see for NGNP in that we have similar FC  
3 curves, the event frequencies are always per reactor-  
4 year so inherently account for multi-module effects.

5 And it was interesting to note that what  
6 we now are wanting to call beyond design basis events  
7 were at that time called emergency planning basis  
8 events. So the terminology has changed a little but  
9 there's a lot of similarity in the approaches.

10 So all of the issues that we are talking  
11 about we have developed our feedback in view of all  
12 relevant prior staff positions and all ACRS comments  
13 on those staff positions and Commission direction on  
14 these issues in various SECY documents. Starting most  
15 notably with SECY-93-092 and the NUREG-1338 which  
16 documented the preliminary safety evaluation of the  
17 MHTGR.

18 And then more recently SECY-03-0047 which  
19 was about the pebble bed reactor review, pebble bed  
20 modular reactor, SECY-05-006 which was an information  
21 policy SECY paper that talked about modular HTGRs but  
22 also technology-neutral framework. And then NUREG-  
23 1860 which was about the technology-neutral framework.  
24 And a year and a half ago SECY-11-0152 which Arlon  
25 Costa will be talking about later in the presentation

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1 on emergency preparedness.

2 DR. KRESS: Are all of these available  
3 from ADAMS?

4 DR. CARLSON: Absolutely. And I think you  
5 have links to all of them that I provided to Maitri.

6 Another point to emphasize is that these  
7 are risk-informed performance-based approaches that  
8 have been proposed for NGNP are similar to approaches  
9 that have been or may be considered for NUREG-1860.  
10 NUREG-2150, a Near Term Task Force recommendation, et  
11 cetera. So a revised -- a new framework resulting  
12 from all of these other efforts may very well change  
13 the staff positions that we're describing today for  
14 NGNP.

15 Again as Anna emphasized we're not talking  
16 here about any of those other efforts. We're talking  
17 strictly about our evaluation of the proposals for  
18 licensing a modular HTGR, namely the NGNP.

19 Now, Dr. Corradini had a question earlier  
20 about how this relates to the notion that we were  
21 going to do a pilot study test-driving the technology-  
22 neutral framework NUREG-1860. And this is --

23 MEMBER CORRADINI: Am I remembering some  
24 Commission directive incorrectly?

25 DR. CARLSON: You're remembering it very

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1 correctly I believe.

2 MEMBER CORRADINI: Okay, all right.

3 DR. CARLSON: And what we said in that was  
4 -- what we were told to do and what we committed to do  
5 was to do a pilot study of that type of approach in  
6 parallel with adapting existing regulations as  
7 described here.

8 And so did we start doing that? No.  
9 Would we start doing that sometime before expecting to  
10 receive an application like this? I believe we would.  
11 So.

12 CHAIRMAN BLEY: That's still in the plan  
13 for expanding the guidance.

14 DR. CARLSON: That's what we committed to  
15 do and until we have a different commitment that  
16 remains what we --

17 CHAIRMAN BLEY: But it has not begun.

18 DR. CARLSON: It has not begun because  
19 there's nobody -- no scheduled for getting an  
20 application for NGNP or any other gas-cooled reactor.

21 CHAIRMAN BLEY: Can't give the example  
22 without a design.

23 MEMBER CORRADINI: So what would -- you  
24 described it well. So what would trigger you starting  
25 planning to do that? Somebody actually putting in a

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1 pre-application intention with you guys?

2 DR. CARLSON: The notion of course for a  
3 technology-neutral framework is to be able to handle  
4 any technology so it would be applicable to a liquid  
5 metal-cooled reactor.

6 MEMBER CORRADINI: Oh no, I understand  
7 that.

8 DR. CARLSON: So right now --

9 MEMBER CORRADINI: Planning to do it would  
10 occur when?

11 DR. CARLSON: I would say a few years  
12 before we expect, you know, 2 to 3 years before we  
13 expect to get an application, something like that.

14 CHAIRMAN BLEY: Certainly after you have  
15 a design.

16 MS. BRADFORD: If I could just clarify for  
17 one second. I think what you're talking about is a  
18 SECY paper from a couple of years ago where we said we  
19 would do a pilot study of a technology-neutral  
20 framework for the HTGR, specifically the NGNP design.  
21 And in that paper we said following submittal of the  
22 NGNP design application the staff would conduct a  
23 limited comparison study of the application in  
24 parallel with our review of the design.

25 So in terms of actually doing that work it

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1 was meant to be after receiving the design  
2 application. Of course we would need to prepare  
3 beforehand.

4 Like Don said we do put out a RIS once a  
5 year asking potential applicants or vendors when they  
6 think they might come in and we take that into account  
7 in our scheduling and resources. And we do plan at  
8 some point to be ready to address a technology-neutral  
9 framework review.

10 CHAIRMAN BLEY: Okay. But it's also in  
11 that extension to the SRP. You had a Rev 1 that  
12 talked about how you'd look at the small modular  
13 reactors. And it was like stage 3 of that process I  
14 think.

15 MR. MAYFIELD: This is Mike Mayfield from  
16 --

17 CHAIRMAN BLEY: Good to see you, Mike.

18 MR. MAYFIELD: -- Reactors. I like this  
19 column. Unfortunately Dr. Kress can see me all too  
20 well.

21 We did, when it looked like we were going  
22 to be challenged to see an application under NGNP we  
23 started looking for alternatives where we could try  
24 and test drive some of it, it being the technology-  
25 neutral framework.

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1           And so we were going to try and use  
2 NuScale as the test case. Some vagaries with their  
3 schedule. They are -- that vendor is still committed  
4 to be part of it. However, vagaries in their  
5 submittal schedule coupled with current budget  
6 stressors make pursuing that at this time not tenable.

7           CHAIRMAN BLEY: Fair enough.

8           MR. MAYFIELD: We haven't zeroed things  
9 yet but it's getting dangerously close and likely that  
10 we will not be able to proceed with that anytime soon.

11           But that's -- going back to Dr.  
12 Corradini's question if we start getting serious  
13 indicators of a submittal we'll go back to the  
14 Commission and try and figure out how we could fund  
15 such a thing. It would not be a trivial budget  
16 impact.

17           MEMBER CORRADINI: So can I ask a kind of  
18 follow-up, Mike? So, some of the conclusions in the  
19 summary, in the summary report which kind of toss it  
20 back to the Commission from a policy standpoint. Is  
21 that one way of saying that things that are really  
22 going to be tough to address the Commission is going  
23 to come back with a policy decision? There are things  
24 relative -- now I've forgotten. There were three or  
25 four of them. And you really can't go forward with a

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1 technology-neutral framework until some of those are  
2 clarified.

3 MR. MAYFIELD: That's correct. And what  
4 we have talked about with some of the Commission  
5 assistants is we're not going to bring them something  
6 that's ill-defined and ask for a policy determination.

7 In fact, that's a conversation I'd had  
8 with Tom O'Connor when we started talking about what  
9 we could do with this assessment report was what of  
10 these could we dress up as policy determinations and  
11 put in front of the Commission at this time. And the  
12 dialogue with some of the Commission assistants was  
13 that's just not going to take them anyplace useful  
14 because they need to have something specific to  
15 address the policy on.

16 So this -- we felt like the effort that  
17 Don and the team are going to describe this afternoon  
18 was probably as far as we could push it at this stage,  
19 recognizing that there will be issues that we will  
20 want to take to the Commission for policy  
21 determination as we would move this forward based on  
22 a specific design application. And being able to move  
23 those forward could predate an application. We'll  
24 just have to see how this unfolds with a little time.

25 DR. KRESS: Will the TVA plans on small

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1 modular plant fit in here anywhere?

2 MR. MAYFIELD: I'm sorry, please say it  
3 again?

4 DR. KRESS: Will the TVA plans on doing a  
5 small modular LWR fit into this anywhere? Or do you  
6 know? Maybe I'm bringing it up too soon.

7 MEMBER CORRADINI: So are you asking about  
8 mPower?

9 DR. KRESS: No, I'm talking about the TVA  
10 plans to use the Clinch River Breeder Reactor site.

11 MR. MAYFIELD: Well, TVA has told us that  
12 they intend to put the mPower, and in fact in their  
13 RIS response put mPower on the old Clinch River site.

14 DR. KRESS: Right.

15 MR. MAYFIELD: So they're moving forward  
16 with that. They have been less enamored -- well, BMW  
17 has been less enamored with being the pilot on this.

18 DR. KRESS: Yes, they're probably use the  
19 normal procedure I guess.

20 MR. MAYFIELD: Normal meaning Part 52  
21 where B&We and TVA continues to look at Part 50.

22 DR. KRESS: Thank you.

23 DR. CARLSON: Okay, so I'll get back to my  
24 presentation. Again, we will finalize and issue these  
25 to DOE as enclosures to a letter publicly after ACRS

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1 review in May.

2 The presentations today are based on this  
3 first product, the issue summary report, but we will  
4 also dip into the more detailed white paper assessment  
5 reports for certain details.

6 Major conclusions, and we'll get into the  
7 details, but just very high-level. The staff used the  
8 proposed approaches to these licensing issues are  
9 generally reasonable with a number of caveats.

10 And at the high level the caveats are that  
11 deterministic elements of the RIPB approach should be  
12 strengthened. Really what that means is instead of  
13 what we thought should look like an option 2 we think  
14 some of it looks like option 3 in certain respects.  
15 And so this is the staff's advice on how to get it  
16 back more into option 2.

17 Another key element is consistent with the  
18 licensing strategy report to Congress. It called for  
19 licensing the NGNP within -- by adapting the current  
20 licensing framework as a prototype specifically under  
21 the prototype testing provisions of Title 10 Code of  
22 Federal Regulations 50.43(e)(2).

23 Our review of some of the technical issues  
24 under fuel qualification and mechanistic source terms  
25 reinforced that with specific issues that would have

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1 to be resolved by prototype testing. And we'll get  
2 into that.

3 MEMBER CORRADINI: Okay. So you're going  
4 to explain what all that just meant. Because early on  
5 in the licensing strategy when ACRS wrote the letter  
6 saying go forth, that looks like a good strategy,  
7 originally DOE had the option of using this as a demo.  
8 It wasn't 10 C.F.R. 50.43(e), it was another part  
9 where it would be a test reactor and the test reactor  
10 would have various power stages and they would only  
11 get an ascension from zero power to 5 percent, from 5  
12 percent to 10 percent as they proved out. So how is  
13 (e) different than that? DOE chose not to do that and  
14 NRC agreed with that at that time. Is this different?  
15 This sounds very similar.

16 DR. CARLSON: It is.

17 MR. MAYFIELD: This is Mike Mayfield  
18 again. It is. That's essentially the prototype  
19 provision. So through licensing conditions on the  
20 design you would impose either additional trip set  
21 points, a power ascension program.

22 MEMBER CORRADINI: And that's proven  
23 empirically --

24 MR. MAYFIELD: As proven empirically.

25 Then you would start to remove -- well, upon request

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1 you would start to remove those license conditions or  
2 modify them to allow power increase, to remove some  
3 more conservative trip set points, whatever conditions  
4 you might have imposed to assure safe operation while  
5 you were proving out the design.

6 MEMBER CORRADINI: Okay. And then you're  
7 going to explain it, but just at a high level. So DOE  
8 has seen this second conclusion. Have you seen any  
9 response from DOE? Because this has been discussed in  
10 the past, 10 years ago with DOE and this was not a  
11 path chosen. So I'm kind of curious on the back and  
12 forth in terms of the philosophy of this.

13 DR. CARLSON: We have had some discussion.  
14 I didn't detect that there was fundamental  
15 disagreement on this point.

16 MEMBER CORRADINI: Okay. Because just to  
17 take you back historically, in 2003 the INL's internal  
18 independent review team suggested this approach if I  
19 remember correctly in 2003.

20 DR. CARLSON: That said, when we do  
21 discuss these things and it's in public meeting  
22 records there's an indication that the NNGP industry  
23 alliance is hesitant to go to prototype depending on  
24 what you mean by prototype. A prototype can look a  
25 lot like the standard plant and that's what they want.

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1 MEMBER CORRADINI: Okay, fine.

2 DR. CARLSON: Yes.

3 MEMBER CORRADINI: All right, thank you.

4 DR. CARLSON: So, important qualifiers.

5 Of course this is pre-application review. It's for a  
6 design that's pre-conceptual at best. And we haven't  
7 seen any real analysis. So the staff feedback is  
8 advisory and represents no regulatory decisions and no  
9 final positions on any issue.

10 Our regulatory positions will be based on  
11 the NGNP license application and related Commission  
12 policy determinations that may be provided in the  
13 future.

14 And again there were comments today and  
15 back during the January 17th briefing about applying  
16 this as a technology-neutral framework. And indeed  
17 certain elements have been described by DOE as  
18 technology-neutral. The top-level regulatory  
19 criteria, the frequency consequence curve itself is,  
20 in principle that's all technology-neutral.

21 We did not look at it from a technology-  
22 neutral perspective. We looked at it solely as it  
23 would apply to a modular HTGR design concept. If we  
24 were to look at it for other technologies I'm not sure  
25 we'd reach the same conclusions.

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1           So, what do we mean by modular HTGR design  
2 concept? I think DOE-INL has presented that very  
3 well.

4           I have been immersed in high-temperature  
5 gas-cooled reactor technology off and on, mostly on,  
6 since 1978 so you might guess that I have presented  
7 some overviews of what an HTGR, in particular what a  
8 modular HTGR is. And I've always found that there are  
9 one or two slides that make people say ah, that's what  
10 it's all about.

11           First of all, the early history of HTGRs.  
12 There was the first generation of HTGRs, the Dragon  
13 reactor in the UK 1966 to `75. Then in Germany the  
14 AVR 1967 to 1988. That's a picture of the AVR taken  
15 from the building where I worked from 1978 to `83. So  
16 I was part of that German R&D program, very intimately  
17 familiar with the AVR.

18           So it was a pebble bed reactor, 46  
19 megawatts thermal. It was truly very high  
20 temperature, 950 degrees C outlet temperature for much  
21 of its operating life. And it had about 70 percent  
22 capacity back there as a test reactor.

23           Then there was Peach Bottom 1 in the  
24 United States in the same time frame, `67 to `74, a  
25 block type, 115 megawatts thermal, 725 degrees C

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1 outlet.

2 Then the second generation, Fort St. Vrain  
3 and THTR. THTR was at a high level a lot like Fort  
4 St. Vrain except the core was different, it was pebble  
5 bed, not prismatic.

6 So this is one of those pictures that make  
7 people say aha. I would like to present a version of  
8 this slide that shows the AVR, the German, because  
9 it's very similar. So you could replace Peach Bottom  
10 with the AVR. You could replace Fort St. Vrain with  
11 THTR and you could replace the large one there with  
12 PNP-3000. When I worked in Germany I did a lot of  
13 analysis on the PNP-3000.

14 Then TMI happened and the reaction of the  
15 HTGR community in the U.S. and Germany, and there was  
16 very close collaboration. The HTGR community  
17 consisted of General Atomics and mostly Oak Ridge at  
18 that time were having a lot of exchanges and  
19 interaction with the Germans. Mike Kania certainly  
20 can attest to that. He was part of that.

21 And their reaction to TMI was saying how  
22 can we make this really inherently safe. So this  
23 graph I think says a lot. You see on the ordinate the  
24 peak fuel temperature, the maximum fuel temperature in  
25 their accidents. So basically these are accidents

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1 where you depressurize the helium and it heats up  
2 gradually to some peak temperature.

3 So you see for Fort St. Vrain with large  
4 HTGRs you would get up to temperatures that would  
5 sublimate the graphite and melt the fuel if you did  
6 nothing. So they relied on active features to prevent  
7 that.

8 The mind shift that occurred post TMI, and  
9 it happened over a couple of years, and I was  
10 fortunate to witness it there in Germany was through  
11 a series of seminars. Ended up really in late 1981  
12 with the seminal paper by Lohnert and Reutler, the  
13 advantages of modular. And so that was the birth of  
14 the modular concept and General Atomics was right on  
15 board. So in the early eighties we saw the emergence  
16 of what we now call the modular HTGR design concept.

17 And as you heard today it's lower power  
18 density, different core geometry, long, slender,  
19 passive conduction of decay heat through to the  
20 reactor vessel to a reactor cavity cooling system so  
21 that the peak temperature in the core and localized in  
22 the core is below a safe temperature, well below  
23 2,000. Sixteen hundred has been a limit. Dr. Petti  
24 is suggesting that that limit may be 1,700 or higher  
25 depending on how their fuel program works.

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1           So, before I move onto the next slide I'd  
2 also like to point out there were two factors that  
3 converged, TMI in 1979 and then in 1980-81 the Germans  
4 for the first time demonstrated really high-  
5 performing, high-quality TRISO fuel. So those two  
6 factors were crucial to coming up with this concept of  
7 modular HTGR safety.

8           So these are modular reactors. And  
9 sometimes they're called small modular reactors  
10 meaning low in power. But in terms of geometry the  
11 word "small" doesn't apply.

12           So this picture shows two PWR reactor  
13 vessels fitting neatly in the reactor vessel of a 600  
14 megawatt thermal prismatic HTGR design. So a key  
15 point is that that's really what low power density  
16 means, big reactor.

17           Per-unit power, modular HTGRs are much  
18 larger than light water reactors. They have much,  
19 much lower power density, on the order of two orders  
20 of magnitude lower. They have much less fuel in the  
21 active core in terms of volume.

22           Light water reactors are 30 percent fuel,  
23 HTGRs in the active core are a half percent. If you  
24 improve the reflectors which have a lot to do with the  
25 thermal inertia it's less than 0.2 percent. So the

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1 big message here is they have tremendous thermal  
2 inertia. And so with that, that's the modular HTGR  
3 design concept we're talking about.

4 So, now we're going to start going through  
5 our feedback on the issues. And we're going to start  
6 with licensing basis event selection. And again we're  
7 doing it based on the contents of our issue summary  
8 report.

9 And we start with licensing basis event  
10 selection because that's the most obvious thing. If  
11 you're -- the licensing basis events that you use for  
12 light water reactors don't really apply to this  
13 technology and so you have to come up with a new set  
14 of licensing basis events and the option 2 framework  
15 is what we're trying to implement to do that.

16 So I'm going to now turn it over to Tom  
17 Boyle and Jonathan DeGange, first Tom who provided our  
18 feedback in response to specific requests for feedback  
19 in the July 6 DOE letter. And in so doing we're going  
20 to briefly paraphrase the requests and then provide  
21 our feedback in summary form. So I turn it over to  
22 Tom Boyle and he'll turn it over to Jonathan.

23 MR. BOYLE: My name is Thomas Boyle. I'm  
24 a project manager in the Division of Advanced Reactors  
25 and Rulemaking. And I'm going to begin with a brief

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1 review of the licensing basis event selection material  
2 that the staff reviewed when preparing these  
3 assessment documents.

4 All the material on these slides and the  
5 one following is in reference to the white paper  
6 submitted by DOE-INL. DOE-INL proposes a process for  
7 selecting, categorizing and evaluating licensing basis  
8 events that combines both risk-informed and  
9 deterministic outlooks.

10 This is meant to be consistent with option  
11 2 of the 2008 licensing strategy report to Congress  
12 which indicates that deterministic engineering  
13 judgment and analysis should be complemented by NGNP  
14 design-specific PRA information.

15 Additionally, in the SRM to SECY-03-0047  
16 the Commission approved the staff recommendation to  
17 allow the use of a probabilistic approach in the  
18 identification of events to be considered in the  
19 design provided there is sufficient understanding of  
20 plant and fuel performance and deterministic  
21 engineering judgment is used to bound uncertainties.

22 The approach proposed by DOE-INL appears  
23 reasonably consistent with this guidance and would  
24 yield four risk-informed event categories, the  
25 anticipated events, design basis events, design basis

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1 accidents, and beyond design basis events.

2 MEMBER SKILLMAN: Tom, before you proceed,  
3 on your bullet number 1, please. Is there a clearly  
4 defined demarcation between where deterministic stops  
5 and probabilistic must begin?

6 MR. BOYLE: I'm not sure about that but we  
7 can -- when we can get into the staff evaluation of  
8 these different issues we can touch on some examples  
9 if that would help.

10 MEMBER SKILLMAN: We'll come back to it.  
11 Thank you.

12 MR. BOYLE: And this set of design basis  
13 accidents would be derived from DBEs assuming only  
14 safety-related SSCs are available to mitigate the  
15 consequences.

16 Offsite dose consequences of LBEs would be  
17 evaluated against the top-level regulatory criteria  
18 and EPA protective action guidelines. And the next  
19 slide will show this on their frequency consequence  
20 curve.

21 The SSCs would be classified according to  
22 their safety significance, safety-related and non-  
23 safety related. SSCs that are relied upon to perform  
24 safety functions that prevent or mitigate the  
25 consequences of DBEs or to prevent the frequency of

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1 certain DBEs from entering the DBE range would be  
2 classified as safety-related. SSCs that are relied on  
3 to perform functions that prevent or mitigate the  
4 consequences from AEs or that prevent the frequency of  
5 certain DBEs from entering the AE range would be  
6 classified as non-safety related but would be subject  
7 to special treatment commensurate with their safety  
8 significance. All other SSCs would be classified as  
9 non-safety related and would not be subject to special  
10 treatment. Next slide.

11 MEMBER STETKAR: Tom, before you switch  
12 that I need to understand something fundamental  
13 because I've missed something somewhere. Could you  
14 tell me what an event sequence is?

15 MR. BOYLE: It's the entire plant response  
16 to an event. Not just the initiating event but all  
17 subsequent events to go along with that.

18 MEMBER STETKAR: Okay, I've got that.  
19 Could you tell me what an event sequence is in terms  
20 of the way it's used in this process? Let me give you  
21 an example because, you know, in the interest of time.  
22 The white paper and the staff's assessment of the  
23 white paper seems to bounce back and forth among the  
24 concepts of an event sequence family and an event  
25 sequence.

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1           Now I will refer you to Figure 4 in the  
2 white paper which is a little picture cartoon of an  
3 event tree. The event tree has a couple of functions  
4 in it. One is shut down the reactor. The other is  
5 take heat away from the reactor.

6           The take heat away from the reactor  
7 function has three top events and they are listed in  
8 that event tree in a certain order with failure  
9 probabilities associated with each top event.  
10 Depending on the order of those top events you will  
11 have different frequency assignments to each end state  
12 which will give you different conclusions regarding  
13 whether a particular sequence in my connotation of a  
14 sequence, a path through the event tree, is either an  
15 AE, a DBE or a BDBE.

16           So that the definitions of top events and  
17 the sequence of those top events in this particular  
18 event tree, defining a path through the event tree,  
19 determine whether a particular sequence is assigned to  
20 a DBE, BDBE, or AE category. So I need to understand  
21 what an event sequence is.

22           MR. BOYLE: Well, when you --

23           MEMBER STETKAR: Because I understand that  
24 each sequence has supporting it, you know, tens of  
25 thousands or billions and billions of cut sets that

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1 all lead to that same failure of a top event. And in  
2 that sense each failure, top-event failure is the  
3 accumulation of several functionally identical cut  
4 sets. And some people will call a cut set a sequence.  
5 But in the context of the way the methodology is  
6 presented in the white paper it is presented along the  
7 lines of tracing a sequence through an event tree.

8 So I need to understand what that sequence  
9 means because if I develop a sequence by just taking  
10 those three heat removal top events and switching the  
11 order of them I get a much different characterization  
12 of AEs, DBEs and BDBEs. The BDBE is the same because  
13 it's failure of everything.

14 But an event sequence is a combination of  
15 successes and failures. And the intermediate success  
16 states could really result in different release  
17 categories, not the worst possible release category,  
18 but different intermediate categories which you then  
19 play against your frequency consequence curve. So  
20 it's important for me to understand how those  
21 successes and failures combine and have you thought  
22 much about that.

23 MR. BOYLE: I'm not sure I understand the  
24 problem here. So you're saying that a given --

25 MEMBER STETKAR: We can -- in the interest

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1 of time maybe at the break I'll show it to you  
2 graphically a bit. But the definition -- if a  
3 sequence is a path, a functional path through an event  
4 tree, combinations of successes and failures, as it's  
5 presented in this Figure 4 then the order of the top  
6 events and how you define a particular top event can  
7 change your conclusions.

8 MR. BOYLE: Right.

9 MEMBER STETKAR: So I'm curious how that  
10 process is going to be implemented in practice so that  
11 there's consistency from one design team doing one PRA  
12 for one particular design to a different design team  
13 doing a different PRA for their design. And I didn't  
14 see anything in your assessment paper that addressed  
15 that.

16 DR. CARLSON: There were some very high-  
17 level statements in the licensing --

18 MEMBER STETKAR: There are very high-level  
19 statements.

20 DR. CARLSON: Exactly, talking about event  
21 sequence families and that they would exercise SSCs in  
22 similar ways. And one that would be more challenging  
23 would be representative of that family.

24 MEMBER STETKAR: But there are also  
25 examples in the white paper, for example, where an

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1 event tree is developed partially and a failure branch  
2 in that event tree is not developed further because  
3 that failure branch drops below the magic  $1E^{-8}$   
4 frequency. And they say well, okay, there's a half a  
5 dozen other sequences out in here but because this  
6 drops below.

7 The problem is that some of those half a  
8 dozen other sequences actually add up to more than  
9 your problem. So there they're truncating on this  
10 failure path through an event tree, not families of  
11 cut sets. They're truncating actually on this cartoon  
12 figure path through the tree which doesn't seem to be  
13 consistent with the notion of event sequence families.  
14 It seems to be a literal interpretation of a flow path  
15 through the tree.

16 DR. CARLSON: I think we understand your  
17 comment in general and truly we understand that need  
18 to fully develop this concept.

19 MEMBER STETKAR: You can do it in practice  
20 but I was surprised that I didn't see more discussion  
21 of it in the exchanges.

22 DR. CARLSON: It was presumed at a high  
23 level and so we didn't get beyond the high level.

24 MEMBER STETKAR: I get it at the high  
25 level. I honestly get it at the high level provided

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1 that this accumulation process, this development of  
2 whatever you call an event sequence family, whether  
3 it's a bucket of cut sets or whether it's similar  
4 paths through an event tree is done according to the  
5 high-level discussions that I can read.

6 But a lot of the specific examples that I  
7 see seem contrary to that notion, or at least not  
8 fully consistent with that notion let's say.

9 DR. CARLSON: Yes, we agree. There's a  
10 need for a lot of specificity that we really didn't  
11 get to in this process.

12 MEMBER STETKAR: Okay.

13 DR. CARLSON: We kept it at a high level.  
14 But what is the event sequence family, how is it  
15 defined, how is it treated. We don't have --

16 MEMBER STETKAR: Okay. I've gotten a  
17 little bit of my answer back so thanks. I appreciate  
18 that.

19 CHAIRMAN BLEY: The paper, your paper  
20 doesn't quite warn -- because you wrote the white  
21 paper of concern in this area.

22 DR. CARLSON: It's a good point. No, it  
23 doesn't. I think that's true.

24 MR. BOYLE: Anything else about this  
25 slide?

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1 CHAIRMAN BLEY: Not yet.

2 MR. BOYLE: Sounds good. Let's move onto  
3 the next slide then.

4 I'll briefly point at some of these event  
5 categories and everything on this just to kind of  
6 rehash. And note that these event frequencies are  
7 shown per plant year rather than per reactor year. In  
8 the DOE-INL proposal event frequency cutoffs are  
9 independent of the number of modules. But as a plant  
10 consisting of 10 modules would have the same event  
11 frequency cutoffs as a plant consisting of 1 module.

12 At the top we have the anticipated events  
13 that are expected to occur within the lifetime of the  
14 plant. They're expected to be more than 1 times  $10^{-2}$   
15 per plant year. The basis for the dose consequence  
16 criteria for AEs is 10 C.F.R. Part 20. The reference  
17 value is 100 mrem TEDE cumulative annual dose, the  
18 EAB, mechanistically modeled, realistically  
19 calculated.

20 Design basis events expected to maybe  
21 occur within the lifetime of a fleet of plants range  
22 from 1 times  $10^{-2}$  to 1 times  $10^{-4}$  per plant year. And  
23 the design basis accidents as we said before are  
24 derived from the DBEs by assuming only safety-related  
25 equipment responds.

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1           The basis for the dose consequences for  
2 both DBEs and DBAs is 10 C.F.R. 50.34. The reference  
3 value is 25 rem TEDE at the EAB mechanistically  
4 modeled and conservatively calculated.

5           Beyond design basis events are off-normal  
6 events of lower frequency than DBE. They are  
7 evaluated to ensure they do not pose an unacceptable  
8 risk to the public. Frequency is greater than 5 times  
9  $10^{-7}$  and the dose circumstance for these DBEs are  
10 based on NRC's QHOs, mechanistically --

11           DR. KRESS: Did I understand you  
12 correctly, that 5 times  $10^{-7}$  is on module basis rather  
13 than plant basis?

14           MR. BOYLE: That's per plant year. It's  
15 per plant year.

16           DR. KRESS: It's per plant.

17           MR. BOYLE: That's correct.

18           DR. KRESS: I misunderstood.

19           DR. CARLSON: Always on the ordinate for  
20 plant year. Since the late eighties.

21           DR. KRESS: I misunderstood what he said  
22 about the cutoff frequency.

23           MR. BOYLE: Let's go to the next slide.

24           MEMBER STETKAR: Tom, is it appropriate to  
25 ask my question about why the apparent inconsistency

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1 in the use of uncertainties on the consequence scale  
2 is applied in this framework? At this time or do you  
3 want to address it later?

4 MR. BOYLE: I believe Mr. DeGange will get  
5 to field that question.

6 MEMBER STETKAR: Okay. That's fair.

7 (Laughter.)

8 DR. KRESS: How about my comment on the  
9 fact that those stair steps give some inconsistencies.  
10 And that it probably would have been better to have a  
11 straight line top-level regulatory criteria because  
12 you get rid of those little ambiguities about when you  
13 cross over one spot and another.

14 DR. CARLSON: We did have an RAI on that  
15 and there was a good response to that. And where the  
16 staff said we're not proposing an FC curve but what if  
17 and we came up with the straight line curve and we  
18 discussed that a little.

19 DR. KRESS: Okay.

20 DR. CARLSON: And we have a backup slide  
21 on that too if you want to get into it a little more.

22 MEMBER CORRADINI: With various colors no  
23 doubt.

24 DR. CARLSON: Of course.

25 MR. BOYLE: In general the staff feels

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1 that the DOE-INL approach is reasonable. It appears  
2 to be too risk-based in some places.

3 The LBE selection process should  
4 incorporate more deterministic elements as described  
5 in the coming slides. And we have a selection of  
6 licensing policy technical issues related to LBE  
7 selection that the staff has identified during its  
8 review such as the frequency cutoffs for DBEs and  
9 BDBEs, the per-plant year method of assessing multi-  
10 reactor module frequencies, processing criteria used  
11 for selection of DBAs and alternate TLRC and FC curves  
12 for future HTGRs or technology-neutral frameworks.

13 DR. KRESS: Frequency cutoff is just to be  
14 sure you're below the fatality QHO.

15 MR. BOYLE: Okay.

16 CHAIRMAN BLEY: I'm a little curious as to  
17 why they're per-plant year approach requires  
18 Commission policy decision. It's -- I don't want to  
19 use the more conservative, it's more realistic than  
20 what we're currently doing. Doing it for them doesn't  
21 say you have to do it for everybody but it's certainly  
22 something some of us have long thought ought to be  
23 applied on a particular site. So I'm just curious why  
24 -- what they're doing which is really restricting  
25 themselves to meet the rules for the whole site

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1 requires a policy decision.

2 MR. BOYLE: I believe it was an unresolved  
3 issue in a SECY paper that never got a response. I  
4 believe Mr. DeGange will talk about that a little bit  
5 too.

6 CHAIRMAN BLEY: He's stuck with  
7 everything.

8 (Laughter.)

9 DR. KRESS: The reason for my question  
10 about the prompt fatality and safety really being the  
11 reason for the cutoff value is that worries me because  
12 there is such a thing as societal risk, total number  
13 of deaths, land contamination, cost of all that stuff  
14 which probably controls the where you're cutting off  
15 the frequency on the basis of prompt fatality safety  
16 goal. Are you really going to evaluate the total  
17 societal risk for beyond design basis accidents?

18 MR. BOYLE: I'm not sure we're cutting off  
19 the frequency based on when the consequences at the  
20 QHO. They're saying --

21 DR. KRESS: You'll go ahead and do the  
22 level 3 no matter what the frequency is.

23 MR. DEGANGE: I think that what this  
24 bullet's trying to get at is the frequency that would  
25 be used for categorizing is it going to be in the

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1 design basis event region or beyond design basis event  
2 region. Not looking at the actual QHO.

3 DR. KRESS: Well, okay, but that's the  
4 reason -- if it meets the top-level regulatory  
5 criteria. Pretty darn sure it meets the QHOs. Only  
6 if the QHOs and the two you've got then, then I'm  
7 questioning whether or not those are the right place  
8 to look at. And maybe you ought to think about that.

9 DR. CARLSON: Yes, I think the staff is  
10 thinking about having criteria for --

11 DR. KRESS: Come up with another QHO  
12 maybe? A new one?

13 DR. CARLSON: I don't think that there's  
14 anything pending but it's certainly just being  
15 discussed.

16 DR. KRESS: As long as you're aware of it.

17 DR. CARLSON: Yes.

18 MR. BOYLE: With that we go to the first  
19 issue. This first issue is the DOE-INL's event  
20 categories and proposed descriptions. Again those  
21 categories are anticipated events, design basis  
22 events, design basis accidents and beyond design basis  
23 events.

24 These event categories and descriptions  
25 appear generally reasonable. However, the staff feels

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1 that the full selection of LBEs should include more  
2 deterministic elements.

3 For example, the definition of DBA  
4 proposed in DOE-INL's LBE white paper is different  
5 from the one traditionally used by the staff. To be  
6 more consistent with current regulatory practice and  
7 to be more in keeping with option 2 in the licensing  
8 strategy report the staff feels that the full set of  
9 DBAs should include event sequences populated by the  
10 applicant and/or the staff even if those events would  
11 otherwise fall within the BDBE frequency range or  
12 below.

13 MEMBER STETKAR: Why is that, Tom? I mean  
14 if you -- if this is a reasonable regulatory framework  
15 and if the PRA is developed to comprehensively  
16 evaluate the whole spectrum of internal events,  
17 external events, any hazard to the plant, why require  
18 a separate special evaluation of, as you characterize  
19 it, postulated deterministic event sequences, or I've  
20 seen them listed as hypothetical event sequences.  
21 Because the PRA should already have evaluated those  
22 event sequences.

23 MR. BOYLE: If that's the case then we  
24 won't have any additional postulated events. If the  
25 PRA really does cover everything that the staff feels

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1 would be --

2 MEMBER STETKAR: Okay, I didn't get that  
3 from your assessment paper because --

4 CHAIRMAN BLEY: Neither did it.

5 MEMBER STETKAR: -- my interpretation of  
6 the PRA as has been characterized in the DOE white  
7 paper is it is a full-scope, comprehensive, all  
8 internal/external hazards, all modes of operation PRA.  
9 That it's comprehensive. And I thought you were  
10 interpreting it that way and still saying yes, but  
11 even though they've quantified an event sequence at  
12  $10^{-100}$ , pick a number, I'm going to require them to  
13 evaluate this because I think it's an important event.

14 DR. CARLSON: I can take a stab at that.  
15 You want to go first?

16 MR. BOYLE: I'll just say that could be.  
17 It's possible that the staff would want to see that  
18  $10^{-100}$  event. It's unlikely something that ridiculous.  
19 But it's --

20 MEMBER STETKAR: But my question is why.  
21 Why. Because if you adopt this notion that the risk  
22 assessment, and it addresses uncertainties so you have  
23 both horizontal and vertical uncertainties quantified.

24 MR. BOYLE: I'm thinking it's just too  
25 drastic a departure from what we're doing now. Like

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1 we're switching gears very fast going from basically  
2 purely deterministic to this is entirely almost risk-  
3 based.

4 MEMBER STETKAR: But --

5 MEMBER CORRADINI: Can I ask the question  
6 differently? Just to take the gas reactor out of it.  
7 If you had their backup slide and you essentially  
8 mapped onto it the light water reactor instead of a  
9 full-scope PRA are you trying to tell me that the  
10 design basis accidents that you're requiring of  
11 current reactors don't exist in that population of  
12 little circles with bars and you've picked something  
13 that's stylized enough that it doesn't appear in the  
14 PRA? I don't think so. I'm looking at these guys  
15 since I haven't had one.

16 CHAIRMAN BLEY: It would be an indication  
17 that there was something wrong with the PRA.

18 MEMBER CORRADINI: Well, it infers a lack  
19 of completeness. So I can understand that, that  
20 there's always a lack of completeness. But on the  
21 other hand I'm trying to figure out that if I took  
22 away this technology -- I'm sorry I'm driving you back  
23 to technology-neutral but it seems the logical thing  
24 -- and you put back in the light water reactor which  
25 is when we started arguing about 1860 6 years ago, I

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1 think you were still on the committee.

2 DR. KRESS: Yes, I was.

3 MEMBER CORRADINI: You almost do a test  
4 drive on light water and ask the question how I get  
5 the DBAs from the LBES. And their approach at least  
6 assuming they do all of this in a relatively complete  
7 manner would be essentially what you do for light  
8 water reactor. Otherwise you have to say everything  
9 in the PRA for light water reactor is incomplete and  
10 so we're going to invent one over here just to make  
11 sure we've captured it. That strikes me as odd.

12 DR. CARLSON: I would like to take a stab  
13 at answering the question why and I think it will help  
14 the other questions as well.

15 The option 2 was selected for this  
16 technology and not option 3. And I think a big  
17 reason, a big thought process, a major thought process  
18 behind selecting option 2 was we don't have a lot of  
19 operating experience with this technology, we have --  
20 there has never been a modular HTGR design built or  
21 operated. So it's going to be difficult to assess the  
22 reliability of the PRA information. There's going to  
23 be more than the usual amount of subjectivity in  
24 determining what are the uncertainties, et cetera.  
25 Whereas for light water reactors there's a

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1 considerable database of being able to say yes, we  
2 understand the reliability of PRA information pretty  
3 much for that technology.

4 So perhaps if we were thinking about a  
5 licensing approach and change out modular HTGR for  
6 some light water reactor design maybe we would say  
7 something more like option 3.

8 MEMBER CORRADINI: Can I say it back to  
9 you, what you just said? What you're telling me is  
10 that not only might the PRA be immature but even the  
11 uncertainties in the PRA would be immature. So you  
12 wouldn't necessarily take the upper right-hand corner  
13 of all their uncertainties. You'd have to add  
14 something to it because you're not sure. That's what  
15 I hear you just saying.

16 DR. CARLSON: One of the recommendations  
17 that we'll talk about further, we mentioned it in our  
18 documents, is it's important to have a peer review of  
19 the PRA. And I can just imagine the peer review  
20 having a lot of diverse opinions about how well you  
21 characterized uncertainties.

22 CHAIRMAN BLEY: I think in this entire  
23 framework, now we're just talking about licensing  
24 basis event selection. But you also have the defense-  
25 in-depth side which is framed to allow you -- them to

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1 as they do their PRA consider areas where they might  
2 not have a good basis for evaluating the uncertainty  
3 and that would call for some deterministic defense-in-  
4 depth support.

5 I'm not sure why it belongs in here. If  
6 it's the kind of thing that Tom was mentioning there's  
7 a scenario they didn't consider. Well, when you  
8 review the PRA it ought to be added in. If there's a  
9 real scenario. The scenarios we usually use for PWRs  
10 and BWRs might not be appropriate here. So that's not  
11 the place to go. So it seems to me there's a place  
12 already in this structure to account for that rather  
13 than saying well I had some deterministic events here.

14 And I agree with these two guys that we'll  
15 add new events seems really surprising. And if there  
16 are some that aren't in the PRA that ought to be  
17 added. But this issue of maybe there are  
18 uncertainties here that we don't fully understand  
19 might call for additional defense-in-depth to protect  
20 us.

21 DR. CARLSON: That is the value of course  
22 being risk-informed. It helps to identify sequences  
23 that you wouldn't identify using pure engineering  
24 judgment deterministically. And so that's the value.

25 But, okay, how much can you rely on the

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1 risk information and how much do you need to  
2 compensate for uncertainties with engineering  
3 judgment.

4 CHAIRMAN BLEY: Of course that works both  
5 ways. The PRA really would have brought engineering  
6 judgment in and expanded what you might have had if  
7 you hadn't done that full structure as well.

8 DR. CARLSON: So we definitely would  
9 consider events that are identified from the PRA. And  
10 so their LBE approach that is built around PRA would  
11 be a source of licensing basis events including design  
12 basis events, design basis accidents. But we think  
13 that to cover uncertainties we would need to postulate  
14 some deterministic events. And we'll have --

15 CHAIRMAN BLEY: I guess I still fall back  
16 -- if you come up with new event sequences, new  
17 initiators, new event sequences, you shouldn't just  
18 postulate them as DBAs. They ought to go back in the  
19 PRA to get fully evaluated.

20 MEMBER RAY: What do you mean fully  
21 evaluated?

22 CHAIRMAN BLEY: Evaluated  
23 probabilistically. As part of the PRA. The complete  
24 PRA.

25 MEMBER RAY: -- stage is that practical?

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1 I mean it seems to me like it's almost a semantic  
2 discussion.

3 Take for example the blowdown of the  
4 helium system. Has that got a potential to interact  
5 with the passive cooling system in such a way as to  
6 disable it? Well, God knows.

7 CHAIRMAN BLEY: Well, we can -- I suspect  
8 we can do a lot better than God knows on that  
9 question.

10 MEMBER RAY: Well, I don't know. At this  
11 stage is what I'm asking.

12 CHAIRMAN BLEY: Oh, at this stage. Of  
13 course not. At the stage we have a real design --  
14 this only comes up when you have a real design using  
15 that. This isn't being done now. This is just how  
16 we'll do it when we get there.

17 MEMBER CORRADINI: But I guess just to  
18 make sure at least where I'm coming from. I think  
19 we're all asking kind of the same question. It's not  
20 that I wouldn't disagree with your judgment that  
21 things are not at the appropriate stage of maturity so  
22 you're going to have to add some level of we'll call  
23 it engineering judgment on top of it. That I don't  
24 mind.

25 It's just the way it's characterized I

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1 would expect the reasoning is that I'm uncertain in  
2 this direction, I'm uncertain in this direction. They  
3 probably have identified some sort of set of sequences  
4 that I'm worried about. But it might be over here and  
5 it may even be more than over here because they don't  
6 even understand the uncertainties. So I'm going to  
7 add adjustment.

8 But that's not the same thing as saying  
9 I'm going to come up with a stylized thing that out of  
10 the blue, blink, it's over here. Although it strikes  
11 me it's much more you've got to work within the  
12 context of what they're already identifying. And then  
13 you say well, because of some physical process that  
14 we're unsure of we're going to add some judgment, some  
15 wiggle room. That I can understand.

16 DR. KRESS: Let me ask a maybe related  
17 question for the LWRs that determine safety categories  
18 and SSCs by using importance measures. These are  
19 importance measures on the core damage frequency  
20 usually. I don't see -- I'm not sure that this  
21 process we're looking at to see if it meets the top-  
22 level regulatory criteria is actually equivalent to  
23 that.

24 DR. CARLSON: You're right. There is no  
25 level 1 PRA for this technology that we can make sense

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1 of. There is no CDF in this technology. A core  
2 damage state that relates to the type of core damage  
3 --

4 DR. KRESS: I hate to admit to that but  
5 you could have an FC curve that is equivalent to the  
6 core damage frequency and a LERF together. I don't  
7 know if you've thought about it but you could have  
8 one.

9 DR. CARLSON: For this technology you're  
10 talking about.

11 DR. KRESS: Oh yes, you can for this  
12 technology. It's an FC curve.

13 MEMBER CORRADINI: But Tom, can I ask Tom  
14 a question? If we go back to what Dave presented  
15 relative to his testing at high temperatures you're  
16 looking for a release of radionuclides at some  
17 temperature. That's no different than a degraded  
18 state. You can have an intermediate analysis based on  
19 --

20 DR. KRESS: Exactly what I was thinking,  
21 yes.

22 DR. CARLSON: We have talked about it will  
23 be other criteria that you use in reviewing a  
24 licensing basis event that engineers use. We talked  
25 later about equivalent to a specified acceptable fuel

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1 design limits for this technology hasn't been  
2 developed yet.

3 DR. KRESS: Well, talk to you about this  
4 compiling the original deterministic approach I'll  
5 call it to this new technology-neutral approach. If  
6 you did that on just looking at the safety  
7 significance of SSCs I don't think you'd get the same  
8 integers. That's what bothers me. I think you'd get  
9 different categories, different SSCs classified as  
10 safety compared with the old process which just uses  
11 importance measures compared to what we're doing now.  
12 I'm not sure because I haven't done any myself but it  
13 just appears to me like you would. But it's just a  
14 question.

15 DR. CARLSON: Well, we'll take it as a  
16 comment now and we'll try to address it later.

17 MEMBER STETKAR: I think a little bit of  
18 my concern is this notion of what is a postulated  
19 deterministic event sequence. Okay, I can postulate  
20 a deterministic event sequence that says you must  
21 assume that you have full core damage. That's a  
22 postulated deterministic event sequence. Now, you  
23 must protect the public from that.

24 DR. CARLSON: I don't think that that was  
25 what we proposed to the Commission in past SECY papers

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1 on this topic. It was very event sequence-specific  
2 mechanistic. And so you're postulating --

3 MEMBER STETKAR: And if that's the case  
4 then I fall back to what Dennis and Mike were saying  
5 is that identifies a deficiency in the PRA which ought  
6 to be resolved through the PRA process, that sequence  
7 that you've identified.

8 MEMBER CORRADINI: In the meantime though  
9 you would identify it's something you've got to  
10 consider.

11 MEMBER STETKAR: Yes. But it's something  
12 that needs to be considered in the context of the risk  
13 assessment with its evaluation of the consequences,  
14 the uncertainty, the frequency and its allocation  
15 among the three nominal categories of events. It  
16 doesn't automatically become a design basis event  
17 requiring special attention simply because you've  
18 identified it.

19 CHAIRMAN BLEY: But once it's in there  
20 then if you're still not comfortable with the way the  
21 uncertainties have been characterized and think they  
22 might be greater than certainly defense-in-depth calls  
23 for doing something more I suppose.

24 DR. CARLSON: So the balanced approach of  
25 risk-informed and deterministic methods, basically the

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1 policy is use risk information and use deterministic  
2 engineering judgment to bound uncertainties. So I  
3 think that's the spirit of our overall recommendation  
4 that you need. Hard to say what the uncertainties are  
5 in the PRA for this technology because there's just  
6 not a lot of -- you have to get them operating to see  
7 what surprises there are.

8 DR. KRESS: I wasn't sure whether or not  
9 the air ingress accident was part of the PRA. It  
10 sounded like one of these things you're talking. The  
11 air ingress.

12 DR. CARLSON: We'll talk about that during  
13 my talk after the break. Okay.

14 MR. BOYLE: Well, we were also -- there's  
15 also the issue of the SAFDLs. The staff noted that  
16 INL stated that it plans to develop specified  
17 acceptable fuel design limits, or SAFDLs, for the HTGR  
18 fuel since the SAFDL structure that's been established  
19 for LWRs is not applicable to HTGR fuel. The staff  
20 would expect any SAFDLs for modular HTGR to ensure  
21 substantial margin to dose limits in the AE region.

22 DR. CARLSON: If you want a surrogate this  
23 might be the one you're after.

24 MR. BOYLE: This next issue is related to  
25 SSC classification. The staff believes that the DOE-

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1 INL approach, the safety classification of SSCs, is a  
2 reasonable one. Staff believes that this approach is  
3 consistent with NRC's policy statement on PRA and  
4 expects that the applicant's selection of safety-  
5 related SSCs will comply with the regulations at 50.2.

6 The SSC classifications also appeared to  
7 reasonably address applicable traditional AOOs or  
8 anticipated operational occurrences. For AOO type  
9 events that fall within the AE region SSCs classified  
10 as non-safety related with special treatment would be  
11 available to prevent and mitigate the consequences.

12 Should one or more of these non-safety  
13 related with special treatment SSCs fail to respond to  
14 the event then the event might now fall within the DBE  
15 region where there would be safety-related SSCs to  
16 prevent and mitigate the consequences.

17 The special treatments for safety-related  
18 and non-safety related with special treatment SSCs  
19 would be in accordance with the safety significance of  
20 the functions performed by that SSC. Specific special  
21 treatments would likely be determined when more design  
22 information or when the application is received.

23 MEMBER SKILLMAN: Let's go to my question  
24 from 45 minutes ago on your first bullet. Where do  
25 you see in practice this demarcation between where

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1 your deterministic method seems to give confidence and  
2 where you need to begin to invoke probabilistic  
3 thinking?

4 MR. BOYLE: I'm going to defer that to Don  
5 to be on the safe side.

6 DR. CARLSON: I hope this is helpful but  
7 when you look at what we traditionally do. And again  
8 we're adapting the traditional framework, adding some  
9 more insights of course at the option 2 but not option  
10 3 level. But the traditional framework has design  
11 basis accidents like large break LOCA. We have rod  
12 ejection events. And so put frequency numbers on that  
13 and I don't think they'll necessarily fall in what  
14 they're calling the DBE range.

15 But we think that that's a reasonable way  
16 to go, especially for the prototype. Until we get  
17 some actual experience with the technology, see if  
18 there are any surprises when they actually build the  
19 prototype. Some uncertainties will be reduced by a  
20 few years of operation on the prototype with of course  
21 testing and surveillance, et cetera, to meet the  
22 requirements of 10 C.F.R. 50.34(e). Does that help?

23 MEMBER SKILLMAN: That does. Thank you.

24 MEMBER STETKAR: You're not going to gain  
25 a lot of experience for large break LOCAs, rod

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1 ejection events.

2 (Laughter.)

3 MEMBER STETKAR: Well, one would hope not.  
4 So you'll still face that issue hundreds of years in  
5 the future.

6 CHAIRMAN BLEY: Hundreds of plant years.

7 MEMBER STETKAR: Hundreds of plant years.  
8 I'm sorry. Reactor years.

9 DR. CARLSON: Some of the uncertainties  
10 are associated more with normal conditions or  
11 potential anomalies in normal operating conditions.  
12 So you can --

13 MEMBER STETKAR: Those you'll get.

14 DR. CARLSON: Yes.

15 MR. BOYLE: That's all. I'll hand the  
16 reins off to Mr. DeGange.

17 MR. DEGANGE: Hi, I'm Jonathan DeGange.  
18 And alongside Don and Tom I also work in NRO in the  
19 Division of Advanced Reactors and Rulemaking. This  
20 next slide is covering the third issue pertaining to  
21 licensing basis event selection regarding NRC  
22 agreement with proposed placement of top-level  
23 regulatory criteria on a frequency consequence curve.

24 The overall staff view on this is that the  
25 approach is reasonable. The TLRC as you'll see them

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1 in the FC curve that was shown a moment ago proposed  
2 to be used with the FC curve to establish limits on  
3 frequencies of event sequences and their associated  
4 radiological consequences. And then they would be  
5 used in the categorization and evaluation of licensing  
6 basis events and ultimately in categorizing the  
7 treatment of SSCs.

8 Staff feels that this approach is  
9 consistent with the approved recommendation found in  
10 SECY-03-0047 regarding issue 4 in that it places  
11 greater emphasis on the use of risk information to be  
12 considered in the licensing approach by allowing a  
13 probabilistic approach in the identification of  
14 events.

15 So as Tom had previously discussed one  
16 point about the FC curve in noting the top-level  
17 regulatory criteria are effectively looking at dose.  
18 In addition to addressing dose consequences in their  
19 associated TLRC the staff does believe that DOE-INL  
20 should pursue an appropriate regulatory limit to  
21 ensure the required level of integrity of the fuel  
22 barrier to assure safe operation.

23 DOE-INL has acknowledged this and the need  
24 for the development of these limits in both our  
25 interactions with them over the past few years and in

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1 a 2011 NGNP project status report.

2 DR. KRESS: Does that mean limit on the  
3 number of failed particles that exist in a given pure  
4 load? You know, the full source term comes from --  
5 there's some particles that aren't -- that are failed  
6 before you load them in. And they're talking about a  
7 quality assurance program to control that. And I  
8 presume there must be a limit on it. Is that the one  
9 that you're talking about?

10 MR. DEGANGE: I think we were talking more  
11 about in the relation to SAFDLs or something along the  
12 lines of that. You're looking at operating  
13 temperatures and --

14 DR. KRESS: I see in case of temperature  
15 and the radiation and accumulation might fail  
16 particles. You're talking about limit on that part.

17 MR. DEGANGE: Right. Yes, sir.

18 DR. KRESS: Okay.

19 MEMBER CORRADINI: Wouldn't it be both?  
20 I mean I guess I was looking for an example. You read  
21 it. I looked at it. And I'm still a bit cloudy. So  
22 I thought there would be -- in some sense there would  
23 be some manufacturing QA --

24 DR. KRESS: Quality --

25 MEMBER CORRADINI: -- requirement --

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1 DR. KRESS: Yes, that's what I thought.

2 MEMBER CORRADINI: And then some sort of  
3 temperature limit just in case. I'm waiting for the  
4 DOE to come up and say something. I'm just, I'm  
5 trying to spur some --

6 DR. CARLSON: We will certainly get to  
7 that. We talk about the fuel performance under  
8 containment functional -- functional containment.

9 MEMBER CORRADINI: Okay.

10 DR. CARLSON: And so I'll be talking about  
11 that. And so we can continue this discussion during  
12 that presentation after the break.

13 MEMBER CORRADINI: I'm just trying to  
14 understand what the bullet -- an example of the  
15 bullet. I can think of two and I wanted to mention  
16 them to see if I could get the DOE staff and their  
17 contractors engaged.

18 DR. CARLSON: I don't know, it's up to the  
19 --

20 MR. DEGANGE: I think maximum temperature.

21 MR. PETTI: Do you want me to say  
22 something, Don? Do you want the DOE perspective?

23 CHAIRMAN BLEY: I'd almost rather have  
24 that separately from this. The way we came in.

25 MR. DEGANGE: So yes. So finally one last

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1 thing is because we have never actually licensed a  
2 reactor with this approach the staff does feel that  
3 future Commission consideration may be appropriate for  
4 determination of using the TLRC as dose acceptance  
5 criteria for the event categories. Go to the next  
6 slide, please.

7 This next slide on issue 4 is covering the  
8 fourth issue pertaining to licensing basis event  
9 selection which is NRC established frequency ranges  
10 based on mean event sequence frequency. And overall  
11 again the staff finds that the proposed approach by  
12 DOE-INL for categorizing each event sequence based on  
13 mean frequency to be reasonable.

14 In the approach the mean frequency would  
15 be used to categorize an event sequence as an AE, DBE,  
16 or BDBE based on where the mean frequency falls in  
17 relation to the respective event category frequency  
18 ranges.

19 And as several have indicated earlier, I  
20 think Fred did in his presentation, in the event that  
21 -- when they're looking at uncertainties it would be  
22 comparing both the upper and lower bounds of the  
23 frequency uncertainty distributions. They would be  
24 looking both at mean frequency and mean consequence of  
25 event sequences.

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1           And so in the event that you had events  
2 that straddled multiple regions the proposal would be  
3 to compare against the dose criteria for both of those  
4 regions.

5           Overall the staff has no issue with this  
6 approach and in light of the remarks from the previous  
7 slide about the licensing basis we find the approach  
8 reasonable. The staff views the approach to be  
9 reasonable.

10           DR. KRESS: So the straddle you're talking  
11 about would be 95 percent confidence level?

12           MR. DEGANGE: If I'm not mistaken that is  
13 the proposed approach. So they would look at 95  
14 percent confidence on the entire distribution and then  
15 ultimately you'd be looking at the mean to determine  
16 in the event that --

17           DR. KRESS: You say you'd go ahead and put  
18 it into the other category.

19           MR. DEGANGE: Right. Where these can be  
20 compared against both categories. And so the one that  
21 was more restricted.

22           DR. KRESS: Well, that's a defense in  
23 depth concept.

24           MEMBER STETKAR: On the vertical scale,  
25 yes.

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1 DR. KRESS: Well, yes, that's where I'm  
2 stuck.

3 MEMBER STETKAR: Yes, it is. Now do I get  
4 a chance to ask you?

5 MR. DEGANGE: Oh, I don't know. I might  
6 have to defer back to Tom.

7 (Laughter.)

8 MEMBER STETKAR: And then they postpone  
9 you. That's okay.

10 CHAIRMAN BLEY: I think we're at the  
11 point, yes.

12 MEMBER STETKAR: Should I ask?

13 CHAIRMAN BLEY: Yes.

14 MEMBER STETKAR: Thanks. And I understood  
15 that. You know, I understood because people  
16 traditionally have thought about uncertainties and  
17 frequency. Everybody's grown up by modeling pumps and  
18 pipes and valves and their frequency of core damage  
19 and all of that kind of stuff.

20 In this framework there is also  
21 uncertainty in the consequences. And I'll come back  
22 to my question of why in the DBE range and only that  
23 range do I compare the 95th percentile of the  
24 consequences with the FC curve but not in the AE  
25 region or the BDBE region.

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1 CHAIRMAN BLEY: Where do you use the mean?

2 MEMBER STETKAR: Where I only use the  
3 mean. Because, for example, if I have a 30 percent  
4 probability depending on my uncertainty distribution  
5 if there's a 30 percent probability that I exceed the  
6 acceptance criteria for a BDBE event I'm okay as long  
7 as the mean is below it. Even though there's a 30  
8 percent probability I don't need to necessarily  
9 consider any other additional defense-in-depth  
10 measures to reduce that uncertainty or to actually  
11 reduce the consequences if I think of it in an  
12 absolute sense. And I don't understand that. I  
13 honestly don't understand why.

14 DR. CARLSON: I think Jim who's going to  
15 present later has some --

16 MEMBER STETKAR: If he's going to do it  
17 later -- that's fine, I'll wait.

18 DR. CARLSON: He can help us respond to  
19 that now if he'd like.

20 MR. SHEA: We can do it now or later. Or  
21 both.

22 MEMBER STETKAR: Why don't we do it now  
23 because we keep pushing me off.

24 MR. SHEA: One of the concepts is --

25 MEMBER STETKAR: You have to identify

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1 yourself.

2 MR. SHEA: Oh, I'm sorry. This is Jim  
3 Shea of the staff. One of the things you want to  
4 think about is this frequency consequence curve is  
5 really you're looking at the mean values of all these  
6 frequencies. And then you then apply for the various  
7 regions what makes sense.

8 And for example, DBE range, I mean I  
9 should say the AE range you're talking about actual  
10 plant operation conditions which in real life you  
11 measure the actual consequence. And so what you want  
12 to do is compare that against a best estimate or  
13 actual consequence type analysis.

14 And one could say for the BDBE range it's  
15 a similar concept is when you're advising your  
16 emergency -- I've got to make sure I'm saying this  
17 right -- emergency preparedness program for your  
18 procedures to get your, for example, your best  
19 estimate result of how an accident would progress you  
20 would want to use more realistic evaluation versus in  
21 the DBE range which actually are there to influence  
22 the DBAs or even the BDBEs would influence what your  
23 DBA is.

24 Once you've selected your DBAs out of this  
25 frequency consequence curve, whether it's through PRA

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1 or some deterministic selections those DBAs against a  
2 top-level regulatory criteria, siting, specifically,  
3 would be done on a very conservative analysis, a 95  
4 percent type analysis. Does that make sense?

5 MEMBER STETKAR: No.

6 (Laughter.)

7 MEMBER STETKAR: It makes perfect sense to  
8 me in the DBE range. It makes perfect sense. I  
9 understand. I understand it. You know, and it is as  
10 Tom's mentioned a way -- you can think of it in terms  
11 of defense-in-depth. You can think of it in terms of  
12 confidence in your margins to whatever regulatory  
13 acceptance criteria you've set by whatever shape of  
14 that frequency consequence curve.

15 I still don't understand why the same  
16 concept does not apply in those two other regions.  
17 And especially if I'm using this whole process to  
18 inform the design and the licensing of the plant.

19 MEMBER CORRADINI: You're worried about  
20 inconsistency being developed as you cross across  
21 those lines. That's what I thought you were getting  
22 --

23 MEMBER STETKAR: I'm worried about -- yes.  
24 I mean I'm worried about why in the top region I don't  
25 look at the 95th percentile of the consequence and see

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1 where am I relative to that curve. And I don't -- I  
2 also don't down in the bottom region on the very  
3 severe accidents.

4 DR. CARLSON: I'm going to tag-team with  
5 Jim on this. Jim started to explain that. I would  
6 like to just amplify with regard to the AEs that that  
7 10 C.F.R. 20 limit is not an event-based limit.  
8 That's an annual cumulative limit. Moreover it is  
9 monitored.

10 MEMBER STETKAR: I understand that. And  
11 if indeed my monitoring program suddenly determines  
12 that 7 years into the life of the plant I've exceeded  
13 that because I hadn't thought about something that I  
14 should have thought about when I designed the plant,  
15 then everybody has a problem. The regulator has a  
16 problem, the designer has a problem and the operator  
17 has a problem. So why not think about the possibility  
18 that those things might occur when I'm designing and  
19 building the plant.

20 There might be uncertainties in those  
21 annual cumulative releases that you've not thought  
22 about simply by looking at a mean value estimate for  
23 what you guess is a mean value.

24 DR. CARLSON: So you believe with -- by  
25 using the mean values you're creating a likelihood or

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1 a possibility that you would get into this situation  
2 where the monitoring will show that you're outside the  
3 limits.

4 MEMBER STETKAR: If you talked to  
5 financial planners back in 2006 on a mean value basis  
6 everybody was making an awful lot of money.

7 DR. CARLSON: Okay. So yes, Jim.

8 MR. SHEA: And when people violated the  
9 law using -- exceeding those values they went to jail.  
10 So it's almost the same concept. If you're designing  
11 your plant based on a best estimate in the AE range  
12 and then however you find in actual operations you're  
13 exceeding your limits then, you know, that's why we  
14 have those limits there. So the concept is really,  
15 you know, you can think of it as a design concept.

16 But the other aspect of it is in that AE  
17 range, and we struggled with this for a while till we  
18 kind of -- the light bulb went on and that is even in  
19 those range to protect the fuel limits which haven't  
20 been described yet through the design. But when the  
21 design comes in there will be some sort of fuel  
22 limits. We've alluded to them.

23 But at that point those fuel limits, and  
24 we fed back into our paper that those would also be  
25 done on some conservative basis. Maybe not

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1 necessarily 95 percent confidence but on a -- some  
2 sort of conservative level so that you have some --  
3 you have some margin to your limits on your fuel.

4 MR. DEGANGE: The staff has talked on  
5 this. I was going to save this and talk about this a  
6 little bit later on. They're all kind of related.

7 In SECY-05-0006 the staff kind of hit on  
8 this point. And that did get brought up in the  
9 writeup that we did I believe. But we discussed the  
10 use of scenario-specific source terms for licensing  
11 basis there. And there was some issue of -- was  
12 brought up about using conservative calculations for  
13 -- versus best estimate.

14 MEMBER STETKAR: Okay. You know, in the  
15 interest of time, Dennis, I think I'll -- we've  
16 discussed this probably enough. I'll go look up that  
17 SECY if that's got a little more information in it.  
18 Thanks.

19 CHAIRMAN BLEY: And the committee will  
20 probably talk some about this offline.

21 MR. DEGANGE: So this slide is covering a  
22 request from DOE-INL regarding endorsement from the  
23 NRC staff on their proposed per plant year method for  
24 addressing risk at multi-reactor module plant sites.

25 So in the approach to account for multi-

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1 module plants the approach proposes expressing the  
2 frequencies of licensing basis events in units of  
3 events per plant year where a plant is defined as a  
4 collection of reactor modules that have selected  
5 shared systems.

6 Overall the staff feels that the proposed  
7 per plant year method being called upon is reasonable  
8 and takes no issue in its assessment. The staff  
9 believes that an integrated risk approach is  
10 ultimately more conservative and comprehensive than  
11 the treatment of modules on an individual basis.

12 DR. KRESS: Instead of the word  
13 "reasonable" I would have said "necessary."

14 (Laughter.)

15 MR. DEGANGE: It would enable the risk  
16 assessment to include event sequences that involve  
17 source terms from one reactor module or multiple  
18 reactor modules. So the staff overall finds it  
19 reasonable. The staff does believe that future  
20 Commission direction may be appropriate for this  
21 topic.

22 CHAIRMAN BLEY: I guess I'm still -- to do  
23 this I don't see why you need anything special. But  
24 if the Commission speaks on this then it may have  
25 implications for everybody else out there.

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1                   MEMBER STETKAR: I mean in some sense the  
2 Commission already has though in terms of the post-  
3 Fukushima issue of looking at multi-unit site  
4 accidents for conventional operating LWRs.

5                   MR. DEGANGE: Back in SECY-03-0047 there  
6 were a number of different issues that were brought to  
7 the Commission to vote on. And one of those was  
8 consideration of a per plant year approach. And that  
9 was denied. And the reason being was that we needed  
10 to go to the ACRS first on that. And we did go to the  
11 ACRS with the issue. And what happened really in the  
12 letter back was there was a pretty mixed review of --  
13 there were opinions both ways on the topic. And there  
14 was really never a definitive line of thinking that  
15 came out.

16                   CHAIRMAN BLEY: My memory which could be  
17 really faulty on this was back then the request for a  
18 position from the Commission was really aimed at  
19 applying it to all sites for -- rather than just new  
20 modular reactors. But I'm not sure of that. Don, do  
21 you remember?

22                   DR. CARLSON: I'll have to refresh my  
23 memory as well.

24                   CHAIRMAN BLEY: Anyway, you don't have to  
25 go further on this. That's all record we can work

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1 from.

2 MR. DEGANGE: Okay. So the next slide,  
3 issue 6, is covering a request from DOE-INL regarding  
4 agreement on frequency cutoffs being established for  
5 the design basis event and beyond design basis event  
6 regions of the proposed FC curve.

7 They provide justification for these  
8 frequency cutoffs in their RIPB white papers that we  
9 have looked at thoroughly. I'd like to note that in  
10 the assessment we have done we have, as Don pointed  
11 out, are looking at their usage in the context of  
12 modular HTGR licensing and have not been assessed in  
13 terms of a technology-neutral context.

14 So as seen on the FC curve the proposed  
15 cutoffs for the beyond design basis event sequence  
16 frequency would be between  $10^{-4}$  and 5 times  $10^{-7}$  per  
17 plant year. And the QHO of the prompt fatality safety  
18 goal seen in NUREG-0880 limits the increase in an  
19 individual's annual risk of accidental death to a  
20 tenth of a percent of  $10^{-4}$  per year which sizes out to  
21 an incremental increase of 5 times  $10^{-7}$  per year.

22 So consistent with this QHO the NRC staff  
23 views that the lower-frequency cutoff for the beyond  
24 design basis event region of 5 times  $10^{-7}$  per plant  
25 year is reasonable.

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1           Regarding the DBE region with frequencies  
2           between  $10^{-2}$  and  $10^{-4}$  per plant year the staff believes  
3           that the lower cutoff of  $10^{-4}$  is reasonable as long as  
4           the PRA used in the LBE selection process assessed  
5           multiple failures from common cause events and as long  
6           as it accounts for both operating in shutdown modes as  
7           well as internal and external plant hazards.

8           So like some of the other issues that the  
9           staff has talked about we think that future Commission  
10          direction may be appropriate for deciding the actual  
11          cutoff values when it comes time to actual licensing.  
12          So the next slide, please.

13          The last issue here on LBEs is covering a  
14          request from DOE-INL for an endorsement of the overall  
15          process for performing assessments against the TLRC  
16          addressing specific issues with uncertainties,  
17          calculational methodologies and the adequate  
18          incorporation of determinism.

19          So as previously discussed the staff feels  
20          that the approach overall their use of engineering  
21          judgment to address uncertainties is a reasonable  
22          approach for assessing licensing basis events in a  
23          risk-informed manner.

24          And additionally we think that the  
25          calculational methodologies proposed to be employed,

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1 they assess full event sequences using best estimate  
2 models with either mean or conservative analysis.

3 One potential point to point out that I  
4 think we've talked about just recently here. The  
5 staff position in SECY-05-0006 which discusses the use  
6 of scenario-specific source terms for licensing  
7 decisions.

8 In that SECY there is a discussion about  
9 using source terms for compliance and the usage of  
10 conservative values based on best estimate  
11 calculations. And this is consistent with DOE-INL's  
12 proposal for design basis events and design basis  
13 accidents.

14 However, for the anticipated events and  
15 beyond design basis event regions compliance with the  
16 top-level regulatory criteria the staff views the  
17 proposed approach of realistic source term  
18 calculations as meritable but would need further  
19 consideration. And notes that it would probably  
20 involve new regulatory interpretations likely to  
21 require consideration by the Commission.

22 Another thing to point out was the, as I  
23 think Tom mentioned earlier was on the topic of design  
24 basis accidents. DOE-INL proposes as you all are well  
25 aware that design basis accidents would be derived

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1 from design basis events with only safety-related SSCs  
2 responding and being available.

3 The staff believes that NRC approval of a  
4 complete set of design basis accidents would likely  
5 consider supplementing DOE-INL's proposed DBE-derived  
6 DBAs with deterministically postulated but physically  
7 plausible events.

8 So like on some of the previous issues  
9 discussed certain elements of the proposed approaches  
10 are somewhat overly risk-based and deterministic  
11 elements should be strengthened. And future  
12 Commission direction may be appropriate for some of  
13 these topics. No questions I'll go to the next slide.

14 So, overall to summarize while only looked  
15 at in the context of modular HTGRs the proposed  
16 approach is indeed a technology-neutral approach.  
17 It's comprehensive in that it considers full plant  
18 response to a wide spectrum of events. And the  
19 quantitative approach does enable the adequate  
20 assessment of safety margins.

21 The proposed approaches are generally  
22 consistent with past staff positions and Commission  
23 guidance. And I've got a few listed there, especially  
24 the advanced reactor policy statement, the MHTGR  
25 NUREG-1338, the technology-neutral framework and a few

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1 of the pertinent SECYs that have been brought up. And  
2 that is all I have.

3 MEMBER SKILLMAN: Question, please.

4 CHAIRMAN BLEY: Go ahead.

5 MEMBER SKILLMAN: Jonathan, a question.

6 In each of these seven items DOE is requesting the NRC  
7 staff to comment on the direction that DOE is taking.  
8 Is that a fair statement?

9 MR. DEGANGE: I think that's a fair  
10 statement.

11 MEMBER SKILLMAN: Okay. In these seven or  
12 among the seven are there any differing professional  
13 opinions within the NRC staff and what conscious  
14 reflection has been given to groupthink for the  
15 staff's agreement to these seven items?

16 MR. DEGANGE: Well, I would --

17 MEMBER SKILLMAN: Number one, any DPOs.

18 DR. CARLSON: No, there were no DPOs.

19 There was never any non-concurrence really. I think  
20 the reason is because we really haven't gone beyond  
21 very much past staff positions, ACRS comments,  
22 Commission-approved direction in these SECY papers, et  
23 cetera. We're advancing the ball just a little by  
24 providing a little more detail. We're really staying  
25 where the staff has already had staff established

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1 positions. So we were able to get to concurrence  
2 relatively easily because of that. It was a matter of  
3 how you say it more than what we're saying.

4 MEMBER SKILLMAN: Thank you.

5 CHAIRMAN BLEY: Don, I've got -- I didn't  
6 know where to ask this so I'll ask it now. You talked  
7 about -- and this is a concern to me because of this  
8 difference. Now we have white papers and we have an  
9 evaluation of white papers. The process is a lot  
10 different from having an application and having an  
11 SER.

12 When you have the SER, when you have all  
13 these RAIs if they're important issues they get  
14 reflected back in the revised application. Is there  
15 -- and you said that the RAIs were really more  
16 extensive at least in pages than the white papers  
17 themselves.

18 There's no process that pushes those back  
19 into the white papers. Is there anything -- well, I  
20 guess you've just got the big pile of them. I was  
21 just wondering would it make sense to somehow publish  
22 precis of the RAIs would be a companion to these two  
23 sets of documents.

24 I'm worried about us losing track of that  
25 useful information in the interim between now and when

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1 -- should there ever be an application using this  
2 approach.

3 DR. CARLSON: Yes, I think you're pointing  
4 to the fact that as agreed with DOE-INL there was a  
5 decision not to update the white papers as we were  
6 going through this assessment process. And so the  
7 proposals that we're assessing are not exactly what's  
8 in the white papers.

9 CHAIRMAN BLEY: Right.

10 DR. CARLSON: In fact as one would hope  
11 through our assessment process they considered some of  
12 our feedback and clarified and I think modified to  
13 some degree their original proposals in the white  
14 papers. And so capturing that would best be done by  
15 some kind of future submittal. If not a revised set  
16 of white papers then a future submittal that reflects  
17 the staff feedback in future submittals.

18 Of course they don't have to take all of  
19 our feedback. It's just advisory. But they certainly  
20 should consider our feedback in developing future  
21 white papers, future submittals.

22 And I would point out that in our  
23 assessment reports, particularly the fuel  
24 qualification and mechanistic source terms, less so  
25 for the RIPB, we do have fairly clear linkage between

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1 each topic and the related RAIs. So anybody reading  
2 those topics would do well to go back and read each  
3 and every one of the RAIs and RAI responses associated  
4 with that.

5 CHAIRMAN BLEY: Okay, thank you. Before  
6 we take a short recess, break for the afternoon, I  
7 just wanted to turn back to the DOE and INL and ask if  
8 there are any short comments or issues of -- points of  
9 clarification you'd like to make at this point in  
10 time.

11 MR. KINSEY: Yes, I think we have two  
12 points of clarification not so much to cover in this  
13 meeting but that we'd like to see when we get the  
14 final output.

15 One is sort of a general item. A number  
16 of the bullets in the slides on event selection point  
17 to the fact that the staff feels more deterministic  
18 elements need to be rolled into the process. We're a  
19 little -- we're struggling a little bit to understand  
20 exactly what those are because the cutoff frequencies  
21 and the application process including the use of  
22 engineering judgment has generally been agreed to. So  
23 we just need a little clarification on what those  
24 additional elements are envisioned to be.

25 And then the second key item is the

1 question that I think you raised related to the need  
2 to add design basis accidents that are  
3 deterministically developed from a plausible  
4 evaluation sequence. We'd like to better understand  
5 how that process would work, where they would come  
6 from and what regulatory limits would apply to them  
7 once they're established.

8 CHAIRMAN BLEY: Okay, thank you. I think  
9 at this point we'll recess, take a short break. We'll  
10 be back here at 3 o'clock. Thank you all.

11 (Whereupon, the foregoing matter went off  
12 the record at 2:41 p.m. and went back on the record at  
13 3:00 p.m.)

14 CHAIRMAN BLEY: The meeting is back in  
15 session and welcome back. I'll turn it back over to  
16 Don.

17 DR. CARLSON: Yes. So we're resuming with  
18 our feedback based on the feedback in the issue  
19 summary report. And so we've been through the first  
20 set of issues under licensing basis event selection.  
21 And now we're going into the issues under mechanistic  
22 source terms.

23 And Jim Shea has a very good background in  
24 source terms. He's been working in a more generic  
25 sense on source terms perhaps for IPWRs. He was a

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1 contributor in various phases of our work on  
2 evaluating the mechanistic source terms white paper.  
3 And so he's going to give his presentation.

4 CHAIRMAN BLEY: Excellent.

5 MR. SHEA: Good afternoon. My name is Jim  
6 Shea of the Division of Advanced Reactors and  
7 Rulemaking of the Office of New Reactors.

8 And just to clarify one point about the  
9 DPO. Our little slide there, mechanistic source term,  
10 I almost put a DPO in because Don wanted it to be  
11 called mechanistic source terms. And I told him that  
12 was wrong.

13 (Laughter.)

14 MR. SHEA: You can say that there's  
15 certainly not any groupthink when it came --  
16 especially when it came to mechanistic source terms as  
17 even Stu Rubin who was part of a working group for a  
18 good part of 2 years. Those were very interesting  
19 meetings and I was kind of the ringleader of that  
20 circus. And a lot of disagreements and let me tell  
21 you. So it all kind of boils down to what we're going  
22 to show you here in the next 5 to 8 minutes. So next  
23 slide, Don.

24 First we'll start with definition. A  
25 mechanistic source term or MST is a best estimate

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1 analysis of fission product release from specific  
2 accident sequences including the necessary and  
3 assurance of plant and fuel performance as well as  
4 deterministic judgment to bound uncertainties. Now  
5 Stu, don't yell at me because that's probably not your  
6 definition that we came up with but it's just  
7 paraphrased from what we see in the slide. It shows  
8 that in SECY-03-0047 and 93-092.

9 The staff and the Commission approved the  
10 concept for mechanistic source term and in fact over  
11 -- since the early nineties the staff, the Commission  
12 including the ACRS have been receptive to the concept  
13 of mechanistic source term.

14 CHAIRMAN BLEY: And just for those of us  
15 who haven't followed this forever I assume what that  
16 compares to is just assuming some fraction is released  
17 without looking at any of the specific physical  
18 mechanisms or chemical mechanisms. Is that right?

19 MR. SHEA: No. We're talking about  
20 specifically a mechanistic source term. Deterministic  
21 source term you assume a certain fraction or the  
22 release from the core.

23 CHAIRMAN BLEY: You're saying the same  
24 thing. I was saying that was the comparison.

25 MR. SHEA: Right.

1 DR. CARLSON: Again, the definition of  
2 mechanistic source term in this case, it's event-  
3 specific.

4 MR. SHEA: Even.

5 DR. CARLSON: Yes.

6 MR. SHEA: And we'll get there. So slide  
7 3. In general feedback the NRC staff believes that  
8 the proposed MST for the NGNP as outlined in its white  
9 paper are reasonable with some significant caveats.

10 And specifically what was requested in the  
11 July 6 letter to us was three main issues regarding  
12 mechanistic source term. And in addition to answering  
13 those three we're going to go into a little bit of  
14 what we said in the fuel qualification mechanistic  
15 source term assessment paper Rev 1 because we didn't  
16 want to be redundant in the summary paper. A lot of  
17 the information we already had covered. So we kind of  
18 briefly evaluated this feedback in the summary paper  
19 and then there's some more details. And we'll go over  
20 some of the details that we had in the -- the  
21 highlights I should say in the fuel qualification and  
22 MST assessment report.

23 Okay, issue 1 was the definition. The  
24 NGNP MST definition: event-specific radionuclides  
25 released from the reactor building to the environment.

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1 Paraphrased.

2 The staff believes that the DOE-INL  
3 definition for NGNP mechanistic source term is  
4 reasonable and consistent with past Commission SRMs  
5 and staff SECY papers regarding the treatment for  
6 advanced reactors. Next.

7 These are pretty actually simple issues  
8 compared to the last stage. But issue 2, can the NGNP  
9 MST be event-specific? Mechanistically modeled and  
10 account for specific reactor design characteristics.  
11 The NRC staff believes that the described NGNP MST is  
12 reasonable and is again consistent with past SRMs, NRC  
13 and staff SECY precedents which is -- again was  
14 approved both -- in both SECYs the Commission approved  
15 the use of a mechanistic source term.

16 Issue 3 has DOE-INL identified the key  
17 NGNP fission product transport and associated  
18 uncertainties? The NRC staff believes the ongoing and  
19 plant testing and research activities for the NGNP FQ  
20 (fuel qualification) and MST (mechanistic source term)  
21 development are generally reasonable.

22 Here's where the rub is though. However,  
23 we do -- the NRC staff does expect more information on  
24 the issues of fuel qualification and accident testing  
25 and potential prototype testing as you might have seen

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1 through common themes that we've been going over as  
2 the staff.

3 MEMBER RAY: I've got a question. Just I  
4 can't put it off till the end without just becoming  
5 too distracted. Are we -- when you said mechanistic  
6 I thought we would include, for example, the issue  
7 that was brought up this morning briefly, that is,  
8 dust-related inventory blowdown. Is that included  
9 here?

10 MR. SHEA: Yes. And we're going to get to  
11 that very next slide.

12 MEMBER RAY: That's fine. It's just, it  
13 sounded like we were diverging off into something more  
14 narrow.

15 MR. SHEA: No. What we're trying to do is  
16 we give the real big picture and then we're going to  
17 go into some little bit of the detail, what the  
18 mechanistic source term is for the NGNP which is  
19 starting the next slide.

20 DR. KRESS: And when we did the  
21 mechanistic source terms for light water reactors we  
22 needed -- for the whole range of fission products we  
23 needed the volatilities, the LOCA pressures as a  
24 function of temperature. We needed affected  
25 diffusivities through various layers of the fuel and

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1 how to get out into the stream. Then we needed  
2 condensation rates. And then we needed how did they  
3 behave inside the containment in RCCS. That took a  
4 lot of labor. Do you see that you need this kind of  
5 data for the gas-cooled reactor stuff? That took  
6 forever to get all that data.

7 MR. SHEA: Yes. When you think of what  
8 you're talking about, referring to is really all the  
9 effort that went into NUREG-1465.

10 DR. KRESS: Basically, yes.

11 MR. SHEA: Which then culminated into the  
12 Reg Guide 1.183 which became the AST. And if you look  
13 at that effort and my colleagues here maybe could even  
14 chip in here if they want to, but if you look at that  
15 effort big picture they were taking some experience  
16 from TMI and they used that, and using MELCOR, et  
17 cetera, and trying to model that.

18 And then they tried to homogenize it over  
19 -- for all the different types of plant design. So  
20 there are some significant deficiencies in my mind as  
21 far as like plant-specific mechanistic source terms.  
22 Because in some cases one could argue in that effort  
23 that they were overly conservative in some aspects and  
24 maybe in another aspect not conservative enough.

25 And in fact not to go too detailed but you

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1 might remember in that effort we basically halted the  
2 core melt after 2 hours and didn't evaluate anything  
3 further. So the strength of a real mechanistic source  
4 term is to go beyond that type of like artificial  
5 deterministic cut it off because obviously we can't  
6 have a meltdown more than 2 hours, right? And look at  
7 each design and each plant individually and apply  
8 these fundamental physics.

9 And you know, obviously, as you know, as  
10 time has gone by MELCOR and other type plant analysis  
11 codes have gotten a lot better in characterizing this  
12 type of phenomenon.

13 DR. KRESS: Do you envision staff maybe  
14 working on the HTGR version of MELCOR?

15 DR. CARLSON: You may recall that the  
16 Office of Research has I believe reported to the  
17 subcommittee about 3 years ago on their effort to  
18 adapt MELCOR and other tools to provide an independent  
19 tool for the staff to use for a modular HTGR. And  
20 very few of those activities are continuing, just the  
21 work at Oregon State, the EPTF, the collaboration with  
22 the Japanese and that's about all.

23 MR. SHEA: Okay, so here's a little more  
24 detail of how NGNP would be treating its mechanistic  
25 source term. Now I have another picture courtesy of

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1 DOE on the next slide that will just go through some  
2 of these attributes so we can just skip to that next  
3 slide.

4 If you look at this I think they referred  
5 to it as the pill model which I think I first saw that  
6 when DOE-INL first came and presented the HTGR concept  
7 to us. And I think it really depicts everything  
8 that's going on in a mechanistic source term model.

9 So we'll start with basically the fuel  
10 kernel goes through all the various multi-layered  
11 coating boundaries you can see depicted there. And  
12 then through the core graphite block.

13 Now, you've got to remember that the main  
14 safety case obviously is that most of the fission  
15 product radionuclides are all trapped within that in  
16 the fuel kernels -- or in the actual fuel particle.  
17 So 98.99 something. If you look in the white paper  
18 they have it. It's a very small amount of fission  
19 product actually is released.

20 And so then after the fission product  
21 makes it through the core and out to the helium  
22 pressure boundary which is depicted by the pill. And  
23 you can see the various mechanisms that would be  
24 evaluated in the model in a mechanistic source term.

25 And essentially so you'd have the model of

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1 how all of that fission product got out to the helium  
2 pressure boundary and then the helium pressure  
3 boundary and then the helium pressure boundary is a  
4 whole other problem in how it then is released.

5 And you notice some of the things we've  
6 already talked about today. There's plateout. We  
7 talked a little bit about the dust which is more of an  
8 issue associated with the pebble bed. It doesn't seem  
9 to be as much of an issue here.

10 MEMBER RAY: Why do you say that?

11 MR. SHEA: Well, DOE-INL have suggested  
12 that and I can give you some anecdotal evidence from  
13 some staff members who went to Fort St. Vrain after it  
14 was -- for decommissioning and couldn't find any  
15 radioactivity to clean. So that's just an anecdotal  
16 evidence that there really wasn't a lot that was  
17 produced even in Fort St. Vrain years of operation to  
18 decontaminate.

19 DR. CARLSON: I'll put a little caveat on  
20 that because as -- we did have a dust workshop with  
21 DOE-INL. And the predominant view there was it's  
22 probably not a big issue for prismatic block but there  
23 was a caveat on that.

24 In particular I provided a reference to a  
25 German paper, the chief chemist at the AVR, the pebble

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1 bed reactor Julich had a notion that the dust  
2 generated in the PBR was chemically produced. And we  
3 can describe that to you. But I translated that paper  
4 for the workshop.

5 And so a caveat, a note was made that that  
6 mechanism potentially could apply to a prismatic block  
7 reactor under certain conditions, notably if they have  
8 a high partial pressure of carbon monoxide and  
9 hydrogen in the helium.

10 MEMBER RAY: I've been to Fort St. Vrain  
11 too but I thought that maybe it was sensitive to flow  
12 velocities and the extent to which erosion might occur  
13 over a longer period of time than Fort St. Vrain was  
14 able to operate. Things like that.

15 In any event, any piece of information is  
16 useful. I just think it needs to be demonstrated that  
17 it's not an issue because the inherent presumption  
18 might be well, over time you will see erosion of the  
19 block prismatic forms. And if you're not, well why  
20 not. It's just a little --

21 DR. CARLSON: There are other mechanisms  
22 of dust. I mean oil can intrude into the primary vent  
23 and then that becomes dust. But where those were well  
24 discussed at the workshop. And so I think that  
25 provides a good basis for further review of these

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1 issues.

2 MEMBER RAY: It's a big deal. I mean  
3 because it's an immediate source term as opposed to  
4 something spread over days and weeks.

5 DR. CARLSON: Well, I think we have given  
6 due attention, we'll continue giving due attention to  
7 dust. So I'll turn it back over to Jim.

8 MR. SHEA: Yes, and well, just to follow  
9 up on that. I mean one of the things that DOE-INL are  
10 talking about as far as a conservative use of the  
11 mechanistic source term is to apply this buildup of  
12 whatever dust and plateout on the helium pressure  
13 boundary over the life of the plant and use that as  
14 their design basis accident dose source term. So  
15 that's a fairly conservative use of that whole  
16 concept.

17 MEMBER RAY: Yes and the flow circuits may  
18 have unique traps in them I suppose, things like that.

19 MR. SHEA: Yes.

20 MEMBER RAY: I have no idea what to  
21 expect.

22 MR. SHEA: Right. And I think it also  
23 falls on how would one -- if a plant would operate for  
24 40 years how would you know that you're actually  
25 meeting these design goals. Well, I think we talked

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1 about it before but in the purification system and in  
2 actually monitoring the radionuclides in the helium  
3 pressure boundary you can get a good idea of what met  
4 those goals.

5 So okay. So the concept is as -- so you  
6 build up a source term essentially in the helium  
7 pressure boundary and from there depending on the  
8 event sequence, the specific event sequence that could  
9 be -- that would have maybe separate release  
10 parameters.

11 And then you notice that it gets released  
12 to the reactor building. There was a lot of  
13 discussion about the reactor building today. One of  
14 the key concerns is that then the release to the  
15 reactor building, it's the release from the reactor  
16 building to the environment that is the definition for  
17 their source term.

18 Now one of the treatments of the reactor  
19 building that would be an issue going forward is the  
20 credit for that decontamination factor that we were  
21 discussing earlier. And the staff has not ever  
22 credited reactor building for a decontamination  
23 factor. So that would be an issue going forward.

24 MEMBER CORRADINI: Can I ask you a  
25 question I guess? And maybe this has been -- maybe

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1 when it's appropriate for DOE because there's a couple  
2 of things the staff, the DOE staff and the contractors  
3 may want to comment on. But in this case the thing  
4 that's different about this reactor at least as I see  
5 it is there is no water. So it's a dry system.

6 So is the source term, the mechanistic  
7 source term that's being developed going to be  
8 developed mainly empirically by the DOE tests, not by  
9 any sort of calculational procedure?

10 MR. SHEA: Well, the tests are going to  
11 validate the empirical. They have empirical models to  
12 predict how the transport. And then there's the AGR  
13 testing that's ongoing.

14 MEMBER CORRADINI: Right. But in my  
15 simple mind there's enough parameters they're going to  
16 tune the models to what the tests show to make sure  
17 the models meet the test results.

18 DR. CARLSON: They have, in the AGR  
19 program there's a distinction between -- there's the  
20 early testing phase that focuses on providing data to  
21 develop the fission product transport models. And  
22 later in the phase the emphasis shifts with induced  
23 separation to validation of those models.

24 MEMBER CORRADINI: Right, and that's AGR-  
25 567 if I --

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1 DR. CARLSON: Yes.

2 MEMBER CORRADINI: No. I'm remembering  
3 wrong. Can you at least tell me the numbers, Dr.  
4 Petti?

5 MR. PETTI: Eight.

6 MEMBER CORRADINI: Eight. Okay. That's  
7 the fuel qualification.

8 MR. PETTI: No, that's the validation.

9 MEMBER CORRADINI: Validation, excuse me.  
10 I'm sorry. Okay.

11 MR. SHEA: Okay, getting back. The key  
12 issue about the reactor building, the staff feels that  
13 a license applicant would need to provide adequate  
14 justification to credit the reactor building as a  
15 barrier for release of the source term. So that's an  
16 issue I think that's going to be ongoing for a number  
17 of the advanced reactors as far as taking credit for  
18 the reactor building.

19 CHAIRMAN BLEY: Have you done any work  
20 along those lines? What kind of -- any idea what  
21 they'll need to provide to justify?

22 MR. SHEA: I personally haven't done any  
23 work. Michelle, do you have any thoughts on where  
24 staff is heading? I promised I wouldn't pick on  
25 Michelle at this point.

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1 MS. HART: I'm Michelle Hart from the  
2 Radiation Protection and Accident Consequences Branch  
3 in NRO.

4 And we haven't really done a lot of  
5 thinking about what they need to do. I mean they'll  
6 have to justify the paths that they're going to take,  
7 the kind of flow paths through the building and the  
8 deposition rates.

9 We've given credit for some holdup in some  
10 buildings where they have like a secondary containment  
11 where they have tech spec leak rates and they test it.  
12 I don't know what it's going to look like for a  
13 reactor building that may not have those kind of  
14 criteria. But they'll have to justify the models as  
15 far as some reasonable deposition rates.

16 MEMBER CORRADINI: Can I just ask a  
17 follow-on question? So we're talking for the DBA  
18 part?

19 MS. HART: For the DBA part, correct. To  
20 show compliance with the siting criteria.

21 MEMBER CORRADINI: Okay. With the siting  
22 criteria. And so I'm looking for an analog in the  
23 LWR. In the LWR there's a required -- if I remember  
24 correctly there's a percentage of the fuel that is  
25 failed within essentially a release based on the

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1 alternative or the older source term, right?

2 MS. HART: That's correct. And it's  
3 released to the containment and then a tech spec  
4 testable release rate from the containment to the  
5 environment.

6 MEMBER CORRADINI: But it's a tech spec  
7 testable release rate of the stuff inside containment  
8 with no decontamination of whatever. Whatever gets  
9 out of the core is assumed to be in the atmosphere.

10 MS. HART: We do give credit for  
11 decontamination within the containment. And also  
12 spray removal.

13 MEMBER CORRADINI: Okay.

14 MS. HART: So natural --

15 MEMBER CORRADINI: And all that is  
16 empirically testable. I'm trying to make -- I heard  
17 what Jim said. I'm trying to make an analog to what's  
18 done currently in the DBA for the LWRs. That's what  
19 I'm trying to make the analog clearly.

20 MS. HART: Right. The deposition rates  
21 are -- do have some empirical basis but as far as  
22 testing within a containment to determine the kind of  
23 deposition rates it's not really that. I mean there's  
24 an empirical model that actually Dr. Powers developed  
25 that we use for natural deposition in containments.

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1 We've used that for large light water reactors and  
2 some of the current light water reactors as well.

3 MEMBER CORRADINI: And so there's some --

4 MS. HART: It's correlated --

5 MEMBER CORRADINI: -- there's some removal  
6 rate.

7 MS. HART: -- to power. Yes. And size of  
8 the containment. So it's a correlation there. It's  
9 not a first principles type model. But it's based on  
10 empirical data from small-scale tests.

11 MEMBER CORRADINI: Okay, fine. So just so  
12 I say it differently, from a natural analog standpoint  
13 given the fact that this design or these types of  
14 designs would rely on some sort of decontamination  
15 there would have to be a combination of testing and  
16 modeling and tuning of the model to essentially get  
17 some sort of credit for it.

18 MS. HART: And you may be able to build on  
19 those models that we already have or that we've  
20 already used in developing some of the models that we  
21 use. It's just we're used to giving credit for safety  
22 systems and for systems, leak-tight containments or  
23 secondary containments that are testable. What would  
24 that look like for this. I don't think we've quite  
25 gotten there yet.

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1                   MEMBER CORRADINI: Okay. And can I ask  
2 another question? A technical one. Which is to go  
3 back. I'm back to dust. The reason I guess I'm  
4 trying to struggle with it technically is that it  
5 seems to me at least for this sort of -- I'm kind of  
6 with Dr. Kress who had some comments from the January  
7 meeting where trying to bottle this up makes no sense  
8 in terms of a concept.

9                   If you were going to have some sort of  
10 confinement or I'll call it controlled leakage  
11 environment or containment or confinement that's  
12 perfectly fine, but that means then the whole concept  
13 of what you have in there that you vent has to be  
14 fairly well known. Or you have to know the  
15 uncertainty band of it. So, because you're just going  
16 to release it. All right. And so that kind of goes  
17 back to what I think Harold was saying. Interesting  
18 in how the dust -- where it is and how much is there  
19 that might be the source of your vented inventory.

20                  DR. CARLSON: That was the subject of that  
21 workshop that we had on dust.

22                  MR. SHEA: Okay. So, next slide we'll go  
23 on to. I just want to highlight some of the  
24 highlights from the fuel qualification MST Rev 1 staff  
25 assessment paper.

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1                   And essentially staff again believes that  
2 the proposed approaches to the MST are reasonable with  
3 some caveats. And we really describe most of those in  
4 the fuel qualification MST paper.

5                   But the highlights are the fuel  
6 qualification obviously in the AGR testing is ongoing.  
7 And still having plans in the future to do that.

8                   Part of that AGR testing is the accident  
9 testing that will go on where they fail fuel and they  
10 actually test what the transport would be through some  
11 failed fuel particles. Also as part of that post-  
12 irradiation fuel testing as part of all that.

13                   And also the idea of validating the codes  
14 and the methods and the mechanistic source term after  
15 a prototype reactors designs and use that as a means  
16 of validating the methods and codes and the transport  
17 in the mechanistic source term.

18                   Another big issue obviously with this  
19 concept is to -- is the PRA, the quality of the PRA.  
20 It's going to be a little different obviously than  
21 what we've done in the past where we never reviewed  
22 it.

23                   And we just, in our slide we talk about  
24 the peer review requirement in the ASME/ANS. And in  
25 addition the staff feels that the staff itself may

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1 have to review that PRA if it's going to be used for  
2 licensing purposes.

3 MEMBER CORRADINI: Can I ask on this one?  
4 It's the DOE's plan with the contractor to finish  
5 these fuels testing. So will staff come back and look  
6 at the results of that and remove some of these  
7 caveats? Is it the plan of the staff to --

8 DR. CARLSON: We don't have any plan. If  
9 there is an application for a modular HTGR then of  
10 course we would expect them to look to the AGR program  
11 for the technical basis for the mechanistic source  
12 term. Everything has been discussed here including  
13 dust.

14 MEMBER CORRADINI: Okay.

15 DR. CARLSON: And at that time then we  
16 would take a very close look at that.

17 MEMBER SKILLMAN: For a peer review of a  
18 PRA for an HTGR are the human resources available to  
19 conduct that peer review?

20 DR. CARLSON: That's an interesting  
21 question. I think we have seen that DOE-INL has  
22 brought together a group of HTGR experts, some of  
23 them, most of them from General Atomics. And they're  
24 all rather gray-haired. So the question is that  
25 hands-on expertise from actually having built and

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1 operated an HTGR, how much longer is that available.  
2 Interesting question.

3 That said, the program -- Oak Ridge work  
4 in the past and their recent work with INL is  
5 developing new expertise. So they can fill some of  
6 that gap.

7 MEMBER SKILLMAN: Okay, thank you.

8 MR. SHEA: Next slide. The last couple of  
9 things I want to point out on the fuel qualification  
10 MST paper are the staff feels that -- or I should say  
11 the staff believes that the siting DBA should include  
12 postulated bounding events which may include air  
13 ingress and water ingress.

14 In addition, the safety train study should  
15 be evaluated to inform selected LBE DBAs used in  
16 establishing the EPZ and emergency preparedness  
17 requirements.

18 Also, the DOE-INL research plan for air  
19 and water ingress that was recently submitted we feel  
20 represents a reasonable approach to addressing the  
21 issue of air and water ingress and its effect on the  
22 TRISO fuel particle.

23 And the last point is that the SECY-05-  
24 0006, the staff there recommended that for compliance  
25 source term should be based on a 95 percent confidence

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1 level. And that's I think been -- if you notice  
2 that's been a standard theme throughout all of our  
3 presentations.

4 MEMBER STETKAR: Jim, back to the first  
5 bullet. If I read that. That presumes that the PRA  
6 would not include those types of events.

7 MR. SHEA: I'm glad I had the opportunity  
8 to answer this question because I was sitting on the  
9 sidelines listening to this. And the thought is that  
10 the applicant, the licensee would have a complete PRA  
11 that would include not only all the events that we  
12 would consider for licensing which would be DBAs but  
13 also they would have done the safety train studies  
14 that we would be interested in seeing.

15 And I think of one specifically that the  
16 Commission requested for the last effort in SECY-93-  
17 092 where they requested basically a chimney effect.  
18 And during the last effort they evaluated that and  
19 even though the staff came back and concluded that  
20 that was not required for licensing purposes, it's  
21 just too incredible.

22 So, but that would be an example of where  
23 safety terrain on any of these advanced reactors, it  
24 would behoove the applicant to look at all those type  
25 of events. And the staff then -- that doesn't mean

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1 the staff when they -- when we get an application or  
2 in pre-application space wouldn't suggest that we may  
3 be missing something there to look in the safety train  
4 or maybe it's possible he has a DBA.

5 Because you think about it, you know, and  
6 your earlier question I was thinking if you look at  
7 how they do this license-based event selection it's  
8 really a deterministic effort. Because they have to  
9 go and actually pick the events. For example, start  
10 with station blackout and then run it through the  
11 models. Start with the LOOP event. Run it through  
12 the models and see how it goes and on and on. Start  
13 with the flood and see where that heads or start with  
14 -- or maybe even a safety train would be to say that  
15 we're looking at a seismic event that's, you know, 0.6  
16 instead of -- some seismic event that would exceed  
17 licensing basis. And determine if there's a cliff  
18 edge.

19 MEMBER STETKAR: But in the way the PRA  
20 has been characterized at least in the white paper is  
21 that they're not discrete necessarily events the way  
22 you characterize them. They would look at the full  
23 range of seismic events, anywhere from zero g out to  
24 in principle 200 g if you could support that, or a  
25 couple of g for example peak ground acceleration which

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1 might have very low occurrence frequency but a very  
2 high consequence. They would look at all of those.  
3 So the scope of the PRA would indeed include all of  
4 those. They would include all of the possible fires  
5 in the plant regardless of the size and the location.  
6 You know, unless they were physically impossible.

7 MR. SHEA: I'll be getting more into the  
8 safety terrain --

9 MEMBER STETKAR: So that's where I'm  
10 getting in terms of -- you're characterizing it as  
11 safety terrain. I'm characterizing it as scope of the  
12 risk assessment.

13 And in that sense, you know, the risk  
14 assessment ought to include air ingress and water  
15 ingress events because one -- unless physics prohibits  
16 them from ever occurring under any condition the PRA  
17 ought to evaluate them with the frequency of  
18 occurrence, the consequences if they do occur both in  
19 terms of fuel protection and the ultimate consequences  
20 in terms of releases at the EAB.

21 So one ought not to necessarily focus on  
22 those events and say well you have to postulate those  
23 separately. They ought to be in there. If they're  
24 not in there the peer review both industry-related  
25 peer review and the staff's review ought to identify

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1 that as a deficiency in the PRA that should be  
2 evaluated. Once it -- if they refuse to evaluate it  
3 that's a different issue.

4 MEMBER RAY: Well, you aren't assuming  
5 this has to be a Part 52 application, are you? You  
6 may presume it would be. So it could be a Part 50  
7 application. Any sensible applicant that's what they  
8 would do. But that's just my two cents' worth.

9 MEMBER CORRADINI: How does that --

10 MEMBER RAY: It has to do with what your  
11 expectations are in the application.

12 CHAIRMAN BLEY: But this is that option 2  
13 I guess from the paper which says it's a risk-informed  
14 approach as well as the traditional approach.

15 MEMBER RAY: I saw that and I wondered at  
16 the time are they meaning to exclude Part 50  
17 applicants. Because that's far and away the most  
18 likely application.

19 DR. CARLSON: The technical standards  
20 whether it's Part 52 or Part 50 are really in Part 50.

21 MEMBER RAY: So it's whatever is required  
22 for Part 50. Okay.

23 CHAIRMAN BLEY: Well, but they've modified  
24 it in this licensing framework to include a number of  
25 probabilistic approaches that aren't in the standard.

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1 DR. CARLSON: So yes, the idea is to adapt  
2 the existing framework without perturbing it  
3 unnecessarily.

4 MEMBER RAY: Well, I'm just making the  
5 point, Dennis, that you're not going to have the same  
6 level and quality of detail in a Part 50 application  
7 that you would have to have in a Part 52 where you're  
8 seeking a certification.

9 DR. CARLSON: Well, by the time you grant  
10 the operating license it will be the same.

11 MEMBER RAY: Oh well, operating license is  
12 helmets. Start with the construction permit.

13 DR. CARLSON: Yes. You're done, okay. So  
14 I will --

15 CHAIRMAN BLEY: Is that all there is?  
16 That's it. Unless you want another question.

17 DR. CARLSON: Well, we're going to cover  
18 some of the same ground under this heading too.

19 CHAIRMAN BLEY: Okay, well let me ask a  
20 question because I didn't think about it earlier. In  
21 fact, if you flip back to your picture on page 30.

22 DR. CARLSON: And I said courtesy of DOE  
23 and DOE got that from Dave Hansen who created that  
24 many years ago.

25 (Laughter.)

1 MR. SHEA: I wasn't sure why it wasn't in  
2 their presentation this morning. I was looking for  
3 it.

4 CHAIRMAN BLEY: It's been there before.  
5 I was thinking about Dave Petti's discussion this  
6 morning about how they think a lot of the -- what  
7 they've measured is coming out of the matrix around  
8 the TRISO pellets that's accumulated during neutron  
9 exposure. And they're going to do the tests without  
10 having that matrix to see just what's coming out of  
11 the TRISO.

12 But when the source term is developed it's  
13 at least in principle to look at what's coming out of  
14 the TRISO particles, what would be coming out of the  
15 matrix, what would be coming out of -- if there's  
16 anything in the graphite or in the dust. All of those  
17 things contribute.

18 DR. CARLSON: Yes and when we're talking  
19 about -- if you have a large depressurization, you  
20 know, it's the circulating activity, the dust, the  
21 plateout, the washout, everything that happens. But  
22 then as Dave explained there's a delayed heat-up that  
23 takes a day or more to develop and during that heat-up  
24 you're getting -- you may get additional fuel particle  
25 failures but a lot of what you're getting is fuel

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1 that's already -- fission products that are already  
2 outside coated particles. Or that are in --

3 CHAIRMAN BLEY: That are --

4 DR. CARLSON: -- in kernels that don't  
5 have intact coatings and just the heating dries that  
6 out into the ultimately the reactor building.

7 CHAIRMAN BLEY: But even if you learn  
8 nothing has come out of the particles in the accident  
9 you still have this other stuff that's out in other  
10 places that you have to account for.

11 DR. CARLSON: So that's actually in --

12 CHAIRMAN BLEY: That accumulates --

13 DR. CARLSON: -- it's larger than the  
14 initial release from the circulating plateout and all  
15 that.

16 CHAIRMAN BLEY: Okay. That was all.

17 Thank you.

18 DR. CARLSON: So, containment function  
19 performance. Okay, the proposed definition of  
20 functional containment, and I quote, "the collection  
21 of design selections that taken together ensure that  
22 first radionuclides are exchanged within the multiple  
23 barriers with emphasis on retention at their source in  
24 the fuel. And that ensure that NRC regulatory  
25 requirements and plant design goals for release of

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1 radionuclides are met at the exclusion area boundary."  
2 And so we considered that definition.

3 And they have also asked then for specific  
4 requests, specific feedback on three elements of this  
5 approach to NGNP functional containment. Feedback on  
6 the AGR fuel program activities for the fuel  
7 qualification.

8 On options for containment functional  
9 performance standards and a little more definition on  
10 how we would go about selecting events for plant  
11 siting and functional containment design decisions.

12 So issue 1 is AGR fuel program activities.  
13 And they have asked the staff to confirm that plans  
14 being implemented in the AGR fuel program are  
15 generally acceptable and provide reasonable assurance  
16 that TRISO fuel can retain fission products in the  
17 predictable manner. And they would like us to  
18 identify any additional needs for testing for other  
19 information.

20 So the overview of our feedback is that  
21 the scope of the AGR activities, mainly the fuel  
22 irradiation and post-irradiation testing and accident  
23 heat-up testing that are being planned and carried out  
24 are generally reasonable within the context of pre-  
25 prototype testing. And that leads ultimately to the

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1 point that there is additional data that would be  
2 needed for prototype.

3 The AGR program has been -- has achieved  
4 very encouraging results to date. I mean Dave Petti  
5 has said that for AGR-1 they irradiated 300,000  
6 particles at high temperature, high burnup and high  
7 fluence and got zero failures. And he's talked about  
8 the results of heat-up testing to date. That likewise  
9 is indicating that they seem to be on target to meet  
10 or exceed the level of performance that the Germans  
11 showed 30 years -- or close to 30 years ago.

12 So yes, the early AGR irradiation safety  
13 testing results do show promise for demonstrating much  
14 of the desired TRISO fuel retention capability. But  
15 we would need additional data from the NGNP prototype  
16 to provide reasonable assurance of targeted fission  
17 product retention in the fuel.

18 And we have particular needs. One is for  
19 test data on fuel irradiated in an HTGR for effects of  
20 plutonium fission products, palladium and silver in  
21 particular on TRISO fuel particle coatings.

22 Also, related to that testing in the  
23 prototype to confirm NGNP core operating conditions  
24 and the ability to detect potential core hot spots and  
25 any of their affects on fission product retention and

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1 fuel performance.

2 As was said in the licensing strategy  
3 report to Congress that we would be licensing this  
4 under 10 C.F.R. 50.43(e)(2) such that the requirements  
5 for testing would not be able to be met prior to a  
6 fuel loading in the reactor and that the testing  
7 requirements would have to be plated by testing and  
8 surveillance in the prototype. This regulation allows  
9 the staff to impose additional requirements on the  
10 prototype in terms of siting, design features,  
11 operating limits during the testing period to protect  
12 the staff and the public during that period.

13 So, under issue 1 we have additional  
14 feedback on what constitutes a good fuel qualification  
15 and testing program. We think they have a good one  
16 but their description of it in our view could have  
17 been clearer. Under the heading of adequately  
18 deciding the fuel service conditions and performance  
19 requirements for both normal operations and accidents.

20 As we have seen in the TRISO fuel PIRT  
21 that the NRC did, Stu Rubin was a key factor in that  
22 10 years ago. Dr. Powers and Dr. Petti were part of  
23 that PIRT panel. And one of the things that was noted  
24 in the PIRT was the importance of palladium in  
25 particular for its potential to interact with the

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1 coating layers but in particular corrode the silicon  
2 carbide layer.

3 Well, the two principal sources of  
4 plutonium and silver are from plutonium fission. The  
5 yields are 50 times more than from uranium fission or  
6 something like that.

7 So, we feel that because of the importance  
8 and Dr. Petti is developing new insights on the  
9 importance of palladium, because of the importance of  
10 palladium and potentially silver on performance of the  
11 TRISO fuel particle coatings we think that plutonium  
12 burnup should be something that is specified in your  
13 testing program.

14 We also have in the FQ MST report a  
15 section on potential effects of irradiation parameter  
16 path dependence. And Dr. Petti in his January  
17 presentation provided a scatter plot of what actual  
18 irradiation testing conditions they have for the  
19 various particles.

20 And you see that the emphasis is on the  
21 high end of everything, the higher end of the burnup  
22 range, the higher end of fluence, the higher end of  
23 operating temperatures. So the question becomes is it  
24 possible that if you irradiate fuel to high burnup in  
25 high fluence but at a moderate temperature that that

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1 somehow affects fuel particle coating performance in  
2 a way that's not addressed by the testing. And of  
3 course we have -- I mean Dr. Petti has developed some  
4 model, the PARFUM code that would provide some insight  
5 on that.

6 And so in our discussions with DOE-INL on  
7 this issue over the last year it was noted that we  
8 really don't have a good -- a design such that we  
9 could have a map of the parameters that an actual HTGR  
10 core would have to compare against that scatter plot.

11 Dr. Petti did show, however, in January an  
12 example of that and it did indicate that the -- much  
13 of the fuel would be at these less extreme irradiation  
14 conditions.

15 MEMBER CORRADINI: So, I'm sorry, maybe I  
16 missed it. You're saying that they looked at two  
17 extreme conditions. There could be some middle range  
18 conditions that caused -- I didn't appreciate what  
19 your --

20 DR. CARLSON: It's a question. It's a  
21 question that we don't have an answer to yet. And so  
22 it's just in terms of being thorough that the  
23 presumption is in their testing program that if you  
24 irradiate at these aggressive conditions you would  
25 have addressed all the other conditions as well.

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1                   MEMBER CORRADINI: So there's something  
2 not monotonically increasing about release rates.  
3 Somehow it would go through an inflection and I get  
4 more release in the middle?

5                   DR. CARLSON: Just --

6                   CHAIRMAN BLEY: The chemistry.

7                   DR. CARLSON: -- are very temperature-  
8 dependent, right? The irradiation creep phenomena.  
9 And that's an important phenomenon in their PARFUM  
10 model.

11                   MEMBER CORRADINI: But I have it right in  
12 my head. I just want to make sure I'm not missing  
13 anything. There's some set of conditions that I would  
14 actually get due to chemistry and time and temperature  
15 more release at a lower temperature. So I'd get some  
16 sort of effect like this.

17                   DR. CARLSON: What we're talking about is  
18 preconditioning of the fuel for its performance during  
19 accidents. So these are the normal irradiation  
20 conditions.

21                   MEMBER CORRADINI: Okay. So is there  
22 something about irradiation at less extreme  
23 conditions?

24                   DR. CARLSON: Lower temperatures, for  
25 example. That conditions the fuel differently. I

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1 think that the popular wisdom, the conventional wisdom  
2 is that the more extreme conditions cover that but we  
3 need to see a technical basis for that.

4 MEMBER CORRADINI: So lead me through the  
5 -- it was on the slide before where you said 10 C.F.R.  
6 50.43(e)(2) allows the NRC to impose additional. So  
7 your thinking is that potentially the prototype demo,  
8 whatever word you want to call it, would have to go  
9 through some sort of in-flight testing to find a  
10 better word to make sure you have confidence as you  
11 increase the allowable range of how it would operate.

12 DR. CARLSON: We see a potential need for  
13 that.

14 MEMBER CORRADINI: Okay, fine.

15 DR. CARLSON: It will be a continuing  
16 topic of review.

17 MEMBER CORRADINI: So let me reverse it.  
18 Let me pretend I'm the DOE and the contractor. So is  
19 there any set of tests that is finite and discrete  
20 that would relieve this other than essentially  
21 prototype power ascension testing?

22 DR. CARLSON: I think the overall message  
23 is there are a number of issues that get you into this  
24 regulation prototype testing, core operating  
25 conditions.

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1                   MEMBER CORRADINI: But I'm trying to get  
2 you -- you're very clever. I'm pushing you here and  
3 you're over there next time. So I'm trying to  
4 understand.

5                   DR. CARLSON: I'm sorry, I'm sorry.

6                   MEMBER CORRADINI: But what I'm kind of  
7 hearing is that save that there's very little, little  
8 compared to light water reactor, data you'd like to  
9 see essentially -- I'm reading it this way, that I'd  
10 like to almost see the demo built and watch it work  
11 its way through a series of in-service, in-flight  
12 testing to make sure you have confidence and your  
13 confidence builds.

14                  DR. CARLSON: In the prototype you would  
15 want -- it's very difficult to do in core measurements  
16 in HTGR. In the prototype you could do that on a  
17 provisional basis.

18                  Then I think the ultimate proof would be  
19 you would do PIE on fuel that's been irradiated in the  
20 prototype.

21                  MEMBER CORRADINI: Okay.

22                  DR. CARLSON: Over the full spectrum of  
23 parameter path-dependent conditions.

24                  MEMBER CORRADINI: Okay. Fine.

25                  DR. CARLSON: Okay. So again, as I was --

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1 the potential for hot spots. I've been talking about  
2 hot spots a lot for years. People remember my  
3 references starting 12 years ago to the AVR net wire  
4 experiments and the hot spots that they revealed.

5 It's an issue that we consider applies to  
6 all designs. It's been -- received particular  
7 attention for pebble beds but we can talk about it.  
8 But I do believe that there are issues to be  
9 considered in this realm also for the prismatic block  
10 designs.

11 Okay, also we want to adequately identify  
12 fuel service conditions and performance requirements  
13 for accidents. The design information is needed to  
14 confirm the assumed lack of specific testing  
15 requirements for reactivity excursion events.

16 So that to us would be an issue to be  
17 considered once we have de-scaled design information  
18 to determine whether, for example, is a rod excursion  
19 indeed a plausible, credible event or is it really  
20 precluded by design features such that it's not  
21 credible.

22 As Jim alluded to we -- because some of  
23 our interactions on this DOE has followed through with  
24 a report, a research plan for moisture and air  
25 ingress. We think it's important to implement the

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1 activities outlined in that plan to provide the data  
2 needs on fission product transport for -- and fuel  
3 performance for bounding events that involve those  
4 phenomena.

5 So, what are the particular issues that we  
6 identified in relation to TRISO fuel performance?  
7 It's realtime versus accelerated testing. In  
8 accelerated testing do you get the time and  
9 temperature? No, you don't. It's always condensed in  
10 time.

11 And in an HTGR environment you have a  
12 harder thermal neutron spectrum and a higher  
13 epithermal neutron spectrum. The higher epithermal  
14 neutron spectrum gives you more plutonium breeding.  
15 The harder thermal spectrum for a given amount of  
16 plutonium gives you more fission of plutonium in  
17 relation to breeding because the HTGR spectrum peaks  
18 near the 0.3 EB resonance, thermal resonance fission  
19 -- fission resonance for plutonium-239 and -241.

20 So there was actually a report that DOE  
21 and INL developed on this to actually compare the  
22 plutonium burnup in the AGR-1 test. You see the AGR-1  
23 tests are being performed in a water-cooled spectrum  
24 so they don't have that prototypical spectrum. And  
25 the differences were significant but not orders of

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1 magnitude.

2 Okay, another --

3 MEMBER CORRADINI: If I might, just so I  
4 -- so given the larger plutonium content we're back to  
5 the palladium and the silver in terms of how it  
6 affects the TRISO fuel pellet or fuel kernel?

7 DR. CARLSON: How it affects the coatings,  
8 in particular the silicon carbide coating layer.  
9 Palladium, there's been sporadic evidence over the  
10 years particularly in the Japanese literature of  
11 palladium attacking the silicon carbide layer and  
12 corroding it. Dr. Kania is an expert in this area.  
13 There's been some indications in the German program  
14 that they might have been starting to see some of  
15 those effects in the German testing. Certainly the  
16 INL program, the AGR program is looking at these and  
17 we think they should continue looking at these  
18 effects.

19 Another, you know, it's important to  
20 recognize. I was talking about hot spots earlier.  
21 That in an HTGR it's the helium. So for all gases  
22 viscosity increases with temperature. And these  
23 reactors have downward coolant flows. So the  
24 viscosity of the coolant and the buoyance effects tend  
25 to exacerbate the development of hot spots during

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1 normal operation. So that and the fact that you have  
2 -- there are various pathways for bypass flow between  
3 the blocks and the prismatic block. In a pebble bed  
4 and a prismatic block there's increasing flow through  
5 the reflectors.

6 As the reflectors -- over operating time  
7 the effects of radiation on the reflector blocks  
8 causes the blocks to shrink and so the bypass flows  
9 through the reflectors tend to increase with operating  
10 time. So those are all things that you consider under  
11 the issue heading that I call core operating hot  
12 spots, core operating anomalies.

13 Additionally you talked about in the  
14 prismatic block core you have a closed core coolant.  
15 You have individual coolant holes. And so you always  
16 have to add -- wonder if there's a potential for  
17 individual coolant holes to be obstructed in some way.  
18 And that gives you during quasi, ostensibly normal  
19 operation a hot spot. The question is can you detect  
20 that with whatever's available including monitoring  
21 circulating activity, plateout probes and whatnot.

22 Those would be things that you would have  
23 to actually demonstrate in a prototype and in a sense  
24 calibrate your plateout probes in your circulating  
25 activity.

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1 Another issue was evaluation of  
2 irradiation temperature uncertainty. We heard that --  
3 I think Dr. Petti gave a good discussion but we had an  
4 RAI that I wrote actually on they're having  
5 thermocouple failures during these irradiations and  
6 how is that affecting the uncertainties in the  
7 irradiation temperatures.

8 And so they provided a couple of reports  
9 that I noted there, especially the uncertainty  
10 quantification for AGR-1 and that is evolving for the  
11 different tests as Dr. Petti indicated in his  
12 presentation.

13 Bottom line, it's very important to  
14 understand how the irradiation temperature  
15 uncertainties are quantified and how they are affected  
16 if at all by increasing thermocouple failures.

17 The initial understanding from INL is that  
18 once you've calibrated and validated the way you  
19 calculate the fuel temperatures during irradiation the  
20 effect of thermocouple failures is not very  
21 significant. So that was to me counterintuitive. It  
22 will be an area for further review.

23 Another question was it was always kind of  
24 an article of faith that you could irradiate fuel in  
25 an HTGR or a test reactor, take it out and weeks or

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1 months or years later do these heat-up tests in an  
2 autoclave. And that would be representative of how  
3 the fuel performs in fission products transport in an  
4 actual reactor accident, either -- at power.

5 So you do have a hot spot. So at power  
6 does the fuel -- does the data you get on fuel  
7 performance and fission product transport in these  
8 delayed heat-up tests apply to at-power heating  
9 conditions, overheating conditions or the delayed  
10 heating that you get in the loss of core cooling  
11 event.

12 And the answer was always kind of  
13 qualitatively, well, it's the long-lived and stable  
14 fission products that dominate. And the short-lived  
15 fission products are not important.

16 And then there would be also the question  
17 well, maybe there are other things that change in that  
18 interim between irradiation and heat-up testing. You  
19 know, phase changes, something transports.

20 So I've been in the HTGR community in and  
21 out for decades and I never really saw a really  
22 scrutable analysis. So if you're saying that long-  
23 lived and stable isotopes dominate, that's something  
24 called the ORIGIN code can calculate for you, you can  
25 actually quantify that.

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1           And so that's what -- in response to an  
2 RAI and some discussions on that RAI they did provide  
3 this report TIB-1543 by Jim Sturbens at Idaho. And it  
4 does actually provide quantified results. They do  
5 support the application of data from the lead fuel  
6 heat-up testing. We described that in the summary  
7 level in the FQ MST assessment report. And so we do  
8 have a scrutable case that does seem to support the  
9 case.

10           So issue number 2. The options for  
11 containment functional performance standards. Again  
12 this was the subject of some SECY documents in the  
13 SRMs. The SRM said to ask the staff to develop  
14 functional containment performance standards.

15           And the staff in an information SECY paper  
16 05-0006 went back with the Commission to note the  
17 functional containment or the reactor building  
18 functions in addition to those for the functions we've  
19 been discussing under mechanistic source term. And  
20 those functions listed in SECY-05-0006 are protector  
21 significant, SSC, et cetera.

22           And DOE-INL, we all seem to agree that  
23 those are good functions. And we've added at the end  
24 this important one, limiting air ingress after helium  
25 depressurization accidents. So we think we have some

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1 degree of convergence in general terms of what  
2 functional containment performance standards should  
3 look like. That said we see this as an area where  
4 Commission direction may be appropriate.

5 CHAIRMAN BLEY: One thing I neglected to  
6 ask you as you began all of this. Since we don't have  
7 a follow-on response report from DOE are there areas  
8 in these exceptions you've been going through, all of  
9 you have been going through, where there's substantial  
10 disagreement or is most of this you're getting  
11 reasonably close and expect to see some of this in the  
12 following performance testing?

13 DR. CARLSON: In my eyes I think that we  
14 don't have any major divergence on this topic. I  
15 think we're -- we don't have full convergence but it's  
16 reasonable.

17 CHAIRMAN BLEY: Okay.

18 MEMBER CORRADINI: Can we ask the DOE do  
19 they have the same view of the apple?

20 DR. CARLSON: I think this brings it to --

21 CHAIRMAN BLEY: We'll give them a shot in  
22 a minute.

23 DR. CARLSON: I think this -- the big  
24 issue really, and Jim started talking about it during  
25 his talk, but they asked about -- they asked us for

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1 feedback on event selection for plant siting. So we  
2 agreed with them that the core melt accident assumed  
3 for light water reactor siting may not be adequate to  
4 monitor HTGRs and this is consistent with what the  
5 staff thought going back to MHTGR.

6 And so of course we would have to look at  
7 a detailed application, et cetera, to be sure of that  
8 but it seems that, myself included, I can't come up  
9 with an event that melts the fuel in an HTGR. And  
10 I've been trying. And a lot of people have.

11 We think it may not be applicable to  
12 modular HTGRs. That's a footnote. It's not  
13 necessarily a requirement. And so it's something that  
14 can be interpreted. And they have offered alternate  
15 wording. It's an event that would maximize -- a  
16 credible event that would maximize releases from the  
17 fuel to the reactor -- from the actual helium pressure  
18 boundary to the reactor building.

19 MEMBER CORRADINI: So this is -- can I  
20 just rewind, make sure I've got it right? So this is  
21 not the DBA.

22 DR. CARLSON: Well, whether you call it a  
23 DBA or not it's the event that you use for the siting  
24 source term.

25 MEMBER CORRADINI: In the world of 10

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1 C.F.R. 100 and TIB-1484 it was called the MCA, the  
2 maximum credible accident.

3 DR. CARLSON: That's Jim Shea's term.  
4 Maximum hypothetical accident.

5 MEMBER CORRADINI: Is that what they  
6 called back in -- in '58 I thought it was called the  
7 MCA.

8 MR. SHEA: And they used that also, both  
9 those terms.

10 MEMBER CORRADINI: Okay. And it's the  
11 associated source term therein.

12 DR. CARLSON: So we can talk to the  
13 terminology but the ideas I think are clear.

14 MEMBER CORRADINI: So then if I might just  
15 make sure that I get it. Then this is not the  
16 discussion about how I select the DBAs from the  
17 licensing basis events. This is how I come up with  
18 some sort of stylized source term that the containment  
19 function has to withstand to meet either the  
20 regulation or their EPA PAG.

21 DR. CARLSON: The focus is on plant siting  
22 and Jim noted that if not the identical event the same  
23 kind of thinking there on these other areas.

24 MEMBER CORRADINI: Okay, all right. Fine.  
25 Got it. Thank you.

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1 DR. CARLSON: So, the history is very  
2 important here. For the MHTGR and SECY-93-092 and  
3 NUREG-1338 is a very good document. I think DOE-INL  
4 has summarized that for you a couple of times now.

5 The staff employed some staff-selected  
6 bounding events with the idea that that would  
7 ultimately inform the selection of a siting source  
8 term that would determine functional containment that  
9 would be used in functional containment design  
10 decisions.

11 Well, the SRM on SECY-93-092 approved tat  
12 specific mechanistic source terms subject to adequate  
13 understanding of the fuel and fission product, and  
14 that's what the AGR program is all about, establishing  
15 that technical basis. In a sense in terms of policy  
16 the Commission says this is the way to go. Now it's  
17 a technical issue assessing how well we understand the  
18 fuel and fission product performance.

19 But in the SRM the Commission said your  
20 bounding events were good but we want to see more.  
21 And in particular they said, I'm going to read it,  
22 "The Commission believes that for the MHTGR the staff  
23 should also address the following type of event, the  
24 loss of primary coolant pressure boundary integrity  
25 whereby air ingress could occur from the chimney

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1 effect resulting in graphite fire and a subsequent  
2 loss of integrity of the fuel particle coatings."

3 Now, people have reacted to that in  
4 various ways including wow, that is an event that's so  
5 improbable it's hard to put a number on it. I  
6 characterize that as a good example of the questioning  
7 attitude that we all need to bring to this. This is  
8 a technology that not everybody understands and the  
9 people that do understand it probably are going to  
10 understand it better after all this testing is done.

11 And so I guess, I've been talking about it  
12 in terms of the safety terrain. It's the questioning  
13 attitude. What would it take regardless of -- step  
14 back of what the PRA says and say what would it take.  
15 Let's postulate things.

16 And I can go back to we started doing that  
17 for the MHTGR actually before I joined the NRC. I  
18 picked up the reins from Pete Williams when he left  
19 NRC and joined DOE in 1991.

20 And I think at a presentation in this  
21 room, I think it was for the PIRT that we did for PBMR  
22 I presented some studies where we with Syd Ball and  
23 his code in the late eighties and early nineties, we  
24 looked at things. Well, what-ifs and what-ifs and we  
25 looked at what would happen if you had a rod

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1 withdrawal accident and no SCRAM and somebody turned  
2 on the helium circulators. Well, it turns out that  
3 according to the models at that time you could get  
4 fuel temperatures way up there.

5 Now, we're not saying that's credible,  
6 we're not saying that should be a licensing basis  
7 event but it's surveying the safety terrain. Out  
8 there somewhere, maybe it's not a cliff edge but there  
9 is an interesting terrain and now we need to  
10 understand what are the SSCs, what is the plant  
11 capability, what is the programmatic DID that keeps us  
12 far from there. And so we're viewing it in that  
13 light.

14 Let's look at things like this extreme air  
15 ingress event, the extreme moisture air ingress event.  
16 There have been published studies in the literature.  
17 Matt Richards, former General Atomics employee, Syd  
18 Ball, Oak Ridge National Lab, published some papers in  
19 the last 4 years or so that do studies of this type,  
20 extreme air ingress events.

21 I would put a caveat on that that all of  
22 the studies that I've seen today use the graphite  
23 oxidation properties for pristine unirradiated  
24 graphite. And it's important to note that  
25 contaminated graphite will tend to oxidize a bit more.

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1 Pebble graphite isn't really graphite, so that tends  
2 to be more reactive than true reactor graphite. And  
3 irradiation damage to graphite tends to increase  
4 oxidation of the graphite.

5 MEMBER RAY: If you can have extreme air  
6 ingress, you've mentioned that a number of times.  
7 John mentioned earlier water. This being an embedded  
8 plant, a flood level sustained over some considerable  
9 period of time, water ingress, it seemed to be a  
10 possibility. If you're submerged for a week that's  
11 not -- it doesn't sound to me like a terribly  
12 incredible event for many sites.

13 DR. CARLSON: Well, I think the water  
14 ingress that we're talking about here is that for the  
15 MHTGR and for NGNP we're talking about a helium cooled  
16 reactor that has a steam generator on it.

17 MEMBER RAY: I know that. But I'm asking  
18 about a siting question since that was the essence of  
19 the discussion. And you talk about air ingress. Is  
20 there any reason why water ingress wouldn't be a  
21 problem given what you've said about there being a  
22 pathway for air ingress. What would prevent -- in a  
23 flood scenario what would prevent water ingress?

24 DR. CARLSON: Okay, well obviously as you  
25 heard there's the ingress from the steam generator.

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1 Then to your question --

2 MEMBER RAY: No, I understand that  
3 perfectly well.

4 DR. CARLSON: To your question it's a  
5 perfectly good question. I mean one of the  
6 discussions that we had when Fukushima was happening  
7 is well, what would it do to the reactor vessel if you  
8 suddenly got a bunch of cold water from a flood.

9 MEMBER RAY: Yes. I mean we're talking  
10 about that we don't need a building that is LWR  
11 containment style as far as releases are concerned.  
12 I'd certainly subscribe to that. But of course you're  
13 giving up then, and you're embedding the thing below  
14 grade. You're giving up the protection that might be  
15 afforded by. I mean it's just a siting issue. It  
16 perhaps isn't relevant to --

17 DR. CARLSON: -- the safety implications  
18 of having water where you don't want it in the  
19 reactor.

20 MEMBER RAY: Yes, and lots of it.

21 DR. CARLSON: Yes, and lots of it. That's  
22 a very good question that certainly will be  
23 considered.

24 I would just point out that in talking  
25 about how you mitigate an air ingress some people say

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1 well, maybe preventing the air ingress by flooding  
2 with water.

3 MEMBER RAY: Well, that might be the  
4 answer you'd give. Yes, I understand that, right.  
5 But you can't only assume it's air or some limited  
6 amount of water from a steam generator.

7 DR. CARLSON: If there were an event that  
8 would give you moisture ingress then air ingress we  
9 would evaluate that. Or vice versa.

10 So we had -- this is not in their white  
11 paper. This is one of those things that we iterated  
12 on with DOE-INL over the past year or so. And they  
13 came up with the following approach which I think is  
14 reasonably how we would characterize it.

15 The applicant should submit for NRC  
16 consideration a risk-informed selection of siting  
17 events building on the types of bounding events  
18 considered by the staff in NUREG-1338 for mhtgr. And  
19 they've been presented to you by DOE-INL.

20 And to get to the SRM, the SECY-93-092  
21 safety terrain studies if you want to call it that to  
22 assure that there are no cliff edge effects. Credible  
23 events. And let's not talk about probabilities, let's  
24 just look for the cliff edges. Credible events with  
25 high dose consequences. That's what a cliff edge

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1 effect is.

2 And to understand the ultimate safety  
3 capability we look at bounding event selection to be  
4 further informed by these exploratory studies of  
5 postulated extreme events. The rules of these  
6 exploratory studies should be that the events are  
7 physically plausible. You don't suspend the laws of  
8 physics. You do take credit for the inherent features  
9 of the modular HTGR design, the inherent behavior.

10 We think that is a path to informing the  
11 selection of the siting event. Does it give you the  
12 siting event? No, that depends on a lot of detail and  
13 a lot more discussion and possibly Commission  
14 direction.

15 MEMBER STETKAR: So are we hoping, by  
16 doing this though, the HTGR, the NGNP to a much, much,  
17 much more restricted standard than we do any  
18 considerable light water reactor that's either  
19 operating or being licensed today?

20 DR. CARLSON: That's an underlying thought  
21 that we've all --

22 MEMBER STETKAR: Here you go. I have to  
23 say this in every meeting. We don't require existing  
24 light water reactors to postulate a physically  
25 plausible event that I'll call an asteroid. Call it

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1 a meteorite. It's an external event. I've seen them.  
2 I know what their frequencies are. We don't require  
3 them to do that.

4 It's a physically plausible event that  
5 could result in a catastrophic set of consequences.  
6 We don't require them to do that because we say well,  
7 that's an acceptable level of risk on a frequency  
8 basis. So why -- we heard that frequency argument in  
9 the context of this particular design.

10 DR. CARLSON: Well, a light water reactor,  
11 certainly current generation light water reactor,  
12 there's no mystery about that. We know that the fuel  
13 will melt in those kinds of extreme events.

14 MEMBER STETKAR: I just use that as kind  
15 of an absurd example of extending that thought  
16 process.

17 DR. CARLSON: But the point here is we  
18 don't have that level of understanding. The modular  
19 HTGR design concept is basically an attempt to make it  
20 meltdown-proof. And so people naturally say hey, it's  
21 our job. We're the NRC. If there's a way to melt  
22 this or if there's a way to get a massive release,  
23 particularly one that doesn't take a lot of time to  
24 develop, it's our job to identify that.

25 And so does PRA the way we normally think

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1 of it with we don't go below certain frequencies, does  
2 that really give you that insight? To some degree  
3 maybe yes but I think to really understand the safety  
4 terrain you have to just say what if I didn't have  
5 whatever, a reactor building. What if somebody did  
6 turn on the helium circulator after you had a rod  
7 withdrawal event. What if somebody turned on the  
8 helium circulator, Stu Rubin will remember this, after  
9 a large break. That would be a way to get very rapid  
10 graphite corrosion, right?

11 And we had NRC delegations going to China  
12 to visit their HTR-10, their small pebble bed reactor.  
13 And in one of those visits Stu Rubin went in the  
14 control room, with the delegation went in the control  
15 room and Stu Rubin asked the host to ask the operators  
16 what they would do if they had a rapid  
17 depressurization and they saw the temperatures going  
18 up. And their response was we'd turn on the helium  
19 circulators. Wrong answer.

20 Actually that's what happened at  
21 Windscale. They saw the temperatures going up and  
22 what did they do? Well, that was an air-cooled  
23 production reactor. They blew more air on it.

24 By the way, if we were to update NUREG-  
25 1338 1989 version today I think we would want to

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1 correct a couple of things. There's a chapter in  
2 NUREG-1338 called graphite fires. And in that chapter  
3 they describe Windscale as a graphite fire. And I  
4 think you heard from Dr. Srinivasan among other  
5 people, probably Dr. Petti also that they actually  
6 looked inside the Windscale reactor about 6-7 years  
7 ago, have pictures, and most of the graphite is still  
8 there which reinforces the interpretation the experts  
9 had over the years that that was predominantly a metal  
10 fire and it did take some graphite with it. Likewise,  
11 the role of graphite oxidation in Chernobyl was not  
12 significant.

13           So I think by writing that section the way  
14 we did in NUREG-1338 we exacerbated this false  
15 perception that graphite and coal are the same thing.  
16 Dr. Srinivasan and others have shown you that it's  
17 very hard to get graphite to oxidize. That said, when  
18 you do have air ingress or oxygen ingress, hey, we're  
19 talking about cogeneration. One of the things that  
20 our PIRT panel for cogeneration identified was the  
21 potential for ground-hugging plumes, potentially  
22 oxygen.

23           So oxygen ingress can -- we're not going  
24 to say burn -- oxidize graphite. It's an exothermic  
25 reaction. And if you don't do something eventually it

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1 gets to the point perhaps if it's an extreme event  
2 where -- but it takes a long time to develop, where  
3 you could get increasing releases. So that's what  
4 SECY-93-092 SRM was asking us to do. We need to  
5 understand that better and I agree. The staff agrees.

6 MEMBER CORRADINI: So can I take John's  
7 point? Since he started so I won't give up on it. If  
8 I went back to the MCA and the originally TIB-1484 now  
9 where we are, now not in '58 but in 2013 I can run a  
10 MELCOR calculation and with the right knob adjusting  
11 I can create a source term inside containment that  
12 looks a whole lot like that first source term, right?

13 DR. CARLSON: Yes.

14 MEMBER CORRADINI: Okay. And then now by  
15 turning the knobs I have a sequence of events that  
16 gets me there which means I can actually compute a  
17 probability, a likelihood of getting it.

18 But your point is, I'm just trying to  
19 repeat your point, that we have no -- we have no MCA  
20 for this sort of design. You want to come up with one  
21 and you want to relieve yourself of the worry how I  
22 got there probabilistically, just how can I get there  
23 mechanistically. So I don't -- have I got it  
24 approximately right?

25 DR. CARLSON: Yes. Somewhere -- we don't

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1 want to use probability cutoff necessarily. But we  
2 don't want to go to something that's beyond credible.  
3 So where is it? Well, we'll be informed by these  
4 cliff edge effect studies. And like you say, once you  
5 identify all the design features inherent.

6 MEMBER CORRADINI: So has DOE suggested  
7 something in this regard? Because I think I know now  
8 what you're getting at. And I see why the fuels  
9 testing program of INL is important to that because  
10 it'll tell you what really is physically possible  
11 given some sort of temperature thresholds. But has  
12 there been a suggestion as to what you'd use as  
13 essentially the equivalent of the MCA by the DOE?

14 DR. CARLSON: Their original proposal  
15 would be that it would be more risk-informed. What  
16 we've been talking about is well that's not what the  
17 SRM to SECY-93-092 says. And I think it was  
18 reasonable that they said what they said. We need to  
19 understand the cliff edges.

20 MEMBER CORRADINI: Okay.

21 DR. CARLSON: And so once we have that  
22 that will inform the selection of something that's  
23 credible. And where it is in PRA space may be very --

24 MEMBER CORRADINI: So let me take you a  
25 totally different place. When staff I think issued

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1 the equivalent of the SER for Clinch River that never  
2 got built the equivalent was a sodium fire for  
3 containment and an HCDA for the core. Is that what  
4 we're getting at? It's essentially -- because there  
5 was no -- we didn't suspend the laws of physics. On  
6 the other hand we didn't do a probability estimate of  
7 what would be essentially the Clinch River had to  
8 contend with for essentially siting. So that's what  
9 we're talking about. I hate -- pick another  
10 technology because this is going to come up again.

11 DR. CARLSON: Yes, I think we're talking  
12 about the same language here.

13 MEMBER CORRADINI: Okay.

14 DR. CARLSON: So, with that we can turn it  
15 over to Arlon Costa on emergency preparedness if there  
16 are no more questions.

17 CHAIRMAN BLEY: Okay.

18 MR. COSTA: My name is Arlon Costa. I'm  
19 a senior reactor project manager with NRO, the  
20 Division of Advanced Reactors and Rulemaking. I'll be  
21 addressing emergency preparedness as one of the major  
22 issues referred to in the DOE-INL draft summary  
23 document shared previously with ACRS.

24 I will follow a similar format as that of  
25 my colleagues where I'll discuss only NGNP pertinent

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1 background information, a summary of the staff's  
2 feedback on the issues and then I'll presents practice  
3 feedback on the issues.

4 The issues are related to DOE-INL's  
5 request for NRC to propose new policy or revised  
6 regulations and establish guidance on emergency  
7 preparedness requirements for emergency response plans  
8 and related issues such as emergency planning zones.

9 So I'll start with a background. We  
10 received this white paper that's in bullet 1 there  
11 that described -- that was submitted by DOE-INL in  
12 2010. And it contains important information obviously  
13 addressing emergency preparedness, specifically  
14 information on the modular HTGR core.

15 It provides information as we've seen  
16 extensively today on the TRISO barriers that are  
17 associated with radiological releases and many other  
18 important information. All that is in support of a  
19 smaller size emergency planning zone when compared to  
20 current EPZ's required for light water reactors.

21 The NRC did not provide a formal feedback  
22 to DOE-INL on this white paper submittal but emergency  
23 preparedness framework issues were addressed in  
24 various public meetings. And the main reason for the  
25 postponement of the formal review was that key EP

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1 staff resources were prioritized for other projects  
2 and later on to Fukushima.

3 But 1 year later in October 2011 the staff  
4 issued the policy information SECY paper mentioned  
5 there, SECY-11-0152 titled "Development of an  
6 Emergency Planning and Preparedness Framework for  
7 Small Modular Reactors."

8 During the development of this SECY paper  
9 the staff considered information as outlined in the  
10 above described DOE-INL white paper. And also before  
11 issuing the SECY the staff had discussions with  
12 various governmental and private sector stakeholders  
13 in discussions related to alternative EP frameworks.

14 So regarding the SECY it focused on an EP  
15 framework that describes a general approach to  
16 scalable emergency planning zones. And we'll talk  
17 about that a little bit later.

18 So but let me give you now a short summary  
19 because we don't have time on the described EPZ  
20 categories that the SECY states. It states that EPZs  
21 could be based on a radio distance from the source and  
22 that the use of conservative calculations of the  
23 postulated accident dose can be defined by the  
24 actionable lower limit of the EPA PAGs which is 1 rem.

25 The SECY also contains discussion from

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1 other critical interrelated issues impacting EPA  
2 requirements such as we discussed today a little bit  
3 on source term and also it takes about modularity and  
4 process heat applications.

5 So just quickly as a past historical  
6 perspective I would like to mention that emergency  
7 preparedness and planning included small reactors that  
8 operated in the U.S. And we are all aware that they  
9 had 5-mile EPZ. And they were obviously Fort St.  
10 Vrain which was an HTGR but the other two were BWRs,  
11 Big Rock Point and La Crosse.

12 But what is important to state here is  
13 that the fact that the regulations in 10 C.F.R.  
14 50.47(c) (2) allows for an emergency planning zone size  
15 for gas-cooled reactors to be considered on a case-by-  
16 case basis.

17 I'll discuss further in my presentation  
18 but just a quick summary. And maybe I can use the  
19 favorite word of the day before addressing the EP  
20 issues which were presented to the NRC, DOE, INL by  
21 saying that DOE-INL's proposed approaches are  
22 reasonable. So that's the favorite word of the day.  
23 You've heard this probably 90 times today.

24 And also that the proposed approaches are  
25 responsive to the Commission's policy statement on

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1 advanced reactor. Now, that doesn't mean that there  
2 aren't policy implications. So plain and simple we're  
3 basically saying that it's important to emphasize that  
4 modular HTGR issues could have policy implications  
5 that would require future direction from the  
6 Commission as appropriate.

7 As far as alternative to EP requirements  
8 as a feedback the staff is open to considering  
9 alternatives. EP requirements and framework for  
10 advanced reactors and in fact the SECY that we wrote  
11 was for small modular reactor facilities. And we kind  
12 of included NGNP in some of the writing in there.

13 But here's a key feedback on the DOE-INL's  
14 request. And their request was that NRC establishes  
15 new policies, guidance, or revised regulation related  
16 to NGNP EP. Here's the feedback.

17 The staff does not plan to propose  
18 additional new EP policies or to revise the existing  
19 guidance for addressing NGNP EP requirements at this  
20 time. And I'll discuss this a little bit further.

21 Starting with what we call issue 1 DOE-INL  
22 requests that NRC proposes a new policy or revised  
23 regulation on how EPZ size can be scalable. And this  
24 is also seen today and throughout this presentation  
25 that their goal is to justify a 400 meter exclusion

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1 area boundary for the EPZ.

2 The feedback that the staff is providing  
3 is consistent with the policy information SECY paper  
4 that I just described. Let me additional a little bit  
5 more on the SECY paper that we wrote. As a broad  
6 summary the staff focused it on small modular  
7 reactors, namely integral pressurized water reactors.  
8 But obviously appropriate information was provided  
9 there in the discussions that were relevant to NGNP.

10 And reiterating once again the policy  
11 information SECY describes a dose distance scalable  
12 approach to determining emergency planning zones.  
13 This paper also discusses how emergency preparedness  
14 requirements can be simplified by applying a graded  
15 approach to addressing guidance used in demonstrating  
16 compliance with existing regulatory requirements.

17 So, the staff does not intend to offer  
18 anything further. And let me repeat the words in the  
19 summary report that we sent. It says that the staff  
20 does not plan to propose additional new EP policy or  
21 to revise guidance for specific changes to EP  
22 requirements at this time.

23 But as far as future proposals is  
24 concerned in the other bullets the staff is open to  
25 considering further proposal from industry or

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1 established pre-applicants. So topics for inclusion  
2 in the NGNP proposal are described in the last  
3 bullets. Actually the dash is there and which is  
4 related to PRA approach. I'm not going to read it to  
5 you. And the other one is the risk-informed criteria  
6 associated with the EPA PAG values which is talking  
7 about an acceptably low value.

8 So this way of looking into these future  
9 proposals is consistent with a purported reduced risk  
10 associated with modular reactor HTGR design.

11 CHAIRMAN BLEY: So this is really not  
12 saying anything new. It's just saying if you want to  
13 submit something that's new we'll look at it. Right?

14 MR. COSTA: That's a good way to say it.

15 CHAIRMAN BLEY: Okay.

16 MR. COSTA: Okay. On issue 2 DOE-INL's  
17 request that NRC establishes -- and these are key  
18 words -- establish specific guidance on EPZ graded  
19 approaches to applying to EPZ requirements in relation  
20 to the EPA PAGs. So the staff assessment is that NRC  
21 expects proposal from an NGNP applicant just like you  
22 just finished saying. But the proposed approaches  
23 should include -- and now we're talking about the  
24 considerations to be supported by the details of the  
25 design, the site and co-location use of facility.

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1 We'll talk about co-location a little bit later.

2 And also considerations on how potential  
3 emergency preparedness basis events may be influenced  
4 by co-location and external events impacting the site.

5 Another consideration, and we mentioned  
6 prototype earlier, is that an EPZ graded approach may  
7 be different from an NGNP prototype plant as compared  
8 to subsequent standard plants. So the staff also  
9 makes it clear that NGNP EP approach addressing the  
10 EPA PAGs must be developed by the site applicant.  
11 That is because emergency preparedness is an operating  
12 license and a combined license issue holder.

13 And I also want to make it clear that  
14 obviously future Commission direction may be  
15 appropriate to address these NGNP frameworks. As you  
16 said, as they come to us.

17 CHAIRMAN BLEY: A question not related to  
18 NGNP but related to the other work you're doing which  
19 you put on hold unless you get an application for an  
20 SMR. When you do that -- I guess that would fall the  
21 same way. When you look at establishing review  
22 criteria for an SMR using the technology-neutral sort  
23 of approach would this still apply for EP that it's  
24 only if they include something on EP that you would  
25 look at, or might there be a review of those issues

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1 more generically to support that work? Is that  
2 something you can talk about now?

3 MR. COSTA: Oh no, in general EP is a  
4 defense-in-depth program. You know, so as far as the  
5 SECY paper we mentioned that in the SECY paper about  
6 technology-neutral. And I think Don also mentioned  
7 something about association with Nuscale.

8 The real point is that it's open. I mean  
9 the EP emergency preparedness is here to stay and  
10 we're basically providing an opportunity for this  
11 scalable approach that they can come and present to us  
12 to address emergency planning zones. But keeping in  
13 mind that emergency preparedness requirements is an  
14 overall -- has an overall umbrella into all the  
15 programs of preparedness, response and everything else  
16 that comes with the defense-in-depth program.

17 But this, the last issue is the issue that  
18 has to do with co-location and DOE I know requested  
19 that NRC propose guidance on how this works out for  
20 multi-module plants.

21 The staff responded to this request to  
22 propose guidance by noting the co-location similarity  
23 to existing water reactor plants. And noteworthy, I'd  
24 like to mention, Waterford which is located near an  
25 industrial park in Killona, Louisiana.

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1           So in this case, and I'm separating the  
2 two cases here. My thoughts will come through right  
3 here. That emergency preparedness co-locations for  
4 current light water reactors are largely applicable  
5 for NGNP. And in case that the plant is solely  
6 designed to produce electricity and that it's co-  
7 located by nearby facilities. So that's one way of  
8 looking at it. So in this case regulatory guidance  
9 are already incorporating -- incorporated into  
10 existing emergency preparedness plans.

11           Now the other case, and you can see  
12 probably in your minds you've seen the NGNP cartoon of  
13 the steam or the power going in different directions.  
14 So that's what I'm calling here the coupled mode for  
15 cogeneration. This mode implies that co-located NGNP  
16 modules are utilizing nuclear heat byproducts such as  
17 steam to be subsequently used by industrial  
18 facilities. In this mode it can potentially produce  
19 electricity as well.

20           This NGNP cogeneration coupled mode  
21 carries a different regulatory nexus for emergency  
22 preparedness. And so therefore emergency preparedness  
23 must consider challenges and issues arising from the  
24 modular HTGR being coupled to the industrial facility.

25           Let me just mention some challenges that

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1 are related to this. For example, shared industrial  
2 facility SSCS, standoff considerations, potential  
3 explosions and missiles or fires, external events, the  
4 effect of chemical gases and radioactive hazards from  
5 industrial facilities.

6 And here are other interesting challenges  
7 that are related to this. Response coordination with  
8 the co-located industrial facility with the state,  
9 federal and county agency. And here's another one  
10 related to the resolution of jurisdiction issues  
11 associated with radioactive material monitoring and  
12 plant security. So you can see there is a gamut of  
13 challenges that could be there.

14 MEMBER STETKAR: Arlon, how did the Agency  
15 address all of those issues back in the mid-eighties  
16 when the Midland Plant was being licensed? Midland,  
17 Michigan.

18 MEMBER CORRADINI: And was operating.

19 MEMBER STETKAR: No, it never operated.  
20 But it was being evaluated to be licensed. It was a  
21 nuclear plant that --

22 MEMBER CORRADINI: -- steam to --

23 MEMBER STETKAR: Supplied steam to Dow  
24 Chemical, exactly your second sub-bullet under there.

25 MEMBER CORRADINI: In fact --

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1                   MEMBER STETKAR: It was -- that's what it  
2 was designed to do, Unit 1 anyway. Co-located is --  
3 Dow was across the river but Dow was the biggest  
4 chemical plant I've ever seen in my life. I'm sure  
5 there are bigger ones elsewhere in the world.

6                   But my own point is that in principle the  
7 Agency has addressed or should have thought about that  
8 issue anyway 30 years ago. And I was wondering  
9 whether you looked at any of that history in  
10 relationship to this current discussion. Or whether  
11 those concerns were even addressed at that time.

12                   MR. COSTA: That's a good point and I must  
13 admit that I'm not familiar totally with -- I know  
14 what you're talking about, I have a recollection of  
15 it, but I did not --

16                   MEMBER STETKAR: What happened was it  
17 basically was a B&We plant and they were delayed so  
18 long that Dow eventually figured a different way to  
19 get heat.

20                   DR. CARLSON: If I remember correctly in  
21 our PIRT report for -- the one that was developed.  
22 There were several PIRTs that were done about 5 or 6  
23 years ago DOE and NRC together, and I facilitated a  
24 panel on co-generation and NGNP. I believe there's  
25 discussion of that in there as kind of background

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1 information.

2 MEMBER STETKAR: I'm just curious because  
3 it would seem that there would at least be some  
4 regulatory discussion anyway if not a firm precedent.

5 CHAIRMAN BLEY: Can you remember the name  
6 of the river?

7 MEMBER STETKAR: Tittabawassee.

8 CHAIRMAN BLEY: Yes, me too.

9 MR. COSTA: So, but the two different  
10 views as you can see, one of them is pretty clear and  
11 the other ones we need to look into it.

12 You know, in fact in summary for NGNP co-  
13 location we need to expect staff considerations of new  
14 regulations. Especially as we look into lessons that  
15 we could have learned from the past, hazards  
16 assessments, accident evaluations, and security  
17 issues, all these things may come up.

18 In fact, we have an example in our SECY-  
19 11-0112. And there's a section there that we write on  
20 industrial facilities using nuclear-generated process  
21 heat.

22 And it states that any effects of the  
23 industrial facility on the reactor will be addressed  
24 as part of the NRC staff's review as part of the  
25 offsite hazards analysis. So we're not totally

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1 unaware of what's going on.

2 And then in fact on SECY-11-0152 we do  
3 mention NGNP and a statement related to that. It says  
4 that the staff does not have sufficient information at  
5 this time to determine who to propose emergency  
6 preparedness frameworks. They might need to be  
7 adjusted. So it's one of those things that we need to  
8 wait for that applicant.

9 MEMBER RAY: Well, but the applicant is  
10 waiting for some better idea of what the NRC is going  
11 to require. And so you've got a chicken and an egg  
12 situation here for which there seems to be no  
13 solution.

14 Is the problem that there isn't an  
15 applicant, or is the problem that you don't have  
16 specifics sufficient to answer the questions that DOE  
17 is trying to answer?

18 MR. COSTA: It's both. It has to do with  
19 the design, the specificity on the design and  
20 obviously it's chicken and an egg. They need to --

21 MEMBER RAY: Well, we have criteria  
22 otherwise that don't depend on having an applicant or  
23 a specific site. But they depend on --

24 MR. COSTA: Right.

25 MEMBER RAY: They state what the

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1 requirements are to provide adequate assurance.

2 MR. COSTA: Right. Well, there is an  
3 element of timing here also as I stated before. Since  
4 this is an issue for operating license or a combined  
5 license it's something we can look into the future.

6 MEMBER RAY: Why do you say that, by the  
7 way?

8 MR. COSTA: Because that's the nature of  
9 emergency preparedness.

10 MEMBER RAY: Okay. So I mean this  
11 wouldn't be, you know, basically what you're saying is  
12 that you can't address these criteria just with a Part  
13 50 application that has a site but doesn't satisfy all  
14 the information requirements for an operating license.

15 MR. COSTA: Well, an applicant has an  
16 opportunity to provide emergency preparedness  
17 information even during an ESP application.

18 MEMBER RAY: That's right.

19 MR. COSTA: So, but the staff would need  
20 information in order to assess the design and the  
21 specificity on the designs in order to understand  
22 things as we discussed. In fact the whole meeting  
23 today came to this point of emergency preparedness,  
24 everything that was set up to now enforces the issue  
25 of emergency preparedness. And we need to understand

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1 all that in order to come up with emergencies.  
2 Especially if you want to have a scalable emergency  
3 planning zone and then you want to be meeting the EPA  
4 PAGs. So it's pretty challenging.

5 MS. BRADFORD: This is Anna Bradford. I  
6 would just make one point about the chicken and the  
7 egg situation. I don't think it's quite a chicken and  
8 egg just because we do have EP regulations and  
9 guidance on the books. If they wanted to just meet  
10 those we wouldn't even need to have the discussion.  
11 They want to do something different. So if you want  
12 to do something different tell us what you want to do.

13 MEMBER RAY: Well, precisely.

14 MS. BRADFORD: Right, and we'll evaluate  
15 that in the context of our regulatory framework.

16 MEMBER RAY: Yes, well they have tried to  
17 do that I guess and it falls short of what you need is  
18 the best I can figure out. But the point is that,  
19 yes, there are requirements so why can't we have  
20 requirements that apply to something other than what  
21 the existing frameworks were developed for.

22 And you know I realize you have to have a  
23 certain amount of information in order to do that.  
24 But on the other hand it almost seems as if we're not  
25 prepared to do anything until somebody appears in the

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1 form of an applicant. But that's not going to happen  
2 until they have some better assurance of what the  
3 answer's going to be. And that's why I called it a  
4 chicken and an egg.

5 MS. BRADFORD: I think I would argue it  
6 the other way and say I'm not sure we would spend our  
7 resources to develop a proposed alternative, and that  
8 alternative might not be what the applicant wants to  
9 do either.

10 MEMBER RAY: That's, you know, that's  
11 fair. I mean it does take time and effort to do this.  
12 That's why we're all sitting here instead of my being  
13 at home or en route here as I would otherwise be. But  
14 the upshot turns out to be that we're basically not  
15 achieving anything productive. And I guess that's the  
16 conclusion you have to draw from it.

17 MR. COSTA: well, there is a path. One of  
18 the things that we coded was the case-by-case basis.  
19 So that was always there available.

20 And then as part of this progression we  
21 credited the white paper that they wrote and then  
22 after we considered that in public meetings we also  
23 provided to the applicant an approach that can be  
24 scalable specifically for EPZ. And then what we're  
25 basically said is reinforcing what Anna's saying. I

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1 mean we do have regulations that we can license in  
2 HTGR but there is possibly a better way. So just come  
3 and tell us and we'll be ready to listen.

4 CHAIRMAN BLEY: Well, I think, you know,  
5 when this whole business came out of the law saying  
6 DOE and NRC work together on this. And in most of the  
7 areas you've taken a look at their proposed framework  
8 and said yes, we kind of agree with this with a few  
9 exceptions for you to fill in.

10 In this area you kind of said well, submit  
11 an application and then we'll look at it. So it seems  
12 like you treated it a little bit differently than you  
13 did all the other issues on the table. Am I missing  
14 the boat on that?

15 DR. CARLSON: We didn't say submit an  
16 application because the advanced reactor policy  
17 statement says you engage before they submit an  
18 application. Pre-application review. So when we're  
19 in a pre-application review whether it's -- we expect  
20 a submittal and some plant item at a time. That's the  
21 time to engage. But that does require some level of  
22 design information, some specific proposals.

23 MEMBER RAY: Well, that's what I guess I'm  
24 saying is that you don't have enough that you can  
25 respond to even hypothetically. And it may be that

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1 your hypothesis would be -- not suit the applicant.  
2 But anyway, as I say, the aim here, the SECY  
3 requirements are probably if not the most important,  
4 one of the most as you know. For this thing to get  
5 any prospect of going forward.

6 And I still, I'll stick with my chicken  
7 and egg metaphor.

8 CHAIRMAN BLEY: But at this point why  
9 don't we go ahead.

10 MR. COSTA: Okay. I turn it over to you,  
11 Don.

12 DR. CARLSON: So that's all we had. Of  
13 course if you have other questions we have backup  
14 slides but I think we've gone through everything that  
15 we planned to present.

16 CHAIRMAN BLEY: Thank you. At this point  
17 I'll ask if there's anyone, a member of the public or  
18 otherwise here in the room who would like to make a  
19 comment. We'll listen to you at this point. And  
20 we're checking to see if there's anybody left on the  
21 line and if anyone else has comments.

22 DR. CARLSON: We didn't ask Mike Kania for  
23 his expert insights but I appreciate his being  
24 available and I hope he found it a good meeting.

25 CHAIRMAN BLEY: Okay. Mike, are you there

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1 on the line? Can you hear us and can we hear you?

2 MR. KANIA: Yes, I am on the line. I  
3 appreciate it. Thank you.

4 DR. CARLSON: If you feel that we failed  
5 to say something essential you can say it now.

6 MR. KANIA: The only comment I wanted to  
7 make is that you were asked earlier on that you know,  
8 all these RAIs were generated such and there was  
9 interaction between NRC and INL, DOE and INL, on  
10 these. But I think there was an excellent  
11 interaction.

12 And where you see the changes kind of  
13 effect is in the program plan that the DOE is looking  
14 at. I mean they're doing things nowadays that just  
15 wasn't possible 20-30 years ago. They're  
16 systematically doing the math balances, they're using  
17 techniques that were never applied before. The amount  
18 of mileage we're getting out of the R&D nowadays is  
19 just, it's just orders of magnitude more than what we  
20 got previously.

21 CHAIRMAN BLEY: Okay, thanks Mike.

22 Anybody else on the line care to make any  
23 comments? Then at this point I'll ask members of the  
24 subcommittee to offer up any of their comments. I'll  
25 start with Mike Corradini. Oh, I'm sorry.

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1                   MEMBER CORRADINI: So I cede some of my  
2 time to DOE and their contractors about some of the  
3 questions we asked.

4                   CHAIRMAN BLEY: You don't need to cede  
5 time.

6                   MEMBER CORRADINI: I know, I'm just  
7 joking.

8                   CHAIRMAN BLEY: I did say I wanted to give  
9 you folks a chance to make any closing comments you'd  
10 like if you want to make them.

11                  MR. KINSEY: I don't have anything. I  
12 think Dr. Petti may have a couple of.

13                  MR. PETTI: Just I did not get into  
14 details but some of the issues that you have raised  
15 about path dependence and temperatures, the  
16 irradiation. Unfortunately you won't be able to  
17 attend our R&D meeting but you'll see that we have  
18 incorporated those in AGR-5/6/7 that's going to have  
19 a much broader irradiation envelope than say I think  
20 10 years ago when we started. Stay tuned. It's very  
21 active and interactive.

22                  DR. CARLSON: So I don't know how much  
23 that would reduce the scope of prototype testing but  
24 that would be good information.

25                  CHAIRMAN BLEY: Okay, thank you.

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1                   MEMBER CORRADINI: So I have two things.  
2                   The first one, first of all I think DOE and their  
3                   contractors have done a nice job of reminding us what  
4                   we heard in January. And staff, I appreciate their  
5                   responses, very specific responses to some of what the  
6                   DOE had asked.

7                   I guess there's two things that came out  
8                   of this that I hadn't put it in perspective but I'm  
9                   looking at the chairman for the intent of something to  
10                  put in the letter. So two things.

11                  So first, provocative which is it seems to  
12                  me with all due respect staff is back in 1958. You're  
13                  basically saying I've got a siting study, I've got an  
14                  MCA for the siting study and I don't know how I got  
15                  the numbers but show me an MCA. And now if I now move  
16                  forward 55 years to where we are we don't want to use  
17                  any sort of risk insights as to the probability of  
18                  these events to rank-order or think through this. To  
19                  me that's interesting, surprising, not appropriate.  
20                  Okay?

21                  And the reason I'm saying that is if I put  
22                  the same sort of argument for light water reactors and  
23                  I went back to the TIB-1484 and I said what did I ask  
24                  licensees at the beginning of their light water  
25                  reactor generation to do. And then I now have the

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1 ability to calculate and see what's the frequency of  
2 that accident sequence that gave me that it would be  
3 at some number.

4 And I'd be willing to bet the frequency to  
5 get an engineering judgment extreme event for the  
6 HTGR, whatever it's called, the gas reactor is going  
7 to be a frequency not at that same frequency level but  
8 much lower. And to say that we're not going to at  
9 least acknowledge the fact that it's less frequent, of  
10 lower probability or at least have something as that  
11 as part of the mix surprises the heck out of me.

12 So I thinks somehow in the letter we have  
13 got to express the need to say we ought to have pretty  
14 much of a fair comparison to what we can analyze  
15 relative to both the consequence as well as the  
16 probability. Because I do think staff is right, there  
17 is not as mature as the light water reactors today,  
18 but I don't think we have to go back to an approach  
19 where we kind of just use engineering judgment without  
20 calculational expertise as to what the frequency of  
21 some of these events are that lead us to these.  
22 That's one. Two.

23 The second thing I think the staff said  
24 that I still don't completely appreciate but it really  
25 is something that I think DOE has got to worry about

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1 is that if the fuels testing program is very good or  
2 extremely good but still is lacking in some area I  
3 hear staff saying, I could be misinterpreting, that  
4 you're going to have to do some sort of ascension  
5 testing with the first one of these which makes some  
6 plausible sense.

7 But it seems to me that's got to be  
8 discussed with DOE now or otherwise they're going to  
9 leave here when we close all of this because of lack  
10 of funding going forward and they're going to expect  
11 X and staff is going to expect Y and there's going to  
12 be a divide there. And anybody that comes back to  
13 this that actually wants to build one of these as a  
14 prototype are going to have to do a whole series of  
15 ascension testing.

16 And I just sense a bigger gap there than  
17 maybe I first expected. And it may be just as I  
18 wasn't paying close enough attention.

19 DR. CARLSON: I would like to say  
20 something if it's okay that I probably should have  
21 said early on. Mike Mayfield has been very clear  
22 about this whenever he has a chance to say something.

23 MEMBER CORRADINI: I'm sure he has. I  
24 know him.

25 DR. CARLSON: And the vision is let's

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1 figure out how to get the prototype to exist. So as  
2 far as we're talking about the first of the kind  
3 prototype, whatever you want to call it, the lack of  
4 maturity, the PRA technology, it's something we have  
5 to keep in mind.

6 And once you get the prototype up and  
7 running that -- and there are no huge surprises. And  
8 you learn something by doing actual measurements and  
9 testing. Well, maybe we can back off on some of these  
10 conservatisms.

11 Like I said before, if we were talking  
12 applying similar ideas to a light water reactor then  
13 maybe something like an option 3 would be appropriate.  
14 So again, Mike Mayfield says over and over again let's  
15 figure out how to license the prototype. And then the  
16 licensing basis for the standard plant may be adjusted  
17 based on those insights.

18 MEMBER RAY: Yes. I'd make the prototype  
19 of Part 50 application. But who's going to pay for it  
20 is still an open question.

21 MR. SHEA: I just want to address another  
22 issue brought up about the source term in 1958. I  
23 actually think we're probably closer to 1972. I've  
24 got my bell bottoms on. But in reality in 1958 we  
25 assumed the core melted without a lot of knowledge on

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1       how and it was a safety case that designed a  
2       containment so that you would protect the public.

3               So if you look at what they're proposing  
4       here and that the staff is accepting is a mechanistic  
5       source term that says there's no way that we can melt  
6       the core. That's a tremendous fast-forward. That's  
7       definitely an advance of thinking over the years.

8               So, and combine that with the fact that  
9       we're not saying the PRA can't be used. In fact no,  
10       we're saying that in fact the PRA is a strength  
11       because what it does in reality is it does not buy us  
12       the defense-in-depth in terms of all prevention. It  
13       puts some into mitigation.

14               In the past, in 1958 we put all the eggs  
15       into prevention. And we got a lot of accidents  
16       because of simple things like the loss of offsite  
17       power that could have been -- if it was evaluated  
18       under PRA and saw the strengths in both the prevention  
19       and mitigation those things might have been prevented.  
20       So no, I think it's definitely a modern look at how to  
21       evaluate reactors.

22               And I'd also comment that I think what we  
23       have outlined in our assessment given that there's a  
24       lot of like, you know, of course words where there's  
25       no policies, et cetera. However, if you look at it

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1 we've provided a clear path in my mind on how to  
2 license one of these reactors or any advanced  
3 reactors.

4 CHAIRMAN BLEY: Okay, thank you. Mr.  
5 Skillman.

6 MEMBER SKILLMAN: The concerns that I had  
7 were pretty much addressed when we went through the  
8 discussion about the strength of the probabilistic and  
9 deterministic methods being used. Your example of the  
10 rod ejection and actually needing to get a design up  
11 and operating in order to have greater understanding  
12 of how the machine is going to behave.

13 I think that there are some real  
14 challenges that lie ahead and that is seeing how the  
15 TRISO fuel operates in a real situation. And I think  
16 that the complexities of operating multiple reactors  
17 at a single site brings with it operational issues  
18 concerning staffing and attention to detail, how  
19 multiple units might behave individually and together.

20 I believe the emergency planning problems  
21 -- I shouldn't say problems. The emergency planning  
22 challenges will be new for this new type of reactor.  
23 We continue to discover new issues even in the current  
24 fleet relative to emergency preparedness and emergency  
25 planning and interaction with the state and local and

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1 federal authorities.

2 This will be a brand new learning  
3 experience should one of these ever be built or should  
4 a group of these ever be built. And so I think there  
5 needs to be extreme attention to detail because in a  
6 way this is introducing a new reactor thank you to  
7 civilian users.

8 I believe that even though there have been  
9 prototypes, there have been other gas reactors, this  
10 will be new. And so there needs to be a sense of  
11 caution that accompanies progress for this reactor  
12 type. Thank you.

13 CHAIRMAN BLEY: Thank you. Mr. Stetkar.

14 MEMBER STETKAR: Yes. I'd echo Mike's  
15 concerns about however you want to characterize  
16 deterministic versus probabilistic approaches to  
17 maximum credible accidents. He's much more eloquent  
18 about these things than I am.

19 A couple of other things, and I mentioned  
20 them earlier, just to kind of reiterate. And that is  
21 a bit of a concern about what I still believe is an  
22 inconsistent approach to addressing the effects of  
23 uncertainty and the consequences among the three or  
24 four depending on whether you consider DBAs a  
25 different category of licensing basis events.

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1           And something I mentioned pretty quickly  
2 because it gets into a lot of details but I think  
3 there's some need for improved clarity on the notion  
4 of what event sequences are and how that notion of  
5 event sequences is and will be used to identify and  
6 categorize licensing basis events. Because there  
7 seems to be I don't want to call it a disconnect.

8           There seems to be a gap there. Because I  
9 can read words that sound like they say the right  
10 things but I see examples that might not implement  
11 those words. So with that that's basically what I  
12 have.

13           CHAIRMAN BLEY: Okay, Harold.

14           MEMBER RAY: Well, I certainly buy the  
15 idea that the best path forward is a prototype that  
16 doesn't have to solve all of the problems as if they  
17 were being solved for all time and that isn't  
18 dependent upon the usual commercial considerations in  
19 order to move ahead. That may be the only way that we  
20 can deal with some of these issues.

21           I think there's a general feeling that  
22 there are inherent safety advantages that should be  
23 recognized and particularly with respect to the  
24 ability to site a plant like this. But there are also  
25 obviously unanswered questions as well.

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1           And at this point in time to be committed  
2           as the regulator to recognize those advantages without  
3           knowing more of the details is probably a bridge too  
4           far. So I hope DOE feels like it's been a worthwhile  
5           exercise to this point. But it certainly falls short  
6           of what some had hoped we'd be able to accomplish.

7           Having said that I can't suggest what we  
8           might put in the letter. I'll have to think about.

9           CHAIRMAN BLEY: I'd appreciate any  
10          thoughts. Tom, I know you're going to send us a  
11          report but if you want to summarize those vast number  
12          of comments I'd appreciate it now.

13          DR. KRESS: I would like to say that I'm  
14          glad to see this exercise going on because I consider  
15          the approach an improvement in the way we regulate  
16          licensed reactors. And that it's superior to what  
17          we've been doing.

18          And I think it's more what's -- I see it  
19          is more closely associated with option 3 in terms of  
20          probabilistic versus deterministic. That doesn't  
21          bother me because as best I recall the ACRS letter we  
22          recommended option 3.

23          But anyway, it really doesn't bother me.  
24          I don't know how to separate out deterministic versus  
25          probabilistic too well anyway.

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1 I do agree with a number of comments,  
2 Corradini's and Gordon, but especially Gordon. I  
3 worry about one control room and one operating people  
4 for modular reactors. I don't know if that's a  
5 problem or not but it's something we're not used to  
6 and it could give operational problems. I don't know  
7 what they are and I don't know if we'll ever find out.  
8 But I kind of agree.

9 I particularly agree with John Stetkar's  
10 issues with the questions of inconsistencies in using  
11 the uncertainties. And also the clarifying what  
12 actually is a sequence is. When I first read all this  
13 I thought the sequences were every sequence I'd get  
14 out of a PRA. That's a lot of sequences and I don't  
15 know if they bundled them or not. But for gas-cooled  
16 reactors you don't really have that many sequences.  
17 You might be able to just look at all of them.

18 But I had some questions about the top-  
19 level regulatory criteria. Because you do have to  
20 specify up front how many modules you're going to have  
21 before you can see whether you're approaching the top-  
22 level criteria.

23 And I think the tendency would be maybe to  
24 choose those number of modules that keeps you below  
25 the criteria but gets you up close enough to it. And

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1 I don't see any criteria on how close we ought to  
2 allow in terms of uncertainties.

3 There was some on selecting SSCs. And I  
4 also worry about that because I think having a stair  
5 step top-level regulatory criteria can affect the SSCs  
6 you come up with depending on how close you are to  
7 that line. I would much prefer a straight line non-  
8 risk averse thing. I think Tom had talked about  
9 before.

10 I also thought, and I'm not sure I got the  
11 answer right, I looked at the effect of the dropping  
12 and SSC to see what its effect was on both risk and  
13 consequence. I got the impression that you looked at  
14 those SSCs one at a time.

15 I had the same problem that John had. It  
16 depends on what order you do the safety function as to  
17 what kind of answer you would get. Plus, I see that  
18 maybe one SSC puts you into a different frequency  
19 category or consequence.

20 But if you did two of them even if they're  
21 not in the same safety function if you're separating  
22 down the line on the thing then those two together  
23 might put you in the unacceptable regions of a top-  
24 level criteria. And I was wondering why -- those  
25 being the safety-related. But they're relatively

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1 independent. Maybe that's the issue.

2 So, the one thing that I keep harping on  
3 every time because it's an issue I've had back when I  
4 was on the ACRS was we're still using the prompt  
5 fatality safety goal as our risk acceptance criteria  
6 for all the -- building all the PRA events.

7 I'm still saying that's not the control  
8 room, it's the societal risk of total deaths and all  
9 the dollars. And I'm glad to hear Tom mention that.  
10 That has been looked at to some extent. But we don't  
11 have any acceptance criteria for societal risk to  
12 compare it to. Or we don't -- maybe we need some.

13 I think this is appropriate for these new  
14 reactors because even though meeting the PAGs at the  
15 EAB probably means they're going to meet the two QHOs  
16 very well, but you may not meet the societal risk  
17 because we don't know what it is and it's bigger and  
18 doesn't take as much release to get a pretty good  
19 amount. So that's been one of my issues. I think we  
20 need to think about the total effects of the release.

21 I think there's going to be a lot of work  
22 to -- and I think some of it's going on to get good  
23 fission product release in transport models,  
24 particularly issues with the plateout and re-  
25 vaporization from primary systems, and effects of

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1 dust. How do we know how much dust is going to be  
2 there.

3 And I think there's still some issues on  
4 how you address air ingress. Every time I talked  
5 about gas-cooled reactors when I used to work, that's  
6 before I quit working, I always asked how about  
7 dropping a vein with air in there. You know, we had  
8 Chernobyl with all that burning going on. I don't  
9 think burning of this graphite with air ingress is a  
10 big issue but I think it needs to be put to bed and  
11 say oh, we're really not going to have that kind of  
12 frequency of air ingress or I don't think you're going  
13 to have -- with this kind of graphite I don't think  
14 you're going to have so much of a problem with the  
15 burning of it.

16 But I do think you need to address the  
17 issue. You need to know what the effects of air  
18 ingress and the graphite interaction are. I'm not  
19 sure I saw that in the proposed research program.

20 And I'd also think that -- I would support  
21 one of these operational processes where you raise the  
22 power up in steps. Because I'm worried about -- I  
23 mean the fuel quality has to be so good that it  
24 doesn't take much of a mistake to not have the fuel  
25 quality you think.

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1 I think one of the things you're going to  
2 need to do is be able to assess the fuel quality as  
3 you operate. And I was glad to hear there's  
4 intentions to putting in instrumentation and measuring  
5 reactivity, plateout and airborne, in the RCCS as you  
6 go along.

7 But I think, I haven't seen any criteria  
8 yet on what would you do when you start getting too  
9 much activity, and what is too much, and when do you  
10 decide on when to shut down. I would like to see more  
11 on that.

12 And I think the issue with PRA being not  
13 quite as mature as we'd like is an issue. I think you  
14 address it with trying to determine what the  
15 uncertainties are. And I don't know if we have  
16 programs or ways to get the uncertainties. You know,  
17 you look at all the safety functions and the failure  
18 of SSCs and how they lead to the final product in both  
19 frequency -- frequency is easier to get consequences.  
20 But I think you need a lot of data to get a mature  
21 PRA.

22 Let's see. And I don't know how to -- I  
23 think to do with modular reactors my feeling is it's  
24 probably sufficient to use consequences for one module  
25 and just deal with the frequencies for multiple

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1 modules. But I haven't thought through the issues of  
2 simultaneous initiating events. Even those I think  
3 it's probably all right to do it that way but maybe  
4 not. I haven't thought that one through yet.

5 But I think we need to do a little more  
6 thinking about what actually defense-in-depth is, how  
7 we define it. When is it we have sufficient -- how do  
8 we deal with it in terms of uncertainties and  
9 confidence levels. And how we deal with it in terms  
10 of redundancy and that sort of stuff.

11 In general, you know, in spite of the fact  
12 that I'm throwing up things like this I like what I've  
13 heard. I think the staff's doing a good job. I think  
14 that the applicant or whatever, the DOE-INL people, I  
15 think it's a good piece of work. I'm glad to see it  
16 going on.

17 CHAIRMAN BLEY: Thank you. And I just  
18 have a few comments. I said most of the things I  
19 wanted to during the session.

20 I dwelled a lot on an issue of the  
21 deterministic DBAs. And I think that's probably not  
22 a big issue because to my thinking when they go  
23 through building the best PRA they can with all the  
24 scenarios they can think of. They use the same kind  
25 of process you're talking about. If one generates new

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1 sequences they didn't think about they must get  
2 reflected back into the PRA and get evaluated.

3 In the end I think the format they laid  
4 out, the framework for defense-in-depth is perhaps  
5 more thorough than most I've seen and gives a good way  
6 to require additional protection in areas where we're  
7 not completely confident on the uncertainties that  
8 have been evaluated or any of the technology issues  
9 that we'd hope to get to see through the prototype.

10 We keep hearing credible events, and we're  
11 only going to look at credible events, we look at  
12 credible events. It's an ill-defined term and it gets  
13 us into trouble every time. You look at things that  
14 are physically possible and once you do that you  
15 either take care of them because you're not sure if  
16 they can occur or not, or you look at them  
17 probabilistically and evaluate them. I just get  
18 uncomfortable with that phrase tossed around so much.  
19 It's really ill-defined.

20 In the same vein I don't think a  
21 deterministic look solves our problems. I mean, where  
22 we started way back when was we had a bunch of smart  
23 guys think up everything they could think of that  
24 would happen as judgment. Well, we've now got a bunch  
25 of guys trying to think up everybody they can account

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1 for and maybe analyze them a little more thoroughly.

2 But I don't see those as separate things.  
3 You need that same process to come up with the events.  
4 If you come up with more than people thought of you  
5 incorporate that in the process.

6 The one interesting thing about what John  
7 brought up, and I haven't gone back and looked  
8 carefully enough because I didn't notice it, and Tom  
9 did too, this idea that when you change the ordering  
10 of the things in the event trees and you get into a  
11 different category so that what you've really got is  
12 a model that's not coherent for some reason. And  
13 there are lots of reasons that can happen. So I think  
14 it would behoove everyone to go back and look at that  
15 and see what's going on and find a way to account for  
16 it.

17 It needs to be done and there's a whole  
18 source of technical issues that can be involved in  
19 that and they range from shadowing of one thing with  
20 the other to incorporating the effects of one and the  
21 other. And if you think of it as conditional, you  
22 have to look at that whole set as conditional and make  
23 sure we get it right.

24 Having a system that lets you come out  
25 with different categorizations depending on the whim

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1 of the analyst and how they break out their model or  
2 how they order it is something you've got to find a  
3 way around. That could be a really significant  
4 problem.

5 And I'd throw out the PRAs when they  
6 finally come in for a real design need to incorporate  
7 all those external events, the whole group of them.  
8 But they also need to incorporate human actions  
9 including what's historically been called errors of  
10 commission. But the kind of things you brought up,  
11 turning on the circulators.

12 If that's a big deal that needs to be in  
13 the model as a possible thing that could happen. And  
14 it eventually gets worked into the training and  
15 everything else to make it much less likely that they  
16 take the wrong action.

17 But you can't just look at operators doing  
18 what you expect them to do. You have to look at what  
19 they might do to get us into trouble. And the  
20 thinking process you talked through is what has to be  
21 there and has to be in the PRA as well.

22 Anyway, thanks everyone. I was very  
23 impressed with the presentations and the discussions  
24 and how this went on. I don't know what happens in  
25 the future. We're interested in hearing how the fuel

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1 work continues. I wish more were continuing in other  
2 areas but I guess it won't for some time.

3 Thanks everyone and my compliments to you.  
4 And at this point the meeting is adjourned.

5 (Whereupon, the foregoing matter went off  
6 the record at 5:16 p.m.)

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U.S. DEPARTMENT OF  
**ENERGY**

**Nuclear Energy**

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# **ACRS Future Plant Designs Subcommittee Meeting**

## **NGNP Introduction**

**Carl J. Sink**  
**NGNP Program Manager**  
Office of Nuclear Energy  
U.S. Department of Energy

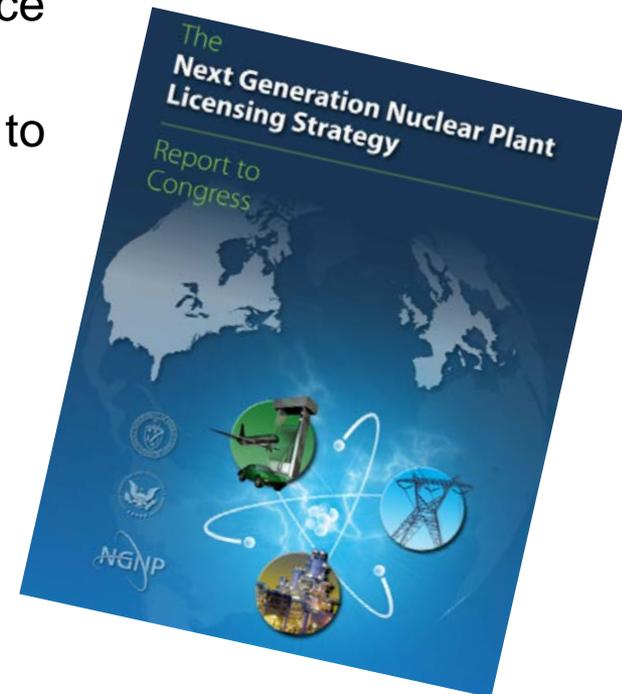
**April 9, 2013**



# NRC-DOE Licensing Strategy – 2008 (Report to Congress)

■ **“It will be necessary to resolve the following NRC licensing technical, policy, and programmatic issues and obtain Commission decisions on these matters”**

- Acceptable basis for event-specific mechanistic source term calculation, including the siting source term
- Approach for using frequency and consequence to select licensing-basis events
- Allowable dose consequences for the licensing-basis event categories
- Requirements and criteria for functional performance of the NGNP containment as a radiological barrier



# Continued DOE Focus on Licensing Framework

**Secretary Chu letter to Congress in October, 2011 reinforces the priority that DOE places on establishing the HTGR licensing framework, based on the related NEAC recommendation**

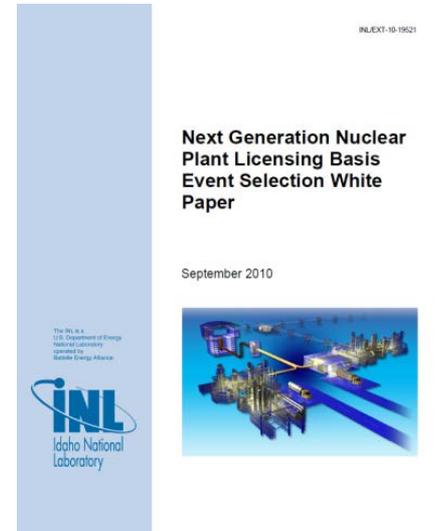
- “The NEAC also recommends that the Department continue research and development, as well as interactions with the Nuclear Regulatory Commission, to develop a licensing framework for high temperature gas-cooled reactors.”



# Licensing Framework Interactions with NRC

**DOE appreciates NRC's support of the significant level of interaction that has taken place within the NGNP program for licensing framework development:**

- Jointly established Licensing Strategy for adaptation of existing regulations
- Review and feedback on NGNP white papers covering various licensing framework topics
- Significant number of public meetings (18 total) over the past 3 years
- Review of the NGNP responses to approx. 450 requests for additional information
- Review of technology development plans
- Approval of the applicable portions of the NGNP Quality Assurance Program Description
- Feedback on the highest priority licensing issues, as described in NGNP's July 6, 2012 letter



## NRC Staff Positions Requested by DOE

- **NGNP transmitted a letter to NRC on July 6, 2012 reinforcing areas of priority for licensing framework development**
  - Consistent with focus areas summarized in NRC to DOE letter dated February 15, 2012
  
- **NRC staff positions have been requested in four key areas**
  - Licensing Basis Event Selection
  - Establishing Mechanistic Source Terms
  - Functional Containment Performance Requirements
  - Development of Emergency Planning and Emergency Planning Zone Distances

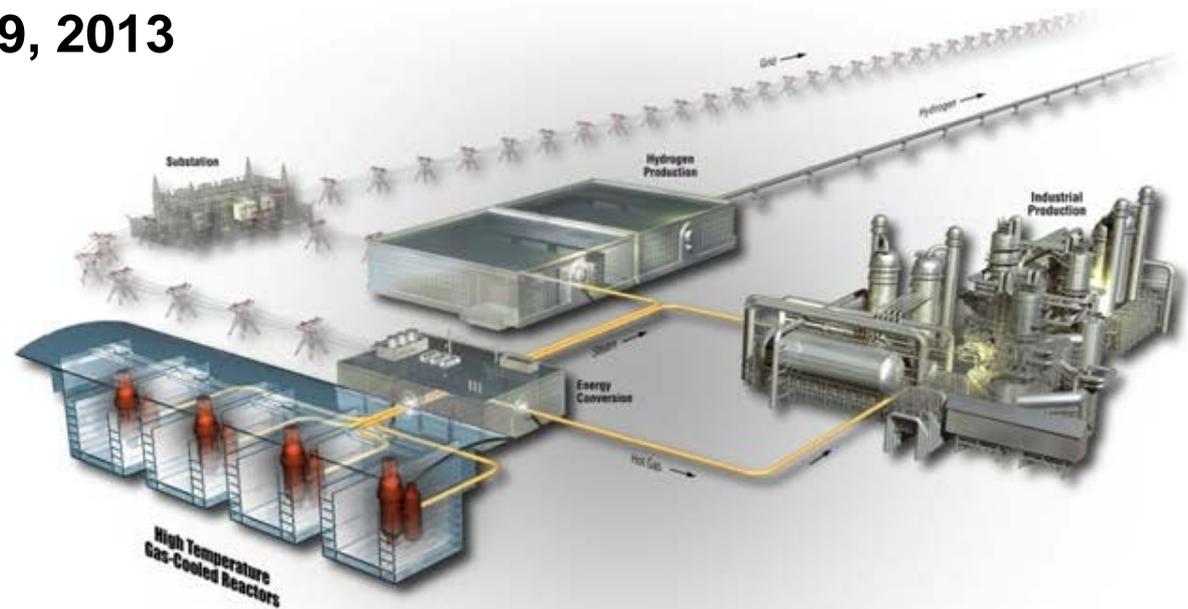
# Reducing Regulatory Uncertainty for HTGRs

- DOE is focused on the resolution of long-standing HTGR licensability issues, and the establishment of key parts of the NGNP licensing framework
- The proposed NGNP framework provides a process for assuring, with associated fuel qualification program results to date, adequate protection of the public over a wide spectrum of internal and external events at a multi-reactor module plant facility, with significant margin to the regulatory requirements for offsite dose
- DOE looks forward to today's follow-on meeting regarding the most significant topics affecting the licensing framework for NGNP

# Summary of January 17 NGNP Presentations

## ACRS Future Plant Designs Subcommittee Meeting

April 9, 2013



## ***NGNP January 17 Presentations to the Subcommittee Addressed Five Areas***

- High Temperature Gas-Cooled Reactor (HTGR) Safety Approach and Design Basis
- Licensing Basis Event (LBE) Selection Process
- Functional Containment and Mechanistic Source Terms
- Siting Source Terms (SST)
- Fuel Qualification and Radionuclide Retention

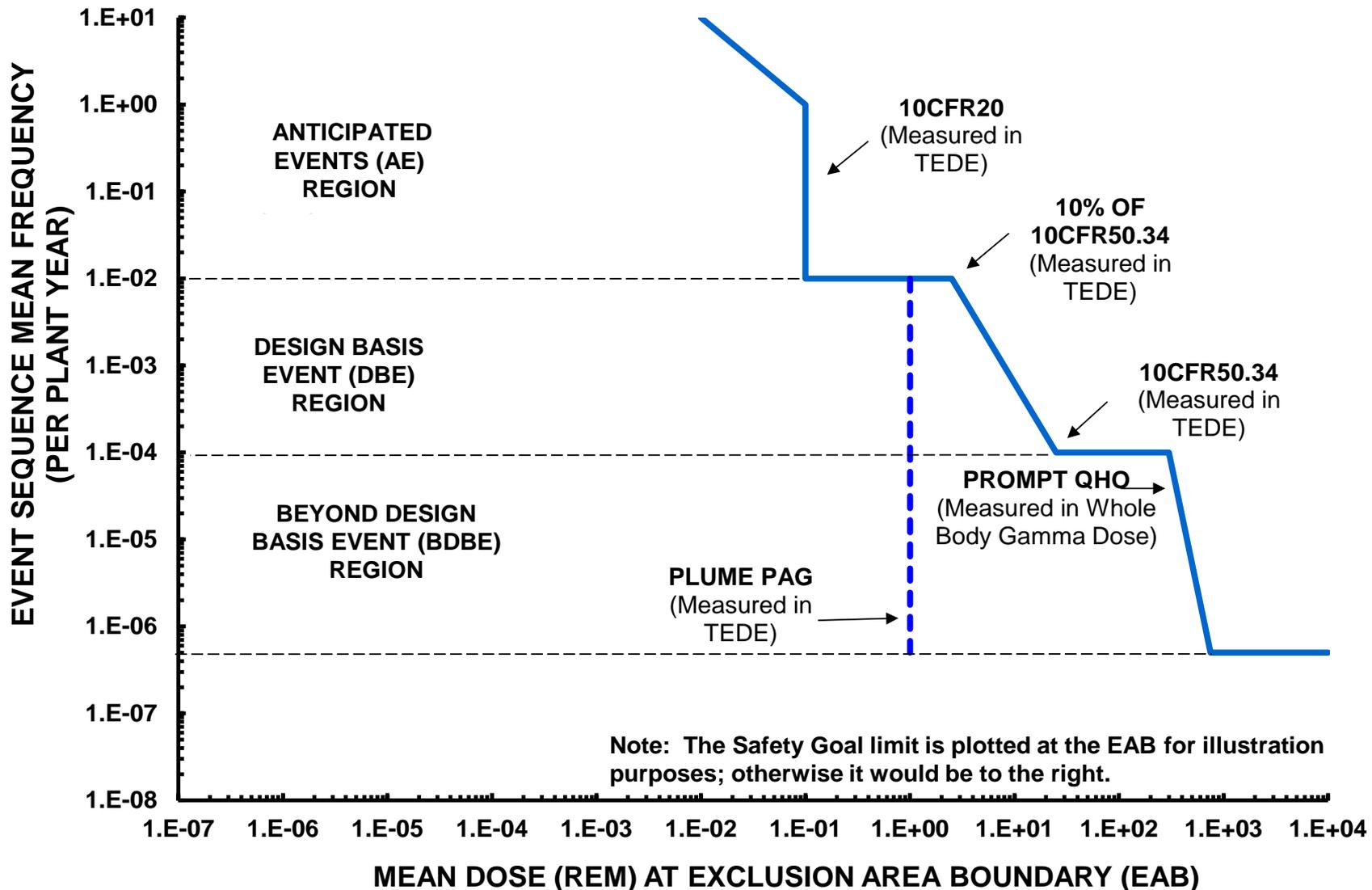
# ***Safety Approach and Design Basis Summary***

- Top objective is to meet the NRC offsite dose requirements and EPA Protective Action Guides (PAGs) at the Exclusion Area Boundary (EAB) for spectrum of events within and beyond the design basis
- Responsive to Advanced Reactor Policy
- Modular HTGR designs employ multiple concentric, independent barriers to meet radionuclide retention requirements – these barriers comprise the Functional Containment
  - Fuel Elements
    - Fuel kernels
    - Particle coatings (most important barrier)
    - Compact matrix and fuel element graphite
  - Helium Pressure Boundary
  - Reactor Building
- Emphasis is on radionuclide retention at the source within the TRISO fuel coatings
  - Passive heat removal
  - Control of heat generation
  - Control of chemical attack

## ***LBE Selection Summary***

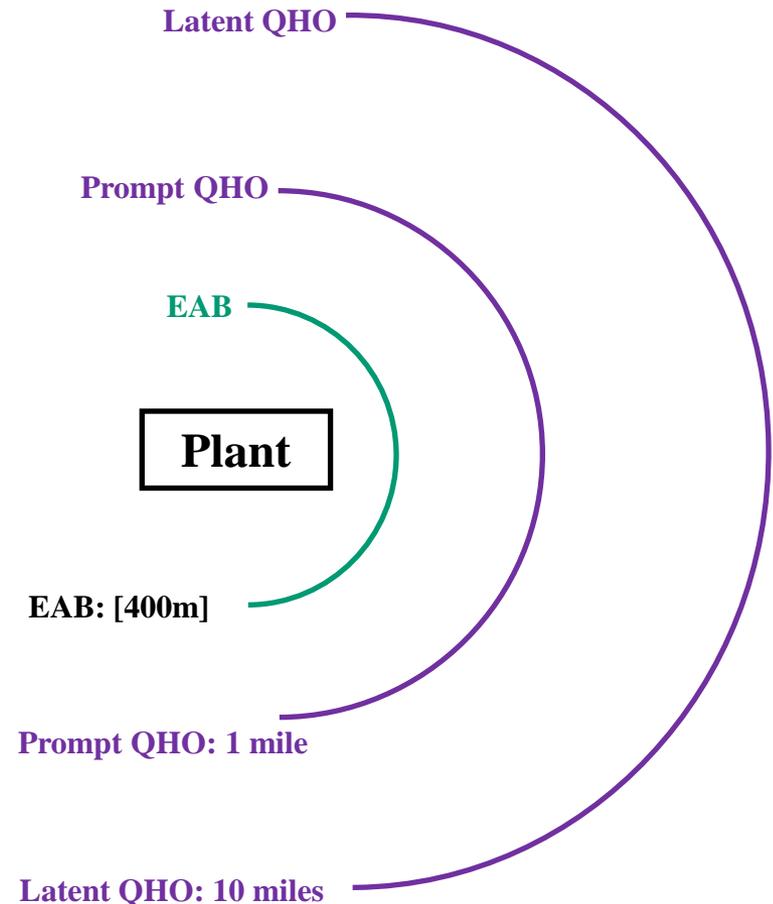
- Licensing Basis Events determine when Top Level Regulatory Criteria (TLRC) must be met
- Selected during design and licensing process with risk insights from comprehensive full scope PRA that considers uncertainties
- Include anticipated events (AEs) (expected in life of plant), design basis events (DBEs) (not expected in plant lifetime), beyond design basis event (BDBEs) (not expected in fleet of plant lifetimes), and design basis accidents (DBAs) (Ch 15 events derived from DBEs with only safety related structures, systems, and components [SSCs] available)
- Safety classification focuses on examining SSCs available and sufficient to successfully perform required safety functions to mitigate spectrum of DBAs

# NGNP Frequency-Consequence Curve



# Selection of TEDE and EAB for TLRC Dose Limits

- Mean total effective dose equivalent (TEDE) selected for consequence measure
- The EAB was selected based on the following considerations:
  - It is the distance specified for the 10CFR20 and one of the 10CFR50.34 dose limits
  - Design objective is to meet the PAGs at the EAB to avoid public sheltering during off-normal events, with the goal of having the LPZ and EPZs at the same distance as the EAB (approximately 400m)
  - If met, the plant will have large margins to the average individual risk Quantitative Health Objective (QHOs) as measured within annular regions from the EAB to 1 and 10 miles, respectively
  - Supports co-location with industrial facilities



# Licensing Basis Event Evaluation Structure

Event Category/Type	10CFR20 – 0.1 rem	10CFR50.34 – 25 rem	EP PAGs – 1 rem	QHOs – Individual Risks
AEs	Mean Cumulative @ EAB			Mean Cumulative @ 1 and 10 miles
DBEs		Upper Bound @ EAB	Mean @ EPZ*	Mean Cumulative @ 1 and 10 miles
BDBEs			Mean @ EPZ*	Mean Cumulative @ 1 and 10 miles
DBAs		Upper Bound @ EAB		

\*Design Objective: EPZ = EAB

## ***Design Basis Accident Derivation and Dose Limits***

- DBAs (analyzed in Chapter 15 of SARs) are deterministically derived from DBEs by assuming that only safety-related SSCs are available
- The event sequence frequency for some DBAs is expected to fall in or below the BDBE region
- Consistent with traditional practice, DBAs must meet the DBE dose limits based on conservative (upper 95%) analyses, including those with event sequence frequencies in or below the BDBE region
- DBAs are not derived from BDBEs. BDBEs must meet the NRC QHO on a cumulative basis based on an expected (mean) analysis

# ***Performance Standard for Functional Containment***

NGNP's upper tier performance standard for the functional containment ensures the integrity of the fuel particle barriers rather than allowing significant fuel particle failures and then relying extensively on other mechanistic barriers (e.g., the helium pressure boundary and the reactor building). This standard is characterized by the following:

- Ensure radionuclide retention within fuel during normal operation with relatively low inventory released into the helium pressure boundary.
- Limit radionuclide releases to the environs to meet the onsite and offsite radionuclide dose acceptance criteria at the EAB with margin for a wide spectrum of off-normal events.
- Maintain the capability to establish controlled leakage and controlled release of delayed accident source term radionuclides.

# ***Functional Containment Performance Summary***

- Radionuclide retention within fuel during normal operation with relatively low inventory released to helium pressure boundary (HPB)
- Limiting LBEs characterized by
  - an initial release from the HPB depending on leak/break/pressure relief size
  - a larger, delayed release from the fuel
- Functional containment will meet 10CFR50.34 (10 CFR 52.79) at the EAB with margin for the wide spectrum of DBEs and DBAs without consideration of reactor building retention
- Functional containment (including reactor building) will meet EPA PAGs at the EAB with margin for wide spectrum of off-normal events

# ***Functional Containment and Mechanistic Source Terms Approach Summary***

- Mechanistic models of fission product generation and transport that account for reactor inherent and passive design features and the performance of the radionuclide barriers that comprise the functional containment
- Event specific and applied to the full range of licensing basis events affecting one or more modules
- Consistent with the NRC Advanced Reactor Policy Statement
- Consistent with discussions of containment function and mechanistic source terms in various NRC SECY documents and with approaches previously reviewed by the NRC staff for modular HTGRs

## *Siting Source Term Summary*

- The NGNP approach to SSTs is essentially the same as that proposed by DOE in the MHTGR PSID and accepted by the NRC staff in NUREG-1338
- The approach is consistent with discussions of containment function and mechanistic source terms in more recent NRC SECY documents and with approaches previously reviewed by the NRC staff for modular HTGRs
- The approach implements a modular HTGR-appropriate interpretation of the 10CFR50.34 (10CFR52.79) footnote regarding siting evaluation
- Limiting DBAs are evaluated to determine SSTs
- Further, to ensure that there are no cliff edge effects, physically plausible Bounding Event Sequences (with frequencies below the BDBE region), including those involving graphite oxidation, are considered

# ***Fuel Qualification and Radionuclide Retention Summary***

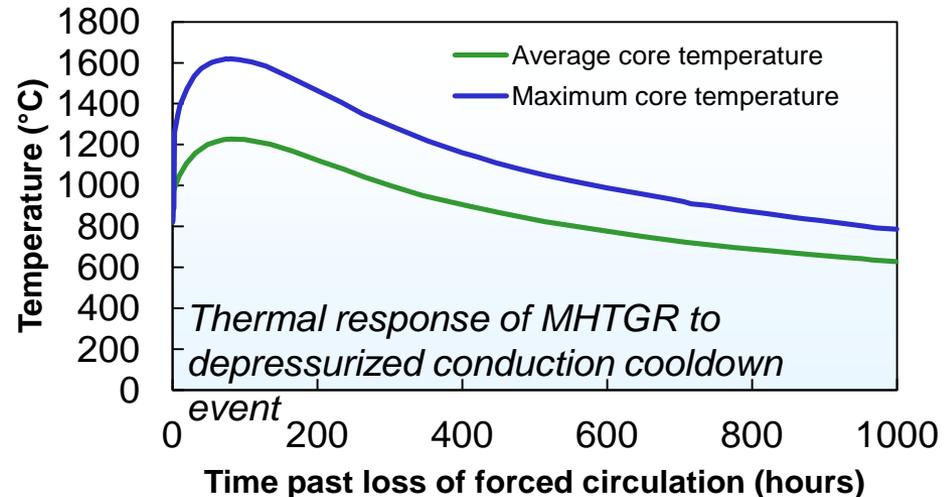
- The Fuel Development and Qualification Program is providing data, under an NRC-accepted QA program, necessary to better understand fuel performance and fission product behavior for modular HTGRs
- The Fuel Program is laying the technical foundation needed to qualify UCO TRISO fuel made to fabrication process and product specifications within an envelope of operating and accident conditions that are expected to be bounding for modular HTGRs
- Results to date are consistent with current design assumptions about fuel performance and radionuclide retention. The program is obtaining additional data to support model development and validation
- Results to date support the safety design basis, including the functional containment and mechanistic source term approaches

## Key Results of On-going Fuel Research

- Improved understanding of TRISO fuel fabrication process
- Improved fabrication and characterization of TRISO fuel produced by fuel vendor
- Outstanding irradiation performance of a large statistically significant population of TRISO fuel particles under high burnup, high temperature HTGR conditions
- Expected superior irradiation performance of UCO at high burnup has been confirmed
- Post-Irradiation examination of AGR-1 indicates:
  - Ag release consistent with model predictions
  - No Cs release from intact particles under irradiation
  - No Pd attack or corrosion of SiC despite large amounts of Pd outside SiC
- Initial safety testing for hundreds of hours at 1600, 1700, and **1800°C** demonstrating robustness of UCO TRISO under depressurized conduction cooldown conditions

# Accident Safety Testing of TRISO Fuel

- Simulate heatup of fuel compacts following depressurized conduction cooldown event
- Isothermal testing for hundreds of hours at 1600, 1700, and 1800°C
- Six isothermal 1600, 1700, and **1800°C** tests have been completed
- Actual time-temperature test to be performed this year
- Testing of deconsolidated particles will occur in late 2013 or early 2014



## KEY RESULTS

- Releases not seen from the intact TRISO particles during the high temperature heating
- Releases that have occurred are very low and are from one or more of the following:
  - Fission products that diffused into the matrix during irradiation
  - Presence of a defective particle
  - A particle that fails during safety testing

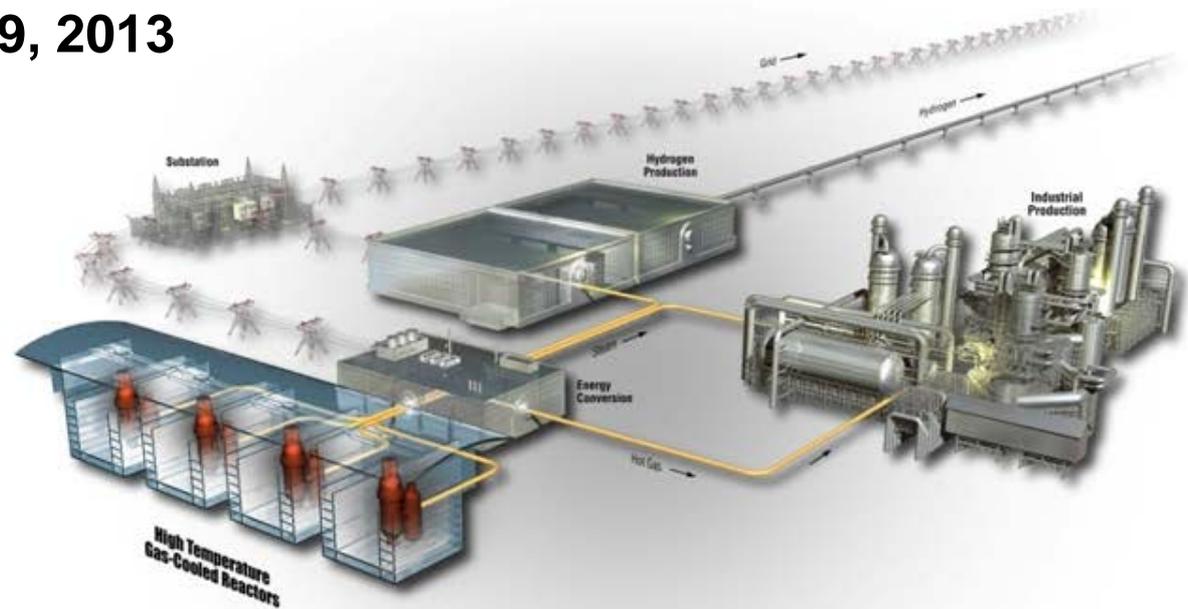
## ***The Subcommittee Asked Questions in Two Areas to be Addressed at Today's Meeting***

- What is the role of the reactor building in defense-in-depth?
- What is NGNP's approach to defense-in-depth?

# Reactor Building Design Alternatives

## ACRS Future Plant Designs Subcommittee Meeting

April 9, 2013



## ***Key Modular HTGR Safety Attributes***

- The fuel, helium coolant, and graphite moderator are chemically compatible under all conditions
- The fuel has very large temperature margins in normal operation and during accident conditions
- Safety is not dependent on maintaining the helium coolant pressure, and loss of coolant pressure does not transfer large amounts of energy into the reactor building
- Post accident heat removal is accomplished by passive means
- Response times of the reactor are very long (days as opposed to seconds or minutes)
- The HTGR has multiple, concentric, independent radionuclide barriers. A breach of the helium pressure boundary does not result in failure of the fuel or the reactor building

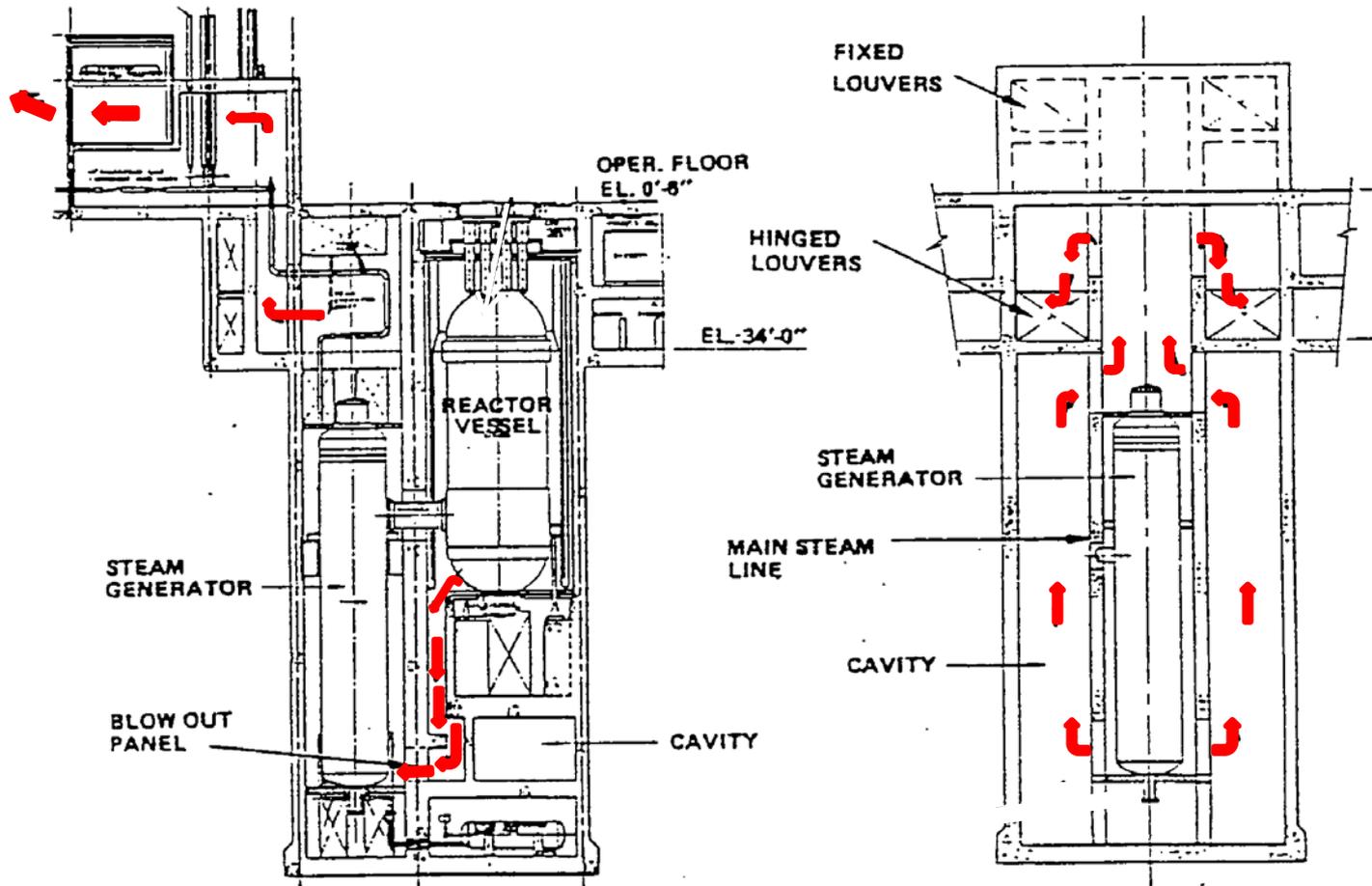
# ***Role of the Reactor Building (RB) in Safety Design***

- Required safety function of the RB is to provide structural protection, from internal and external events and hazards, for passive heat removal from Reactor Vessel to Reactor Cavity Cooling System (RCCS)
  - Maintain Vessel System/Helium Pressure Boundary (HPB) geometry
  - Maintain RCCS geometry
- The RB provides other functions not required to meet regulatory requirements for offsite dose
  - Provides additional radionuclide retention (needed to meet EPA PAGs at EAB)
  - Limits air available for ingress after HPB depressurization

# ***Vented Reactor Building Addresses Several Modular HTGR Specific Design Issues***

- Compatible with non-condensing helium coolant
- Matched to modular HTGR accident behavior
  - Vented early in transient when radionuclides released from helium pressure boundary are relatively low
  - Closed later in transient when radionuclides released from fuel are relatively high
- Provides a more benign environment (e.g., heat, pressure, and structural loads) for passive Reactor Cavity Cooling System

# MHTGR Reactor Building Vent Path from Reactor or Steam Generator Cavities

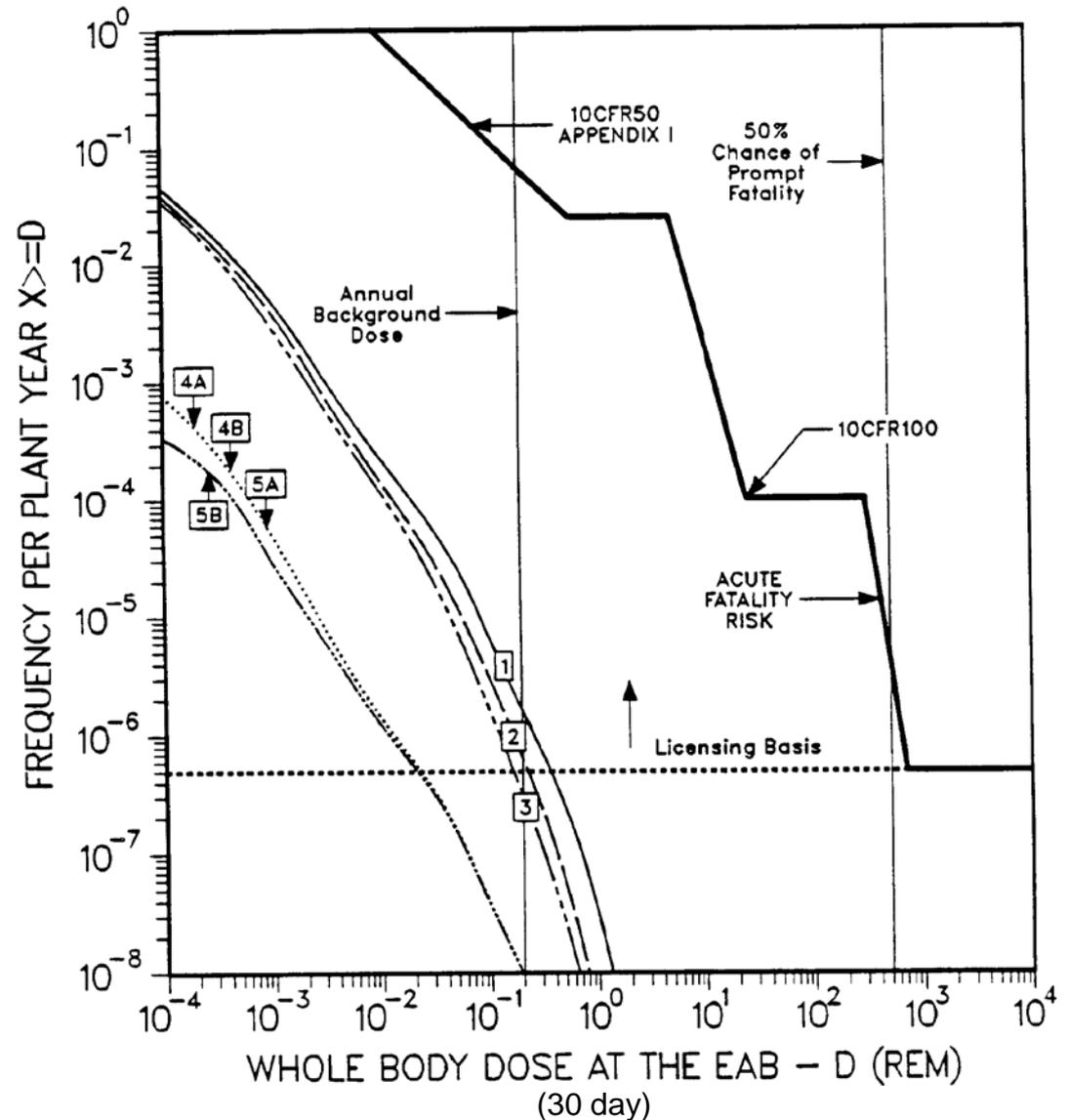


## ***Alternative RBs Considered in Containment Study for MHTGR\****

1. Vented, moderate leakage (100%/day) (Reference)
2. Vented, filtered, moderate leakage (100%/day)
3. Vented, filtered, low leakage (5%/day)
- 4A. Unvented, moderate pressure, low leakage (5%/day) air RCCS
- 4B. Unvented, moderate pressure, low leakage (5%/day) water RCCS
- 5A. Unvented, low pressure, low leakage (5%/day)
- 5B. Unvented, low pressure, low leakage (1%/day)

\* "Containment Study for MHTGR," General Atomics Report, DOE-HTGR-88311, November 1989

# All Alternative Reactor Buildings Considered for MHTGR Met the TLRC with Substantial Margin

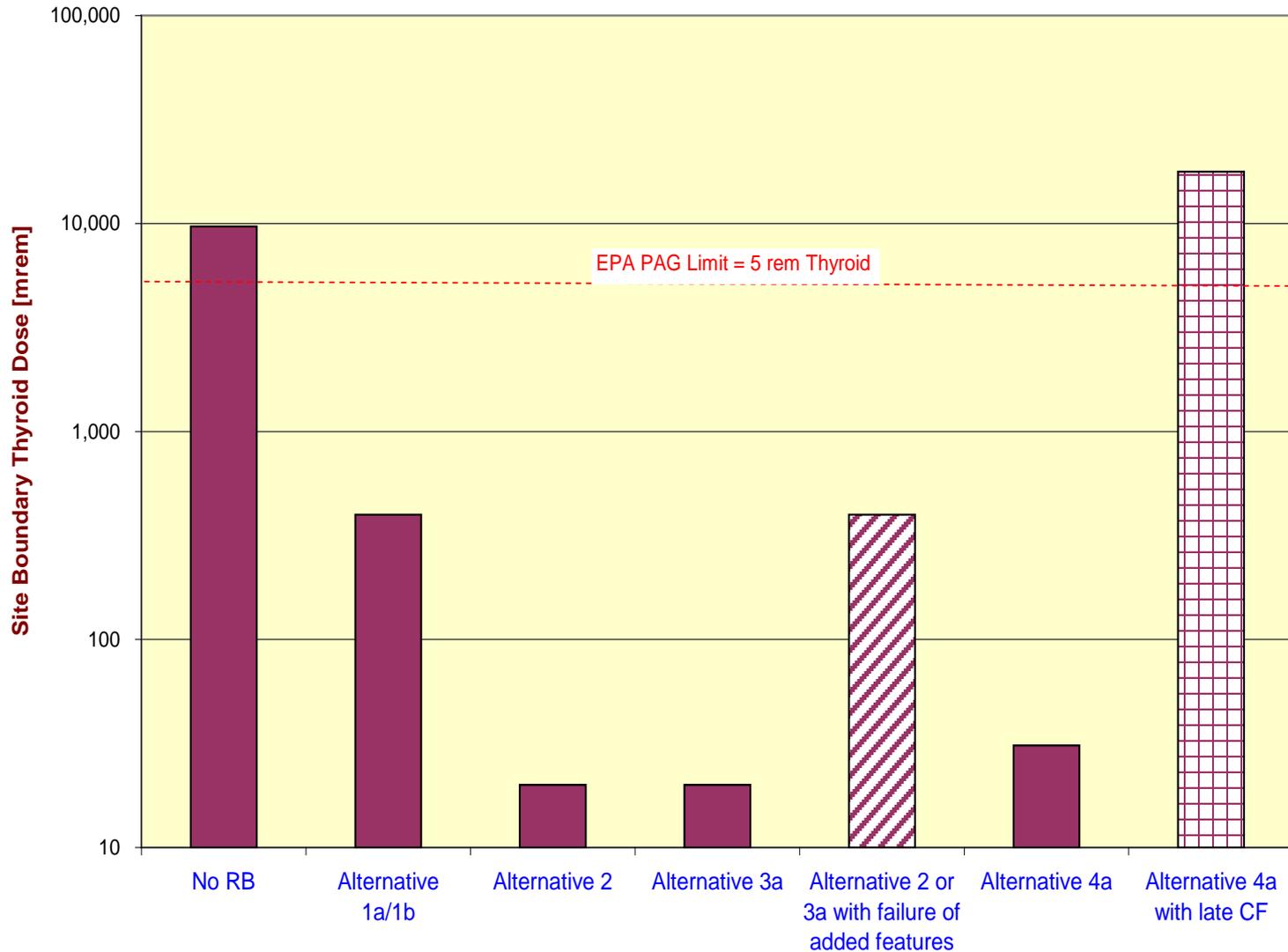


## ***Alternative PBMR RB Design Configurations***

- 1a. Unfiltered, vented, moderate leakage (50-100%/day)
- 1b. Unfiltered, vented with blowout panels, moderate leakage (50-100%/day)
- 2. Partially filtered, vented with blowout panels, moderate leakage (50-100%/day)
- 3A. Filtered, vented with blowout panels, lower leakage (25-50%/day)
- 3B. Filtered, vented with blowout panels and expansion volume, lower leakage (25-50%/day)
- 4A. Pressure retaining with internal blowout panels, low leakage (<1%/day)
- 4B. Pressure retaining with internal blowout panels and expansion volume, low leakage (<1%/day)

\* “Reactor Building Functional and Technical Requirements and Evaluation of Reactor Embedment,” NGNP-NHS 100-RXBLDG, Rev 0, Westinghouse PBMR Team Report, September, 2008.

# PBMR Reactor Building Alternatives 1a thru 4a Met the EPA PAG at the EAB with Substantial Margin



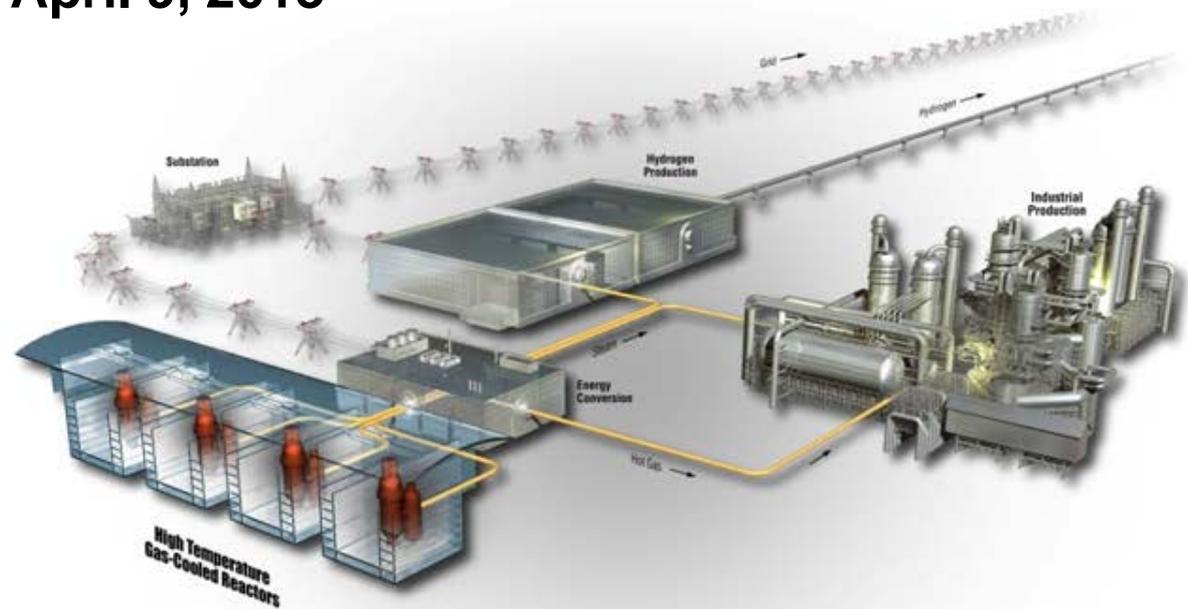
# ***Summary of Findings from MHTGR and PBMR Alternative RB Evaluations***

- Vented building provides best match for modular HTGR characteristics and passive design
- For modular HTGRs, high pressure, low leakage LWR-type containment designs increase radionuclide release in low frequency events
- Added filters and/or active HVAC systems that may not be available for low frequency events (e.g., seismic or station blackout) provide little additional margin relative to the TLRC
- Confirmed decision to place emphasis on retention at the source within the fuel
- More detail can be found in the response to RAI FQ/MST-82 and in its references

# ***NGNP Defense-in-Depth Approach***

## **ACRS Future Plant Designs Subcommittee Meeting**

**April 9, 2013**



# ***Presentation Agenda***

- Defense-in-Depth (DID) Overview
  - DID Approach
  - DID Elements
  - NRC's DID Strategy
- NGNP DID Approach
  - Plant Capability DID
  - Programmatic DID
  - Risk-Informed Evaluation of DID
- Integrated DID Framework
- NGNP DID Approach Summary
- Key NGNP Attributes

## ***DID Approach***

- Develop a structured system for evaluating DID adequacy for licensing

## ***DID Elements***

- Plant Capability DID
- Programmatic DID
- Risk-Informed Evaluation of DID

## ***Recent Summary of NRC's DID Strategy***

*“To protect public health and safety from the inadvertent release of radioactive materials, the NRC's defense-in-depth strategy includes multiple layers of protection:*

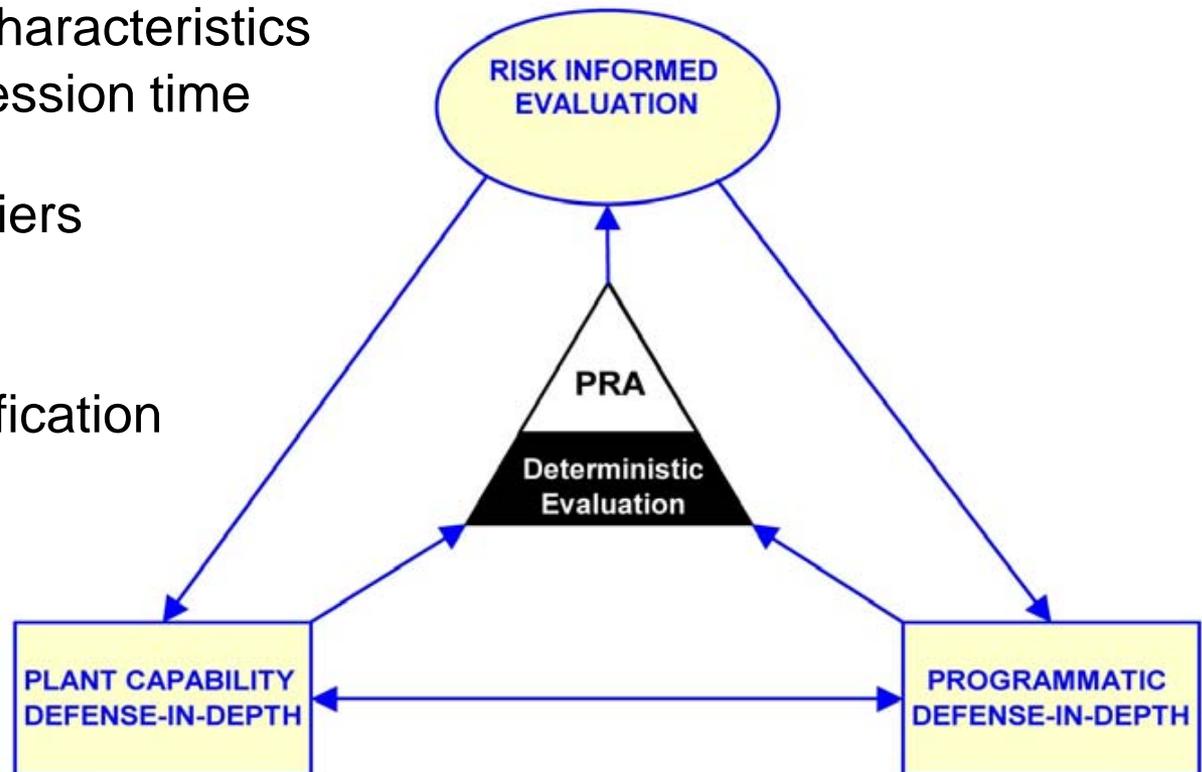
- (1) prevention of accidents by virtue of the design, construction and operation of the plant,*
- (2) mitigation features to prevent radioactive releases should an accident occur, and*
- (3) emergency preparedness programs that include measures such as sheltering and evacuation.*

*The defense-in-depth strategy also provides for multiple physical barriers to contain the radioactive materials in the event of an accident.”*

EA-12-050, “Issuance of Order to Modify Licenses with Regard to Reliable Hardened Containment Vents,” Page 6, March 12, 2012.

# Plant Capability DID

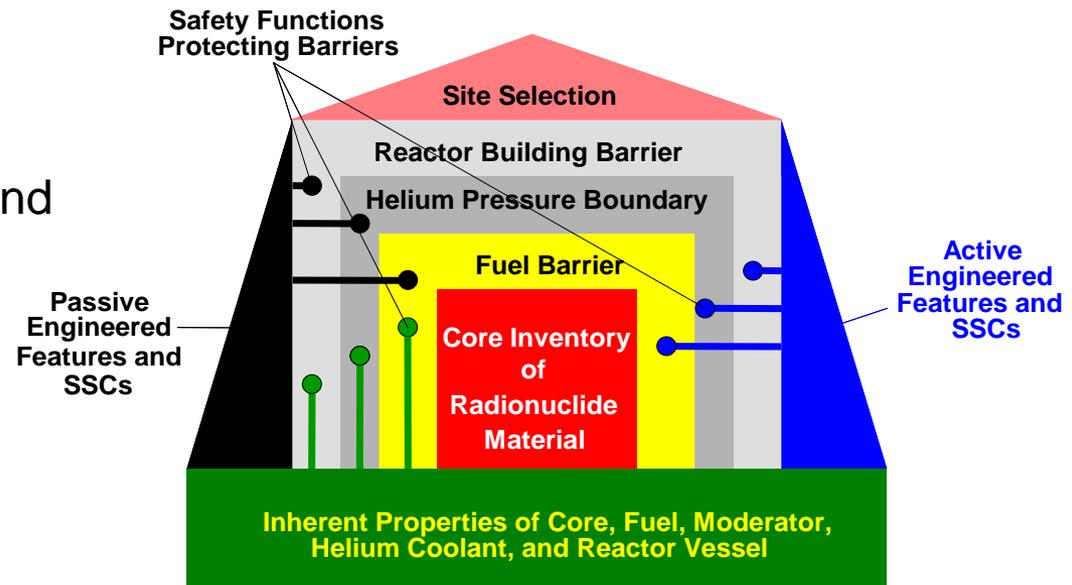
- Reflects the decisions made by the designer in the selection of functions, structures, systems and components (SSC) for the design that assure defense-in-depth in the physical plant
- Examples:
  - Inherent reactor characteristics
  - Long event progression time constants
  - Radionuclide barriers
  - Passive SSCs
  - Active SSCs
  - SSC safety classification
  - Design margins



# Radionuclide Barriers

## Use multiple barriers for radionuclide retention

- The radionuclide barriers are concentric and independent
- Emphasis is on the performance of the fuel barriers
- Reactor Building provides DID for meeting top level regulatory criteria (TLRC)
- Active (typically non-safety related) SSCs and passive (typically safety related) SSCs work in concert with the inherent design characteristics to reduce the frequency of challenges to radionuclide barriers
- Challenges to barrier integrity and independence are considered
- Safety margins and conservative design approaches are used to address uncertainties in barrier and SSC performance



## ***Control of Core Heat Generation***

- Large negative temperature coefficient intrinsically shuts reactor down
- Two independent and diverse systems of reactivity control for reactor shutdown drop by gravity on loss of power
  - Control rods
  - Reserve shutdown system
- Each system capable of maintaining reactor subcritical
- Either system capable of maintaining cold shutdown during refueling

## Removal of Core Heat

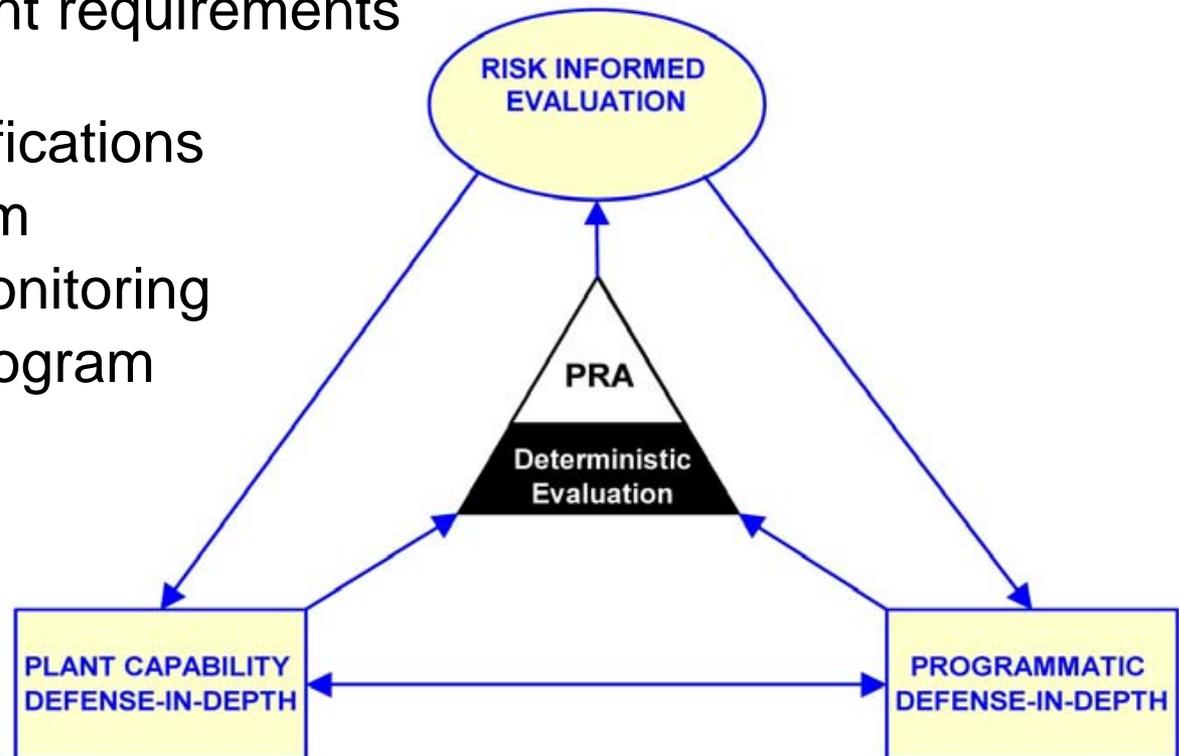
- Heat Transport System (active)
  - Used for process steam/cogeneration during normal operations
  - Residual heat removal with forced cooling of pressurized or depressurized helium from core to steam generator to secondary heat sink
- Shutdown Cooling System (active)
  - Provides heat removal during planned maintenance and unplanned events for investment protection
  - Residual heat removal with forced cooling of pressurized or depressurized helium from core to shutdown cooling water system
- Reactor Cavity Cooling System (passive)
  - Provides heat removal for investment and public protection during off-normal events
  - Residual heat removal from low power density, high heat capacity annular core with convection, conduction, and radiation to reactor vessel with helium pressurized or depressurized
  - Radiation from uninsulated reactor vessel to natural convection system in reactor cavity (air or water)

# Control of Chemical Attack

- Air Ingress
  - Non-reacting coolant (helium)
  - High integrity nuclear grade pressure vessels make a large break exceedingly unlikely
  - Slow oxidation rate (high purity nuclear grade graphite)
  - Limited by core flow area and friction losses
  - Reactor building embedment and vents that close after venting limit potential air ingress
- Water Ingress
  - Non-reacting coolant (helium)
  - Limited sources of water with moisture monitors, steam generator isolation (does not require AC power) and steam generator dump system
  - Water-graphite reaction is endothermic, requires temperatures  $>$  normal operation, and has a slow reaction rate
- Graphite fuel element, fuel compact matrix, and ceramic coatings protect fuel particles

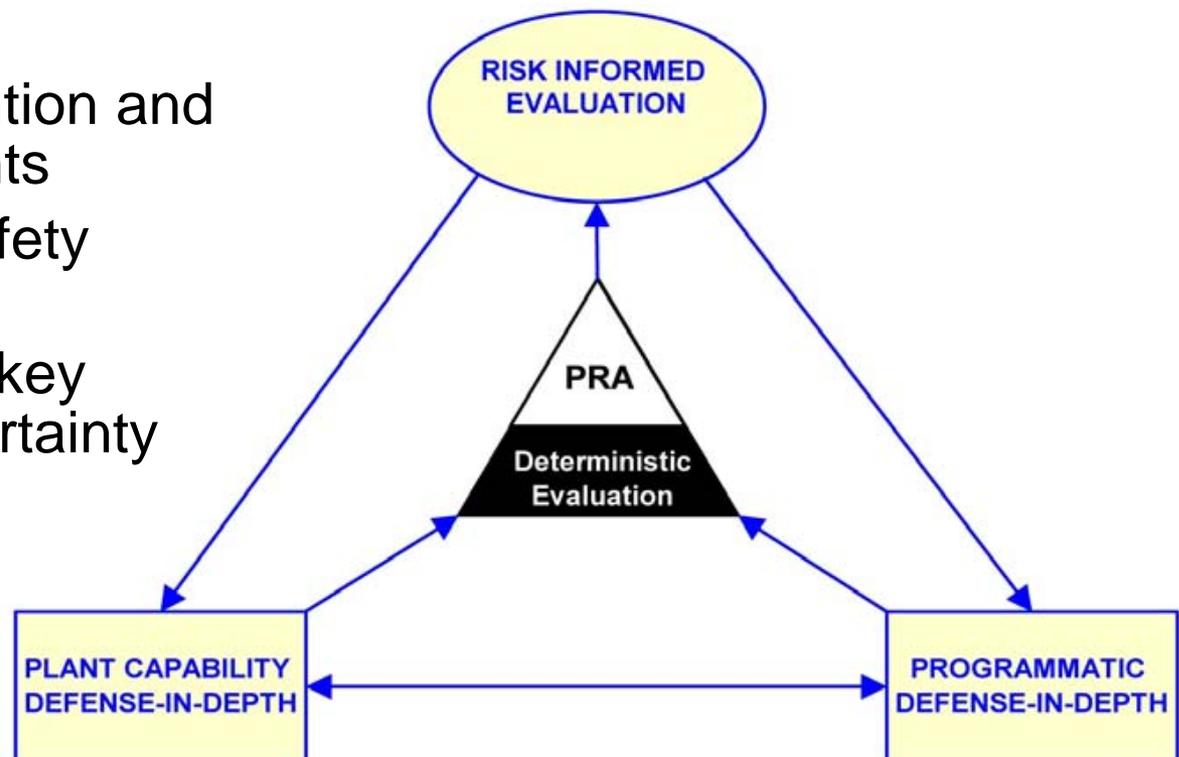
# Programmatic DID

- Processes of manufacturing, constructing, operating, maintaining, testing, and inspecting the plant that assure plant safety throughout the lifetime of the plant
- Examples:
  - Special treatment requirements for SSCs
  - Technical specifications
  - Training program
  - Performance monitoring
  - Maintenance program



# Risk-Informed Evaluation of DID

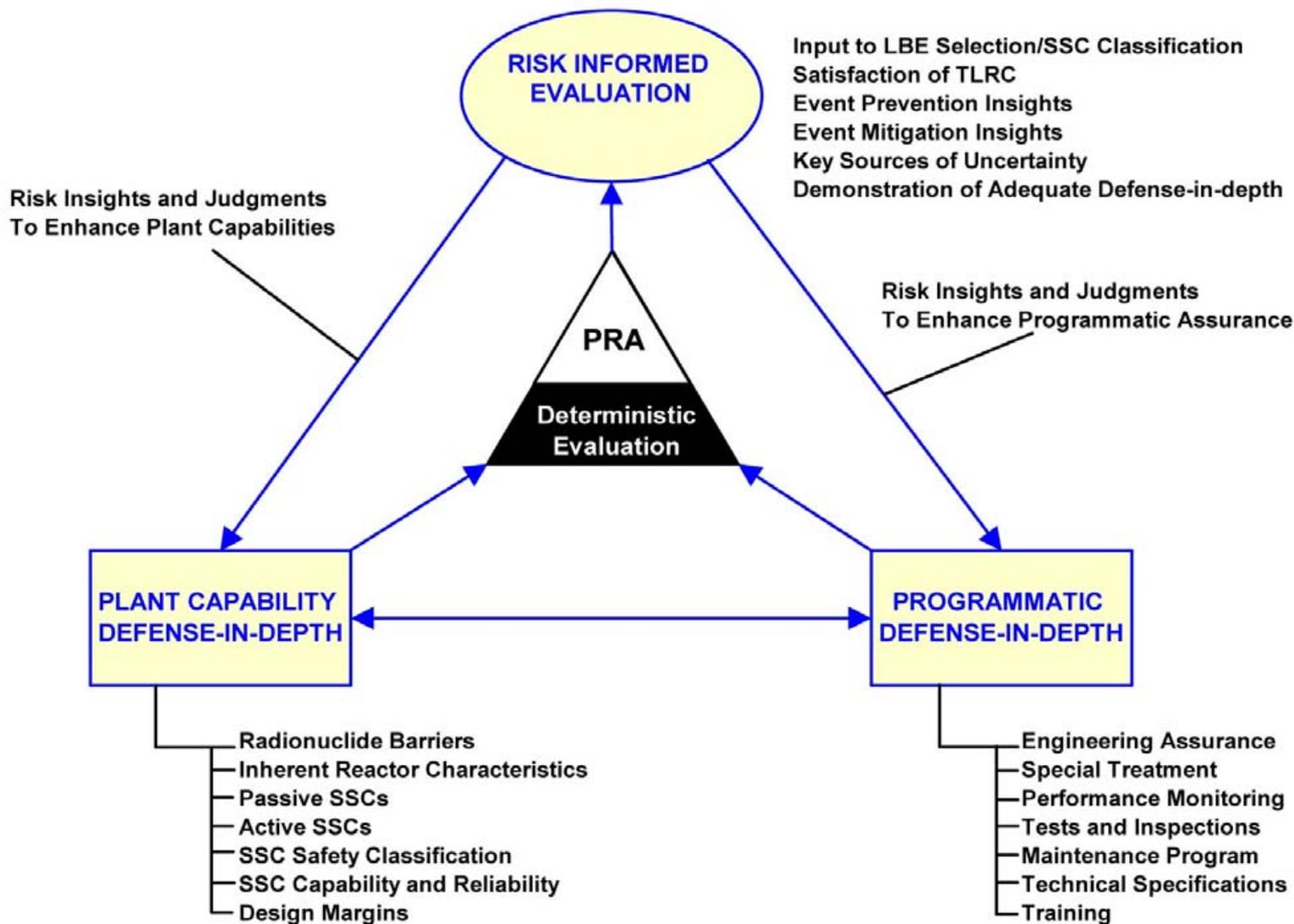
- Provides the framework for performing deterministic safety evaluations and risk assessment evaluations to determine how well various Plant Capability and Programmatic DID strategies have been implemented
- Provides:
  - Accident prevention and mitigation insights
  - Input to SSC safety classification
  - Identification of key sources of uncertainty



## ***Risk-Informed Evaluation of DID***

- Identify credible failure modes and challenges to the radionuclide barriers; include dependencies and interactions among barrier and other SSC failure modes
- Identify the roles of SSCs in the prevention and mitigation of accident sequences and quantify the extent to which the accidents are prevented and mitigated
- Establish that there are no events with a significant frequency of occurrence that rely on a single element of design or programmatic approach in protecting the public from a release whose dose would exceed the TLRC

# Integrated DID Framework



# ***NGNP DID Approach Summary***

Evaluates plant design capability features and programmatic elements in an integrated risk management approach to identify opportunities to reduce risk and to ensure that an adequate treatment of DID has been achieved after considering a full spectrum of events

## **Prevention**

- Ceramic fuel resistance to melting
- Long event progression time constants
- Low power density; high heat capacity; slender, annular core geometry for heat transfer

## **Mitigation**

- Multiple (independent) barrier approach against radionuclide releases
- Active SSCs and passive SSCs work in concert with the reactor's inherent characteristics to protect the public
- Addresses uncertainty by employing safety margins and special treatments to ensure SSC capability and reliability

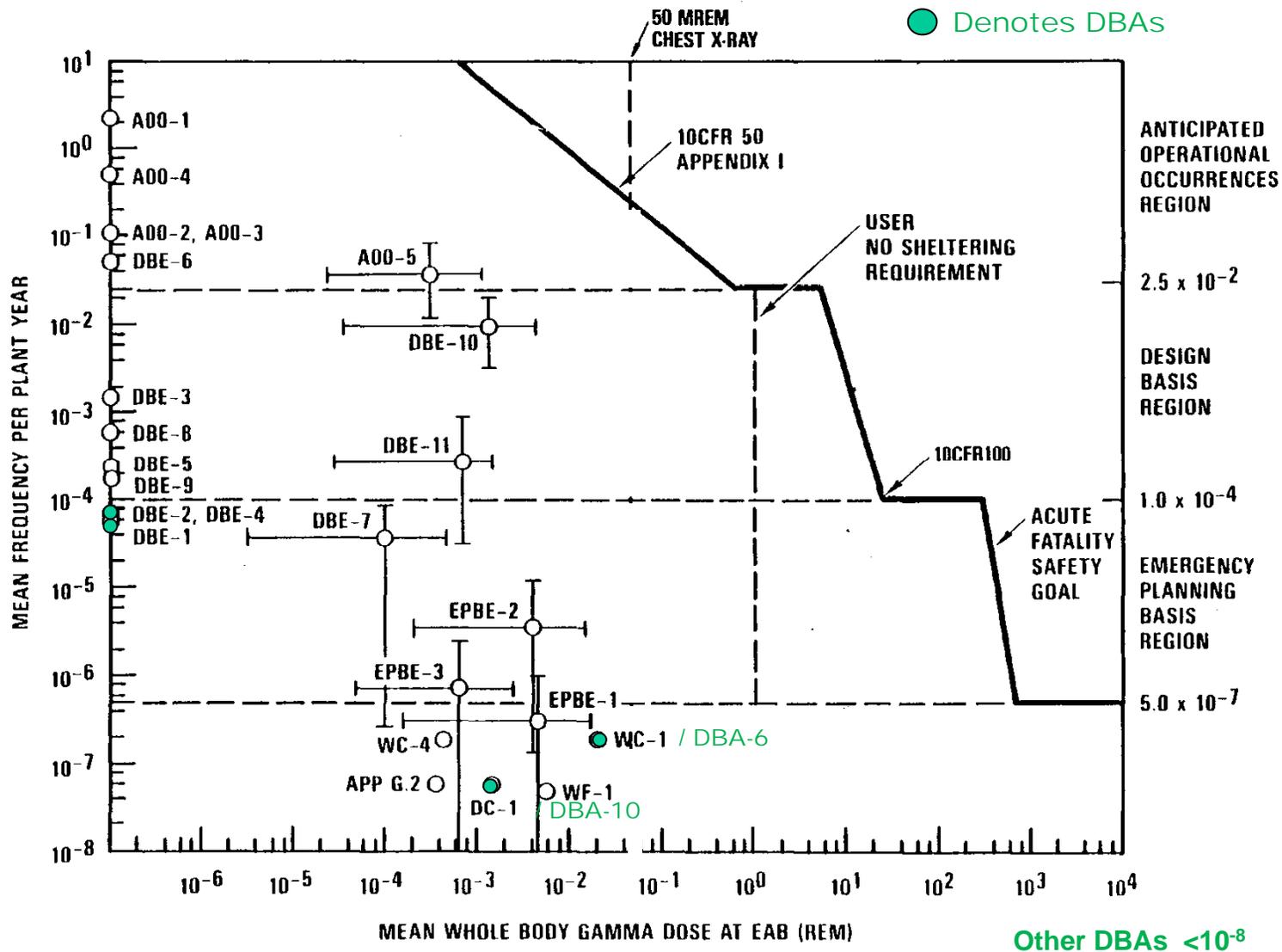
## **Emergency Preparedness**

- Design goal to meet the PAGs at the site boundary (EPZ) for DBEs and BDBEs provides margin to the TLRC

## ***Key NGNP Attributes***

- Addresses a full-spectrum of internal and external events on a per plant-year basis
- Includes events that could affect multiple reactor modules to assess plant risk
- Uses ceramic fuel that will not melt when challenged by a full-spectrum of internal and external events
- Includes a “cliff edge” review to assure that the safety landscape is adequately addressed
- Assures that safety will not be wholly dependent on any single element of the design, construction, maintenance, or operation of the facility
- Provides successive compensatory means to prevent accidents or lessen the effects of damage if a malfunction or accident occurs
- Uses multiple, concentric, independent radionuclide barriers; breach of the helium pressure boundary does not result in failure of the fuel or the reactor building

# MHTGR DBEs, DBAs, and BDBEs (aka EPBEs) on F-C Plot (circa 1987)



# Staff Assessment of Next Generation Nuclear Plant (NGNP) Key Licensing Issues

Advisory Committee on Reactor Safeguards (ACRS)  
Future Plant Designs Subcommittee Meeting  
April 9, 2013

Donald Carlson, James Shea, Arlon Costa  
Thomas Boyle, Jonathan DeGange

Office of New Reactors (NRO)  
Division of Advanced Reactors and Rulemaking (DARR)

## ASSESSMENT OF NGNP LICENSING ISSUES – OVERVIEW

- Project Background, History, and Status
- Assessment Process and Staff Products

## ASSESSMENT OF ISSUES IN 4 KEY AREAS

- Licensing Basis Event Selection
- Source Terms
- Functional Containment Performance
- Emergency Preparedness

## STAFF PRESENTERS

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## NGNP Project Mission, Energy Policy Act of 2005:

- Department of Energy (DOE) and Idaho National Laboratory (INL) will demonstrate by 2021 a prototype modular high temperature gas-cooled reactor (HTGR) for co-generating electricity and process heat
- NRC has licensing and regulatory authority for the prototype plant

## Major NGNP Pre-Application Activities to Date

- Joint DOE-NRC Licensing Strategy Report to Congress, 2008:  
Option 2 risk-informed and performance based approach: Use deterministic engineering judgment and analysis, complemented by PRA insights, to establish NGNP licensing basis
- NRC assessment of DOE/INL white paper submittals, 2010-present

## DOE decision in letter to Congress, October 2011:

- DOE will not proceed with NGNP detailed design activities at this time
- NGNP Project will continue to focus on high temperature reactor R&D, interactions with NRC to develop a licensing framework, and establishment of a public-private partnership

## RESOURCES

- NRC has been using DOE reimbursable funds to assess NGNP licensing issues in 4 key areas

## NRC issued preliminary assessment reports to DOE, February 2012

- Assessment of Fuel Qualification and Mechanistic Source Terms (Rev. 0)
  - NGNP Fuel Qualification (FQ) White Paper
  - NGNP Mechanistic Source Terms (MST) White Paper
- Assessment of Risk-Informed and Performance-Based (RIPB) Approach (Rev. 0)
  - NGNP Defense-in-Depth Approach (DID) White Paper
  - NGNP Licensing Basis Event Selection (LBE) White Paper
  - NGNP Safety Classification of Structures, Systems, and Components (SSC) White Paper

## NRC issued letter to DOE, February 2012

- Focus remaining NGNP interactions on issues in four key areas
  - (1) Licensing Basis Event Selection      (2) Source Terms
  - (3) Functional Containment Performance      (4) Emergency Preparedness

## DOE/INL letter clarified approaches to key issues, July 6, 2012

- Public meetings and conference calls between NRC and DOE/INL, thru Nov 2012
- NRC staff review of supporting technical documents submitted by DOE/INL

## DOE/INL provided information briefing to ACRS, January 17, 2013

## ISSUE SUMMARY REPORT

- Staff report: “Summary Feedback on Four Key Licensing Issues”

## FQ-MST ASSESSMENT REPORT (REV. 1)

- Updated staff report: “Assessment of White Papers Submittals on Fuel Qualification (FQ) and Mechanistic Source Terms (MST).”

## RIPB ASSESSMENT REPORT (REV. 1)

- Updated staff report: “Assessment of White Paper Submittals on Defense-in-Depth (DID), Licensing Basis Event (LBE) Selection, and Safety Classification of Structures, Systems, and Components (SSC).”

## SUMMARY FEEDBACK ON FOUR KEY LICENSING ISSUES

- i. Licensing Basis Event Selection
  - ii. Source Terms
  - iii. Functional Containment Performance
  - iv. Emergency Preparedness
- Issues highlighted in DOE-NRC NGNP Licensing Strategy Report to Congress (2008)
  - Considered key issues in earlier NRC pre-application activities for proposed modular HTGRs, i.e., MHTGR (DOE/General Atomics, 1986-1995) and Pebble Bed Modular Reactor (Exelon, PMBR Pty, 2001-05)
  - All issues are considered in view of relevant prior staff positions, ACRS comments, and Commission direction (e.g., SECY-93-092, NUREG-1338, SECY-03-0047, SECY-05-0006, NUREG-1860, SECY-11-0152).
  - The RIPB approach proposed for NGNP is similar to RIPB approaches that have been or may be considered for NUREG-1860, NUREG-2150, and NTTF Recommendation 1. A revised or new framework resulting from these other efforts may change the current NRC staff positions for NGNP.

## OVERVIEW

- After ACRS review, NRO will finalize the three staff products and publicly issue them to DOE
- Presentations today are based on the staff's Issue Summary Report

## MAJOR CONCLUSIONS

- Staff views DOE/INL's proposed approaches to NGNP licensing issues as being generally reasonable, with caveats
  - Deterministic elements should be strengthened
  - Technical issues should be resolved through prototype testing under 10 CFR 50.43(e)(2)

## QUALIFIERS

- Staff feedback is advisory; regulatory decisions will be based on NGNP license application and related Commission policy determinations
- Staff has assessed the proposed approaches solely as they apply to the modular HTGR design concept (next slides)

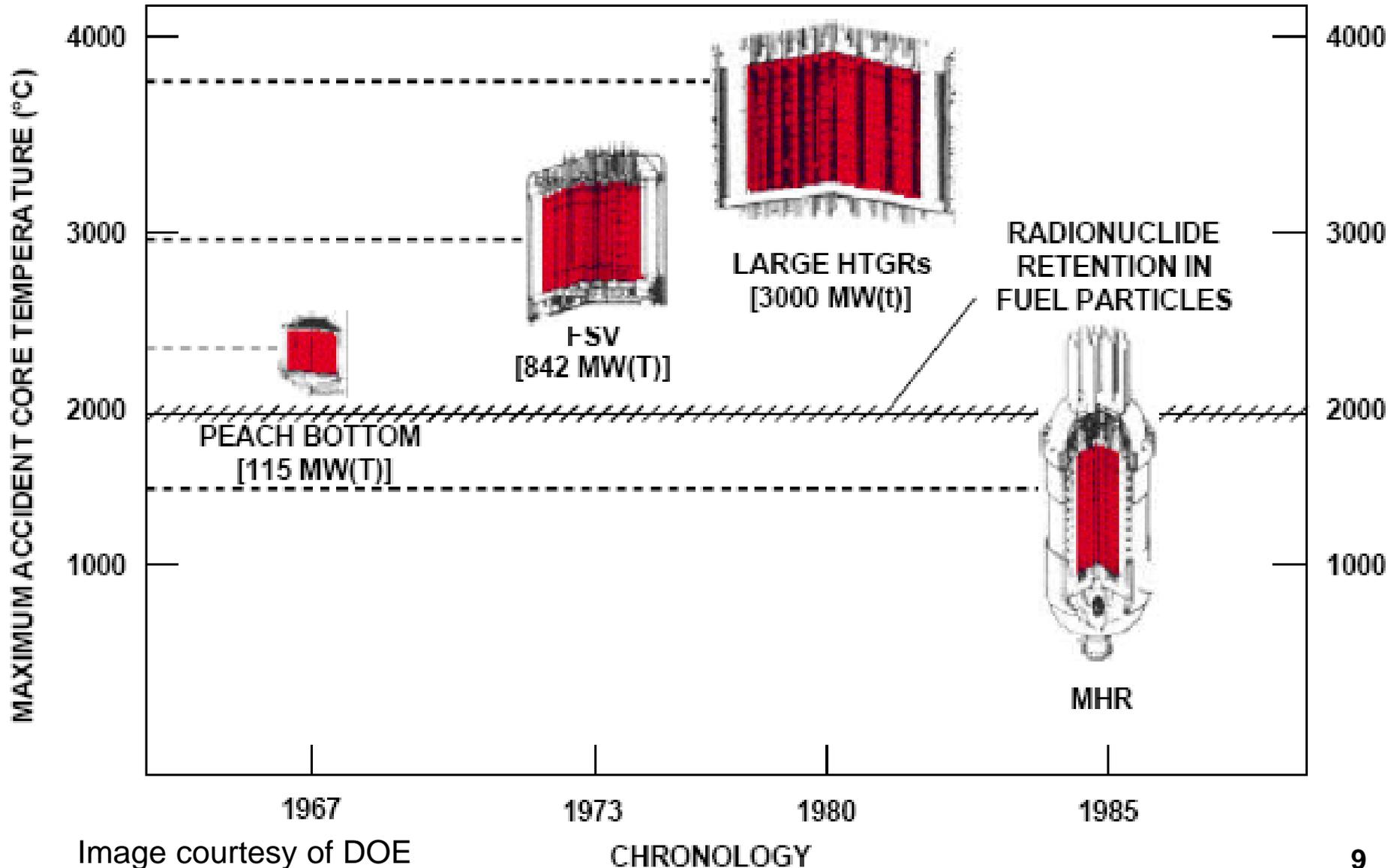
# Early History of HTGRs

- **Dragon** - United Kingdom, 1966-75
  - Block type, 20 MWt, 750 °C Outlet
- **AVR** - West Germany, 1967-88 →→
  - Pebble bed, 46 MWt (15 MWe), 950 °C
- **Peach Bottom 1** - United States, 1967-74
  - Block type, 115 MWt (40 MWe), 725 °C Outlet
- **Fort St. Vrain** - United States, 1976-89
  - Block type, 840 MWt (330 MWe), 785 °C Outlet
- **THTR** - West Germany, 1985-89
  - Pebble bed, 750 MWt (300 MWe), 750 °C Outlet



# HTGR Design Evolution (U.S. & Germany)

## Post-TMI Shift to Modular HTGR Safety Concept



## Size Comparison

- Per unit power output, modular HTGRs are much larger than LWRs
- Relative to LWRs, modular HTGRs have
  - Much lower core power density
  - Much lower fuel volume fraction in active core
    - LWRs ~30%
    - HTGRs ~0.5%
  - Much greater thermal inertia

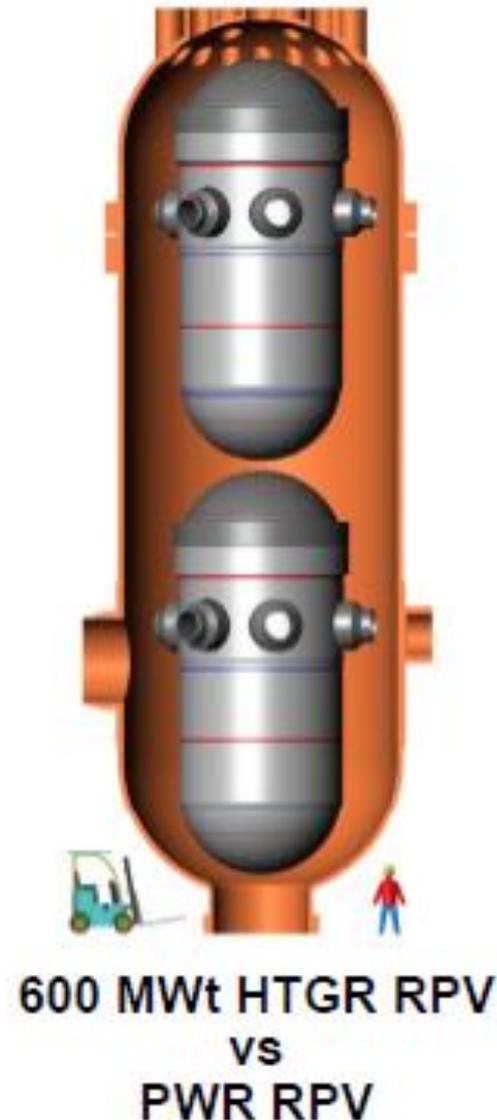


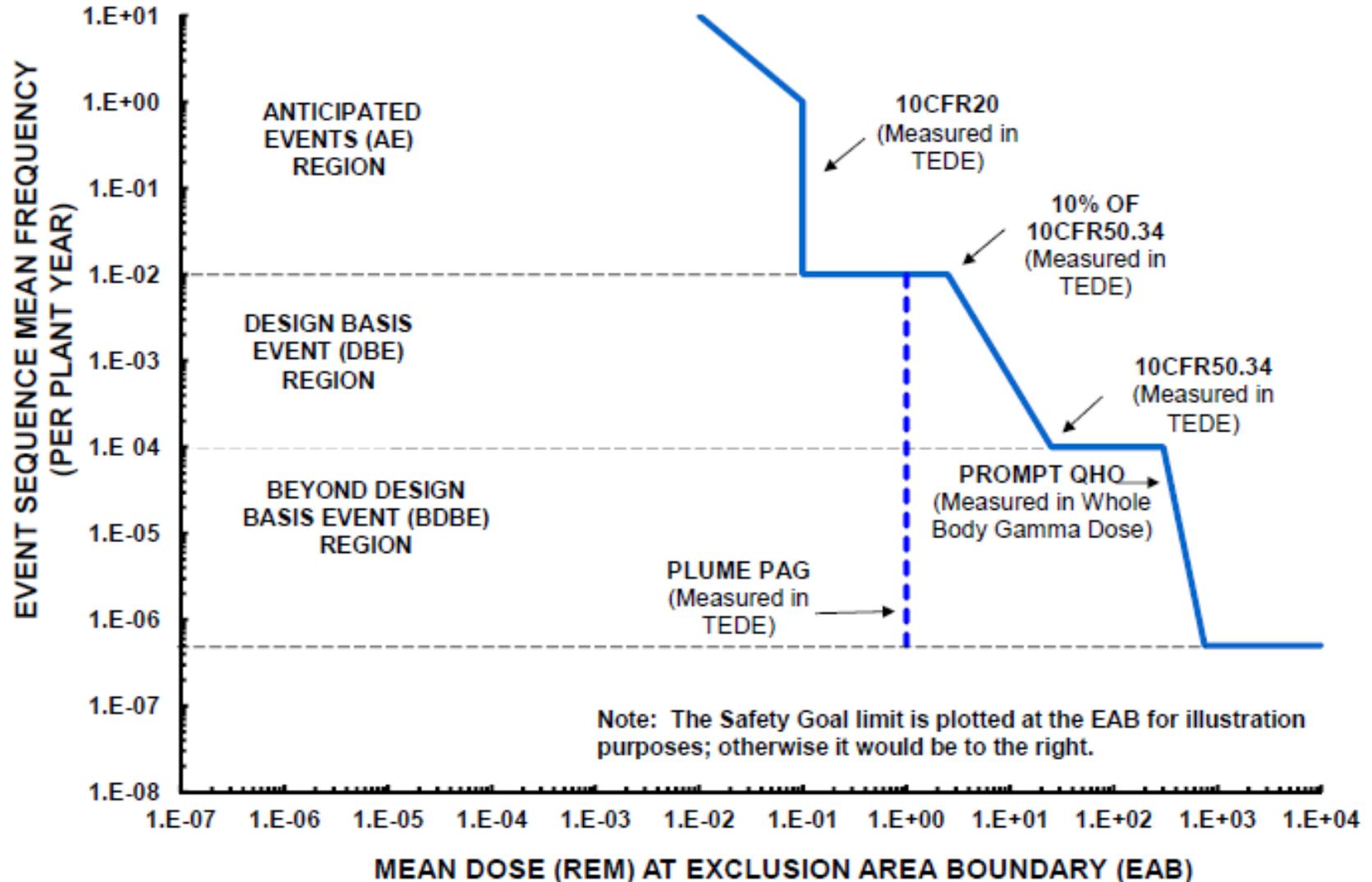
Image courtesy of DOE

## LICENSING BASIS EVENT SELECTION

## SUMMARY OF DOE/INL PROPOSAL

- DOE/INL proposes a process for selecting and evaluating NGNP licensing basis event sequences (LBEs) that seeks to blend the strengths of probabilistic and deterministic methods
- The process would yield LBEs categorized as Anticipated Events, Design Basis Events, Design Basis Accidents, and Beyond Design Basis Events
- Offsite dose consequences of LBEs would be evaluated and assessed against Top Level Regulatory Criteria (TLRC) and EPA Protective Action Guidelines (PAGs) placed on a Frequency-Consequence (F-C) curve
- The LBE process would incorporate a risk-informed approach to safety classification of structures, systems, and components (SSCs)

## DOE/INL's Proposed Frequency-Consequence Curve



## SUMMARY OF STAFF FEEDBACK ON LBE SELECTION

- Proposed LBE selection approach is generally reasonable but overly risk-based in some respects. Deterministic elements should be strengthened
- Future Commission direction may be appropriate for issues such as:
  - Frequency cutoffs for Design Basis and Beyond Design Basis Events
  - “Per-plant-year” method for addressing risk at multi-reactor module plant sites
  - Process and criteria used for selection of DBAs to demonstrate regulatory compliance
  - Consideration of alternate TLRC and F-C curves (e.g., NUREG-1860) in the contexts of
    - Future licensing of NGNP or other modular HTGRs
    - Developing a Technology Neutral Framework, etc.

Issue 1: DOE/INL requests NRC agreement on key terminology and naming conventions for its proposed event categories.

## **NRC Staff Feedback**

- Proposed event category names and descriptions are reasonable
- Full set of approved LBEs may have to include more deterministic events
  - Postulated DBAs and BDBE-derived DBAs in addition to DBAs derived from DBEs
  - AEs evaluated against specified acceptable fuel/core design limits (SAFDLs) for HTGR
- Final selection of DBAs may need to include postulated deterministic event sequences

Issue 2: DOE/INL requests that NRC endorse the proposed process and categorizations for SSC classification.

## **NRC Staff Feedback**

- Approach blends the strengths of probabilistic and deterministic methods in accordance with the NRC's policy statement on PRA
- Applies a risk-informed approach while addressing traditional deterministic definition of safety-related SSCs in 10 CFR 50.2
- Special treatments for the safety-related and non-safety-related with special treatment (NSRST) categories of SSC classification commensurate with ensuring that SSCs can perform required safety functions for LBEs, provide DID
- Processes and categorizations for SSC safety classification are reasonable

Issue 3: DOE/INL requests NRC agreement with its proposed placement of TLRC on an F-C curve.

## **NRC Staff Feedback**

- The selected TLRC and their placement on an F-C curve are reasonable
- DOE/INL should pursue an appropriate regulatory limit to ensure the required level of integrity of the fuel barrier
- Deterministic elements of the proposed approach should be strengthened.
- Future Commission direction may be appropriate for determination of dose acceptance criteria for various event categories

Issue 4: DOE/INL requests that NRC establish frequency ranges based on mean event sequence frequency.

## **NRC Staff Feedback**

- The approach for categorizing each event sequence based on mean frequency is reasonable
  - Uncertainties would be considered in deriving both mean frequency and mean consequence of event sequences
  - Upper (95%) and lower (5%) bounds of the event frequency uncertainty distribution will be compared against the frequency boundaries of the LBE categories
  - If the upper or lower bounds of confidence intervals straddle frequency boundaries between LBE categories, the consequences of the event sequence will be compared against the criteria for each LBE category

Issue 5: DOE/INL requests that NRC endorse the “per-plant-year” method for addressing risk at multi-reactor module plant sites.

## **NRC Staff Feedback**

- Proposed “per plant-year” method for addressing risk at multi-module plants is reasonable
- The staff believes that an integrated risk approach is more conservative and comprehensive than the treatment of modules on an individual basis
- Proposed method would appropriately address event sequences that involve source terms from one reactor module or multiple reactor modules
- Future Commission direction may be appropriate for this topic

Issue 6: DOE/INL requests that NRC agree on the frequency cutoffs for the DBE and BDBE regions.

## **NRC Staff Feedback**

- Top design objective is to meet the EPA PAGs at the site boundary for all event sequences more frequent than  $5E-7$  per plant year
- DOE/INL provide justification for frequency cutoffs in their LBE white paper
- Uncertainties would be considered in deriving both the mean frequency and mean consequence of event sequence
- Staff believes frequency cutoffs are reasonable for modular HTGRs as long as the PRA used in the LBE selection process:
  - assesses multiple failures from common-cause events
  - account for both operating and shutdown modes, internal and external plant hazards
- Future Commission direction may be appropriate for deciding frequency cutoffs for modular HTGR licensing

Issue 7: DOE/INL requests that NRC endorse the overall process for performing assessments against TLRC such as issues with uncertainties and PRA, calculational methodologies employed, and adequate incorporation of deterministic elements.

## **NRC Staff Feedback**

- DOE/INL's proposed approach to using engineering judgment to address uncertainties is a reasonable approach for assessing LBEs in a risk-informed manner
  - LBEs with frequency uncertainty distributions that straddle two event category regions at the 95% confidence level would be analyzed using the dose acceptance criteria of each region
  - Calculational methodologies to be employed assess full event sequences using best-estimate models with mean or conservative analysis (95% confidence)
- For AE and BDBE compliance with the TLRC, the proposed approach of realistic source term calculations needs further consideration and would involve new regulatory interpretations for potential future consideration by the Commission
- Certain elements of the proposed approaches are overly risk-based. Deterministic elements should be strengthened

## **NRC Staff Feedback cont'd**

The process is described by DOE/INL as:

- Technology neutral
- Comprehensive; considers full plant response to a wide spectrum of events
- Quantitative; so safety margins can be assessed

Proposed approaches are generally consistent with relevant past staff positions and Commission guidance such as:

- Advanced Reactor Policy Statement
- NUREG-1338 MHTGR PSER
- NUREG-1860 Feasibility Study for Performance-Based Reg. Structure
- SECY-93-092, SECY-95-299, SECY-98-0300
- SECY-03-0047, SECY-04-0157, SECY-05-006

## MECHANISTIC SOURCE TERM

## BACKGROUND

- Commission approved the use of event-specific mechanistic source term (MST) as proposed in SECY-93-092 and SECY-03-0047

*A mechanistic source term is the result of an analysis of fission product release based on the amount of cladding damage, fuel damage, and core damage resulting from the specific accident sequences being evaluated. It is developed using best-estimate phenomenological models of the transport of the fission products from the fuel through the reactor coolant system, through all holdup volumes and barriers, taking into account mitigation features, and finally, into the environs. [SECY-93-092]*

*[T]he use of scenario-specific source terms [is allowable], provided there is sufficient understanding and assurance of plant and fuel performance and deterministic engineering judgment is used to bound uncertainties. [SECY-03-0047]*

## SUMMARY OF STAFF FEEDBACK

- The NRC staff's overall assessment is that the proposed approaches to mechanistic source terms are generally reasonable, with some potentially significant caveats

Issue 1: Endorse the proposed NGNP mechanistic source terms definition - the quantities of radionuclides released from the reactor building to the environment during the spectrum of LBEs, including timing, physical and chemical forms, and thermal energy of the release.

## **NRC Staff Feedback**

- Consistent with SRMs to SECY-93-092 and SECY-03-0047
- The NRC staff concludes that DOE/INL's proposed definition of NGNP mechanistic source terms aligns with the current staff position on the treatment of advanced reactor mechanistic source terms and is thus reasonable for use in DOE/INL's proposed approach to determining licensing parameters for modular HTGRs

Issue 2: Agree that NGNP source terms are event specific and determined mechanistically using models of radionuclide generation and for transport that account fuel and reactor design characteristics, passive features, and the radionuclide release barriers.

## **NRC Staff Feedback**

- Consistent with SRMs to SECY-93-092 and SECY-03-0047
- DOE/INL's proposed approaches to developing event-specific mechanistic source terms are reasonable

Issue 3: Agree that NGNP has adequately identified the key HTGR fission product transport phenomena and has established acceptable plans for evaluating and characterizing those phenomena and associated uncertainties.

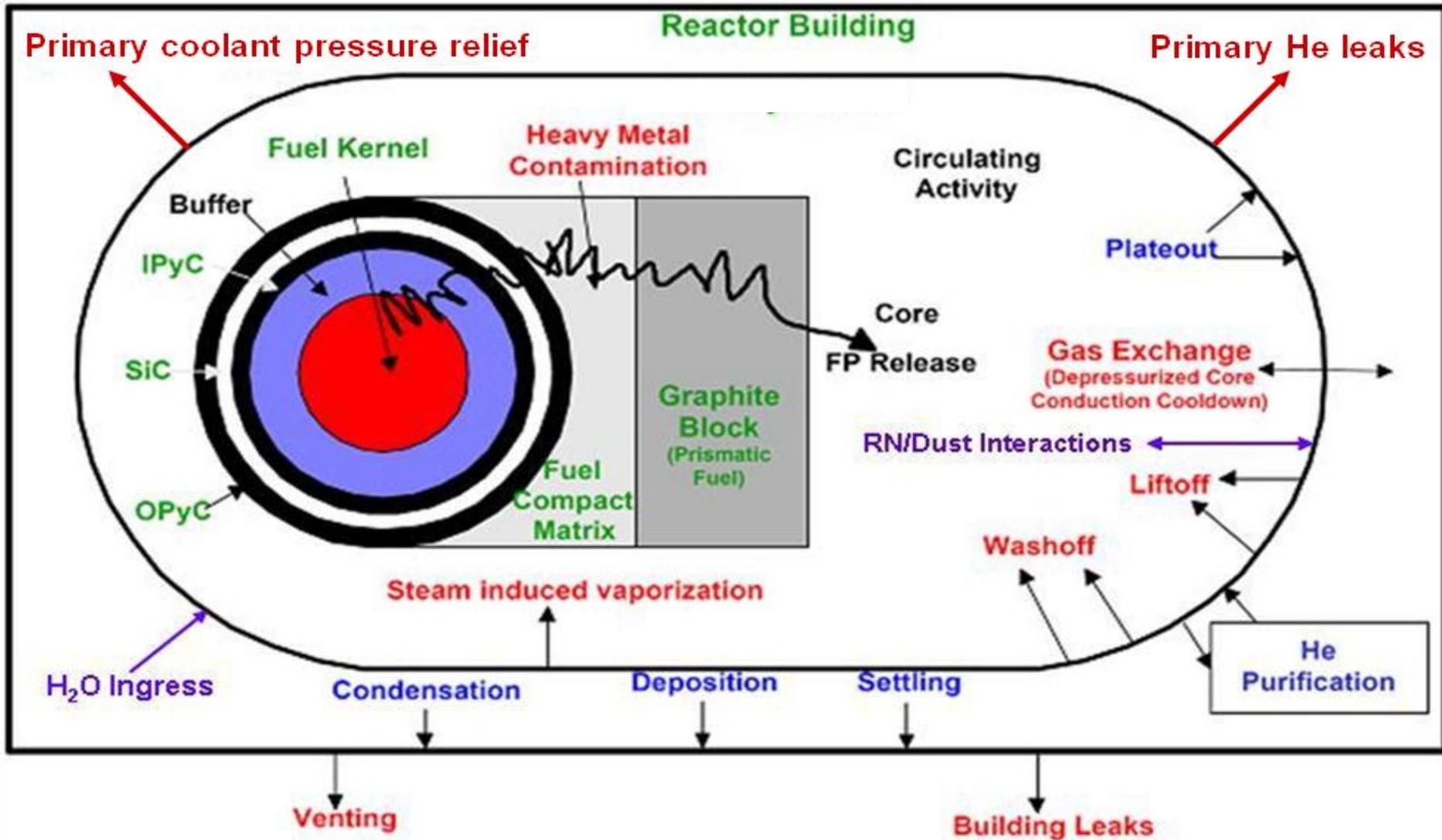
## **NRC Staff Feedback**

- Ongoing and planned testing and research activities for NGNP fuel qualification and mechanistic source terms development are generally reasonable
- Staff expects more information on release and transport phenomena through event-specific pathways to be developed as DOE/INL's activities in these areas proceed
- Data from NGNP prototype tests would be needed to verify and supplement the technical basis for NGNP fission product transport modeling and validation

DOE/INL proposes to include in their fission product transport models:

- Transport of radionuclides from their point of origin through the fuel to the circulating helium
- Circulating activity in the helium pressure boundary (HPB)
- Distribution of condensable radionuclides in the HPB (plateout and dust)
- Radionuclide release from HPB and distribution in the reactor building (i.e., circulating activity, lift-off, wash-off; heat-up)
- Radionuclide release from the reactor building to the environment (source term)
- In addition to providing source terms, these calculations provide radionuclide inventories throughout the plant.

# Mechanistic Source Term



## ADDITIONAL NRC STAFF FEEDBACK

The NRC staff's overall assessment is that the proposed approaches to mechanistic source terms are generally reasonable, with some potentially significant caveats.

- Staff's preliminary view is that some fuel qualification elements should to be supplemented to support the MST and the NGNP safety case
- The NRC staff believes satisfactory completion of a post-irradiation fuel inspection and testing program including fuel from an NGNP prototype is necessary to verify and supplement the technical basis for NGNP MST code validation
- The draft ASME/ANS PRA standard states that it is required that all PRA elements (including the mechanistic source term element) have a peer review. The staff views such peer review as having particular importance for the implementation of risk-informed approaches to NGNP licensing

## ADDITIONAL NRC STAFF FEEDBACK

- LBEs for siting should include postulated bounding events that adequately challenge all available barriers in the assessment of event-specific mechanistic source terms. Postulated events could include:
  - Bounding events with air ingress
  - Bounding events with water ingress
- Safety terrain studies related to BDBEs of low probability should be evaluated to inform the selection of LBEs used in establishing the EPZ and EP requirements
- Staff believes that DOE/INL's Research Plan for Moisture and Air Ingress (PLN-4086, April 2012) presents a reasonable approach for providing data needed for developing and validating models for predicting the effects of air and moisture ingress on NGNP TRISO fuel performance and fission product transport
- In SECY 05-0006, the staff recommends that source terms for compliance should be 95% confidence level values based on best-estimate calculations

## FUNCTIONAL CONTAINMENT PERFORMANCE

## OVERVIEW OF DOE/INL PROPOSAL

- Proposed definition of Functional Containment: *The collection of design selections that, taken together, ensure that*
  - *Radionuclides are retained within multiple barriers, with emphasis on retention at their source in the fuel*
  - *NRC regulatory requirements and plant design goals for release of radionuclides are met at the Exclusion Area Boundary*
- DOE/INL requests NRC feedback on three elements of its approach to NGNP functional containment:
  - AGR Fuel Program activities
  - Options for containment functional performance standards
  - Event selection for plant siting and functional containment design decisions

## Issue 1: AGR Fuel Program Activities

Confirm that plans being implemented in AGR Fuel Program are generally acceptable and provide reasonable assurance that TRISO fuel can retain fission products in predictable manner. Identify any additional information or testing needs.

### **NRC Staff Feedback - Overview**

- Scope of AGR activities is generally reasonable in context of pre-prototype testing
- Early AGR irradiation and safety testing results show promise for demonstrating much of desired TRISO fuel retention capability
- Additional data are needed from fuel and core testing in NGNP Prototype to provide reasonable assurance of targeted fission product retention in fuel
  - Test data on fuel irradiated in HTGR for effects of plutonium fission products (Pd, Ag) on TRISO particle coatings
  - Testing in prototype to confirm NGNP core operating conditions and ability to detect potential core “hot spot” operating anomalies
- 10 CFR 50.43(e)(2) allows NRC to impose additional requirements on prototype plant during testing period

## Issue 1: AGR Fuel Program Activities (cont.)

### **Additional Staff Feedback**

- Adequately define fuel service conditions and performance requirements
  - Normal operations
    - Pu burnup for potential effects of Pu fission products (Pd, Ag) on TRISO fuel particle coatings
    - Potential effects of irradiation parameter path dependence
    - NGNP core operating condition uncertainties and anomalies (hot spots)
  - Accidents
    - Design information is needed to confirm DOE/INL's assumed lack of specific fuel testing requirements for reactivity excursion events
    - DOE/INL's Research Plan for Moisture and Air Ingress (April 2012) should be implemented to address data needs for fuel performance and fission product transport in bounding events
- Supplement AGR data with data from fuel irradiated in NGNP prototype
  - Real-time versus accelerated testing
  - Prototypic plutonium burnup

## Issue 1: AGR Fuel Program Activities (cont.)

### **Additional Staff Feedback**

- Evaluation of irradiation test temperature uncertainties
  - Additional information provided in two INL submittals
    - “AGR-1 Thermocouple Analysis,” May 2012
    - “Uncertainty Quantification of Calculated Temperatures for AGR-1 Experiment,” June 2012
  - Important to understand how AGR irradiation temperature uncertainties are quantified and affected by increasing thermocouple failures
- Assessment of applicability of delayed fuel heatup testing
  - DOE/INL report (TEV-1543, June 2012) analyzes potential changes in fuel composition during the interim between irradiation and heatup testing. Results support application of data from delayed fuel heatup tests to the modeling of fuel performance and fission product transport in NGNP accidents.

## Issue 2: Options for Containment Functional Performance Standards

### **NRC Staff Feedback**

- Proposed approach presents a reasonable option for establishing modular HTGR functional containment performance standards (per SRM to SECY-03-0047)
  - Radionuclide containment function: reduce releases to the environs
  - Other “containment” functions as discussed in SECY-05-0006
    - Protect risk-significant SSCs from internal and external events
    - Physically support risk-significant SSCs
    - Protect onsite workers from radiation
    - Remove heat to keep risk-significant SSCs within design and safety limits
    - Provide physical protection (i.e., security) for risk-significant SSCs
    - Reduce radionuclide releases to environs (including limiting core damage)
    - Limit air ingress after helium depressurization accidents
- Future Commission policy direction may be appropriate for determining specific criteria applied to modular HTGR functional containment

## Issue 3: Event selection for plant siting and functional containment design decisions

### **NRC Staff Feedback**

- Core melt accident assumed for LWRs may not be applicable to modular HTGRs
- Proposed approach to event selection for siting source terms is generally reasonable when supplemented with insights from “safety terrain” studies
  - *Applicant should submit for NRC consideration a risk-informed selection of siting events, building on the types of bounding events considered by staff in NUREG-1338 for MHTGR*
  - *To assure there are no “cliff-edge effects” [credible events with high dose consequences] and to understand ultimate safety capability, bounding event selection should be further informed by exploratory studies of postulated extreme events, including bounding events with air oxidation of graphite per the SRM to SECY-93-092. Such exploratory events should be physically plausible, may have estimated frequencies below the BDBE region ( $< 5E-7$ ), and will consider inherent behavior of the modular HTGR design*
- Future Commission direction may be appropriate for the selection of siting source term events for functional containment criteria

## EMERGENCY PREPAREDNESS

## BACKGROUND

- In October 2010, DOE/INL submitted a white paper on “Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR”
  - NRC staff did not formally review this white paper submittal and provided no formal feedback to DOE/INL on its contents
  - DOE/INL participated in NRC public meetings in 2011 on emergency preparedness framework issues for small modular reactors (SMRs)
- In October 2011, NRC staff issued SECY-11-0152, Development of an Emergency Planning and Preparedness Framework for Small Modular Reactors
  - Described a general approach to scalable EPZs
- 10 CFR 50.47(c)(2) allows Emergency Planning Zone (EPZ) size for gas-cooled reactors to be considered on a case-by-case basis

## SUMMARY OF STAFF FEEDBACK

- DOE/INL's proposed approaches are generally reasonable and are responsive to the Commission's Policy Statement on Advanced Reactors
- Future Commission direction may be appropriate for this area
- The staff is open to considering alternative EP requirements and frameworks for advanced reactors and SMR facilities
- The staff does not plan to propose additional new EP policies or to revise the existing guidance for addressing EP requirements at this time

Issue 1: DOE/INL requests that NRC propose a new policy or revised regulations on EPZ sizing. NGNP goal is to justify EPZ at 400-meter Exclusion Area Boundary.

## **NRC Staff Feedback:**

Consistent with SECY-11-0152

- Describes dose-distance scalable EPZ approach
- Staff will more fully address EP issues in the context of site-specific pre-application reviews
- Staff would be open to considering future proposals from industry or established pre-applicants on such topics as:
  - PRA-informed approach that includes dose assessment versus distance
  - Risk-informed criteria for determining the point at which the probability of exceeding the PAG values is acceptably low

Issue 2: DOE/INL requests that NRC establish specific guidance on graded approaches to applying EP requirements in relation to the PAGs.

## **NRC Staff Feedback:**

- NRC expects specific proposals from NGNP pre-applicant to be supported by details of the NGNP design, site, and co-located user facilities
- Proposed EP approaches for NGNP should include consideration of how potential EP basis events may be influenced by co-location and external events impacting the site
- NGNP EP approach addressing PAGs must be developed by the site applicant
- Graded EP may be different for NGNP prototype plant versus subsequent standard plants

Issue 3: DOE/INL requests that NRC propose guidance on how issues related to modularity of the designs and the co-location of multi-module plants near industrial facilities should be considered in EP.

## **NRC Staff Feedback:**

- Co-location considerations for current LWRs are largely applicable
  - Regulatory guidance already incorporated in existing EP plans
- Co-generation implying co-located utilization of nuclear heat sources
  - Different regulatory nexus
  - Safety strategy must consider challenges and issues arising from the modular HTGR being coupled to the industrial facility
- Expect staff considerations of new regulations, hazards assessments, accident evaluations, and security issues

THANK YOU