

**NUCLEAR REGULATORY COMMISSION**

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522nd Meeting

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

May 6, 2005

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

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UNITED STATES OF AMERICA  
NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS  
(ACRS)

522<sup>nd</sup> MEETING

+ + + + +

FRIDAY,

MAY 6, 2005

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B3, 11545 Rockville Pike, at 8:30 a.m., Graham B. Wallis, Chairman, presiding.

COMMITTEE MEMBERS:

GRAHAM B. WALLIS, Chairman

WILLIAM J. SHACK, Vice Chairman

GEORGE E. APOSTOLAKIS, Member

MARIO V. BONACA, Member

RICHARD S. DENNING, Member

THOMAS S. KRESS, Member

DANA A. POWERS, Member

VICTOR H. RANSOM, Member

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COMMITTEE MEMBERS: (cont.)

STEPHEN L. ROSEN, Member

JOHN D. SIEBER, Member

ACRS STAFF PRESENT:

JOHN T. LARKINS, Executive Director

ASHOK C. THADANI, Deputy Executive Director

THERON BROWN

SAM DURAISWAMY

JENNY M. GALLO

NOBLE GREEN, JR.

MICHAEL L. SCOTT

NRC STAFF PRESENT:

RICH BARRETT, RES

JAMES A. DAVIS, RES

WILLIAM E. KEMPER, RES

MICHAEL MAYFIELD, RES

MICHAEL E. WATERMAN, RES

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A-G-E-N-D-A

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(I&C) Systems Research Plan

Adjourn

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

9:10 a.m.

CHAIRMAN WALLIS: The meeting will now come to order. This is the second day of the 522nd meeting of the Advisory Committee on Reactor Safeguards. During today's meeting the Committee will consider the following, the Steam Generator Tube Integrity Program, Digital Instrumentation and Control Systems research plan, reconciliation of ACRS comments and recommendations, future ACRS activities, report of the Planning and Procedures Subcommittee, and the preparation of ACRS reports.

This meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act. Mr. Sam Duraiswamy is the designated Federal Official for the initial portion of the meeting.

We have received no written comment, nor request, for time to make oral statements from members of the public regarding today's sessions. A transcript of portions of the meeting is being kept, and it is requested that the speakers use one of the microphones, identify themselves, and speak with sufficient clarity and volume so that they can be readily heard.

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1 I'll remind you that we are having our  
2 annual ethics training over lunch today. John Szabo  
3 will be here at 12:15, and you may have been told  
4 that it will be in the small room, but it will  
5 actually be held here.

6 Without more ado, I'd like to proceed  
7 with the meeting, and I'd ask my colleague Dana  
8 Powers to lead us through the first item.

9 MEMBER POWERS: Thank you, sir. We're  
10 going to discuss the Steam Generator Tube Integrity  
11 Program, most of which is, many aspects of which are  
12 being done at Argonne National Laboratory.

13 It's part of -- it's one of the topics  
14 that we're going to address in our ACRS quality  
15 research review. And so maybe we should look upon  
16 this as background for the presentation on that  
17 quality review.

18 We're going to try to do this over the  
19 course of an hour and 25 minutes, James, so we need  
20 to move right along.

21 MR. DAVIS: Okay.

22 MEMBER POWERS: I'll introduce James  
23 Davis from the Office of Nuclear Regulatory Research  
24 to at least get us started here. I don't -- I have  
25 no idea who the goat sitting next to him is. I'm

1 sure you will introduce that.

2 MR. DAVIS: It's Bill Shack. He's a  
3 program manager for this program at Argonne National  
4 Lab.

5 MEMBER POWERS: Oh, he's just a manager.  
6 I thought he was a technical pursuance --

7 MR. DAVIS: Yes, but he also does a lot  
8 of the other. Okay. We're doing research in quite  
9 a few areas on steam generators. I've specifically  
10 been asked to cover Task 3, which is tube integrity.

11 The reason that we're doing this work in  
12 tube integrity is user needs from NRR are related to  
13 the in-service inspection capabilities, reliability  
14 of in-service inspection. And then models for  
15 rupture burst and leak of steam generator tubes.

16 And NRR plans to use this information to  
17 review licensee submittals. In addition to the work  
18 that we're doing for the user needs, we're also  
19 doing work on crevice chemistry, tube support  
20 plates.

21 ACRS told us that they didn't feel that  
22 we had a -- anybody has a good enough understanding  
23 of what causes degradation of steam generator tubes  
24 at the tube support plates.

25 So we're doing a pretty good study in

1 that area.

2 MEMBER POWERS: Is this destined to be  
3 an anachronism? I mean as people go through and  
4 change out steam generators, aren't they eliminating  
5 the crevices?

6 MR. DAVIS: No, they're not. They still  
7 have the tube support plates.

8 MEMBER POWERS: But I mean --

9 MR. DAVIS: They have a different  
10 design.

11 MEMBER POWERS: -- isn't that a broached  
12 hole kind of design so you don't have narrow  
13 crevices anymore?

14 MR. DAVIS: Well they still have  
15 crevices, and we feel it's very important that we  
16 understand what's going to happen with 690 over the  
17 long-term, and these crevices.

18 And that's what the real objective of  
19 that work is, is with these new stainless steel tube  
20 support plates and with the different design. We  
21 feel it's very important to know what's going to  
22 happen over the long-term.

23 MEMBER POWERS: What's the potential  
24 difference between the stainless steel and the 690?

25 MR. DAVIS: I'm not exactly sure. I

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1 know I don't think it's very big because of the low  
2 conductivity of the solution, but we haven't  
3 physically measured it at this point.

4 We're working on that. What I'm going  
5 to present today, I'm going to emphasize Task 3,  
6 which is tube integrity and integrity and  
7 predictions. I'll give you the objective.

8 I'm going to go through some of the leak  
9 rate models. I'm also going to discuss  
10 pressurization rate testing because there are some  
11 questions about the effect of pressurization rate on  
12 testing when you actually pull tubes in the field.

13 I'm going to discuss the main steam line  
14 break, study what we did where you have a  
15 depressurization on the secondary side. We've done  
16 some very interesting work recently on constant  
17 pressure crack growth, and I'll get into that.

18 Okay. And then I'm going to tell you  
19 how we statistically treat the models and then I'll  
20 summarize the results. And I'll mention some of the  
21 future work that we have planned.

22 I'm not sure we're really going to have  
23 time to discuss Task 1, 2, and 3, which are  
24 assessment of inspection reliability, ISI technology  
25 and degradation modes, but I put it in the package

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1 just so -- just for reference material.

2 The objective of Task 3 is to evaluate  
3 and validate models for leak and rupture behavior,  
4 failure pressures, and leak rates for degraded  
5 tubes.

6 And this is under normal and accident  
7 conditions.

8 MEMBER POWERS: Can you give us, maybe  
9 not immediately but in the course of the  
10 presentation, can you give us an idea when you say  
11 you want to evaluate and validate these models, what  
12 kinds of levels of precision of accuracy you're  
13 looking for from these models?

14 Plus or minus one percent sort of  
15 things, or plus or minus factors of two?

16 MR. DAVIS: We're not to that point with  
17 real cracks yet because part of the problem is the  
18 assumption that we know exactly what the crack looks  
19 like and we don't always know that.

20 That's one of the problems. With the  
21 idealized cracks we do a very good job with the EDM  
22 notch -- notches and we just don't do quite as good  
23 a job with real cracks because --

24 MEMBER POWERS: Wait a minute. The  
25 question I'm driving at is you can take these

1 notches that you prepared, that you know very well,  
2 and you can model those, and then you try to apply  
3 them to these cracks that have ligaments and whatnot  
4 running through them. How do you know when you're  
5 good enough?

6 MR. DAVIS: Good enough?

7 MEMBER POWERS: Yes. I mean you're  
8 never going to get it exactly because there's  
9 stochastic component and what the crack looks like,  
10 but there's a point where continued refinement of  
11 the model's not going to do you any good.

12 MR. DAVIS: Yes.

13 MEMBER POWERS: You're not going to get  
14 over that, so how good is good enough here?

15 MR. DAVIS: I don't know if I actually  
16 know the answer to that.

17 VICE CHAIRMAN SHACK: Well, you know,  
18 that's almost a question for NRR to answer. But our  
19 -- with essentially a well -- a good geometry, we're  
20 typically, you know, somewhere on the order of ten  
21 to 15 percent.

22 So when we know the geometry -- as Jim  
23 says, the difficulty with the real crack is that you  
24 don't know the geometry. You can be very  
25 conservative, you know.

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1           The typical response now is to take a  
2 complex crack, shape, and bound it with a  
3 rectangular crack that's, you know, as long as the  
4 real crack, and as deep as the deepest portion of  
5 the real crack.

6           And that can be very conservative by  
7 factors of two. So you're looking for something to  
8 get you closer to the 15 percent or so.

9           MEMBER POWERS: I guess I'm still  
10 struggling. Okay. I mean what's important here, how  
11 fast you depressurize, how fast you put liquid out?

12           VICE CHAIRMAN SHACK: Well again, I  
13 think in many cases it's a question of whether  
14 you've met your -- you know, when you do your  
15 operational assessment, like most of these rules,  
16 you know, if you've made the limit you're golden and  
17 if you haven't made the limit --

18           MEMBER SIEBER: You're brown.

19           VICE CHAIRMAN SHACK: -- you have a  
20 problem. And so you'd like to avoid access  
21 conservatism, but you'd like to understand whether  
22 you really do have the margins that you intend to  
23 have.

24           You know, I can't give you a risk number  
25 for what happens if you don't meet the ASME margin

1 on your condition assessment, but that is what the  
2 regulations require. So it is a compliance problem.

3 MEMBER DENNING: Now is it a question of  
4 plug-in criteria? Is that what it is? I mean it's  
5 how confident you want to be that you'll detect a  
6 crack and it'll be a certain size, and then you'll  
7 decide to plug? Is that what it comes down to?

8 VICE CHAIRMAN SHACK: Well, I mean  
9 certainly you want to be able to do that, but I  
10 think the bigger problems is when you're doing the  
11 operational assessment at the end of the cycle and  
12 the -- you know, you have to demonstrate that you  
13 have the required margins, that, you know, you know  
14 you're operating with cracks.

15 You know, in most of these alloy 600  
16 steam generators there's not much question about  
17 that. The question is whether you've really got the  
18 required margins when you're done, and --

19 MEMBER POWERS: But doesn't that again  
20 come down to the question of plugging criteria and  
21 the degree of confidence you want to have that in  
22 the next cycle you're not going to --

23 VICE CHAIRMAN SHACK: No, it's -- I  
24 think -- you mean that's an important question, but  
25 the question that you're immediately answering is

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1 you've come to the end of the cycle and you're  
2 looking at all the cracks that are in the steam  
3 generator, making sure that you have enough margin,  
4 that is you know, you predicted that you would go  
5 through the cycle and always have tubes that met all  
6 the ASME requirements.

7 When you get to the end of the cycle you  
8 have to find out whether that prediction was in fact  
9 true. And if you haven't made that then you've  
10 essentially violated your condition, which is to  
11 always operate within the proper margins.

12 So you then look at your worst cracks  
13 and you try to determine whether you've had enough  
14 margin or not.

15 CHAIRMAN WALLIS: Now you inspect every  
16 tube?

17 VICE CHAIRMAN SHACK: That's a -- in  
18 many alloy 600, it's close -- it's basically 100  
19 percent. You know, most of them have enough.

20 They meet all the expansion rules that  
21 you're ever going to have.

22 MEMBER KRESS: What purpose does it  
23 serve to find out after the fact that you violated  
24 your condition?

25 VICE CHAIRMAN SHACK: Well I think it --

1 you know, because you're going -- you're going to  
2 make an assessment now for the next cycle. You, you  
3 know, --

4 MEMBER KRESS: Then change your model,  
5 or --

6 VICE CHAIRMAN SHACK: Well, yes, you may  
7 add conservatism. I think, you know, that's, you  
8 know,

9 MEMBER KRESS: So it's for the next  
10 assessment?

11 VICE CHAIRMAN SHACK: I mean it's  
12 basically --

13 MEMBER KRESS: You want to know how good  
14 your model is, then?

15 VICE CHAIRMAN SHACK: It's a  
16 verification of your prediction method --

17 MEMBER KRESS: I see.

18 VICE CHAIRMAN SHACK: -- you know, for  
19 all the uncertainties that we have. And we, you  
20 know, we have uncertainties in crack sizing,  
21 uncertainties in growth rate, you know.

22 So you've made those predictions. You  
23 now find out whether your -- you've met all your  
24 requirements or you haven't. If you haven't,  
25 obviously you have to justify what you're going to

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1 be doing for the next cycle.

2 MEMBER KRESS: So you're going to change  
3 the model?

4 VICE CHAIRMAN SHACK: Which typically is  
5 to presumable assessment conservatism.

6 MEMBER DENNING: Now wait a second, I  
7 don't understand. But the safety concern or  
8 consideration is if in the next cycle you're going  
9 to have a tube rupture which has safety concerns  
10 associated with it, right?

11 So I mean there's all these questions  
12 about models, but isn't the real issue am I going to  
13 plug tubes or am I not going to plug tubes. Isn't  
14 that what it comes down to? I'm missing --

15 MEMBER APOSTOLAKIS: Or change the  
16 models.

17 MEMBER DENNING: No, no, no. I mean the  
18 -- you can change the model but that's secondary.  
19 The real question is are you going to burst the next  
20 time, and if you have to make more conservatism that  
21 means that you have to plug more tubes, right, or  
22 plug at a lower level?

23 VICE CHAIRMAN SHACK: Well I think the  
24 answer -- you certainly don't want to burst any  
25 tubes in the next cycle but you also don't want to

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1 run the tubes even with less margin that you intend  
2 to have.

3 I mean you're not only supposed to get  
4 through the cycle without bursting tubes, that's,  
5 you know, that's --

6 MEMBER DENNING: Sure, sure.

7 VICE CHAIRMAN SHACK: -- requirement  
8 number one.

9 MEMBER DENNING: No, no, no. I agree.  
10 I agree, but I think getting back to Dana's  
11 question, how accurate to we have to be, the  
12 question is what risk are we willing to take that we  
13 will not have a sufficiently conservative plugging  
14 criterion that you'll have a -- too large of a  
15 probability of another break.

16 MEMBER APOSTOLAKIS: Which is -- I mean  
17 in a broader sense, the question is at which point  
18 reducing the uncertainties doesn't change the  
19 decision. And that's where Rich is going.

20 What is the decision that they have to  
21 make, and you know, if I have uncertainty say that's  
22 only five percent, I reduce it from ten to 15  
23 percent to five percent.

24 Would the decision change? If it  
25 doesn't change then I can tolerate it, right? I

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1 don't care about reducing it anymore. And that's  
2 where Rich is going.

3 I mean what decision is that, plugging  
4 the tubes or what?

5 MEMBER DENNING: And I think that the  
6 decision is do I plug or don't I plug.

7 MEMBER APOSTOLAKIS: Yes, yes.

8 MEMBER DENNING: Right? Am I  
9 simplifying it too much?

10 MR. KARWOSKI: This is Ken Karwoski from  
11 the NRR Staff. I think it's important to recognize  
12 what plant procedures are what type of safety  
13 factors are built in to all these plugging criteria  
14 and plant practices because, you know, one, it's  
15 important to know the uncertainty in predicting the  
16 burst pressure of the flaws, but lets look at a  
17 typical plant with mill anneal tubing who has  
18 cracking.

19 Most plants, unless they have an  
20 alternate repair criteria approved, plug all flaws  
21 on detection. And as Bill was pointing out, so when  
22 they find these flaws they want to make sure that  
23 they had the margins that they thought they did.

24 And so when you look at a given plant  
25 with mill anneal tubing, if you just look at

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1 pressure loading, they're trying to maintain a  
2 safety factor of 3 against burst during normal  
3 operation.

4 So the key consideration is are they  
5 meeting that. And so it's tolerable not to meet it.  
6 It's not something that the plant wants to exceed,  
7 but it is tolerable for the plant to have a reduced  
8 safety factor of let's just throw out 2.9, because  
9 the tubes still won't burst during normal operation,  
10 nor during accident conditions.

11 So there's a lot of margin built into  
12 the acceptance criteria for these inspections. In  
13 addition, when we're talking about probability of  
14 burst we're -- in assessing degradation, we're not  
15 using the mean value.

16 We tend to use like a 95 percent  
17 confidence value. So the real consideration is do  
18 we have enough confidence in the uncertainty  
19 associated with those burst pressure predictions.

20 And so it is tolerable to exceed this  
21 performance criteria. It's not something that we  
22 want plants to do, but when they do exceed, or if  
23 they do, because it doesn't occur that frequently,  
24 but if they do then they take prompt corrective  
25 action.

1 MEMBER DENNING: Well, you're --

2 MEMBER POWERS: We've probably spent  
3 enough on this question. But when you tell me that  
4 you're developing a model and validating it, I  
5 really feel like I need to have some sense if when  
6 you can say QED, and I don't have that sense here.

7 MEMBER ROSEN: On another point, I think  
8 you were correct when you said that most mill anneal  
9 600 plants will inspect 100 percent but I don't  
10 think that's the picture that's really out there  
11 now.

12 I mean so many of those plants have  
13 replaced their steam generators. I don't know how  
14 many are left in operation, but the new 690 plants,  
15 after the first cycle where they do do 100 percent,  
16 the baseline -- I don't think they're doing a full  
17 100 percent anymore.

18 MR. DAVIS: No, they don't.

19 MEMBER ROSEN: There's much -- the  
20 amount of inspection after the first baseline is  
21 much reduced. And that picture will continue to come  
22 into focus as more and more mill anneal 600 alloy  
23 plants go out of service.

24 So we're dealing really with a future  
25 that looks like less inspection typically.

1 MEMBER DENNING: Yes.

2 MEMBER ROSEN: Unless, you know, unless  
3 the 690 plants behave badly. I mean if you don't  
4 get into -- what is it (C)(1), you know, where you  
5 have more than one percent and have to go into one  
6 of these expansions, you're going to do a fairly  
7 limited inspection.

8 MR. DAVIS: That's right.

9 MR. KARWOSKI: This is Ken Karwoski from  
10 the NRR Staff. I just wanted to clarify all plants  
11 that replace their steam generator, the industry  
12 guidelines, and to my knowledge, all plants who  
13 currently replace, they do 100 percent inspection in  
14 the first outage after replacement to identify the  
15 condition of the tubes.

16 MR. DAVIS: Right.

17 MR. KARWOSKI: After that they may do  
18 less inspections, and that's frequently what we see,  
19 but --

20 MEMBER ROSEN: I'm aware of that. Now  
21 after that what is it typically?

22 MR. KARWOSKI: It varies from plant to  
23 plant. For the 600 thermally treated plants, they  
24 typically inspect two of their four steam  
25 generators, you know, in a four-loop plant, every

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1 other outage.

2 They'll inspect two steam generators one  
3 outage. The next outage they'll inspect the other  
4 two, and they'll go on. But those practices evolved  
5 with time, and it's difficult to --

6 CHAIRMAN WALLIS: How many tubes in  
7 those SGs?

8 MR. KARWOSKI: Five thousand.

9 MEMBER POWERS: We're really getting off  
10 the track here. I failed to see --

11 CHAIRMAN WALLIS: And how many do they  
12 test?

13 MEMBER POWERS: I mean one of the  
14 problems I'm running into here is I don't understand  
15 how these models relate to all of this regulatory  
16 inspection and things like that.

17 MEMBER ROSEN: Could I ask -- Graham  
18 asked the final question which we never quite got  
19 to, which was the ones they inspect, what's the  
20 percentage?

21 MR. KARWOSKI: It varies from plant to  
22 plant, but we can provide you tables of historic  
23 practices for like thermally treated 600, but  
24 plants, -- some plants do 100 percent when they look  
25 at those two steam generators, others do 50 percent.

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1 MEMBER ROSEN: That much?

2 MR. KARWOSKI: Yes, yes.

3 MEMBER ROSEN: On a new steam generator?

4 VICE CHAIRMAN SHACK: It's a thermally  
5 treated 600. Six ninety would typically be --

6 MR. KARWOSKI: Be even less.

7 VICE CHAIRMAN SHACK: -- less.

8 MEMBER POWERS: You can go ahead.

9 MR. DAVIS: The steam generator tube  
10 materials are very ductile, and so in the models  
11 what we consider is that the failure under design  
12 basis conditions is by plastic instability.

13 Under severe accident conditions where  
14 you're at higher temperature it's more likely at  
15 creep or at plastic instability. Now the real  
16 cracks have complex shapes, and as Bill said, we use  
17 a rectangular -- equivalent rectangular crack method  
18 to give conservative results.

19 And we're developing methods to give  
20 more realistic predictions of the ligament rupture.  
21 An efforts ongoing to develop more realistic  
22 predictions for burst.

23 We don't do as well on bursts as we do  
24 on ligament rupture. The first model I'm going to  
25 discuss is for an axial flaw that's through wall and

1 it's idealized.

2 And Erdogan came up with a model for  
3 predicting the rupture, and it's -- the critical  
4 pressure is  $\sigma H$ , where H is the wall thickness  
5 over the mean radius, and factor M, which comes out  
6 of linear elastic fracture mechanics modeling.

7 MEMBER KRESS: What's a flow stress?

8 MR. DAVIS: Right.

9 MEMBER KRESS: What is a flow stress?  
10 I've never heard that term.

11 MR. DAVIS: Flow stress is the average  
12 of the yield in the tensile.

13 MEMBER KRESS: Why do you call it a flow  
14 stress?

15 MR. DAVIS: That's just what they call  
16 it in fracture mechanics.

17 VICE CHAIRMAN SHACK: It's a way of  
18 accounting for work hardening with an elastically  
19 perfectly plastic model. It's just a  
20 simplification. It turns out to work quite well for  
21 ductile materials.

22 But if you use the yield stress you're  
23 being extremely conservative because the materials  
24 can work hard in a great deal.

25 MEMBER KRESS: Right.

1 VICE CHAIRMAN SHACK: Use the ultimate  
2 stress, you're non-conservative, --

3 MEMBER KRESS: So it's a --

4 VICE CHAIRMAN SHACK: -- realistically.

5 MEMBER KRESS: -- somewhere in between  
6 those two?

7 VICE CHAIRMAN SHACK: It's the average  
8 of the two, and that turns out to be quite good for  
9 ductile and work hardening materials.

10 CHAIRMAN WALLIS: So you're misusing a  
11 word from thermal hydraulics to make it more  
12 respectable?

13 MEMBER KRESS: Yes, that must be it.

14 VICE CHAIRMAN SHACK: Well actually it  
15 comes from GI Taylor, so we know it's got to be  
16 right.

17 MEMBER KRESS: Oh, it has to be good  
18 then.

19 MR. DAVIS: Another case that we have a  
20 model for is where you have a ligament where you  
21 part-through crack. And here you come up with a --  
22 instead of M an M sub-p.

23 And this is related to the crack size  
24 and the wall thickness and the M factor, which is  
25 the linear elastic fracture mechanics. Once you do

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1 rupture a ligament, now if the critical pressure is  
2 higher than the ligament pressure then you're not  
3 going to burst the tube you're just going to leak.

4 And what we found in our work at Argonne  
5 in that the -- this model works well for long cracks  
6 but it doesn't work so well for short, deep cracks.  
7 So Argonne modified this expression and included the  
8 term alpha, which is a geometric factor as well.

9 And it turns out that the modification  
10 that Argonne did gives us much better results on  
11 short, deep cracks.

12 CHAIRMAN WALLIS: What do you mean by  
13 short, deep cracks?

14 MR. DAVIS: Like a quarter inch crack  
15 that's 80 percent through wall.

16 CHAIRMAN WALLIS: A quarter inch wide,  
17 or what's the --

18 CHAIRMAN WALLIS: Well then long and  
19 deep sound to me -- seem to be the same thing.

20 MR. DAVIS: It's -- a short, deep crack  
21 is like a quarter inch crack that's 80 percent  
22 through wall. A long crack is like maybe a half  
23 inch or an inch long and --

24 CHAIRMAN WALLIS: It's long this way and  
25 then it goes through the wall that way.

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1 MR. DAVIS: Yes. But if it's --

2 CHAIRMAN WALLIS: Tangentially is

3 length?

4 MR. DAVIS: If it's short and deep --

5 VICE CHAIRMAN SHACK: Length is axial or  
6 circumferential.

7 CHAIRMAN WALLIS: Well I would say wide  
8 and deep, not --

9 MR. DAVIS: No.

10 MEMBER POWERS: It matters not what you  
11 would say it only matters what they say.

12 CHAIRMAN WALLIS: Okay, but --

13 MR. DAVIS: What we've done with the  
14 actual stress corrosion cracks is we've -- or  
15 irregular cracks is we've come up with this  
16 rectangular crack method.

17 The problem that we run into with this  
18 model is that it -- sometimes we don't account for  
19 ligaments.

20 CHAIRMAN WALLIS: Now rectangular crack  
21 means that this shortness and this depth are sides  
22 of a rectangle?

23 MR. DAVIS: Yes.

24 CHAIRMAN WALLIS: Is that what you mean?

25 MR. DAVIS: Yes. And you take a rough

1 crack and you take the best rectangle that you can  
2 find.

3 CHAIRMAN WALLIS: And it has sharp  
4 corners, does it?

5 MR. DAVIS: Yes. It has sharp corners.  
6 For our model that's what you use.

7 CHAIRMAN WALLIS: Does it make the  
8 computation more difficult when there's sharp  
9 corners?

10 MR. DAVIS: No.

11 CHAIRMAN WALLIS: No?

12 MR. DAVIS: No. It simplifies it  
13 actually.

14 CHAIRMAN WALLIS: Okay, okay.

15 MR. DAVIS: But what we do is we take a  
16 series of these rectangular cracks and we calculate  
17 M sub-p and we take the one with the highest M sub-p  
18 for conservatism and use that in the model.

19 The problem that you have is if you have  
20 ligaments or you have a meandering crack, the -- you  
21 have an -- when you calculate it with the equivalent  
22 crack method you don't account for the entire length  
23 of the -- of what's going on.

24 And that's why you sometimes don't get  
25 very good results.

1 MEMBER ROSEN: Can you be a little more  
2 expressive when you talk about ligaments? I know  
3 what they are in my leg. What, exactly, what do you  
4 mean when you say ligament?

5 MR. DAVIS: So you have an inch long  
6 crack but it consists of a series of short cracks  
7 with metal in between them. And so to rupture that  
8 you have to rupture those ligaments.

9 It's not really an inch long crack it's  
10 a series --

11 MEMBER ROSEN: So you think of it as a -  
12 -

13 MR. DAVIS: -- of short --

14 MEMBER ROSEN: Look at my hands and the  
15 two branches are cracks.

16 MR. DAVIS: Right.

17 MEMBER ROSEN: And the space in between  
18 is the ligament?

19 MR. DAVIS: That's a ligament and that's  
20 solid material.

21 CHAIRMAN WALLIS: The ligaments are  
22 still hanging on.

23 MR. DAVIS: They're still there and  
24 they're holding it together. And part of the  
25 problem is --

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1 MEMBER ROSEN: It's quite strong.

2 MR. DAVIS: You're assuming you know  
3 what the length is using, say, eddy current to  
4 determine the length. But sometimes eddy current  
5 won't see the ligaments. And so --

6 MEMBER SIEBER: Volumetric.

7 MR. DAVIS: -- results will tell you  
8 that the crack's longer than it is. Or you'll  
9 assume it's longer than it really is and that's why  
10 you don't get really good results sometimes.

11 VICE CHAIRMAN SHACK: Ligaments just  
12 make life very -- they make it complicated for your  
13 inspection because they fool the eddy current. They  
14 provide a conductive path, and so --

15 MEMBER SIEBER: Right.

16 VICE CHAIRMAN SHACK: You know, it makes  
17 it difficult to detect because you're, you know, you  
18 want a high impedance for the detection so it makes  
19 it difficult to detect.

20 It screws up your burst calculation  
21 because although these ligaments are very narrow  
22 they add a surprising amount to the strength of the  
23 whole crack.

24 So you tend to be overly conservative  
25 with these bounding crack models. And you end up

1 greatly over-predicting leak rates because again the  
2 crack turns out to be very, very sensitive to how  
3 wide the -- and this -- we use wide to say how much  
4 the crack opens up.

5 So it's long, wide, and deep. And so a  
6 ligament greatly reduces the width of the crack  
7 opening and greatly reduces the flow through the  
8 flaw, and so you're almost all the time -- our  
9 simplified crack type models over-predict the leak  
10 rate.

11 They essentially over-predict the burst  
12 pressure.

13 MEMBER ROSEN: So coming back to my  
14 hands model where my hands are the cracks, the  
15 material in between is still intact.

16 VICE CHAIRMAN SHACK: Yes, there's --

17 MEMBER ROSEN: And you're measuring this  
18 crack as being the width of to the back of my hands  
19 --

20 VICE CHAIRMAN SHACK: Your hand, right.

21 MEMBER ROSEN: -- whereas really it's  
22 got a lot other material in between those facing the  
23 cracks.

24 VICE CHAIRMAN SHACK: It doesn't take  
25 much material, you know. You have a half inch crack

1 and you put a sort of a 32nd inch ligament in the  
2 middle of it and it makes a tremendous difference in  
3 the leak rate through that crack. A little ligament  
4 goes a long way.

5 MEMBER SIEBER: With enough ligaments  
6 you can actually be through wall and have it not  
7 burst.

8 VICE CHAIRMAN SHACK: Oh, yes. Now in  
9 the fact -- when we talk about ligament rupture  
10 that's the whole point, that we can predict when the  
11 crack goes through wall quite well even for a  
12 complex crack shape.

13 But the margin that you then have to  
14 actual bursts where you get an unstable tearing, you  
15 know, it's one thing to pot through and have a very  
16 small, tiny crack that's popped through in just a  
17 small portion of it.

18 It's another one to rip the whole length  
19 of the crack and to have an unstable burst that  
20 keeps on going. And again, we can predict the  
21 ligament rupture to go through wall quite  
22 accurately.

23 What we can't tell you is the margin you  
24 then have to the unstable burst.

25 CHAIRMAN WALLIS: The ligament must be

1 very material dependent, brittle material. I  
2 presume you don't have ligaments in certain  
3 materials. You have lots of ligaments because of  
4 the structure of the material.

5 VICE CHAIRMAN SHACK: In our gooey,  
6 rubbery alloy 600 we have lots of ligaments.

7 CHAIRMAN WALLIS: And so the flow is  
8 like a sticky stuff --

9 VICE CHAIRMAN SHACK: Right.

10 CHAIRMAN WALLIS: -- and pulls these  
11 bits of glue out.

12 VICE CHAIRMAN SHACK: And the stress  
13 corrosion cracks grow that way. They kind of  
14 meander through various grain boundaries rather than  
15 cleanly rupturing grains so that you get this  
16 complex --

17 MEMBER POWERS: Even in brittle ceramics  
18 they talk about ligaments.

19 VICE CHAIRMAN SHACK: But there it tends  
20 to be more a big bang kind of a failure.

21 MR. DAVIS: This is what Bill just  
22 covered, so -- we also have developed models for  
23 circumferential cracks. And there we didn't use the  
24 plastic instability as much as we used a fracture  
25 mechanics approach because it's a little more

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1 complicated to deal with.

2 CHAIRMAN WALLIS: I would think the  
3 ligaments would be subject to creep, that they would  
4 actually creep away because of the high stresses on  
5 them. Don't they?

6 VICE CHAIRMAN SHACK: Yes, we'll get to  
7 that.

8 CHAIRMAN WALLIS: Okay.

9 MR. DAVIS: We also develop models for  
10 severe accidents where you're at a higher  
11 temperature. At lower temperature you wouldn't  
12 expect a lot of creep, but at the higher temperature  
13 a creep rupture model has been developed.

14 And it -- and also it predicts a lot  
15 better than the flow stress model. To move on to  
16 the leak models, we developed a leak model based on  
17 simple orifice flow through a crack.

18 MEMBER KRESS: Is the area, the opening  
19 area -- you know, the crack has areas at front end  
20 and back end, a small area at the back end?

21 VICE CHAIRMAN SHACK: Yes, that also  
22 turns out to be an interesting question, but it's  
23 the smallest area which is typically at the OD.

24 MEMBER KRESS: At the OD?

25 VICE CHAIRMAN SHACK: Yes. And --

1 MEMBER KRESS: So the .6 is discharged  
2 from an orifice into a reservoir?

3 VICE CHAIRMAN SHACK: Right.

4 CHAIRMAN WALLIS: Sharp-edged orifice?

5 MEMBER KRESS: Sharp-edged orifice into  
6 a reservoir.

7 CHAIRMAN WALLIS: There's no friction or  
8 anything in all this crack?

9 VICE CHAIRMAN SHACK: Again --

10 CHAIRMAN WALLIS: If you're being  
11 conservative, you're saying.

12 VICE CHAIRMAN SHACK: Well, with leak  
13 rates it's hard to know when you're being  
14 conservative. If you're looking at -- if you want  
15 to do leak-before-break then every time you over-  
16 predict the leak you're being non-conservative.

17 If you're looking at how much fluid  
18 you're losing from the reactor then it's  
19 conservative to over-predict the volume of leak. So  
20 conservative is a kind of a dangerous thing.

21 But what is surprising here is that  
22 everybody sort of thinks of this as clearly a two  
23 phase situation. The flow is going to go  
24 through.

25 MEMBER KRESS: Right.

1 VICE CHAIRMAN SHACK: You're going to  
2 have flashing, you know. You would expect these  
3 flows to always be choked. What was surprising to  
4 us was that many of the -- much of the time the  
5 crack acts as an orifice of a single phase fluid.

6 I mean this is just an orifice flow for  
7 a single phase fluid. You know, you really are  
8 looking at the time it takes to flash. And by the  
9 time it gets through the wall it hasn't flashed yet  
10 and so the fluid acts as though it's a single phase  
11 fluid.

12 And this becomes important under  
13 accident situations when you have the 2,500 and the  
14 crack opens fairly wide. So --

15 CHAIRMAN WALLIS: This is true of small  
16 dimensions, it takes a small time to go through.

17 VICE CHAIRMAN SHACK: A small time to go  
18 through.

19 CHAIRMAN WALLIS: If you go to Marviken  
20 everything is homogeneous because the length is so  
21 long.

22 VICE CHAIRMAN SHACK: And so for these  
23 kinds of accident flows the crack tends to be open  
24 and you get this single phase behavior, this orifice  
25 type behavior.

1                   Now in the normal operation when, you  
2 know, the leak rate is 150 gallons per day and  
3 you're dealing with very tight cracks, then clearly  
4 you have very large fluid losses.

5                   Frictional losses are very important.  
6 Getting the transition between when you have this  
7 orifice flow and when you have this much more  
8 restricted frictional flow is one of the things that  
9 we're still working on.

10                   We have some explanations of when that  
11 happens and under the conditions in which you switch  
12 from one flow to the other.

13                   MEMBER BONACA: I have a question. This  
14 is a response to a need from NRR, okay. Now the  
15 licensees must have similar models that they use to  
16 predict a fact from cycle to cycle, what's going to  
17 happen? Okay.

18                   VICE CHAIRMAN SHACK: Yes. Well one of  
19 the differences is the licensee models up until now  
20 have always assumed that the flow has been choked.

21                   MEMBER KRESS: Okay.

22                   VICE CHAIRMAN SHACK: And that's not the  
23 case for these, you know. A crack that's larger  
24 than about five millimeters under a main steam line  
25 break condition that's not the case.

1 A crack that size, that open acts like a  
2 single phase fluid with no choking, and a simple  
3 orifice flow model.

4 MEMBER KRESS: So you're going to get a  
5 lot more flow?

6 MEMBER POWERS: Bill, --

7 VICE CHAIRMAN SHACK: You're going to  
8 get more flow.

9 MEMBER POWERS: Bill, in this equation,  
10 or this model -- or maybe Jim, I'm not sure who to  
11 ask on this. When they do a drill plate for an  
12 orifice flow meter, anything like that, I have to go  
13 calibrate it, okay, because this equation never  
14 exactly works.

15 Okay, what do you adjust, your discharge  
16 coefficient or the area?

17 VICE CHAIRMAN SHACK: The uncertainty is  
18 generally really with the area. You know, you're  
19 right, I mean there is a variability in the orifice  
20 coefficient.

21 MEMBER POWERS: Yes.

22 VICE CHAIRMAN SHACK: And if I was  
23 dealing with a drilled hole I would adjust the  
24 orifice coefficient. It turns out in dealing with a  
25 real crack, my difficulty is always in computing the

1 crack opening area, because if I take, as I usually  
2 do, my sort of rectangular bounding crack, I'm going  
3 to over-predict the crack opening area.

4 So I have a very strong tendency over-  
5 predict leak rates. I sort of ignore ligaments.  
6 And again, I don't know whether Jim will have it  
7 come up here, you know, sooner or later when we do  
8 the fraction mechanics prediction you find that this  
9 area varies to about the fifth power of the length  
10 of the crack.

11 So if I put a ligament in the middle of  
12 that crack, I've suddenly changed the thing by a  
13 factor of about 30.

14 MEMBER POWERS: I mean the discharge  
15 coefficient used there is very simple.

16 VICE CHAIRMAN SHACK: Is very --

17 MEMBER POWERS: But it doesn't make any  
18 difference because all your problem is in the area.

19 VICE CHAIRMAN SHACK: All my problem is  
20 in the area.

21 MR. DAVIS: For an axial crack this is  
22 the expression that we use, and -- where  $V_0$  is a  
23 function of the  $C_e$  in the --

24 CHAIRMAN WALLIS: What shape is this  
25 area?

1 MR. DAVIS: It's a crack.

2 VICE CHAIRMAN SHACK: It's an ellipse.

3 CHAIRMAN WALLIS: It is?

4 VICE CHAIRMAN SHACK: Well, --

5 CHAIRMAN WALLIS: It's idealized to be  
6 an ellipse.

7 VICE CHAIRMAN SHACK: It's idealized to  
8 be an ellipse.

9 CHAIRMAN WALLIS: But really it isn't.

10 VICE CHAIRMAN SHACK: Well if you told  
11 me the shape of the crack I would tell you the shape  
12 of the opening.

13 CHAIRMAN WALLIS: That's part of the  
14 uncertainty.

15 VICE CHAIRMAN SHACK: That's part of the  
16 uncertainty. But when I bound everything with an  
17 equivalent rectangular crack it idealizes as an  
18 ellipse.

19 MR. DAVIS: I think we've discussed most  
20 of this, but the test show that due to short transit  
21 time across the steam generator tube wall leaks over  
22 a range of crack sizes can be described by a single  
23 phase orifice flow model with an opening based on  
24 the crack opening area.

25 The leak rate's a function of L over D,

1 where L is the length and D is two times the crack  
2 opening. Now we get a very good agreement, as Bill  
3 said, for slits, orifices, and open cracks.

4 CHAIRMAN WALLIS: Wait a minute, this  
5 crack is going in both directions. Doesn't that  
6 make a difference which way it's growing, whether  
7 it's growing wide-wise, or I mean --

8 VICE CHAIRMAN SHACK: Lengthwise?

9 CHAIRMAN WALLIS: Lengthwise or whatever  
10 the other thing you call it.

11 VICE CHAIRMAN SHACK: Oh, you mean axial  
12 or circumferential?

13 CHAIRMAN WALLIS: Right, it makes a  
14 difference which way it's growing.

15 VICE CHAIRMAN SHACK: Oh, yes. It's  
16 makes a very large difference.

17 MR. DAVIS: Very big difference.

18 CHAIRMAN WALLIS: Yes, so --

19 VICE CHAIRMAN SHACK: We're dealing with  
20 axial cracks here, not --

21 MR. DAVIS: Axials here.

22 VICE CHAIRMAN SHACK: We have equivalent  
23 models.

24 CHAIRMAN WALLIS: It's not growing any  
25 other way. It's already grown as much as it wants

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1 to the way and then it's just going that axial way,  
2 is that it?

3 VICE CHAIRMAN SHACK: Yes, the length of  
4 the crack increases either axially or  
5 circumferentially.

6 CHAIRMAN WALLIS: Right.

7 VICE CHAIRMAN SHACK: The width is not  
8 really a growth, it's --

9 CHAIRMAN WALLIS: No, no, no, that's  
10 right. The length --

11 VICE CHAIRMAN SHACK: That's an opening.

12 CHAIRMAN WALLIS: What do you call --  
13 the other one is the depth? Length or the depth?

14 VICE CHAIRMAN SHACK: Yes, the length is  
15 how long the crack is either axially or  
16 circumferentially.

17 CHAIRMAN WALLIS: But is the length  
18 growing or is the depth growing or is just the  
19 length fixed and the depth is growing or what's  
20 happening here?

21 VICE CHAIRMAN SHACK: No, they're both  
22 growing.

23 CHAIRMAN WALLIS: They're both growing?

24 VICE CHAIRMAN SHACK: They're both  
25 growing. It's growing longer and it's growing

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1 deeper.

2 CHAIRMAN WALLIS: But it's still  
3 elliptical when it gets to the --

4 VICE CHAIRMAN SHACK: Well, --

5 CHAIRMAN WALLIS: -- other side?

6 VICE CHAIRMAN SHACK: The elliptical is  
7 the width if you're looking head on at the crack.

8 CHAIRMAN WALLIS: Yes.

9 VICE CHAIRMAN SHACK: You know, the  
10 mouth of the crack opens up into an elliptical  
11 shape.

12 MR. DAVIS: They'll be bigger on the  
13 side they initiate.

14 CHAIRMAN WALLIS: Right. That's from  
15 the theory, and it has this concentration into the  
16 ellipse, and --

17 VICE CHAIRMAN SHACK: By the time we get  
18 to the fish mouth the game is over.

19 CHAIRMAN WALLIS: Okay.

20 MR. DAVIS: As Bill mentioned with  
21 actual cracks, because of ligaments --

22 CHAIRMAN WALLIS: What if some of these  
23 things grew like a smile instead of an ellipse?

24 MEMBER POWERS: That's fish mouth and  
25 that's when the game is over. Please continue.

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1 MR. DAVIS: But the ligaments do tend to  
2 cause us to overestimate the leak rates. Real  
3 stress corrosion cracks tend to undergo incremental  
4 ligament rupture with increasing pressure before the  
5 cracks become unstable.

6 And this causes the leakage to occur at  
7 lower pressures than predicted. The equivalent  
8 crack method has been generalized to predict  
9 incremental ligament rupture after initial ligament  
10 rupture.

11 CHAIRMAN WALLIS: Doesn't this  
12 incremental ligament rupture even occur at fixed  
13 pressure because of creeping of the ligament?

14 VICE CHAIRMAN SHACK: That --

15 MR. DAVIS: It appears that it does,  
16 yes.

17 VICE CHAIRMAN SHACK: We will be  
18 discussing that in more detail.

19 MR. DAVIS: What we found, one of the  
20 assumptions of course, you know, what the crack  
21 looks like. And we found that when you  
22 destructively examine the cracks that you get  
23 better, more accurate results than when you use eddy  
24 current, which is not surprising.

25 MEMBER BONACA: At some point though, I

1 would like to understand, these are models that  
2 you're using to predict.

3 MR. DAVIS: Yes.

4 MEMBER BONACA: Okay. Now a number of  
5 the inputs of the model is the size of the crack,  
6 the length, the depth, --

7 MR. DAVIS: Depth.

8 MEMBER BONACA: -- what you measure.  
9 How accurate are the measurements? You know, how  
10 accurately can you measure the length of the crack,  
11 the depth of the crack? Try to understand that,  
12 because you're using them as inputs to predict.

13 MR. DAVIS: Yes.

14 MEMBER BONACA: And depending on how  
15 well you can measure you can get different answers.

16 MR. DAVIS: That's something that we've  
17 looked at in a great deal of detail, and we  
18 developed this -- Argonne's expert system --

19 MEMBER BONACA: Okay.

20 MR. DAVIS: -- with the rotating pancake  
21 coil in order to try to get a better prediction than  
22 using a bobbin coil does.

23 MEMBER BONACA: Yes.

24 MR. DAVIS: And what we're found is that  
25 you do get much better results with the rotating

1 pancake coil than you do with just a bobbin coil.  
2 But what we do is we verify it by doing destructive  
3 analysis and looking at the actual crack profile to  
4 see how well we predicted the shape.

5 And that's one of the biggest  
6 assumptions in this whole thing. And we spend a lot  
7 of effort on that.

8 MEMBER BONACA: If you want to verify  
9 what the licensee is telling you, or the predictions  
10 that he's making, --

11 MR. DAVIS: Right.

12 MEMBER BONACA: -- you will need to have  
13 from the licensee sentence predictions of well,  
14 measurements.

15 MR. DAVIS: Yes.

16 MEMBER BONACA: Okay.

17 MR. DAVIS: Okay. I'm going to describe  
18 briefly. We have two facilities that we use for  
19 doing this testing. You know, one's a room-  
20 temperature, high-pressure facility.

21 And this has a maximum pressure of 7,500  
22 psi. We use a pump to provide the pressure, and  
23 we're limited to 12.8 gallons per minute in this  
24 facility.

25 We have it hooked up to a water supply

1 so we can test forever in this basically. We don't  
2 run out of water. We have a high-temperature and  
3 pressure leak rate test facility, also called a  
4 blowdown facility.

5 And there we have a maximum temperature  
6 of 650 F. We have a maximum pressure of 3,000 psi.  
7 And we thought the leak rate was going to be a  
8 little lower than it turned out to be, but we can  
9 actually have a leak rate of 400 gallons per minute.

10 But we have a storage tank that holds  
11 200 gallons, so if we have a 400 gallon per minute  
12 leak rate we only have 30 seconds for testing. And  
13 so further limitations we have on the high-pressure  
14 facility, we've done a lot of our testing on the  
15 room temperature facility.

16 It's a lot easier to use and we think  
17 we're getting similar results. To verify things  
18 though, we do run test on the high-pressure, high-  
19 temperature facility.

20 MEMBER POWERS: Is there a reason for  
21 retaining the English set of units?

22 MR. DAVIS: Not really.

23 MEMBER POWERS: Just curious.

24 VICE CHAIRMAN SHACK: The reports are  
25 always written in scientific units, the discussion

1 is always carried out in English units.

2 MR. DAVIS: Yes.

3 CHAIRMAN WALLIS: Gallons are horrible  
4 units because you never know what pressure --

5 MEMBER POWERS: These are godless  
6 creatures, or --

7 CHAIRMAN WALLIS: Mass flow should be  
8 mass flow, not gallons per minute. A gallon is an  
9 undefined quantity.

10 MR. DAVIS: We really do pounds per  
11 minute.

12 CHAIRMAN WALLIS: It's not dependent --  
13 the mass depends upon the temperature and pressure  
14 and so on. A gallon in this sort of context is not  
15 defined until you add something to it, you see,  
16 gallons at room-temperature and pressure, or so on.

17 MR. DAVIS: That's right.

18 MEMBER POWERS: Well you have the same  
19 problem with mass.

20 CHAIRMAN WALLIS: No you don't. Mass is  
21 the same at room temperature as at other  
22 temperatures, I think.

23 MR. DAVIS: That's how we measure it for  
24 those.

25 MEMBER POWERS: It depends on which

1 planet you're on.

2 CHAIRMAN WALLIS: That's weight, that's  
3 not mass.

4 MR. DAVIS: We don't measure gallons per  
5 minute. We convert to gallons per minute.

6 MEMBER POWERS: Go ahead.

7 MR. DAVIS: Okay, the --

8 CHAIRMAN WALLIS: Why? Why convert to  
9 something bizarre when you've got the good unit  
10 already?

11 MEMBER POWERS: Because they like it.

12 CHAIRMAN WALLIS: Because the NRC likes  
13 it? Is that the NRC standard?

14 MEMBER POWERS: Mr. Chairman, if you  
15 continue to slow me down I will ask you to leave.

16 CHAIRMAN WALLIS: I'm sorry, I thought I  
17 was debating with you, but okay. Let's move on.

18 MR. DAVIS: Okay, the industry actually  
19 conducted some tests and what they found was they  
20 found an effect of pressurization rate on burst  
21 pressure.

22 And to NRR asked us to look into this  
23 and see if there was a pressurization rate effect on  
24 burst. When we looked into what the industry was  
25 doing it was actually -- Westinghouse did this

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1 testing.

2 And they used two different protocols  
3 for the slow and the fast test rates. And we  
4 thought that that could have a big effect on what  
5 they were saying looked like a pressurization rate  
6 effect.

7 And also, when we looked at their  
8 results we felt we could explain the differences in  
9 pressurization rate just by geometry of the  
10 specimens that they were testing.

11 And so we weren't convinced that there's  
12 a pressurization rate effect.

13 CHAIRMAN WALLIS: Does foil and bladder  
14 mean anything to anybody in this room?

15 MEMBER KRESS: Pardon?

16 CHAIRMAN WALLIS: Does foil and bladder  
17 mean anything to anybody in this room except the  
18 presenter?

19 MR. DAVIS: Okay. What happens is if  
20 you have a through wall crack and you try to burst  
21 it, somehow you have to keep the pressure in there.  
22 You have to be able to put the pressure in. So what  
23 you do is you put a foil in --

24 CHAIRMAN WALLIS: A bladder.

25 MR. DAVIS: -- and then a bladder, which

1 is like a piece of Tygon tubing, inside so that  
2 you're not loosing all you're --

3 VICE CHAIRMAN SHACK: Fluid.

4 MR. DAVIS: -- fluid and loosing your  
5 pressure so that you can actually burst the  
6 specimen. And if you have a large crack it's  
7 difficult to make it burst if you have a large leak  
8 rate. It depends on your --

9 VICE CHAIRMAN SHACK: The leak rate is  
10 limited to 12.8 gallons. Your through wall crack  
11 size that you can deal with is --

12 MEMBER SIEBER: It's the capacity.

13 VICE CHAIRMAN SHACK: -- pretty small.

14 MEMBER KRESS: Is there any reason  
15 theoretically to expect a rate effect such as give  
16 you time for work hardening if your doing it slow or  
17 having something to do with the time to reach its  
18 strain limit, or --

19 MR. DAVIS: Well, I think it's pretty  
20 common when you're mechanically testing materials  
21 that you have to control the pressurization rate.  
22 For like a stress-strain curve you do it at a  
23 certain rate --

24 MEMBER KRESS: At a certain rate.

25 MR. DAVIS: -- because if you change

1 your strain rate you're going to change -- you can  
2 change your yield strength.

3 MEMBER KRESS: These are not momentum  
4 effects, because --

5 VICE CHAIRMAN SHACK: No, no, no.

6 MEMBER KRESS: -- they're strictly  
7 something like work hardening or --

8 VICE CHAIRMAN SHACK: Yes, this -- you  
9 know, you could eventually get to something like a  
10 momentum effect but --

11 MEMBER KRESS: Yes.

12 VICE CHAIRMAN SHACK: -- that's with  
13 rates that are --

14 MEMBER KRESS: Really --

15 VICE CHAIRMAN SHACK: -- phenomenal  
16 here. But we are talking about changing things like  
17 work hardening.

18 MEMBER KRESS: You're actually changing  
19 properties of the material?

20 VICE CHAIRMAN SHACK: You're changing  
21 the properties of the material.

22 MR. DAVIS: What we did was we took  
23 different shaped flaws and we also had ligaments  
24 that we put in, which is shown at the bottom. You  
25 know, we had an axial ligament and a circumferential

1 ligament.

2 And it's kind of hard to explain so I  
3 showed you the diagram. And what we did was we  
4 tested these at quasi-static, where you pressurize  
5 and then you increase the pressure in steps.

6 And then we did 1,000, 2,000, 6,000, and  
7 10,000 psi per second pressurization rates. And  
8 what we found was there's no real pressurization  
9 effect up to 6,000 psi.

10 MEMBER KRESS: Now if you did this in  
11 steps, how would you see a pressurization rate  
12 effect?

13 MR. DAVIS: Okay, we did the first, the  
14 quasi-static in steps, but then --

15 MEMBER KRESS: Then you went back.

16 MR. DAVIS: And then we went and we went  
17 1,000 psi per second, 2,000 psi per second.

18 MEMBER KRESS: Okay, I'm sorry. So you  
19 did two times, the test.

20 MR. DAVIS: And we didn't see any  
21 pressurization effect up to 6,000 psi per second.  
22 We talked to the industry and what they say is the  
23 maximum they ever use is 2,000 psi per second for  
24 their industry tests.

25 So we feel that under the actual field

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1 testing condition there is no pressurization rate.

2 CHAIRMAN WALLIS: If you had a water  
3 hammer or something you'd get pressure rate rises  
4 which would be much more rapid than that.

5 MR. DAVIS: Right.

6 MEMBER SIEBER: You could, yes.

7 MEMBER KRESS: But if there is a  
8 pressurization rate it means you need higher  
9 pressure first.

10 MR. DAVIS: Right.

11 MEMBER KRESS: So by neglecting  
12 conditions like that you're probably being  
13 conservative, and once again you have this  
14 conservative word.

15 VICE CHAIRMAN SHACK: Right. And I  
16 don't think water hammer is generally a concern in  
17 the steam generator tube.

18 MR. DAVIS: We were concerned about --  
19 or I think what NRR requested us was if they used  
20 different pressurization rates on their field  
21 samples are they getting good results. And that was  
22 a question we wanted to ask --

23 VICE CHAIRMAN SHACK: One-way to get  
24 your margin is to --

25 MEMBER POWERS: And then so you were

1 attributing the Westinghouse observation and to some  
2 differences in their protocols?

3 MR. DAVIS: Yes. It was two things. It  
4 was the different ways they tested and the shape of  
5 the actually curves that they were -- I mean the  
6 cracks that they were testing.

7 VICE CHAIRMAN SHACK: Actually in their  
8 test it was probably most the shape, because they  
9 were trying to deal with complex shapes and  
10 reproducing those complex shapes even when they were  
11 reproducing them as EDM notches.

12 You know, the geometry variations were  
13 essentially on the order of what you might expect  
14 from a rate effect.

15 MEMBER POWERS: I understand.

16 MR. DAVIS: Another study that we  
17 conducted was secondary side depressurization study.  
18 And what this was was to simulate a main steam line  
19 break where you have a larger -- you lose pressure  
20 on the secondary side.

21 And the typical analysis of  
22 depressurization events did not --

23 CHAIRMAN WALLIS: We heard about this  
24 six months ago or something.

25 MR. DAVIS: Yes, you did. You heard

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1 this in detail. So the ACRS had raised some  
2 concerns several years ago about dynamic loads on  
3 the steam generator tubes.

4 So what we did, we calculated the  
5 dynamic loads using RELAP5 and benchmarked it  
6 against experiments. What we found was a large -- a  
7 main steam -- a large main steam line break creates  
8 a much greater pressure than a small steam line  
9 break or a feedwater line break.

10 And it was quite a big difference. And  
11 the pressure loading acting on the tube support  
12 plates is transferred to the tubes which are locked  
13 by corrosion products and deposits.

14 And we conducted a detailed finite  
15 element analysis and a fracture mechanics analysis  
16 for -- and we used the Model 51 Westinghouse steam  
17 generator, tube support plates, and tubes.

18 What we found out, the loads are  
19 primarily axial so then the dynamic loads have no  
20 effect, virtually no effect on axial cracks because  
21 the loads are axial.

22 Now if only one or two tubes are locked  
23 for circumferential cracks, the stress exceeds the  
24 ultimate tensile strength. But what you have to  
25 understand is it's very unlikely that only one or

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1 two tubes would be locked.

2 Also because the tubes are -- because  
3 the displacements are limited, unflawed tubes would  
4 not rupture, but the tolerance for circumferential  
5 cracks would be severely limited if you just had a  
6 few.

7 If greater than one and a half percent  
8 of the tubes are locked then the loads are very low,  
9 and cracks less than 180 degrees are stable. And  
10 these are through wall cracks.

11 So if you had cracks greater than 180  
12 degrees through wall, you would -- they would be  
13 plugged and that would not be a problem.

14 MEMBER KRESS: What finite element  
15 analysis code do you use, ABACUS?

16 VICE CHAIRMAN SHACK: ABACUS.

17 MR. DAVIS: And then one of the more  
18 recent studies that we've done is constant pressure  
19 crack growth studies. A couple years ago we ran a  
20 limited number of specimens in the high-temperature  
21 facility and we noticed that we were getting some  
22 constant pressure crack growth.

23 So what -- the objective of this program  
24 was to determine the influence of flaw geometry on  
25 flaw tearing and the subsequent leak rate behavior.

1 And then determine the mechanism for flaw growth,  
2 and increase leak rates at constant pressure.

3 And since I made this slide up we've  
4 actually done a high-temperature verification of  
5 this, but most of the testing was conducted in the  
6 room-temperature facility.

7 We've run one test in the high-  
8 temperature facility. So as I said, the early work  
9 that we had done showed that there was some time  
10 dependence on the leak rate.

11 And we attributed this to ligament  
12 tearing and opening of the crack due to some type of  
13 limited time-dependent deformation. We had a number  
14 of theories on what was causing it.

15 What we found in some recent tests is  
16 that at room-temperature the crack grows at a fairly  
17 high rate. What we did was we took alloy 600. It  
18 was seven eighth inch diameter and it was 50 mil  
19 wall thickness.

20 We had trapezoidal cracks that were .2  
21 inches on the OD and one inch on the ID. And then  
22 we had the reverse case where the ID was one inch  
23 and the -- I mean the OD was one inch and the ID was  
24 .2 inches.

25 And then we had, just to further look at

1 it, we had rectangular cracks that were .2, .4, and  
2 .6 inches. We tested with and without a foil and  
3 bladder.

4 We tested them open to air. And then to  
5 simulate an actual steam generator what we did was  
6 we put shrouds around the cracks to see what effect  
7 that had, so like the adjacent tubes se tried to  
8 simulate.

9 The trapezoidal flaw design was just to  
10 -- is to show you what it looked like. And it's --  
11 this is of course not to scale. It's 50 mils thick.  
12 It's a very thin ligament almost.

13 And one of the things we looked at was  
14 if you have a -- we thought if you have a jet that  
15 contributes. You know, you have large leakage in  
16 the jet, causes some of the problem.

17 So what we did was we tested jet-free to  
18 see what would happen, where we used a foil and a  
19 bladder. And then we have some pump oscillations  
20 when we test normally, and we thought that might be  
21 contributing.

22 So what we did was we pressurized with  
23 nitrogen. And we were wondering if there was some  
24 type of a corrosion effect. So we actually put  
25 moisture on the outside with the foil and bladder to

1 see if that had any effect.

2 And what we saw was no crack growth with  
3 the -- using the pressurized nitrogen. When we  
4 tested with the pump on at the same pressure, this  
5 was at 1,300 psi, what we found was we get smaller,  
6 slight crack growth.

7 The pump gives you about a 30 psi  
8 oscillation just in the way the pump operates, and  
9 that's why we ran these tests. Then we started  
10 running tests with active jets.

11 And what happened was with an active  
12 leak the crack increased with -- from the original  
13 .2 inches to one inch in just a number of hours. It  
14 was like eight hours we went from the OD -- crack  
15 from .2 to one inch.

16 CHAIRMAN WALLIS: So does the crack  
17 growth rate change much when you have the flow  
18 rather than not having the flow?

19 MR. DAVIS: Yes, dramatically.

20 CHAIRMAN WALLIS: It does? So flow  
21 changes the crack growth rate?

22 MR. DAVIS: Right.

23 CHAIRMAN WALLIS: That's not in the  
24 fracture mechanics than is it?

25 MR. DAVIS: Well, we're looking into

1 that, but --

2 CHAIRMAN WALLIS: Some kind of fluid-  
3 structure interactions?

4 MR. DAVIS: There's some fluid-structure  
5 interaction, definitely.

6 VICE CHAIRMAN SHACK: I mean that's what  
7 we try to do with the bladder tests, you know.

8 CHAIRMAN WALLIS: Right.

9 VICE CHAIRMAN SHACK: We've sort of  
10 eliminated the possibility there was an  
11 environmental effect. We showed that any fatigue  
12 growth from the pump was very small.

13 So you're sort of left with the jet as  
14 being the mechanism --

15 CHAIRMAN WALLIS: There's a water-  
16 cutting phenomenon, is it?

17 VICE CHAIRMAN SHACK: No, it's -- Jim  
18 doesn't have a picture. You know, it's not as  
19 though it's cutting. I mean it really looks like a  
20 very tight fatigue crack so that the -- the thought  
21 is that it is a jet structure interaction leading to  
22 low amplitude, very high frequency fatigue crack  
23 growth.

24 So you get these very tight fatigue  
25 cracks coming out of the notch growing --

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1 CHAIRMAN WALLIS: So the water is  
2 creating stresses rather than removing the --

3 VICE CHAIRMAN SHACK: The water is  
4 creating stresses. And the crack growth rates are,  
5 you know, two to three orders of magnitude higher  
6 than you would expect from stress corrosion.

7 MEMBER RANSOM: Well when you have a  
8 bladder don't you omit the forces that are being --  
9 due to the pressure in the crack itself, tending to  
10 open the crack?

11 VICE CHAIRMAN SHACK: No, no. The  
12 bladder doesn't really reduce the stress on the  
13 crack tip. You know, the -- if you're thinking of  
14 the pressure acting on the crack face that's a very,  
15 very small part of the load acting on the crack,  
16 that when you have the bladder in -- you know,  
17 that's why we can do the burst tests with the  
18 bladder and it really doesn't make much effect.

19 In this particular case, that kept the  
20 load on the crack, but we -- what we missed of  
21 course was the -- you know, we had the static load  
22 was equivalent, but wed miss the whole dynamic load  
23 due to the jet action.

24 CHAIRMAN WALLIS: So I guess it's  
25 reasonable because, you know, the jet has the whole

1 pressure imposed on it so the velocity is your  
2 square root of P over O.

3 That goes back into P if you stop the  
4 jet somewhere. So the jet is going around or has  
5 velocity fluctuations, pressure fluctuations could  
6 be comparable with the applied pressure.

7 So they're significant, they could be  
8 significant.

9 VICE CHAIRMAN SHACK: Yes. Measuring  
10 those is very difficult, and even detecting just  
11 what frequency range we're interested in is kind of  
12 a difficult question.

13 What we sort of settle on at the moment  
14 is that we can get very high crack growth rates.  
15 What was a little surprising to us, we did the first  
16 tests with a -- a kind of an eighteen inch  
17 confinement so that it was a truly free jet.

18 And we actually thought that well, when  
19 we muffled this jet if we sort of, you know, in a  
20 steam generator the tubes are only a quarter inch  
21 apart and so the jet isn't free, it's really much  
22 more muffled by the surrounding --

23 CHAIRMAN WALLIS: I think with ligaments  
24 I can see how the wake of the flow around the  
25 ligament could easily shake the ligament and break

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1 it.

2 MEMBER KRESS: Yes. But --

3 VICE CHAIRMAN SHACK: Vortex shedding,  
4 you know, simpleminded dynamic effects are --

5 MEMBER KRESS: Well can you back out.  
6 Looking at your fatigue -- assuming some fatigue  
7 rate growth, can you back out of frequency and  
8 pressure to give you that rate and then see if it  
9 corresponds to anything you might guess?

10 VICE CHAIRMAN SHACK: At the moment,  
11 what we do since we don't know the delta p or the  
12 frequency, what we have -- we select frequencies and  
13 then we compute the delta p that have to have in  
14 order to get the crack growth rate that we observe.

15 MEMBER KRESS: Okay, you do it --

16 VICE CHAIRMAN SHACK: But we don't know  
17 --

18 MEMBER KRESS: Both of those are  
19 variables.

20 VICE CHAIRMAN SHACK: We need to know  
21 one of those.

22 MEMBER KRESS: Yes.

23 VICE CHAIRMAN SHACK: And so the thought  
24 might be -- is that we can actually probably  
25 determine something about the frequency from

1 accelerometers to so that when we do -- if we do --  
2 when we do subsequent testing we will probably try  
3 to determine the frequency --

4 MEMBER KRESS: That's probably too small  
5 of an amplitude for an accelerometer to pick it up.

6 CHAIRMAN WALLIS: I don't know,  
7 microphone, I mean this thing could sing if it's  
8 really got that characteristic frequency.

9 MEMBER KRESS: Microphone might do it,  
10 yes.

11 VICE CHAIRMAN SHACK: Well --

12 CHAIRMAN WALLIS: You've got a musical  
13 instrument.

14 VICE CHAIRMAN SHACK: We don't think the  
15 frequencies, if they're audible, are high enough,  
16 that we -- it depends on how large you think the  
17 delta p has to be.

18 When we look at this we think the delta  
19 ps, to get the delta ps we think are reasonable we  
20 have to get the frequencies that are not in the  
21 audible range.

22 CHAIRMAN WALLIS: Not by you.

23 VICE CHAIRMAN SHACK: Well, coming back  
24 to my thing, when we put the surrounding tube on to  
25 essentially muffle the jet, of course the crack

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1 growth rate increased by a factor of three or four.

2 CHAIRMAN WALLIS: Well that's  
3 interesting too.

4 VICE CHAIRMAN SHACK: Then again, we did  
5 that with two kind of muffled jets, you know. And  
6 again the first tests were done with the jet off in  
7 air. And the thought was well if we put the jet  
8 into water that would dampen the vibrations in some  
9 sense.

10 CHAIRMAN WALLIS: It might make them  
11 worse.

12 VICE CHAIRMAN SHACK: Well it did.

13 MR. DAVIS: We tried looking with a  
14 scanning electron microscope at the fracture surface  
15 to see if we could see striations and we couldn't --

16 CHAIRMAN WALLIS: If a jet got into  
17 water it usually produces vortex rings around the  
18 jet.

19 MR. DAVIS: Here are the results  
20 graphically. What the muffled jet is is we just  
21 laid a plate over the crack and still allowed it to  
22 leak. But it was -- that was the slowest rate that  
23 we got other than the --

24 CHAIRMAN WALLIS: It's interesting that  
25 you cannot explain what's happening entirely by

1 material's behavior.

2 MEMBER POWERS: The thermal-  
3 hydraulicists start to salivate. I am strictly  
4 reminded of the sage advice that came from Ivan  
5 Catton who pointed out that there was the big bang  
6 and everything else was thermal-hydraulics.

7 MR. DAVIS: Well we've sort of discussed  
8 this but the mechanisms that we're looking at are  
9 jet erosion of the crack faces, rapid lock erosion  
10 at room-temperature, which I think we can eliminate,  
11 jet-flaw structural dynamic interaction resulting in  
12 fatigue crack growth, which is what we think is the  
13 major contributor here, and then pressure  
14 oscillation from the pump causing crack growth.

15 And we think that's only a very minor  
16 part of this overall phenomenon.

17 CHAIRMAN WALLIS: Those are small  
18 fluctuations compared with the overall pressure.

19 MR. DAVIS: That's right. And we've  
20 actually hired a consultant to help us look into  
21 this.

22 VICE CHAIRMAN SHACK: And as Jim  
23 mentioned, you know, the next thought, the non-  
24 prototypical situation was we were dealing with a  
25 single phase fluid at room-temperature, would we

1 still see this same phenomenon at high-temperature  
2 when we did have the two phase situation.

3 We ran the high-temperature test and we  
4 haven't finished the analysis but what it appears is  
5 that the crack growth rates, if not exactly the  
6 same, are really quite comparable to those we see in  
7 the room-temperature situation.

8 So the, you know, the flashing is not  
9 going to save your, you know, the -- locally it's  
10 still everything happens on a timescale for the  
11 flashing.

12 CHAIRMAN WALLIS: Is that true when you  
13 have a shroud around it as well?

14 VICE CHAIRMAN SHACK: We were shrouded -  
15 - I have to go back the look at the exact -- you  
16 know, we did -- we can't run the high-temperature  
17 test without a shroud because it --

18 CHAIRMAN WALLIS: It goes everywhere.

19 VICE CHAIRMAN SHACK: It's in a -- you  
20 know, it has to be in a confinement. And the  
21 confinement, you know -- so we -- it's probably the  
22 confinement we have is sort of equivalent to our  
23 medium size shroud in the room-temperature test.

24 And so that's the kind of baseline to  
25 compare against.

1 MR. DAVIS: The last area I'm going to  
2 discuss is the statistical treatment of our models.  
3 And what we've done -- Dominion Engineering  
4 developed CANTIA model which is a CANDU Tube  
5 Inspection Assessment model for the Canadian Nuclear  
6 Safety Commission.

7 And we obtained that code. What it  
8 does, it determines the probabilities of failure in  
9 leak rate from primary to secondary side during  
10 normal operation and during design basis accidents.

11 The models in the CANDU code are  
12 intended for the CANDU reactors -- the CANTIA code I  
13 mean, for integrity leak rate and degradation  
14 models. What Argonne did was they modified the  
15 CANTIA code maintaining the basic Monte Carlo  
16 structure but incorporating the Argonne models for  
17 predicting ligament rupture, unstable burst, and  
18 crack opening area, and leak rate for -- of flawed  
19 600 tubes.

20 The source language was updated from  
21 Visual Basic 3.0 to Visual Basic 6.0, and the big  
22 advantage in doing that is that Visual Basic 3.0  
23 limited you to 30,000 iterations for your simulation  
24 whereas the Visual Basic 6 has unlimited iterations.

25 MEMBER POWERS: The problem with it is

1 that your random number generator on the Monte Carlo  
2 system is flawed, and you add in the additional  
3 iterations. You're not doing any variance  
4 reduction.

5 VICE CHAIRMAN SHACK: We are at the  
6 moment using the built in Monte Carlo in Visual  
7 Basic.

8 MEMBER POWERS: Yes.

9 VICE CHAIRMAN SHACK: We sort of know  
10 there's a problem with that.

11 MEMBER POWERS: Yes, it only -- after  
12 about 32,000 you're just repeating the cycle again.  
13 It's a flawed random number generator in that code.  
14 You need to use something like a Mersenne Twister or  
15 something like that.

16 VICE CHAIRMAN SHACK: Yes. We're sort  
17 of aware that, you know, we're still worried about  
18 incorporating the models rather than actually  
19 exercising the Monte Carlo thing, so we're not --

20 MEMBER POWERS: Yes.

21 VICE CHAIRMAN SHACK: going to address  
22 that, but --

23 MEMBER POWERS: I agree with you but  
24 you've got an inherent flaw in that Monte Carlo mess  
25 there. I mean it's just not -- increasing the number

1 of iterations is not going to do you any good at  
2 all.

3 CHAIRMAN WALLIS: If it's above your  
4 32,000.

5 MEMBER POWERS: Yes, I think that's the  
6 cycle frequency on that particular random number  
7 generator. It's a linear congruential generator  
8 that's been floating around in the literature for  
9 dozens of years.

10 People write theses about how bad it is  
11 but it never goes away.

12 MR. DAVIS: The other change that we  
13 made is we went from a 1-D flaw model to a 2-D. And  
14 then we've added two crack growth rate models. One  
15 is the Scott model and the other is the Ford and  
16 Andresen model.

17 MEMBER POWERS: I think I don't get rid  
18 of that. We got rid of it.

19 MEMBER RANSOM: These models have  
20 uncertainties associated with them so when you do  
21 the Monte Carlo you're getting a distribution of --  
22 I'm wondering why you don't only need like 69  
23 iterations if you want a 95/95 result.

24 MEMBER POWERS: Well if you want to get  
25 the entire distribution with some precision you need

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1 to go up substantially beyond 69.

2 CHAIRMAN WALLIS: Sixty-nine is just for  
3 your one thing. If you want a distribution you need  
4 a tremendous amount more.

5 VICE CHAIRMAN SHACK: Gazillions.

6 MEMBER POWERS: Well, you don't need  
7 gazillions, but --

8 CHAIRMAN WALLIS: To find distribution  
9 you need an infinite amount of stuff.

10 MEMBER POWERS: You need -- I mean you  
11 need to know how precisely you want that  
12 distribution. If you just want to know a point  
13 value, yes. With 69 you know that you have samples  
14 about 90 percent of the distribution so you take  
15 you're highest value in that.

16 You can be reasonable confident that  
17 that's your 90th percentile value. But if you want  
18 to know the whole distribution with some accuracy --  
19 the accuracy increases as only the square root of N  
20 so it takes a lot.

21 MEMBER RANSOM: When you say accuracy  
22 though, aren't the models themselves -- you know,  
23 have high degrees of uncertainty, presumably?

24 MEMBER POWERS: Yes, and what he's  
25 getting is a distribution of a result. And the

1 problem is he's taking -- he's getting that  
2 distribution from finite sample, so the distribution  
3 itself is uncertain just because he's taking a  
4 finite number.

5 And to refine that distribution down, go  
6 slowly.

7 MR. DAVIS: Well, to summarize I  
8 presented models for plastic collapse of a tube with  
9 a through wall axial crack and a part-through wall  
10 axial crack.

11 And the -- also I presented the  
12 equivalent rectangular crack method. The original  
13 model underestimated ligament rupture pressures for  
14 short, deep cracks.

15 The Argonne modification provided much  
16 better results. The equivalent crack method was  
17 presented. It gives very good results for initial  
18 ligament rupture but not as good for subsequent  
19 tearing.

20 And then I presented the simple orifice  
21 model. It gets very good agreement for slits,  
22 orifices, and open cracks.

23 CHAIRMAN WALLIS: Now what's very good  
24 agreement? We've seen somebody's results of  
25 materials, research, and orders of magnitude here

1 and there. Presumably you're not talking about  
2 that.

3 MR. DAVIS: No.

4 CHAIRMAN WALLIS: Five or ten percent  
5 agreement?

6 MR. DAVIS: Yes.

7 VICE CHAIRMAN SHACK: Give us 15.

8 CHAIRMAN WALLIS: You haven't shown us  
9 any data. If Peter Ford were here he'd say show me  
10 the data. Show me the data.

11 MEMBER POWERS: But we got rid of him.

12 VICE CHAIRMAN SHACK: We don't care  
13 about data now.

14 MR. DAVIS: I also presented the  
15 pressurization rate effects that we've discovered.  
16 And we're still not quite sure what the implications  
17 of that are, but it may be that the one industry is  
18 doing leak rate tests.

19 They may have to do them for a longer  
20 time. I presented the results of the results of the  
21 secondary side depressurization study, which you  
22 presented in much greater detail last February.

23 And basically what we've found is one  
24 and a half percent of the tubes are locked. Most  
25 likely they'll all be locked. It's very unlikely

1 that only a couple would be locked.

2 CHAIRMAN WALLIS: When they're new  
3 they're not locked are they?

4 MR. DAVIS: They lock very quickly, the  
5 drilled hole.

6 CHAIRMAN WALLIS: But there must  
7 presumably be an instant when there's one locked if  
8 they're starting with none locked.

9 MR. DAVIS: You're absolutely right.  
10 And the thing that you have going for you in that  
11 case is that you don't have any degradation at that  
12 point.

13 So by the time you start getting  
14 degradation the tubes are locked.

15 CHAIRMAN WALLIS: Assuming you didn't  
16 put flaws in when you made the thing.

17 MR. DAVIS: You do a baseline and you  
18 hope that there's not --

19 CHAIRMAN WALLIS: Yes, you've inspected  
20 them all.

21 MR. DAVIS: And then --

22 CHAIRMAN WALLIS: And then putting the  
23 thing together you don't produce dents and --

24 MEMBER POWERS: You used to.

25 CHAIRMAN WALLIS: I bet they do.

1 MR. DAVIS: At Palo Verde the actually -  
2 - they drilled a hole in one of the tubes that was  
3 degrading that they put in.

4 CHAIRMAN WALLIS: Hammer it in because  
5 it didn't fit and things like that.

6 MR. DAVIS: Actually Westinghouse came  
7 to us and asked us about the orifice model for that  
8 case. And then I presented the constant pressure  
9 crack growth studies, and the active jets appear to  
10 be causing increased growth rate with time.

11 I think we have more work to do in that  
12 area. And then I presented the statistical  
13 treatment of the models that were presented. The  
14 future work that we're going to do is conduct tests  
15 on complex morphology cracks and develop predictive  
16 models for leak and rupture pressure.

17 CHAIRMAN WALLIS: There's no evidence of  
18 erosion of these walls? I mean there's pretty high  
19 velocity coming out there, isn't it? And water jets  
20 do erode nozzles pretty effectively.

21 You try to make a high pressure water  
22 jet, you've got to make it out of pretty hard and  
23 robust material otherwise it disappears after  
24 awhile.

25 MR. DAVIS: We did something similar

1 where we looked at the jets impacting adjacent  
2 tubes.

3 CHAIRMAN WALLIS: And it depends how  
4 clean the water is. If you have small particles in  
5 this water you can erode that -- the wall.

6 VICE CHAIRMAN SHACK: We see no signs of  
7 that in these jet tests. I mean when you look at  
8 the crack, you know, it's clearly a very fine type  
9 extension going out.

10 It's kind of a, you know, it's a low  
11 amplitude. You know, it's -- since you've  
12 eliminated stress corrosion as the mechanism you're  
13 really forced to conclude it's a low amplitude  
14 fatigue crack growth kind of thing that leaves you  
15 with very tight cracks, no evidence of any kind of  
16 the rounding that one would expect to see in an  
17 erosion type situation.

18 What, you know, what we haven't  
19 discussed here is okay, you get this jet driven  
20 crack growth. Obviously you don't get jet driven  
21 crack growth at 150 gallons per day.

22 That doesn't give you much of a jet. So  
23 the thresholds for this kind of behavior, you know,  
24 between the regulatory limits that you place on  
25 leakage and the kind of leaks that produce this jet

1 drive crack growth are difficult to understand.

2 CHAIRMAN WALLIS: If you have a shape-  
3 edge orifice model for your flow, but shape-edge  
4 orifices are the ones that I'm familiar with that  
5 erode very -- that sharp edge doesn't last you very  
6 long.

7 VICE CHAIRMAN SHACK: You know, the long  
8 -- in the operation of equipment, you know, it may  
9 happen relatively rapidly. In the long that we're  
10 worried about, you know, we don't see any effect.

11 Now what we do need to understand, as  
12 Jim mentioned, you know, there's time-dependent leak  
13 growth in addition to this fatigue driven growth,  
14 that we really do see this notion that ligaments  
15 fail under creep or some kind of time-dependent  
16 deformation cracks open up, and to understand this  
17 whole scale over which we could go from a low leak  
18 rate to this, -- you know, once we get to this jet  
19 drive crack growth, you know, the jig is up.

20 You know, this all happens very quickly.  
21 But to understand the thresholds for that growth are  
22 sort of the problem we have at the moment. And you  
23 can't do that with an EDM notch because that's, you  
24 know, a three millimeter EDM notch gives you a far  
25 greater jet than a 3 millimeter crack would.

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1                   And so using our EDM notches is okay to  
2 demonstrate phenomena and to kind of sort things  
3 out, but it doesn't really give you quantitative  
4 results that you can use.

5                   MEMBER ROSEN: So what I'm taking away  
6 from that discussion is that the typical operational  
7 behavior that you see of a crack is that it tends to  
8 -- the leak rate tends to increase gradually, and  
9 that you're saying that that is not erosion of the  
10 crack, it's typically crack growth that's causing  
11 that.

12                   VICE CHAIRMAN SHACK: It could be a  
13 number of things. I mean it could be crack growth  
14 in the sense of stress corrosion crack growth, which  
15 proceeds, you know, at eight millimeters per year,  
16 you know.

17                   That's that kind of a rate. It could  
18 them begin to open up and ligaments fail by creep  
19 which gives you increases in crack growth rate that  
20 take place over days.

21                   And eventually that could lead to this  
22 jet driven crack growth which gives you crack growth  
23 rates on the order of a millimeter per hour.

24                   MEMBER ROSEN: Well, yes. Plants don't  
25 monitor that. That's just the day it cracked.

1 VICE CHAIRMAN SHACK: Right, but it does  
2 sort of suggest that the margin we thought we had is  
3 smaller than it really was, that is you know, you're  
4 always computing well, you know, 150 gallons per day  
5 has to be a crack less than -- if it's going to grow  
6 to failure by stress corrosion, you know, it gives  
7 me essentially a year's worth of growth or more, you  
8 know.

9 But in fact I'm going to get to say, 6  
10 millimeters, and you know, the game is going to be  
11 over. And I'm not sure that it's so inconsistent,  
12 you know, what always surprises me is how quickly  
13 steam generator tube ruptures develop in the field,  
14 that is that, you know, in theory -- I'm a leak-  
15 before-break kind of guy.

16 You should never get a rupture, you  
17 know. I should -- if I go from 150 gallons a day I  
18 should see impending leak rate increases that give  
19 me plenty of warning before I ever get to rupture.  
20 Well we get ruptures. And, you know --

21 CHAIRMAN WALLIS: Is this because of the  
22 liquid interaction with the --

23 VICE CHAIRMAN SHACK: Well, I'm not sure  
24 why.

25 CHAIRMAN WALLIS: It seems to be.

1 VICE CHAIRMAN SHACK: But things happen  
2 much more quickly -- now you can either argue that,  
3 you know, the growth and the degradation is  
4 occurring and you get a sudden pop-through.

5 But this to me provides another  
6 mechanism for how you go from relatively innocuous  
7 leak rates to rupture in timeframes that seem very  
8 short compared to our sort of classical leak-before-  
9 break arguments based on SCC crack growth rates.

10 So that, again, at 150 gallons per day  
11 it's not a problem, it's just that your margin  
12 between the 150 gallons and rupture, I don't think,  
13 is as large as you thought it was.

14 That's my takeaway from this situation.  
15 Now exactly how big that margin is we don't  
16 understand very well, but it's a lot smaller than  
17 you think it is if you're basing it on a kind of a  
18 stress corrosion crack growth picture.

19 CHAIRMAN WALLIS: You have flow, but you  
20 have rapid decrease in pressure near the hole, so  
21 you're actually imposing a stress gradient near that  
22 hole just because of the flow itself, no  
23 fluctuations at all.

24 That's in your -- that appears in your  
25 model too, does it?

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1 VICE CHAIRMAN SHACK: No, it doesn't.

2 CHAIRMAN WALLIS: The fluid, if you've  
3 got a sharp orifice, is going from 3,000 psi to  
4 nothing in that tiny little length --

5 VICE CHAIRMAN SHACK: Yes, but --

6 CHAIRMAN WALLIS: -- which is imposed on  
7 the wall

8 VICE CHAIRMAN SHACK: But for fatigue,  
9 you know, I don't -- the 3,000 to nothing, you know,  
10 that doesn't grow anything by fatigue, you know.  
11 What I need --

12 CHAIRMAN WALLIS: No, no, no. But it's  
13 an imposed stress. It's a steady stress.

14 VICE CHAIRMAN SHACK: It's an imposed  
15 stress.

16 CHAIRMAN WALLIS: Yes, a steady stress  
17 field.

18 VICE CHAIRMAN SHACK: But you know, what  
19 I need to account for is the fact that this can  
20 fluctuate at a rapid rate at some unknown amplitude.

21 MEMBER POWERS: Bill, lithium niobate  
22 detectors won't do that for you?

23 VICE CHAIRMAN SHACK: Pardon me?

24 MEMBER POWERS: Lithium niobate kid of  
25 piezo electric detectors won't do that for you?

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1 VICE CHAIRMAN SHACK: Oh, they probably  
2 will. We're sort of at this point, you know, we had  
3 a number of questions. One, was it fatigue drive,  
4 jet driven, you know.

5 And we think we settled that -- we  
6 settled that for the single phase room-temperature  
7 condition. Then the next question was is this an  
8 artifact of a room-temperature test or does it  
9 really exist under the more prototypical conditions.

10 We think our last test has settled that  
11 issue. Now it's time to go back and sort of think  
12 about --

13 MEMBER POWERS: Instrumenting --

14 VICE CHAIRMAN SHACK: Well, and we have  
15 to come up with tests that are more prototypical,  
16 that is we -- EDM notches won't tell you -- I mean  
17 we could do EDM notches to study frequency effects,  
18 but I think we really need to get, you know, if  
19 we're going to look at threshold crack sizes for  
20 which this takes over we need geometries that give  
21 us prototypical leak rates for lengths.

22 And EDM notches don't do that. They  
23 give us far too much leak rate for a given length.

24 MEMBER POWERS: I understand.

25 VICE CHAIRMAN SHACK: So they're very

1 conservative. And so we need to essentially do this  
2 with cracks, either fatigue cracks or growth stress  
3 corrosion cracks. And that's something that --

4 MR. DAVIS: That's something that we've  
5 been discussing a lot.

6 VICE CHAIRMAN SHACK: We're discussing  
7 at the moment.

8 MR. DAVIS: On how to produce the  
9 cracks.

10 MEMBER POWERS: I understand what the  
11 situation is.

12 MR. DAVIS: Yes, we talk about putting -  
13 - drilling a very small hole, and then use a 2 point  
14 or three point bending. But then you're got the  
15 hole there and that you don't really want.

16 So we're looking at other options.  
17 Maybe a surface scratch and then produce a fatigue  
18 crack. But we haven't decided yet. Or we could do  
19 the room-temperature stress corrosion cracks.

20 CHAIRMAN WALLIS: We have to speed up  
21 now.

22 MR. DAVIS: The other area we're working  
23 on is using other shapes than the rectangular crack  
24 method to model the cracks. And that might be like  
25 a trapezoidal crack or something like that.

1                   And then we're -- as we develop and  
2 improve these models we're going to incorporate  
3 those into the CANTIA code as well. That's all I  
4 was planning on presenting.

5                   CHAIRMAN WALLIS: That's what you're  
6 planning? I thought you were going to present the  
7 rest of it.

8                   MR. DAVIS: I can present it if you'd  
9 like. Or --

10                  MEMBER POWERS: We're only covering  
11 really Task 3.

12                  MR. DAVIS: Task 3 is all you asked to  
13 cover.

14                  CHAIRMAN WALLIS: You planned it very  
15 well, I'm sorry. I thought you were going to have  
16 another ten slides or so.

17                  MR. DAVIS: Well I put those in --

18                  CHAIRMAN WALLIS: Just in case.

19                  MR. DAVIS: -- just in case there were  
20 no questions.

21                  MEMBER POWERS: In the embarrassing case  
22 of no questions. Are there any other questions for  
23 the speaker?

24                  MEMBER SIEBER: I'm curious about one  
25 thing. You know, they have a tech spec on it of 150

1 gallons a day, and it seems to me that if you had a  
2 single tube with a crack in it that was leaking 150  
3 gallons a day is sort of a meaningless number as far  
4 as using it as a way to predict that that tube is  
5 going to fail.

6 You can measure down to a couple of  
7 gallons a day using radiological techniques, and I  
8 wonder why that number is so high. Is the  
9 presumption that you've got 50 tubes that are  
10 leaking?

11 You know, what is the assumptions behind  
12 that number?

13 VICE CHAIRMAN SHACK: Well I think if  
14 you look -- if you took the conservative assumption  
15 that it was all coming from a single crack --

16 MEMBER SIEBER: Yes.

17 VICE CHAIRMAN SHACK: -- but it was a  
18 stress corrosion crack, that would give you a large  
19 margin between -- I mean that's, you know -- the  
20 intent was to make it quite conservative.

21 And based on a single crack, which is a  
22 conservative assumption itself, and a stress  
23 corrosion crack growth rate, there is a quite large  
24 margin between that failure and burst.

25 CHAIRMAN WALLIS: That's with 150

1 gallons a day?

2 VICE CHAIRMAN SHACK: A hundred and 50  
3 gallons a day.

4 MEMBER SIEBER: That's a lot of leakage  
5 from a single tube.

6 VICE CHAIRMAN SHACK: It's a small  
7 crack, you know.

8 MEMBER SIEBER: That's what I say.

9 VICE CHAIRMAN SHACK: If it's, you know,  
10 a few millimeters long and it takes you roughly a 25  
11 millimeter crack to fail and it's growing by stress  
12 corrosion crack growth rates which are eight to ten  
13 millimeters per year, you nominally have, you know,  
14 a large margin to failure, which is you know, I  
15 think why that was selected as a --

16 CHAIRMAN WALLIS: Does fluid fluctuation  
17 effect this growth rate of these other cracks, these  
18 stress corrosion cracks? And once they get loaded  
19 with the fluid fluctuation --

20 VICE CHAIRMAN SHACK: Yes, some -- you  
21 know, this argument would tell you that at some  
22 point it's not going to grow from 3 millimeters to  
23 25 millimeters by stress corrosion.

24 It's going to grow from 3 millimeters to  
25 X millimeters by stress corrosion. Then it's going

1 to grow to 25 millimeters by --

2 CHAIRMAN WALLIS: By this fatigue.

3 VICE CHAIRMAN SHACK: -- this mechanism.

4 MEMBER SIEBER: Right.

5 VICE CHAIRMAN SHACK: And it's going to  
6 grow much faster. So if we knew what X was we'd  
7 know what your true margin was for the 150 gallons  
8 per day. At the moment all I would argue is that  
9 it's substantially smaller than you thought it was.

10 CHAIRMAN WALLIS: That's the thing  
11 that's striking to me is that if you were only doing  
12 materials analysis and you did it perfectly, you  
13 would miss an effect that you seem to have  
14 discovered experimentally, which is that the flow  
15 through the crack enhances the crack growth in a way  
16 which is quite --

17 MEMBER SIEBER: Dramatic.

18 CHAIRMAN WALLIS: And remarkable and --

19 VICE CHAIRMAN SHACK: And what Jim  
20 didn't tell you of course is that we didn't set out  
21 to study that problem.

22 CHAIRMAN WALLIS: You found it, you  
23 found it. I mean that's what happens.

24 VICE CHAIRMAN SHACK: We set up the test  
25 -- we were going to do a fracture mechanics tearing

1 analysis where we would slowly grow this crack under  
2 increasing pressure.

3 CHAIRMAN WALLIS: Now let me ask you  
4 something.

5 VICE CHAIRMAN SHACK: It never got to a  
6 steady pressure.

7 CHAIRMAN WALLIS: You have discovered a  
8 mechanism for growing cracks more rapidly as a  
9 result of fluid structure interaction, which the  
10 experts who did the elicitation didn't know about  
11 perhaps when they were making their study of  
12 frequency of pipe break.

13 You've discovered a mechanism where by  
14 cracks can grow more rapidly than I think was known  
15 to most of those experts. Is that true?

16 VICE CHAIRMAN SHACK: You know, whether  
17 it's at all applicable to a pipe --

18 CHAIRMAN WALLIS: Well, the thing that  
19 concerns me is that, you know, if there's always  
20 this new mechanism that the experts didn't know  
21 about --

22 MR. MUSCARA: Joe Muscara with the  
23 Research staff. I think the thing we need to  
24 emphasize again is we found this phenomenon for a  
25 well developed jet that we get from a notch.

1                   And we're trying to get more and more  
2 realistic in our testing. And then next step is to  
3 see what happens with cracks. We can have very long  
4 tight cracks that don't give the kinds of flows that  
5 we see with the EDM notch.

6                   So it would still be a nice curiosity,  
7 but not really applying to real life.

8                   CHAIRMAN WALLIS: We don't know.

9                   MR. MUSCARA: We don't know.

10                  CHAIRMAN WALLIS: It might be more  
11 important for a crack, a real crack.

12                  MR. MUSCARA: No, I -- we've done work  
13 on real cracks and we have seen this magnitude of  
14 the phenomenon before. What we need to establish  
15 now is for a tight, long crack when do we get the  
16 kind of flow that leads through the fatigue crack  
17 route?

18                  My personal view at this point is that's  
19 a pretty long through wall crack. But we need to  
20 see what happens in the testing.

21                  MEMBER SIEBER: Well I think that you  
22 folks are sort of getting to my point. I think that  
23 when you use a number like 150 gallons a day you're  
24 already in the regime where you're into rapid crack  
25 growth rates now.

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1 VICE CHAIRMAN SHACK: No, no, no.

2 MEMBER SIEBER: No, okay.

3 VICE CHAIRMAN SHACK: No, you know,  
4 we're seeing these rapid crack growths at two  
5 gallons per minute, but there is this whole problem  
6 of, as I say, there's a number of time-dependent  
7 phenomena that occur here that are not stress  
8 corrosion crack growth.

9 MEMBER SIEBER: Yes, right.

10 VICE CHAIRMAN SHACK: You know, the old  
11 models that we did never really considered the  
12 possibility of creep failure, and you know, failure  
13 of the ligaments increasing, you know.

14 So we get this increase in leak rate  
15 initially from other mechanisms that are probably  
16 more closely related to this ligament creep kind of  
17 behavior.

18 Then we get this jet driven thing. And  
19 I'll agree with Joe, you know, we don't -- all I  
20 would argue is that we get this jet driven thing  
21 long before we get to the 25 millimeter failure  
22 under static loading kind of condition.

23 So as I say, the growth from 3  
24 millimeters to 25 millimeters by stress corrosion  
25 overestimates our margin. Now if it turns out that

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1 we don't see this until we get to ten millimeters  
2 you may well decide you still have enough margin and  
3 your, you know, your 150 gallons per day is fine.

4 All you want to do is just understand  
5 your margin, I think, at this point.

6 CHAIRMAN WALLIS: But it's in the  
7 direction of loosing margin.

8 VICE CHAIRMAN SHACK: You're clearly  
9 loosing margin.

10 CHAIRMAN WALLIS: It's something which I  
11 think you've discovered. It wasn't known before?  
12 So this is the sort of thing you have to guard  
13 against in asking experts when there are phenomena  
14 that they don't know about.

15 MEMBER SIEBER: Okay, thanks.

16 VICE CHAIRMAN SHACK: Well I mean we've  
17 looked increasing leak rates for quite awhile before  
18 we, -- you know, we were determined that it was due  
19 to time-dependent deformation and failure of  
20 ligaments because that was the model that we had in  
21 our head.

22 CHAIRMAN WALLIS: Right. And now you  
23 have another one in your head which might also be  
24 wrong. It's very interesting.

25 MEMBER SIEBER: Thank you.

1 MEMBER POWERS: Any other questions?

2 Seeing none I turn it back to you, Mr. Chairman.

3 CHAIRMAN WALLIS: Being ten o'clock,  
4 we're always operating on time, we will have a 15  
5 minute break until 10:15.

6 (Whereupon, the above-entitled matter  
7 went off the record at 10:01 a.m. and  
8 went back on the record at 10:17 a.m.)

9 VICE CHAIRMAN SHACK: Let's come back  
10 into session. Our next presentation is on Digital  
11 Instrumentation and Control Systems Research Plan.  
12 And Dr. Apostolakis will lead us through this  
13 discussion.

14 MEMBER APOSTOLAKIS: Thank you, Bill.  
15 The Office of Research has developed a plan, the NRC  
16 Digital System Research Plan for the fiscal years  
17 2005 through 2009.

18 And this is the subject of today's  
19 meeting of the ACRS. But there is an unusual  
20 situation here. There are memos from NRR that --  
21 well, there is a memo from Mr. Dyer, the Director of  
22 NRR, to Mr. Paperiello, the Director of the Office  
23 of Research which sends a mixed message there.

24 On the one hand he says we believe that  
25 the SRP presently is adequate to provide guidance to

1 the Staff in performing safety reviews. But at the  
2 same time it says we generally support an active  
3 research program in this area.

4 But then there is a memorandum from the  
5 Electrical Instrumentation and Controls Branch of  
6 NRR that is very unusual. Essentially it looks at  
7 each project, almost all the projects that are in  
8 the research plan.

9 And there is a constant theme where they  
10 end by saying for example, there is no aspect of  
11 this project which will assist in risk assessment of  
12 digital systems and therefore is not justified on a  
13 risk basis.

14 There is no aspect of this project which  
15 will assist in risk assessment of digital systems  
16 and therefore is not justified on a risk basis.  
17 Constantly they dismiss all of them, except three  
18 which they feel may have some merit.

19 So here we have now the user  
20 organization saying we don't need it. And I don't  
21 know what to do. This is a briefing for information  
22 purposes today.

23 The idea was to select particular  
24 projects for more detailed review of the  
25 Subcommittee meeting which is coming up in June.

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1 Obviously it seems to me we have to have somebody  
2 from that branch of NRR to explain to us their  
3 position.

4 And then we expect the stuff to come  
5 back to the full committee in July for a more formal  
6 review of the plan. So, with these --

7 MR. MAYFIELD: Dr. Apostolakis?

8 MEMBER APOSTOLAKIS: Yes?

9 MR. MAYFIELD: If I might. This is Mike  
10 Mayfield. I'm the Director of Division of  
11 Engineering at NRR. The memorandum from Mr. Dyer to  
12 Dr. Paperiello is a draft that had not yet been  
13 signed and had not as of this -- as of half an hour  
14 ago we were cleaning up some final issues.

15 The sentiments expressed in the non-  
16 concurrence memorandum from Mr. Calvo were those of  
17 Mr. Calvo. And while we, the Office, will be  
18 providing some recommendations and we believe  
19 constructive comments that address some of the  
20 technical issues raised in Mr. Calvo's memorandum,  
21 the Office has comments that will be provided.

22 It's my understanding the comments that  
23 will be provided in the formal memorandum for Mr.  
24 Dyer to Dr. Paperiello did not reach the same  
25 conclusion as the comments reflected in Mr. Calvo's

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1 memorandum.

2 The technical substance, much of that  
3 will be reflected in recommendations and suggestions  
4 to research for their consideration in the plan.  
5 But the sentiments that you were reading are not  
6 reflected in the comments that are being passed at  
7 the office level.

8 MEMBER APOSTOLAKIS: Okay.

9 CHAIRMAN WALLIS: Well, Mike, didn't NRR  
10 ask for this work in the first place?

11 MR. MAYFIELD: There have been  
12 variations on the user need memoranda and where  
13 those go. The notion that's in the Dyer, at least  
14 the draft Dyer to Paperiello memorandum, today we  
15 believe the standard review plan is adequate for the  
16 work that's in the plate today and in the relatively  
17 near term.

18 However, we do recognize that there's a  
19 lot of interest in new designs, some of this being  
20 somewhat into the future. And as a matter of policy  
21 we think that an active research program in this  
22 general area is useful.

23 There are, however, recommendations and  
24 some suggestions that we will be providing back, and  
25 it was just unfortunate we couldn't get the

1 memorandum finally signed.

2 CHAIRMAN WALLIS: So this isn't in  
3 response to a user need memo, this plan that we see?

4 MR. MAYFIELD: Not the whole plan, no  
5 sir, which I am assuming that Research will explain  
6 how that fits. But I did since Dr. Apostolakis had  
7 this information.

8 MEMBER APOSTOLAKIS: So I was not  
9 supposed to --

10 MR. MAYFIELD: It's fine. I mean it's  
11 where it is. It's just the memorandum from Mr. Dyer  
12 to Dr. Paperiello has not been signed --

13 MEMBER APOSTOLAKIS: Okay.

14 MR. MAYFIELD: -- or hadn't been, simply  
15 just getting --

16 MEMBER APOSTOLAKIS: But it was much  
17 softer than the actual comments from --

18 MR. MAYFIELD: Yes.

19 MEMBER APOSTOLAKIS: -- that branch,  
20 which --

21 MR. MAYFIELD: Yes, sir.

22 MEMBER APOSTOLAKIS: -- were overboard,  
23 in my view. But there's one other thing here that,  
24 I don't know, it says in that memo from Mr. Calvo,  
25 it is recommended that in the future Research

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1 discuss these proposed research activities with  
2 individual NRR branches and sections prior to  
3 issuing their research plan.

4 I would expect that to happen. Doesn't  
5 it happen?

6 MR. MAYFIELD: We will be working as we  
7 go forward with -- and as we pass the comments from  
8 Mr. Dyer back to Dr. Paperiello, we will expect to  
9 have engaged with Research at the division branch  
10 and section levels as we need to, to make sure  
11 everyone understands the basis for the comments and  
12 the recommendations and how they may or may not be  
13 accommodated in the research plan.

14 And that's a dialog that we look forward  
15 to having.

16 MEMBER APOSTOLAKIS: Okay.

17 MR. MAYFIELD: Okay.

18 MEMBER APOSTOLAKIS: Rich?

19 MR. BARRETT: Yes.

20 MEMBER APOSTOLAKIS: I understand you  
21 will step up.

22 MR. BARRETT: Yes, just briefly. Mike  
23 already said a good bit of what I was hoping to say.  
24 But I do want to point out that the Instrumentation  
25 and Control Research Plan is a significant

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1 initiative for the Office of Research.

2 It's an area where we anticipate  
3 innovation in the future within the industry. And  
4 it's an area where safety and security challenges  
5 can be anticipated, especially as we go into follow-  
6 up licensing.

7 We have been discussing this plan with  
8 NRR for sometime, and also with NMSS and NSIR. And  
9 we look forward to getting feedback from all of the  
10 user offices on this end, and to interacting with  
11 them on an ongoing basis.

12 To support this effort, we in the past  
13 year have created a new section within the  
14 Engineering Research and Applications branch. And  
15 we've selected Bill Kemper to be the Section Chief  
16 who comes to us with considerable industry  
17 experience.

18 Bill is here today in spite of the fact  
19 that his daughter is graduating from college tonight  
20 in Florida, so if we run a little long this morning  
21 you're going to see go Bill get up and leave.

22 It's not -- please be aware he has good  
23 reason. We also note that the ACRS has -- now has  
24 an I&C Subcommittee. And that -- we think that's a  
25 very important step.

1 We look forward to interacting with you  
2 early and often, and we look forward to your input  
3 on this plan.

4 MEMBER APOSTOLAKIS: After I read that  
5 memo I thought maybe we had asked him to form a  
6 subcommittee. Nothing is needed. This is great.

7 MR. BARRETT: I think that the way we  
8 view it is that this is an area where we can  
9 anticipate a great deal of need. So with that brief  
10 introduction let me turn it over to Bill Kemper.

11 MR. KEMPER: Thank you, Rich. Again,  
12 I'm Bill Kemper.

13 MEMBER APOSTOLAKIS: Again, I don't know  
14 how I got this memo by the way, but what I do is I  
15 just go back to my computer and download and print  
16 it before I come here. So some --

17 MR. MAYFIELD: The memorandum isn't a  
18 great secret. It's part of an internal process.

19 MEMBER APOSTOLAKIS: Okay, all right.

20 MR. MAYFIELD: And --

21 MEMBER APOSTOLAKIS: I just didn't know  
22 -- and also of course when you get something on the  
23 computer I don't think the signature is on it.

24 MR. MAYFIELD: We see, you know, this is  
25 something where the office welcomes views, and that

1 informs --

2 MEMBER APOSTOLAKIS: So it wasn't  
3 anything inappropriate?

4 MR. MAYFIELD: It was nothing  
5 inappropriate, and the information will inform Mr.  
6 Dyer, --

7 MEMBER APOSTOLAKIS: Okay.

8 MR. MAYFIELD: -- as he moves forward.

9 MEMBER APOSTOLAKIS: Thank you.

10 MR. MAYFIELD: Thank you.

11 MEMBER APOSTOLAKIS: Please

12 MR. KEMPER: Again, thank you.

13 MEMBER APOSTOLAKIS: Who me?

14 MR. KEMPER: Closer to me? Okay, can  
15 you hear now? Well again, I'm Bill Kemper. Thanks  
16 for having us and it's nice to meet you all. I am  
17 relatively new to the Agency, as Rich eluded to.

18 Most of my experience has been in the  
19 nuclear power industry. I have worked at three  
20 different utilities in three different power plants  
21 with a lot of experience in operations and also in  
22 instrumentation and control engineering from a  
23 commercial standpoint.

24 This committee has reviewed the previous  
25 research plan, I believe in 2001, and that covered

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1 from 2001 to 2004. We're here to present the draft  
2 Digital Safety -- Digital System Research Plan which  
3 covers the next five years basically, up through  
4 2009.

5 Some of the projects we discuss are  
6 carryover items from the previous plan so you may be  
7 familiar with them. And I know that we've been  
8 before this committee on various occasions talking  
9 about selected projects, but there's also many new  
10 projects that we're going to discuss as well.

11 This briefing really is intended to  
12 provide the Committee with the information needed to  
13 determine what further interactions are needed from  
14 us with you all regarding individual programs and  
15 projects.

16 Also we have a lot of material to cover,  
17 you'll see when Mike gets into his presentation, and  
18 a relatively short time to do it, so we're going to  
19 try our very best to stay on schedule.

20 And so really with that, I'd like to  
21 introduce Mike Waterman. He's a Senior I&C Engineer  
22 in our section. He's going to provide the overview.

23 MR. WATERMAN: Good morning. My name is  
24 Mike Waterman. As Bill told you, I work for him in  
25 the instrumentation and control section. I started

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1 to work for the NRC in 1990, and for the first 14  
2 years I was in what is now the Instrumentation and  
3 Control Section of the Electrical and  
4 Instrumentation Controls branch in NRR.

5 During that period of time I reviewed  
6 quite a few safety systems. Approximately 20 of  
7 those have been digital safety systems ranging in  
8 complexity from systems as such simple as aux  
9 feedwater systems, load sequencers, up through all  
10 of the oscillation power range monitoring systems  
11 used in BWRs today.

12 I also reviewed the Teleperm XS, so -- I  
13 came to the Office of Research with kind of a  
14 regulator perspective on the things that I thought I  
15 needed to get my job done as a regulator.

16 For the past ten years I've been on two  
17 working groups, IEEE working groups, the IEEE 10-12  
18 Verification and Validation working group, and the  
19 IEEE 7-432 working group.

20 I was secretary on that group. In  
21 addition to that, in the past year by invitation I  
22 served as a member of the management board of the  
23 IEEE Software and Systems Engineering Standards  
24 Committee.

25 That management board oversees the

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1 development of all software and systems engineering  
2 standards for IEEE. So with no further ado, that's  
3 just some of my background, I'd like to get into the  
4 presentation first with an overview that the  
5 research plan as we wrote it provides a flexible,  
6 adaptable framework for identifying NRR, NMSS, and  
7 NSIR research initiatives.

8 The original research plan, the 2001 to  
9 2004 plan simply addressed the NRR research  
10 initiatives. We felt that for safety related  
11 systems we should write a plan that also supported  
12 the other offices.

13 The research plan is oriented toward  
14 providing a more consistent process for regulating  
15 nuclear applications. My perspective as a regulator  
16 was that I was getting a lot of technical guidance  
17 but sometimes I wasn't getting a lot of regulatory  
18 based acceptance criteria.

19 So when our -- so in the process of  
20 writing this plan we decided that what we would do  
21 is expand the plan's responsibilities such that in  
22 addition to regulatory guidance we would also  
23 develop a regulatory based acceptance criteria that  
24 we're objective, that a person can say either yes or  
25 no on the acceptance criteria.

1                   Additionally, sometimes we needed  
2                   assessment tools and methodologies that I did not  
3                   have available to me as a regulator. I felt that  
4                   including, acquiring if at all possible instead of  
5                   developing assessment tools to help the regulator  
6                   evaluate the licensee submittals against the  
7                   regulatory based acceptance criteria consistent with  
8                   the technical guidance.

9                   CHAIRMAN WALLIS: Can I ask, are these -  
10                  - are objective acceptance criteria and assessment  
11                  tools that things that the author of this memo  
12                  thinks are not needed?

13                  MR. WATERMAN: Yes, I suspect --

14                  CHAIRMAN WALLIS: It seems to me they're  
15                  very desirable things to have.

16                  MEMBER APOSTOLAKIS: No, but the point  
17                  is that maybe it's also a matter of language. I  
18                  mean when you say more consistent processes, you're  
19                  implying the current processes are not consistent.

20                  And the guy who's implementing them may  
21                  get offended by that. You're saying that you're  
22                  going to have more objective acceptance criteria and  
23                  the guy who's doing it now thinks that his criteria  
24                  are objective.

25                  So is it a matter of communication,

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1 really?

2 MR. WATERMAN: Well, as I --

3 MEMBER APOSTOLAKIS: You're cutting them  
4 off?

5 MR. WATERMAN: Well, sir, as I recall  
6 the phrase was that the standard review plan had  
7 acceptance criteria.

8 MEMBER APOSTOLAKIS: Yes.

9 MR. WATERMAN: It doesn't mean it's all  
10 objective. Some of the acceptance criteria could be  
11 subjective. For example, take Branch Technical  
12 Position HICB-14 on software quality assurance.

13 I went through that Branch technical  
14 position, identified something like 183 different  
15 attributes with associated acceptance criteria.  
16 About half of those acceptance criteria for those  
17 attributes were subjective.

18 For example, I just happened to have the  
19 report here on style. Where you're supposed to  
20 check the style you're supposed to check the style  
21 against this NUREG-6463 which is review guidelines  
22 for software languages in nuclear power plant safety  
23 systems.

24 That's one acceptance criteria, right?

25 Make sure that the style is in conformance with this

1 but there was no way to really assess that. It's  
2 fairly subjective, do you use the book, what parts  
3 of the book do you use, etcetera.

4 I consider that to be kind of a  
5 subjective acceptance criteria about what parts of  
6 the book would go into particular review. And part  
7 of that is the way it's structures right now in my  
8 experience was that depending upon the impressions  
9 of the person doing the review you could come out  
10 with different results of the review simply because  
11 some of the acceptance criteria were not objective  
12 enough.

13 And it seemed to me that when a licensee  
14 has somebody show up at the site, it shouldn't  
15 really matter which regulator shows up at the site,  
16 or which regulator reviews their products, the  
17 results should always be the same.

18 The licensee should be able to expect a  
19 consistent review process. And what I found was  
20 that even with one person doing all of the reviews,  
21 the process wasn't always consistent because a lot  
22 of times I just didn't have assessment tools or  
23 detailed enough methodologies to keep myself  
24 consistent, especially when you think that over 20  
25 -- over 14 years I reviewed only 20 projects, so it

1 wasn't like I was going from project to project to  
2 project doing reviews.

3 I had other duties in between so  
4 consequently sometimes I lose the focus a little  
5 bit. You know, come into the next review and I'd  
6 have new anecdotal evidence to think about  
7 reviewing.

8 So I was sort of frustrated as a  
9 regulator by the fact that I did not have all of the  
10 objective acceptance criteria I thought I needed to  
11 be either justified putting my thumb down or putting  
12 my thumb up and saying this system is safe enough.

13 I reviewed a lot of systems. I approved  
14 those systems on the basis of the information I had  
15 available to me at the time, which was mainly I  
16 reviewed for quality.

17 And if the quality was high, and I did a  
18 couple thread audits to look at a couple safety  
19 functions and if those were okay, then I inferred  
20 the safety of the system from the quality of the  
21 development process.

22 Well it seems to me that I need  
23 something more than just quality to acceptance  
24 criteria when I do that. So that's where I'm coming  
25 from as formal regulator.

1                   And I came over to research with the  
2                   intent, really, of trying to improve that regulatory  
3                   process to make it easier for the next regulator to  
4                   come along to do his job.

5                   Additionally, we don't have any formal  
6                   training right now for bringing along new staff.  
7                   When I was asked to train a new staff person my  
8                   training involved taking that person with me on a  
9                   software review at a licensee site and giving him on  
10                  the job training while I was trying to do reviews.

11                  It seemed to me that on the job training  
12                  is really not the way we want to go. We want a  
13                  systematic training process where when we bring in  
14                  new staff they're actually trained in a consistent  
15                  -- to review things in a consistent manner.

16                  So I'm on a soap box now and I'm getting  
17                  way off of the review right here. I think we really  
18                  need to move on. I would like to say that in  
19                  addition to their assessment tools and  
20                  methodologies, I think we need to develop review  
21                  procedures, and in some cases inspection procedures,  
22                  so that we can codify exactly how a review is to be  
23                  conducted.

24                  And then also in the play you'll notice  
25                  that we say we should develop curricula for each one

1 of these projects, not a onetime training shot, but  
2 an actual training program so that when people come  
3 in as a regulator they can go through that training  
4 program and understand the technical guidance,  
5 understand what the objective acceptance criteria  
6 mean, and know how to use the tools.

7 So with that in mind I just want to say  
8 the plan is in draft mode right now. I expect it to  
9 change. There's things in there I can't believe I  
10 wrote to tell you the truth.

11 And those things will come out. And I  
12 really look forward to addressing all of the  
13 comments, whether they be on a non-concurrence or  
14 whatever to make this plan a better plan.

15 And obviously you're an important part  
16 of that.

17 MEMBER ROSEN: It seems to me your  
18 training program should be based on a task analysis,  
19 what you expect the person to do, just as we do task  
20 analysis for operators or engineers in the industry.

21 It seems like you have the same, start  
22 by figuring out what it is you want them to do, and  
23 then proceed from there to a program design.

24 MR. WATERMAN: Yes, sir. That's a good  
25 point. I've got a note here. I'll be sure to

1 incorporate that.

2 MEMBER APOSTOLAKIS: All right, let's  
3 move on to three.

4 MR. WATERMAN: So what's the current  
5 situation? The issues facing NRC is that licensees  
6 are replacing, I've got up here analog systems with  
7 digital systems.

8 Well hey, we must be in the second  
9 generation because they're now starting to replace  
10 digital systems with digital systems. Take the core  
11 protection calculators at Palo Verde that's just  
12 gone in.

13 And licensing these digital systems  
14 presents some challenges to the NRC because of the  
15 increased complexity and the increasing complexity  
16 because we're seeing larger systems coming down the  
17 pipe.

18 There are rapid changes in the digital  
19 technology, and these may introduce new failure  
20 modes. So we believe that the licensing processes,  
21 while they've been serving their function, they  
22 ought to be kept current.

23 The standard review plan, latest  
24 revision 1997. A lot of things have changed since  
25 1997. So we believe that we need to keep updating

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1 that standard review plan for the new issues.

2 We want to go to a risk-informed,  
3 performance-based safety assessment process for  
4 licensing digital systems, 1997 we weren't talking  
5 risk informed, I believe.

6 MEMBER APOSTOLAKIS: Now this is an  
7 important slide, I think, which in my mind should be  
8 expanded. And in general, this committee in the past  
9 when we were reviewing research plans, most notably  
10 the Human Performance Research Plan, we asked two  
11 questions.

12 What is the current situation? Where  
13 are we now? You're addressing some of it here, but  
14 maybe we should have a little bit more detail maybe  
15 at the Subcommittee meeting.

16 And were to we want to be say three,  
17 five years from now? I think that would be a good  
18 guidance, and also a nice framework within each of  
19 the projects can be evaluated.

20 And, you know, there may be specific  
21 issues, and say, you know, the SRP now has this  
22 deficiency, it was developed at some other time, and  
23 now we have new information, you know, and this is  
24 what we want to do.

25 And I, myself, am also all for expanding

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1 our state of knowledge and thinking about things. I  
2 mean we don't have to have a specific tool in mind,  
3 but we should not meet that this particular project  
4 will seek to, you know, broaden our horizons or  
5 whatever.

6 I think this is very important for -- we  
7 found it very important in the past for research  
8 programs. So I would encourage you, maybe by the  
9 Subcommittee time to think a little more about this  
10 and expand it a little bit. And then we'll take it  
11 from there.

12 MR. KEMPER: We do have a specific  
13 section in here we're going to talk about in some  
14 detail about the risk aspect of this, so hopefully  
15 we can answer some of that --

16 MEMBER APOSTOLAKIS: Yes

17 MR. KEMPER: -- as we go through.

18 MEMBER APOSTOLAKIS: Now another thing I  
19 want to say, and the last one, risk-informed  
20 performance-based should be developed. I would say  
21 that your research really should explore whether it  
22 can be developed because there are situations right  
23 now where we are not sure, like safety culture is  
24 one.

25 But this can be in a PRA in the

1 foreseeable future. And maybe this thing, the  
2 digital I&C, I don't know, fundamentally it's  
3 requirements are specification errors, right, which  
4 are really in the broader class of design errors.

5 And nobody knows how to bring these  
6 things into a PRA. Design errors in hardware are  
7 not in the PRA, yes or no. The answer is no.

8 CHAIRMAN WALLIS: Well, I was just  
9 wondering, I have no idea how reliable digital stuff  
10 is going to be compared with pipes and pumps.

11 MEMBER APOSTOLAKIS: That's true, that's  
12 true. But we should --

13 CHAIRMAN WALLIS: Or people.

14 MEMBER APOSTOLAKIS: I mean I think the  
15 --

16 MEMBER POWERS: I know relative to  
17 people.

18 CHAIRMAN WALLIS: All right.

19 MEMBER APOSTOLAKIS: The last one is  
20 stronger really than the current state of the art  
21 allows -- I mean you can't really claim I will  
22 spend, you know, five million dollars and two years  
23 from now I'll have digital I&C in the PRA because  
24 there are fundamental questions there that need to  
25 be addressed.

1 I'm not saying don't to it, I'm just  
2 saying change the words.

3 MEMBER BONACA: One question I have. I  
4 would like to just, you know, I always here about  
5 increased complexity. Do you view the complexity as  
6 necessary or it just as an offspring of the  
7 capability of the digital system to give you a lot  
8 of more information so you can use it for  
9 everything?

10 I mean we have seen what's happening in  
11 the automotive industry where there are some cars  
12 with such complex digital systems, not necessarily  
13 important to run the car, just simply they give you  
14 so many options, and then they don't run.

15 They are even, you know, the -- taking  
16 them back. Is it a similar situation, or is the  
17 complexity necessary?

18 MR. WATERMAN: Well, yes, I think it's a  
19 little bit of both, Dr. Bonaca. First, the systems  
20 are getting bigger. I think Ocone has come in,  
21 Paul Loeser is back there.

22 He's lead reviewer on the Ocone system.  
23 That's a full reactor protection system, engineered  
24 safety feature system changeout. Much more  
25 complexity involved in that system.

1 From the other perspective, part of the  
2 reason digital systems are being used is because  
3 they do provide additional capabilities, such as  
4 self-testing, allowing you to monitor processes more  
5 closely, voting logic and things like that.

6 So it's a little bit of both really.  
7 You know, it's just something we're going to have to  
8 face in the near future here. With regard to your  
9 comment, Dr. Apostolakis, my original draft which my  
10 boss would not allow me to bring in here -- slides,  
11 it had 122 slide in them so they wouldn't allow me  
12 to bring that in here, so now we're down to 29. So  
13 we do have a lot more detail --

14 MEMBER APOSTOLAKIS: At the Subcommittee  
15 you can bring 200 slides.

16 MR. WATERMAN: Thank you.

17 MEMBER POWERS: You'll only use 25 of  
18 them but you can bring 200.

19 MEMBER APOSTOLAKIS: One other thing  
20 that is of general interest and just occurred to me,  
21 because we were discussing it yesterday I think it  
22 was, it seems to me -- and in fact yesterday in that  
23 context we said that belongs to the digital I&C  
24 subcommittee.

25 What is the increasing use of digital

1 I&C doing to operator performance? Okay, somehow  
2 this has to be addressed by somebody. Okay. Are  
3 they bored to death or are they doing something  
4 else?

5 You know, because -- okay that's enough,  
6 let's move on.

7 MR. WATERMAN: The research focus in the  
8 plan is structured to develop better methods and to  
9 understand new technologies. First we know we need  
10 to consider going to risk-informed.

11 For example, by looking at risk  
12 assessment capabilities we want it to be more  
13 performance based. And for that we'd like to take a  
14 look at some methodologies for doing dependability  
15 assessments.

16 And we want it to be objective and  
17 repeatable, which is sort of my area.

18 CHAIRMAN WALLIS: It's not just  
19 dependability, it's whatever the measures of  
20 performance need to be.

21 MR. WATERMAN: Yes, sir. And we want it  
22 to be objective and repeatable, for example,  
23 measuring the software quality with some form of a  
24 methodology.

25 The focus is broad based, and it focuses

1 on improving traditional review methods, not  
2 replacing. All we're trying to do is augment the  
3 traditional methods because there are certain  
4 necessary functions that have to be carried out in  
5 our traditional reviews now.

6 We do that, for looking at new  
7 applications, advanced applications, and looking at  
8 new issues and regulatory requirements. And we've  
9 had some new issues coming up since 9-11, haven't  
10 we?

11 The research plan is broken down into  
12 six basic programs shown here on this slide here.  
13 And I'll discuss each of these programs as we go.  
14 I'm just going to give you a high-level view of the  
15 various projects in these programs or the programs  
16 themselves.

17 MEMBER APOSTOLAKIS: So if I look at  
18 this figure now, which boxes are of immediately  
19 interest to NRR?

20 MR. WATERMAN: Well, system aspects of  
21 digital technology deals with a lot of things that  
22 are going on right now, for example, in the  
23 environmental stressors.

24 So obviously ongoing projects are  
25 immediately concern, right? Now the risk assessment

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1 of digital systems, we've been doing that research  
2 for some time, so that's fairly high priority  
3 because it's ongoing and we're trying to get to an  
4 answer on that.

5 MEMBER APOSTOLAKIS: But is NRR  
6 interested? Probably not. I mean right now they  
7 don't have a need for that. They have to -- I mean  
8 they have to understand the system aspects.

9 They have to say something about the  
10 quality of the software, but rather it contributes  
11 to risk probably is of no interest to them. That  
12 doesn't mean

13 MR. WATERMAN: Well --

14 MEMBER APOSTOLAKIS: -- it's not  
15 important.

16 MR. WATERMAN: Well --

17 MEMBER APOSTOLAKIS: I'm just trying to  
18 understand where they're coming from.

19 MR. WATERMAN: Well the PRA branch in  
20 NRR may have a different perspective on it.

21 MEMBER APOSTOLAKIS: The PRA branch may  
22 have a dir perspective. That's very true.

23 MR. KEMPER: We really have not had a  
24 chance to talk with NRR about this at all, so I  
25 apologize, I just -- we really can't answer any

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1 questions about NRR's perspective, if you will, in  
2 terms of that memo that you read there, so --

3 MEMBER APOSTOLAKIS: Okay.

4 MR. KEMPER: But as Mike said, we are  
5 talking with various portions of NRR, and the risk  
6 branch, particularly. Cliff Dowd, we've been in  
7 communication with him, is interested in  
8 participating with us on this risk aspect of this  
9 project.

10 MEMBER APOSTOLAKIS: Well maybe I should  
11 have put it in a different way. Not which boxes are  
12 of interest to them, which boxes are relevant to  
13 regulatory decisions that are being made now.

14 That's a different way, but it's more  
15 accurate.

16 MR. WATERMAN: Well I think when we get  
17 into the projects area, you know, we'll be able  
18 to --

19 MEMBER APOSTOLAKIS: Okay.

20 MR. WATERMAN: -- you know, maybe touch  
21 on that in a little bit more detail.

22 MEMBER APOSTOLAKIS: But in the future  
23 maybe we should have an answer at this level as  
24 well.

25 MR. WATERMAN: For example, our advanced

1 nuclear power plant --

2 MR. KEMPER: I think they all do.

3 MR. WATERMAN: -- digital systems  
4 project we're kind of on hold right now. Plans that  
5 have been submitted have been differed for further  
6 review.

7 Other designs are potentially being  
8 submitted, so let's get into the system aspects of  
9 digital technology, and we'll start right in. This  
10 seven projects in this particular program -- and let  
11 me talk about what we've done in environmental  
12 stressors.

13 The environmental stressor stuff is  
14 pretty much wrapping up now. We actually had three  
15 subprojects in environmental stressors that dealt  
16 with EMI/RFI.

17 There's one particular area on fast  
18 transient response that we needed to address. And  
19 we've updated Regulatory Guide 1.180 that endorses a  
20 couple of different standards on that.

21 CHAIRMAN WALLIS: Isn't this a moving  
22 target though, digital systems? As you get smaller  
23 and smaller spacings in the memories and so on --

24 MR. WATERMAN: Your IC circuit density.

25 CHAIRMAN WALLIS: -- and the Moore's law

1 and all that, then the breakdown that comes easier  
2 from lightning strikes and so on.

3 MR. WATERMAN: Yes, sir.

4 CHAIRMAN WALLIS: What you may have okay  
5 today may be no good at all next year because if you  
6 update, upgrade your electronics it's more  
7 susceptible to something just shorting out from  
8 lightning.

9 MR. KEMPER: Well, I think what --

10 CHAIRMAN WALLIS: It's going to be  
11 performance-based then.

12 MR. KEMPER: Sure. But as vendors seek  
13 to qualify these platforms, they know they have to  
14 comply with the standards and guides that we have  
15 now.

16 CHAIRMAN WALLIS: So you have to have  
17 some standard tests or criteria or something.

18 MR. KEMPER: Exactly. So as they see  
19 the need to upgrade those they'll invoke changes in  
20 industry standards, you know, I triple E standards,  
21 and therefore we'll follow that with regulatory  
22 guidance.

23 MR. WATERMAN: Additionally part of this  
24 guidance there is on how to harden the installation  
25 more so maybe than hardening the chips is what do

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1 you do for shielding, things like that.

2 For example, in the lightning we really  
3 haven't had any comprehensive guidance on lightning.  
4 We've got a draft guide out there now for public  
5 comment DOING-1137 that looks at several standards.

6 And most of that is addressed not toward  
7 so much, you know, how do you keep a micro  
8 electronics safe when lightning strikes it, but how  
9 you make the station absorb the lightning strike  
10 without it effecting your microelectronic.

11 In the area of environmental  
12 qualification we have a draft guide that's still in  
13 house on DG1077 that endorses a couple of new  
14 standards. IEEE 232 (2003), I think the last  
15 version of that was 1983, 2003, and then there's an  
16 IEC standard 60780 I think, something like that.

17 And Christine Antonesca can talk to that  
18 in more detail. So we're circulating that EQ draft  
19 guide right now through NRR and we've been working  
20 back and forth with them to come to some resolution  
21 on it.

22 I believe the Committee here has  
23 addressed the IEEE standard 323 endorsement in the  
24 past. I've only been in research for a year so I  
25 haven't really been involved in that project.

1 With regard to systems communications,  
2 the trend in digital safety systems, as you know, it  
3 toward networked intrasystem architectures using  
4 dedicated communication.

5 MEMBER APOSTOLAKIS: Is that also in the  
6 nuclear industry?

7 MR. WATERMAN: Yes, sir. If you take a  
8 look at the Teleperm XS the safety systems they're  
9 anticipating developing out of that are all, you  
10 know, internally networked, not networked to the  
11 outside world, but it's a network where you have two  
12 by four voters in every channel sharing information  
13 between channels.

14 You have micro processors that are  
15 dedicated to communicating data back and forth.

16 MEMBER APOSTOLAKIS: Now when you say  
17 intrasystem, what do you mean?

18 MR. WATERMAN: Now within -- our  
19 philosophy with digital safety systems is if there  
20 is a network that network cannot be interfaced with  
21 non-safety networks in such a way that a non-safety  
22 network could adversely affect the safety network.

23 MEMBER APOSTOLAKIS: But all the safety  
24 related systems will belong to the network?

25 MR. KEMPER: Well, you know, I don't

1 know.

2 MEMBER APOSTOLAKIS: Is there separation  
3 between the safety systems?

4 MR. WATERMAN: I beg your pardon?

5 MEMBER APOSTOLAKIS: The digital.

6 MR. KEMPER: There a common data  
7 acquisition, you know, if you will, protocol between  
8 the information busses, if you will. Many of the  
9 safety systems draw information from the same  
10 sensors out in the plant, for example.

11 So that's the type of what we're talking  
12 about as far as the intrasystem architecture so it's  
13 important that we understand these things and make  
14 sure that the communication protocols are  
15 established correctly so that, you know, problems  
16 won't result inadvertently.

17 MR. WATERMAN: And I use the word  
18 intrasystem because the NRC is very sensitive to  
19 having safety related networks connected to non-  
20 safety related networks.

21 MEMBER APOSTOLAKIS: That's a no-no, I  
22 understand.

23 MR. WATERMAN: Absolutely.

24 MEMBER APOSTOLAKIS: That's fine.

25 MR. WATERMAN: But within the network

1       itself it's all safety related. There are certain  
2       issues that need to be addressed. For example, what  
3       are the safety related aspects of proprietary  
4       communication protocol?

5                   What things should a protocol do that  
6       are safe and what things ought a protocol not do  
7       that could adversely affect safety? To tell you the  
8       truth, we really don't review protocol right now.

9                   MEMBER APOSTOLAKIS: Wait, if it's  
10       proprietary, you mean to the company that developed  
11       it, right?

12                   MR. WATERMAN: It may be to the company  
13       that developed it. I believe that Siemens Teleperm  
14       XS, that's the one I have most experience with,  
15       developed their own communication protocols.

16                   So while they're proprietary to the  
17       outside world, we can still for the most part get in  
18       and review the protocols.

19                   MEMBER APOSTOLAKIS: Yes.

20                   MR. WATERMAN: But you have to ask  
21       what's the acceptance criteria for a good protocol.  
22       I don't know. To tell you the truth I really don't  
23       know.

24                   I guess I'm not smart enough to know  
25       that. So we need to provide the Staff with some

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1 guidance so that when they're reviewing a  
2 communication system that's safety related they  
3 understand what they have to look at when they're  
4 looking at a protocol.

5 MEMBER ROSEN: Let me pursue this  
6 separation idea for a -- if you have a process  
7 parameter in the plant that's used for both safety  
8 related purposes and non-safety related purposes,  
9 can you use the same sensor or must you have two  
10 separate sensors?

11 MR. WATERMAN: You can use the same  
12 sensor, but you have to isolate the non-safety  
13 component of that signal from the safety component.  
14 So generally what you do, you have sensor that comes  
15 down.

16 The sensor transmits off to the plant  
17 computer, which is a non-safety system, right? And  
18 that transmission link from the sensor to the plant  
19 computer is an isolated link.

20 Perhaps it's fiber optic, or photo  
21 isolator or something like that. And another  
22 connection goes to your safety system such that  
23 you're non-safety system can't feed back in and  
24 corrupt your safety system.

25 But you can use the same processor. And

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1 I think that's fairly common.

2 MR. KEMPER: Commonly done, right? TF  
3 control, rod control systems, they are often the  
4 same temperature indications, for example, as the  
5 RPS does.

6 MR. WATERMAN: Where we were really  
7 concerned with isolation on safety systems is -- I  
8 know the plant computer is non-safety and it's  
9 receiving a lot of inputs.

10 And if you don't have one-way  
11 communication to that plant computer -- that there's  
12 a potential that some -- by some means the plant  
13 computer could corrupt your safety system.

14 Obviously we have two-way communication  
15 with safety systems with sort of non-safety systems  
16 with you put up a maintenance and test panel to go  
17 in and do an update to your safety system.

18 And then the maintenance and test panel  
19 is disconnected. And that's -- those are some  
20 security concerns there we're also going to address.

21 MEMBER APOSTOLAKIS: Okay.

22 MR. WATERMAN: With regard to COTS  
23 digital safety systems, we have already in house a  
24 ton, if you will, of guidance on how to review COTS  
25 safety systems.

1                   The way the industry dedicates a piece  
2 of commercial off-the-shelf equipment is they use  
3 one or more of a combination of four basic  
4 processes. They do test and special inspections,  
5 source verification, supplier surveys, or use  
6 historical data.

7                   But the historical data has to be used  
8 in combination with one of those other processes.  
9 Two of those processes are fairly qualitative when  
10 you think about it, the source verification where  
11 you go out and watch your equipment being made, and  
12 a supplier verification which is sort of like an  
13 Appendix B auditing process that a licensee or a  
14 vendor would use on somebody who's not an Appendix B  
15 programmer.

16                   What we do when we review the COTS  
17 equipment is we use the qualitative process to  
18 review a qualitative result. It seems to me that  
19 maybe we need some independent way of assessing, you  
20 know, how well a COTS dedication was done.

21                   For example, maybe by using the fault  
22 injection method that's been developed for  
23 estimating digital system dependability in COTS, and  
24 when I say system I don't mean -- you know, when I  
25 think of system I think of the hardware integrated

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1 with the software, the hardware and the software.

2 So you got three components that make up  
3 a system. And that -- whenever I say system just  
4 try to keep that in mind. It's hardware, it's  
5 software, and it's the integration of hardware and  
6 software.

7 MEMBER RANSOM: I guess you include the  
8 communication system or the

9 MR. WATERMAN: Well, whatever system it  
10 is --

11 MEMBER RANSOM: fiber optic or hardwire  
12 --

13 MR. WATERMAN: -- if it's digital it has  
14 they're major components that you have to evaluate,  
15 hardware alone, software alone, and how those two  
16 integrate together.

17 Sometimes the integration is where all  
18 the problems are.

19 MEMBER RANSOM: Yes.

20 MR. WATERMAN: Without what we're  
21 looking at is a way of refining our methods for  
22 reviewing COTS equipment such that we may have an  
23 independent process, which I believe is -- what  
24 we're supposed to be is reviewing things  
25 independently, independent from what the licensee of

1 the vendor did.

2 MEMBER APOSTOLAKIS: How are we doing it  
3 now?

4 MR. WATERMAN: Well, the way we do it  
5 now is we go to the licensee or the vendor and we  
6 take a look at their COTS dedication, we review what  
7 criteria characteristics they felt that they had to  
8 match up with the manufacturing process.

9 We take a look at the documentation that  
10 shows what process they went through and is that  
11 process consistent with an Appendix B process. Take  
12 a look at the results of their special tests and  
13 inspections, for example, or look at their source  
14 verification and look at the scope of that and come  
15 to a conclusion about whether or not they followed a  
16 good process in dedicating that equipment.

17 EPRI has done a pretty good job of  
18 addressing COTS. This goes back to the, as you  
19 recall, the early '90s counterfeit parts issue. And  
20 we've reviewed that COTS -- or that EPRI COTS  
21 technical report and have endorsed it with a safety  
22 evaluation report.

23 I believe Paul Loeser had a lot to do  
24 with that. And that provides some pretty good  
25 guidance, but right now what we're doing is

1 reviewing what the licensee wrote down.

2 And there's -- we haven't had a lot -- a  
3 lot more independence than that. And sometimes that  
4 kind of made me nervous because a lot of times the  
5 licensee writes down what he wants you to see.

6 So with regard to electrical power  
7 distribution systems interactions, this is actually  
8 an internal research project. We're anticipating  
9 supporting our division of safety analysis and  
10 regulatory effectiveness.

11 What they have found is that there's  
12 been a lot of nuclear power plant digital-controlled  
13 power equipment that has reflected sensitivities and  
14 changes to grid voltage.

15 Grid stability goes down, your voltages  
16 fluctuate, and normally we would say well that's not  
17 a big deal because we have uninterruptible power  
18 supplies.

19 We can address that. What they have  
20 found is that sometimes the uninterruptible power  
21 supplies haven't responded as expected. At other  
22 times the plant has been requested to try to make up  
23 for the power and couldn't do it because it's  
24 voltage regulators weren't set correctly.

25 At other times the voltage would

1 fluctuate enough to drop down to the 80 percent  
2 threshold level, which you know, most of you know  
3 nuclear power plants.

4 Eighty percent drop in voltage is a  
5 reason to trip your reactor coolant pumps. It  
6 challenges your safety system. So there's been like  
7 over 100 licensee event reports that have been  
8 identified of grid fluctuations, of challenging  
9 nuclear power plant safety systems.

10 And so we've been requested by the  
11 Office of Research to go ahead and assist them in  
12 the evaluation of this, and kind of come up with  
13 some way of determining the effects of grid voltage  
14 fluctuations on electronic equipment.

15 Now let's take a look at our voltage.  
16 Our voltage and power characteristics, or voltage  
17 and current characteristics inside the plant, which  
18 is taking a look at the total harmonic distortion,  
19 which is all the harmonics in a typical sine wave,  
20 all the extra harmonics divided by the  
21 characteristic wave.

22 And they usually represent that some  
23 percentage of total harmonic distortion. Now when  
24 you talk to most people they'll, you know, say well  
25 what's your sources of total harmonic distortion.

1 And the obvious answer is well, power supplies,  
2 motor control centers.

3 But actually any non-linear load will  
4 introduce additional harmonic distortion into your  
5 power and into your current and into your voltage.  
6 And what's one of your big non-linear loads that are  
7 coming in?

8 Digital equipment. Microelectronics are  
9 all non-linear loads. Right now we've got fairly  
10 simple systems with a few microprocessors involved  
11 in them.

12 Well they all contribute to total  
13 harmonic distortion, but the contribution isn't very  
14 much right now. What happens when we bring in a  
15 full-blown reactor protection system engineered  
16 safety features actuation system where you may have  
17 a couple hundred microprocessors and all the  
18 supporting chips.

19 What is that going to do to your total  
20 harmonic distortion? IEEE stated in IEEE Standard  
21 519 that you ought not to get your total harmonic  
22 distortion above about five percent because if you  
23 do your electronics can start having adverse  
24 effects.

25 You know, back to Dr. Sieber's comment

1 about the chips are getting smaller and bigger,  
2 right, smaller distances between your adjacent  
3 circuits.

4 And they're also getting lower voltage  
5 requirements for changing memory states. It used to  
6 be what, five volts was the threshold voltage for  
7 changing and memory state.

8 It's down to like three or three and a  
9 half volts now. What happens when total harmonic  
10 distortion starts playing around with that? You can  
11 start losing memory states, perhaps with an over-  
12 voltage or an over-current.

13 You start getting migration between  
14 adjacent circuits and things like that. So we feel  
15 that that's something that's worthy of a little bit  
16 more investigation with regard to safety systems.

17 MEMBER SIEBER: But that's covered by  
18 the standards, right?

19 MR. WATERMAN: Well, it's covered by the  
20 standards, but how it's implemented, you know, the  
21 devil is in the details, you know.

22 MEMBER SIEBER: Well the specification  
23 is in the standards. The question is how do you  
24 test to assure yourself that the specifications are  
25 being met?

1                   For example, things like opening and  
2 closing the circuit breakers, particularly opening  
3 of them --

4                   MR. WATERMAN: Yes,

5                   MEMBER SIEBER: -- which impulses on the  
6 RFI and all kinds of things on your power supplies  
7 that go right to the CPUs. And you can end up  
8 resetting or restarting CPUs where it loses scads  
9 of data during the interval when it's down, even  
10 though it will recover and restore itself.

11                   It can really mess up the way things are  
12 being sequenced.

13                   MR. WATERMAN: It certainly can. And  
14 one of the areas is, you know, the conception is  
15 that well if I have great power supplies I don't  
16 have to worry about THD because they'll clean the  
17 power up.

18                   This is all stuff downstream of the  
19 power supply. You got good power coming in and you  
20 got your microelectronics screwing everything up.  
21 So how much does it mess up?

22                   What can we do to prevent that? Those  
23 issues, I think, need to be addressed.

24                   MEMBER SIEBER: How do you deal with  
25 questions like system overloads? You know, if you

1 get into a fast moving plant transient where you're  
2 exercising a lot of actuators and signals are  
3 changing, that puts large additional computational  
4 loads on the computing system which could cause it  
5 to fall behind. How do you test for that?

6 MR. WATERMAN: Well I think most of the  
7 computing systems anymore assume that you have a  
8 certain amount of time to respond and they just  
9 cyclically calculate and pick up the conditions as  
10 when they come around to their next cycle to  
11 calculate.

12 So it's not like an interrupt driven  
13 type system that looks for something to happen and  
14 then responds. It simply continues to calculate  
15 should I trip, wait 50 milliseconds, should I trip,  
16 wait 50 milliseconds, should I.

17 MEMBER SIEBER: So what you're saying --

18 MR. WATERMAN: That type of sequence  
19 there. So when a lot of things are happening in the  
20 plant your design basis will tell you how fast  
21 systems have to respond, and then you just do your  
22 -- the system just continues to run. And instead of  
23 calculating zero for don't trip it calculates a one  
24 for trip, so it's --

25 MEMBER SIEBER: So what you're saying --

1 MR. WATERMAN: I think that's pretty  
2 similar.

3 MEMBER SIEBER: -- is the computational  
4 load really doesn't change.

5 MR. WATERMAN: So, not in safety  
6 systems. That's been my experience with the systems  
7 I reviewed is they pretty well addressed that one  
8 because of that very concern.

9 You just can't interrupt processes and  
10 try to jump on something right away. Just take  
11 things slow and steady. You got plenty of time, as  
12 you know.

13 In a control room when you get a trip  
14 you got plenty of time to address it. Let's not get  
15 in a hurry here, let's just do things right. That's  
16 the way the systems are being developed now.

17 MEMBER SIEBER: Okay, thank you.

18 MEMBER POWERS: Could I understand  
19 something philosophical a little bit in your  
20 approach to defining a research program here? You  
21 posed the question what's the effect of total  
22 harmonic distortion on digital system components,  
23 for instance, okay.

24 Isn't that enough? Can't you say you,  
25 applicant, please answer this question?

1 MR. WATERMAN: Well, yes. We can but  
2 after the answer to the question how do we evaluate  
3 it if we don't have some kind of guidance to say  
4 well is that a good answer.

5 MR. KEMPER: Yes, we feel as though it's  
6 important in some of these areas to have our own  
7 independent confirmatory research to validate some  
8 of these issues.

9 MEMBER POWERS: So you want to be able  
10 to go in and say okay, he's told me this is a great  
11 system and it will do just fine, but I want to now  
12 use my tool which I suspect is different from his,  
13 and of course one of the natural evolutions is that  
14 the applicant will quickly evolve to using your  
15 tool, okay. Is that okay? I mean in --

16 MR. KEMPER: Well as long as it's a  
17 viable process and it satisfies our regulatory  
18 concerns and criteria. I mean what we do, we're  
19 public utility. So you know, if they choose to  
20 follow our path, if you will, I don't see any way to  
21 --

22 MEMBER POWERS: But it seems to me that  
23 it puts a different spin on the way you design your  
24 research program. If I'm doing -- if I have an  
25 individual tool here that nobody knows about except

1 me, and I go through and I look at the system that's  
2 supposed to be great and I say yes, it's great.

3 I mean it's better than any system I've  
4 ever seen before. And you just accept the  
5 licensee's assessment, and the SER gets written with  
6 his assessment in there.

7 If you come back and you say gee, it's  
8 just not quite right. I've got some questions here.  
9 You pose those questions. The licensee  
10 satisfactorily answers them and you write the SER,  
11 okay?

12 So you don't have to -- your tool  
13 doesn't have to be the state of the art or anything  
14 like that. I mean it just has to be adequate for  
15 you to pose questions and assess the answers when  
16 they come back.

17 Now if a licensee is designing his  
18 system using your tool, then you suddenly have an  
19 obligation to say, yes, this is as good as I  
20 possibly want to be.

21 I mean it has to be maybe not next to  
22 the industry state of the art, but it has to be my  
23 state of the art, okay, because I've got no  
24 independent way to check it because he's designed  
25 based with my tool.

1                   It seems to me you design your research  
2 programs a little differently in those two cases,  
3 don't you?

4                   MR. KEMPER: Yes, I agree with that, but  
5 let's take, for example, fault injection. You know,  
6 we're putting effort into fault injection testing as  
7 a way of providing --

8                   MEMBER POWERS: Yes, sure. It's a great  
9 example, yes.

10                  MR. KEMPER: -- reliability, right?  
11 Well there's a number of ways to do that. We're  
12 going to pick one or two. It would be nice, in my  
13 personal opinion, if we successful at this the  
14 vendors pick up on this and they start doing their  
15 own fault injection testing so therefore when they  
16 make the submittals to us, now that issue has  
17 already been addressed, if you will.

18                  Now we may come back with our own tool  
19 and independently validate that to a certain extent,  
20 but this can only help promote a safer and more  
21 reliable process controls industry in nuclear  
22 industry by sharing this information and  
23 methodology.

24                  But that's kind of where I'm coming  
25 from, I guess.

1 MEMBER POWERS: Sure, sure. I mean it's  
2 just a question of philosophy and approach. Now let  
3 me ask you just a little more on philosophy. There  
4 are lots of people in this world that have the same  
5 problem you do.

6 They want to see digital systems used in  
7 nuclear power plants. I mean they're going to see  
8 them. It's not a question they may see them, they  
9 will see them.

10 What else is going on in the world in  
11 this same area? I mean how does your plan compare  
12 to what else is going on in the rest of the world?

13 MR. KEMPER: Well we are on selected  
14 projects. We're trying to interface with NASA. The  
15 train, the rail system in some cases, you know, some  
16 of the testing builds off some of that work.

17 Military, so we are looking at other  
18 agencies and other interests.

19 MEMBER APOSTOLAKIS: How about  
20 international activities?

21 MEMBER POWERS: What I see in the agenda  
22 for the next American Nuclear Society meeting,  
23 simply because I just happen to look at it, is there  
24 must be 20 papers from the Koreans --

25 MEMBER APOSTOLAKIS: Yes.

1 MEMBER POWERS: -- dealing with some  
2 aspect of digital systems. And they look like  
3 they're universally assessment types of things. I  
4 mean they come in and they do something on this  
5 digital system and they get a characteristic out of  
6 it.

7 I don't see anything that comes in and  
8 says okay this is the characteristic and I know  
9 that's good because. I mean they're just deriving a  
10 number.

11 But like I say, it must be 20 papers on  
12 that of some sort.

13 MR. KEMPER: Hopefully we've got some  
14 more projects we're going to get into here.

15 MEMBER APOSTOLAKIS: But you are -- you  
16 are abreast of what's happening internationally?

17 MR. KEMPER: Yes.

18 MEMBER APOSTOLAKIS: You are keeping up?

19 MR. KEMPER: Yes, we are. Yes, we  
20 attend international conferences.

21 MEMBER APOSTOLAKIS: Okay.

22 MR. KEMPER: We --

23 MEMBER APOSTOLAKIS: Let me tell you  
24 this back to the fault injection thing. I know that  
25 in other industries -- I mean you have to be careful

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1 when you say I'm going to look at what other people  
2 are doing because other people don't always have the  
3 perspective of a nuclear regulatory agency.

4 And we had in fact a presentation here  
5 last time by a very well known professor who has  
6 been practicing this for awhile. But you know,  
7 coming from the nuclear perspective, you know, and  
8 looking at this fault injection method and, you  
9 know, they're injecting faults and this and that,  
10 but they when they start using Markov models and  
11 transition rates to estimate reliability from that  
12 they lose me because I want to understand what the  
13 failure rates mean.

14 And apparently that's not important to  
15 these people, okay. So this is where you come in  
16 and say yes, we're going to look at this from the  
17 nuclear power perspective, and we tend to question  
18 things like that.

19 When somebody says the transition rate  
20 lambda from state five to state eight is this, you  
21 have to ask him where did you get that from, and how  
22 do you know there is a constant rate of transition.

23 This seems to me to be a very  
24 significant assumption on their part. And then of  
25 course, you have a nice formula in terms of those

1 failure rates, which excites people.

2 They say well now I got the reliability.  
3 I don't think so. So this is where you come in and  
4 evaluate these methods and question them because  
5 there's a lot of stuff out there, you know.

6 Just because something has been  
7 published doesn't mean that --

8 MEMBER POWERS: Oh, my goodness. A  
9 professor's saying something published is not  
10 sainted.

11 MEMBER APOSTOLAKIS: Unless it's my  
12 journal.

13 MEMBER POWERS: Oh, yes, that's right.  
14 I'd forgotten that.

15 MR. WATERMAN: Moving right along now.  
16 With regard to operating systems --

17 MEMBER APOSTOLAKIS: Well, by the way  
18 the Koreans are publishing a lot. I get lots of  
19 papers on digital --

20 MR. WATERMAN: Oh, yes, I mean it's --

21 MEMBER APOSTOLAKIS: They are really  
22 doing a lot.

23 MR. WATERMAN: It's a bunch of stuff.

24 MEMBER APOSTOLAKIS: The Korean Advanced  
25 Institute for Science and Technology. Okay, great.

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1 So we are what, three quarters of the time?

2 MEMBER POWERS: Yes.

3 MEMBER APOSTOLAKIS: And we are only at  
4 one third done with the presentation? So now you  
5 appreciate why your management reduce your number of  
6 slides from 120 to 29.

7 MR. WATERMAN: Hell, if I had 193 slides  
8 I'd be on slide 12, wouldn't I?

9 MR. KEMPER: Well we've talked about  
10 many of these issues, quite honestly, that are on  
11 subsequent slides.

12 MR. WATERMAN: That would just broaden  
13 it.

14 MR. KEMPER: So if you will we'll move  
15 on through them quickly.

16 MEMBER APOSTOLAKIS: Yes, you can  
17 actually accelerate the process.

18 MR. KEMPER: Okay, thank you.

19 MR. WATERMAN: In the past we really  
20 haven't been able to assess proprietary operating --  
21 COTS operating system characteristics mainly because  
22 we couldn't get into the code.

23 But there is another class of operating  
24 systems where we have been able to review. And  
25 that's typically on the platforms where the vendor

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1 of the platform, the developer of the platform has  
2 developed his own, if you will, 64K kernel operating  
3 system, the stripped down operating system that  
4 handles just specific processes.

5 We, you know, I have difficulty  
6 reviewing those systems because they're usually  
7 written in machine language and I haven't had any  
8 guidance that actually told me the operating system  
9 ought to do these functions and ought not to do  
10 theses functions.

11 So some time ago research initiated a  
12 study to look at operating system characteristics,  
13 and that study was sort of inconclusive and so it  
14 was dropped.

15 And so was the user need requesting it.  
16 But what we found it I believe we need further  
17 research to identify safety critical design aspects  
18 of operating systems. I think we're seeing more and  
19 more kernel type operating systems coming along that  
20 we can actually get into.

21 And we need to develop processes for  
22 performing safety assessments of those operating  
23 systems. Right now, even though we have a lot of  
24 acceptance criteria in the standard review plan,  
25 when it comes to operating systems it's just -- wow,

1 it's -- sometimes it's hard to apply.

2 Now with regard to diversity and  
3 defense-in-depth, as you know, we already have  
4 Branch Technical Position 19. I helped Matt write  
5 that technical position back in the mid '90s.

6 And we have -- that's sort of a  
7 deterministic approach to looking at diversity and  
8 defense-in-depth. Now the nuclear power industry  
9 conversely has proposed using risk insights from  
10 PRAs, for example, using their leak-before-break  
11 analysis to justify not putting in a diverse system,  
12 or arguing that a PRA shows the probability of a  
13 common mode failure is low enough that you don't  
14 need to consider it in severe accidents.

15 So what we propose to do with this  
16 project is actually several things. First, we want  
17 to verify deterministically that existing guidance -  
18 -

19 CHAIRMAN WALLIS: You mean leak-before-  
20 break, you mean they show some symptom that things  
21 aren't right before they completely go wrong? Is  
22 that what you mean?

23 MR. WATERMAN: Well as you recall in the  
24 early to mid '80s plants were required to put in jet  
25 impingement barriers and pipe whip restraints on

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1 their plant unless they could analyze their way out  
2 of it.

3 The way they did that was they analyzed  
4 that a small leak would grow into a large break over  
5 time. The operator would have enough time to  
6 respond.

7 And therefore they really didn't need to  
8 put in the pipe whip restraints. So what they've  
9 tried to do is to shoestring into this position off  
10 of that analysis of leak-before-break.

11 And I think that was Oconee's original  
12 approach. And I don't know what they're doing now.  
13 Paul Loeser can speak to that. What we want to do  
14 it determine whether or not the criteria in the  
15 Branch Technical Position are realistically  
16 conservative.

17 I mean you can have things that are  
18 really conservative that nobody can live up to. We  
19 want to determine whether that's realistically  
20 conservative.

21 MEMBER APOSTOLAKIS: We don't have a  
22 realistic --

23 CHAIRMAN WALLIS: We don't have a  
24 definition of realistically conservative.

25 MEMBER APOSTOLAKIS: It's something that

1 Agency is using now.

2 MR. WATERMAN: Right.

3 CHAIRMAN WALLIS: It's an invocation,  
4 isn't it?

5 VICE CHAIRMAN SHACK: Yes.

6 MEMBER SIEBER: A chant.

7 MR. WATERMAN: Back in the mid '90s we  
8 contract, I believe, Lawrence Livermore to develop a  
9 NUREG/CR on how to implement diverse systems. And  
10 they identified something like seven different  
11 characteristics that have to be diverse.

12 And each one of those had a whole bunch  
13 of bullets under them that ranked various diversity  
14 aspects. For example, software languages was not  
15 considered as diverse as some of the other features  
16 in that category.

17 What we'd like to do -- and those were  
18 called coping strategies. What we'd like to do is  
19 take a look and see if there's an optimal mix of  
20 coping strategies that licensees can actually live  
21 up to.

22 Bill in his experience in the industry,  
23 they've tried to apply it and said it's a fairly  
24 onerous process. And it doesn't appear to be  
25 anything that's really applicable.

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1                   And what we'd like to do is figure out a  
2 way to make that more reasonable.

3                   MEMBER APOSTOLAKIS: I'm listening to  
4 you and I think it's fine what you're saying. I'm  
5 just wondering though, how did you come up with  
6 this? Obviously NRR did not request this, I mean  
7 judging from the memo I read.

8                   So did you have a group of people  
9 sitting around a table and saying this sounds like a  
10 good idea, or how did you decide that this is  
11 something that's worth supporting as a research  
12 project?

13                   MR. KEMPER: Well, it seems to be a --  
14 it's a major industry initiative right now.  
15 Basically, you know, the proliferation of digital  
16 processes in the American industry is far behind the  
17 foreign -- many of our foreign or international  
18 countries.

19                   Complying with diversity and defense-in-  
20 depth is one of the key issues here that is the big  
21 struggle, quite honestly. So based on that, since  
22 it is such a difficult issue between the industry  
23 and the Agency, it seemed prudent to do this  
24 research in an anticipatory basis, quite frankly.

25                   MEMBER APOSTOLAKIS: So has there been a

1 situation where the industry and the Agency  
2 disagreed on some defense-in-depth measures, or --

3 MR. KEMPER: I believe that the --

4 MEMBER APOSTOLAKIS: Apparently there is  
5 an NUREG/CR already.

6 MR. KEMPER: Right.

7 MEMBER APOSTOLAKIS: So somebody must  
8 have decided that the guidance there is not good  
9 enough.

10 MR. KEMPER: Yes. Applications have  
11 been submitted to the Agency for review and then  
12 withdrawn based on, you know, their strategy that  
13 they prescribed for complying with this versus our  
14 push-back to them.

15 So it's not to say that our process is  
16 wrong or bad or anything, we're just -- we just feel  
17 as though it bears some resources to look closer at  
18 this to see if there is some optimum conservatism  
19 that should be applied using this process.

20 MEMBER DENNING: But I think -- weren't  
21 you asking a process question? That's a little bit  
22 different from that specific answer for this  
23 particular thing.

24 And that is in putting together this  
25 research program, how do you actually decide which

1 of these activities are the ones to undertake? Was  
2 that something that your group just got together and  
3 did?

4 MR. KEMPER: Yes, for the most part,  
5 that's right.

6 MEMBER DENNING: That the way you did?  
7 And so you came up with a list them and you  
8 prioritized them --

9 MR. KEMPER: That's right.

10 MEMBER DENNING: -- within their groups.

11 MR. KEMPER: Right. And our intent was  
12 --

13 MEMBER APOSTOLAKIS: But you --

14 MR. KEMPER: And our intent was to  
15 engage out clients, you know, NRR, NSIR, and NMSS.

16 MEMBER APOSTOLAKIS: But you have not  
17 done this yet.

18 MEMBER DENNING: But you haven't done  
19 that yes.

20 MR. KEMPER: Well we have with some.

21 MEMBER APOSTOLAKIS: With some.

22 MR. KEMPER: NSIR and NMSS. We did not  
23 engage anybody else.

24 MR. WATERMAN: But part of that  
25 engagement is writing a draft research plan for them

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1 to review. I guess we did.

2 MEMBER APOSTOLAKIS: I would expect,  
3 though, that you would interact with them before you  
4 wrote anything.

5 MEMBER DENNING: Well, particularly NRR.

6 MEMBER APOSTOLAKIS: Particularly NRR,  
7 yes. Then you wouldn't get this kind of reaction.  
8 Anyway, oh there is -- I'm sorry.

9 MR. CHIRAMAL: I'm Matt Chiramal from  
10 NRR. And --

11 MEMBER APOSTOLAKIS: The infamous  
12 branch?

13 MR. CHIRAMAL: Yes.

14 MEMBER APOSTOLAKIS: Okay.

15 MR. CHIRAMAL: The subject we were just  
16 talking about is something that was reviewed by the  
17 National Academy of Sciences and it was determined  
18 that you had in defense-in-depth is okay.

19 MEMBER APOSTOLAKIS: You need what? I'm  
20 sorry?

21 MR. CHIRAMAL: That defense-in-depth and  
22 diversity is a requirement that will apply to  
23 nuclear plants is a good idea.

24 MEMBER APOSTOLAKIS: No, but I'm not  
25 questioning the value of defense-in-depth, I'm

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1 asking why this particular project. I know that the  
2 Agency has been implementing defense-in-depth and  
3 diversity for awhile.

4 MR. CHIRAMAL: That's correct.

5 MEMBER APOSTOLAKIS: So -- but what it  
6 is that this particular project -- I mean is there  
7 something wrong with the way we're doing it, or is  
8 it something that sounds like a good idea to some  
9 people based on their experience, which is fine?

10 I mean we've been making decisions like  
11 that for a long time.

12 MR. CHIRAMAL: That's correct.

13 MEMBER APOSTOLAKIS: There's nothing  
14 wrong with that. I just want to understand.

15 MR. CHIRAMAL: Yes. And the other point  
16 is that --

17 MEMBER APOSTOLAKIS: Do you agree with  
18 me?

19 MR. CHIRAMAL: The SRP Chapter 7 is  
20 based upon IEEE 7.4-3.2, and the new version of  
21 this, 2003, came out. And mike worked on it and it  
22 adapted all the requirements that we had in the SRP  
23 into the standard.

24 And that's up to date already and none  
25 of these subjects that you're looking at -- they're

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1 all covered by that communications qualification,  
2 and all the requirements that the research is doing  
3 is already covered by the new standard, which is  
4 being endorsed by -- a researcher's going to be  
5 putting out pretty soon.

6 And it includes the requirements for  
7 security added to it.

8 MEMBER APOSTOLAKIS: So what you're  
9 saying is that the objectives of these projects have  
10 already been met by a standard that is about to be  
11 approved?

12 MR. CHIRAMAL: Yes, and that's something  
13 we'll discuss with research when we -- this is  
14 something we'll discussed with research when we get  
15 together on this project.

16 MEMBER APOSTOLAKIS: I assume you would.  
17 Okay.

18 MR. CHIRAMAL: I'm trying to digest all  
19 this, but --

20 MEMBER APOSTOLAKIS: Yes, please, go  
21 ahead.

22 MR. SHAFFER: Can I just say something?

23 MEMBER APOSTOLAKIS: I'm sorry.

24 CHAIRMAN WALLIS: Are we going to be  
25 asked to referee this contest?

1 MEMBER APOSTOLAKIS: I don't know.

2 MR. SHAFFER: I'm Roman Shaffer, I'm on  
3 I&C section.

4 MEMBER APOSTOLAKIS: From which?

5 MR. SHAFFER: Roman Shaffer, I'm in  
6 Bills section.

7 MEMBER APOSTOLAKIS: Okay.

8 MR. SHAFFER: I was involved in the  
9 early stages of revising the research plan. I get  
10 the impression here that maybe the Committee thinks  
11 that we just sat in a room and operated in a vacuum  
12 and came up with these activities.

13 We actually continued some of the  
14 projects from the previous plan, and through  
15 interactions with licensees and the vendors and  
16 other colleagues within the Agency we same up with  
17 these activities.

18 These are areas of research we think we  
19 need to continue or start based on the state of the  
20 industry as well as where we see them going. And  
21 defense-in-depth project is one we think is  
22 particularly important.

23 I mean we don't operate in a vacuum, we  
24 engage various people in groups. So I just wanted  
25 to make that clear.

1 MEMBER APOSTOLAKIS: I understand what  
2 you're saying, but I mean this memo that we've been  
3 discussing, and maybe we shouldn't, but it says --  
4 it actually preaches here, it says it is recommended  
5 that in the future research discuss these proposed  
6 research activities with individual NRR branches in  
7 sections prior to answering the research plan to  
8 gain a better understanding of actual regulatory  
9 needs and practices?

10 Wow, that's pretty strong. And one  
11 would expect that this, you know, would have  
12 happened already. But anyway that's why the issues  
13 are coming up today, not -- even stronger statements  
14 in other places.

15 Let's go on, though. I think we have  
16 exhausted this particular aspect.

17 MR. WATERMAN: With regard to software  
18 quality assurance we have three projects identified.  
19 That's assessment of software quality, digital  
20 system dependability, and self-testing methods.

21 And if I can get through those fairly  
22 quickly here we can still get Bill down to Florida.  
23 On the assessment software project quality, NRC  
24 evaluates digital systems development processes  
25 manually.

1                   And that doesn't sound too bad until you  
2 sit in a conference room with a vendor site and you  
3 ask him to bring in all the documentation for his  
4 system and realize that you've got about a week to  
5 do thread audits across about 10,000 pages of  
6 documentation, which is about what it is.

7                   I usually don't call it pages I call it  
8 feet, because you look at it and say it's about  
9 three feet of documentation. That's about right.

10                  CHAIRMAN WALLIS: We're used to that  
11 experience too.

12                  MR. WATERMAN: So what we're looking for  
13 in this research project here is to develop a more  
14 effective and through supporting process. You still  
15 have to go through the documentation, believe it or  
16 not, because there are interfaces in those phases  
17 that only the human eye can pick up the errors on.

18                  But we need some way of supporting that  
19 process to come up with some more objective  
20 assessments of the quality of the development  
21 process.

22                  And what really kind of perked up my  
23 ears, to tell you the truth, was the University of  
24 Maryland project, which is using metrics to assess  
25 software quality.

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1                   That looks to me like a tool that we can  
2 adapt to be a verification tool, or a testing tool  
3 to see the quality of the verification development  
4 process.

5                   So I look at that tool as the tool that  
6 you would use to assess everything from the concepts  
7 phase through the implementation phase. How well  
8 did the vendor put that product together?

9                   He used a tool so that their assessments  
10 come out consistent. And then you also do the  
11 manual reviews to pick up the little interface  
12 problems that I don't think any tool --

13                   MEMBER APOSTOLAKIS: But again, before  
14 you jump into any of these methods you would  
15 scrutinize the assumptions, right -- and behind  
16 them?

17                   MR. KEMPER: Yes, you would, of course.

18                   MR. WATERMAN: And that tool complements  
19 the fault injection test assessment methodology  
20 already developed for digital system dependability  
21 testing.

22                   I look at the -- and I'll talk about  
23 that in another minute here. Additionally we're  
24 taking a look at what Halden Reactor Program is  
25 doing on evaluating software engineering practices

1 used by other countries.

2 We're paying the money already so why  
3 shouldn't we use some of that data and see if it can  
4 be useful.

5 MEMBER APOSTOLAKIS: I wonder if -- well  
6 Dr. Powers is not here, but is there such a thing as  
7 Swedish operators working on Finnish computers?  
8 That's an inside joke.

9 MEMBER SIEBER: AS long as it's  
10 Microsoft you're okay.

11 MEMBER APOSTOLAKIS: What?

12 MEMBER SIEBER: As long as it's  
13 Microsoft and Windows-based, you're okay.

14 MR. WATERMAN: With regard to digital  
15 system dependability, not all safety significant  
16 errors in digital systems may be detected by V and V  
17 processes.

18 That goes without saying. And so I  
19 think we need an independent method of evaluating  
20 licensee's and vendor's digital systems. And the  
21 fault injection methodology shows some promise in  
22 allowing us to do that.

23 And it's already been developed and they  
24 use it to assess dependability. It's been -- this  
25 particular fault injection tool was used on the Los

1 Angeles Green Line metro system.

2 And they did the equivalent of ten  
3 billion tests on the system. They found three  
4 safety-significant errors, and I'll get into that on  
5 the next project.

6 So what this project will do is produce  
7 a process for using the tool to determine the  
8 dependability safety systems. I look at this tool  
9 as a validation tool.

10 What do you do after implementation?  
11 You've integrated it into your system. How can you  
12 test the system? So that's the validation part.  
13 The toll, this tool by itself isn't going to tell  
14 you everything you know about the system any more  
15 than the University of Maryland tool, or some tool  
16 like that they use in metrics, could tell you  
17 everything you needed to know about the system.

18 But the two tools working together can  
19 give you a better feeling for the quality of the  
20 system, which is really important in the out years,  
21 right, when you have to maintain it, and how well  
22 the system works right now.

23 So I look at those two tools as a  
24 possible adjunct to help the regulators regulate the  
25 systems appropriately.

1 MEMBER APOSTOLAKIS: When you say  
2 evaluate dependability, are you going to get the  
3 number, or is it something that is a concept, you  
4 know, that now I feel better about?

5 MR. WATERMAN: Well, to tell you the  
6 truth, if I was using this tool I wouldn't care  
7 about -- if the dependability number came out. I  
8 don't want the tool to tell me whether or not after  
9 ten billion tests it found any errors in the system.

10 MEMBER APOSTOLAKIS: So it's not the  
11 number?

12 MR. WATERMAN: Well, it produces a  
13 dependability number and Steve Arndt can talk more  
14 to this project than I can, Dr. Apostolakis.

15 MR. KEMPER: Yes, they can be used in  
16 both ways.

17 MR. WATERMAN: And I'm looking at a  
18 validation methodology.

19 MEMBER APOSTOLAKIS: If he comes to  
20 number and I see these Markov results again, I'm  
21 telling you I'm not going to be friendly. I don't  
22 think people have really scrutinized the assumptions  
23 behind those things.

24 Although if you tell me that you did it  
25 ten billion times and you found three faults, I

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1 think that's great.

2 MR. WATERMAN: Can we tunnel down into  
3 this?

4 MEMBER APOSTOLAKIS: That really adds to  
5 my confidence, but when people jump into those  
6 Markov models I have a problem with that.

7 MEMBER SIEBER: How confident are you  
8 that the University of Maryland metrics method of  
9 evaluating software really tells you important  
10 things, characteristics about the quality of the  
11 software?

12 MR. WATERMAN: Well, I haven't really  
13 had a chance to look at the whole tool yet. I've  
14 been sort of a strong advocate for metrics. And it  
15 looks like right now it's a stripped down metrics  
16 tool as opposed to using a lot of metrics.

17 So I've seen all of their integrals and  
18 all that other stuff, but what I'd really like to  
19 see is how the whole thing pans out. But if we  
20 don't do the research we'll never know that answer.

21 MEMBER SIEBER: Yes, I was surprised at  
22 the accuracy that they claim to have in that. But  
23 the link between those metrics and the actual  
24 quality of the product to me -- somehow escapes me a  
25 little bit.

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1 MR. WATERMAN: It's sort of like us  
2 linking the quality of a product with safety, isn't  
3 it?

4 MEMBER SIEBER: That's right.

5 MR. KEMPER: Well it's still a work in  
6 progress, clearly. You know, this is the first  
7 crack now. As we speak they're in the middle of  
8 trying a sophisticated reaction protection system  
9 type of a platform in software.

10 MEMBER SIEBER: Well if they hadn't  
11 achieved remarkable accuracy I would probably  
12 comment that you ought to look as to whether you  
13 ought to finish or not.

14 But some of that work was impressive in  
15 my opinion.

16 MEMBER APOSTOLAKIS: Do you have any  
17 criteria? I mean a lot of this is exploratory,  
18 right?

19 MR. WATERMAN: Yes.

20 MEMBER APOSTOLAKIS: Do you have any  
21 criteria that you would use, objective criteria that  
22 -- yes, we've done enough and this is going to lead  
23 us anywhere.

24 MR. WATERMAN: Well, obviously we need  
25 to shake these projects out, right?

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1 MEMBER APOSTOLAKIS: Because not all of  
2 these projects will actually produce --

3 MEMBER SIEBER: Something.

4 MEMBER APOSTOLAKIS: But they're  
5 claiming they will produce because, you know, a lot  
6 of it is exploratory.

7 MR. WATERMAN: That's true, but you  
8 know, the only way we'll know that answer is to go  
9 ahead and do the work, it seems to me. And so, you  
10 know --

11 MEMBER APOSTOLAKIS: What does --

12 MR. WATERMAN: We've just got to go down  
13 that road until we get what we want.

14 MEMBER APOSTOLAKIS: What does the work  
15 mean? I mean there could be a phase approach where  
16 you're exploring first the feasibility of something  
17 and you get encouraging results you say okay, I'll  
18 go to the next phase, or something like that.

19 MR. KEMPER: Well that's precisely --  
20 well I don't know how we got on that project. We're  
21 kind of ahead of ourselves. But at any rate, that's  
22 precisely what the metrics project is doing, right?

23 It's a three phase process. The first  
24 two phases really were proof of concept. We've gone  
25 far enough. We believe that to be true. We believe

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1 it's a viable concept so now we're trying to invoke  
2 that process on a STAR module system.

3 I think it's -- we got it from Ocone,   
4 right Steve? For a safety related system and  
5 application software. So that really will be the  
6 proof in the pudding, as we say.

7 We can get meaningful results from that  
8 test.

9 CHAIRMAN WALLIS: Well I think this  
10 applies to the whole plan.

11 MEMBER APOSTOLAKIS: Yes.

12 CHAIRMAN WALLIS: I mean the problem I  
13 have with the whole plan was you've laid out all  
14 these things which you want to get done but there's  
15 no indication for me about the likelihood of success  
16 in getting these things done.

17 MEMBER SIEBER: Or even to know when  
18 you're successful.

19 CHAIRMAN WALLIS: Or the competence of  
20 the people or whatever, or the methods you need to  
21 have some phasing or something with all of these  
22 projects.

23 MEMBER APOSTOLAKIS: Yes, that would be  
24 useful because a lot of this stuff is really still  
25 in its infancy.

1 CHAIRMAN WALLIS: So it's a hope?

2 MEMBER APOSTOLAKIS: Well not the plan,  
3 I mean the state of the art out there. And the  
4 other thing that is amazing, I mean I guess it  
5 happens in all field when they're new -- it reminds  
6 me of the '70s and risk benefit analysis, which was  
7 new at the time. People publish something, they  
8 issue a report or a paper or present a paper and so  
9 on that is not really scrutinized by experts because  
10 thee are no experts in the field.

11 Or if there are they're biased and so  
12 on, so a lot of the stuff that's out there not, I'm  
13 not sure how applicable it would be, or it would --  
14 to what extent it would survive a scrutiny from the  
15 nuclear regulatory respect. So we always have to  
16 be --

17 CHAIRMAN WALLIS: But then how do you  
18 get something new started, George? It's --

19 MEMBER APOSTOLAKIS: No, I mean all  
20 these things are elements here that the decision  
21 makers need to take into account. Now we're still  
22 on 17 and we're going project after project.

23 I mean do we really need to continue  
24 doing this? We got an idea.

25 MR. KEMPER: We skim over two or three

1 of those projects.

2 MEMBER APOSTOLAKIS: Are there any  
3 projects that you really feel you ought to talk  
4 about? Like this data on 19 for example, I think  
5 that's an interesting -- unless you disagree.

6 MR. WATERMAN: Okay. Well with regard  
7 to self-testing why are we looking at self-testing?

8 MEMBER APOSTOLAKIS: No, no, no.

9 MR. WATERMAN: It's been my experience  
10 that errors that fail systems are self-testing  
11 errors.

12 MEMBER APOSTOLAKIS: I'm not questioning  
13 why you're doing this. I'm just saying that since  
14 we're running out of time there may be --

15 MR. WATERMAN: Ten minutes.

16 MEMBER APOSTOLAKIS: -- a few that you  
17 want the to point out.

18 MR. WATERMAN: Well, we're continuing  
19 our work on risk assessment digital systems,  
20 obviously.

21 MEMBER APOSTOLAKIS: Okay.

22 MR. WATERMAN: And since we've already  
23 had several meetings with you all I don't know that  
24 we really need to get into great details on that.  
25 We're continuing to move down that road.

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1 MEMBER APOSTOLAKIS: We'll probably  
2 review this during the Subcommittee meeting, so --

3 MR. WATERMAN: Exactly. So into  
4 security aspects of digital systems. We've attended  
5 different conferences and different universities and  
6 things like that to get input on what aspects of  
7 secure systems we probably ought to address.

8 And we identified four projects, cyber  
9 vulnerabilities, electromagnetic attack  
10 vulnerabilities, wireless network security, and  
11 firewall security.

12 Cyber security, as you know, it's always  
13 been a concern of ours. If you look in standard  
14 review plan back in '97 we were talking about cyber  
15 security.

16 Now ever since 9-11 it's kind of become  
17 a heightened issue.

18 MEMBER APOSTOLAKIS: But what can they  
19 do? I mean I don't understand that. I mean what  
20 can they do?

21 MR. KEMPER: It depends on the  
22 connectivity of your system.

23 CHAIRMAN WALLIS: There was one plant  
24 which had a worm in it wasn't there?

25 MR. WATERMAN: Davis-Besse got his with

1 the Slammer worm

2 MR. KEMPER: We just took a trip out to  
3 one of the labs and they gave us a demonstration on  
4 some of their cyber attack capabilities and it was  
5 phenomenal.

6 I mean though the system that they had  
7 set up they were able to just through an e-mail, if  
8 you will, they simulated you acknowledge, you answer  
9 your e-mail, and as soon as that happens they take  
10 control of your PC, and because of it's connectivity  
11 they actually get into the control system and the  
12 process controls the whole application they had,  
13 so --

14 MR. WATERMAN: But that's not the only  
15 security concern we have to concern ourselves with.  
16 It's not just the safety system that we have to  
17 worry about.

18 We're talking about security of our  
19 country and our critical infrastructure. So you  
20 know, if you take a look at the grayouts in  
21 California last year, can you imagine what would  
22 have happened if somebody had attacked the switch  
23 yard?

24 It's way outside the protected area.  
25 You cause the plant the trip. You don't have to

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1 destroy a plant for critical infrastructure. All  
2 you got to do is make the thing shutdown.

3 You don't even have to shut it down  
4 permanently. If you're in a grayout situation  
5 you've already got a blackout on your hands. Now  
6 how many people are going to die from that?

7 And remember one of our missions in the  
8 NRC, besides protecting the health and safety of the  
9 public, protecting the environment, is to ensure  
10 national security.

11 MEMBER APOSTOLAKIS: In the nuclear  
12 arena.

13 MR. WATERMAN: From a security  
14 perspective we have to consider, you know, what are  
15 we doing --

16 MEMBER APOSTOLAKIS: Wait, wait, wait.

17 MR. WATERMAN: -- for critical  
18 infrastructure.

19 MEMBER APOSTOLAKIS: The common defense  
20 and security, I think, refers to nuclear matters.

21 MR. WATERMAN: Well --

22 MEMBER APOSTOLAKIS: We're not going to  
23 stop protecting infrastructures are we?

24 MR. WATERMAN: Critical infrastructure  
25 is a concern for the Department of Homeland

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1 Security.

2 MEMBER APOSTOLAKIS: Yes, and they  
3 should pay for this, not us.

4 MR. WATERMAN: And nuclear power plants  
5 are part of that critical infrastructure.

6 MR. KEMPER: Well I guess more  
7 specifically to us, these cyber attacks have the  
8 ability to challenge --

9 MEMBER APOSTOLAKIS: Yes, I understand  
10 that, and I agree with that.

11 MR. KEMPER: So that's the real --  
12 that's where it really comes home.

13 MEMBER APOSTOLAKIS: But we should limit  
14 ourselves to the nuclear part of it.

15 MR. KEMPER: But at any rate we worked  
16 pretty intensely --

17 MEMBER APOSTOLAKIS: And this will be  
18 classified?

19 MR. KEMPER: Some of the results of this  
20 may very well be classified, or at least SGI.

21 MEMBER SIEBER: I think there's one  
22 thing for sure. The people who write malicious  
23 software are working just as hard or harder than the  
24 ones who write defenses and firewalls against it.

25 MR. WATERMAN: As a matter of fact it's

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1 not just the garage hacker either.

2 MEMBER SIEBER: No.

3 MR. WATERMAN: It's hostile nation  
4 states like -- well I won't name any countries right  
5 now, but we have hostile nation states who  
6 essentially have an unlimited budget and who are  
7 attacking our critical infrastructure on a daily  
8 basis.

9 MEMBER APOSTOLAKIS: There is a lone  
10 forming over there.

11 MR. MORRIS: Hi, I'm Scott Morris. I'm  
12 the Chief of the Reactor Security Section in NSIR.  
13 And Bill and I have worked together on various  
14 aspects of cyber security.

15 In fact we've met with the industry and  
16 we could go -- I could go on for quite a bit, but  
17 suffice it say that we have interacted. My staff's  
18 interacted with Mike and Roman and even NRR, Matt  
19 Chiramal, and --

20 MEMBER APOSTOLAKIS: Even them.

21 MR. MORRIS: Even OIC, even OIS, the  
22 Agencies own IT security people. There's no  
23 question this Agency needs, in my view and I think  
24 in the collective view of the Staff, a more  
25 comprehensive cyber security policy, because we

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1 really don't have one to be quite frank.

2 We all have a common interest in cyber  
3 security. We know it's a big issue. We know the  
4 threats out there. We haven't quantified the  
5 threat.

6 It's certainly not part of our design  
7 basis, threat document to any great degree. So  
8 we're wrestling with these issues right now, and I  
9 think some of the projects that Bill and his staff  
10 have proposed are valid.

11 Or -- I shouldn't say some, they all  
12 have some validity. But they all have a varying  
13 degree of validity to us right now. We have some  
14 urgent needs.

15 We as a staff have generated some  
16 documents to help the existing fleet of reactors  
17 understand the cyber threat, or the cyber  
18 vulnerability of their sites.

19 We've provided them a tool that they can  
20 use to systematically assess the digital system  
21 security. But they're under -- there's no  
22 compulsory means -- they're under no obligation to  
23 employ it right now.

24 So again, we are working on that as a  
25 policy. And I think that some of the projects that

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1 Bill has laid out, some are, you know, some are more  
2 forward looking.

3 They're trying to examine, you know,  
4 some of the newer systems that are coming out that  
5 aren't necessarily in place now. My immediately  
6 focus, quite frankly, from a user needs standpoint,  
7 is to examine what's out there right now.

8 Let's understand the vulnerability of  
9 those systems right now to the existing threat as we  
10 have defined it. And again, the cyber threat isn't  
11 very well defined.

12 So -- but suffice it to say that there  
13 has been a sufficient level of interoffice  
14 interaction on the projects that Bill is proposing.  
15 I understand the issues about switchyards and SCADA  
16 systems and wireless controls, and they're all very  
17 relevant and important.

18 And the industry is very concerned that  
19 they not get more than -- they don't want to be  
20 overregulated and multiply regulated by DHS now, and  
21 FERN and NRC all on relatively the same sorts of  
22 control systems.

23 There's a lot of very difficult issues.  
24 We're interacting closely with the North American  
25 Electrical Liability Council and development of

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1 their cyber security standards.

2 So like I said, as I said, I could go on  
3 for a long time, but there has been quite a bit of  
4 interaction between my staff, Bill's staff, and even  
5 NRR and OIS on this.

6 And to a limited degree we support what  
7 they're proposing here.

8 MEMBER APOSTOLAKIS: I wish you hadn't  
9 said to a limited degree, but --

10 MR. MORRIS: Well it's a matter of  
11 what's more important right now.

12 MEMBER APOSTOLAKIS: And we'll probably  
13 review these things at another meeting but --

14 MR. KEMPER: Yes, I hope so.

15 MEMBER APOSTOLAKIS: Yes. Okay, so we  
16 are convinced that this is important. Next.

17 MR. WATERMAN: Emerging digital  
18 technology and applications. It's the things that  
19 we've been doing all along. It think most of you --  
20 we're wrapping up the wireless technologies.

21 We've got a long term project to look at  
22 new technologies that are coming along to give the  
23 Staff a heads up on those technologies. On the  
24 advanced nuclear power plant digital systems we  
25 broke it down into advanced instrumentation,

1 advanced control, and --

2 MEMBER APOSTOLAKIS: So who's going to  
3 worry about the operators here? I mean advances  
4 nuclear power plants, advanced instrumentation. Is  
5 somebody else worried about it, or you will worry  
6 about it, or it will be joint project?

7 MR. KEMPER: Well it's lead by primarily  
8 Human Factors but we will support that as needed.

9 MEMBER APOSTOLAKIS: Okay, so you're  
10 supporting them?

11 MR. WATERMAN: Yes, sir. We're just --  
12 this is -- yes, somebody wants us to take a look at  
13 something, maybe the robotics on the refueling -- on  
14 the fueling machine bracers, okay we'll take a look  
15 at it.

16 We don't have any research in place  
17 right now, we're just -- this is a placeholder.  
18 Remember it's a flexible, adaptable program. As  
19 things come down the road we'll go ahead and take a  
20 look at them.

21 MEMBER APOSTOLAKIS: Fuzzy logic  
22 controls. All right.

23 MR. WATERMAN: Seimens trip systems.

24 MR. KEMPER: That wraps us up. I  
25 apologize for --

1 MEMBER APOSTOLAKIS: No problem, no  
2 problem.

3 MR. KEMPER: -- going over, but it was  
4 lots of very good energetic discussion.

5 MEMBER APOSTOLAKIS: So I'd like to --  
6 first of all do the members have any questions of  
7 these two gentlemen? Anybody else with to say  
8 anything? Yes, sir, please come to the microphone  
9 and identify yourself.

10 MR. CALVO: Yes, my name is Jose Calvo.  
11 I'm the author of the memo that you're all reading.  
12 I hope you enjoy it. But let me tell you something  
13 about myself.

14 I was hired by the NRC years ago because  
15 I was a computer systems specialist, okay. I had --  
16 as a matter of fact my first system, I went around  
17 the country doing applications of computer and  
18 nuclear processes.

19 As a matter of fact the first computer  
20 is in the Smithsonian as the one as it was used.  
21 But I did work for Westinghouse, and I did work with  
22 the -- facility.

23 And what I was to do, I just analyze  
24 these systems and try to make recommendations what  
25 to do with it, okay. I'm the Plant Chief now. I've

1 been Plant Chief for about five years in the area of  
2 computer systems.

3 We had to review a lot of systems. WE  
4 had to review the Siemens. We reviewed the  
5 Techtronics, and the Common Q. Let me tell you  
6 something. I was the one who reviewed those  
7 systems, because some kind of way I've still got a  
8 hang-up that I want to get involved with those  
9 systems, all right.

10 So I feel that the emphasis here today  
11 it was talking about tools. When I first analyze  
12 these systems I used to go inside the system and  
13 find out how the system will make it work.

14 So when I became the Plant Chief, I  
15 asked everybody else how do you review with the  
16 system, how to you know. They say we'll you're  
17 following a process.

18 What do you mean you're following a  
19 process? Do you know if the system that you -- what  
20 kind of a system do you have? They say well we  
21 don't have the talent, we don't have the expertise.

22 It takes too long. So then they show me  
23 the standard review plan. It follows a process.  
24 They're looking about the life cycle. And then I  
25 say how do you know that you have some problems in

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1 there?

2                   They say well, we're following a  
3 process. If the process is done correctly then the -  
4 - and we verify what the vendors has done, then we  
5 got some reasonable assurance everything is going to  
6 be fine.

7                   Tools, I said why do you want the tools.  
8 I couldn't convince Mike and I couldn't convince the  
9 other much. They want to have a tool, okay. All  
10 right, so let's buy a tool.

11                   So we buy a tool. It costs about 50,000  
12 dollars, all right. Well given that they have to  
13 review one of the systems it takes something like  
14 800 to 1,000 hours.

15                   When that tool comes in we almost double  
16 that number because we spend all the time trying to  
17 figure out what the tool does. So we have to throw  
18 the tool away, all right.

19                   Say I knew that was going to fail  
20 because I had used tools, I have developed tools  
21 before, and you spend all your time with the tool.  
22 And the question is if you've got a tool with  
23 Siemens, Siemens might say no, my tool is better  
24 than you're tool, okay.

25                   What your tool does, what their tool

1 does is do different things. So the tool is a nice  
2 thing to have, but you got to perfect it, you got to  
3 make it accommodate.

4 And you keep in mind the technology is  
5 moving so fast these days that in three years all  
6 those tools are going to be obsolete as well as the  
7 computers being obsolete.

8 Look, the computer systems that we have,  
9 all the platform has been done. All we do, we're  
10 trying to implement the plain and specific. I need  
11 research help in this area.

12 I want to look at what we have done  
13 today, and tell me today if we have done the right  
14 kind of a thing because that's what we need. I  
15 don't want what we do 20 years from now.

16 That's fine. I won't be here 20 years  
17 from now. But just I want to know the Agency, we're  
18 marching along this area and the appropriate manner.  
19 So that's what we do, that's the purpose of the  
20 memo, tell you that all the things that are being  
21 asked in this are looking to the future.

22 I want to know what we can do today.  
23 And let me tell you something else. We value the  
24 ACRS. You provide a good forum for us to discuss  
25 these things and seek some advice so we know how to

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1 proceed.

2 Because some kind of way, you can see,  
3 we don't get together.

4 MEMBER APOSTOLAKIS: Are you willing to  
5 come to the meeting? We will invite you to come to  
6 our Subcommittee meeting.

7 MR. CALVO: Yes. As a matter of fact I  
8 was going to make that request. I like to be here  
9 next time so you hear the other side of the story,  
10 and maybe together the four of us, we can do  
11 something here to help the Agency to move forward.

12 MEMBER APOSTOLAKIS: Mr. Calvo, I just  
13 say that some of the statements you wrote down were  
14 pretty strong. Were you upset at the time?

15 MR. CALVO: Well, my staff was upset.

16 MEMBER APOSTOLAKIS: Or --

17 MR. CALVO: In some kind of way, yes,  
18 they was strong.

19 MEMBER APOSTOLAKIS: Your staff was  
20 upset?

21 MR. CALVO: Keep in mind that we've been  
22 making those statements for five years. For five  
23 years we keep saying please don't proceed this way.  
24 Help us with this one.

25 But again, I know you got some new

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1 people working the research. For the last five  
2 years we were not successful in getting anybody else  
3 to help us out.

4 I'm concerned that we're moving ahead  
5 with 103 plans, we're going to be implementing these  
6 platforms, and we don't have the kind of support  
7 that I needed to find out that we did it the right  
8 way, okay.

9 And again, I don't have the talent  
10 either. And neither does research has the talent  
11 either. Mike is there because I sent him there. He  
12 used to work for me.

13 And they needed some regulatory flavor,  
14 so I say Mike go and help research, and he did. And  
15 that's almost less than a year. So what we got to  
16 do is get together and talk.

17 And we need you guys as the forum so we  
18 can add these things up in here in front of you.

19 MEMBER APOSTOLAKIS: Yes, this is a kind  
20 of an unusual role that you're asking us to play.

21 MR. CALVO: Well --

22 MEMBER APOSTOLAKIS: But we'll be happy  
23 to have a subcommittee meeting and listen to both  
24 sides. And fundamentally do you have anything else  
25 to add?

1 MR. CALVO: Well, keep in mind the UFM  
2 work the same way. We use you as a forum. It was  
3 very soothing. It helped the Staff to get together.

4 MEMBER APOSTOLAKIS: What was soothing?

5 MR. CALVO: The UFM, the ultrasonic flow  
6 meter. That was another one that we had some  
7 problems. This one can be solved the same way. We  
8 need to bring the third party to play a role of  
9 facilitating while he's advising.

10 CHAIRMAN WALLIS: The Agency has no  
11 mechanism apart from the ACRS to do this?

12 MR. CALVO: Well, anyway that's all I  
13 have to say. I think that we need to communicate in  
14 a selected communication situation.

15 MEMBER APOSTOLAKIS: Thank you very  
16 much, and I do appreciate your willingness to come  
17 in June.

18 MR. CALVO: We'll be happy. June we'll  
19 be here.

20 MEMBER APOSTOLAKIS: Thank you very  
21 much.

22 MR. BARRETT: I'd like to answer that  
23 there are a lot of things on the table right now,  
24 but I'd like to start by answering the Chairman's  
25 question.

1 We do have a process for deciding what  
2 research will be pursued by the office of research  
3 in this area and every other area. It's a user need  
4 process, and we also have alternatives to that,  
5 including technical advisory groups.

6 And what we're pursuing right now is  
7 that we have this plan in front of the Office of  
8 NRR, and in front of the other offices, and they're  
9 in the process of deciding what their response will  
10 be.

11 My understanding is that the response  
12 will be supportive to a great extent. And Mike can  
13 discuss that in greater detail. Clearly we've come  
14 to you today at a time when this area is undergoing  
15 a great deal of debate.

16 We're not coming to you and to your  
17 subcommittee for you to decide where the Agency will  
18 go. I mean you have an advisory role, and we look  
19 forward very much to the kind of advice you can give  
20 us.

21 But ultimately it's a management  
22 decision involving the Office of Research and the --  
23 and our user offices which way we'll go. But I  
24 think that given the level of -- the number of  
25 different perspectives that you see throughout the

1 Agency, I think that this is one case where the  
2 advice of the ACRS will be particularly useful to  
3 us.

4 I feel that the Office of Research has  
5 played perhaps a somewhat unusual role here in terms  
6 of defining a plan and putting that plan up for  
7 discussion as opposed to waiting for user need.

8 I think that ultimately that will prove  
9 to have been a wise choice of -- a wise course of  
10 action for the Office or Research to take.

11 CHAIRMAN WALLIS: I think you might find  
12 precedence where this has happened. I'm trying to  
13 remember them. And we used to know some precedence  
14 where an Office of Research pursued research and  
15 then persuaded NRR that it was necessary although  
16 originally they didn't think it was.

17 And it turned out to be a crucial  
18 element in some later decision. And I forget just  
19 what the issues were, but it might help you if you  
20 could quote some of those.

21 MR. BARRETT: You may find that aging  
22 management was one of those.

23 DR. LARKINS: Yes, I think --

24 MEMBER APOSTOLAKIS: Ultimately I think  
25 the -- we have provided advice, not in context like

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1 this, but within professional opinions, right, that  
2 ultimately came to us?

3 CHAIRMAN WALLIS: I think an awful lot  
4 is going to be sorted out by the Staff themselves --

5 MEMBER APOSTOLAKIS: But anyway, let's  
6 listen to the Executive Director.

7 CHAIRMAN WALLIS: --before we hear about  
8 this again.

9 DR. LARKINS: Yes, well George, the DPO  
10 thing is a different process. And that's outside of  
11 the normal role of the ACRS. But the ACRS has  
12 several situations, cases over the past several  
13 years -- made strong recommendations on some  
14 research activities.

15 Sometimes it wasn't always clear to the  
16 user office the value of those, but a lot of times  
17 they were very influential in getting those programs  
18 started.

19 And it turned out to be a value. I can  
20 think of some things, some PRA, license plan again,  
21 and other areas.

22 MEMBER APOSTOLAKIS: So there's nothing  
23 in our charter that prevents us from doing this,  
24 it's just something that we don't do very often.

25 MR. BARRETT: Let me say we're not here

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1 to ask you to resolve a DPL or to resolve this  
2 management issue. We come to you under your -- with  
3 your normal charter, which is to give us independent  
4 technical advice on this plan.

5 CHAIRMAN WALLIS: We're going to have  
6 subcommittee meeting on this, and I think -- I  
7 suspect that by then a lot of these internal matters  
8 will have been sorted out.

9 MR. MAYFIELD: Yes.

10 CHAIRMAN WALLIS: We will not be asked  
11 to be a referee in some sort of kindergarten fight.  
12 Actually it will be a mature presentation by you  
13 guys, and there will be some -- the issues will be  
14 clearly stated, and so on.

15 MR. MAYFIELD: If I could, this is Mike  
16 Mayfield from NRR. I would say that the Office nor  
17 my division, neither have asked the Committee to  
18 engage in this role that was just discussed.

19 We will take this on, as Rich says, as a  
20 management matter. And we will come back with the  
21 committee. We -- historically there have been a  
22 number of issues where the offices have not agreed,  
23 and then as a management matter the Office of  
24 Research engages in a research program they feel is  
25 appropriate.

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1                   And I'm sure that's how this will move  
2 forward. If at some point at we go forward that  
3 offices feel there is value to the Committee to  
4 present the two views on a matter and to ask for  
5 your advice, we will do so, but we will do so  
6 through Dr. Larkins and through the Committee  
7 management.

8                   MEMBER APOSTOLAKIS: Well the thing  
9 that's not clear to me is how to we -- should we  
10 structure the Subcommittee meeting? I mean as I  
11 said at the beginning, whenever we look at the  
12 research plan, we have a couple of questions that I  
13 think are important questions, like what is the  
14 current state of the practice within the Agency.

15                   Where does Agency management feel that  
16 there are needs, that there are holes that we need  
17 to improve things, without necessarily implying that  
18 the way things are now are bad.

19                   I mean there's always room, you know, --  
20 or maybe due to external reasons there is a need now  
21 to get into a particular area and do something about  
22 it.

23                   So where are we now? And why is this --  
24 where is this plan taking us?

25                   CHAIRMAN WALLIS: Well I think, George,

1 we rely --

2 MEMBER APOSTOLAKIS: Five years, ten  
3 years down the line. Some of it is anticipatory.  
4 Some of it is answering immediate needs. I mean  
5 these are important questions that help.

6 And the thing that's confusing this time  
7 is that on the one hand there is a memo that  
8 everything is fine. And on the other hand there is  
9 all these research projects that say well good  
10 enough, you know, we can improve here and there and  
11 there.

12 And I -- what I would not like to see  
13 next time is to have again one person presenting and  
14 saying we don't need anything, and another person  
15 saying no, we needed.

16 MR. MAYFIELD: Dr. Apostolakis, I  
17 started by saying that Mr. Dyer will be signing out  
18 a memorandum. And he speaks for NRR. And I would  
19 encourage you to wait until you get the signed  
20 memorandum.

21 We will make sure that Dr. Larkins  
22 receives a copy as soon as it is signed that he --

23 MEMBER APOSTOLAKIS: Now what you say  
24 wait, what do you mean wait?

25 MR. MAYFIELD: -- can distribute to the

1 Committee.

2 MEMBER APOSTOLAKIS: Should we postpone  
3 the Subcommittee meeting?

4 MR. MAYFIELD: No, sir. I think -- but  
5 rather than assuming what Mr. Dyer may say based on  
6 a draft memorandum and a response to that draft I  
7 would urge you to wait until you get the signed  
8 memorandum and see where the office has come down.

9 CHAIRMAN WALLIS: George --

10 MR. MAYFIELD: And I think that's the  
11 appropriate --

12 CHAIRMAN WALLIS: We rely on your wisdom  
13 and skill to work with Mike and Rich and the other  
14 people to construct a good subcommittee meeting.

15 MEMBER APOSTOLAKIS: Yes, but at some  
16 point I want to get the members views, this  
17 afternoon perhaps.

18 CHAIRMAN WALLIS: We can talk this  
19 afternoon. Now we're going to break. And the break  
20 -- we're not going to have the reconciliation  
21 because we're late, but we'll have it after lunch.

22 We'll have a lunch break for an hour,  
23 and please be back in 15 minutes to be trained in  
24 ethics, in 15 minutes, 12:15, right here. Break.  
25 And we don't need the transcript, you know very

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1 much, after lunch.

2 (Whereupon, at 11:59 a.m. the above-  
3 entitled matter was concluded.)

4

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CERTIFICATE

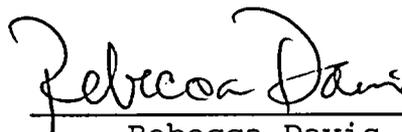
This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on  
Reactor Safeguards  
522<sup>nd</sup> Meeting

Docket Number: n/a

Location: Rockville, MD

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



---

Rebecca Davis  
Official Reporter  
Neal R. Gross & Co., Inc.

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# **STEAM GENERATOR TUBE INTEGRITY PROGRAM**

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522<sup>nd</sup> ACRS Meeting  
May 6, 2005



# Overview

- Research is Being Conducted in a Variety of Areas
- NRR has Requested Research Related to ISI Capabilities, ISI Reliability, and Rupture, Burst, and Leakage Models
- NRR will use this Information in the Review of Licensee Submittals and to Provide Guidance to Regional Inspectors
- In Response to ACRS Feedback, Additional Work is Being Conducted on Crevice Chemistry and the Relative Susceptibility of Various Tube Materials to Cracking



# OUTLINE OF PRESENTATION

- Task 3 - Tube Integrity and Integrity Predictions
  - Objective
  - Failure Models
  - Leak Rate Models
  - Pressurization Rate Testing
  - Secondary side Depressurization Study
  - Constant Pressure Crack Growth Study
  - Statistical Treatment of Models
  - Summary of Results
  - Future Work on Tube Integrity
  
- Task 1 - Assessment of Inspection Reliability
  
- Task 2 - ISI Technology
  
- Task 4 - Degradation Modes
  
- Conclusion



## **Task 3 - Tube Integrity and Integrity Predictions**

- Objective – to Evaluate and Validate Models for Leak/Rupture Behavior, Failure Pressures, Leak Rates for Degraded SG Tubes – Normal and Accident Conditions



# Tube Integrity and Integrity Predictions (Cont)

- SG Tube Materials are very Ductile
  - Failure Under Design Basis Conditions is by Plastic Instability
  - Failure Under Severe Accident Conditions is by Creep and/or Plastic Instability
- Real Cracks have Complex Shapes
  - Bounding Equivalent Rectangular Crack Method can give Conservative Results
  - Methods Developed for Realistic Prediction of Ligament Rupture
  - Effort is Ongoing to Develop more Realistic Predictions of Burst



# Tube Failure Models

- The Model for Predicting the Pressure to Cause Plastic Collapse of a Tube Containing a Through Wall Axial Crack is the Erdogan Model:

$$P_{cr} = \sigma h / m R_m = P_b / m$$

$\sigma$  = flow Stress

$h$  = tube wall thickness

$R_m$  = mean radius of the tube

$P_b$  = failure pressure of the unflawed tube

$m$  = constant related to the flaw size and geometry (Computed from LEFM Model of Erdogan)



## Tube Failure Models (Cont)

- For Part Throughwall Axial Cracks, the Pressure Required to Fail the Radial Ligament is Given by:

$$P_{sc} = \sigma h / m_p R_m = P_b / m_p$$

$$m_p = (1 - a/mh) / (1 - a/h)$$

$a$  = crack depth

if  $P_{cr} > P_{sc}$ , the throughwall crack is stable

- $M_p$  is a Measure of the Stress Magnification in the Ligament; Useful Characterization of the Severity of a Crack for both Design Basis and Severe Accident Conditions



# Tube Failure Models (Cont)

- The Equations for  $P_{cr}$  and  $P_{sc}$  Underestimate the Ligament Rupture Pressures for Short and Deep Cracks
- ANL Proposed the Following:

$$m_p = [1 - \alpha(a/mh)] / (1 - a/h)$$

$$\alpha = 1 + \beta(a/h)^2 (1 - 1/m)$$

$\beta$  is a constant  $\approx 1$

ANL Modification Predicted Better for Short and Deep Cracks



## Tube Failure Models (Cont)

- Equivalent Rectangular Crack Method – Rectangular Cracks have been Considered up to this Point – Actual Cracks may not be Rectangular and may Contain Ligaments
- For Complex Cracks, use the Equivalent Rectangular Crack Method – Crack Depth Profile Determined by Eddy Current or Fractography
- Series of Equivalent Rectangular Cracks Selected and the one with the Lowest Ligament Rupture Pressure ( highest  $m_p$ ) is Selected



# Modeling for Predicting Rupture Pressure, Leak Rate, and Burst Pressure

- Equivalent Rectangular Crack Models Give Reasonable Results for Initial Ligament Rupture, but do not Predict well Subsequent Tearing of the Remaining Ligament Under Increasing Pressure or the Final Burst Pressure



# Models for Circumferential Cracks and Severe Accidents

- Models for Circumferential Cracks
  - Models have been Developed – Using Fracture Mechanics Approach Instead of Plastic Instability
  - Model Correlates with TW EDM Laboratory Results
- Models for Severe Accidents
  - Creep Rupture Model (Combined with ANL  $m_p$  and Linear Damage Rule) Predicts Failure Temperatures more Accurately than flow Stress Model



## Simple Orifice Model

- The Leak Rate Model based on Simple Orifice Flow Through a Crack with an Opening Area  $A$  is:

$$Q = C_d A \sqrt{(2\Delta p / \rho)}$$

$C_d$  = coefficient of discharge = 0.6

$\Delta p$  = is the pressure differential

$\rho$  = mass Density of water



## Simple Orifice Model

- For an Axial Crack:

$$A = 2\pi(c_e)^2 V_o \sigma / E$$

$c_e$  = function of  $c$ ,  $(\sigma/\sigma_y)^2$ , tube mean radius, tube wall thickness

Where  $c$  is half the crack length

$V_o$  = function of  $c_e$ , the tube mean radius and tube wall thickness

$E$  = modulus of elasticity



## Simple Orifice Model (Cont)

- Tests Show that due to Short Transit time Across the SG wall, Leaks over a Range of Crack Sizes can be Described by a Single Phase Orifice flow Model with an Opening Based on the Cracking Opening Area
- The Leak rate is a Function of  $L/D$  where  $L$  is the Crack Length and  $D$  is 2 times the Crack Opening
- Good Agreement for Slits, Orifices, and Open Cracks
- Models tend to Overestimate Leak Rates for Actual Cracks Because Remaining Ligaments the Crack Opening Area and Meandering Crack Paths Increase  $L$



## Simple Orifice Model (Cont)

- SCC tend to Undergo Incremental Ligament Rupture with Increasing Pressure Before Cracks Become Unstable Which Would Cause Leakage at Pressures Lower than Predicted
- The Equivalent Crack Method had been Generalized to Predict Incremental Ligament Rupture After Initial Ligament Rupture
- Predictions Based on Fractography Tend to be more Accurate than Those Based on EC



# Test Facilities

- Room-Temperature, High-Pressure Test Facility
  - Maximum Pressure - 7500 psi
  - Maximum Leak Rate – 12.8 gpm
  - Maximum Volume – Unlimited
- High Temperature, Pressure, and Leak Rate Test Facility
  - Maximum Temperature – 650 F
  - Maximum Pressure – 3000 psi
  - Maximum Leak Rate – 400 gpm
  - Maximum Volume – 200 Gallons



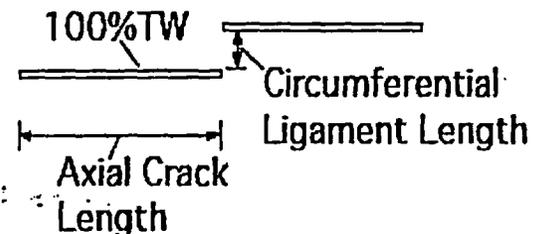
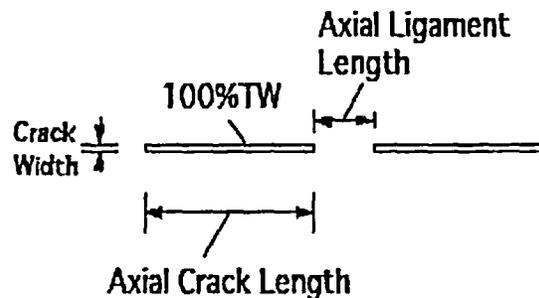
# Testing - Pressurization Rate Effects

- Industry may Conduct Burst Tests to Demonstrate Adequate Margin as part of Condition Monitoring
  - Tests Conducted as part of Assessment of a Flaw at a Domestic Plant Suggested that There is a Pressurization rate Effect on Ligament Rupture Pressure
- Determination of rate Effect Inconclusive Since Protocols for fast and slow rate Tests Differed
  - Slow Rate Tests Conducted in 2 Steps, no Bladder and Foil Until Ligament Rupture, then Bladder and Foil Until Unstable Burst Pressure Reached
  - Fast Rate Tests Conducted with foil and Bladder from the Beginning
- Specimen to Specimen Geometry Variations Could Account for a Major Part of the rate Effect



## Pressurization Rate Effects (Cont)

- Specimens Containing 1 inch Rectangular and Trapezoidal Notches 80-90% TW, and two 0.5 inch 80% TW Flaws Separated by a 0.05 inch Axial Flaw or a 0.05 inch Circumferential Ligament were Tested at Quasi-Steady State, 1000, 2000, 6000, and >10,000 psi/s
- No Effect of Pressurization Rate up to 6000 psi/s
- 2000 psi/s is the Maximum Industry rate





# Secondary Side Depressurization Study

- Typical Analyses of Depressurization Events did not Consider the Bending Loads Imposed on a tube by the TSP when it is Locked to the Tubes by Corrosion Products
  - Concern with Dynamic Loads Raised by ACRS
- RES Calculated Dynamic Loads on TSP with RELAP5 and Benchmarked Against Experiments
  - Large SLB Produces Greater Pressure Drop than Small SLB or FWLB
  - Pressure Loading Acting on TSPs Transferred to Tubes Locked by Corrosion Products and Deposits



# Secondary Side Depressurization Study (Cont.)

- Detailed FEA and Fracture Mechanics Analysis were Carried out for Model 51 SG TSPs and tubes
  - Loads on Tubes are Primarily Axial
  - Dynamic Loads have Virtually no Effect on Failure of Tubes with Axial Cracks
- If only one or two Tubes are Locked, the Stresses on the Locked Tubes Exceeds the Ultimate Tensile Strength
  - Because Displacements are Limited, Unflawed Tubes Would not Rupture, but the Tolerance for Circumferential Cracks Would be Severely Limited
  - If  $> 1.5\%$  of Tubes are Locked, the Maximum Axial load is  $< 3$  Kips and TW Circumferential Cracks  $< 180^\circ$  are Stable



# Constant Pressure Crack Growth Study

- Objective
  - Determine the Influence of Flaw Geometry on Flaw Tearing and Subsequent Leak Rate Behavior
  - Determine the Mechanism for Flaw Growth and Increases in Leak Rates at Constant Pressure
  - All Testing Conducted using the Room Temperature-High Pressure Test Facility



# Time Dependent Crack Growth

- Early work on SCC Showed that the leak Rates are time Dependent
  - Attributed to Tearing of Ligaments and Opening of the Crack due to Limited time Dependent Deformation (Steady-State Creep rate very low at Operating Temperatures)
- Recent Tests show that, at Least at Room Temperature, Actual Crack Growth Occurs and at high Rates

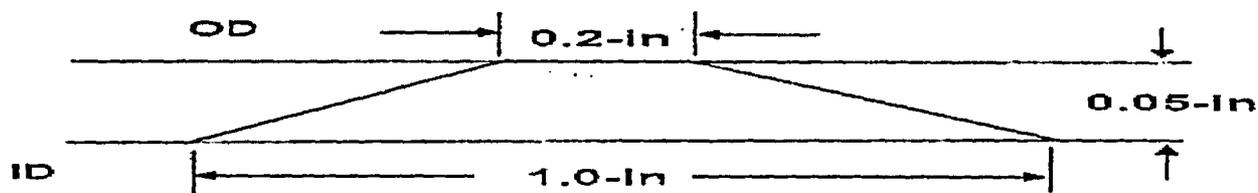


# Time Dependent Crack Growth Tests Program

- Test Material – Alloy 600, 7/8 inch Diameter Tubes, 0.05 inch Wall Thickness
- EDM Flaw Shape
  - Trapezoidal - 0.2 in OD, 1.0 in ID
  - Trapezoidal - 1.0 in OD, 0.2 in ID
  - Rectangular – 0.2 in, 0.4 in, 0.6 in,
  - EDM Notch Width 0.007 in
- With and Without a Foil and Bladder
- Open to air
- With a Small Shroud (1 ½ in Diameter)
- With a Large Shroud (4 in Diameter)



# Trapezoidal Flaw Design



**EDM Notch Approximately 0.007 Inches Wide**

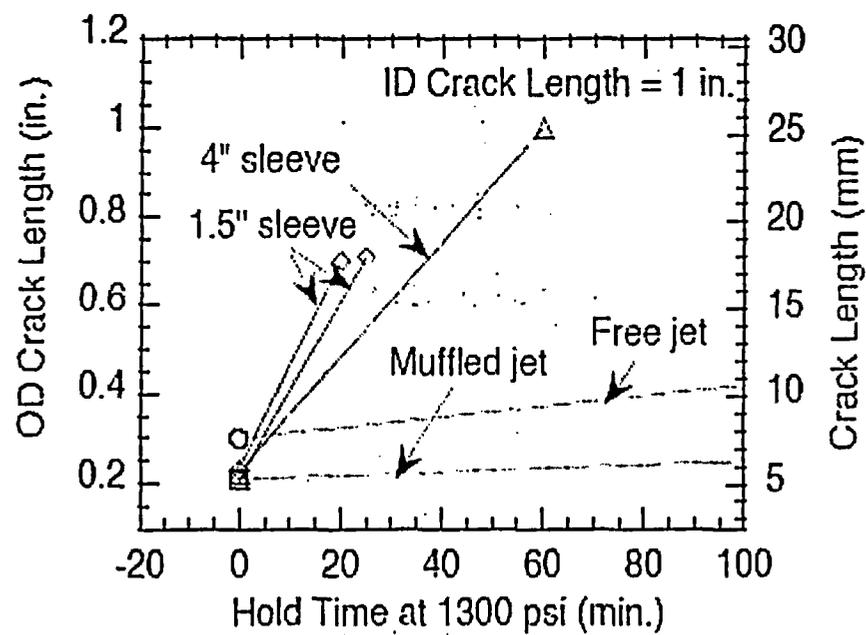


# Test Results

- Jet-Free Tests with Bladder/Foil
  - No Crack Extension when Pressurized Using Nitrogen (wet or dry)
  - Low Crack Growth rate Using the Facility Pump
- Crack Growth Rates with Active jets
  - With Active jets Present, OD Increased from 0.2 in. to 1.0 in. in hours
  - Tests with Shrouds Filled with Water (to Simulate Expected jet Interactions with surrounding Tubes) Produced Higher Crack Growth Rates than Unconfined jets



# Effect of Test Conditions on Crack Length for Trapezoidal Cracks





# Proposed Mechanisms for Increase in Leak Rate at Constant Pressure

- Mechanisms for Crack Growth
  - Jet Erosion of the Crack Faces
  - Rapid Flaw Corrosion at Room Temperature
  - Jet/Flaw Structural Dynamic Interaction  
Resulting in Fatigue Crack Growth
  - Pressure Oscillation from the Pump Causing  
Crack Growth



## Statistical Treatment of Models

- Candu Tube Inspection Assessment (CANTIA) – Developed by Dominion Engineering, Inc. for the Canadian Nuclear Safety Commission
- Determines Probabilities of Failure and leak rate from Primary to Secondary side During Normal Operation and Design Basis Accident Conditions
- Integrity, leak rate, and Degradation Models in CANTIA Specifically Intended for CANDU Steam Generators



## Statistical Treatment of Models

- ANL Modified the CANTIA code Maintaining Basic Monte-Carlo Structure but Incorporating the ANL Revised Models for Predicting Ligament, Unstable Burst, Crack Opening Area, and Leak Rate of Flawed Alloy 600 Tubes
- Source Language was Updated from Visual BASIC 3.0 to Visual BASIC 6.0
- Basic Flaw was Changed from 1-D to 2-D
- Added two Models for Stress Corrosion Crack Growth Rate (the Scott Model and the Ford and Andresen Model)



# Summary of Results

- Models Presented for Plastic Collapse of a Tube with a TW Axial Crack and a Part TW Axial Crack – Original Model Underestimated Ligament Rupture Pressures for Short deep Cracks, ANL Modification Provided Better Prediction
- Equivalent Rectangular Crack Method Presented – Gives good Results for Initial Ligament Rupture, not as good for Subsequent Tearing
- Simple Orifice Model Presented
  - Good Agreement for Slits, Orifices, and Open Cracks
  - Models tend to Overestimate Leak Rates for Actual Cracks Because Remaining Ligaments the Crack Opening Area and Meandering Crack Paths Increase  $L$



## Summary of Results (Cont)

- Pressurization Rate Effects Presented – No Effect at Typical Industry test Rates
- Secondary Side Depressurization Study Presented
  - Dynamic Loads have Virtually No Effect on Axial Flaws
  - If >1.5% of Tubes are Locked, TW Circ Cracks < 180° are Stable
- Constant Pressure Crack Growth Results Shown
  - Active jets Produce Increased Growth Rate with Time
- Statistical Treatment of Models Presented



## Future Work on Tube Integrity

- Conduct Tests on Complex Morphology Cracks and Develop Predictive Models for Leak and Rupture Pressure
- Assess Alternatives to the Equivalent Rectangular Crack Method to Estimate Failure Pressures and Leak Rates
- Continue Development of the CANTIA Code



# Task 1 - ASSESSMENT OF INSPECTION RELIABILITY

- Objective – Evaluation of Existing ISI Methods for Detection of Current Day Flaws
- Review of EC Round Robin on NRC/ANL SG Mockup
  - Mockup also used to Assess new Probe Designs
- Signal-to-Noise Issue
- X-Probe Evaluation



# Steam Generator Mockup Round Robin

- Eddy Current Data Collected by Qualified Industry Team to Current Industry Practices and Qualification Procedures
- 11 Qualified Analysis Teams Participated in the Round Robin Using the ANL/NRC SG Mockup
- Teams Consisted of a Primary, a Secondary, and 2 Resolution Analysts and a Qualified Data Analyst to Resolve Disputes
- The Differences Between the Teams was not Great, Although one team did not do as well as the Others
- Flaws were Missed Because
  - Signals were too Complex (Phase Angle did not show Expected Behavior)
  - Low Signal-to-Noise
  - Human Error



## Task 2 - Research on ISI

- Objective – Evaluate Advanced NDE and Signal Analysis Techniques – Improved Flaw Detection and Sizing
  - Practical need for Advanced Characterization techniques for Round Robin Because is was Impractical to Characterize Hundreds of Flaws Metallographlly



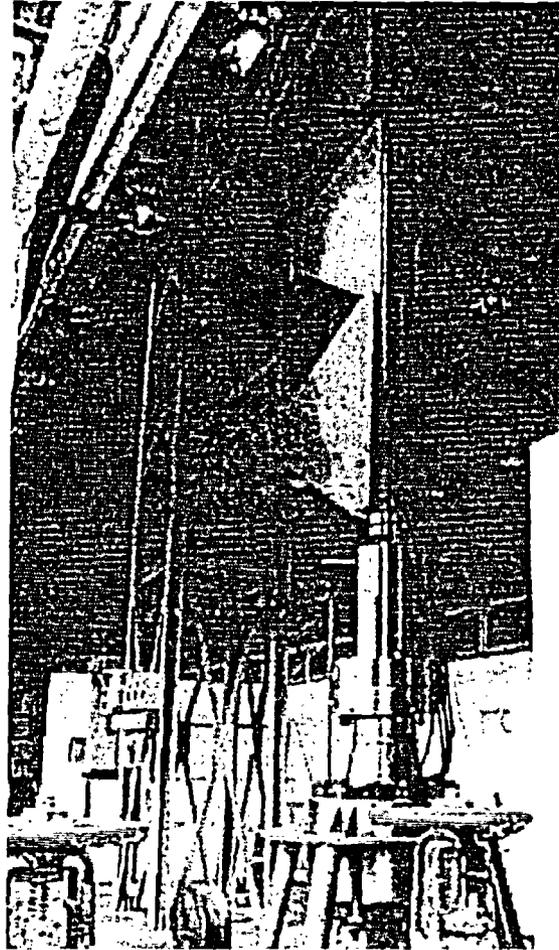
## Task 4 - Degradation Modes

### Objective –

- Evaluate and Validate Models for Degradation Modes
- Improve Understanding – Crevice Conditions, SCC Initiation, Evolution, Growth
  - Assess Implications of Known Susceptibility of Alloy 690 TT to SCC Under some Laboratory Conditions for Future Field Experience

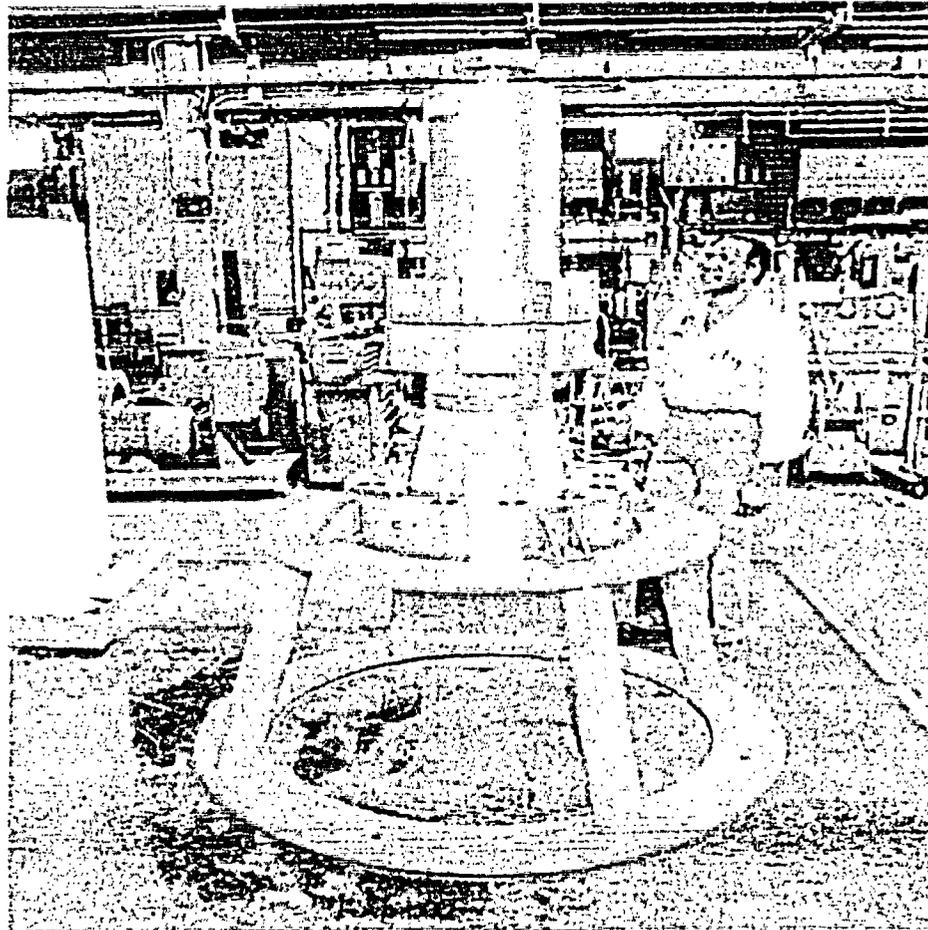


# Model Boiler



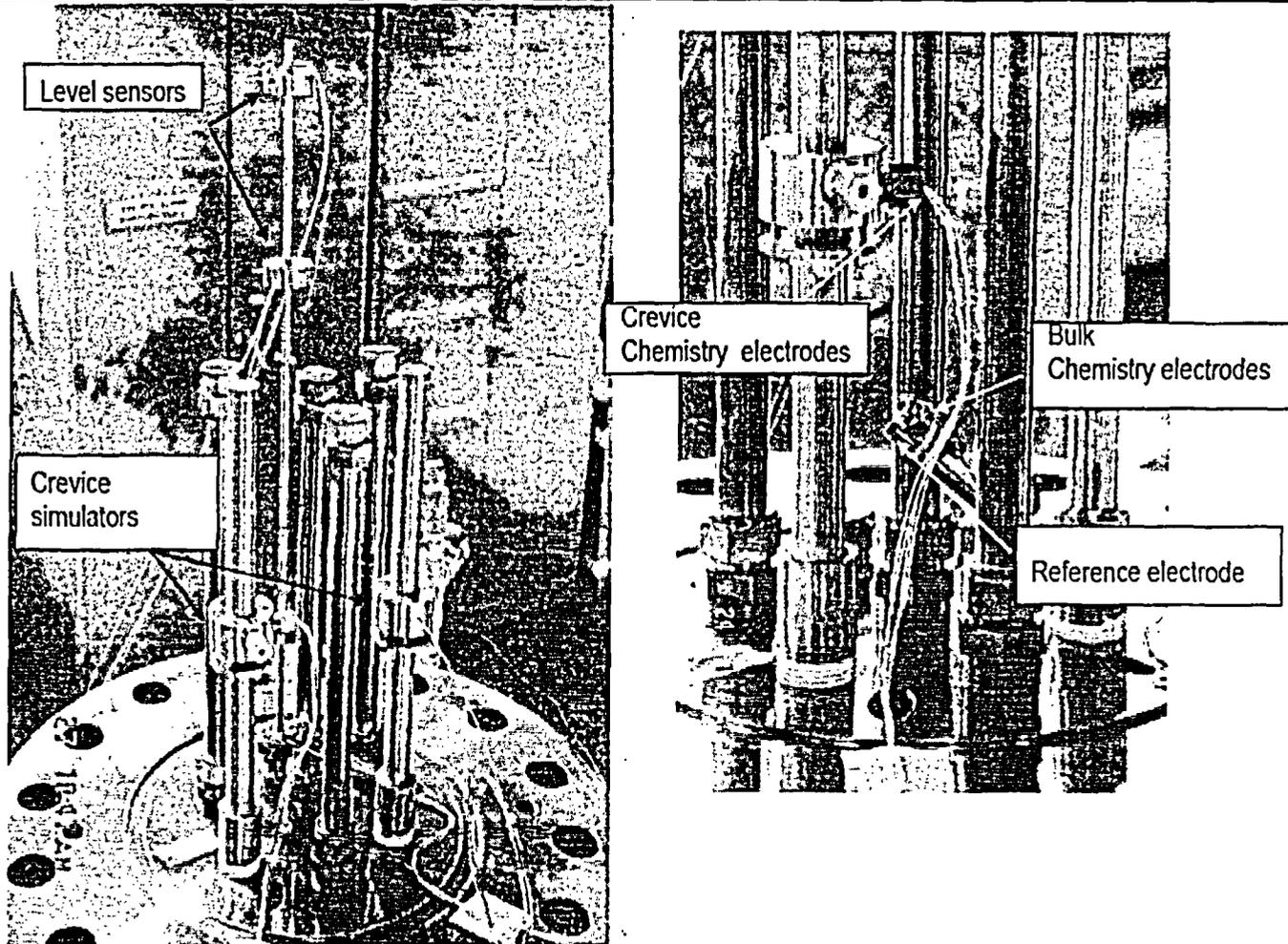


# Argonne Model Boiler (Primary / Secondary Chambers)





# Model Boiler Crevice / Bulk Water Instrumentation





# Overall Conclusion

- Task 3 - Tube Integrity and Integrity Predictions
  - Models Developed for Predicting Rupture and Burst Pressures for Axial and Circ TW and Part TW Cracks
  - Developed Models for Severe Accidents
  - Models tend to Predict Ligament Rupture Better than Burst Pressure
  - Simple Orifice Model Provides Good Agreement for Idealized Cases, not as good for Actual Cracks
  - On Pressurization rate Effect At Industry test Rates
  - Secondary side Depressurization Study Showed no Effect of Dynamic Loads on Axial Cracks, if a few Tubes are Locked, need big TW Circ Cracks to fail
  - Cracks Grow at Constant Pressure if Active Jets are Present



## Overall Conclusion (Cont)

- Task 3 -Assessment of Inspection Reliability
  - SG Round Robin – Teams were Fairly Consistent –  
Flaws Missed due to Complex Signals, Low Signal-to-  
Noise, Human Error
- Task 2 – ISI Technology – Advanced  
Characterization Techniques Developed to  
Supplement Destructive Evaluation
- Task 4 Degradation Modes – Showed the Model  
Boiler



# Overview

- Research is Being Conducted in a Variety of Areas
- NRR has Requested Research Related to ISI Capabilities, ISI Reliability, and Rupture, Burst, and Leakage Models
- NRR will use this Information in the Review of Licensee Submittals and to Provide Guidance to Regional Inspectors
- In Response to ACRS Feedback, Additional Work is Being Conducted on Crevice Chemistry and the Relative Susceptibility of Various Tube Materials to Cracking



# NRC DIGITAL SYSTEM RESEARCH PLAN FY 2005 THROUGH FY 2009

Michael E. Waterman, Sr. I&C Engineer

William E. Kemper, Section Chief

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Engineering Research Application Branch

Division of Engineering Technology

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## OVERVIEW

- Provides a flexible, adaptable framework for identifying NRR, NMSS, and NSIR research initiatives
  - 27 Projects across 6 Research Programs
- Oriented toward providing more consistent processes for regulating nuclear applications
  - Technical guidance
  - Regulatory-based objective acceptance criteria
  - Assessment tools and methodologies
  - Review and inspection procedures
  - Staff training
- Draft – comments to be incorporated



## CURRENT SITUATION

- Issues facing NRC
  - Licensees are replacing analog systems with digital systems
  - Licensing these digital systems presents challenges to NRC
    - Increased complexity
    - Rapid changes in digital technology
    - New failure modes
  - NRC licensing processes should be kept current
  - A risk-informed, performance based safety assessment process should be developed for licensing digital systems

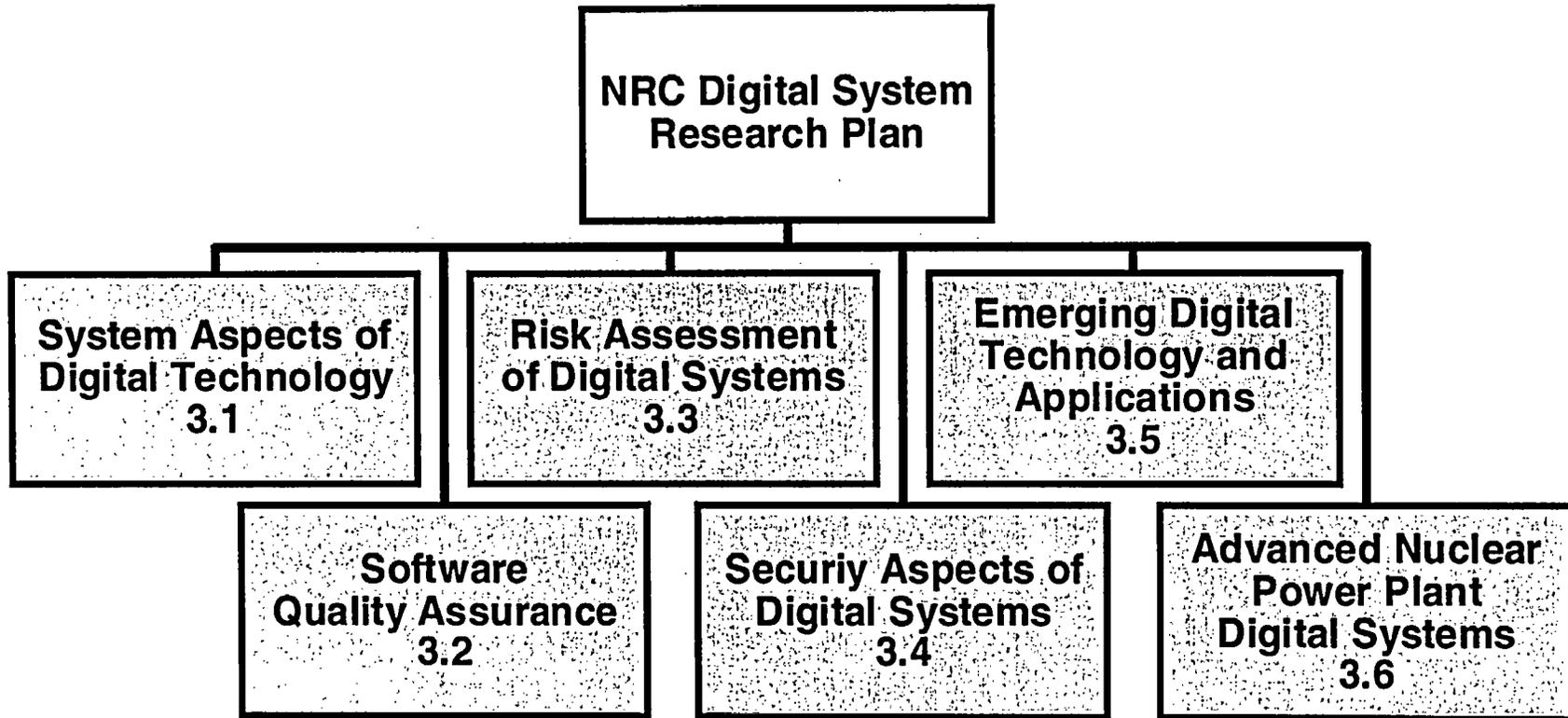


## RESEARCH FOCUS

- Structured to develop better methods and understand new technologies
  - Risk-informed (e.g., risk assessment capabilities)
  - Performance based (e.g., dependability assessments)
  - Objective and repeatable (e.g., software quality evaluation methodologies)
- Broad-based, focusing on improving traditional review methods for
  - New applications of existing technologies
  - Advanced technologies
  - New issues and regulatory requirements

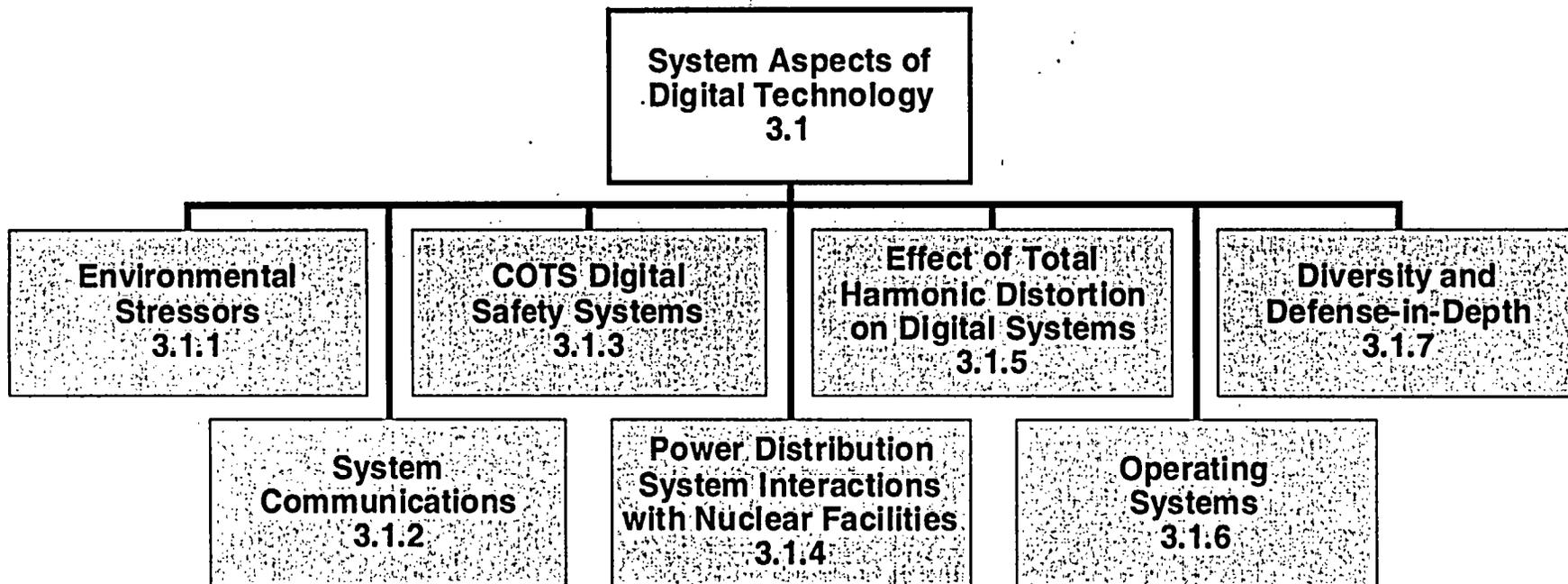


# RESEARCH PROGRAMS





# SYSTEM ASPECTS OF DIGITAL TECHNOLOGY PROGRAM 3.1





# ENVIRONMENTAL STRESSORS

## PROJECT 3.1.1

- Environmental compatibility for safety-related I&C systems depends on maintaining the expected environment in the nuclear power plant and qualifying the equipment to withstand that environment
- Specific, comprehensive regulatory guidance
  - EMI/RFI – Updated RG 1.180
  - Lightning – DG-1137
  - Environmental qualification (EQ) – DG-1077



# SYSTEM COMMUNICATIONS PROJECT 3.1.2

- The trend in digital safety systems is towards networked intrasystem architectures using dedicated communication microprocessors and proprietary communication protocols
- NRC requires expertise to evaluate these complex digital communication systems and the failure analysis techniques for these architectures
- The research will provide acceptance criteria and methodologies for reviewing these systems



## COTS DIGITAL SAFETY SYSTEMS PROJECT 3.1.3

- The nuclear industry is retrofitting existing analog systems with COTS-based digital systems
- Research will evaluate methods for performing more quantitative safety assessments
  - Fault injection method for estimating digital system (HW, SW, HW+SW) dependability in COTS
- This project will further refine these methods for incorporation into NRC review methodologies by using realistic safety-related COTS systems as test beds



# ELECTRICAL POWER DISTRIBUTION SYSTEM INTERACTIONS PROJECT 3.1.4

- NPP digital-controlled power equipment sensitivity to changes in grid voltages has resulted in undesirable equipment responses
- Research will support RES/DSARE/AREAB efforts to model highly distributed, complex systems composed of digital, analog, discrete, high voltage, high current power components to determine the effects of grid voltage fluctuations on digital equipment



# EFFECT OF THD ON DIGITAL SYSTEMS PROJECT 3.1.5

- Newer digital components are more sensitive to total harmonic distortion (THD)
  - Higher IC circuit densities
  - Lower voltage requirements for memory states
- THD could be a potential CMF mechanism
- Currently, no methods exist in NRC to evaluate the effect of THD on digital system components
- This research project will evaluate the effect of THD on digital systems and provide guidance on acceptable THD thresholds



## OPERATING SYSTEMS PROJECT 3.1.6

- NRC has not been able to assess proprietary COTS operating system characteristics
- RES initiated a study of operating system characteristics
- The results were inconclusive
- Further research will
  - Identify safety-critical design aspects of operating systems
  - Develop processes for performing safety assessments of operating systems

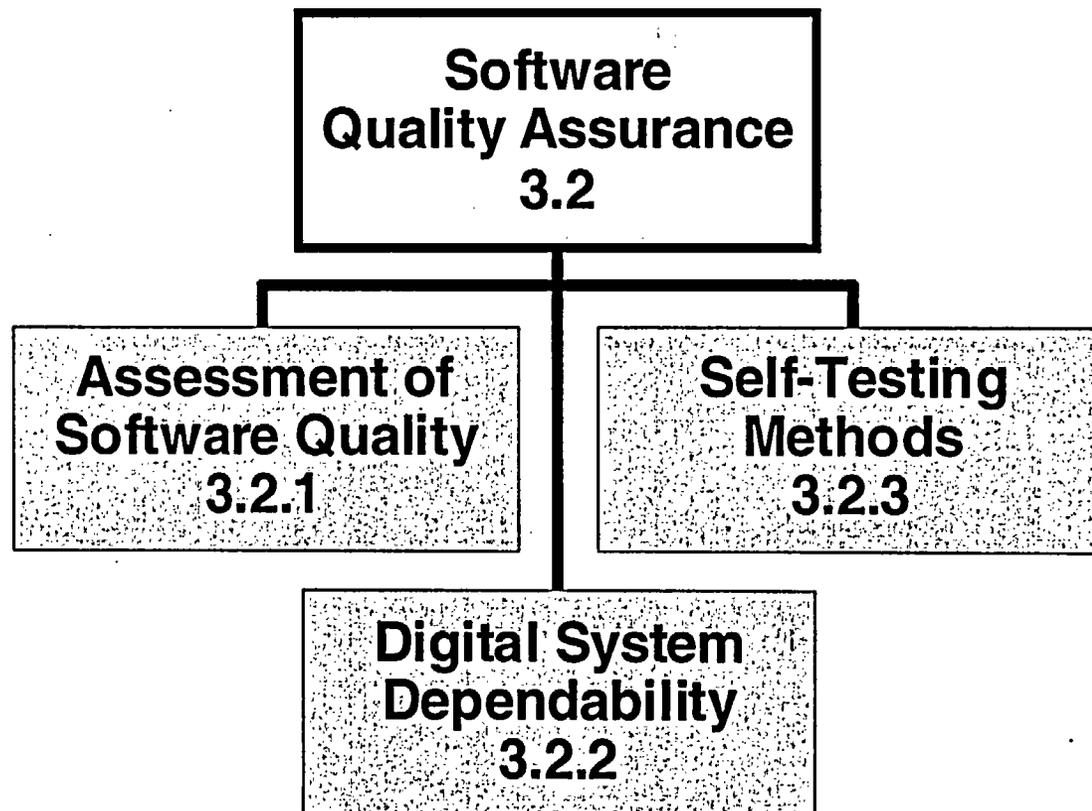


## DIVERSITY AND DEFENSE-IN-DEPTH PROJECT 3.1.7

- D3 position and guidance are deterministic
- The nuclear power industry has proposed using risk insights from PRAs
- This project will
  - Verify, deterministically, that existing guidance (SRP BTP HICB-19) is realistically conservative
  - Evaluate NUREG/CR-6303 coping strategies
  - Perform case studies of digital safety system configurations to evaluate their susceptibility to CMF
  - Evaluate the fault injection process as a methodology for identifying CMF vulnerabilities



# SOFTWARE QUALITY ASSURANCE PROGRAM 3.2





## ASSESSMENT OF SOFTWARE QUALITY PROJECT 3.2.1

- NRC evaluates the quality of digital systems development processes manually
- This research project is developing a more effective and thorough supporting process
- Complements the fault injection testing assessment methodology already developed for digital system dependability testing
- HRP is evaluating SWE practices and criteria that may be effective in assuring software quality



## DIGITAL SYSTEM DEPENDABILITY PROJECT 3.2.2

- Safety significant errors in digital systems may not be detected by V&V processes
- Methods are needed to evaluate digital systems
- A fault injection methodology has been developed to evaluate dependability
- This project will produce a process for using this tool to determine the dependability of digital safety systems
  - Three SR COTS platforms will be evaluated

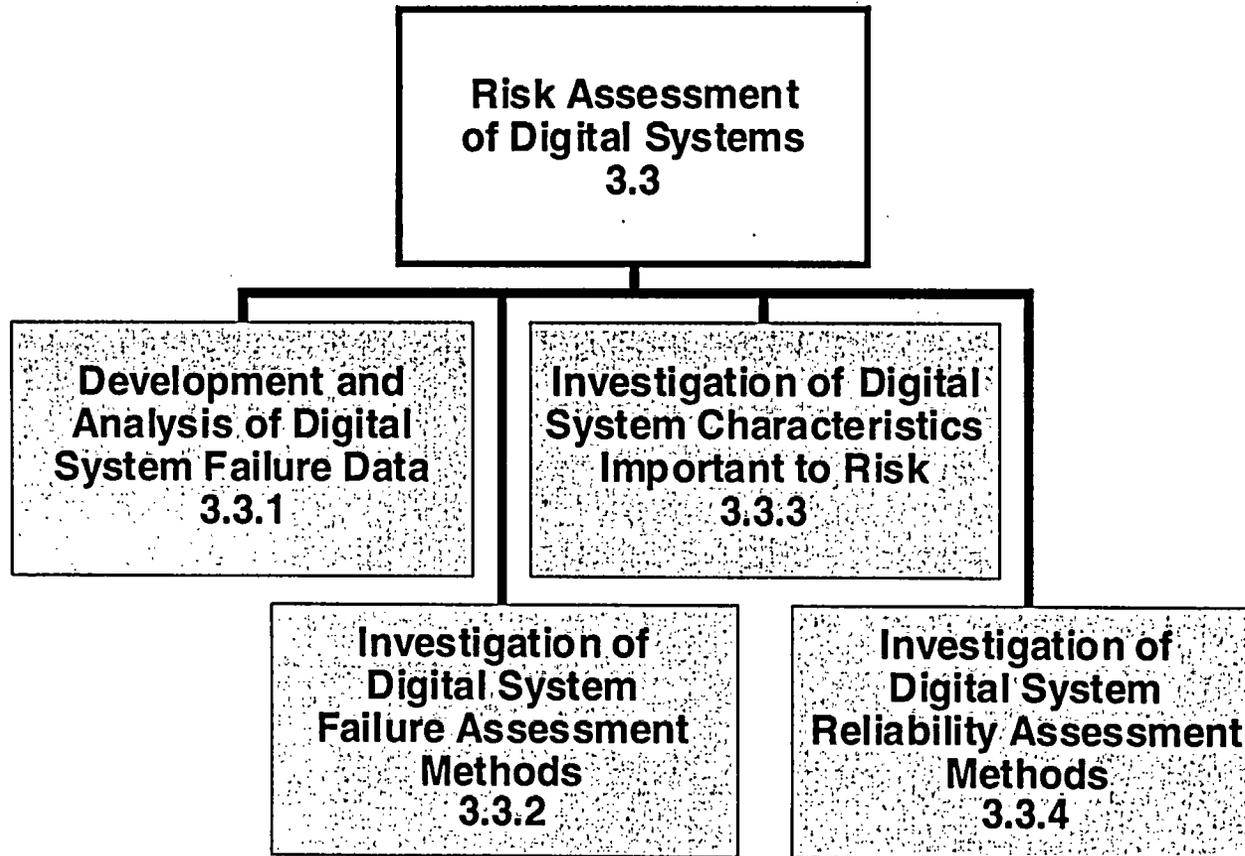


## SELF-TESTING METHODS PROJECT 3.2.3

- Self-testing methods test hardware and software continuously to improve availability
- The technical issues concern
  - Effectiveness in determining system performance
  - Adverse effects on safety system performance
  - Identifying acceptable self-testing methods
  - The amount of self-testing that is sufficient
- This research project will develop technical guidance and review methodologies for evaluating self-testing features in digital systems



# RISK ASSESSMENT OF DIGITAL SYSTEMS PROGRAM 3.3





# DEVELOPMENT AND ANALYSIS OF DIGITAL SYSTEM FAILURE DATA PROJECT 3.3.1

- The NRC is risk-informing its activities
- Assessing failure probabilities requires that the NRC have a standard process for collecting, analyzing, and using digital system data
- The purpose of this research project is to
  - Collect and assess digital system failure data
  - Evaluate digital system failure assessment methods and data used by defense, aerospace, and other industries
  - Develop a process to identify the frequency, severity, cause, and possible prevention of digital system failures
  - Maintain the digital system reliability data for use in modeling digital systems in PRAs



# INVESTIGATION OF DIGITAL SYSTEM FAILURE ASSESSMENT METHODS PROJECT 3.3.2

- To support risk assessments, NRC should develop or identify methods for assessing digital system failure modes
- Guidance and criteria on the use of these methods and how to support risk assessments of digital systems in an integrated process should be defined
- This research project will
  - Survey analytical methods for identifying digital system faults and their impact on safety
  - Describe the advantages and disadvantages of each method
  - Provide guidance for using digital system failure assessment techniques, and the criteria for using the techniques



# INVESTIGATION OF DIGITAL SYSTEM CHARACTERISTICS IMPORTANT TO RISK PROJECT 3.3.3

- PRAs model digital systems as “black boxes”
- Need to incorporate risk models into PRAs
- Need a consistent approach and acceptance criteria for reviewing risk-informed systems
- This research project will
  - Develop risk models of digital systems
  - Identify digital systems to be modeled and the level of detail to be modeled
  - Identify sub-components that may warrant attention
  - Develop a methodology for performing these activities

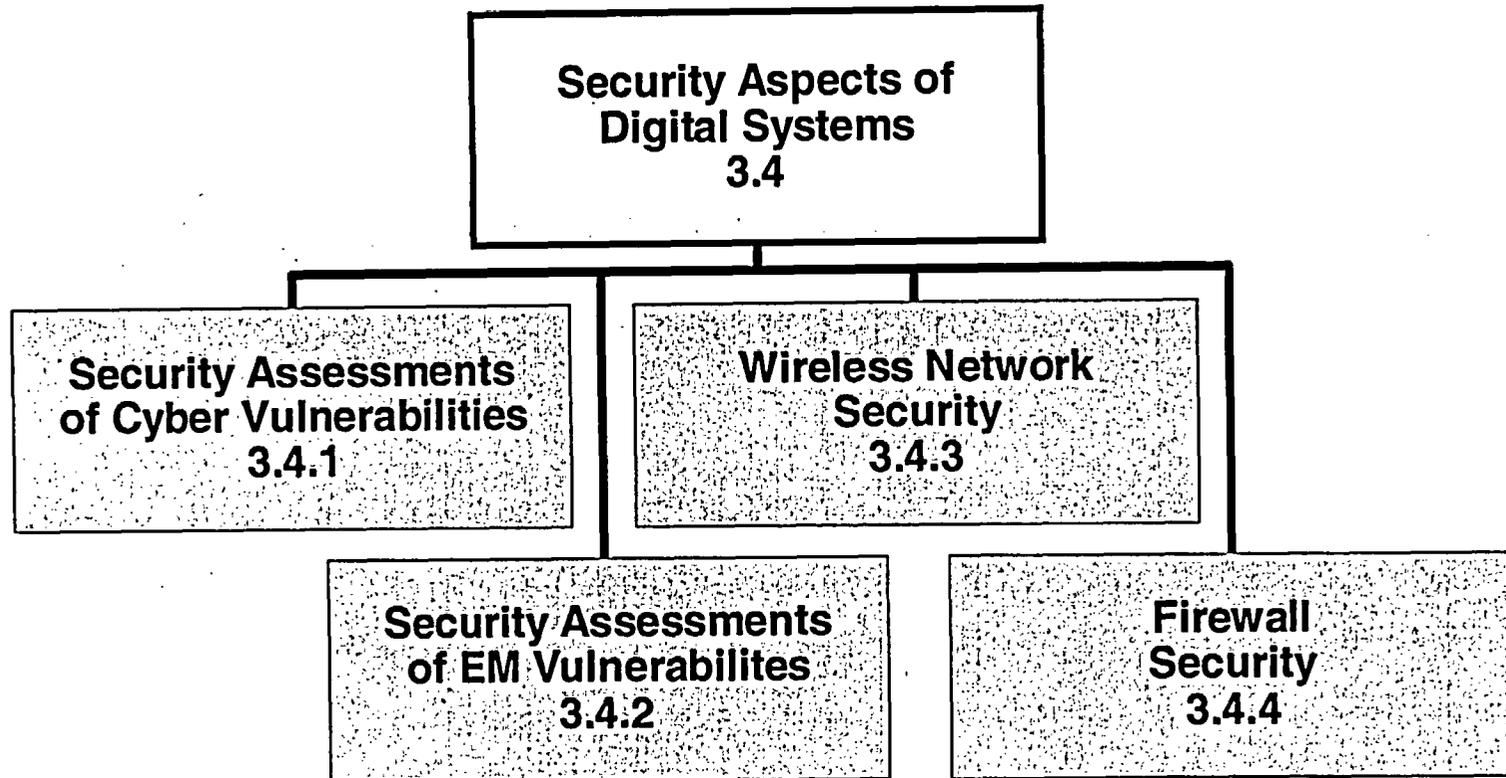


# INVESTIGATION OF DIGITAL SYSTEM RELIABILITY ASSESSMENT METHODS PROJECT 3.3.4

- The NRC needs a standard methodology for analyzing digital system reliability so that acceptance criteria can be applied to risk-inform safety system designs
- This research project will
  - Identify digital system reliability assessment methods
  - Develop a digital system reliability assessment methodology
  - Conduct case studies to assess the methodology
  - Support the development of acceptance criteria (Reg. Guide 1.17x)



# SECURITY ASPECTS OF DIGITAL SYSTEMS PROGRAM 3.4



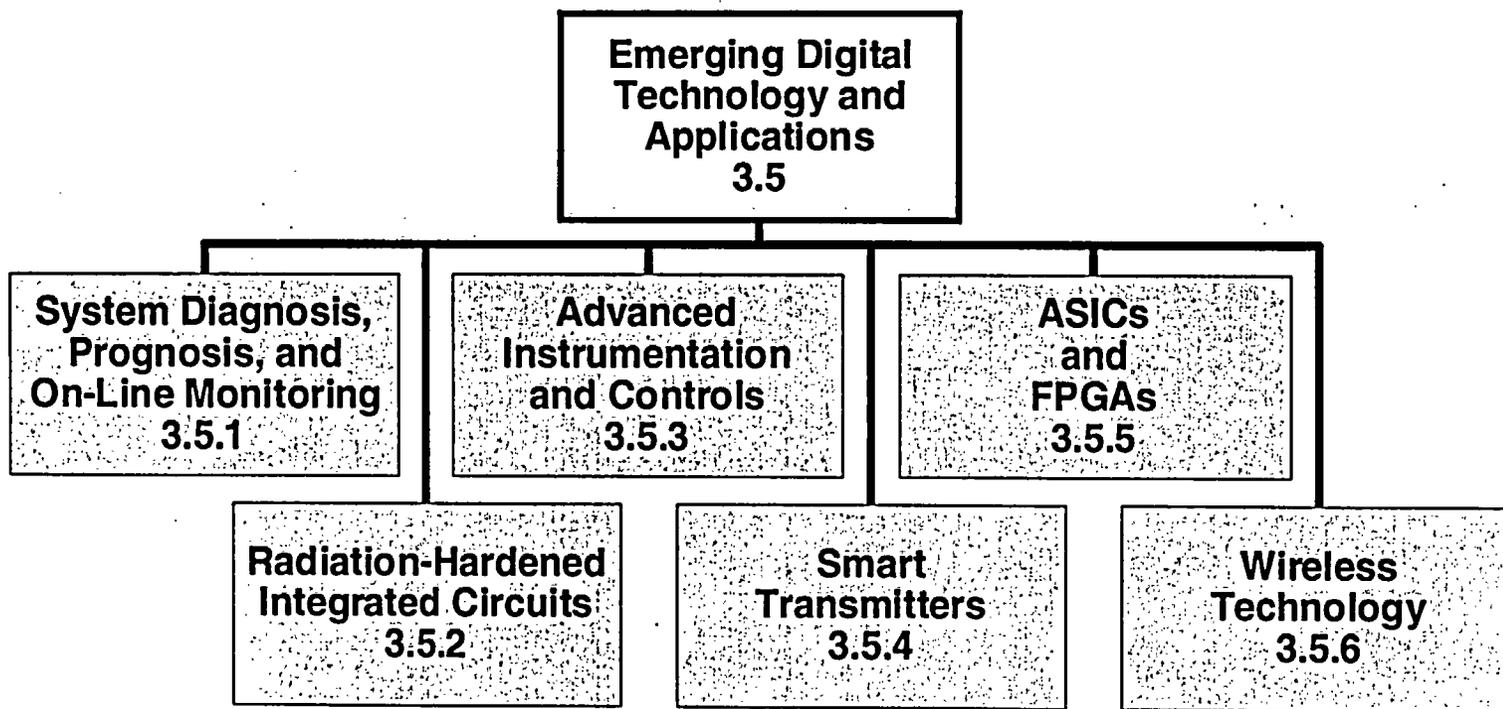


# SECURITY ASPECTS OF DIGITAL SYSTEMS

- Cyber security is an NRC concern that has been heightened since the events on 9/11
- Digital system security requires addressing potential vulnerabilities during system development and after installation
- Four projects are being initiated
  - Security of digital platforms
  - Site-specific protocol analysis
  - Secure network design techniques
  - Guidelines for NPP cyber security policy development



# EMERGING DIGITAL TECHNOLOGY AND APPLICATIONS PROGRAM 3.5



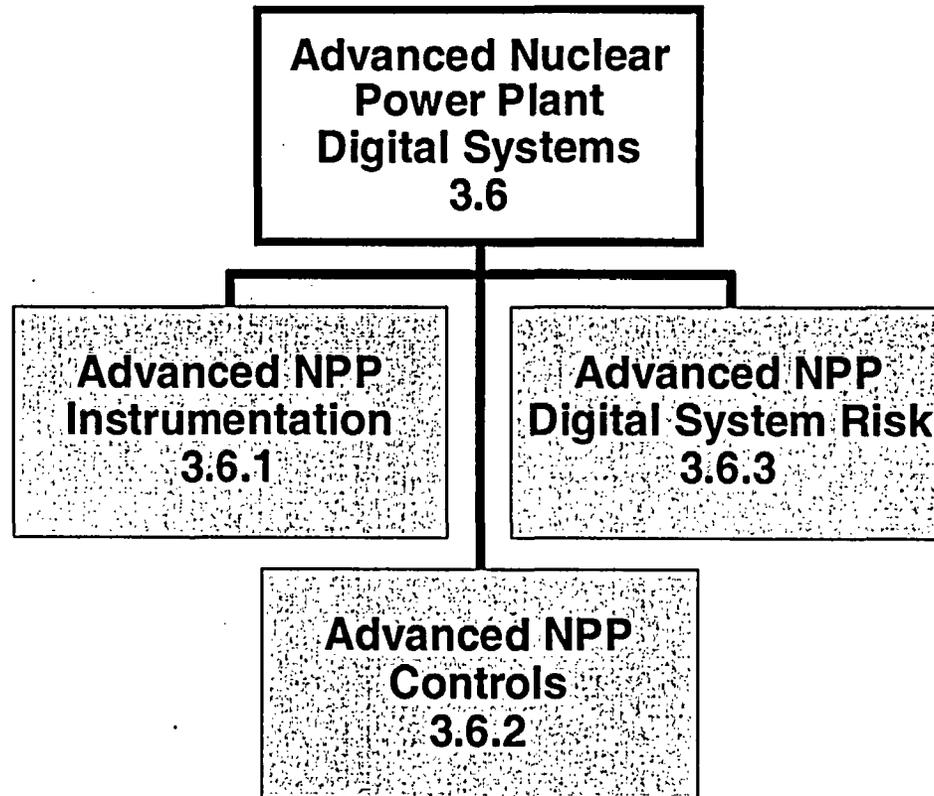


## EMERGING DIGITAL TECHNOLOGY AND APPLICATIONS

- Knowledge about new, emerging technologies is critical for NMSS, NRR, and NSIR staff to license safety related applications in an effective and realistic manner
- This research will provide regulatory guidance for reviewing NPP applications
- Ongoing projects include
  - Emerging technology evaluations
  - On-line Monitoring
  - Advanced flow meters
  - Wireless technologies



# ADVANCED NPP DIGITAL SYSTEMS PROGRAM 3.6





## ADVANCED NPP DIGITAL SYSTEMS

- Advanced reactor designs (ACR-700, EPR, ESBWR, PBMR, etc.) may apply new I&C technologies, and thereby present challenges for identifying risk-informed characteristics
  - Robotics, fuzzy logic controls, autonomous controls, fully integrated DCSs, new instrumentation, etc.
- Research projects are dependent on future advanced reactor design pre-application submittals
  - No research in progress at this time



## SUMMARY

- Provides a flexible, adaptable framework for identifying NRR, NMSS and NSIR research initiatives
- Broad-based program oriented toward providing more consistent processes for regulating nuclear applications; improving review methods for new applications of existing technologies, advanced technologies and new issues; and developing regulatory requirements
- RES is looking forward to working closely with the ACRS as these programs are implemented