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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

SUBCOMMITTEE ON RELIABILITY AND PROBABILISTIC RISK ASSESSMENT

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FRIDAY,

OCTOBER 10, 2003

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ROCKVILLE, MARYLAND

The ACRS met at the Nuclear Regulatory Commission, Two White Flint North, room 2B3, 11545 Rockville Pike, at 8:30 a.m., Chairman George Apostolakis, presiding.

COMMITTEE MEMBERS:

GEORGE E. APOSTOLAKIS, Chairman

MARIO V. BONACA, Member

STEPHEN L. ROSEN, Member

WILLIAM J. SHACK, Member

ACRS STAFF PRESENT:

MICHAEL R. SNODDERLY, Designated Federal Official

MEDHAT EL-ZEFTAWY

ALSO PRESENT:

JOHN FLACK
KENT WELTER
DON DUBE
STU MAGRUNDER
PAT O'REILLY
DALE M. RASMUSON
DON MARKSBERRY
PATRICK BARANOWSKY
BENNETT BRADY
GARY DE MOSS
W. ARCIEN
B. COLAN
SPYROS TRAIFOROS
N. PRASAD KADAMBI
MARK CUNNINGHAM
MIKE CHEOK
ALI MOSLEH
MOHAMMAD MODARRES
DANIEL O'NEAL
J. S. HYSLOP
ALAN RUBIN
CURTIS SMITH
ROY WOODS

A-G-E-N-D-A

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

8:31 a.m.

CHAIRMAN APOSTOLAKIS: The meeting will now come to order. This is a meeting of the Advisory Committee on Reactor Safeguards, Subcommittee on Reliability and Probabilistic Risk Assessment. I am George Apostolakis, Chairman of the Subcommittee.

Subcommittee members in attendance are Mario Bonaca, Steve Rosen and William Shack. The purpose of this meeting is to discuss the status of the Probabilistic Risk Assessment Research Program with representatives of the Office of Nuclear Regulatory Research.

The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions as appropriate for deliberation by the full committee. Michael Snodderly is the designated federal official for this meeting.

The rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the Federal Register on October 1, 2003. A transcript of the meeting is being kept and will be made available as stated in the Federal Register notice.

It is requested the speakers first

identify themselves and speak with sufficient clarity and volume so that they can be readily heard. We have received no written comments or requests for time to make oral statements from members of the public regarding today's meeting. We will now proceed with the meeting and I call upon Mr. Prasad Kadambi of the Office of Research to begin.

MR. KADAMBI: Thank you very much, Mr. Chairman. I would like to ask the Branch Chief of the Regulatory Effectiveness and Human Factors Branch, John Flack, to perhaps come up.

CHAIRMAN APOSTOLAKIS: I'm sorry, John.

MR. FLACK: That's fine. Good morning. My name is John Flack, Branch Chief of Regulatory Effectiveness and Human Factors Branch. I just wanted to mention that this work actually evolved from recommendations from the ACRS about a year ago to use formal decision making in order to provide more transparency, reducibility, consistency, and traceability in light of the uncertainties basically.

What you will hear today is we will give you an overview of where we are on that effort and how we are moving forward in its application to other areas which we are constantly entertaining.

The key eventually would be to get to the

Commission with something and have them support this effort. One of the things I think is advantageous in the effort came up recently when we were just discussing on how to document knowledge and understanding in some formal way to be passed on to the next generation.

By applying methods like this you do leave that behind. People can understand better how decisions were made and what the basis of those decisions were. We are seeing this coming up again in another arena as another important area.

Having said that, let me turn it over to Prasad who will walk you through.

CHAIRMAN APOSTOLAKIS: Very good.

MR. KADAMBI: Thank you very much, John. The outline of my presentation is basically just to introduce a document that we have prepared and introduce the Subcommittee to some ideas about how we can use the information in this document.

What this represents is the completion of the first phase of an activity that we undertook as the recommendation of ACRS. The second phase we see as the application to demonstrate the utility of these ideas. Then we have to get eventually Commission buy-in on this approach. That's what we are aiming towards.

MR. ROSEN: I should acknowledge that was the wrong number, 6833.

MR. KADAMBI: Yes, I'm sorry. I was going to point that out. In some places I have interchanged the numbers and it should be 6833 of the NUREG/CR.

CHAIRMAN APOSTOLAKIS: You are the only one so far dealing with this issue? Obviously John knows what you're doing but you are the only one exploring this?

MR. KADAMBI: Our branch, I think, is really the one that is focusing on this.

MR. FLACK: Yes, we have the lead on it. Basically Prasad's work is doing the format. Now, we recognize that methods like this are being applied without recognizing --

CHAIRMAN APOSTOLAKIS: Sure. Sure. You've been making decisions since 1974.

MR. KADAMBI: Yeah. And I think we want definitely to acknowledge the role of the ACRS in bringing to our attention the merits of this approach. We did tell you back more than a year ago that we would be exploring the feasibility of applying these methods.

In order to provide the context for this, I would like to find out, again, as John also pointed out, that the agency is really more than a lot of activities that have elements of formal methods.

What is seems these activities would benefit from is an overall structure and a predictable process that would at a higher level bring these concepts together so that we will have greater assurance of consistency, transparency, and a way to assess effectiveness and deficiency, I believe.

We got started on this really as part of the advanced reactor research plan when we were looking for different ways that we might prioritize the research that would become necessary if we started getting applications for advanced reactor concepts.

In addition to the phenomena identification and ranking table approach which has been sort of the standard way that we have pursued this, we wanted to see are there other ways of achieving some kind of prioritization so that's how we got started on it.

What we found is that really the methodologies have widespread applicability. Also what we found is that there are many ongoing activities such as the planning, budgeting, and performance management effort, the PBPM which is central to a lot of things that the agency is doing. It is an effort that tries to consider the four performance goals of the agency.

In many ways it represents an application of multi-attribute utility. We would like to see if that and the PIRT process, and also I would like to find out the effort in performance based regulation which the Commission has identified as a strategic goal to improve risk informed and performance based regulatory approaches.

All these would benefit from a formal structuring of objectives. What I see is significant support for this whole effort is the success of the ROP which we would attribute substantially to this formal structuring of objectives.

CHAIRMAN APOSTOLAKIS: Which the ACRS also requested at the time and the staff performed beautifully.

MR. ROSEN: And quickly.

CHAIRMAN APOSTOLAKIS: So we all deserve credit for this. A lot of times people think of, you know, all the analysis and I have to have this and I have to have that. Sure there is a lot of effort going into that but simple things like structuring your objectives, thinking about them as are they independent; am I double, triple counting; am I leaving anything out.

This is a great value. All formal mathematical theory is that they take you by the hand and they say, "Now my friend you have to think about this. The next step is to think about that." I think you really pointed out some of the great benefits even before you put any numbers in by just structuring your approach and saying, "This is what I really care about. I care about reactors. I care about this and I care about that."

Initiating events like the ROP does and in another context you have something else. That's already a major step because it forces you to think about what are the objectives of your analysis and some structure. I think the ROP has benefitted tremendously from it.

That simple diagram that shows the four top tiers is great. People look at it now and think this is what the NRC staff really cares about. They care about initiating events. They care about the primary human boundary. You know, this is wonderful.

MR. FLACK: And just to follow-up to that, we actually when we responded to the need to do advanced reactor research we followed that same logic and it just carried us through.

CHAIRMAN APOSTOLAKIS: It structures everything. It has many, many applications so I'm really glad you guys are doing this.

MR. KADAMBI: Well, this particular NUREG/CR, in fact, does have a whole section devoted to the structuring of objectives. We use the reactor oversight process as an example that demonstrates some of these concepts and how they can be more widely applied.

The NUREG/CR itself, again, I point out at 6833, is not a cookbook. What we try to do is after looking at this whole vast area of decision analysis try to identify certain important concepts and the literature in it. I have to point out our Chairman is responsible for a substantial part of the literature and we have benefitted considerably from it.

CHAIRMAN APOSTOLAKIS: Commissioner Modarres is doing all these things?

MR. KADAMBI: No, the Chairman of the Subcommittee right here. We have compiled this sort of catalog of tools and methods which we hope will make it easier for staff to get into it and to pursue it to the depth that they find necessary to apply it in any particular application because, of course, the context determines a lot of exactly what actually happens in any application.

We did have a peer review of this NUREG/CR and it was very valuable to get the kind of feedback that we did from the other program offices. Everybody recognized the merits of a structured decision process and they also recognized how in their own work they see elements of these things.

But what did seem to throw everybody off was the unfamiliar terminology and the conceptual complexity of a lot of things in here. What we felt was this is something that needs to be addressed recognizing this as an important part of the feedback.

Again, it can be addressed by actually showing how it would work in specific cases using familiar examples. The bottom line is that the evidence from this work provides strong support to pursue these methods.

Again, it's 6833. What a staff member using this document would be introduced to a certain concept such as utility theory, value-of-information techniques, performance measures, something that I believe is quite key to this whole approach as to understand how qualitative objectives can be represented by appropriate performance measures and the concept of hypothesis testing which is, you know, a very familiar thing in science but quite often we don't really use it as much as we can in our work.

There is something called Receive Operation Characteristic that we devote quite a bit of time to in this document. I have to tell you that this is terminology that goes way back to the end of the second World War when they were developing radar techniques to differentiate between false and true signals. The way I use it in this work is basically a formal way of considering the probability of being right versus the probability of being wrong.

CHAIRMAN APOSTOLAKIS: False positive, false negative.

MR. KADAMBI: Right. Exactly. Also there is a section on objectives hierarchies which I think will help a great deal.

We have also tried to cover in this techniques that the staff is somewhat familiar with such as the analytic hierarchy process and CSAU, Code Scaling, Applicability and Uncertainty Evaluation.

CHAIRMAN APOSTOLAKIS: One comment here trying to help you avoid some of the pitfalls. If you mention the analytic hierarchy process to decision theorist, they will attack you because the AHP unfortunately was presented as an alternative to decision theory.

But if you use it to support decision theory, in other words, you know, getting the utilities or eliciting information from experts but not making the decision using the AHP. Then it's a different story. It has its own problems.

I think it's similar to what happened with expert systems. They were oversold in the beginning that expert systems would solve everybody's problems and it turns out that they have not solved everybody's problems but they are very useful. Having interactive problems in the English language is great.

So this one is a tool that supports the decision theory and you probably know that already because it's like hold a red flag. If you mention this to people like Keene Neale or those guys it's something to be careful about.

MR. KADAMBI: I fully agree, Mr. Chairman, and I would say that something in my mind we want to be careful in the whole decision analysis area is we should not oversell it because it may really create unnecessary problems in the future.

CHAIRMAN APOSTOLAKIS: So the AHP is not an alternative. It's just another tool.

MR. KADAMBI: No. This is just to point out that --

CHAIRMAN APOSTOLAKIS: I understand.

MR. ROSEN: Come back to why you want to do this and you would like to have the agency use these techniques or recognize the aspects of the techniques and what they're now doing. Maybe expand the way they do business now to take on some more of the attributes of these techniques to make the decision processes even more formal and more transparent and that sort of thing.

So if you think of what your final objective will be which is to convince people to do something different, then the idea that you not make them mad in the process is very useful.

MR. KADAMBI: Exactly. That's the whole point of it.

CHAIRMAN APOSTOLAKIS: I really found it interesting that the reviewers complained that there was conception complexity. I thought conceptually the method is really simple. Implementing and applying it is a problem and I keep getting surprised myself.

For example, one of the latest problems we've had is how do you accommodate through teaming and maybe losses, economic losses from routine failures, and the same problem with core damage which is huge. You have this tremendous difference. You go from a few thousand dollars to billions of dollars.

That creates a big problem in accessing utilities and all that. The implementation, if seems to me, is more complex and subtle than the conceptual frame work. But, you know, if people found it daunting, then what can you do? We have to educate, right?

MR. KADAMBI: We have to address the issue.

CHAIRMAN APOSTOLAKIS: Sure.

MR. KADAMBI: And hoping that is the sort of thing that we pursue.

MR. ROSEN: I may very well be that the way to introduce this is to talk about way decisions are made now. What aspects of what you do now are, in fact, parts of this which is talk about the way business is done now and say now the formal decision making theory would add this piece to that.

CHAIRMAN APOSTOLAKIS: Exactly. That would be a great way of doing it.

MR. ROSEN: Rather than top down and say these are all the things you have to do.

CHAIRMAN APOSTOLAKIS: Right. Use

something that people are already familiar with.

MR. ROSEN: And are doing.

CHAIRMAN APOSTOLAKIS: And putting in this form now you will have gotten extra help here.

MR. ROSEN: Yes.

MR. KADAMBI: In effect, that's exactly what I was trying to do by pointing out how the planning, budgeting, and performance management activity of the agency is really doing just that. I mean, if you look at what planning involves, it is really a careful identification of objectives and trying to structure it in such a way that you can, in fact, budget appropriately to the priorities.

MR. ROSEN: But, you see, even that is just a piece of a bigger structure which includes the agencies overall goals first and then down to the planning and budgeting. When you see an aspect of a budget come up, there's always the question how does this relate to the agency's goals so it's in this formal structure.

MR. KADAMBI: Exactly. That's the point I'm trying to make. And also I think it sort of encourages one to be more creative in identifying performance measures as you go through this effort and identify the measures at the right level in this structure so that you don't get too deep into details and into the noise level of things and you focus on those things that are important as Dr. Apostolakis pointed out. It's a way to identify what is important.

Again, I go back to the success of the ROP and the Commission's emphasis on performance based regulation as offering opportunities to use formal decision methods. The PBPM process can be seen as a way to express multi-attribute utility theory. We are evaluating options to consider private projects and we certainly would like suggestions from the ACRS on this. What is key is that we do involve the other offices. I think we need to get more people involved from all the difference areas of agency activity.

We have to, I think, point out that the basic benefits that we see from this is a focus on structure, transparency, and treatment of uncertainty. Quite often that is where we, I think, can show improvement in our work. What we are suggesting is that there are some things that we can take from decision analysis to help us do that.

We have tried to identify a five-step process to do this. The first step would be to construct utility function. Again, that sounds to some people, you know, like something complex but it's basically just identifying what is important for the decision maker to make sure that we incorporate in the things that we observe and that we try to measure those things that the decision maker and that depends, of course, on who it is.

Sometimes it's the Commission and sometimes it is the branch chief. It could be anyone in between, too. So, you know, we just formally go through this process and try to identify what the constraints are. Then the second step would be to have a way to think about alternatives.

Quite often what we end up doing is we identify an alternative and all the activity goes in either sort of proving success or failure of an alternative rather than spend more time and effort thinking about what are the different alternatives that will help us optimize the decision maker's preferences.

MR. ROSEN: Well, you hear about the President's decision making process. You always hear that he is presented with a slate of alternatives from do nothing to whatever. That is clearly evidence that down the street they are using it.

MR. KADAMBI: Right.

CHAIRMAN APOSTOLAKIS: One of the senior members of the Clinton administration, Secretary of the Treasury Robert Ruben, he said in an interview in the New York Times that every major decision to be made used this. They asked him, you know, if you have this big thing about the financial crisis in Korea and Japan and all that, the question was whether the United States should intervene and help them.

Congress was against it. He said he used the utility theory. They asked him, "How can you put probability to some of these things?" He said, well, he puts some numbers in and you do some sensitivity studies, the Secretary of the Treasury.

MR. ROSEN: You didn't call him up and lecture him on uncertainty, the fact that sensitivity studies are not substitutes for uncertainty analysis?

CHAIRMAN APOSTOLAKIS: I'm sure he knew that. He's a Harvard graduate. I was so impress. I should have kept that interview.

MR. ROSEN: He got it right and also the Vice Chairman of Citigroup.

CHAIRMAN APOSTOLAKIS: He said that throughout his career --

MR. ROSEN: He did have a job after

government.

CHAIRMAN APOSTOLAKIS: And even before.

MR. ROSEN: Before that he was with Goldman-Sachs.

CHAIRMAN APOSTOLAKIS: Yeah, and he said using this --

MR. ROSEN: He's done all right.

CHAIRMAN APOSTOLAKIS: He decided to help Mexico with their economic crisis. He said he had young people around him who understood these methods so they prepare alternatives using these and then he would make a decision. It was a very impressive interview.

MR. ROSEN: He's an impressive guy.

CHAIRMAN APOSTOLAKIS: You see, you don't have to be too occulant. I mean, if you follow the thought processes, it helps you.

MR. KADAMBI: Again, by way of how we would go about using this, we could generate expected utilities so that we could subject it to some kind of a testing process if we do implement it. We would use qualitative and quantitative factors. Quite often we get trapped into thinking that if you can't quantify it, then we should reject it.

What this approach would tell us at least think about constructive measures that would be applicable to the qualitative aspects. We could look for figures of merit sometimes in very complex situations that may not be easy to do. In fact, it may turn out to be not just one figure of merit but a combination of them.

Again, depending on the context it may or may not be very complex. Also the key is to identify the decision rules to think about this. For example, when the option 2 effort, the risk categories are, in fact, decision rules that have been set up. If we look at it more formally, that way I think it may make it easier to implement some of these.

MR. ROSEN: If I were to think about the ROP in the context of these last few thoughts you offered, I would say that performance index are the performance indicators and the decision rules are the action makers. Am I correct?

MR. KADAMBI: Yes. That's how I would translate it, too.

MR. ROSEN: Because what we are trying to do with the ROP is decide where to apply agency resources.

CHAIRMAN APOSTOLAKIS: And the thought that the various colors should be consistent in the parity of the colors comes from this theory that says when you say yellow here and yellow there, you have to mean the same thing in terms of preference.

MR. ROSEN: Otherwise --

CHAIRMAN APOSTOLAKIS: Otherwise you are arbitrary. That is an interesting input or insight from the theory that would have helped the developers of the matrix.

MR. ROSEN: But my point here is made to reinforce an earlier point I made which was that one needs to personify this for the agency. If you want to get your ultimate objective which is to get people to think more in terms and use it which is a valuable objective I support, then as you go along in these presentations, say, for example, in the ROP, here's how we did it.

We figured up performance index and these are our decision rules. We didn't call them those things at the time. We just used our good judgment and set it up that way. But, in fact, here are the pieces of formal decision method being embodied in the way we do business.

We just didn't know it so don't be too surprised if you find out that two-thirds of what we do follow these informal ways in thinking. It's just a way of heuristically approaching the subject for your audience that I'm suggesting.

MR. KADAMBI: Yes, absolutely. I fully agree with what you said.

MR. BONACA: Among these steps you mentioned a number of times the treatment of uncertainty so it would be also part of this steps that you are describing here?

MR. KADAMBI: Yes. I think you would incorporate it at each step really because uncertainty, in fact, determines a lot of how you go from step to step and what you would consider as important and what you would pay more attention to and what you would pay less attention to.

I think it's sort of one of those background kinds of things that you have to keep in mind. My feeling is that as you start applying it you will be forced to think about it if you do it in a formal way.

MR. BONACA: So really probably the development of mortality is tied to it.

MR. KADAMBI: Yes, it is.

MR. ROSEN: And one alternative that is more preferable than another is one that is less uncertain.

CHAIRMAN APOSTOLAKIS: That's right. Other things being equal.

MR. KADAMBI: Again, I don't know how it will work out in specific cases. There may be certain times when it doesn't quite work out that way but if it doesn't work out that way, I would submit you would at least know why it isn't and so you would know how to either confirm or deny your basic assumption.

MR. ROSEN: Well, I'm a control freak so I like alternatives that have less uncertainty rather than more. Maybe others would not follow that. That's one of my high priority items. I would like to get where I'm going, know where I'm going to start and get there with some reasonable assurance.

MR. KADAMBI: Sure. I understand. Anyway, these are the basic steps that we might think about using and how could we implement these. Again, I offer these as possibilities that we might pursue. What we will try to do along the lines of what Mr. Rosen pointed out is try to close the gap in terminology by pointing out similarities between a lot of what is already being done and what formal decision theory approach it really calls for.

One way of doing this might be to set up an interoffice working group which would provide a focal point for these formal decision methods and develop a nucleolus of knowledgeable staff in this. We could identify case studies and apply them with internal stakeholder input, you know, involved in many of the steps where really having stakeholder input is quite critical.

Of course, at some point we would have to address the resource issues because all these things take resources and resources are always at a premium. We would have to work through these issues one by one.

CHAIRMAN APOSTOLAKIS: Have you found positive response from people when you talk about an interoffice working group?

MR. KADAMBI: Well, not yet. Maybe if the ACRS helps me, I will be able to get more positive --

MR. ROSEN: We could open up each meeting with a discussion what it appears and who is presenting it to us and what they know about formal decision methods and whether they are supporting the other agency.

MR. KADAMBI: I would go along with that. That would make you popular.

MR. ROSEN: We could start with our colleague Dana Powers.

MR. KADAMBI: What we would be looking for is sort of a ripple effect of wider and wider participation in it and gradually have enough people that we can rely on to implement this. What I would foresee is that we prepare some kind of a NUREG report but it has to be something that we can go back to the Commission and say one way or another the staff has explored this approach, has demonstrated one thing or another, and then make sure that the Commission does support this activity.

MR. ROSEN: Do you have a training branch in this agency?

MR. KADAMBI: There is a whole -- you know, it's part of human resources. Training is a very important function.

CHAIRMAN APOSTOLAKIS: Short courses you mean?

MR. ROSEN: Well, we're talking about training. We're talking about training people to understand the value of formal decision methods.

CHAIRMAN APOSTOLAKIS: That's a good point. Maybe you can -- I don't know, maybe it's too soon now but after you've heard some of these case studies of where you demonstrate. You have it right there?

MR. KADAMBI: Well, no.

CHAIRMAN APOSTOLAKIS: I mean, it would be worthwhile having a two to three-day training short course as part of the agency's arsenal.

MR. ROSEN: I would start with a hour just to get the idea to people. Really, my point was that what you are really doing is -- research has looked into these methods and determined that they have value and suggest to the agency that they be used. It seems to me the rest of the job other than some advocacy from you is to support the training organization.

These are the kinds of things that are embedded in a culture, the agency's culture through management training, not through the research group trying to set up an interagency working group pushing on a rope. What you need to be doing is putting in your formal training program for managers so that the managers come to their jobs equipped understanding what FDM is and understanding how to -- where it's applied in the agency already.

When they set up a new project to take out their FDM methods and say, "Okay, let's make sure we're following through this." Otherwise, I feel research is the wrong person to do it and, secondly, pushing on a rope anyway.

MR. KADAMBI: Well, I think that is a

valuable suggestion and we ought to do something about it.

CHAIRMAN APOSTOLAKIS: You have to have case studies. You have to have case studies meaningful to the agency.

MR. ROSEN: You have to support training. You can't just tell training to do it but you would be the support for training. You would help them develop the methods. You would train their trainers. You would sit in on the sessions initially. It's a function of human resources to train managers, supervisors, and employees in general on techniques the agency wants to use.

MR. KADAMBI: It appears to me that could be the central message of a Commission paper as we go up to the Commission with the results of this case study and all the information.

CHAIRMAN APOSTOLAKIS: Are you doing any at all? I mean, what is the plan for this next year now?

MR. KADAMBI: Actually we haven't formulated a plan as such.

MR. FLACK: That's part of what we are here to discuss when Prasad was mentioning implementation and how to go about doing that and I think the focus would be to try to get something to the Commission and draw out a pathway to get us there to demonstrate and to show that it works.

Then as part of that integrating it, I would think it's more a tool that you could integrate it into modules that may be already on the books where you would have a certain part of that in the context of that application and show how it works so there are different ways. Again, we are still trying to figure out in some way the next step in trying to get this laid out and that's what you're hearing today.

CHAIRMAN APOSTOLAKIS: So you are in the process then of thinking about what case studies to do?

MR. KADAMBI: Right. And how to go about doing that.

CHAIRMAN APOSTOLAKIS: Well, you can start by helping Mr. Thadani. I mean, he has to prioritize research efforts every year and I understand that's a contentious issue usually.

MR. FLACK: Well, that's not an easy one.

CHAIRMAN APOSTOLAKIS: It's not an easy one. Maybe you can pick a subset and ask yourself how would one go about it. You have a lot of these qualitative attributes there, of course, but if you can convince him that this would make his life easier, then you made a major step forward I think and that doesn't have to be the only case.

MR. ROSEN: I think, George, you have a good idea. I think using the case studies is valuable and useful. The trouble is with them is they tend to feel like they are isolated. It's just a story for research. It's just a way for research to prioritize efforts. When, in fact, it should be viewed, I think, the other way.

The agency has core values or missions. It has a PBPM process, planning and budgeting process, which is structured around those missions. One of its missions is research which has to support the structure above it. And there is a case study here on how you can prioritize research using this. Don't see this as in isolation is my point.

See this as simply an embodiment of a structured formal decision making approach that the whole agency is really -- I mean, this is the most formal of agencies -- of enterprises compared to a mom and pop shop which may or may not have to do these things but, in fact, would be better off if they did.

The agency has a congressional act that establishes it, a set of regulations. This huge vast structure which all you are really doing is saying, "Well, in this formal structure we are going to use formal decision tools." Case studies are important as anecdotal almost successes, but it should be seen as an overall embodiment of the formal structure you are operating in.

MR. KADAMBI: In fact, I would submit that if you look at our strategic plan you could actually build an objective hierarchy just from the way that is set up. If you go into the plan itself it defines very formally what is a regulatory framework and it defines it exactly the way you did which is it begins with the enabling legislation and comes all the way down to inspection procedures. That is the regulatory framework. I think it's all there.

CHAIRMAN APOSTOLAKIS: You have to be careful. It seems to me we have multiple objectives here. One objective is to do what you and Mr. Rosen have been discussing the last few minutes. But another objective is to build support. You need some influential people to support you.

That's why I said if you prove to Mr. Thadani that this can help you, then you have a powerful man behind you. If you only go up and say this is a good way of doing things, people will say, "Gee, that's probably good," but you will not get the same kind of support.

The other thing regarding what you said about a strategic plan. It's not enough to say that what is in the strategic plan really conforms with this. Then you have to go an extra step and show how developing the plan would have been easier had they used this. Then people will come back and say, "Okay. We are already doing it." You have to demonstrate that there is some value to this.

That what you are doing already is not orthogonal to this but had you used this, you would have gotten something that is valuable that would have made your life easier, you know, some value. I think if you start doing these things you will see what will come.

MR. KADAMBI: I fully agree with you. The point I was also going to make was that we in the staff don't have really much by way of guidance on implementing this strategic plan, you know. This approach and if we sort of decide to use it could offer an easier way for staff which my experience is they sometimes have difficulty in thinking about the relationship between the strategic plan and their own work. This would be a way to help them, in fact, align their activity.

MR. ROSEN: Let me give you an anecdote that supports, I think, very nicely your point, the one you're just making about the need to support the strategic plan and to understand it. In utilities that I have been associated with they have core values which is the kind of thing that the Commission has for its strategic goals.

When it's used appropriately and the staff of the utility understands it, those core values become important day-to-day things and I have experience with decision making groups within a utility asking each other whether or not certain actions of one group or one party is aligned with the core values or not.

In discussions about whether this was a good thing or a bad thing, the discussions brought up -- refer back to the core values and say these actions between these two groups are not consistent with this core value. You should see it in that light and whether I'm having a good discussion or I'm not, and correcting behavior and adjusting approaches.

This is the anecdote I wish to add and that is exactly the kind of thing I think you're suggesting is whether the staff here is working on something and trying to make a decision between A and B. You can think about the formal structure he's operating in including the Commission's objectives and say better or worse this will align us better or worse with the core value, the structure.

CHAIRMAN APOSTOLAKIS: So the purpose of today's meeting was really not to call into the details of what you're doing. As you know, it's more like to familiarize ourselves with the various activities for the Office of Research. I take it this is a fairly low-level in the sense of funding activity. It's not into the hundreds of thousands of dollars.

Although I'm sure your salary would take care of it. But you will pursue it this year? You will try to identify some case? We will be happy to hear from you when you have some case studies and discuss them with you. Obviously the Subcommittee is interested. I think from the full committee you will have some skepticism but they will be willing to be convinced, I think.

MR. ROSEN: That's because the full committee is populated by structuralists rather than rationalists, or some structuralists who we are working on.

CHAIRMAN APOSTOLAKIS: No, you have to demonstrate value. You have to demonstrate value and case studies and perhaps the global approach that was discussed earlier.

Anything else from the members? Prasad, you want to say anything else?

MR. KADAMBI: No. I want to thank you for the opportunity to make this presentation.

CHAIRMAN APOSTOLAKIS: Thank you for coming. And John.

MR. FLACK: I appreciate it.

CHAIRMAN APOSTOLAKIS: Okay. Great. Thank you very much.

The next item is overview of the PRA Safety Research Program but the presenters are not here. We're take a few minutes. Oh, there's a break scheduled.

MR. ROSEN: You're right on schedule, Mr. Chairman, even though you're don't know it.

CHAIRMAN APOSTOLAKIS: Okay. We'll recess until 9:30.

(Whereupon, at 9:19 a.m. off the record until 9:33 a.m.)

CHAIRMAN APOSTOLAKIS: We're back in session. The next presentation is beginning the overview of the PRA Safety Research Program, Mr. Cunningham.

MR. CUNNINGHAM: Yes, sir. I'm here. Mr. Newberry couldn't be here today because he had a wedding in the family that he decided was more important than this. What can I say?

CHAIRMAN APOSTOLAKIS: We'll remember that.

MR. CUNNINGHAM: I'm going to give you a real quick overview of what's going on in the division and then pat will come in and spend a good bit of the morning talking about the details of what's happening in one branch and then after lunch, I guess, we'll talk about the other branch, PRAB.

We're allocated in FY '04 to have 55 FTE in the division, 55 people, and a budget of about $15 million. You've heard many of the things that we do but it's basically we look at operating experience from a risk perspective. We look at some aspects of security.

MR. ROSEN: I hope you're not doing all the security work.

MR. CUNNINGHAM: No, sir. No, we're not. This doesn't include the security money. This is the non-homeland security.

MR. SHACK: Mark, the 55 FTE are staff here. The $14 million is your contracted budget?

MR. CUNNINGHAM: Correct. Correct. That's right. It doesn't include the security. The security in FY '04 for the Office of Security Research budget in '04 is about $8.5 million. That includes a wide variety of things, not just in PRAB, not just in DRAA.

CHAIRMAN APOSTOLAKIS: So what exactly is 14.8?

MR. CUNNINGHAM: 14 is the budget for the PRA -- it's for these things except security.

CHAIRMAN APOSTOLAKIS: Okay.

MR. ROSEN: Contractor support.

MR. CUNNINGHAM: Contractor support. It's separate from the 55 FTE.

CHAIRMAN APOSTOLAKIS: Okay.

MR. CUNNINGHAM: Okay. Develop risk methods, perform risk analyses, develop standards, apply PRA to advanced reactor issues.

Within the Operating Experience Program we have the SPAR Model Development Program Analysis and the Accident Sequence Precursor Program, a new data system to look at basic events coming from the industry, Mitigating Systems Performance Indicator or

Index. Indicator? Index. Okay. I never get that right. Recommendations coming from the Davis Bessy Task Force and a series of things related to international cooperative efforts.

CHAIRMAN APOSTOLAKIS: Which task force is this?

MR. CUNNINGHAM: Davis Bessy Lessons Learned Task Force.

In the security area we've got basically the application of risk methods to certain security issues. We've got the development of guidance for using risk information and security decision making. We've got the lead for the office for integrating the research program supporting answer. Then we do a variety of briefings domestically and internationally to other government agencies, international organizations for foreign governments basically. That sort of thing.

MR. SHACK: Okay. And you have a separate contractor budget for this but the 55 FTEs covers the whole kit and caboodle.

MR. CUNNINGHAM: Correct. Correct. In terms of risk methods development I think I mentioned yesterday the big areas we tend to focus on, or have focused on for the last few years, are HRA and Fire

Risk Analysis. We heard about HRA yesterday. We'll talk a little about fire risk this afternoon after lunch, I guess. I guess we're not going to discuss materials and waste later but we are working with NMSS to develop risk analysis methods and decision criteria, safety goals, that sort of thing.

CHAIRMAN APOSTOLAKIS: So who is reviewing this, ACNW?

MR. CUNNINGHAM: ACNW, correct. The last part. We have talked to them several times I think.

CHAIRMAN APOSTOLAKIS: You have already done that?

MR. CUNNINGHAM: Yes.

CHAIRMAN APOSTOLAKIS: Or is it the joint subcommittee?

MR. CUNNINGHAM: It was just ACNW.

CHAIRMAN APOSTOLAKIS: So what is the purpose of the joint subcommittee? The whole idea was I thought to bring some perspective from the reactor where we have had experience with these things.

MR. CUNNINGHAM: That's a good idea for next year when we review the research programs maybe to have a joint meeting.

CHAIRMAN APOSTOLAKIS: Not just the research program but actually the research that they are doing in establishing the safety goals for NMSS. Some perspective from the NMSS would have been useful. It just occurred to me I'm a member of that subcommittee so it's okay. You go to ACNW.

MR. CUNNINGHAM: ACNW, of course, is not bereft of risk analysis experience with Dr. Garrick on it as chairman.

CHAIRMAN APOSTOLAKIS: I never implied that. There is a certain perspective that the ACRS always brings having dealt with it for a long time.

MR. CUNNINGHAM: Okay. In terms of risk studies we have the lead in the office for investigating potentially risk-informed changes. 5044 is basically done now. 50.46 is in the works.

CHAIRMAN APOSTOLAKIS: Were we briefed on 50.46 recently, Bill, or has it been a while?

MR. SNODDERLY: It's been a while. We have one coming up. November 21st it has been tentatively scheduled.

CHAIRMAN APOSTOLAKIS: Already?

MR. SNODDERLY: Yeah, to be briefed on the expert elicitation and success.

CHAIRMAN APOSTOLAKIS: November? Am I invited to that?

MR. ROSEN: No. 50.69 is really an NRR

problem at the moment.

MR. CUNNINGHAM: 50.69. The technical work has been turned over to NRR. We are in the process of getting a peer review of our work, the research work. The first formal meeting of the peer review is sometime before Thanksgiving.

MR. ROSEN: When they pay attention, could you explain that to me?

CHAIRMAN APOSTOLAKIS: November 21st is valid. Is that set in concrete?

MR. SHACK: I thought we contacted George for an expert elicitation.

CHAIRMAN APOSTOLAKIS: Yeah, an expert elicitation. Nobody asked me if I can make it.

MR. SHACK: We'll talk.

CHAIRMAN APOSTOLAKIS: Can we change it? It's eight weeks from now. Six or eight weeks.

MR. SHACK: November 21st is when it's scheduled for?

CHAIRMAN APOSTOLAKIS: Yeah. Are you available?

MR. SHACK: Yeah. I'm okay with the 21st.

CHAIRMAN APOSTOLAKIS: Then the next week we have the ACRS 508 meeting, right? On the 2nd we have -- we're going to have to move here again.

MR. SHACK: Okay. What does your peer review involve now in the 50.69?

MR. CUNNINGHAM: I haven't been greatly involved in it but it's basically looking at, I believe, both the basic method that's been applied and getting into some of the nastier technical issues related to more the materials aspects of it, I believe. If I could, maybe when I'm back here after lunch I'll come back and give you a better answer.

MR. SHACK: Is there a document or a report? It's not Appendix T because that's been --

MR. CUNNINGHAM: That's correct. It's the technical basis report that research provided to NRR is the subject of the peer review.

CHAIRMAN APOSTOLAKIS: You're talking about which peer review?

MR. CUNNINGHAM: 50.69 PTS.

CHAIRMAN APOSTOLAKIS: That is a peer review group?

MR. CUNNINGHAM: Yes.

CHAIRMAN APOSTOLAKIS: Who are these people?

MR. CUNNINGHAM: I'll have to get you the names after lunch.

CHAIRMAN APOSTOLAKIS: Have we reviewed

the latest 50.69?

MR. CUNNINGHAM: No. We haven't seen the NEI Implementation Guide. That's the most important piece that we haven't seen.

MR. SNODDERLY: The next step is to have a briefing on resolution of the public comments.

MR. CUNNINGHAM: I'm saying 50.69. I don't mean 50.69. I mean PTS just to be clear.

MR. SNODDERLY: That sounds better.

CHAIRMAN APOSTOLAKIS: So there is a peer review on PTRS. Oh, yeah, sure. That was a huge effort.

MR. CUNNINGHAM: Yes. Okay.

MR. SNODDERLY: But 50.69 you have washed your hands of the whole affair?

MR. CUNNINGHAM: Research doesn't have much of a role in the implementation of 50.69.

CHAIRMAN APOSTOLAKIS: Is expert elicitation the only thing that's going on?

MR. CUNNINGHAM: No, no, but that's the biggest aspect of things right now.

CHAIRMAN APOSTOLAKIS: Is there a document I can read at least if I'm not here?

MR. CUNNINGHAM: There is a draft Commission paper in concurrence now that talks about next steps of 50.46.

MR. SNODDERLY: On the 21st we plan to spend about four to six hours on the expert elicitation and then an hour and a half on the second that Mark just mentioned where they are going to -- it will be a negative consent paper that says, "Here is what we think we heard from your March 31st SRM and here's what we're doing. Unless we hear differently, we're going to provide you the following."

CHAIRMAN APOSTOLAKIS: So which subcommittee is meeting on the 21st?

MR. SNODDERLY: We call it a subcommittee but when you include Thermal Hydraulics, PRA, and Bill that's everyone.

MR. ROSEN: We're sort of fixated on the 21st. Maybe the 20th you're thinking?

MR. SNODDERLY: The 20th was not an option. There were two dates that we considered.

MR. ROSEN: What was the other one? Do you remember?

MR. SNODDERLY: The other one was very early in November but then there really wasn't -- the staff couldn't provide us with the results.

CHAIRMAN APOSTOLAKIS: How about Tuesday

of that week which is the 18th?

MR. SNODDERLY: Rob Tregoning is going to be away those first two days. He could do it Thursday or Friday. There's another meeting scheduled on Thursday so Friday was it.

MR. CUNNINGHAM: Okay. So we've looked at the risk associated with dry cask storage of fuel and that's being discussed with ACNW. We did the risk evaluation of GSI 191 on sump performance that I believe you saw fairly recently. We're doing a risk evaluation of accident induced steam generator tube ruptures.

You've seen DG 1122 and heard a lot about it. The ANS external events standards, to my understanding, is just going to publication here within the next week or two so that is basically done for now. We supported the development of that. We are supporting the development of the ANS low power and shutdown standard.

In January there's a multi-organizationally sponsored workshop in Vienna on PRA equality. IAEA and a number of others, NEA and ourselves are sponsoring this workshop and we are --

CHAIRMAN APOSTOLAKIS: What is the purpose of it?

MR. CUNNINGHAM: To look for commonalities, I believe, across countries and organizations about what we can do to get to the -- where do we want to be and what is needed to get there is my understanding.

CHAIRMAN APOSTOLAKIS: What happened to sensitivity?

MR. CUNNINGHAM: We are going to be developing another guide that covers those specific issues.

CHAIRMAN APOSTOLAKIS: This is what Mary mentioned when she was here.

MR. CUNNINGHAM: Correct. For advanced reactors we're helping NOR and the reviews of some of the reactor types, developing some basic tools to support those reviews. We are also trying to work with what we call the technology neutral framework. I'm not sure if the Committee has seen that or not.

CHAIRMAN APOSTOLAKIS: Is there still activity going on there? That's based on Option 3, is it not?

MR. CUNNINGHAM: Yes. Take Option 3 and overlay it onto advanced reactor design.

CHAIRMAN APOSTOLAKIS: There is some activity or is it very low level?

MR. CUNNINGHAM: It's moderate level I would say.

MR. SNODDERLY: Next month, George, Mary is going to be down with Tom King to present the framework to us.

CHAIRMAN APOSTOLAKIS: We have selected the date again, Michael?

MR. SNODDERLY: No, it's to the full committee.

CHAIRMAN APOSTOLAKIS: To the full committee?

MR. SNODDERLY: To the full committee.

CHAIRMAN APOSTOLAKIS: Those dates have been selected. So my question was meaningful.

MR. ROSEN: And we hope you will attend, George.

CHAIRMAN APOSTOLAKIS: What a low blow.

MR. ROSEN: It's no fun without you. Could you go back to that one?

MR. CUNNINGHAM: Yes, sir.

MR. ROSEN: Could you tell me where ACR-700 is? I'm lost on it entirely.

CHAIRMAN APOSTOLAKIS: It's Canadian.

MR. ROSEN: Is this still active? My notice in the research plan is there's a kazillion efforts on it. I'm surprised by that.

CHAIRMAN APOSTOLAKIS: What does ACR stand for?

MR. SHACK: Advanced Canadian Reactor.

MR. ROSEN: Something like that.

MR. CUNNINGHAM: My understanding is, yes, it's still one of the active ones.

MR. ROSEN: That means the Canadians are going to come down here and make presentations and ultimately apply for certification.

MR. CUNNINGHAM: Correct.

CHAIRMAN APOSTOLAKIS: So it will be handled the same way as AP-1000.

MR. CUNNINGHAM: Yes, that's correct. Because it's a different design it introduces different issues.

MR. ROSEN: And they have done the same thing in Britain, I think. The British may decide to do something different than this agency might and that's difficult. It causes difficulty

MR. CUNNINGHAM: It makes life more complicated. Yes, it does.

MR. ROSEN: Okay. I'm asking that in the context of research decisions we have to say we like or don't. One of the puzzling things about the plan that I saw now is the amount of effort that's going into ACR-700.

CHAIRMAN APOSTOLAKIS: What about passive equipment? What's going on there?

MR. CUNNINGHAM: I'm sorry?

CHAIRMAN APOSTOLAKIS: You have a program on PRA passive equipment or processes? Phenomenon?

MR. CUNNINGHAM: Phenomenon. It's more phenomenon.

CHAIRMAN APOSTOLAKIS: It's not passive.

MR. CUNNINGHAM: That's right. It's how do you model the reliability of functions.

CHAIRMAN APOSTOLAKIS: Does anyone have any idea how to do that or you are searching for ideas?

MR. CUNNINGHAM: We are searching for ideas at this point.

MR. ROSEN: This is like reactor vessel heads?

MR. CUNNINGHAM: This is like passive ECCS systems. Passive ECCS systems.

MR. ROSEN: Oh, okay.

MR. CUNNINGHAM: That sort of thing.

CHAIRMAN APOSTOLAKIS: Yeah. So, you know, the AP-1000 is inside the containment at high elevation so gravity works right.

MR. ROSEN: We hope.

CHAIRMAN APOSTOLAKIS: But nobody has come up with any potential failure modes as far as I know. People are skeptical but it says this might happen.

MR. CUNNINGHAM: That's my understanding, too.

CHAIRMAN APOSTOLAKIS: How can we build something that cannot fail? It goes against our nature.

MR. CUNNINGHAM: I don't know.

CHAIRMAN APOSTOLAKIS: Okay.

MR. CUNNINGHAM: The division provides support to a number of different things. We are responsible for updating the implementation plan for managing the PRA steering committee, the internal committee.

CHAIRMAN APOSTOLAKIS: How do you pronounce the second acronym?

MR. CUNNINGHAM: RIRIP. Or IP for short.

CHAIRMAN APOSTOLAKIS: Now you're shortening acronyms. And the other one is RILP? The third one?

MR. CUNNINGHAM: I'm sorry? The other one is already taken by international programs I'm afraid.

CHAIRMAN APOSTOLAKIS: Okay.

MR. CUNNINGHAM: Okay. So that's kind of the overview.

CHAIRMAN APOSTOLAKIS: So all of these are active programs?

MR. CUNNINGHAM: Correct.

CHAIRMAN APOSTOLAKIS: Okay.

MR. CUNNINGHAM: Active in '04, if you will. Some of these things may not be very far along but they are active. With that, Pat Baranowsky and Company will present the program in the Operating Events Risk Analysis Branch.

CHAIRMAN APOSTOLAKIS: We're moving now to our advanced technology.

MR. BARANOWSKY: We're now moving to the real world. Not things that could possibly occur but things that have occurred.

CHAIRMAN APOSTOLAKIS: You're going backwards. You're using transparencies.

MR. BARANOWSKY: Every time I bring a PowerPoint presentation that doesn't work.

MR. ROSEN: This is why operating experience is your job because you know from operating experience that this works.

MR. BARANOWSKY: Briefing experience, yes.

MR. ROSEN: And you have a backup bulb in there in case it blows.

MR. BARANOWSKY: If need be, we'll go up and get a little cartridge and stick in and add the PowerPoint.

MR. ROSEN: You could also, if need be, come over here and hold it up in front of us.

MR. BARANOWSKY: We do have hard copies, I'm sure. I have some people here that should be coming up and sitting down around the table. I thought this would be more of a sort of roundtable discussion.

I guess I'd better introduce myself for the record. Patrick Baranowsky, Chief of the Operating Experience Risk Analysis Branch. I brought a few people from my branch here that are responsible and involved in the key areas. I'll just start from this side.

Don Marksberry who has been doing program management work for the Accident Sequence Precursor Program for the last couple of years at least. Dr. Pat O'Reilly who is heading up the SPAR development work, Dale Rasmuson who is working on both Data Systems and Industry Trends Program, and Dr. Don Dube who is working on support for performance indicator development for the Reactor Oversight Process.

We have other folks, Mike Cheok who is the Assistant Branch Chief, Gary DeMoss who is pretty much our Senior Risk Analyst for ASP events, and Dr. Bennett Brady who is a key person working on data systems and interfaces with INPO also available here.

So, what we are going to cover are pretty much programs I've just identified. I'll give a little introduction to how the branch is organized and what we're about. Then we'll cover data collection analysis, the Accident Sequence Precursor Program, industry trending, SPAR work, and then Mitigating System Performance Index.

Introduction. Just a quick overview of these things. The Accident Sequence Precursor Program is used not only to have a resource that gives us information on significant events over a period of time but now also becoming part of what the agency uses in their report to Congress to identify how well we're doing.

It's sort of an NRC and industry report, if you will. We look at both significant events. If there are certain numbers of them, they would be getting reported to Congress. And whether or not the trends in Accident Sequence Precursors are degrading in some way.

The other thing I would mention about the Accident Sequence Precursor Program, which has been going on for quite awhile, is that it does provide an independent assessment by the Office of Research apart from licensing types of analyses. We try and be realistic without any consideration of whether we are trying to license a plant and have some conservatism or not in there. Sometimes it gives a little bit different spin but usually not too much from what we're seeing in the regulatory area.

In the oversight process we have a couple of activities ongoing. The first is to support the Industry Trends Program which I'll discuss. And also to develop performance indicators, the most recent of which is the Mitigating System Performance Index. In both of those things we have briefed the ACRS on before. I'll say a little bit about it but if there are any updated types of questions that you would like to ask, we are prepared for that.

We have done quite a bit of work on our data collection and analysis to streamline that. It was sort of all over the place in terms of how we were collecting and staring and coding and we really compressed it into a fairly efficient operation.

Now we have a lot of work going on in the SPAR model development area. It's kind of stretched us to the limit on resources. I'll go over the various things there but it's full power, low-power shutdown, LERF, and even some consideration of external events. That's the full scope of what we do in this branch.

The next chart is meant to show how some of this is organized. It's organized so that there is a good interaction between the activities or else we wouldn't be able to do this with a relatively small staff.

Just looking from the bottom up the way our work is organized we have identified a number of databases or sources, if you will, of operating experience information that we process into the databases or that we share with others like INPO, for instance and their EPIX data.

Then you'll see also in this lower tier here reliability and availability data system. That's sort of our common way of treating the information so that we don't have one project with a slightly different approach to calculating parameters or whatever. It's all done in a fairly consistent way.

This information gets fed into a number of analytic activities that used to be done independently when we were first studying initiating events and components to see how we might look at industry trends and get some what I would call industry average or generic insights on these things.

We actually published a number of reports which we presented before the ACRS several years ago. Now what we have done instead of updating the reports as we had one time planned, because that's just way too costly, we have taken what I will call algorithms, if you will, that we developed to do the analyses and the standard approach for collecting the data and the standard approach for displaying the important contributors and insights.

That's all going into a web-based system so that for 10 or 20 percent of the cost we can do all this not only for all the different aspects but we can update it much more rapidly because publishing NUREGs is just a time-consuming process.

The only thing that we would want to be careful about is if we modify our methods and approaches we would want to have an interaction with peers before we incorporate that into our methodology because every one of these reports had pretty widespread review inside of NRC with ACRS and with external entities like INPO, EPRI, and owner's groups.

MR. SHACK: Now, how do you handle that with the web base? Do you put up a private site somewhere and people discuss it?

MR. BARANOWSKY: No. The way it works is if we've already had the methodology and the process peer reviewed, then we just carry it out as a routine production activity. All we're worried about then is QA and that's where we are on this.

But if there is a new element to this that's added, then it has to go through a much more rigorous process, most likely with NUREG production and the usual peer review activity. If we were to expand the items that you see on this list here but suppose we said external event issues, we would do a study that would go through the usual process of development, peer review, resolution of comments, finalizing the methodology and then it would get incorporated into what I would call a production sort of mode.

MR. SHACK: Just on the SPAR, too, when people are using SPAR for SDP that's done by NRR, do you support that or you support it only to the extent that you just hand them a SPAR bottle?

MR. BARANOWSKY: No, we are available for consultation and we are actually working on a more integrated approach for us to deal with SPAR analysis, SDP and ASP analyses so that we can all use a common set of tools and procedures.

I think just the tools alone are not enough. My experience has been that if we don't have a process and procedures to use the tools in a consistent way, we can use them anyway we want and get anything we want and it's not trustworthy as a production activity.

Once we get to the point where we think we know how to do certain types of analyses, we should have ingrained in the process an approach that in most cases gets us to a result we can believe in without having to go back and reinvent the wheel on whether we know how to do an analysis of the reactor coolant pump seal type of accident.

That does lead us up to the next level which is the plant specific analyses and there we have both the SPAR models get developed to support that and the Accident Sequence Precursor Program which takes information from the lower tiers.

You will notice I have also added another little item under the Accident Sequence Precursor Program, inspection reports, because at one time we were just analyzing what came in from LERs I'm going to say about five or six years ago, maybe it was more. More? Okay.

Well, we decided that a precursor is a precursor no matter where it comes from. Even if the LER format isn't set up to capture it, perhaps there are other things such as two or three inspections might uncover problems that don't get reported in a single LER so we wouldn't want to miss that if it was significant.

Now, I don't know that we've run into any like that but I think a few years ago there were some concerns so that gives us some comfort to know that we're not being blinded by just the format and restrictions associated with LER reporting. Then we've taken this information from --

MR. ROSEN: Have you been impacted by the rather sparse nature of recent inspection reports? The ROP seems to have caused inspection reports to be less descriptive perhaps than earlier inspection reports of performance.

MR. BARANOWSKY: The ones that we worked with on the more significant events I think are pretty detailed. Maybe you can help me out here, Don Marksberry.

MR. MARKSBERRY: Yeah. Most conditions which are identified in inspection finding usually results in LER so that's our first go is we read the inspection report and the associated LER. If we need additional information we call the inspector up. We call the SRA in the region to get additional information.

MR. ROSEN: So the kind of things that reach your program are important enough to ultimately generate an LER and you maybe get a clue of it in inspection report. And the kind of thing I'm talking about is there used to be a lot of flowery descriptive language in inspection reports before the ROP. Inspectors were wax poetic about performance at the plants and you could get all kinds of insights from that. Now with the ROP they're a lot more constrained.

Even though they do many of the same things they don't write them all in the reports so there is less peripheral, as we call it, information in these reports than there used to be. But since you're working on the mainline, I can see how that probably hasn't impacted you much.

MR. BARANOWSKY: And plus we follow up informally on many of these things. That's what takes a lot of time sometimes is interacting with the regional inspectors and/or the licensee to get some of that additional information that's not in either the inspection report or the LER.

MR. ROSEN: But you're really talking about something that rises to some level of importance.

MR. ROSEN: But you would have an SDP to work from, wouldn't you?

MR. BARANOWSKY: Not necessarily. I'm not sure of the numbers but I think about 60 percent of the Accident Sequence Precursors have an overlap with the SDP and about 40 percent don't. Remember, the SDP will look at performance deficiencies per their definition. What we're looking at is what is the risk out there. I don't care whether it's because you intended it or didn't intend it. It is what it is. Our scope is broader in that respect.

We also look for overlapping conditions even if they might be related to different aspects of performance, whereas the SDP says we look at this performance issue once and then we go and look at another performance issue. What we're looking for is how is the risk building up as a result of combinations of things or individual items so it's really a different perspective.

The top of the chart here everything sort of feeds up to our ability to develop risk-based performance indicators. We did a study a couple of years ago on risk-based performance indicators which was reviewed by the ACRS. Then since then we did a spin off activity working at NRR and the industry on adapting some of that for the mitigating systems cornerstone. We'll talk about that a little bit toward the end of the discussion.

CHAIRMAN APOSTOLAKIS: Question. One of the problems, Mark, as you know associated with this work is dissemination of the information we generate and even, you know, Carl Fleming's report points out that some from the staff meaning that 20 percent of the events that you identify don't find their way into the PRAs, which is something that is debatable.

This is really -- I mean, there is a lot of useful work that comes out of these precursor studies and other studies that your branch is doing. By in large that is not informing the work that the industry is doing on PRAs. Are we making any progress at all?

MR. BARANOWSKY: You make a good point. I can't say we have made progress but I think it's being addressed finally. The Davis Bessy Lessons

Learned Task Force resulted in a follow-on activity called the Operating Experience Task Force, I think.

I think one of the issues that comes out of that is the dissemination of operating experience, information, and insights. It just so happens one of my key staffers, Don Marksberry, was on that task force. The report is in draft and I'm sure it will come to the ACRS.

MR. MARKSBERRY: I think we're scheduled to brief you in a couple of weeks or so. A couple three weeks.

CHAIRMAN APOSTOLAKIS: A day I cannot come?

MR. BARANOWSKY: That's the way we schedule it.

CHAIRMAN APOSTOLAKIS: Full committee. Does my colleague here want to make a comment?

MR. ROSEN: I don't like it when he misses full committee meetings. Neither does the chairman of the Commission. I would like to point out that some of your colleagues were here yesterday, John Flack and J. Persensky, talking about the Human Factors Research Program.

They gave us three slides on potential performance indicators for the Corrective Action

Program, safety conscious work environment, and human performance. Those were thrilling to me because, you know, we've complained that the ROP needs to have indicators of cross-cutting the issues. Are you the guy that was supposed to do that?

MR. BARANOWSKY: I don't know. If I am, I need to have the resources.

MR. ROSEN: Here they are.

MR. BARANOWSKY: I need to have the resources to do the work.

CHAIRMAN APOSTOLAKIS: As a dean of my school once said, if there is such a set available, anybody can do it.

MR. ROSEN: Exactly. And he was right. You don't need to be smart or determined. I recommend to you if you haven't seen this to get hold of Persensky and Flack's presentation to the ACRS yesterday, to the Subcommittee on the 9th, and to look at the last three charts in their presentation which are potential performance indicators in the areas of the cross-cutting issues.

MR. BARANOWSKY: Okay. I appreciate that. So that's sort of an overview of how we are organized. I guess the one point is that things sort of fit together and if we didn't have some of these things going on, we would actually not be able to operate with the small group and the kind of budget size that we have. We take advantage quite a bit of forming small interactive teams to work up and down this chart and it seems to be working out.

CHAIRMAN APOSTOLAKIS: This is really what happens. This is data. This is real data. We have a course at MIT every June for mid-level managers for utilities on risk formulation. We run it twice now. This is one of the most popular talks. People really appreciate. When you start talking about data people really get excited. It has always been a very successful popular talk.

MR. BARANOWSKY: Okay. Thanks. So let me now just cover the data collection and analysis. This last fiscal year we made significant progress on our integrated data collection and coding system. What we do is we have identified the types of factors and information that we want to extract for all the kinds of studies or risk parameters that we want to generate.

Then in a coding book we have that laid out so that we can take an individual coder and train them and have one person -- or, I should say, do it one time because there may be a couple of people involved -- go through, say, an LER and extract information that feeds into a lot of analytics, if you will. Many of the charts and parameter type estimations that were in all of our system studies are now just together in one activity and we have the algorithms to do the calculations.

We've also worked pretty closely with INPO so that we can extract information out of the EPIX system which is becoming a more and more quality system. Now, it doesn't have the kind of rigor and perfection to it that some folks in licensing applications like to see.

What that means is there is an occasional failure event that is either not include or that is included when called a failure that we might not call a failure which one has to be aware of on a plant specific basis because the numbers of failures to key components on a specific plant are relatively small.

But across the industry if you want to look at, say, certain types of valves or pumps or whatever, there's a pretty good data base there. Let's say there's 100 failures per year of certain types of valves and we're probably getting 98 of those. That's pretty good.

MR. ROSEN: Is it true that EPIX also

collects runtime data for operating equipment and successful tests?

MR. BARANOWSKY: They collect some of that. Dale, can you? Dale Rasmuson.

MR. RASMUSON: They collect information on a quarterly basis for some of the systems such as runtimes and demands and that. In others they estimate it. They should have collected information over like the past year or two years and then they put in an estimate of what the runtime would be for that time.

MR. ROSEN: Well, this is the famous denominator problem that we've talked about. Right?

MR. RASMUSON: Right.

MR. ROSEN: Which EPIX really takes a shot at.

MR. RASMUSON: Which it really does.

MR. ROSEN: Which is a whole lot better than nothing.

MR. BONACA: Now, we asked questions about EPIX three years ago. We actually recommended that everybody would report so I talked to INPO about that. Is everybody reporting?

MR. BARANOWSKY: Everybody is reporting and, in general, they are doing pretty good. If you want a better characterization, I would have to ask Dale.

MR. RASMUSON: Most utilities are doing a good job of reporting on the components that we're interested in. We haven't taken a look at all the things. What we want is just a small subset of all the components there. There are some utilities that report but not real well. I would say like 90 or 95 percent of them are really doing a good job.

MR. ROSEN: Isn't it true, Dale, that INPO checks that?

MR. RASMUSON: They have.

MR. ROSEN: Somebody actually goes to the plant as part of the evaluation and has a look at what they're doing and make sure they are at least getting the main report.

MR. RASMUSON: I don't think that happens but they do have what they call right now -- Bennett, correct me on this if I make a mistake here but right now they have moved to a new data system where they are submitting their data on the Internet. That comes in. They have developed programs to check the data to make sure that the data is coded and that errors are not in there. Like, for instance, negative values for demands or things.

As we have been getting a submittal from INPO and we load it, we have our checks in there and we are finding that -- well, this time we just got one yesterday and I sent it out to Idaho and they loaded the data into RADs and there were no negative values in the thing. We've had them before. Just a few. The quality of the data is increasing and we have good data now. We can do some good analyses and come up with some good estimates.

MR. BONACA: I see the LERs looking for comatose failures so you are looking under EPIX. You find consistency in those assessments that you get from them. I'm asking more about the quality of the information you are getting and if it is, in fact, consistent or if it gives you signs that there are some problems to the reporting.

MR. RASMUSON: Basically I think EPIX is a great improvement over NPRDS.

MR. BARANOWSKY: NPRD.

MR. RASMUSON: Over NPRDS. Sorry. Over NPRDS. We get a lot more narrative in EPIX where in NPRDS you were limited to like three fields of 240 character. Now we have lots and lots of text that goes in there.

MR. ROSEN: You have to remember it was

done in an era when you had to name a file with no more than eight characters.

MR. RASMUSON: Right. I know.

MR. BONACA: My question is more directional. In the past we relied heavily on LERs for identification of common cause failures but they are a limited set of information coming in. Now you get EPIX. Does the information coming from EPIX confirm what you had?

MR. RASMUSON: Yes. In our database before -- our common cause database before about 60 percent of our common cause failures were coming from NPRDS where we actually were building up the failures.

MR. BARANOWSKY: So we have more confidence in EPIX to provide the raw information than we did from NPRDS, plus we've got the LERs. We can cross compare and we have done that to make sure.

MR. BONACA: Common cause is a bad example because, of course, I mean they look at those and they would be in LERs anyway. What about component reliability? Do you get really different information or do you look at the two sources?

MR. RASMUSON: We are just getting to where we can really do some comparisons in that. The system studies had not been updated for quite a while and we have that now. We have just posted on our webpage new system results and now we're working on getting down at the segment train level where we can actually do some comparisons. Some of the comparisons that we did for auxiliary feed water pump, just a real quick spot check, EPIX in our system studies gave very good results.

MR. ROSEN: I would be remiss if I didn't ask a question about fire events. The question I have is fire events that last more than 15 minutes are reportable, I think, under LER, but those fires are -- all fires are important from a risk analysis point of view because little fires become big fires.

Even short duration fires ultimately become big fires if you don't do something about them. My question is are the fire events in EPIX only the reportable fire event or is there some lower categorization of fire?

MR. RASMUSON: There's some lower categorization of fires also and our fire events are also supplemented with information from Neal, the fire insurer.

MR. ROSEN: So you are getting some robust fire database or analysis?

MR. BARANOWSKY: Yes, I think we have a

pretty extensive fire database down to smoke events and don't have fires.

CHAIRMAN APOSTOLAKIS: Interesting.

MR. ROSEN: This is very important, of course, because the importance of fire in the overall risk perspective.

MR. BARANOWSKY: That really covers the consolidated data. I would just mention what the status is on this because we did have to do a fire amount of software work so we've gone through the development and trial testing in August and we have a webpage now that we put together that allows some access for NRC staff. I presume that means ACRS members, too.

We're testing this out and modifying it to see if the information that's conveyed when someone queries the system is useful or could change. Eventually we are going to have this set up so it can be available externally but we have some additional work to do to make that happen.

MR. SHACK: Does that mean somebody can download the Excel database?

MR. BARANOWSKY: I think we want to let them have access to raw information but I don't believe they will be able to download a database.

MR. SHACK: On the internal webpage?

MR. BARANOWSKY: I don't think so.

MR. RASMUSON: No, not really. Not at this time. Right now we're working our way -- we've got some phases outlined here.

MR. BARANOWSKY: Let me just show this picture. This will show you the kind of things that you can find on the website. In other words, all the analysis work that I talked about, we're trying to figure out how to get that out to folks because now we have it available here. We need to not only make it available on the website but then the next step is to make sure that those who use this information would be aware of it.

Activities along that line are going on now. In fact, I think we have a communication plan that we put together. I noticed recently that NRR is giving a briefing on how to get access to operating experience events, information which includes this website. We have the ability on the left-hand side here to do some word searches from reports. Right now it's LER but that can be expanded to whatever anybody wants to put in there.

Then we have the kind of raw data and what I'll call processed data that we've collected which feeds into the charts, tables, etc., that are related to initiating events, components, and so forth. That's the bulk of it, by the way. Then on the far right we do also support the --

MR. ROSEN: Which right? Your right or our right?

MR. BARANOWSKY: Your right.

MR. ROSEN: Okay.

MR. BARANOWSKY: On the far right we have some work that we're doing to make available, for instance, ASP program results and insights as opposed to having someone go and use a special database which is also available but maybe not quite as readily known and accessible.

MR. ROSEN: What I'm taking away from this is that I could go in and look at the fire event database today if I wanted to if I was at my computer.

MR. BARANOWSKY: You can go in and look at the output of the fire event database. I don't know if you could go in and yank the whole database out. Eventually we are going to let you be able to query the database.

The first step was we've collected information on all kinds of fire events, put them into bins, and we have numbers and so forth and some parameters that we calculated and that kind of thing is being put into -- is either in or being put into the website now.

MR. RASMUSON: Right. That's on the website now.

MR. ROSEN: What kind of things? Do you mean like fire event databases in bins like fires that lasted longer than five minutes, 10 minutes in duration?

MR. BARANOWSKY: It could be duration. It could be location. It could be damage. I don't remember what all is stored in there. The idea is to get someone like you or another interested person to go in and say, "I couldn't find this that I was looking for," and then as we collect that, what folks are actually trying to extract out of the database we can adjust it to be able to do that.

It's not set up so that anybody can do anything. That's way, way too costly for us to do. Ultimately you'll get to the point where you can query the database to some extent but we've got to put the tags and flags in there and we can't tag and flag every single possibility. We are trying to flag and tag them based on how they are used in risk analysis but we are open to other ideas, too. I would ask anybody who's interested to go in and take a look.

The next item is the action sequence, precursor analyses. This project has been going on for 20 something years. I don't think the objectives have changed very much in terms of systematically analyzing operating experience events to understand their risk implications.

The methodology and sophistication has actually changed and it's sophisticated enough, I think, that we can use it to understand where there might be some areas in PRAs that we would want to improve the capability not necessarily so much because the total risk might be significantly underestimated but if you want to get down into details where you want to make changes in regulations or plant specific things, you need to know more than the overall risk.

I think we've got a pretty good handle on the overall core damage frequency but when we get down to the lower levels that we make decisions on tech specs or licensing amendments or even changing regulations, that's another story.

MR. ROSEN: This webpage that you talk about in the prior slide, that's accessed through NRC.gov?

MR. BARANOWSKY: Yeah. We should have

given you the -- it's not on here. We should have given you -- does anyone here know the website?

MR. RASMUSON: I will see that you get the URL for it. It's on our internal webpage right now and you can get to it through the RES webpage but I'll get you the address.

CHAIRMAN APOSTOLAKIS: If a graduate student wants to get some curves for the failure rate of a particular component, they can do it?

MR. RASMUSON: Yes.

MR. ROSEN: Well, he has to get to the internal webpage.

MR. BARANOWSKY: Oh, yeah. He has to have access to internal. Because of security we haven't been able to get the external one working.

CHAIRMAN APOSTOLAKIS: But how could -- so that means it's not accessible.

MR. BARANOWSKY: Well, it's not accessible if you're not considered an internal cleared person.

MR. ROSEN: So it's not off NRC.gov.

MR. SHACK: It's internal .NRC.gov.

MR. BARANOWSKY: And we just rolled this out a couple of months ago, by the way, so it's like a beta test version.

CHAIRMAN APOSTOLAKIS: And then what

happens? We can do that?

MR. BARANOWSKY: If Citrix happens to be working that day.

MR. ROSEN: It doesn't work on Government holidays.

MR. BARANOWSKY: Within a year I think we would like to have this thing well accessible and improved to provide information so it's something to think about.

So the accident sequence precursors, let's give you a little picture here of what we've been seeing. Normally we trend the accident sequence precursors over about an eight to 10-year period and we have been trending now for the 1993 events. If you trend that batch of events there, you can't come up with an increasing or decreasing trend with any statistical competence.

But if you look at '97 on, you'll see that we've seen more events. You know some of the big ones as well as us. We've been actually swamped with trying to analyze some of these pretty significant events. They are important to us and they are important to licensees because many of them go into the SDP so there's really a lot of attention to how the analysis is done.

Simple assumptions that used to make it quick and dirty get within a factor of 2 or 3 that I'm happy with are not acceptable anymore. People are concerned about whether the best estimate is 8×10^{-7} or 1×10^{-6}.

MR. ROSEN: Well, it might only be a liberal distinction to that whether or not it goes from white to yellow. That's the thing. Most of these are on the edge when you start arguing about what should be in the model and how the model should be adjusted.

One thing that we have been doing is spending a lot of time looking at model uncertainties and parametric uncertainties. I don't think anybody is systematically incorporating insights from model and parameter uncertainties into their thinking about what does this all mean. They are all taking the point estimates and running with them.

For instance, I've seen 9.7×10^{-6} called something that's in the 10^{-6} range. If I draw a distribution about that and I show you the modeling uncertainties that go along with the parametric uncertainties, over half of what we're worried about is up over the --

CHAIRMAN APOSTOLAKIS: We try not to

sensitize people to the importance of modeling uncertainties. In a couple of years you're going to see some results.

MR. BARANOWSKY: Decisions in light of uncertainty is not something that we're taking on. What we are trying to do, though, is bring the uncertainty out. Don, you had some examples here that maybe I can show. These are backups. Let me show these.

Let me start with this one. This was a low service water flow incident to the diesel generator coolers at the Cook plant. This chart shows the end result of our analysis which included both model and parameter uncertainties. If I can read this, you can see -- I don't know what the point estimate is but -- what are these two marks here, Don?

MR. MARKSBERRY: The licensee.

MR. BARANOWSKY: Oh, licensee doing an estimate. This one? Sorry. This one is the licensee's estimate. This one is --

MR. MARKSBERRY: The STP.

MR. BARANOWSKY: The STP estimate. This range represents our best estimate including both model and parameter uncertainties. Then we had sort of a low and a high model result. This is the high end of model uncertainties and the low end. We don't know how to put these --

CHAIRMAN APOSTOLAKIS: I wonder how you did that. Do you have a report?

MR. BARANOWSKY: We have a report. Here was the key modeling uncertainty that had to do with debris in the forebay and how that impacted the diesel generator cooling system.

CHAIRMAN APOSTOLAKIS: Boy, this is --

MR. BARANOWSKY: This is a routine ASP event.

CHAIRMAN APOSTOLAKIS: This is an aria to my ears. We are making a note here that we will get the written document from you guys?

MR. BARANOWSKY: Yes. You can get it. I need to let you know that it's classified sensitive because of the PRA information in general meets a condition and guideline that was set out almost two years ago. We're trying to get that changed so it can be released to the public because I don't personally think there's any security information in the ASP analyses that we have to worry about.

But, in theory, one could use precursor analysis with location and vulnerability information to identify security issues. We pretty much scrubbed this so you don't have that in there and we're trying to get the criteria changed. But certainly internally ACRS you can see this so just be aware that will have --

CHAIRMAN APOSTOLAKIS: The model uncertainty, I mean, I don't know if you've seen the last letter from the ACRS on this.

MR. CHEOK: This is Mike Cheok. I have a comment on the Cook analysis. That's draft right now. We will put the file out in about a month so we might want to wait until a month from now before we sent out the final analysis.

CHAIRMAN APOSTOLAKIS: Do you have any other examples?

MR. CHEOK: We have several other examples.

MR. BARANOWSKY: We can send you probably three or four.

CHAIRMAN APOSTOLAKIS: If you can. I'm not interested in just Cook.

MR. SHACK: Now, that SDP, that was a SPAR analysis point estimate or that's a notebook analysis?

MR. BARANOWSKY: No, no. Oh, who knows?

DR. O'REILLY: It was -- this is Pat O'Reilly. I believe it was a Phase 3 analysis and it was not necessarily using a SPAR model. It was kind of a hybrid type of analysis.

MR. SHACK: We're supposed to get conservative results. Right?

MR. BARANOWSKY: Well, normally you are supposed to but when you read the report on Cook you will the level of sophistication that went into our analysis. I doubt that the SDP at this point can afford to move up to that standard. The question is whether or not what they did is adequate for identifying performance issues that should be followed up on as opposed to whether they got the risk number right to within a factor of 10.

MR. SHACK: What does right mean?

MR. BARANOWSKY: The thing about the accident sequence precursors is we apply this standard basically to all of our work so you can compare and add A and B together and not have apples and oranges if you want to get some notion of whether we're looking at the really significant ones or not.

I think from the SDP point of view they are identifying things that we ought to follow up on in inspections and that is what they are supposed to do. Hard to explain to the public sometimes why they are different but that's the thing.

George, you had mentioned that we had some insights. These are what I would call pretty high-level insights. What we haven't done is gone and really scrubbed the ASP work to see if there are more profound things than just saying 20 percent of the incidents have some unique characteristics to them that are not usually captured in PRAs.

If you are making decisions at that level in the PRA, you might have some problems drawing the right conclusion if these things weren't incorporated in there. There are reports on each of these. There was one that was an RCS blowdown into the refueling water storage tank at hot shutdown which was a fairly high risk contributor. A couple of strange things happened when the reactor tripped and loss of surface water.

CHAIRMAN APOSTOLAKIS: So the question is if I go now to the PRA, which is done for hot shutdown, am I going to see a failure mode like this?

MR. SHACK: I don't think so.

CHAIRMAN APOSTOLAKIS: That's the thing that we need to spread the word and make them more realistic.

MR. SHACK: Yeah. This is something like an event B sequence but not exactly. It's an interesting way that it got there. There weren't dials that failed or anything. This was an operator made a mistake or got confused.

DR. O'REILLY: They had conflicting operations going on at the same time, George, and neither of the two were in communication with the other.

CHAIRMAN APOSTOLAKIS: Okay. So the industry doesn't know this but do our own guys know these things? When they receive a PRA or a piece of a PRA in support of a risk informed decision do our own guys know about these things?

MR. BARANOWSKY: Well, the information is available and, as I said, it's not always so easy to go to so they may not go to it. One of the insights from the operating experience task force is we need to make this easy to get to.

CHAIRMAN APOSTOLAKIS: If a reviewer from NRR is dealing with shutdown modes, is there anyway he or she can press a couple of buttons and get all these insights regarding these modes? Do we have that yet?

MR. BARANOWSKY: No.

CHAIRMAN APOSTOLAKIS: Think about it. Maybe that's what we need.

MR. BARANOWSKY: You are right. As I

said, if we had the resources we would go through and put together a little better package that would allow you to dig down. Start off with high-level considerations and then lead you down to the details so you could use it appropriately.

Right now the way it is is you would have to just go in and scroll through all the ASP events and be able to figure out which ones you want to look at. We don't have them categorized and classified.

CHAIRMAN APOSTOLAKIS: They're never going to do that.

MR. BARANOWSKY: They aren't going to do that. You're right.

CHAIRMAN APOSTOLAKIS: Unless it's easy access, they're not going to do it. They have so many other pressures. I mean, it's not because they are bad guys. They have lots of things to do.

MR. BARANOWSKY: I'm trying to get Don Marksberry to work Sundays -- he's already got Saturday booked -- to do this but he just says he's got to have a day off.

CHAIRMAN APOSTOLAKIS: I don't know about that.

MR. BARANOWSKY: This is an identified issue.

I'm not going to say too much about the Industry Trends Program because we had a briefing -- how long ago was that, Dale?

MR. RASMUSON: Just a month ago.

MR. BARANOWSKY: Two months maybe. Let's talk a little bit about it for the benefit of anyone who either wasn't there or some update things. I'll let Dale do some updating, too.

The Industry Trends Program is a complement to the reactor oversight process. It's not actually a part of it.

CHAIRMAN APOSTOLAKIS: You guys want to take a five-minute break?

MR. BARANOWSKY: That's fine.

CHAIRMAN APOSTOLAKIS: Okay. Back in five minutes.

(Whereupon, at 10:42 a.m. off the record until 10:50 a.m.)

MR. BARANOWSKY: Okay. Just briefly on the Industry Trends Program, it focuses primarily on industry-wide implications of things and trends so it complements some of the more generic activities that the NRC does. What we are doing is supporting NRR on this project and they are using a lot of the information that we have in our initiating event and systems studies that trend the performance of equipment or initiators over time.

If there is a significant deviation in time for this integrated look, then that should spur us on to look more closely at whether or not there is a generic issue here. Then we could take either the lack of such conditions or their existence and report them to Congress as part of the NRC's performance and accountability requirements. That is one of the major things that pushes this project.

There is a process, and this is really an NRR process but I just wanted to show it, in which data is fed into the process and we analyze it and looks for trends on specific things. The items that are going to be trended are not just any old thing. We go through a process of picking what's going to be trended, what the scope is and so forth.

For instance, I think we picked six specific initiating event categories with specific definitions and the counts for those things are sort of rigorously defined so that we don't have differences every year that's based on the way people count things or do their work and we wouldn't be able to get a reasonable trend.

That goes into the process, as I said, in which we, meaning the agency, looks to see if there is something evolving here. If there is a significant degradation, then the senior managers have their meeting once a year and talk to the Commission and it could be identified there and discussed in terms of agency response activities which normally would be underway by that time.

And if it meets certain criteria, it can actually get report up to Congress where it's a deviation in performance that's degrading to the point we think we have to go and tell Congress that there is a problem evolving here. That's the process.

What we've been working on lately is an integrated indicator in which we can take most of the risk significant, if not all the risk significant, events which have different risk importances and weight them accordingly and come up with a single indicator more for the reporting to Congress than anything else.

We still have the information disaggregated down into the 10 or 15 types of indicators and we use that as safety engineers at the NRC. But how do we report trends on 15 or 20 initiating events with different risk significance. And if this ever gets expanded into the other cornerstones, we could have literally 100 indicators and that wouldn't make any sense. The idea was to come up with a way of rolling this up.

Currently what happens is they're just counted. A large break LOCA would be counted the same as an innocuous reactor trip, turbin trip, in which the plant started up a few hours later. That's not the way this is set up. It goes into the risk importance measure and it weights it and its potential impact on core damage frequency for the specific plant that had the incident and we used the SPAR models for this.

Then we collect the information for a year and then year by year we can put it together and show the trend. That's what we presented at the last ACRS meeting. The point that we got to now is we finished the initial development at work and we're sending it over to NRR shortly and a decision needs to be made as to whether or not they want to do some trial and specific implementation kinds of activities while we fine tune things. You know, make sure it has QA. Make sure it's a production thing instead of a research activity. That's pretty much where we are on that.

The next item is the SPAR model

development program. I'll go through this in the order that we identified types of SPAR models that we are developing. First thing is the so-called level 1 Revision 3 models which are the full power SPAR models and we now have 72 of these models developed which represent all the operating reactor configurations.

A couple of them are close enough that we can use virtually the same model but we can make as-necessary adjustments on, say, performance data or even some recovery factors. Are there any other things we would change?

We're done the on-site QA reviews for all of these which actually was an ACRS recommendation two years ago. We went out to every site. We gave our model to the licensees, we got theirs, and we compared them and we saw where there were differences. Where we had the designation "i" means we haven't addressed those differences yet so there's quite a few of them that we haven't been able to address the differences yet. When we do address them, then we just call them 3.

DR. O'REILLY: We have about 25 models left to complete the follow-up on those on-site QA reviews.

MR. ROSEN: I'm delighted to hear that.

I think I was one of the people who sort of suggested that. In fact, I went further. I suggested why don't you just throw these away and get an agreement with the licensee to use their model.

I think I understand the reasons you don't do that now, but clearly you didn't want to be in the situation you're in where your model was just plain wrong and the licensee would tell you that the first time you tried to use it. You wanted to find out your model was wrong and not up to date before you tried to use it in some contentious proceeding.

DR. O'REILLY: Well, you should be aware that there are some cases in which we have agreed to disagree with the licensee's PRA.

MR. ROSEN: As long as you know that the plant has three of these and not two.

DR. O'REILLY: Correct. That was the main purpose of these on-site QA reviews which, by the way, we did in conjunction with NRR's benchmarking of the SDP notebook for the plant.

MR. ROSEN: And more than just three of these, not two, that there's a connection between here and here which is modeled that they can take credit for in their analysis. You ought to understand that, too.

DR. O'REILLY: Yes.

MR. BARANOWSKY: We have a good understanding now of the physical plant as operated which we're trying to incorporate into the models at the level of detail that we work with. We also went one step further and that's this third bullet here as part of our Mitigating System Performance Index.

There were 20 plants that were part of the pilot program and we did what I call an enhanced SPAR model which now goes down to the level necessary to model the plant for the key systems in the Mitigating System Performance Index, support systems and all their interconnections some of which were put in as undeveloped events in our simpler models.

This work has been getting pretty high marks from folks that we worked with because we are really understand where there are any differences and what those differences are between what an NRC model and standard set of assumptions might give versus licenses. I believe we have a very good agreement in many cases.

We have identified a few issues which while we have our standard of approach might be to, say, use a RELAP generated success criteria and a licensee might be using MAP. We're just saying those are differences which should be resolved and we're looking at how that might happen over the next year or so.

At least we're aware of it. We are aware if their risk number is a little bit different than ours, we understand it's because of slightly different success criteria. We can now focus in on the things that are driving those success criteria and hopefully get to a much closer result.

Don Dube gave a presentation to -- I don't remember which subcommittee it was but we had some extremely close calculations and core damage frequency and importance measures. These are our own models. We did them ourselves and all we wanted to know is how is the plant designed and operated. We didn't use their model.

MR. ROSEN: What do you mean by close?

MR. BARANOWSKY: Close to the core damage frequency.

MR. ROSEN: Close to the licensee's estimate.

MR. BARANOWSKY: The licensee's estimate and then if it was different we could say exactly why it was different. What we are trying to come up with is a list of items that we can work in some form.

We're not sure how. Possibly through the ASME standard activity to resolve these things so that we don't argue about those kind of modeling things on regulatory applications. We argue about other things like thresholds and risk philosophy and whatever.

MR. BONACA: This is level 1, no external events at power?

MR. BARANOWSKY: Yes. We've done a lot of work at the at power. I think we either have very good models or where there are limitations, we understand what we're missing in the models.

In fact, we're planning on putting I'll call it a warning of some sort or an advisal up front in our SPAR models indicating the specific limitations for their use so that when those folks who didn't develop them go out and use them, they will know that they have to be concerned about the level of detail, say, in the service water across connect model and you've got to use accordingly. Supposedly these things are to be used by skilled practitioner stuff, just push button.

I'm going to skip the next one. Let's go to low-power shutdown. With low-power shutdown I think we had a briefing on this.

DR. O'REILLY: A year ago.

MR. BARANOWSKY: Okay. We have completed the BWR and PWR templates. We have some SPAR models. This low-power shutdown is a little bit different because plants don't go through the same exact evolutionary characteristics or process every time they shutdown so it's not a push-button model by any stretch of the imagination. It's more of a model with procedure for making it fit what you have actually observed.

MR. ROSEN: And the difference is enormous.

MR. BARANOWSKY: Yes.

MR. ROSEN: For instance, if a PWR does a hot early mid LOOP or doesn't, the risk number for that shutdown will be enormously different. Wildly heterogeneous in time and enormously different from outage to outage.

MR. BARANOWSKY: I mean, more so than for sure the normal operating condition plants you have to have an analyst who can work with these models.

DR. O'REILLY: Because of that, we are concentrating on an approach that does plant categories versus trying to have a low-power shutdown for each individual plant.

MR. BARANOWSKY: So it would be sort of a general model, if you will, that you have to make adjustments for some guidelines.

DR. O'REILLY: Correct.

MR. ROSEN: So when you advertise this to the agency and say here is the standard outage for PWR, let's say, and put a risk number on it, you will be making a mistake. You're going to have to say here is a range of outages.

Someone is going to ask you ultimately and you're going to have to say something like, "Well, it depends what you do. Here's a range of outages. Here's one that is pretty low risk and here's one that's pretty high risk and you'll notice the differences."

DR. O'REILLY: Right. We've tried to capture the several most risk important configurations for low-power shutdown but you're right. A particular plant one of those might not be quite as risky.

MR. ROSEN: Or you can do it at a different time during the outage when decay heat is down and it will change the structure again. Not only whether you do it but when you do it will be important.

DR. O'REILLY: That's right.

MR. BONACA: You could blow the whole

core.

MR. ROSEN: Right.

MR. BONACA: I mean, so you have no mid LOCA concern.

MR. ROSEN: Right. Sometimes it's zero

MR. BARANOWSKY: You'd have to go back and look at their past history of what they did and I can only tell you what their risk exposure was. Or if they will tell us what they are going to do in the future, then we can do that, too.

MR. ROSEN: They won't do that because they don't know.

MR. BARANOWSKY: So that's the limitation. You're going to have to be an analyst that can work this thing as you go through it.

So we'll be conducting QA reviews and we have a couple of more, what do you call these, these standard models or whatever.

DR. O'REILLY: Lead plant models.

MR. SHACK: Now, is this built on top of the enhanced SPAR or is this a 3 or 3i?

MR. BARANOWSKY: It's different.

DR. O'REILLY: I'll tell you what will happen is enhancing the Revision 3 SPAR models can result in enhancements to the low-power shutdown models because we pull in the fault trees from the Rev. 3 models into the low-power shutdown configuration.

MR. SHACK: Okay. But in the event diagram this all overlaps. There are low-power shutdowns on enhanced models and on non-enhanced models.

DR. O'REILLY: It could happen that way, yes.

MR. ROSEN: So this fiction that's being perpetrated that there's no risk analysis for shutdown is clearly demonstrated to be wrong here.

DR. O'REILLY: We hope so.

MR. ROSEN: You need to contest the people who some up with this fiction now and then that plants only know yellow, red, and orange. There are lots of plants that do better than that.

DR. O'REILLY: There are a few. We are finding out there aren't a majority but there are some out there, yes.

MR. SHACK: Have you computed some comparisons with yellow, red, and orange?

DR. O'REILLY: We've only gotten one on-site QA review of low-power shutdown model completed because most of the ones that we have models for are also participating in this MSPI comparison exercise and we did not want to put additional burden on the licensee's PRA staff so we had to delay the rest of those.

We reported to the subcommittee last October about the results of the one on-site QA we did at the Surrey plant. As I said before, we got mixed results out of that. Part of the problem was the lack of knowledge on the part of the licensee's PRA staff about their low-power shutdown model. They had it done by a contractor and were no longer working with that contractor at the time.

MR. BARANOWSKY: Okay. The next thing that we're doing is we are developing the large early release frequency models. We've done some development work here that we completed including the bridge trees and containment of entries. The bridge trees bridge from the level 1 models basically to the core damage states and containment failure states. We have incorporated peer reviews. Who was involved in that peer review? Can you remember?

DR. O'REILLY: It was an internal peer review but I do believe that the reports came to the ACRS.

MR. BARANOWSKY: I don't know that we have briefed the ACRS on this. Have we?

DR. O'REILLY: No. We talked to you about this last year but you couldn't fit it on your schedule.

MR. BARANOWSKY: So let us know. We would like to hear more about it. There's not a lot of ability to do LERF analysis without going through extremely detailed and time consuming and costly process like the NUREG 1150 type of things. Or just pulling things out of the air saying, "I think that's going to be a big release and an early one," and just calling it that.

This gives us some capability in between there. It's not perfect but based on what we understand to be important in talking to folks who are doing the more sophisticated developmental activity, we are incorporating those features that seem to have the biggest drive in here. Again, it's another one of these things that is going to have to have procedures for its application.

DR. O'REILLY: Yes.

MR. BARANOWSKY: More than just the level 1 core damage frequency models.

MR. CHEOK: Let me say something about that, Pat. Remember when we were talking when you were developing the 174 reg guide and we had this NUREG on LERF, a lot of the small LERF models starts up with that NUREG where we can convert from CDF to LERF.

MR. BARANOWSKY: So we'll continue to develop these models for lead plants and if it seems appropriate, we would be glad to brief the committee.

I'll also mention that we haven't started yet but have future plans to do external event models. Again, we don't know exactly whether they would be more of a procedure and process approach or a hard model that is mostly push button. We would have to come up with a scheme.

MR. ROSEN: I think you know you're going to treat fires as an external event. Right?

MR. BARANOWSKY: Fire, flood, seismic, and external winds.

MR. ROSEN: High winds.

MR. BARANOWSKY: High winds. And they are all different enough in the way you are going to analyze them that it's not just a simple matter. We put that off to the end, but there is a crying need for us to have that, in particular, in the significance determination process.

When we did it for the power states, we

had fairly detailed PRAs and lots of them that we could work back from including our own. I mean, licensees and PRAs. You go to the external events and there's just a few studies and a few PRAs.

MR. ROSEN: If I asked you what happened during Hurricane Isabel to certain plants that tripped, you know, what was the risk, do an ASP analysis?

MR. BARANOWSKY: We could do the analysis but it would cost.

DR. O'REILLY: We would have to create our own custom model.

MR. BARANOWSKY: We've done that.

MR. ROSEN: Those plants tripped because of salting on the insulators because there was a lot of high winds and they are seacoast sites and there was no rain to wash the insulators. How do you model that, the high winds?

MR. BARANOWSKY: Actually it becomes easier to model something that has already failed and just what the consequential situation is and we predicted just that.

MR. ROSEN: But I'm not interested in just that. I'm interested in how likely was the event.

MR. BARANOWSKY: That's different. That's what we would have to spend some time on.

The last item is the Mitigating System Performance Index which we briefed the committee on a few months I guess. I think I mentioned that this did evolve from some work that we did on risk-based performance indicators.

It was put together in response to a request to promptly address some problems associated with the current performance indicators. It's what we call highly risk informed but there are a number of things that are done that make it not risk based per se but it's highly risk informed.

It accounts for unavailability and unreliability consistent with PRAs which gives us a nice connection there. It's more plant specific by far than the current set of indicators, it eliminates the fault exposure time problem, eliminates the cascade of cooling system support system failures onto front line system issue.

MR. ROSEN: In other words, it treats it properly.

MR. BARANOWSKY: Well, treats it properly. And the thresholds are consistent with the current performance indicators.

MR. ROSEN: And it's DOA, I understand.

MR. BARANOWSKY: And it's DOA. No, it's not DOA.

MR. ROSEN: Good. Why isn't it dead on arrival?

MR. BARANOWSKY: I'm going to explain that, I hope.

MR. ROSEN: I hope it's not dead on arrival.

MR. BARANOWSKY: Let me just finish this and I'll address that and then we'll see if it's DOA. We did do a pilot program on this. Did we report the pilot program the last time we came here?

SUBCOMMITTEE MEMBER: No.

MR. BARANOWSKY: Okay. And we are planning, by the way, a future ACRS briefing to follow up the last one plus the new stuff that happened. Don, when did we have that approximately scheduled?

MR. DUBE: I think probably early January or sometime.

MR. BARANOWSKY: And in December we are shooting to release the draft report that analyzes all the issues that evolved from the pilot program and how we came to a conclusion as to how they could be addressed technically. So the pilot program went through an exercise, the original version of what the

Mitigating System Performance Index was.

Until you try something out you never know what kind of bugs are in there and whatever. And then we found things that needed to be fixed up and we did. I'm not going to go through the details but this was part of our validation and verification effort because the licensees were the ones who were actually trying out the performance index and we were just doing some double checking validation verification work.

That included the need for us to upgrade the SPAR models which I described earlier in order for us to do that. We couldn't even do it with the original SPAR models. They weren't detailed enough or accurate enough.

They were good enough to get the overall core damage frequency and some key sequences but you have to go down into a level where the importance of key components is really fairly close if you are going to be making decisions that may change and performance pushes you over a threshold with a delta CDF 10^{-6} which is basically in the second or third decimal place of your overall knowledge on the core damage frequency.

MR. ROSEN: It turns out when you go out to plant, systems they are made of components.

MR. BARANOWSKY: You do what?

MR. ROSEN: It turns out when you go out to plants and put your hands on the equipment, systems are made of components together.

MR. BARANOWSKY: Right.

MR. ROSEN: It's a nasty fact of life.

MR. BARANOWSKY: It is. We came up with a neat little approach to incorporate components into the system in whatever levels allow us to work with a performance threshold that is based on what was promulgated in SECY 99007 when we did the reactor oversight process which is these 10^{-6} levels that get you from the green to white to yellow to red and so forth.

Okay. So what's the status now? We've had several meetings to go over technical issues. Of concern are whether or not we will be getting false positive or false negative indications of degradation and performance and equipment that is highly risk significant.

It only takes a few failures if you are looking at a short period of time to call a failure rate high, let's say, when normally you would collect data over a longer period of time. That's an issue and we have come up with schemes for dealing with that which we did not present to the ACRS.

Why don't you give a summary of a couple of the key items that we resolved and then we're just going to come and talk to you again.

MR. ROSEN: Put your last slide back on just so I don't have to look at that white background.

MR. DUBE: This is Don Dube. There were a number of issues identified but there were really six major issues. Of those we presented proposed solutions in the July 23rd meeting and had some go arounds. Industry has concurred with five out of the six resolutions that we have proposed.

These have to do with invalid indicators where there is only one failure -- one failure results in a white indication. Or, at the other extreme, insensitive indicators where it takes dozens and dozens of failures to reach a white indication. What we have proposed is putting a front stop and a back stop to address both sides of the issue.

They have agreed on those approaches pretty whole heartedly. The only outstanding issue is the extent to which we include the contribution of common cause failures to the importance measures and whether that should be part of the MSPI methodology. Really there's only one outstanding issue and I think we can come up with a resolution on that.

MR. ROSEN: So it's not that other arm. The minds have been greatly exaggerated.

MR. DUBE: No.

MR. BARANOWSKY: Let's talk about some of the things that have come out. You might have even read about these in Inside NRC. There are issues related to whether or not we can use licensees, PRAs as they exist to do the Mitigating System Performance Index calculation mainly because of the concern about PRA quality and what that means.

What we have done is try to identify the specific aspects of the PRAs that if you make a different assumption such as using the success criteria from RELAP versus the MAP code, what impact that has on calculating the MSPI values.

Because we are putting in these performance based approaches with front stops and back stops, it becomes less sensitive to the precision of the PRA. We need to run some simulations to verify how sensitive any of those issues are. We haven't done that yet.

MR. DUBE: Well, we've started. In fact, one interesting result is that at the July meeting I presented to you and I said that one particular plant has a difference in success criteria than what we assume in the SPAR model. They said their success criteria is one out of two PORC for feed and bleed and many plants of that design have two of two PORC as a success criteria. We know the change in core damage frequency.

Now what we're doing is our MSPI sensitivity studies and looking at how differences in the PRA models and outputs affect the MSPI results. In this particular case depending on which assumption you use you may either get a white indication because of some failures of feed water pumps or a yellow indication. It's extremely sensitive. But other cases what we found is there are differences in let's say failure rates between the SPAR model and industry PRA. Some people are saying those are unacceptable. What we've done is rolled all the differences and doing sensitivities on those and we find, hey, it doesn't even affect the results to more than a factor of 1.5 or 2.

We are doing these sensitivity studies and getting a feeling for how sensitive is the output, which is the MSPI result, to the input. As you do enough of these you start to see an interesting trend.

CHAIRMAN APOSTOLAKIS: Mr. Cunningham

mentioned it today but Mary also a month or two ago. The stuff is developing a regulatory guide on how to do sensitivity and uncertainty analysis. It's all within the bigger context of PRA quality and PRA standards and so on. I think it will benefit a lot from the insights that you gentleman have collected over the years.

In particular how sensitive certain things are to assumptions because this is one of the requirements in the PRA standard, the ASME standard, that you have to identify the key assumptions that affect your results. The regulatory guide will deal with how to do that. I think you have to talk to them. Are you in contact with them at all or shall we intervene?

MR. BARANOWSKY: No, the PRA quality issue needs to be resolved in a manner that is consistent with what they're doing. We're testing some things out. In theory, they are going to learn from what we're doing.

CHAIRMAN APOSTOLAKIS: No, but this issue of two PORCs versus one and so on, these are examples they have to be aware of. These are key assumptions.

MR. BARANOWSKY: We are feeding this into them. The feed is from us to them. We have the actual experience of doing the analyses.

CHAIRMAN APOSTOLAKIS: That's what I'm asking. There is a connection?

MR. BARANOWSKY: Yeah, and we are trying to feed that in.

CHAIRMAN APOSTOLAKIS: But they never tell you what they do, right? It's only one way?

MR. BARANOWSKY: Well, the concern that I have is we are working with specifics and then when you start getting into generalities of what PRA quality is, it becomes a discussion of philosophy as opposed to -- what I'm interested in is can I get a reasonably close analytic result so that when I apply it in a quantitative situation I don't get two potentially different decisions. That's all I care about.

CHAIRMAN APOSTOLAKIS: But this regulatory guide is not really dealing with the big issue of quality. It's dealing with the specific issue of what does it mean to do sensitivity analysis and what does it mean to do uncertainty analysis and how should I do these two things.

Obviously they have to be fully aware of some of the key assumptions that you guys are identifying. Anybody can talk about success criteria that are important but here is an example where it does make a difference what kind of success criteria you assume. That's all I'm saying. And this is happening.

MR. BARANOWSKY: I think I can give accident sequence precursor cases where we did the same thing. We would run through point analysis. We had like 20 issues raised. We went through 19 of them that had no impact but it took a lot of effort to go through them. We said only one causes the bottom line to change. The others are peripheral.

CHAIRMAN APOSTOLAKIS: I would like to get some of this information for my own benefit.

MR. BARANOWSKY: We're going to get you some of these accident sequence precursor things.

MR. ROSEN: So tell us the bottom line on MSPI.

MR. BARANOWSKY: Okay. The bottom line is we think we can resolve all the technical issues and there are still issues related to its acceptability as a replacement for the current process which involves a performance indicator and/or a significance determination evaluation on single component failures. I think that's about the bottom line.

Some people want to do SDPs on single

component failures and our position is that is best done through reliability analysis because of the context of false positives and false negatives if you don't look at it in that regard. We factored that into the front and back stop issues that Don has talked about.

MR. ROSEN: Why doesn't that resolve the issue? Now you have an MSPI that recognizes that you ought to not make broad generalizations based on one event. You use the back stops and front stops to make sure that you don't and now you move the MSPI into the ROP replacing those other outdated -- let's say those other partial indicators which I began developing in the '80s with something that is much more robust. I think you're doing great. Don't give up early.

MR. BARANOWSKY: We're going through the process and we're trying to address issues that people are raising about why they like to do it one way or another. I think we're slowly just making progress. It's a little bit more difficult than we thought it would be. I don't think we can just say it's our opinion you --

MR. ROSEN: Not necessarily disabling. Things that are difficult sometimes turn out to be good things. I think working with the industry is great but at some point you can declare victory and go ahead and make a recommendation to the agency that you move the ROP along. We didn't ever expect ROP to be the way it was on day zero forever.

MR. BARANOWSKY: I think we need to recognize that what we're proposing is not the perfect fix to performance indicators but a pretty good improvement that gives us a good handle on where we should spend our inspection resources.

MR. ROSEN: Look at the chart behind you, the one I had you put up. It just so happens to be that those bullets that you list, unavailability and unreliability are consistent with the PRA. It accounts for plant specific design and performance data which was one of ACRS' big complaints about it.

It eliminates fault exposure time which the industry complained about. It cascades properly the support systems, especially the cooling support system, and so on. Those are very significant advantages and I don't want to lose them. I think they are valuable. The longer we wait to accrue those advantages, that's lost opportunity.

MR. BARANOWSKY: One last point on that also is that this is new and different from the way anybody has done detailed performance indicator calculations and so there is a concern about what effort will be involved in implementing this.

We think we figured out how to handle the industry side and I think the industry folks are comfortable with it but there is a concern about how much inspection activity is appropriate and would be required. Do they have to inspect the PRAs? Do they have to inspect all the interpretations of data?

MR. ROSEN: Got it across the line into the agency, the concerns, which is wonderful because we could help you with that. This is the right direction for the ROP and I support it. You've presented me with a target rich environment so I'll confine my comments besides MSPI to just two others.

These PIs for the cross-cutting issues that we have been looking for and worried about, you gave me a troubling answer to what I said before when I said, "Look, you need to look at Persensky's and Flack's presentation from the other day and look in the potential performance indicators that he proposed on Safety Conscious Work Environment Corrective Action Program and Human Performance."

You said, "I don't know if I'm the right guy." Well, I'll hold you responsible. I don't know if you are either but I see you. It's troubling to me to have an agency person of your caliber and elevation in the agency to say, "I don't know who's in charge of this," because, you know, somebody has to be and you're as good a target as anybody.

This is important. Very important, Pat. We need to get this resolved. We brought it up in letters from ACRS to the Commission that here is an avenue. Please, between you and Flack and Persensky and whoever else, would you take the lead to say, "Okay, here's a way to go forward. Let's at least look at it." I'm not saying do it. I'm just saying here is a suggestion.

CHAIRMAN APOSTOLAKIS: Maybe we can say something in our research board about this because he needs help with that. He cannot take the lead.

MR. ROSEN: I know. I'm just troubled by somebody like him saying, "I don't know who's in charge."

CHAIRMAN APOSTOLAKIS: We'll make sure we raise that when we write the appropriate report because then I think some people may pay attention.

MR. ROSEN: I'll try. I'll try. Okay.

CHAIRMAN APOSTOLAKIS: We'll turn you into a psychologist.

MR. BARANOWSKY: Well, I'm sure you'll get me in trouble, but okay.

MR. ROSEN: I'm trying to get you in trouble.

CHAIRMAN APOSTOLAKIS: Because you don't get into trouble on your own.

MR. ROSEN: I want to get you into trouble and then out of it as a hero.

MR. BARANOWSKY: All right.

MR. ROSEN: All right. One more. On your slide 18, this was on integrated initiating event indicated development, you talked about rolling up the indicators and collect communications to Congress and other stakeholders. It seems to me that you've gone a long way to make some very important integrations of this information. This is just for initiating events, right?

MR. BARANOWSKY: Um-hum.

MR. ROSEN: But, at least, it says from a perspective of the industry and over time now as you trend this stuff you're going to be able to say whether this really is meaningfully going up or down. I think that's a very big value of it. In other words, it doesn't say how well the events were handled but it says whether they are occurring or not.

I think you can say over time that it has a lot to do with how well the industry is maintaining the plants and other things like grid reliability. It's a very important statistic to be watching over time now. It becomes valuable because of the things you've done with thinking about risk. For example, as you've quantified, don't just add numbers and send them to Congress.

My God, what could be worse than handing those guys loaded guns. They could shot them any place. They could shoot themselves with it. I think it's a very valuable thing and over time I think it could become even more valuable as long as we trend it properly and draw appropriate risk-based conclusions, risk-informed conclusions. Thank you.

CHAIRMAN APOSTOLAKIS: Any other comments by any members? You want to make any comments?

MR. BARANOWSKY: No, but we appreciate the briefing.

CHAIRMAN APOSTOLAKIS: Thank you very much for coming. This has been excellent as usual. Appreciate it. Thank you.

Okay. We will recess until 12:30.

(Whereupon, at 11:32 a.m. off the record for lunch to reconvene at 12:30 p.m.)

A-F-T-E-R-N-O-O-N S-E-S-S-I-O-N

12:34 p.m.

CHAIRMAN APOSTOLAKIS: The next item is Planned Activities in Development of PRA Methods and Standards. Mark Cunningham will open it up.

MR. CUNNINGHAM: Yes, sir. Thank you. We have four speakers this afternoon in addition to myself.

CHAIRMAN APOSTOLAKIS: We have to finish by 2:30.

MR. CUNNINGHAM: No problem.

CHAIRMAN APOSTOLAKIS: If you don't finish, we're gone.

MR. CUNNINGHAM: We'll be done by 2:30. We're talking in the broad category of things about SAPHIRE peer review. We've talked in the past about two aspects of it. One is how do you review and try to improve the basic models that are in PRAs that show up in codes like SAPHIRE.

Then there is also how do we test the

code, if you will, itself to ensure that it's representing the models correctly and that sort of thing. You'll hear a little bit about both this afternoon. Our friends from the University of Maryland are here, Dr. Modarres and Dr. Mosleh, and they will be talking about improvements and how we model things in PRAs.

Following them we'll have a brief discussion on the work we're doing in fire risk analysis from J. S. Hyslop of the staff. That's one slide, I believe. Then we'll talk some more about the technical review, the DMB review of SAPHIRE. And we'll talk a bit about what we're doing in low-power and shut-down risk analysis. Both of those could be very short if we are pressed for time.

CHAIRMAN APOSTOLAKIS: Geez, are you going to go through all of these?

MR. CUNNINGHAM: No.

MR. ROSEN: But look at the subject, George. This is what you've been bugging us about.

CHAIRMAN APOSTOLAKIS: Not on a Friday afternoon. Not on Friday afternoon.

MR. ROSEN: Now they deliver it and you're in a hurry.

MR. CUNNINGHAM: Is every other slide a

good move?

CHAIRMAN APOSTOLAKIS: Yeah, every other slide would be good.

DR. MOSLEH: I should probably start with some introduction.

CHAIRMAN APOSTOLAKIS: Sure. Tell us who you are first of all for the record.

DR. MOSLEH: I am Ali Mosleh. I'm the Professor of the University of Maryland in Reliability Engineering. We have had a number of research projects with the Office of Research in the general area of uncertainty and various applications. We were informed of the desire to have a presentation on some of our work and progress.

It was short notice, Wednesday morning, so we tried to put together something that is representative of what we have done and what we are currently working on. About four separate topics under the broad topic of uncertainty treatment and we will try to cover as much of those and as many of the details as possible.

In fact, if it is preferred, we can take one of the several topics and spend more time on it. These are the topics that we have plans for presentation. These are a subset of several topics under the topic of uncertainty. The first one was a project that we had like about four years ago or five years ago. It was kind of a two-year project under the collaborative agreement that we have between NRC and CTRS, Center for Technology Risk Studies.

The second one is topics that we have addressed and those that are kind of subject of ongoing research. I'm here with my colleague Professor Mohammad Modarres. We are kind of the co-project principal investigators in this activity. And one of our graduate students Mr. Paul Copahanna.

I plan to start with the first topic, the integrated model and parameter uncertainty with the stated objectives of developing a conceptual unified framework and methodology for treating model uncertainty, model and parameter uncertainty.

To provide guidance for practical applications. That was kind of a key requirement. And apply the method and techniques to representative cases from fire risk models. Later we extend that and expand that to other applications including thermal-hydraulic model uncertainty.

The results can be summarized in this viewgraph where we develop the Bayesian framework for treating model uncertainty in which the Baysesian framework treats model as a source of evidence and information concerning the unknown of interest.

Demonstrated that many popular methods such as model averaging can be demonstrated to be a special case of the general Baysesian framework so as a general framework that's a good property to look for.

Formulated solutions for several important classes of model uncertainty problems encountered in PRA, namely the types of evidence that we have the types of models which we try to address a good subset of those in terms of developing methods and algorithms within the general Baysesian framework. And demonstrated that the method, you know, could be applied in two cases involving fire models.

One case was COMBRN model uncertainty, kind of a remake and reassessment of the work that was done several years back using a variation of the same general principles. Another one is the line fire temperature model uncertainty in two applications within the fire risk discipline.

What we mean by model uncertainty, essentially we're talking about capturing the difference between reality and model that we develop for various applications. That delta, which is the difference between reality and M meaning the model representation of that reality, whatever the source of that delta or that difference might be we try to capture that in our model uncertainty framework.

We view models as at least having these key components. They rely on certain input from reflecting characteristics of the environment and other parts of the boiler system. They provide an output function or product. In the middle you have a model that is based on some concept, the conceptual design and implementation.

Both of these could result in uncertainty. Certainly uncertainty in the input. Certainly uncertainty in conceptually capturing aspects of reality and how you formulate that model implemented in whatever language, numerical methods or analytical equations and the like, that all these could be subject or sources of uncertainty.

We tried to clarify a kind of subject or terms that people have used in this context, form versus parameter. We realize that parameter and form distinction is kind of arbitrary and it's a context and level of tecal dependent. For instance, something that at one level is a parameter is a structured element of a model.

In this case you're looking at a gradual degradation or elaboration of a conceptual model for heat release rate recognized as a function of time. Then when you go down to kind of the next level you have two structural kind of models. One is linear and the other one is exponential. In each of these two models you have a set of parameters.

Now, the moment you specify these parameters they become structure properties of them all. In the left-hand side if alpha is one it's a linear model. If alpha is two, it becomes a nonlinear model. There is no solid line between parameter and model and that is something that one needs to be careful when we talk about model uncertainty propagation and parameter uncertainty propagation.

MR. ROSEN: Let me complain at the outset and maybe Mike and you can fix it. When you put six of these on one slide -- on one page, as you have, I can't read them.

DR. MOSLEH: It's useless. I agree.

MR. ROSEN: Would you see if you can't get them two on a page so I can read the terminology?

MR. WOODS: This is Roy Woods. I'm sorry. I did that. I got those about a half hour ago and I thought you would probably complain if I killed a tree with all these slides so I did it that way.

MR. ROSEN: If you could get them two on a page, I could at least study them later.

MR. SHACK: Or send us a pdf file.

MR. WOODS: I can do that, too.

DR. MOSLEH: These are available in electronic format. One of the points is that effectively a case of successful treatment of model uncertainty is a case where you can state with certainty if you have confidence that you think the true value falls in the range that you expressed.

Obviously we know from history of science and engineering that a lot of cases non-negligible probability that the true value would fall outside the models that you use to make a prediction.

This is kind of represented in this picture where we have -- the question here is which question here are we trying to answer? The first question, the ideal case, is the case where you have the true value captured within the uncertainty range, the best representation.

The other case is something that is a little more practically achievable, although falls short of addressing the fundamental question in the broadest possible sense, and that is what can I say about the unknown of interest if I have input and information from various models so unknown interest being X and there's no guarantee that obviously the true value would fall within range and there needs to be some modification and correction in this second representation on the lower right to bring it back to the types of representation that we have on the upper left.

We took in the first round at this and at the point we closed this project under the NRC collaborative agreement we addressed the lower right. We said what can we say about the unknown interest given IM and IM being information from models and information about models.

If you state the problem this way, remember one of the issues we wanted to wrestle is there a framework, a rational, logical framework for addressing the question of model uncertainty. The moment you phrase the question this way, in other words, what can you say about the unknown X given IM information from and about model.

Then based here is really the natural choice as a framework because exactly mathematically based theorem tries to answer that question. Given a piece of information what can you say about the unknown of interest.

This is a familiar equation form to the Committee. Again, symbolically we have a posterior distribution given the information from the singular model.

CHAIRMAN APOSTOLAKIS: There are a lot of slides. Can you skip the mathematical details?

DR. MOSLEH: Sure. Okay. I think maybe --

CHAIRMAN APOSTOLAKIS: Maybe an example or something.

DR. MOSLEH: Yes. The key step we took is, of course, in the base theorem the key question we need to address is the construction of the likelihood function fundamentally. One of the first steps we took was the information on models would go into the structure of the likelihood function. Information about models from models will go as a condition just as given a piece inside the likelihood function. This is how we capture both types of information.

In constructing the likelihood function in terms of capturing information about models, we use a parametric representation. In other words, you structure the likelihood function in such a way that the parameters of the likelihood would represent information about the models of interest.

CHAIRMAN APOSTOLAKIS: The fundamental issue here is really -- I don't know how familiar the members are with the likelihood function but the likelihood function is essentially the probability that if you knew the true answer, the model would be closed in qualitative terms which is really a judgment about how good the model is.

In other words, if you had infinite confidence in the model, it would be a dental function. If you know the true value, then it gives you the true value. When you start having doubts about the model, then you have a distribution.

You know, if the true value is here, there's a probability that the model will give me something over there. This is where you have to evaluate the credibility of the model predictions. How are you doing that? I mean, in qualitative terms. What inputs do you use?

DR. MOSLEH: I have a couple of examples. For instance, here on the second bullet, information about models, performance data is a piece of evidence like you have experimental measures and then prediction of the model. Assessment, this is now a qualitative or quantitative judgment, subjective judgment about quality and applicability of the model.

Not only the quality or credibility of the model within its domain application as it was intended and designed for, but also sometimes you use models in other domains of applications so applicability is another question.

Taking this information from model and this combination of performance data or other subjective assessment about the quality of the model would be the two pieces of information that would go into the likelihood function, the second going into parameters you define to capture this type of information.

So, for instance, in the case of when you have performance data, a set of numbers from experiment, that's E1 through En measurements, then you can use a simple error, model which we have used in other applications such as expert opinion modeling, to basically relate the prediction of the model and the actual data.

CHAIRMAN APOSTOLAKIS: But this is where your judgment comes into the picture, right?

DR. MOSLEH: Right. Including the choice of the error model.

CHAIRMAN APOSTOLAKIS: Have you developed any guidance as to how I'm going to do that? I mean, the formulation is fine, and it's the right formulation, of course, but when it comes to saying something, let's say, I have one model and somehow I have to decide how credible the results are. You have an example, I think. Maybe you can speak in terms of an example because we don't have much time.

DR. MOSLEH: Here is a case where you have data so I think the question of using data to see how good the model has performed with respect to the data is a simpler problem. You have the actual data to tell you the magnitude of error. For that you use the error model.

CHAIRMAN APOSTOLAKIS: Let's look at this.

DR. MOSLEH: I think another one is better because this one talks about use of data, performance data. Here is a case where we have a prediction of point source model, fire models. Then we are dealing with the line fire like the cable along the length as a fire. If you are using a code designed for one application, how do you now take it for a different application.

Here we are assessing applicability which is now reduced into one parameter, one number between zero and one. That number would be used to adjust the likelihood function. You can raise the likelihood function to a number between zero and one and you would change that number.

The strength of the likelihood function, therefore, data representation of your confidence in your model would change going from a flat distribution to fully, as Dr. Apostolakis mentioned, delta function that represents the full confidence in a model.

Now, who do you estimate such quantities in a number, a credibility factor, or applicability factor? We use a simple method of decomposition of attributes of a model. You have a context alpha. The model is designed for context alpha and you are using it for context beta.

You list the attributes within context alpha that are important in context alpha and you list the attributes, the physical models, the aspects of the physical process, for instance, that you need to address, and a number of other things that go deeply inside the specifics of the model.

So you list those and you go through this comparison of what I have in context A and the way that the model is treating those. To what extent in that particular case, say in the case of attribute E how well is it addressing the question. Do I need, for instance, to introduce a bias term. Do I need to introduce like take it totally as being applicable.

Do I need broaden my uncertainty range because this thing would give the answer but with kind of a bigger error. That kind of a one-to-one assessment is the method we use to take a comparison between the two context and the model attributes within the two context, and reduce them to a single number. We use something like AHP in that area. That's analytic hierarchy type process.

At the end you get a number that is an overall qualitative assessment of applicability of a model alpha to context beta.

CHAIRMAN APOSTOLAKIS: So essentially you are structuring the judgment process.

DR. MOSLEH: Exactly. Right. In the area of confidence in the model in its context, also context alpha, we use the same type of approach. Here is the specific case that you work with an expert in the fire phenomenology looking at the point source fire model and a line fire model and looked at different attributed in the terms of geometry, ventilation, fire characteristics, plume characteristics, and the attributes of each of these categories.

They will judge one by one once. Then at the end the expert, in this case there were two experts, collectively look at the number that was just a single number as a result of this process, and essentially to converge to kind of one number to be used.

CHAIRMAN APOSTOLAKIS: In this particular case, though, wouldn't you make also a point -- I mean, it is a model uncertainty issue but you are really trying to take a model that was developed for one physical situation applied to another from a point source to a line source. The question is why don't you go straight and develop a line source model.

Do you have any examples where for the same physical situation there were more than one models? In other words, people have made different assumptions. Like in the human reliability you are familiar with the benchmark exercise. Have you dealt with any problems like that?

DR. MOSLEH: Not in a real application in the example I can give you. There is another project that we have and and that's the software reliability where you use the exact same thing but on multiple models.

The process of judging -- according to the procedure that we've been following in every case there are judgments in terms of comparing models in terms of their relative strength and weaknesses. We look at the structure and the details of the model. But we have not made an attempt in terms of covering the unknown or nonexisting model. In other words, the issue of completeness.

CHAIRMAN APOSTOLAKIS: But you have dealt with a situation where I can say six models attempting to do the same thing but they are using different assumptions and different methods. Again, it's a matter of structuring the judgment process that will tell you eventually I believe the model is biased or I believe this and that.

DR. MOSLEH: Precisely.

CHAIRMAN APOSTOLAKIS: I mean, there is no -- ultimately you have to rely on experts. Anything else you want to tell us?

DR. MOSLEH: That's basically -- I wanted to say --

CHAIRMAN APOSTOLAKIS: The thermal hydraulic uncertainties, you want to do that?

DR. MOSLEH: If I may add one point in terms of limitations of this thing, this methodology has focused on model output and if it's a model output methodology. When you deal with more complex systems such as thermal hydraulic models and you need to really go inside and then construct model uncertainty from looking at model uncertainty with these submodels you need to do a lot more obviously.

That's the type of thing that we're dealing with in the model uncertainty application to thermal hydraulics. Dealing with complex situations where you have --

CHAIRMAN APOSTOLAKIS: I remember in the PTS a couple of years ago it was either you or Mohammad who told us that the various boxes there in the big diagram there is model uncertainty and had to do with materials.

DR. MOSLEH: Yes.

CHAIRMAN APOSTOLAKIS: Have you done that?

DR. MOSLEH: Yes.

CHAIRMAN APOSTOLAKIS: Okay. So you're going to talk about it?

DR. MOSLEH: After I'm done, Mohammad will. I do need to leave about 10 minutes before 2:00 for a conference and then I think you have until 2:30 to cover that material.

I need to go back to the other presentation. This is -- I have two presentations on thermal hydraulic uncertainty. One is the work we did under the PTS risk assessment. The other one is a more general uncertainty for thermal hydraulic codes. I make a few comments on this one and then try to focus on the other one in the interest of time.

In this case we were in the middle of many activities and disciplines. As you can see, there was a PRA event sequence analysis, thermal hydraulic analysis, and PFM analysis. Initially we started just focusing on thermal hydraulic and uncertainty analysis and immediately realized that it's just almost impossible. In the middle of an integrated assessment you have to be involved pretty much in all --

MR. ROSEN: Not impossible. It's not irrelevant.

DR. MOSLEH: Yes.

MR. ROSEN: What would be the good of doing a good thermal hydraulic analysis and uncertainty analysis in the midst of a see of other uncertainties that are unquantified?

DR. MOSLEH: You have to really look at the context you're doing the uncertainty.

MR. ROSEN: You've got to do the whole thing if you're going to do it at all.

DR. MOSLEH: Yes. We should have known

that maybe by taking two minutes but we jumped in thinking it was going to be a small task but we ended up being involved pretty much in all the activities of PTS just to address the uncertainty.

So there were kind of genetic lessons that we drew from this experience and became kind of the motive for another task or activity to see if you are addressing a complex technical assessment how do you address the uncertainties, what would be the procedures, techniques, and tools. That's kind of a more recent activity.

In this project some of the things that we had to address obviously other than -- you know, we have an overall process to follow. Namely, you have uncertainties from the PRA side event sequences in terms of frequencies. You go through a process of reduction in terms of the number of sequences that you want to carry, grouping and classifying.

You have to wrestle with the limits and the number of RELAP runs you could run. Then ultimately you have interface constraints. In other words, the PFM analysis code would take an input in a particular format of representation. These establish certain constraints over what we could do.

MR. ROSEN: Would you go click on the

model so we can expand this?

DR. MOSLEH: Yes. So there is this discipline, this discipline, the connection, and then we have to do through the binning and representation of the uncertainty of the three key parameters, many of those, and the PFM analysis. But the point that I wanted to make is that in context when you do uncertainty analysis you have now additional concerns that are imposed on you and that changes the nature of the methodology or tools that apply.

In this case we have to almost kind of completely rely on a diskatized version of the universe by treating uncertainties in bins, in groups, in categories and go through the systematic and force reduction of number. A 100 or 200 thermal hydraulic runs reduce to 50 or so runs that would go ultimately to PFM analysis. The runs were supposed to represent the range of uncertainty that you have for each of the groups or categories, namely the ones in the middle right here. Three curves per set of --

CHAIRMAN APOSTOLAKIS: The age of uncertainty, the aleatory uncertain so now you have --

DR. MOSLEH: This is a one scenario class and then you're talking about epistemic uncertainty.

CHAIRMAN APOSTOLAKIS: You had 50 runs for one scenario and these 50 are presented different from the measures of the parameters that appear in the scenario.

DR. MOSLEH: Yes.

CHAIRMAN APOSTOLAKIS: Another scenario you had another 50.

DR. MOSLEH: That's right, 50 combinations. The lines that you see represent the epistemic uncertainty of the parameters in an interesting way. Then when I go to the other one, I will comment on this because this is something that is a common mistake on many people who are doing thermal hydraulic uncertainty and maybe physical phenomenon.

CHAIRMAN APOSTOLAKIS: Okay. So this is making mistakes?

DR. MOSLEH: It's not the thermal hydraulic expert who makes the mistake but those who try to do uncertainty.

CHAIRMAN APOSTOLAKIS: That was a very good way of getting out of it, Ali. Have you seen any numbers from the PFM analysis that are higher than 10^{-8}?

DR. MOSLEH: Oh, yes.

CHAIRMAN APOSTOLAKIS: They are capable of doing this?

DR. MOSLEH: Absolutely, after a lot of complaints.

CHAIRMAN APOSTOLAKIS: I have yet to see a PFM calculation that is more than 10^{-6}.

MR. SHACK: I have.

CHAIRMAN APOSTOLAKIS: You have?

MR. SHACK: Oh, yeah. I can pop nozzles off the SRDM housings.

CHAIRMAN APOSTOLAKIS: I have never seen that. I would like to see that just as a new experience in life.

Okay. Go ahead.

DR. MOSLEH: So in this process given the constraints obviously one thing that really these constraints or context really helped us is that sometime the boundary condition uncertainties were dominant so you change the boundaries that were kind of well defined physical --

CHAIRMAN APOSTOLAKIS: What do you mean boundary conditions?

DR. MOSLEH: Such as the temperature and the season. Seasonal change in the temperature as a boundary condition. Then it was the judgment of the RELAP and the thermal hydraulic experts that some of the uncertainties and the actual code calculations were much smaller in those cases compared to the variation in input parameters. That helped us kind of escape and skip some of the more difficult TH uncertainty issues we were not kind of equipped or prepared or had the time to address in that project.

MR. SHACK: You're not addressing the uncertainties in RELAP itself.

DR. MOSLEH: That's right, yeah. It's the uncertainty in the boundary conditions or the way of developing the boundary conditions that the aleatory part now takes over.

CHAIRMAN APOSTOLAKIS: Some of the boundary conditions are aleatory, right?

DR. MOSLEH: They are, mostly.

CHAIRMAN APOSTOLAKIS: Oh, mostly.

DR. MOSLEH: The ones that don't vary. Not all.

MR. SHACK: Aren't they really epistemic? I mean, if you knew when the event was going to take place at the time of year --

CHAIRMAN APOSTOLAKIS: Then you would know.

MR. SHACK: -- then you would know.

MR. ROSEN: If we knew when the event was going to take place, we would know a lot more about it and we would make sure the event didn't occur.

DR. MOSLEH: On philosophical grounds there's only one type of uncertainty. They are all epistemic, right? But, you know, in terms of how much control we have on those, we have a line that puts some of them in the aleatory domain and other in the epistemic but it's an arbitrary line depending on analysis resources and knowledge.

CHAIRMAN APOSTOLAKIS: It's not arbitrary. It's convenient.

DR. MOSLEH: It's convenient.

CHAIRMAN APOSTOLAKIS: It's not arbitrary. People are not doing it capriciously.

DR. MOSLEH: No.

CHAIRMAN APOSTOLAKIS: That's a nice word.

DR. MOSLEH: I think in a sense the philosophers would say, "Look, this is a minor point. If you want to draw the line here and there, you need certain criteria but fundamentally it's the same uncertainty. Uncertainty is uncertainty.

CHAIRMAN APOSTOLAKIS: So when you say RELAP model uncertainty there, what do you mean?

DR. MOSLEH: Meaning you have two submodels that you kind of invoke one versus another or two numerical conversation criteria. When you invoke one versus another you get a difference in the results.

CHAIRMAN APOSTOLAKIS: Didn't you just answer that the uncertainty RELAP itself is not --

DR. MOSLEH: In those cases we didn't need to address the RELAP uncertainty that we uncovered.

MR. SHACK: If I only know the temperature within plus or minus 70 degrees but I don't know what time of year it is, it doesn't matter that when I specify the temperature exactly RELAP has an uncertainty in the calculation because I get such a wide variation because I don't know the --

CHAIRMAN APOSTOLAKIS: But that presumes that they have some idea what the RELAP uncertainty is.

MR. SHACK: Yes. It is an implicit assumption.

CHAIRMAN APOSTOLAKIS: And you know that.

MR. SHACK: Yeah.

DR. MOSLEH: These were looked at case by case and examined in context, specifically what case you're talking and what sources of uncertainty in RELAP exist, whether those are covered or not. So it's not a general statement or generic statement.

That was something that helped us again doing analysis.

CHAIRMAN APOSTOLAKIS: Let me understand this. How did you find out that the boundary condition had such an impact? Somebody told you or you found out?

DR. MOSLEH: No, we would run. We would actually run the cases.

CHAIRMAN APOSTOLAKIS: So you filed through simulations?

DR. MOSLEH: Absolutely. In order to zoom in on important parameters, the numbers that we need to run, we ran about 1,000 RELAP cases to kind of get a feel for it.

CHAIRMAN APOSTOLAKIS: But one could conceivably have a formal sensitivity analysis to guide you.

DR. MOSLEH: Yes.

CHAIRMAN APOSTOLAKIS: This is important by the way, Mark, to the regulatory guide that you guys are thinking of developing now in sensitivity and uncertainty.

MR. CUNNINGHAM: Certainly.

CHAIRMAN APOSTOLAKIS: It would be nice to have a method that guides you to do the sensitivity analyses that will uncover cases like that rather than relying on the expertise of the analyst who bury things. I think that is one of the most important things.

DR. MOSLEH: I think I agree in the sense that the way we have to kind of develop our own procedure because how many and which particles we change and then modify so we develop kind of an internal set of guidelines to help us minimize the number of runs we have to make until we get the insights that we need.

CHAIRMAN APOSTOLAKIS: Very good.

DR. MOSLEH: Some of those were summarized and shared with ACRS before in the PTS presentation but also some of them are here. Here is a quick list of uncertainty sources that we looked at and tried to address. This is the entire process of uncertainty propagation from the PRA side all the way to the input to the PFM fracture mechanics code input.

Model uncertainty, of course, sequence modeling and grouping and mapping those thermal hydraulic runs is a source of uncertainty. The way we treated them sometimes by recognizing that we needed to add more details or further rebin things to address things properly. In some cases they were not treated because they were judged to be small.

MR. SHACK: You mean, you did the rebinning basically to reduce your uncertainty, right? If you left the bins the original way you would have just been left with huge uncertainty bands.

DR. MOSLEH: To reduce the uncertainties like binning is uncertainty management in a way. Some of it was dictated not by a desire to reduce or manage uncertainty but just basically input/output requirement from the parts of the analysis, from the PRA side all the way to PFM.

For instance, in the PFM we have to produce 30 sets of uncertainty curves, 30 times 3, 90 inputs to the code. We have to kind of compress things into fewer bins defined by that requirement.

So one is how you structure the model in terms of its interface with the rest of the model. The other aspect of uncertainty we tried to capture obviously was use of the TH code itself, internal model uncertainties, and input model uncertainties. Then the caliber of parameter uncertainty --

CHAIRMAN APOSTOLAKIS: Aren't the input parameter -- input uncertainties parameter uncertainties?

DR. MOSLEH: By input deck preparation is the structure aspect of it. You know, nodalization, how many nodes do you use.

CHAIRMAN APOSTOLAKIS: Oh. Did you find the parameter uncertainty was not important?

DR. MOSLEH: I can't say that because actually we have aleatory uncertainties. We also call them parameters of the model such as temperature variations or state of components, degradation and all that. We really didn't do the separation.

CHAIRMAN APOSTOLAKIS: In PRAs there's a growing belief that the so-called parameter insurance which is failure rates and initiating figures. I really found that useful because the results of the PRA are not affected.

MR. ROSEN: Just in the PRAs but, of course, this was bigger. We had talked about physical phenomena and parameter uncertainties can be very large.

CHAIRMAN APOSTOLAKIS: But even in the PRAs when we say parameter uncertainty, we really mean initiating event frequency and failure rate.

MR. SHACK: We end up treating everything as a parameter uncertainty.

CHAIRMAN APOSTOLAKIS: Eventually

everything is a parameter uncertainty.

MR. SHACK: In the context that you're meaning parameters.

CHAIRMAN APOSTOLAKIS: Yes. So we have to be careful.

MR. ROSEN: You used a lot of crackgos in your stuff and it can never be small.

CHAIRMAN APOSTOLAKIS: Well, you can always model the acceptance rate for potential parameters. Then those parameters are important.

Okay. Great. Let's keep going.

DR. MOSLEH: Certainly I believe --

CHAIRMAN APOSTOLAKIS: So your message here is there isn't one thing that can be called model uncertainty. Depending on the problem there are lots of things --

DR. MOSLEH: It's very context dependent. There are certain principles that you can share that draw from these things and then share and develop as kind of a procedural method. In application it's very context dependent in terms of even, you know, obviously the types of tools that you use, the attention you pay to one aspect versus another.

In the fire case the focus was on, for instance, the relevance of the data to the application so there's a lot of detailed statistical modeling. In this case a lot of decisions is about the quality, the interface, the logic model.

CHAIRMAN APOSTOLAKIS: If we want to sensitize people in general without referring to specific context, to sensitize people to the issue of model uncertainty as opposed to parameter uncertainty, first of all, we have to make sure we understand what parameter uncertainty means because, as we just said, there are certain instances where that's important.

I guess what people tend to ignore is, for example, the possibility that you may use more than one model to model the same thing. The possibility that certain things that you are doing like the nodal skin themselves introduce uncertainty so we will have to sensitize them to that.

I don't know, there are things that you mentioned like formal inputs and so on, things that are not obvious, in other words, but I doubt there is a generic approach to these things. I mean, there is a philosophical approach but --

DR. MOSLEH: I think -- I'm sorry?

CHAIRMAN APOSTOLAKIS: Mathematical approach?

DR. MOSLEH: No, not mathematical. That's why I mentioned the fact that the statistical procedure is insufficient in terms of the full spectrum of issues that you need to deal with in model uncertainty.

But in the other areas as well, I think there are common characteristics that you can kind of abstract out of these various experiments and exercises and applications that is quite promising. For instance, I mentioned, I think -- let me see. This is a case where we have to generate three curves and the meaning of these curves.

There are three actual traces of thermal hydraulic power which is pressure and temperature. Each has an assigned probability that is the result of our binning, reduction, and probability manipulation, parameter, and propagation of uncertainty.

The reason that this particular representation had to be the way it is is not only because of the input requirements for another part of the analysis required this type of thing, but also it goes back to a fundamental question that if you have a physical coat that generates results on behavior of the physical system in time. You change the input parameters or the model parameters and all that and you get a spaghetti of results.

CHAIRMAN APOSTOLAKIS: Explain what these curves are.

DR. MOSLEH: Say that this one is the downcomer temperature as a function of time and then you have three curves that are, say, in this case this one is the result of a RELAP run for a specific combination of parameter values, input values. The red one is also for another one and the green.

These were selected as representatives of many, many combinations that you get out of varying the parameters which on the left-hand side you see a density function and when you vary 11 parameters, each would require a thermal hydraulic RELAP run.

You get many, many results, of course, 1,000 combinations, and we have to select three out of these to represent the whole spectrum. And for each of these combinations we'll have probability -- out of 900 combinations you have the probability that add up to one so you're talking about the density function.

You kind of collapse these into three -- you go through kind of three possible combinations in terms of expected average temperature here and there. If I run a case that comes close to this area, that covers this range of probability like about 30 percent. This is another 30 percent and another 30 percent.

All this range of output or thermal hydraulic cases are now going to be represented by just a single run carrying the probability of that range. It's a characterization of the spaghetti up of distributions, a continuum. At the end then you end up with these three curves each of which has maybe 30 percent or 35 percent probability.

When you go to the PFM analysis, you take the green curve and the probability of that green curve is the probability of the initiating event that led to that thermal hydraulic condition multiplied by .35 which is the probability that --

MR. ROSEN: The events that class will have.

DR. MOSLEH: That class will have.

CHAIRMAN APOSTOLAKIS: So you have significant uncertainty there. I mean, if you look at 5,000 seconds, you can go anywhere from 320 all the way to 470 on the left. Right?

DR. MOSLEH: Yeah.

CHAIRMAN APOSTOLAKIS: By the way, you said you would finish at 1:50. No, you have until 2:30 because you have the SAPHIRE discussion.

MR. CUNNINGHAM: That's correct. We can

shorten that depending on what you would like to hear more of.

DR. MOSLEH: Tell me how much time I have. Ten minutes?

CHAIRMAN APOSTOLAKIS: I would say so.

DR. MOSLEH: Okay.

CHAIRMAN APOSTOLAKIS: Then Mohammad will need what?

DR. MODARRES: Ten or 15 minutes will do.

DR. MOSLEH: Maybe I go to the other presentation that is kind of the general thermal hydraulic uncertainty because there's a few things that I want to mention there.

Initially in the SAD there is observations from the PTS experiment or experience. Some of the generic lessons are there. These are important insights but we are working on those to see if we can get more of these lessons learned.

Treatment of uncertainties in complex TH codes. These are our objectives. We are currently working on these so it's a computational approach for propagation of uncertainty in the complex models and codes, identification of various sources of uncertainty, and methodology for characterizing and quantifying the uncertainties and the impact of those uncertainties.

Then hopefully at the end suggesting some says of modifying the code that it will be a layer over the typical TH code that would kind of guide it to do uncertainty.

We looked at initially a number of methods, what GRS is doing, University of Pisa is doing, and a number of other known methods like at CSAU in terms of assessment and characterization of uncertainty. If you look at these methods, they look at one aspect or the other put none of them in a comprehensive way as in terms of our desired objectives. We are addressing a number of dimensions.

For instance, one methodology focuses on the propagation of uncertainty using multi-color maps. Another approach tries to modify and adjust the final results of codes based on experimental data, test facility, and special effects to test the facility data to adjust and modify.

But our objectives go beyond that. We want to have kind of a comprehensive coverage. The major steps of the methodology is evolving now and involved a number of -- combining some of the best features of various methods that they have seen and then some of the techniques that we are introducing under a broader umbrella.

You can see the steps, identification of uncertainty, important phenomena models, something that PIRT could initially obviously help there; assessment of uncertainty, model and parameter, propagation and application.

In each case I think we have pretty much have a framework. In some cases we have decided and settled and tested the methodology and we know that it works.

CHAIRMAN APOSTOLAKIS: What is Wilks method?

DR. MOSLEH: It's a statistical method of kind of reducing the number of samples that you want to run a complex code with. As you can imagine, you have so many parameters and how many samples do you need to ensure certain coverage.

CHAIRMAN APOSTOLAKIS: So why not use latin pipes?

DR. MOSLEH: This, I am told by the experts including our student, that this is by far more efficient. It's really good if -- I mean, have you tested that?

CHAIRMAN APOSTOLAKIS: I think Graham's paper.

DR. MOSLEH: Yes.

CHAIRMAN APOSTOLAKIS: What did you see?

DR. MOSLEH: It was exchanged within Dr. Wallis and --

CHAIRMAN APOSTOLAKIS: Right, but now there is a new paper from Graham Wallis and William Knot.

MR. SHACK: Which hasn't appeared yet.

CHAIRMAN APOSTOLAKIS: No. That's why I was surprised.

DR. MOSLEH: Yeah.

MR. SHACK: The original exchange.

CHAIRMAN APOSTOLAKIS: Yeah, the original exchange.

DR. MOSLEH: I view this purely and strictly as kind of a statistical, numerical method. We found it, we tested it. GRS uses in their code uncertainty assessment and they are happy.

CHAIRMAN APOSTOLAKIS: Something is replacing latin hypertism.

DR. MOSLEH: In this case, yeah. There is a lot to be said obviously about the differences and merits and all that but all I can say at this point given the time is that it works based on the tests that we have done which have been the smallest test and the largest test, namely testing with RELAP.

Here is an overview of the types of things that we are trying to adjust and how we adjust them. If we end with this viewgraph I'm happy because I can comment about a lot of the attributes and characteristics of the methodology we are developing. One is obviously we need to do --

CHAIRMAN APOSTOLAKIS: Where do you start in this figure, from the left?

DR. MOSLEH: Where do I start? I start with the biggest box here in the background. That kind of takes care of an obvious thing, that one needs to do uncertainty propagation. How is the question. The other thing is internally you need to invest model uncertainties internal, structural model uncertainties inside the code. That's this box.

Then you have certain types of evidence information. That's in this box here. Analytical solutions, field data, test data, and expert opinion. That's kind of your base information. You see a number of modifiers or processes or procedures. One is that obviously there is a scaling that needs to be done in some cases from test facility or modifications and adjustments that should go into kind of an assessment of the model uncertainty. That's the meaning of this box.

You have input to the power process which is the user affects or nodalization as an example. And you see a number of places where we say Baysesian model uncertainty. Here is a Baysesian uncertainty on input to the model so, if you remember, you have a soft model of parameters.

You see a Bayesian updating using a standard procedure. The Bayesian model uncertainty trying to adjust the structural as well as parametric aspects of submodels and the overall model refers to the methodology that I presented in the first presentation and the extensions of that.

There are a couple of places where we do Bayesian updating with the evidence. One is here any evidence that they have in terms of empirical correlations or test data that would help us understand the credibility, the nature and accuracy of specific models within the code. That's one.

Another one is at the end if you have, say, integrated test results and something that points to the performance, the entire code, we do another Bayesian updating of modifying the code results with whatever evidence we have from test and experience so that's another one.

And there's another issue of code, the output representation which is very context dependent. A couple of points. One is when you're looking at propagation of uncertainty, for instance, inside the code, it is not a straightforward process of taking samples and running those through.

There are important points to consider such as if I have alternative models one and two, and suppose I use a methodology that would enable me to kind of look at the credibility of this model and this model or even a compact assessment of those, one question that one needs to address is that does it make sense to, for instance, mix these models in some weighted average or procedure like that or any other numerical mixing and then proceed.

In some cases yes and in some cases no because the mix may not be physically meaningful and the mix may not max with the rest of the procedure or process that you will encounter. Going from this point to this point maybe this model matches this model.

MR. ROSEN: Like a plant where you have three feed water pumps in one cases and two in another and the model is either two are running or three are running and somebody wants to say two and a half are running.

DR. MOSLEH: Yes.

MR. ROSEN: Well, you can't have that. That doesn't sound reasonable.

DR. MOSLEH: In some cases it makes sense and it some cases it doesn't make sense. The procedure for propagation of uncertainty, you trace it inside the code, would be different obviously. We have a number of structural characteristics that we have identified that we need to address in developing the procedure for uncertainty propagation. That is beyond just the assessment within individual blocks and boxes.

Another feature is the dynamic nature of such codes. You have in one time step you're invoking submodel 2 and then you go to 4 but not 2. In another time step you go from submodel 2 you go to 3 and 4 maybe. So as you exercise the model the structure of the model changes and you're uncertainty tracking overlay needs to track these things, needs to be sensitive to these.

It's almost running risk scenarios or probabilistic scenarios inside the code. In other words, you need to do uncertainty as it relates to the specific cases or path through the computational process. I have examples of these. What I wanted to say about this thing was that this is the result of applying the sampling method using the PTS uncertainty data involving 11 parameters.

All the color curves that you see are actual PH runs based on Wilks sampling method so you get 100 runs. That gives you a spectrum of variation. Just for fun or just to see how well we perform in the PTS case, we look at the PTS uncertainty bounds we selected based on our own procedure and they nicely fit.

Gives us a little bit more confidence about the performance of the Wilks uncertainty propagation and also a little bit of verification of what we did in the previous one. The Wilks methodology works in terms of generating the spaghetti of distribution.

The question is actually what do you take out of that spaghetti as a representative uncertainty found in the lower box. The comment I made earlier about the thermal hydraulic uncertainty procedures that we have seen, some of them -- couple of them, the prominent ones, make a mistake that you can actually trace the upper bound of these curves just right over the top of this spaghetti or right under using a certain counting procedure like, you know, the number of curves that fall within or the percentile of the statistical distribution at the specific time windows and call those upper bound and lower bound. Obviously these are not physical. The upper bound is not a physical representative.

CHAIRMAN APOSTOLAKIS: This is the same in the waste depositories where they calculate the dose and they report the results with a 90 percentile curve. These curves are not actual runs. They are the 90 percentile of many, many curves underneath which are the actual runs.

MR. ROSEN: And they end up with a human receptor who eats so much that he would explode if he ate that.

DR. MOSLEH: That's the same thing. Exactly.

CHAIRMAN APOSTOLAKIS: So it's a bunch over 90 percentile but it's not one run.

MR. SHACK: But sometimes it's the right way to do it.

DR. MOSLEH: And sometimes it's not. I would say that in the cases we had, the TH runs we were dealing with in all that, to me, and obviously to everybody else also, they did not accept. That's why we went through an elaborate process of selecting three curve representative and it confused a lot of people. But the point was this, that you can't just go to upper bound and lower.

MR. SHACK: But, you know, just taking this case, I mean, why wouldn't looking at the 90th percentile -- if you wanted to look at the 90th percentile of the temperatures and pressure that the vessel would see, I mean, you're not using it to really judge the thermal hydraulic model but you want to know what's the whole range of temperatures and pressures that the vessel would see.

DR. MOSLEH: If you just want to see at any moment what would be the maximum pressure or temperature that the vessel would see, yes. But connecting those points of design is not a physical trace. Basically the system will not experience that.

CHAIRMAN APOSTOLAKIS: For communication purposes it's good but if you want to use it as an input --

MR. SHACK: If you were looking for a state dependent thing that wasn't history dependent, then it would be reasonable.

DR. MOSLEH: Exactly.

MR. SHACK: But if it's history dependent then --

CHAIRMAN APOSTOLAKIS: Or just communication.

DR. MOSLEH: Just communication. And I think, unfortunately, misleading. It's really amazing that people came with physics and hydraulics background would just accept this even though it is the type of thing that should get a kind of rapid quick negative reaction from that perspective. These are not physical places. I'm giving you a sample of a number of issues that you're addressing.

CHAIRMAN APOSTOLAKIS: Okay. Great. Is this work continuing now or is it over?

MR. CUNNINGHAM: It will continue.

CHAIRMAN APOSTOLAKIS: Are you done?

MR. CUNNINGHAM: Or a follow-up to it or something.

CHAIRMAN APOSTOLAKIS: Thank you very much. Professor Modarres.

MR. ROSEN: I would comment while Professor Modarres is coming up that the presentation that you skipped, the one on observations of treatment of uncertainties and complex multi-disciplinary technical assessments is very useful for common understanding of why doing uncertainty analysis is important and also when to do uncertainty analysis and who should do it and how it should be done. I think it has some useful insights so thank you.

CHAIRMAN APOSTOLAKIS: Let me ask what would it take for these methods to become usable routinely by people other than Modarres and Mosleh?

DR. MOSLEH: Are you asking me?

CHAIRMAN APOSTOLAKIS: I mean, should the agency always come to you? That would be nice for you.

DR. MODARRES: Good afternoon. Let me introduce myself. I'm Mohammad Modarres from University of Maryland. I'm also a professor of nuclear engineering and also reliability engineering. The answer to Dr. Apostolakis' question is that actually one of the objectives of this research is to bring at the end the lessons that we learned into the code development.

There is a task at the end to put some procedure of the analysis that will be perhaps we are thinking of a P process or kind of a thing before a RELAP or trace which is being done now which then the analyst would look at the aspects of the uncertainty analysis that should be considered before actually embarking on the calculation. We haven't started thinking about it but ultimately the idea is to bring it down to something that everyone can use it. That was the original idea and still is.

CHAIRMAN APOSTOLAKIS: Okay. Go ahead.

DR. MODARRES: Okay. What I wanted to talk about here is an aspect of the fracture mechanic uncertainty analysis that we were involved some three or four years ago we started and ended about two years ago. I actually originally borrowed this from a previous presentation made by Mark Kirk but this kind of captures the totality of the aspects of what the PTS analysis is involved that be used as fracture mechanic uncertainty as part of it.

Basically the focus was on the probabilistic fracture mechanics box which is the -- Ali talked about the thermal hydraulic analysis uncertainty aspects also here. That box was traditionally analyzed prior to the PTS analysis as primarily deterministic.

Essentially the stresses were calculated at a given scenario and the strength was used using a redesigned curve of deterministically and then if the two crossed each other it was assumed that the vessel will fail and if it doesn't, they don't fail.

Basically they will go through the

variations and distribution of flaws and then test this for every flaw there and then find out the likelihood that the vessel would fail because of the variability and the number of flaws.

We took that and we said, okay, what about the uncertainties which are involved in actually the models representing the strength of the vessel and also the measurement of the stress which applies to the vessel given a scenario occurs. The focus was basically on the fracture mechanics here.

The first steps that we got involved, of course, we were PRA analyst and tried to actually understand the physical phenomena which was the underlined physical phenomena which goes here. We have to break down the elements here down to the individual contributors to the uncertainty to understand that.

First the stress, the box H on the top left basically describes what we are trying to calculate ultimately which is the toughness of the vessel. You can think of it as the strength of the vessel. Then that changes over the -- there are two factors that are affecting this.

One is the temperature that is applied on the vessel, and the second one is, of course, is the embrittlement which over the time changes this characteristic. So we wanted to see how to calculate that. Of course, this is the value that was considered as a fixed number prior to us entering and we wanted to bring this distribution into it.

We wanted to see what actually contributes to this so we can represent it by distribution. By going through this it was realized that actually there are two kinds of uncertainties here. One is the uncertainty associated with the basic variability into the vessel to vessel variabilities and the material variabilities that exist in the vessel which gives rise to this distribution.

The second one is, of course, this temperature shift, what is called a temperature shift which is a product of the vessel being irradiated over the time. In order for the NRC to take care of this temperature shift, there was a measure called RT_{NDT} which was calculated based on -- I'm sure Dr. Shack knows far better than me how the history of this came up.

Technically this RT_{NDT} came from calculations of the current temperature and some other irradiation here which was calculated from another parameter, delta T_{30} which involved, again, a number of other assumptions.

There were quite a bit of uncertainties here was coming actually to the picture of how this RT_{NDT} itself was calculated. There were uncertainties as to the measurement of the X axis and there were uncertainties to the value of the Y axis both here. The question was how to characterize and compute this.

Of course, there is the lower box here is a toughness uncertainty and that is that once a crack starts to grow, it's possible to be arrested and then this is the arrest toughness is how that can be stopped from actually growing and going through the vessel wall completely and then causing a failure of the vessel.

So here if you're looking at actually by going through the history of this, we found out actually that if you're looking at it there were about 200 or so data points which are shown on the left box here to calculate this K_{1C} which is the strength distribution. Then a model by assumption of viable model was forced into it to see how actually a Weibull model fits into it.

Originally this is the ASME curve which NRC used. Someone at AME sat and basically drew a language in the bottom of all of these to say this is the most conservative line I can get. Therefore, it encompasses everything. Of course, this doesn't include all this variability you see in the data, as you can see here.

Of course, one process was to go through these data and either use this Weibull distribution which is a function of the temperature here, or use some other -- use this deterministic. Of course, our standing was that you should capture somehow this variability.

But by going to a more careful evaluation of this, we wanted to see what part of this is aleatory in nature and what part of it is epistemic in nature. When we went through the data here and looked at the data very carefully looking at this temperature, we found actually that this variability here comes because of a cleavage fracture in the steel.

This cleavage fracture comes because of a break basically on the weakest link of the carbides. In other words, it was very dependent on the carbide distribution itself. In fact, the weakest link and the distribution of carbide gave rise to the Weibull distribution.

In fact, if you take this weakest link

model and try to find a weakest link with the sizes of these carbides and combine the two together, you can derive, in fact, a Weibull distribution. That is how originally Weibull distribution came about to begin with.

This was very well described by an aleatory distribution because the carbides then -- the size of the carbides distribute themselves in an aleatory way and, therefore, the Weibull distribution is actually an inherent physical characteristic representing that kind of a distribution. That was the first thing.

We said, okay, this must be treated and must be treated as an aleatory representation in this case of the K_{1c}. We went back and said, okay, one way is to, of course, take the data and use the fitted Weibull distribution that you have. The second one was actually another method which is a common talk and we learned about it.

The other thing that we had to deal with was that indexing temperature which brought in -- we have to understand what kind of uncertainty involves in that indexing. The indexing, as I earlier noted, comes about because of the embrittlement and because of the temperature variation that comes in because of the cooling scenario of the reactor vessel it.

So this indexing temperature is also very important to bring the heat-to-heat variability between the vessels and also the embrittlement aspects. But it causes actually a significant uncertainty into the result that you would get ultimately. We looked at this in three ways.

We said, "Okay, you can look at it and the first graph represents a case that we said earlier a Weibull distribution of K_{1c} as it's shown for a given temperature is basically an aleatory distribution. Then the indexing could be precisely measured is one way to looking at it.

In fact, this is what is done currently with a method called Master Curve. This was actually standardized and, therefore, this reference temperature can be measured exactly for a given vessel and, therefore, there would be no variability here given that you know exactly the embrittlement in the vessel.

Therefore, this would be the case that you have only an aleatory distribution. Or you have uncertainty about this indexing temperature and, therefore, you would have a distribution here but that distribution is epistemic in nature because you can't really determine if there is a real temperature of indexing.

Finally, originally Oak Ridge came with some kind of the mixing of the two so we tried to actually separate and that was a third way of analyzing. This is the Master Curve that I was talking about. This is actually the trend and NRC had some reservations at the time to use it because of the newness and there were some issues to be addressed at that time. It actually is the cleanest and more physically based model that could be used and it would lead into, if I go to the previous graph, it would really represent this situation.

The second way was to use basically an empirical model of the K_{1C}. That is, to use the data, fit a Weibull distribution to the data, and then come up with an indexing temperature which is appropriate which is systemic in nature and that's what we came up with.

Because of the fact that actually NRC had a reservation on the use of the Master Curve originally because of a number of factors involved we came up with a procedure here, an empirical procedure, for Oak Ridge to use and, therefore, to calculate the RT_{NDT} and bring in only the epistemic aspects of this calculation.

Note that these data, in order to calculate these data, these particular data points to plot them, you have to use this RT_{NDT} to actually come up with the Weibull distribution originally. To separate them we have to go through this procedure.

In other words, you have to go through this procedure to actually come up with the distribution itself by going through and finding how much bias this has with the original model of the -- if I go actually to my backup here.

If you go through the data here, the RT_{NDT} and T_0 which is exact temperature has a bias here. It has a consistent bias. We came up with a methodology to sample from this distribution so that you can find the corresponding RT_{NDT} and then correct the data for that.

Once you correct the data, then what you would be left with is just the aleatory distribution and then you can really plot the empirical distribution here and using this adjustment.

So the idea was here to go and represent the -- if I go is to this case. This was ultimately what we set out to be used at the code which Oak Ridge is developing, favor code, and this is the model that they are now using. Basically the RT_{NDT} is calculated and is an epistemic distribution and that procedure was developed so that the sampling is done properly.

That is, for instance, a sample of RT_{NDT} was taken and this whole area of distribution was actually propagated for the calculation of the probability of the vessel fracture all the way through. Consistent with this procedure was developed that ultimately then Oak Ridge used for that. So the message here is that -- I think going back to your question earlier, Dr. Apostolakis, the 10_{-6} there are, indeed 10^{-2} and so on. It just depends on the temperature.

CHAIRMAN APOSTOLAKIS: That was done in jest.

DR. MODARRES: Okay.

CHAIRMAN APOSTOLAKIS: From my colleague on my left.

DR. MODARRES: Okay. But there are some of that. There were a number of other uncertainties. For instance, one issue was the treatment of multiple flaws in a vessel. Originally we proposed the use of this model that the probability of each flaw failing due to a given trace or a given scenario is probability is given by this, then the total vessel failure probability would be calculated from that.

Favor used that and later the industry had reservations about this because they couldn't understand why probability comes like that. In other words, there was a difficulty understanding what is the marginal contribution of each flaw to the total probability of the whole vessel.

Then we had to go through, for instance, an exercise to show that, indeed, this is exactly the same as saying that because the question was that there is only one bad flaw which is the worse flaw and then that's the flaw that actually ultimately causes the vessel to fail so why not only calculating for that one flaw this probability and that's the one.

Then we showed from the fact that if you go through and calculating the minimum that if you calculate the time that each of these flaws would ultimately go to failure if this scenario will continue that the minimum of that time is really the one you are interested because that is the first flaw that ultimately will break.

This would yield exactly the same answer. We have to go through mathematical proof that this actually comes exactly the same as the previous model. Ultimately we settled on a simpler approach which is this approach. These were kinds of things that we had also go through the process of coming up in the analysis of uncertainties.

Again, the experience here is that bringing probability into the physical analysis is kind of you come to these kinds of issues that are on the surface quite obvious for us but from the people who are only mechanistic analysis is not too obvious. We have to go through some learning curves here of how to communicate with each other in a way because these two models are exactly the same, in fact.

MR. SHACK: Why isn't that a product rather than a sum?

DR. MODARRES: Sorry. This is a mistake here. Sorry. This is last minute. Sorry. This should be product. You're right.

CHAIRMAN APOSTOLAKIS: Well, they're all Greek letters.

DR. MODARRES: They are all Greek letters. This should be a product. This is last minute that we put together.

CHAIRMAN APOSTOLAKIS: That's it?

DR. MODARRES: Yeah.

CHAIRMAN APOSTOLAKIS: Okay.

MR. SHACK: You missed some of this,

George, but this was a very interesting case where it was very important to track between the epistemic and the aleatory. It made a real difference in the way that you did the calculation.

CHAIRMAN APOSTOLAKIS: Yeah, sure.

DR. MODARRES: You could find the answers by several of these factors. I wouldn't say order of magnitude but several factors different if you are taking samples differently. This made a big difference.

CHAIRMAN APOSTOLAKIS: Very good.

MR. ROSEN: You know, I pointed out when Ali was still here that this presentation that he skipped on treatment of uncertainties and complex multi-disciplinary technical assessments was very valuable. It's only six slides. It seems like the most important one and the easiest one to grasp to the staff.

Certain things like the fact that uncertainty analysis is not an isolated task that could be done by uncertainty specialists. It's integrated into the analysis. It's something that the analysts need to understand and do as they develop the models and use as part of what they are doing. There is such a thing as uncertainty management when you are using models.

You can use models that create uncertainty and, therefore, cast ultimate doubt on your answers or you can use models that are less uncertain and contribute to better acceptance of your models. And that technical and organizational coordination and communication are essential during the process of analysis to reduce uncertainty.

Those are just a couple I read off the first slide. I think this is a particularly useful presentation and might be useful to us in discussing uncertainty in the future. I wish he had actually spent a little time with this.

CHAIRMAN APOSTOLAKIS: Maybe I gave you the wrong impression, Mark, when we spoke on the phone but this is really something that should be discussed in a separate meeting on the subject of uncertainty.

MR. CUNNINGHAM: Certainly.

CHAIRMAN APOSTOLAKIS: Today really we're trying to figure out what the problem is, where it's going. But it was good you guys gave us these presentations because I don't think we've had -- I mean, we've had pieces in the past but from the perspective of uncertainty we haven't had. I hope you are going to go out and present these in conferences.

DR. MODARRES: Yeah, we have --

CHAIRMAN APOSTOLAKIS: The problem is in order to appreciate the subtle points there is so much else you have to learn that the local people are not willing to learn. I mean, how much would the average attendee be willing to learn about PTS and all that in order to reach the point where he would appreciate calling something aleatory or epistemic. It's really a major problem.

MR. ROSEN: You might disconnect from PTS and just talk about in general.

CHAIRMAN APOSTOLAKIS: But can you do it, though, in general without the context of PTS?

MR. ROSEN: Take a look at this point. It says here, "Initially we adopted the philosophy that uncertainty analysis can be performed after the best estimate analysis is produced." This is the standard practice. When you get someone to do uncertainty, they do a best estimate and then they think about uncertainty and the answer.

The insight here is that this practice can easily resolve not only inadequate uncertainty analysis but also an incorrect best estimate. In other words, you have to imbed the uncertainty analysis in what you do as you develop your best estimate, not later.

MR. SHACK: It took somebody's ingenuity to figure out how to come up with that uncertainty in the RT_{NDT} the way that they did so they can break that thing out. I'm not sure who the clever guy was that came up with the scheme but it was a good idea and it sort of made the whole thing possible because otherwise you were left with an intractable kind of a problem.

CHAIRMAN APOSTOLAKIS: I suspect part of the reluctance on the part of some of the industry groups to do uncertainty analysis is precisely because they have not integrated it into analysis and they don't appreciate the value of uncertainty analysis. We have seen many times people say that you don't need to do it.

MR. ROSEN: Well, I think you pointed out in the past, Dr. Apostolakis, that's because people have equated uncertainty analysis in general with parameter uncertainties. They struggle through a parameter of uncertainty analysis and come out with 9 percent uncertainty and they say, "Compared to what I know I have never claimed it was better than a factor of 2 or maybe 5 away from the real answer. Here is 9 percent and you're beating me up about 9 percent so this is irrelevant."

Of course, that wasn't the point. The point wasn't just to do parameter uncertainty. It was to do uncertainty which includes model uncertainty in the way you're treating the data and all these other things, not just the parameter.

CHAIRMAN APOSTOLAKIS: Very good. Very good. Now, given that we are rapidly running out of time, we will thank you. Thank you, Mohammad.

Who is next, Mark?

MR. CUNNINGHAM: Dan O'Neal from the staff is next.

CHAIRMAN APOSTOLAKIS: Okay. How much time do you need? Are you coming?

MR. O'NEAL: I'm on the way.

MR. CUNNINGHAM: Dan will need no more than 27 minutes.

CHAIRMAN APOSTOLAKIS: For this?

MR. CUNNINGHAM: Yes. And we'll just --

CHAIRMAN APOSTOLAKIS: How about SAPHIRE?

MR. CUNNINGHAM: That's in this.

CHAIRMAN APOSTOLAKIS: Oh, that's in there?

MR. CUNNINGHAM: Yes. Dan is covering two subjects, SAPHIRE, low power and shutdown.

CHAIRMAN APOSTOLAKIS: Oh. Peer review. Didn't we ask for it two years ago?

MR. CUNNINGHAM: Yes.

MR. O'NEAL: Good afternoon. I'm Dan O'Neal. I'm the man for SAPHIRE. I would like to discuss the peer review that we did.

CHAIRMAN APOSTOLAKIS: We're developing a pattern here, you know. A pattern. You propose something, the staff says no, and two years later it's done.

MR. ROSEN: So we could save a lot of time by not saying no up front.

CHAIRMAN APOSTOLAKIS: Go ahead.

MR. O'NEAL: We earlier this year did a peer review for SAPHIRE.

CHAIRMAN APOSTOLAKIS: Do we have a handout of this?

MR. O'NEAL: It's over on the chair over there.

CHAIRMAN APOSTOLAKIS: On the chair. These?

MR. ROSEN: As long as it's not six to a page.

CHAIRMAN APOSTOLAKIS: SAPHIRE 7. If I go now to the website this is what I download?

MR. O'NEAL: You can download both version 6 and version 7. Actually, version 7 is the current least model. As I'll talk about, we also have in the concept stage version 8.

What we did earlier this year was form a peer review of the SAPHIRE verification and validation process. I just wanted to say very quickly SAPHIRE itself is the code which helps develop and run the probabilistic safety assessment models. What we did was we actually did the TV&V for the code.

TV&V is testing, verification, and validation. It's the process basically which ensures that the underlying code is performing correctly to its requirements. There's a pretty detailed verification validation process set up at the laboratory where SAPHIRE is maintained and developed.

MR. ROSEN: Which is?

MR. O'NEAL: Which is the Idaho National Environmental Laboratory.

MR. ROSEN: I've heard of it.

MR. O'NEAL: What I would like to do today is to discuss what were the objectives of the review and a little --

CHAIRMAN APOSTOLAKIS: Who were the reviewers? Can I ask who the reviewers were?

MR. O'NEAL: Yes. We put together an internal team of risk analysts and a TV&V expert. It was basically an internal team review.

CHAIRMAN APOSTOLAKIS: By internal you mean internal to what?

MR. O'NEAL: NRC team review of SAPHIRE.

CHAIRMAN APOSTOLAKIS: Did you get anybody from other national laboratories?

MR. O'NEAL: No. Actually the team was just NRC personnel. There are other users of SAPHIRE but they weren't involved in the review of this.

CHAIRMAN APOSTOLAKIS: Okay.

MR. O'NEAL: And so the objective basically, you know, we're going to take a look and see how does the cold -- how does the verification validation meet what we expect it to do for the NRC. That's basically how we are gearing this review towards, to determine what type of improvements might be needed, if any. I'll talk a little bit about all those objectives.

I would also like to give a brief discussion of what is the TV&V currently. Finally, I'll talk about our insights and recommendations.

We took a look to see if any improvements were actually needed based upon whether or not we felt it might be -- whether or not it might be applicable to staff applications. For example, if the current TV&V process if there were any specific or general recommendations that we might have developed based upon our review, that we would put together a proposed plan which I can talk about a little bit later, too.

In addition, we felt it might be useful to consider the possibility of taking a look at what we viewed, what we saw from the results of our review in determining if there was a need to have a compliance with a formal software standard for verification and validation. Also we tried to cover a broad area, whether or not the types of reviews that were being done for SAPHIRE code was sufficient or if it needed to be improved.

Currently there's the automated testing verification and validation process. It's a beneficial process since it's very quick. It relies upon -- basically it takes a look at a change or a new feature and it runs the tests for that change or new feature. There's a large data base of test suites that can be run. The automated process is a useful feature but it also has some boundaries which we considered in our review.

The bases for the current process is

documented in that NUREG. It considers the IEEE standard for software verification of validation, as well as the NRC's software procedure guidance, software quality assurance procedure guidance, in determining the current TV&V. Those two documents or verification of validation were considered in determining for the current TV&V what type of actions might actually improve the process.

This document, of course, as you see, is for the year 2000. It looked at -- it has the bases for what has occurred prior to 2000. Since this publication we have provided additional -- we have provided additional, I guess, structure to the design and testing process by establishing a procedure for testing, for evaluating a change and documenting it.

It looks at the change to ensure that it meets the expected goal. It also looks at the interactions of SAPHIREs features that might be affected by the change. Also trying to look at the -- make the change in the most useful way. For example, if you want to make a specific change because of a specific request, make that change in the most general way that would be most useful. Of course, we have documentation and we want to update the test suite.

Was all this satisfactory for the current

NRC applications? This is the approach that we looked at that we used to evaluate the current testing, the verification of validation process. It involved looking at the processes that are in place at the laboratory, looking at the changes that were made over the time period as the subversions of the SAPHIRE code were changed to account for various errors or new features or new requirements. We took a look at --

MR. SHACK: Who developed the test suite?

MR. O'NEAL: The test suite is developed by the Idaho National Laboratory. That was one thing we considered here, whether or not the test suite, for example, has an adequate -- is it complete enough. Are the test acceptance criteria adequate for what we expect for staff applications. The TV&V process has to be maintained consistent and synchronized with the applications that the staff uses SAPHIRE for. That was another aspect to be considered.

In particular we had two supporting activities. One was to see how the current TV&V process matched up with the IEEE standard for software verification validation. There's various life cycle processes that a software project goes through so we took a look to see if what we're doing now matches up with the formal standard.

We also made a database for the number of changes that were made and we analyzed the database. For example, we looked at whether or not the change in the change log for the SAPHIRE code was related to a vital feature of the SAPHIRE code or a vital feature of something which would affect the PRA results.

We would also take a look at whether or not the change was repetitive, for example. Whether or not it was related to a risk measure, importance measure, uncertainty analyses, and whether or not it was significant. We had a pretty large database of which we could analyze the changes and, in fact, there were about 500 changes that we looked at. Those were over version 6 and version 7.

We wanted to determine of the verification validation process was okay or if we needed to make some improvements, specific or general, and whether or not there was enough -- if there were insights that would support or suggest that compliance with a more formal standard, a more formal approach than what is currently being done is warranted.

Of course, we also wanted to ensure that the SAPHIRE V&V and the underlying code for the PSA models are receiving the types of reviews that they should be receiving. Our general insights --

CHAIRMAN APOSTOLAKIS: That's where you lose me. It seems to me you are reviewing the review process. I don't see anything here that has to do with SAPHIRE. Are you talking about the process? You found it to be formal? The process this or the process that? Where are your findings regarding SAPHIRE itself? Is the code usable? Is it useful? Does it have problems?

MR. O'NEAL: The SAPHIRE code, as I mentioned, is subjected to the process. When I say the process, it means it's subjected to a series of tests which test the vital features of the code. Does it calculate risk measures?

CHAIRMAN APOSTOLAKIS: So what are you findings? The third bullet seems to touch upon those. The other bullets refer to the process itself. That may be useful but it doesn't tell me about SAPHIRE.

MR. O'NEAL: That's right. As I pointed out, we did an assessment of the performance of the code by an analysis of the change log, for example. And we also looked at what are those findings telling us.

CHAIRMAN APOSTOLAKIS: So what are they telling us? What are they telling us about the code?

MR. O'NEAL: Okay.

CHAIRMAN APOSTOLAKIS: You say a number of changes in the change logs they viewed were significant. "Code error that affects the correct result for risk measures." What does that mean? That the results of SAPHIRE was produced but not right or what?

MR. O'NEAL: What it means is in the change log which documents the changes over the versions 6 and 7, it means that when the change was made, it was made for a reason. We evaluated whether or not the change could affect the correct result for these types of considerations.

If it does, what it means is that it puts a lot of emphasis on the user to understand that there was an error in the code and to detect it himself. The TV&V process is the process which is set up to detect the errors in the code.

CHAIRMAN APOSTOLAKIS: Fine. So you did find an error then. That's what you're saying.

MR. ROSEN: Significant errors.

CHAIRMAN APOSTOLAKIS: Did you find significant errors?

MR. O'NEAL: Yes. Well, this is what I meant by significant was that when we looked at the changes, did the change result in an error. I mean, was it related to an error in the code which could affect the correct numerical results but it does not alert you if you are a model developer.

CHAIRMAN APOSTOLAKIS: Oh, so you didn't get the error fixed. You just identified it.

MR. O'NEAL: These were fixed. Once they are identified, of course, they are fixed.

CHAIRMAN APOSTOLAKIS: So there is no reason to alert the user because the user doesn't know.

MR. O'NEAL: It becomes important if it bypasses the TV&V process and the user, for example, is using a model with the underlying code that still has the error in it.

MR. ROSEN: Do you alert past users who may have used it for importance to 6 or 7 or whatever and you later found an error in the code? Do you have a method to alert the users as to what was found and what the importance might be?

MR. O'NEAL: Well, we do have a website which has the change logs on it so anytime that there is an error or a change made to the log because of something that was found it's posted but that is a very recent feature.

CHAIRMAN APOSTOLAKIS: NASA, for example, is using this to do a major PRA. Are they using the version that has the error? Shouldn't you let them know? I don't think that they are going back to the website every week to check whether there were errors found. The code has wide use.

MR. O'NEAL: There's going to be errors in almost every PRA computer code. There has to be a process to alert anybody who needs to know that.

MR. ROSEN: There's a user's group I'm sure.

MR. O'NEAL: There is a SAPHIRE's users group.

MR. ROSEN: They can alert and they talk to each other.

MR. O'NEAL: The NRC has meetings for both the SAPHIRE and SPAR model users group so there are mechanisms to relay these things.

CHAIRMAN APOSTOLAKIS: I hope that at some point there would be no major errors.

MR. O'NEAL: That's what we were looking at when we looked at the database. Are there errors that we might have -- are we seeing anything in the database which could have bypassed TV&V process. That was one of the objectives to see if we were comfortable with the number of changes that might represent this type of condition.

CHAIRMAN APOSTOLAKIS: So the bullet before last is kind of ominous. "The number of changes representing both non-significant and significant changes." What does that mean? You mean errors. Somewhere there should be errors.

MR. O'NEAL: There are errors that are changes in the change log corrected. Once they're corrected, they are updated in a new subversion so that's why there's the second bullet. It shows that every time --

MR. SHACK: This is indicating these errors were found by users rather than by the TV&V process.

MR. O'NEAL: Well, actually, I think it was a mixed bag. The documentation was not very clear on who found it, whether it was a TV&V, whether it was users. But I am aware that there have been users that have found significant change errors in the code and those get fed back to us and we provide it to the laboratory. The laboratory corrects it and puts up a new subversion. What we also wanted to see by our review were things getting better. As you released a new subversion are you improving the reliability?

CHAIRMAN APOSTOLAKIS: There is one last

question. Are these changes controlled? One of the complaints I heard from people outside is that somebody picks up the phone, calls and says, "Hey, I found this error." The guy on the phone goes and fixes it and that's it. There is no formal mechanism evidently for actually evaluating the error or fixing it and announcing to the world. Has that been fixed now?

MR. O'NEAL: There is a formal process for making the changes and I discussed that earlier.

CHAIRMAN APOSTOLAKIS: This guy you talk to him and he goes and changes the code. That's too sloppy.

MR. O'NEAL: Well, there's many, many users of SAPHIRE and the person who is using it may come from a national laboratory, may be an NRC user or somebody else. The mechanism is --

CHAIRMAN APOSTOLAKIS: He can change his own version but the center one shouldn't change that way. Anyway, we are running out of time so I guess we're going to have another opportunity to talk about it sometime. Do we need to give some time to J.S.?

MR. CUNNINGHAM: We have two options at this point in the remaining time. We can talk about low power and shutdown, we could talk about fire risk.

MR. ROSEN: Yes. Let's get fire up here and then low power and shutdown right after that.

CHAIRMAN APOSTOLAKIS: It's only one slide.

MR. HYSLOP: My name is J. S. Hyslop. I have one slide that I imagine was put in back for the presentation. I'm in the PRA branch of the Office of Research and I'm the project manager for the Fire Risk Research Program.

I have a general remark. We have a plan for the Fire Risk Research Program which is being updated for 2004 to 2006. We're in that process. I think you'll see from my slide that the program is continuing to provide critical support to regulatory activities for nuclear power plants.

MR. ROSEN: Is that plan a NUREG or something like that?

MR. HYSLOP: At this time it's not publicly available. We've received some internal comments and we're updating it. I would have to talk to my management to find out what's been done in the past.

MR. ROSEN: Typically it's an internal document, a memorandum from somebody to somebody not published as a NUREG.

MR. HYSLOP: I'll go ahead and start because you've got the slide.

MR. ROSEN: Go ahead.

MR. HYSLOP: There's about eight activities on the slide for the Fire Risk Research Program. The first is the fire protection SDP revision. The fire protection SDP is to evaluate the risk significance of fire protection inspection findings.

Research is playing a large role. We developed a time based framework. We are leading a task group to resolve issues on frequency and database, providing support in other areas like the fire scenario group and circuit analysis.

We are also writing the revision with inputs from task groups. I guess you guys if you're not familiar with this revision process there are many task groups have been developed to address technical issues consisting of NOR, research, industry, and EPRI playing a role also.

MR. ROSEN: That's on the SDP?

MR. HYSLOP: That's on the fire protection SDP revision alone. The next topic is circuit analysis. About a month ago in front of the fire protection subcommittee I present research activities and circuit analysis. Basically from the history of research we supplemented the Omega Point Test to identify the probability of spurious operations and supported the expert elicitation for the interpretation of that data.

More recently we supported public meetings. We helped to identify important circuit analysis features for planned resumption of associated circuit inspections. We just published a NUREG which I'm sure you're on the distribution list for, NUREG CR-6834 entitled Circuit Analysis, Failure Mode, and Likelihood Analysis.

We're supporting NOR and development of a NUREG particularly for associated circuits. We've recently accepted a user's need from NOR. We will determine if there are any additional circuit features beyond those identified in that meeting that should be added when the associated circuit inspections begin.

The third bullet, we are providing review guidance for NOR specialist to support changes which would occur during the risk informed performance based rulemaking which endorses 805. In particular we're providing guidance to enable people to evaluate fire models.

To do that we're performing a V&V on a set of fire models from simple to sophisticated fire models running from empirical zone to CFD. We will be using an ASTM standard 135597 which is specifically developed for fire model V&V. We'll also be providing guidance to help reviewers evaluate the worthiness of inputs to fire models, in particular heat release rates.

Heat release rates have been one of the more interesting areas because you need to make sure you covered it all. You need to make sure you cover those low-probability potentially high-consequence fires. Of course, lastly we're going to be providing review guidance for FRA methods tools and data.

The next bullet, the ANS full power fire standard. That standard will eventually provide a bases for changes under 805 and Research is providing two writing members to the standard committee.

MR. ROSEN: Do you know if they are addressing fire in the low-power shutdown model?

MR. HYSLOP: No, they're not. The standard is not. However, later in my talk I will talk to you about a little something we're going to be doing.

MR. ROSEN: I'm worried about fire, especially during shutdown because of the number of people and activities increases so much over operation.

MR. HYSLOP: Right. This is a full-power standard.

MR. ROSEN: You need to do more for the low-power standard.

CHAIRMAN APOSTOLAKIS: The database mostly.

MR. ROSEN: Right. I think he knows that and I'm reinforcing the point.

MR. HYSLOP: I'll talk a little bit more about that later in my presentation. The next topic is the NRC/EPRI fire risk requantification studies. These studies are being performed under a joint memorandum of understanding between NRC and EPRI. The goal there is to provide state of the art guidance for the conduct of FRA.

In that program there is debate between EPRI and NRC specialists and that debate is based upon our existing research programs. The results will have broad application to regulatory activities and issues. It's impacting the SCP revision.

It's going to be providing a support for technical bases on the manual actions rulemaking. It's going to be assisting the ANS fire risk standard.

And it will assist in review guidance, as I said, for the 805 rulemaking. Also it will provide guidance for licensees who are developing applications.

MR. ROSEN: The fire risk requantification studies debate between you and this EPRI? Is that the word you used, debate?

MR. HYSLOP: Yes. Deliberation and debate. Yes, because there are two parties. Obviously we have research programs and we are debating with the goal of developing consensus. We've been very successful in that endeavor so far.

CHAIRMAN APOSTOLAKIS: Do you disagree in some areas?

MR. HYSLOP: At this point we have come to resolution on all areas.

CHAIRMAN APOSTOLAKIS: Very good.

MR. HYSLOP: Now, we've gone further in some areas than others. The HRA in particular. We haven't gotten as far in that area as some of the others and naturally it's a harder area. The research programs aren't as far developed as you might be for circuit analysis where we put several years in fire induced circuits.

Now regarding your comment on low-power and shutdown, net week we're going to have a meeting with EPRI and a licensee about looking at doing a low power and shutdown requantification study. This meeting is the first part of a couple of meetings to evaluate the feasibility of doing that.

We are hopeful. We've had good experiences in the low power. We've got a range of players who can sit around the table and make decisions about where we need to go and what the challenges are. It's a feasibility study and we haven't agreed to do it yet.

MR. ROSEN: Okay. Good. You're working on it.

MR. HYSLOP: Working on it. Now, the next bullet is the FAR model benchmarking and validation. My days leading this activity and we've performed some analytical exercises on cable tray fires and fires in turbo halls. This has been a part of a fairly large international collaboration called the International Benchmark Studies.

We completed a fire test at NIST and we are currently analyzing the data on that test. We have additional test planned. The tests at NIST which are planned are to be determined. However, we are planning test with the French at the DIVA facility and those particularly tests are for multi-compartment effects.

The next to the last bullet is a planned activity. This is Hemyc and MT fire barrier testing. This has been tested before. However, these formal tests have come into question so NOR has developed a test plan which identifies configurations to be tested, includes public comment.

Research is going to perform that test plan. We are also considering developing a model to extrapolate the results of the test beyond the test configurations. We are going to assess if any additional testing is appropriate.

Last comment or bullet is international activities. The international activities besides the fire modeling support circuit analysis and fire event data. The circuit analysis there's a group called FIDEC under the Cooper Working Group. FIDEC stands for the Fire Induced Damage to Electrical cables and circuits and they are performing some tests. The Germans will perform some tests in November and December on that.

The last activity, fire event data, that's being done in the auspices of the OECD. They are developing an international fire events database and we are participating in -- it's my understanding from talking to the people running that that we are supplying LER data.

That's it. I hope I haven't gone too fast but I was aware that we were trying to get through this quickly.

MR. ROSEN: Well, I'm sorry to have to ask you to come here because you know I'm the Fire Protection Subcommittee Chairman and have heard most of this before but I think the reliability of the PRA subcommittee players who were here and needed to hear some of this. At least it's on the record and they did hear it. Thanks very much, J.S.

MR. HYSLOP: You're welcome.

MR. CUNNINGHAM: One last topic would be low power and shutdown.

MR. ROSEN: Right.

MR. CUNNINGHAM: Dan, if you want to go ahead and do that.

As Dan is getting up, I'll remind the Committee members that this is a topic where we have been somewhat constrained in what we can do in the area of low power and shutdown risk analysis by some Commission decisions on budget and that sort of thing.

You don't see as robust a program in low power and shutdown risk as you do, for example, as in fire risk analysis. Dan will kind of talk about most of the work that we're doing is supporting the development of standards for low power and shutdown PRAs.

MR. O'NEAL: I'll quickly talk about the other activities that we've been doing. I think you heard earlier about the SPAR models. There's a number of other activities going on. First and foremost, we are actively supporting development of low power shutdown standard which is being written by the American Nuclear Society.

We're on the writing committee so we are actively involved in writing those standards. The standard itself is projected to be completed around December 2004. Just recently work started again on it back in the early spring of this year so there's been a little bit of delay.

MR. SHACK: When is a draft going to be available?

MR. O'NEAL: That's usually -- I would project around summertime next year. It's usually available about six months before.

The supporting work that we're doing for the ANS low power shutdown standard is a revision to our NUREG/CR-6595 which provides a simplified method for evaluating larger release frequencies. We've added a chapter specific to shutdown conditions, how to estimate larger release frequency for low power and shutdown conditions. That's in our draft NUREG which is actually out for public comment right now. The public comment period ends the end of October. In addition to low power shutdown standards work --

MR. ROSEN: Do you have these review graphs for us to take home and think about?

MR. O'NEAL: Yes, they are back on the chairs over there.

MR. SNODDERLY: In the SAPHIRE packet?

MR. O'NEAL: It's separate. We're also taking a look at expanding the scope for the fire requantification project from full power to low power shutdown. We are going to be doing a feasibility study for that which is actually underway right now so there's not much right now to talk about but maybe later.

In addition, we are supporting the worker fatigue rule effort by looking at low power shutdown events, reviewing the LERs to see what type of insights we may gain and provide that to the staff that's working on the rulemaking.

Another important topic is our activities in the international community for trying to learn about the low power shutdown risk. We actively participate in the international meetings for a couple of the international low power shutdown groups. One is called the Cooperative PRA Working Group for low power shutdown. The other one is CSNI, or the Committee on the Safety of Nuclear Installation.

Both of these organizations have something in common in terms of wanting to improve the regulatory decision-making process by sharing the information on low power shutdown PRAs, the different approaches that have been taken, the different insights, different types of data and methods that are available. It's a learning process and we are actively participating in those.

A little bit more about what we're doing for COOPRA group. The United States had the lead for writing a topical report on initiating events. That was based upon responses to a questionnaire from the various member countries taking a look at what can we learn from initiating events in terms of the uniqueness of the low power shutdown initiating events, the types of, I would say, data that's not there and the types of data that might have to be obtained to improve the insights.

MR. ROSEN: Well, there's a lot of data there. Right? For instance, RHR flow interruptions during shutdown.

MR. O'NEAL: That was one of the things. One of the objectives was to see. For example, what is based upon operational experience and what is not. Those types of initiating event questions have been asked in that questionnaire to help gain some insights. What is the completeness, you know. Do we have enough data to look at the initiating event frequency. Do we have enough data.

MR. ROSEN: Let me see if maybe the regulatory guys. If you're in shutdown mode and you're on RHR and you have a flow interruption that last long enough to actually get some heat up, is not that an event that is reportable, LER reportable?

MR. CUNNINGHAM: I believe the answer is yes it is.

MR. ROSEN: So you have data. You have some data, at least.

MR. O'NEAL: Yes.

MR. ROSEN: The presumption always is that reportable events are reported.

MR. O'NEAL: Right, but this is for the COOPRA group itself so it's not only the United States but other countries.

MR. ROSEN: Well, we will eventually include the foreign data but just the domestic database so that you have some view of ability to at least attempt to calculate the reliability of residual heat removal. Given that, you also have the ability to study the events that happened and fortunately none of them has resulted in really serious problems.

But if you have an initiating event frequency, you can then understand that there are periods when you are eight to 10 minutes away from boiling, a maximum reduced inventory situation and PWR at mid LOOP for a hot early mid LOOP.

Then you can make some estimates of how likely it would have been to get into a really significant bind. It's only a matter of probabilities. The point is there have been these interrupts. They just haven't happened at the worse possible time yet.

MR. O'NEAL: Yes. That data is out there and we have incorporated it into the models that we are developing. I think there are also issues about human induced initiating events so that's another --

MR. ROSEN: Well, loss of RHR could be human induced. I don't care how it's induced.

There's lots of different ways but the point is the first output of something like this might be some people are feeling about the global risk of loss of RHR in terms of frequency consequences. We know something about frequency more than you seem to imply but I think when you study it, you'll see that it's there.

MR. CUNNINGHAM: There's a document that was completed a year or two ago by this same COOPRA group that got into what are the perspectives globally about the risk associated with low power and shutdown. That report got to just what you're saying, it can be significant and it's this type of scenario and that sort of thing so there is an initial report.

It led to two or three reports being developed one of which was this. Given that we see that general pattern, what are the things as technical people we could work on to improve the quality of them and getting an initiating event frequencies was a key piece that people thought needed to be standardized, if you will.

MR. ROSEN: There are some in this agency who think that the risk of low power and shutdown is negligible and I beg to differ. I think some data analysis and evaluation might be helpful. There is an answer. It either is or it isn't or it is under certain circumstances perhaps. I think it would be a useful contribution to put some data rather than just intuition on the table.

MR. O'NEAL: I think that's what the second activity where we are developing a database for initiating events might help out with since we're going to maintain a database and keep it updated with initiating events frequencies for a particular plan operational status.

MR. ROSEN: Also it's going to lead you right into the shutdown risk SDP.

MR. O'NEAL: Yes. And I think the initiating events for DSDP have already taken into account the updating of RHR.

MR. ROSEN: I don't know if it's already happened but sooner or later someone will have an event during shutdown under the ROP and then there will be a big debate about whether it was white or red or yellow or what and it would be helpful to have a better database.

MR. O'NEAL: We are also developing the models for low power shutdown. Office of Research is developing the low power shutdown models. Updating the frequencies in those models is being done. There is some updating going on for those models.

The other international activity that we've been participating in the CSNI low power shutdown working group. The work here is broader than what we've been doing for COOPRA. It covers the major elements for a low power shutdown PSA anywhere from a cooling initiating event to definitions of plant operational states to the consequence to how low power shutdown PSA is being used, and identifying areas of research.

A major product for this group is to produce a technical report based upon the results of a questionnaire. What can we learn from what other countries are doing with their low power shutdown studies. What type of methods and data are out there to help us.

For example, if you see the objectives there to improve risk tradeoff decision making between full power operation and low power shutdown operation. Once we identify what are the significant areas that have to be addressed, how will those areas be addressed. The report that we're putting together is a summary of the responses and what we've learned from those responses.

It takes a look at what types of methods and data are being used and what else do we have to learn. What are the areas of interest for further research. We expect to learn a lot from this effort. An example of something that might be useful or further useful to look into is, for example, HRA during low power shutdown.

HRA would benefit for simulator type of data which is a noted limit for low power shutdown studies is a lack of that type of data where you might have simulator data for full power types of scenarios. There's some information on what other countries have done in that area so that is one example. We are continuing to work on this report and expect to be able to learn a lot and share information.

MR. ROSEN: When do you think this report will be done? Do they have a schedule?

MR. O'NEAL: Well, let's see. We're going to -- we just recently had a meeting over in Paris and it was decided at that meeting to allow further information to be presented for completion of the report so it's not a really definite time right now but at least we are going to be updating our report later on. Those countries who want to update their input can do it and they will provide information to us by the end of the year.

MR. ROSEN: The end of this year?

MR. O'NEAL: Yes. And the report itself is actually -- I haven't heard a completion date for that report but we will have another meeting discuss it. The various member countries will look at it and have another chance to discuss it. There is a final draft. That's going to take place some time after we get some updated responses to the questionnaire.

The format of the report is actually going to be combined with what we are doing for the COOPRA effort so we are going to take the work for COOPRA which is more than the initiating report which I presented. We are going to take what COOPRA is doing as well as what CSNI is doing and combine it to one report and have a couple of appendices. I don't have a time scale for that yet.

MR. ROSEN: Any guess? This is important work and it sounds to me it's drifting without someone saying when we're going to get to the finish line.

MR. CUNNINGHAM: The answer is probably within six to nine months.

MR. ROSEN: You think next year sometime?

MR. CUNNINGHAM: Yes.

MR. ROSEN: Okay. This would be fairly useful. This thing you introduced there with your bullet No. 1, the differences between methods used and tradeoffs is something we call cycle risk optimization. That is, you can do -- you have to do something to maintain a component of importance. The question is when you do. Do you do it online which may be possible under certain sets of tech specs or do you wait until shutdown?

It may turn out for equipment that's of particular use during shutdown like electrical power equipment. It may be less risk in terms of overall cycle risk optimization to do it during operating periods rather than during shutdown and clearly vice versa. The important thing to a risk analyst is not when you do but what is the overall cycle risk from breaker to breaker and breaker to breaker.

When does the strategy that reduces overall cycle risk. In other words, the interval of risk over time. That is the important parameter, not we're using risk during operation and then shutting down and having a whole lot more risk during shutdown and the overall risk is higher than you would have been if you did it during shutdown. Cycle risk optimization if an important point.

A lot of people are doing it implicitly, I think, and getting the wrong answer. They are doing it the way we always used to. A lot of people are doing it while they are shutdown when really they are probably better off doing it when they are running for equipment that's important for risk control during shutdown. I also think there is some of the reverse.

If once we could have a shutdown risk calculation method that is, as you suggest here, that would allow meaningful risk comparisons or tradeoffs among these operational conditions we would be in much better shape. I think this is a worthwhile effort and I think you can do whatever you can to try to move it along.

MR. O'NEAL: Okay.

MR. ROSEN: If there are no further comments from my colleagues? I doubt there will be any. Or from members of the staff? I'm not as sure there wouldn't be any. Members of the public? Members of ACRS staff? Okay. We'll stand adjourned.

(Whereupon, at 2:59 p.m. the meeting was adjourned.)

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 Reliability and Probabilistic Risk Assessment Subcommittee

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.

Jennifer Rosario
Official Reporter
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FEASIBILITY OF APPLYING FORMAL DECISION METHODS TO NRC ACTIVITIES

Presentation to ACRS Subcommittee on Reliability and Probabilistic Risk Assessment

October 10, 2003

N. Prasad Kadambi, REAHFB

Office of Nuclear Regulatory Research

OUTLINE

- Background

- Context for Formal Decision Methods (FDM)

- NUREG/CR-6388, "Formal Methods of Decision Analysis Applied to Prioritization of Research and Other Topics"

- Ideas for formal methods.

- Implementation possibilities.

- Summary

BACKGROUND

- The ACRS noted in a letter to the Commission on February 14, 2002 that their review of the safety research program had recommended exploration of formal decision methods.

- Specifically, under "Use of Formal Decision-Making Methods to Support Regulatory Decisions" it was stated that:

  - In NUREG-1635, Vol. 4, we observed that the decision-making processes used in the regulatory framework process often appear overly subjective and recommended that the staff initiate a research program to investigate how best to use formal decision-making methods to make regulatory decisions more objective and transparent and, thus, more defensible."

- On March 29, 2002, the EDO responded that, "... RES recognizes the merits of the recommendations and will explore the feasibility of applying these methods in its work."

- Soon after, we initiated a technical assistance Task Order and the NUREG/CR-6833 is the result.

CONTEXT FOR FORMAL DECISION METHODS

- Exploration of FDM for prioritization of research was opportune in early 2002 because of the "Advanced Reactor Research Plan" (SECY-03-0059).

- We recognized all along that the methodologies had widespread applicability.

- Elements of FDM are practiced in a number of ongoing activities:

    - The agency effort in Planning Budgeting and Performance Management (PBPM), including consideration of the four performance goals, represents identification of elements of the NRC's utility function.

    - The existing methods for prioritization, including the Phenomena Identification and Ranking Table (PIRT) have a degree of formality.

    - Performance-based regulation, which attempts to set performance measures at as high a level as practicable, reveals the importance of a formal structuring of objectives.

    - Success of the Reactor Oversight Process (ROP) can substantially be attributed to the formal structuring of objectives.

NUREG/CR-6388, "FORMAL METHODS OF DECISION ANALYSIS APPLIED TO PRIORITIZATION OF RESEARCH AND OTHER TOPICS"

- Our objective for NUREG/CR-6833 was to provide NRC staff with a compilation of tools and methods from the vast field of FDM that would likely be useful for regulatory application.

- In addition to the customary management review, the report was reviewed by staff from NRR, NMSS, and NSIR. The comments from these reviews were extremely valuable.

    - Comments recognized value of structured decision process.

    - Elements of FDM were recognized in various ongoing NRC activities.

    - Unfamiliar terminology and conceptual complexity were considered to be significant obstacles.

    - The importance of demonstrating usefulness by application to familiar examples was a common theme among the comments.

- Overall, the research provided evidence in support of NRC continuing to pursue FDM.

NUREG/CR-6388, "FORMAL METHODS OF DECISION ANALYSIS APPLIED TO PRIORITIZATION OF RESEARCH AND OTHER TOPICS" (Contd)

- Staff using NUREG/CR-6833 would be introduced to:
  - Utility theory
  - Value-of-Information techniques.
  - Types of performance measures, scales and indicies.
  - Hypothesis testing.
  - "Receiver Operating Characteristic" Curves.
  - Objectives hierarchies.
- The information is presented in a context that addresses some current regulatory issues, such as decision making under uncertainty. Information is also provided on the Analytic Hierarchy Process and the Code Scaling, Applicability and Uncertainty Evaluation Methodology, which are more familiar to staff.
- Mention is made of potentially useful performance measures for research such as value added by assessing change in uncertainty.

IDEAS FOR FORMAL DECISION METHODS

- The success experienced by the ROP, and the Commission's stress on performance-based regulation, offer the potential that familiarity with FDM could increase.

- Opportunities could arise from diverse activities, e.g. the PBPM process stresses consideration of the strategic performance goals. Multi-attribute utility theory may have potential application for developing guidance for the staff for implementing the Strategic Plan.

- RES is evaluating options, including consideration of pilot projects, while establishing the required foundation of tools and methods available from decision theory.

- Participation by other program offices is essential for the eventual success of our initiative to offer to the staff improved decision making tools and methods. External factors, such as OMB's recent requirements relative to formal program assessment and rating, as well as internal factors, such as common prioritization of staff activities, may combine to create opportunities for FDM based concepts.

- Suggestions from other stakeholders, such as ACRS, would be most welcome and appreciated.

IDEAS FOR FORMAL DECISION METHODS (Contd)

- Formal adoption of FDM would improve the focus on structure, transparency, and the treatment of uncertainty.

- We are proposing five steps using the utility concept as the basic process for FDM.

- The first step is to construct the utility function.
  - Identify elements of the utility function.
  - Combine the elements with preferences of the decision maker.
  - Formulate and screen scenarios; note constraints such as legal requirements.

- The second step is to formulate action alternatives.
  - With stakeholder input, test for incorporation of elements and preferences.
  - Also test for policy preferences, eg. RI, PB, RIPB, and traditional approaches.

- The third step is to generate expected utilities.
  - Identify quantitative/qualitative factors with natural/constructed measures.
  - Identify figure-of-merit (performance index)
  - Identify decision rules.

- Rank order alternatives

- Select alternative, if appropriate.

IMPLEMENTATION POSSIBILITIES

- The initial focus for implementation should be closing the gap in terminology.
- Establish Inter-Office Working Group
  - Provide focal point for FDM
  - Develop nucleus of FDM-knowledgeable staff
- Identify case studies
  - Explore regulatory issues that could benefit from FDM
  - Develop internal consensus on expected benefits
  - Address resource issues
  - Establish assignments, schedules, deliverables

IMPLEMENTATION POSSIBILITIES (Contd)

- Obtain wide range of stakeholder input
  - Higher level management briefings
  - Advisory Committee presentations
  - Public meetings, as appropriate.
- Conduct case studies
  - Working group interacts with staff for appropriate level of FDM application.
  - Compare results with expectation
- Prepare NUREG report
  - Internal stakeholder interaction (including Advisory Committees)
  - External stakeholder interaction
- Report to Commission

SUMMARY

- RES followed up on ACRS's suggestions on FDM and agrees that NRC activities could benefit significantly from such applications.
- The staff's exploration has resulted in NUREG/CR-6833, which could provide a resource for tools and methods that would enable staff to get started.
- An evolutionary approach that gradually expands on applying decision theoretic methods is considered to be the most practical path forward.
- Successful case studies may alleviate discomfort with terminology, and offer evidence that objectivity and transparency can advance performance goals.
- Identifying appropriate regulatory issues to use as case studies is a significant challenge. ACRS suggestions are welcome.
- It is crucially important to obtain Commission acquiescence on a broad application of FDM in NRC activities.
- If the Commission agrees that FDM is worth pursuing beyond the exploratory phase, the staff now has the requisite foundation on which to build.

Division of Risk Analysis and Applications

Mark Cunningham

Acting Deputy Division Director

October 10, 2003

DRAA Overview

- Staff – 55 FTE
- Budget - $14.8M
- Major Responsibilities
  - Operating Experience
  - Security
  - Risk Methods
  - Risk Studies
  - PRA Standards
  - Advanced Reactors

Operating Experience

- SPAR Program
- ASP Growth
- New data system
- MSPI
- Task Force recommendations
- Support international meetings/workshops

Security

- Vulnerability Study Use
- Research Plan
- Decisionmaking
- Briefings for international community

Risk Methods

- HRA
  - Atheana
  - Human reliability data
  - Halden
- Fire Risk
  - Requantification studies
  - Barrier testing
  - SDP revision
- Materials and Waste
  - Draft safety goals
  - Tools, methods, data, guidance

Risk Studies

- Option 3 - 50.44; 50.46
- PTS
- Dry Cask
- GSI 191 - PWR Sumps
- Steam Generator Tube Rupture

PRA Standards

- DG 1122 – ASME/Peer Review
- External Events - ANS
- Low Power & Shutdown- ANS
- IAEA/NEA/NRC/CNSC PSA Quality Workshop
- Support Guidance
  - Sensitivity
  - Uncertainty

Advanced Reactors

- Technology Neutral Framework
- ACR-700
- PRA Tools - Passive equipment

Support

- PRA Steering Committee
- RIRIP
- RILP
- NMSS Risk Steering Committee

RISK-BASED ANALYSIS OF REACTOR OPERATING EXPERIENCE

Presentation for ACRS Subcommittee on

Reliability and Probabilistic Risk Assessment

OCTOBER 10, 2003

PATRICK W. BARANOWSKY, CHIEF

OPERATING EXPERIENCE RISK ANALYSIS BRANCH
OFFICE OF NUCLEAR REGULATORY RESEARCH

CONTENTS

Introduction

OERAB Support to Agency

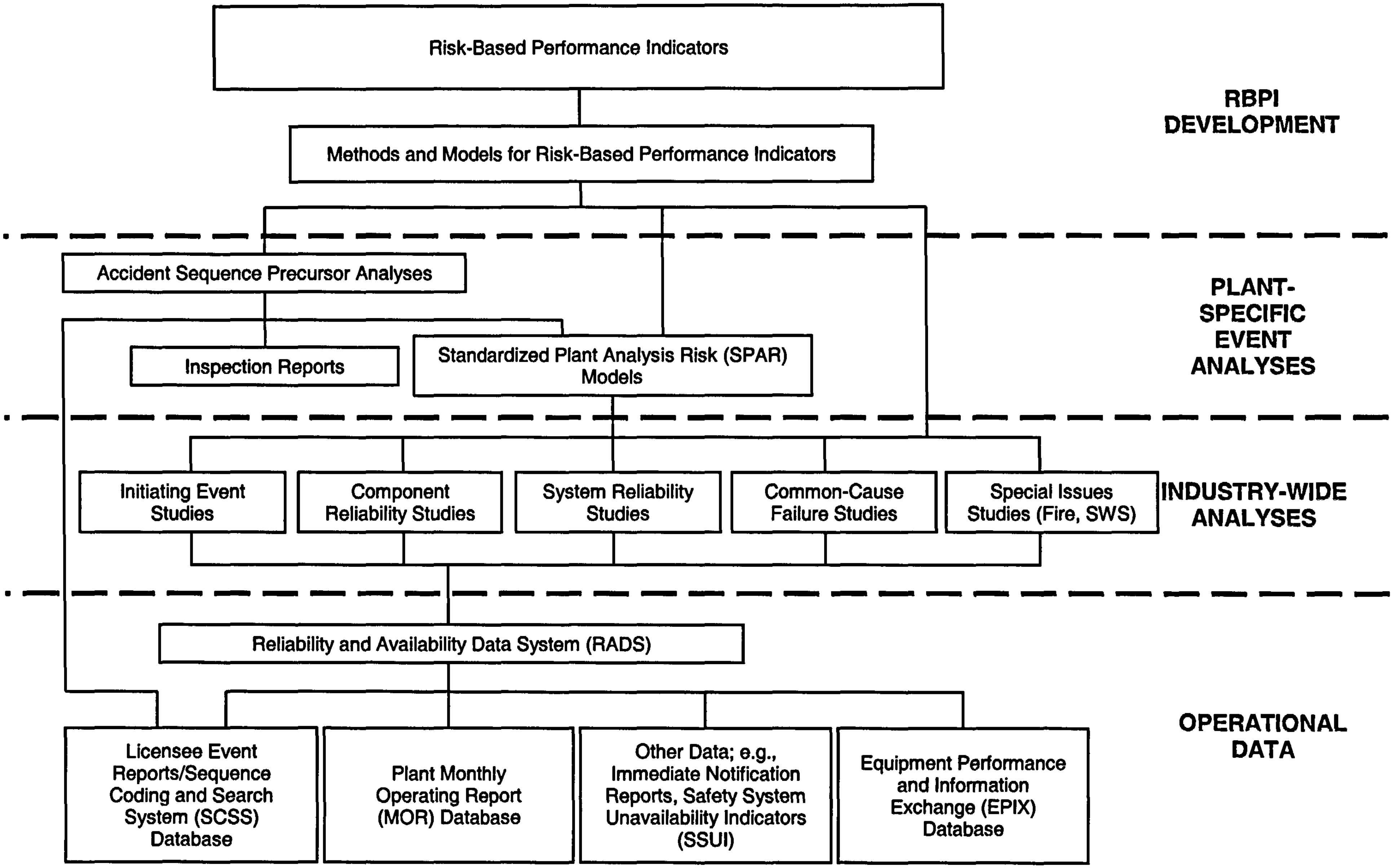
- **Accident Sequence Precursor Program**
  - Report to Congress Input
  - Trends
  - Independent Analysis

- **Reactor Oversight Process and Trends Support**
  - Performance Indicators and industry trends (initiating events, safety system reliability, common-cause failures, component performance, etc)
  - Thresholds for trends

- **NPP Performance Data Collection and Analysis**
  - Initiating Events
  - Safety System Performance Data
  - Component Performance Data
  - Common-Cause Failures

- **SPAR Model Development Program**
  - Power operation (Rev. 2QA, Rev. 3i)
  - Low Power/Shutdown
  - Level 2/LERF
  - External events (earthquake, flood, and fire)

RISK-BASED ANALYSIS OF REACTOR OPERATING EXPERIENCE PROGRAM



Data Collection and Analysis

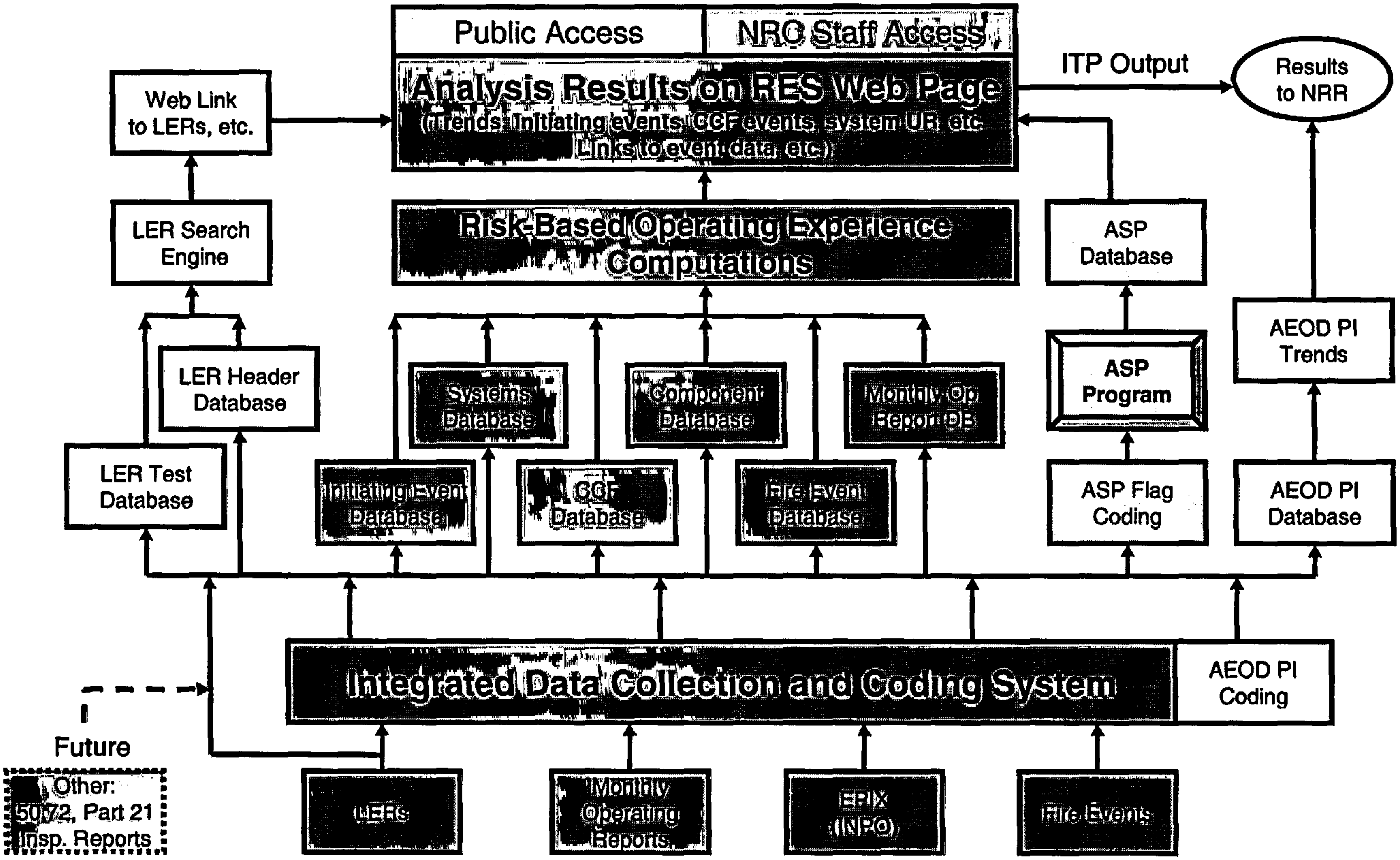
CONSOLIDATED DATA COLLECTION AND ANALYSIS

- Integrated Data Collection and Coding System
  - LERs are reviewed and coded once for:
    - Initiating events
    - Systems reliability
    - Component reliability
    - Common-cause failures
    - Fire events
    - Candidate ASP events
  - Similarly, EPIX data from INPO reviewed and coded once for:
    - Component reliability
    - Common-cause failures
    - Fire events
  - Standardize data coding and analysis
    - Same definition for fields such as "failure cause" for all studies
    - Analysis techniques standardized for all studies
    - Data structure being standardized (Microsoft Excel database)

CONSOLIDATED DATA COLLECTION AND ANALYSIS (Continued)

- Status and schedule
  - System developed and trial testing started - August 2003
  - Reactor Operating Experience Results and Databases web page available in beta version on NRC internal web site - October 2003
  - Available on NRC external web site - TBD
    - Questions need to be addressed on security, proprietary data, Operating Experience Task force recommendations
    - Add text search of other document types such as inspection reports, 10 CFR 50.72 reports, and 10 CFR 21 reports - TBD

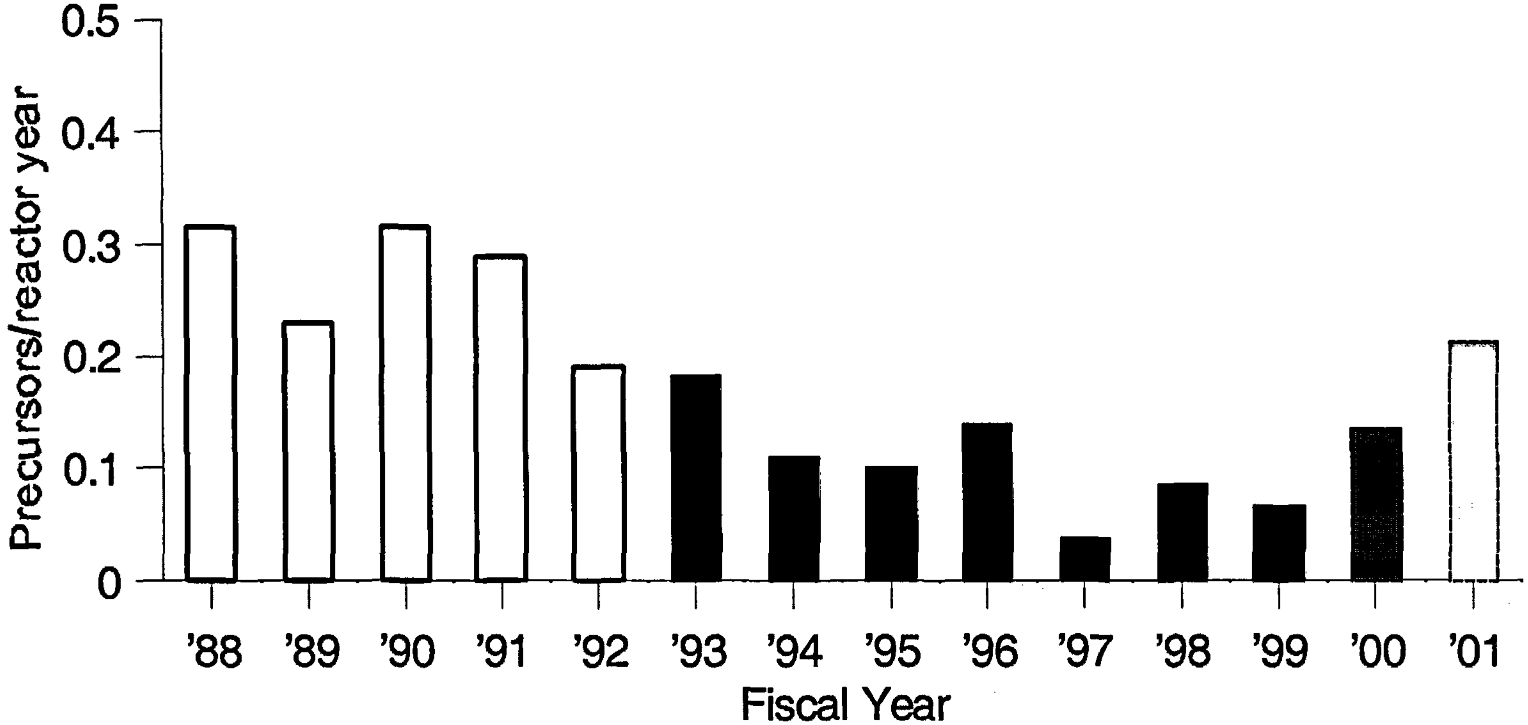
Integrated Operating Experience Data Collection and Analysis



Accident Sequence Precursor (ASP) Program

ACCIDENT SEQUENCE PRECURSOR (ASP) ANALYSES

- Objectives
  - Systematically evaluate U.S. nuclear plant operating experience to identify, document, and rank operating events most likely to lead to inadequate core cooling and severe core damage (precursors), if additional failures had occurred.
  - Provide a measure for trending nuclear plant core damage risk.
  - Provide a partial check on PRA-predicted dominant core damage scenarios.



All Precursors – occurrence rate, by fiscal year. No trend detected during the FY 1993-2001 period.

INSIGHTS FROM ASP PROGRAM (FY 1993-2002)

- Analysis of trends in ASP events for period FY 1993-2002
  - May be an increasing trend over past 6 years
  - "Significant" precursors (CCDP or ΔCDP $\geq 1 \times 10^{-3}$) occur about once every 4-5 years; last one in 1996 (potential one in 2002)

- Most (~80%) precursors are consistent with IPE/PRA results in frequency of occurrence and also in dominant contributors

- However, a number (~20%) of precursor events involved event initiators or conditions that are typically not modeled in PRAs/IPEs
  - Blowdown of the RCS to the RWST at hot shutdown
  - Reactor trip with loss of one train of essential service water due to frazil ice and the unavailability of the turbine-driven AFW pump
  - Potential failure of all CCW pumps due to steam intrusion resulting from a high-energy line break
  - Potential LOCA due to control rod drive mechanism degradation and reactor vessel head corrosion

Industry Trends Program

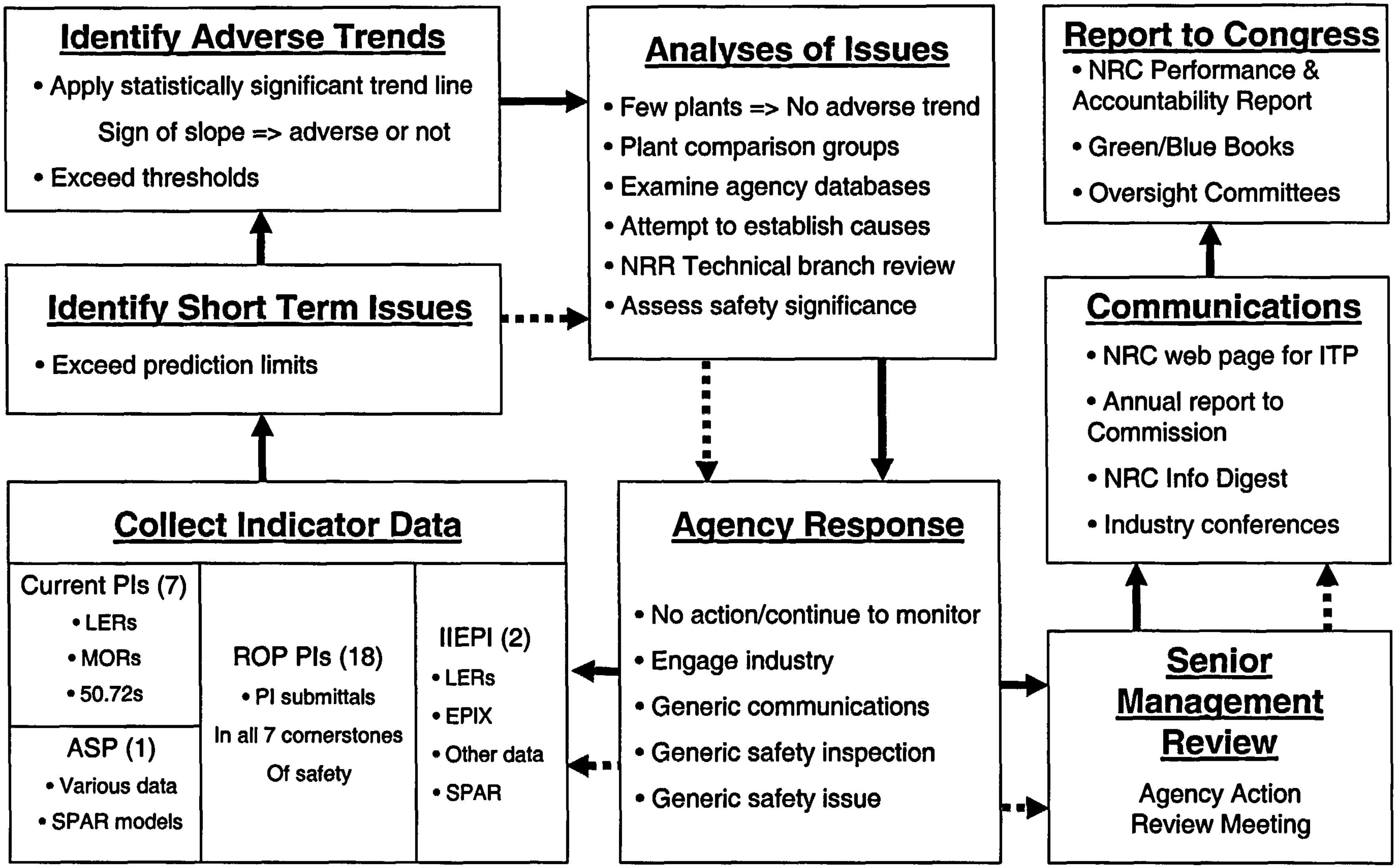
Industry Trends Program (ITP)

- The ITP is designed, in part, to complement the Reactor Oversight Process (ROP).
- The ITP focuses on multi-plant/ multi-site performance, while the ROP focuses on plant-specific performance.
- ITP complements generic communications and generic safety issues processes.

ITP Objectives

- Collect and monitor industry-wide data to assess whether the nuclear industry is maintaining safety performance of operating plants and to provide feedback to the ROP and other NRC processes.
- Assess the safety significance and causes of any statistically significant adverse trends.
- Communicate industry-level information to Congress and other stakeholders.

ITP Process



Identify Adverse Trends
• Apply statistically significant trend line
Sign of slope => adverse or not
• Exceed thresholds
Analyses of Issues
• Few plants => No adverse trend
• Plant comparison groups
• Examine agency databases
• Attempt to establish causes
• NRR Technical branch review
• Assess safety significance
Report to Congress
• NRC Performance & Accountability Report
• Green/Blue Books
• Oversight Committees
Identify Short Term Issues
• Exceed prediction limits
Communications
• NRC web page for ITP
• Annual report to Commission
• NRC Info Digest
• Industry conferences
Collect Indicator Data
Current PIs (7)
• LERs
• MORs
• 50.72s
ASP (1)
• Various data
• SPAR models
ROP PIs (18)
• PI submittals
In all 7 cornerstones
Of safety
IIEPI (2)
• LERs
• EPIX
• Other data
• SPAR
Agency Response
• No action/continue to monitor
• Engage industry
• Generic communications
• Generic safety inspection
• Generic safety issue
Senior Management Review
Agency Action Review Meeting

Integrated IE Indicator Development

- Monitoring 10-15 risk-significant IEs can provide better insights than current set of industry indicators.
- Roll-up indicator can simplify communications to Congress/stakeholders.

SPAR Model Development Program

LEVEL 1, REVISION 3 SPAR MODELS

Accomplishments through 9/30/2003

- Completed production of entire set of 72 Revision 3i SPAR models on November 2002.
- Completed onsite QA reviews of all 72 models on August 2003.
- Performed review/evaluation of comparison exercise results for the 11 SPAR models representing the 20 plants in the MPSI pilot program.

LEVEL 1, REVISION 3 SPAR MODELS

Future Plans/Enhancements

- Upgrade level of detail based on results of MSPI pilot program comparison exercise.
- Improve models to address issues identified from onsite QA reviews.
- Revise models as necessary to address user feedback.

LOW POWER/SHUTDOWN (LP/SD) SPAR MODELS

Accomplishments through 9/30/2003

- Completed BWR and PWR templates.
- Completed eight preliminary LP/SD SPAR models.
- Conducted onsite QA review of LP/SD SPAR model for Surry 1 & 2.

LOW POWER/SHUTDOWN (LP/SD) SPAR MODELS

Future Plans

- Conduct additional onsite QA reviews.
- Produce additional LP/SD SPAR models (e.g., Diablo Canyon 1 & 2; River Bend).

LERF SPAR MODELS

Accomplishments through 9/30/2003

- Completed draft bridge trees and containment event trees.
- Incorporated peer review comments.
- Completed initial quantification of LERF SPAR model for first lead plant (W PWR w/large, dry containment [Comanche Peak]).

LERF SPAR MODELS

Future Plans

- Revise model to address comments from key users.
- Develop LERF SPAR models for other lead plants.

Mitigating Systems Performance Index (MSPI)

Mitigating Systems Performance Index (MSPI)

- MSPI evolved from feasibility study of Risk-Based Performance Indicators (RBPI) in NUREG-1753.
- MSPI addresses recognized issues with current PIs.
- MSPI is highly risk informed simplification to RBPIs with the following features:
  - Unavailability and unreliability consistent with PRA.
  - Accounts for plant specific design and performance data.
  - Eliminates fault exposure time.
  - No cascade failure of cooling water support systems.
  - Scope consistent with at-power internal events level-1.
  - Performance thresholds consistent with basis for current PIs.

MSPI Pilot Objectives

- Exercise MSPI Guidance:
  - System boundary and component identification.
  - Data collection.
  - MSPI computation.

- Validation and Verification:
  - Issue identification & special studies.
  - SPAR model comparisons.
  - Duplication of Pilot Plant results.
  - Comparison to SDP (Table top).

- Perform Temporary Instruction Inspections.

- ACRS Subcommittee briefed in July 2003; follow-up to present Pilot results anticipated early 2004.

SAPHIRE PEER REVIEW

Daniel O'Neal
Reliability and Risk Engineer
RES

OVERVIEW

- SAPHIRE provides the capability to develop and run probabilistic safety assessment models
- Peer review was performed for the testing, verification, and validation (TV&V) of SAPHIRE
- Discuss the objectives of the review
- Discuss the SAPHIRE TV&V
- Discuss the review approach and the resultant insights and recommendations

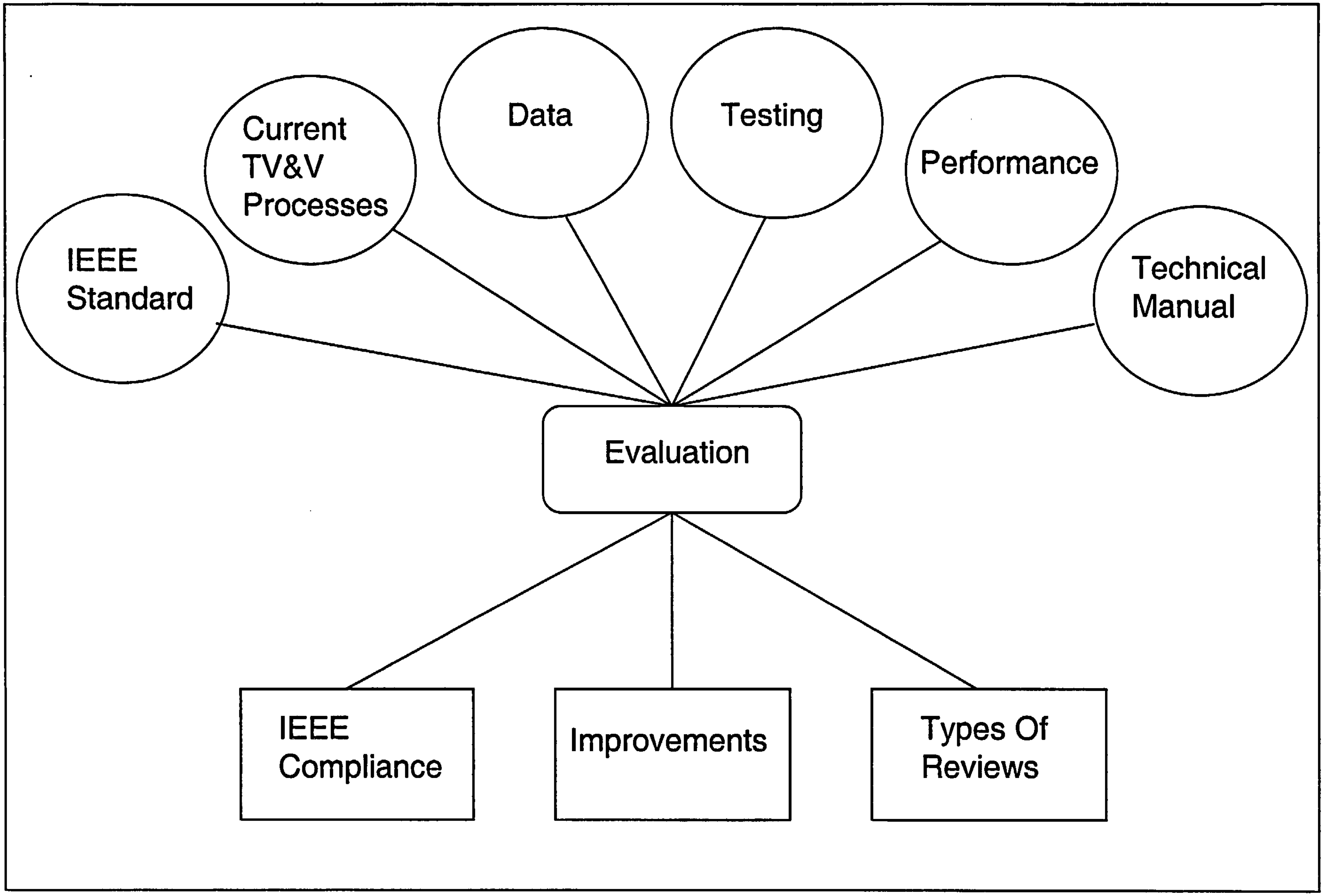
OBJECTIVES

- Identify potential TV&V improvements
- Provide recommendation on formal software standard compliance
- Consider types of reviews for SAPHIRE

SAPHIRE TV&V

- Automated TV&V process used for SAPHIRE versions 6 and 7
- Bases for TV&V provided in NUREG/CR-6688, "Testing, Verifying, and Validating SAPHIRE 6.0 and 7.0", October 2000
- Change design and test procedure
  - Ensure the change meets the expected goal, identify interfaces and interactions with other SAPHIRE features, and optimize use
  - Users test the new features
  - Document the change
  - Update the test suite

REVIEW APPROACH



GENERAL INSIGHTS

- Process is formal for only some of the software life cycles
- Process relies upon continual release of new sub-versions
- A number of changes in the change logs reviewed were "significant" in that the change was related to a code error that affects the correct result for risk measures, importance measures, or uncertainty analysis and an error message does not appear to be generated to alert the model developer or code user
- Number of changes representing both non-significant and significant changes does not necessarily decrease with each newly released sub-version
- Insights support the need for improving the current TV&V process

RECOMMENDATIONS

- Process should be slowed down - more time up front spent on TV&V before issuing a new sub-version
- Current versions could benefit from formalizing some life cycle processes and implementing specific recommendations
- IEEE standard for software verification and validation compliance should be pursued for the future version 8
- Types of reviews that should be considered to improve the process are:
  - Acceptance reviews by the staff before general release
  - Periodic independent audits for the future version 8
- Proposed plan for implementation of recommendations follows a phased approach for specific and general recommendations

FIRE RISK RESEARCH PROGRAM ACTIVITIES

- Fire protection SDP revision
- Circuit analysis
- Risk-informed, performance-based fire protection rulemaking (NFPA 805)
- ANS full power fire standard
- NRC/EPRI fire risk requantification studies
- Fire model benchmark / validation
- Hemyc and MT fire barrier testing
- International activities, e.g. circuits, fire event data

An Overview of UMD Research in Treatment of Uncertainties

Center for Technology Risk Studies
University of Maryland

ACRS October 10, 2003

Topics

- Integrated Model and Parameter Uncertainty
- Physical Models Uncertainty
  - Thermal-Hydraulics
  - Fracture Mechanics

2

Framework for Integrated Treatment of Model and Parameter Uncertainties

Ali Mosleh
Center for Technology Risk Studies
University of Maryland

ACRS October 10, 2003

3

Objectives

- Develop a conceptual, unified, framework and methodology for treating model and parameter uncertainties
- Provide guidelines for practical applications
- Apply to representative cases from fire risk models

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Results

- Developed a Bayesian framework treating models as sources of evidence concerning the unknown of interest
- Demonstrated that many popular methods are special cases of the general Bayesian framework
- Formulated solutions for several important classes of model uncertainty problems encountered in PRA applications
- Demonstrated the method in two fire risk analysis problems (COMBRN model uncertainty, and line fire temperature model uncertainty)

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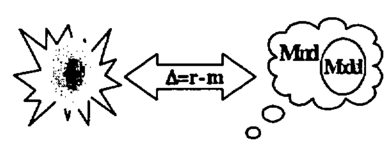
Model Uncertainty



Examples of Sources of Model Uncertainty:
- Conceptualization of a reality aspect
- Implementation into a particular form
- Several plausible models reflecting different interpretations of reality

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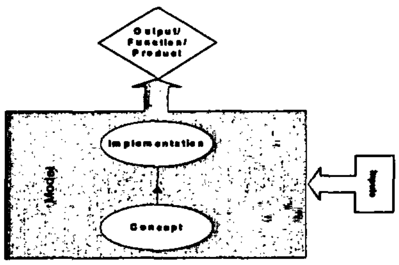
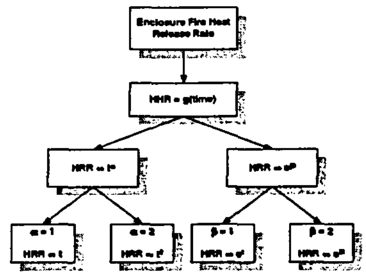
Models



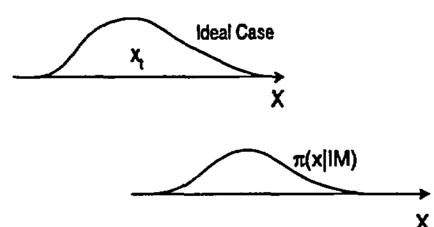
Form and Parameter



Model Uncertainty

- A successful treatment of model uncertainty results in an expression of uncertainty that includes the true value at some stated level of confidence.
- History of science provides ample evidence that in any modeling endeavor there is a non-negligible chance that the spectrum of the available models at a given point in time may not actually include the appropriate model

Which Question Is Being Answered?



Restating the Question

"What can we say about *X* given *IM* ?"

- *IM* refers to:
  - Information *from* the model(s)
  - Information *about* the model(s)
- With the problem stated in this way, Bayes Theorem is the natural choice as a framework for utilizing the available information *IM* to express the state of knowledge about *X*

Bayesian Framework

$$\pi(x|IM)=\frac{L(IM|x)\pi_0(x)}{\int_x L(IM|x)\pi_0(x)dx}$$

$$IM=(IM_1, IM_2, \ldots, IM_n)$$

where

$\pi(x \mid IM)$:	uncertainty distribution of X given information IM
$\pi_0(x)$:	the distribution for X before the evidence IM is available
$L(IM \mid x)$:	(likelihood function) the probability of observing evidence IM when the true value is x

Characterization of IM

- The evidence, IM, can be grouped into two major categories:
  - Information from models ($\underline{x}^*$, an estimate of X):
    - Point estimate
    - Probability distribution
    - Bounds for the unknown X, such as $x_l \le x \le x_h$
    - A statement concerning X, such as "X is high"
  - Information about models (D):
    - Performance data
    - Assessment of the quality and applicability of the model

$$IM = \{\underline{x}^*, \underline{D}\}$$

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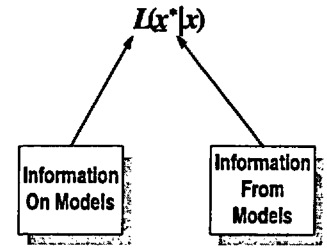
Constructing The Likelihood Function



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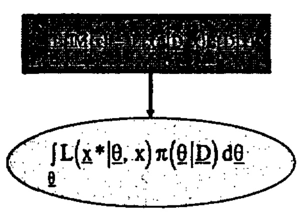
Constructing the Likelihood Function (Parameterization Strategy)



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Likelihood Function: An Example

- Information about the model: $\underline{D} = \underline{D}^p, \underline{D}^a$
  - $\underline{D}^p = \{E_1, \ldots, E_n\}$: Performance data
  - $\underline{D}^a$: Qualitative information on model quality and applicability
- Corresponding parameters in the likelihood: $\underline{\theta} = \{\underline{\theta}^p, \underline{\theta}^a\}$
- An example is the Error Model:

$$L\left(x^* \middle| \underline{\theta}^P, x\right) = L\left(x^* \middle| b, \sigma, x\right) = \frac{1}{\sqrt{2\pi}\,\sigma} e^{-\frac{1}{2}\left[\frac{x^* - (x+b)}{\sigma}\right]^2}$$

where

$$\underline{\theta}p = \{b, \sigma\}$$

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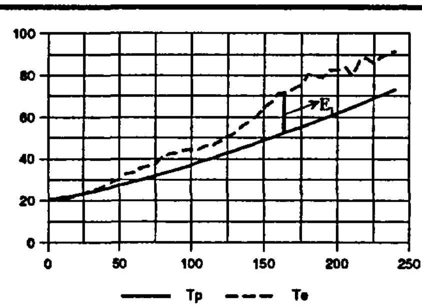
Likelihood Function: An Example (cont)



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Multiple Models

- Posterior Uncertainty Distribution

$$\pi(Q \mid Q_1, Q_2) = \frac{L(Q_1, Q_2 \mid Q)\,\pi(Q)}{\int_Q L(Q_1, Q_2 \mid Q)\,\pi(Q)\,dQ}$$

- For independent models:

$$L(Q \mid Q_1, Q_2) = \prod_{i=1}^{2} L(Q_i \mid Q)$$

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Example: Cable Jacket Temperature Prediction

COMPBRN is used to estimate the cable jacket temperature, T_{cj}, at time t, of a group of cable trays in compartment fires.

COMPBRN was used to simulate a group of experiments performed by SNL.

Question: Given COMPBRN prediction, T, and what we know about COMPBRN performance, what can we say about the actual cable jacket temperature ?

Example: Cable Jacket Temperature Prediction

- The performance information is based on the SNL/UL ex. 2

Time (sec)	Cable Jacket Temperature (K): Experimental Result (T^*_{cj})	COMPBRN III $\eta = 0.85$: T'_{cj}	COMPBRN III $\eta = 0.85$: T'_{cj} / T^*_{cj}
60	360	375	1.042
180	425	430	1.012
300	455	470	1.033
480	505	500	0.990
720	575	520	0.904
900	575	500	0.870

Construction of the Likelihood (Homogeneous Performance Data)

- Posterior:

$$\pi(T_{cj}|T,D)=\frac{\int_b\int_\sigma L(T|b,\sigma,T_{cj})\pi_0(b,\sigma|D)\,db\,d\sigma}{\int_{T_{cj}}\int_b\int_\sigma L(T|b,\sigma,T_{cj})\pi_0(b,\sigma|D)\,db\,d\sigma\,\pi_0(T_{cj})\,dT_{cj}}$$

- Likelihood function:

$$L(T|b,\sigma,T_{cj})=\frac{1}{\sqrt{2\pi}\,\sigma T}e^{-\frac{1}{2}\left[\frac{\ln T-(\ln T_{cj}+\ln b)}{\sigma}\right]^2}$$

Construction of the Likelihood (Homogeneous Performance Data)

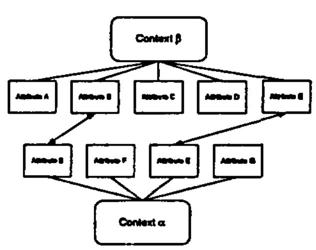
- Updating model predictive capabilities:

$$\pi(b,\sigma|E_1,E_2,\ldots,E_6)\propto\prod_{i=1}^{6}\frac{1}{\sigma}e^{-\frac{1}{2}\left(\frac{\ln E_i-\ln b}{\sigma}\right)^2}\pi_0(b,\sigma)$$

- Assumption: (E_1, …, E_6) are independent and each E_i is distributed according to a Lognormal distribution:

$$L(E_i|b,\sigma)=\frac{1}{\sqrt{2\pi}\,\sigma E_i}e^{-\frac{1}{2}\left(\frac{\ln E_i-\ln b}{\sigma}\right)^2}$$

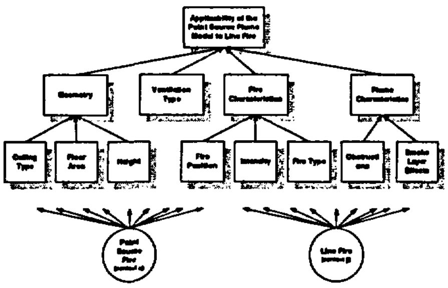
Applicability of Models



Applicability of Models (cont)

- Establish what is important in estimating the unknown in context β;
- Identify what is covered by model *M* under context α;
- Perform a similarity assessment by comparing the attributes under context α with the attributes under context β, i.e., assess the degree of match;
- Perform an importance assessment, i.e., assess how important are each of these attributes in applying model α as a model for β.

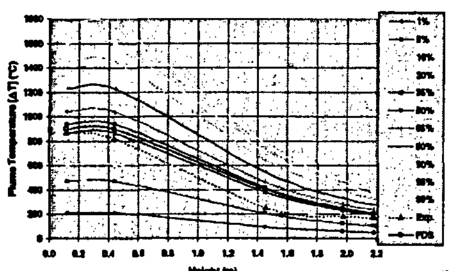
Example: Line Fire Plume Temperature



Example: Line Fire Plume Temperature

- Estimate plume temperature in a line fire by using a point source fire model prediction
- Available information:
  - 4 experimental tests by NRC/SNL on point source fires
  - Experimental data on line fires
- Approach:
  - Assessment of the applicability concerning the FireDS model
  - Assessment of the line fire plume temperature uncertainty given FireDS prediction and point source data

Posterior Uncertainty Distribution



In Summary...

- Bayesian framework for an integrated assessment of model and parameter uncertainties
- Treats models as source of evidence concerning the unknown
- Accounts for an individual model's bias and precision as well as possible dependencies among models
- Allows for the use of various types of information *from* models:
  - Quantitative
    - o Point estimates
    - o Probability distributions
  - Qualitative statements

In Summary... (cont)

- Provides the flexibility to incorporate performance data as well as subjective evidence ***about*** the models themselves into the state of belief about the unknown
- Procedures are suggested for assessing
  - Confidence in a model
  - Model applicability
  - Dependence among models

Limitations

- Methodology focuses on the model output, and the assessment of uncertainty is based on the perceived quality of the model.
- Does not present an explicit way of "deriving" the measure of model quality and credibility as a function of quality and credibility of its elements and sub-models.
- The method does not provide a way of propagating sub-model uncertainly to arrive at model uncertainty.
- Such propagation is naturally problem and context specific, and therefore more resistant to generalization and procedural formulation.

Limitations (cont)

- Many complex technical assessments involve multiple models, each possibility composed of sub-models covering different domains.
- This is exemplified in large multi-disciplinary assessments such as PRAs, which involve interface among many models (e.g., plant thermal -hydraulic response model, accident scenarios defined by event tress, and other physical and mathematical model of deterministic or stochastic behaviors of plant systems and operators).

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Limitations (cont)

- The practical difficulty is carrying the results across models or sub-models that may be subject to additional constraints, requiring further assumptions or simplifications.
- Obviously this also introduces model uncertainty that cannot be simply viewed in a "model output" framework.
- Similarly it is difficult to "combine" the effects of modeling errors at conceptualization level with those arising during implementation.

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Treatment of TH Uncertainties in PTS Risk Assessment

Ali Mosleh
Center for Technology Risk Studies
ACRS October 10, 2003

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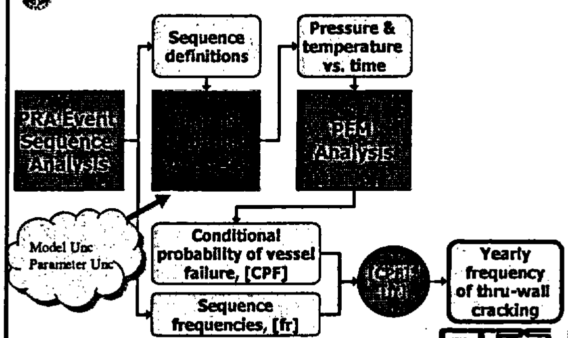
PTS Integrated Analysis



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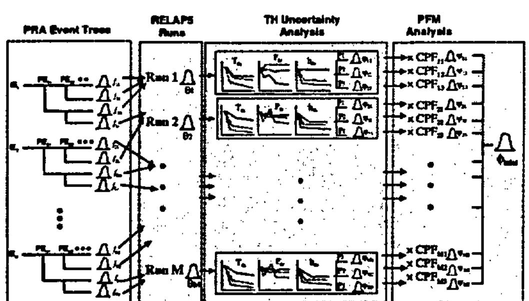
Conceptual Model



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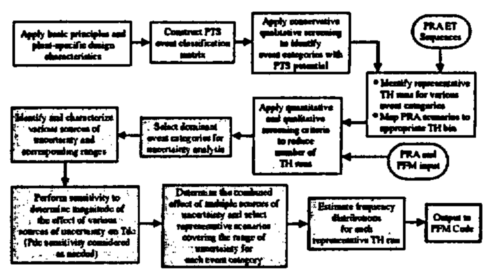
TH Uncertainty Assessment Process



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Practical Considerations

- Settle for less accurate method or solution in a sub-model in order to comply with interface requirements of other sub-models
- Accept that some uncertainties and variabilities of contributing factors are suppressed by grouping or aggregating them into "bins"
- Accept a somewhat uneven treatment of uncertainties among different modeling domains *[no model uncertainty in FTs]*

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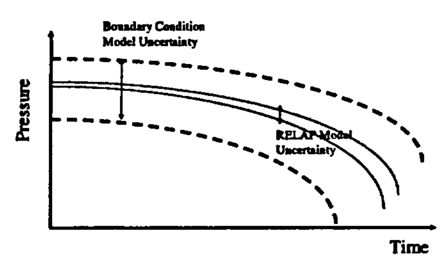
Context Dependency of Uncertainty Assessment



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Important TH Parameters

Temperature
- Heat Capacities
  - Primary and secondary system
- Heat Sources
  - Decay heat and RCPs
- Heat Sinks
  - Primary system breach, SGs, HPI, CFTs, and LPI
- RCS Coolant Flow Rate
  - RCPs state
- RPV Energy Distribution
  - Mixing of core water in downcomer phenomenon (RPV Vent Valves)
  - RCS flow interruption-and-resumption caused by vapor in candy cane
  - Boiling-condensation

Pressure
- RCS coolant mass change
  - Primary system breach
  - HPI
- RCS energy change
  - Heat sources
  - Heat sinks
- Short term rapid RCS steam condensation
  - Mixing of core water in downcomer phenomena
  - Boiling-condensation
  - PZR spray

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Event Category Selected for TH Uncertainty Analysis

[illegible]	[illegible]	[illegible]	
		[illegible]	[illegible]
[illegible]			6.1e-4 8.9e-4
[illegible]	3.7e-6	2.7e-7 6.3e-8	
[illegible]	2.7e-8	1.6e-7 4.9e-8 3.3e-6	3.1e-6 1.2e-6
[illegible]			
[illegible]	1.3e-6		

(1) HPI activated without being controlled
(2) HPI activated and controlled
(3) HPI is failed or not required
(4) HPI fails and is recovered

After screening out non-PTS risk sequences, 94% of the total sequence Frequencies fall in this cell; TH uncertainty analysis focuses on this dominant cell

The cell is further divided into four categories for TH uncertainty analysis:
1. PZR SRV stuck open and remains open with valve open area greater than 1.5-inch in diameter
2. PZR SRV stuck open and is reseated with valve open area greater than 1.5-inch in diameter
3. LOCA between ~ 1.5-inch and 4-inch in diameter
4. LOCA between 4-inch and 8-inch in diameter

8

Uncertainty Sources

- Model Uncertainty
  - Event Sequence Modeling and Mapping to TH Runs
    - Level of Details in Event Tree Models (e.g. explicit representation of component degraded states) *[Treated by adding needed details]*
    - Assignment of Event Tree Scenarios → TH Bins *[not treated, believe to be small]*
    - Assignment of Representative RELAP Runs → TH Bins *[Treated explicitly]*
  - Use of TH Code
    - RELAP5 Internal Modeling Uncertainties *[Several important factors treated explicitly]*
    - RELAP5 Input Deck Preparation(e.g., nodalization) *[not treated, believe to be small]*
- Parameter Uncertainty (all parameters associated with modeling steps, as well as those used within models) *[Important parameters treated explicitly]*

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Known RELAP5 Limitations

- 1-D code
  - Included experimental and CFD results
  - Oregon State APEX program
- Volume averaged calculation
  - Included experimental and CFD results
- Empirical correlations
  - Perform uncertainty analyses and sensitivity studies
  - Several treated explicitly
- Nodalization choices
  - Used standard nodalization

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Characterization of Uncertainty Sources Treated

- **Parametric (Boundary Condition) Uncertainty**
  1. Primary Side Breach Size (1.5", 2", 2.8", 4", 5.7", 8" and 12" in diameter) *[Aleatory]*
  2. Primary System Breach Location (HL, CL, and PZR SRVs) *[Aleatory]*
  3. Decay Heat (Reactor trips at Infinite operation and Hot Zero Power) *[Aleatory]*
  4. Season (Fall/Spring, Winter, Summer - used different T values for SI and AFW) *[Aleatory]*
  5. HPI State (Success, ¼ Failed, ½ Failed, and Failed) *[Aleatory]*
  6. HPI Flow Rate (± 10%) *[Aleatory]*
  7. Core Flood Tank Pressure (± 50 psi) *[Aleatory]*
- **RELAP5 Code Model Uncertainty**
  1. RPV Vent Valves State (0%, 33%, 67%, and 100% Open) *[Epistemic]*
  2. Component Heat Transfer Coefficient (± 30%) *[Epistemic]*
  3. Flow Resistance (+100%) *[Epistemic]*
  4. Break Flow Rate (± 30% break area) *[Epistemic]*
  5. Numerical "Mixing" (removed by conservatively using a high cold leg reverse flow resistance)

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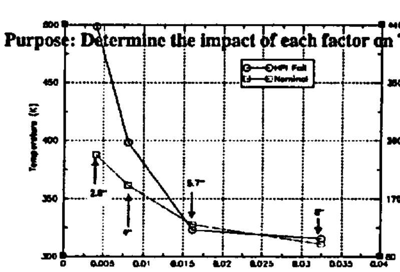
Example of Sensitivity Study Results

Impact of HPI State

Purpose: Determine the impact of each factor on Tdc.



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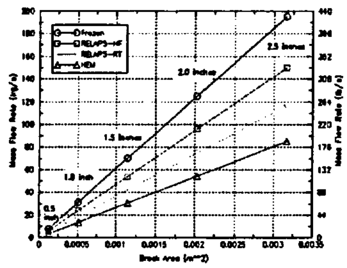
Treatment of Break Flow Rate Model Uncertainty
(Break Upstream Pressure: 7MPa/1028 psia)



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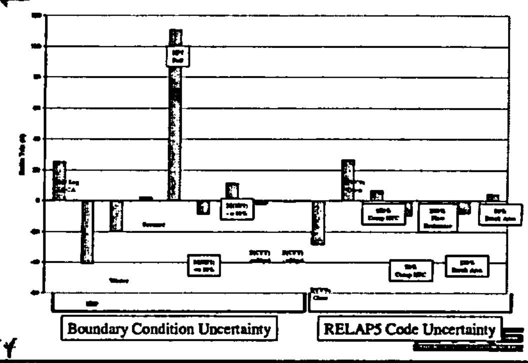
Impact of Various Sources of Uncertainty for Fixed Break Size
(2.8-inch LOCA)



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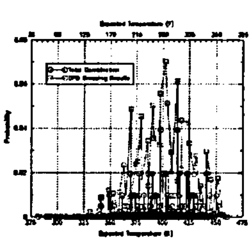
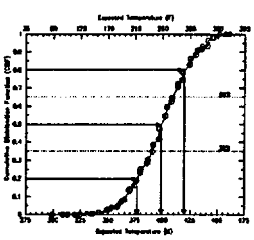
PZR SRV Stuck Open and Remains Open
PDF and CDF of Combined Effect of Multiple Uncertainty Variables





(992 combinations in total)

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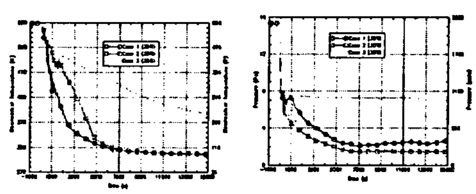
PZR SRV Stuck Open and Remains Open
T_{dc} and P_{dc} Trends for TH Runs Covering Uncertainty



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Observations on Treatment of Uncertainties in Complex Multi-Disciplinary Technical Assessments

Ali Mosleh
Center for Technology Risk Studies

ACRS, October 10, 2003

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Lessons Learned

- Uncertainty analysis cannot be done as an isolated task, run by "uncertainty specialists"
  - uncertainty analysis is an integral part of model development
  - as such uncertainty analysis should be everybody's business
- Integrated assessments using independently evolved disciplines, models, and tools, add to the complexity of
  - uncertainty assessment
  - uncertainty propagation
- Uncertainty assessment and "uncertainty management" become intertwined
- Technical and organizational coordination and communication are essential

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Lessons Learned (cont.)

- Initially we also adopted the common philosophy of most technical assessments that uncertainty analysis can be performed after "best estimate" analysis is completed
- This practice can easily result in not only an inadequate uncertainty analysis, but also incorrect "best estimate"
  - best estimate of the final result of a complex model is not necessarily achieved by combining best estimates of the sub-models

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Lessons Learned (cont.)

- One reason for delaying uncertainty analysis until after completing best estimate analysis is the prevailing belief that performing uncertainty analysis requires significantly more resources than point estimate analysis
- This is not necessarily true. In some cases concurrent uncertainty analysis can actually reduce the scope of issues to be considered

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Some Technical Issues

- At every step of the analysis a distinction needs to be made between *model structure* and *model parameter*
- Treatment of Model Uncertainty affects the structure of models (new event tree branches, additional top events)
- Characterization of uncertainty as *aleatory* or *epistemic* is also important as the former often impacts the structural of the model

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Potential Consequences of Inadequate Treatment

- Failure to account for dominant contributors to uncertainty
- Failure to properly characterize various types of uncertainty, possibly leading to incorrect method of uncertainty propagation
- Failure to properly carry uncertainties across sub-models and disciplines

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Treatment of Uncertainties in Complex TH Codes

Ali Mosleh
Center for Technology Risk Studies

ACRS, October 10, 2003

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Objectives

- Development of a computational approach for propagation of uncertainties in complex models and codes
- Identification of various sources of uncertainty in predicting TH behavior with TH codes (RELAP 5) including
  - User specification of the computer model
  - Specification of initial and boundary conditions
  - Internal model and parameter uncertainties
- Methodology for characterization and quantification of identified uncertainty sources (experimental data, expert opinion)
- Test of methodology
- Suggestions on TH code modification to incorporate model and parameter uncertainties
- Implementation on TH Code (e.g., TRACE)

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An Evaluation of Existing Methodologies

N	General Characteristics	AEAT	CSAU	ENUSA	GRS	IPSN	UMAE
1	Restriction on the number of input uncertain parameters	Y	Y	Y	N	N	NA
2	Deriving input uncertainty ranges	Y	Y	Y	Y	Y	N
3	Assigning subjective probability distributions	N	Y	Y	Y	Y	N
4	Use of [illegible]	N	Y	Y	Y	Y	Y*
	Use of response surface technique	N	Y	N	N	N	N
5	Need of specific data for scaling	N	Y**	N	N	N	Y
6	Need of biases on the results	N	Y	N	N	N	Y
7	Determination of input uncertain parameters and related ranges	EJ***	EJ	EJ	EJ	EJ	NA
8	Selection of uncertain parameter values within the determined ranges	EJ	EJ	[illegible]	[illegible]	[illegible]	NA
9	Support to identification and ranking of input uncertain parameters	Y	Y	Y	N	N	N
10	Account for state of knowledge of input uncertain parameters	Y	Y-EJ**	Y-EJ	Y-EJ	Y-EJ	N
11	Number of code runs independent from number input and output parameters	N	N	Y	Y	Y	NA
12	Typical number of [illegible] code runs	[illegible]	[illegible]	[illegible]	100	100	[illegible]
13	Typical number of uncertain input parameters	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NA
14	Sensitivity measures of input parameters on output parameter	N	N	Y	Y	Y	N

* To a limited extent
** At a qualitative level during code validation
*** Expert judgment needed

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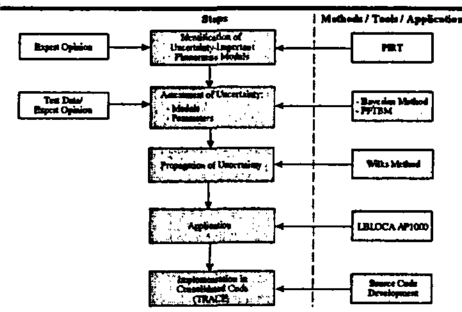
Major Steps and Methods



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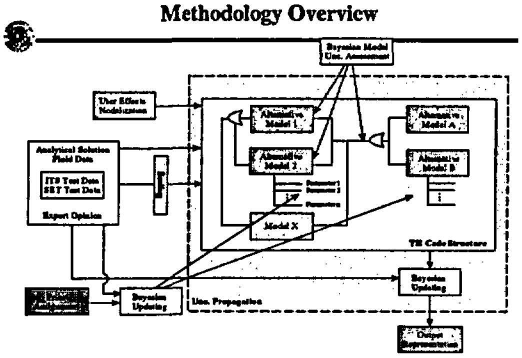
Methodology Overview



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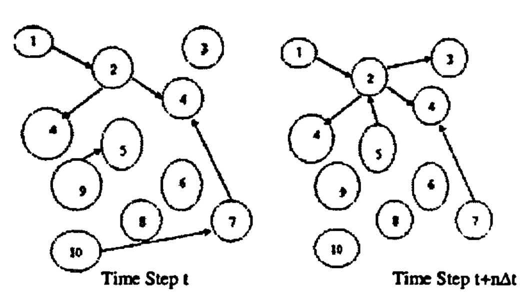
Dynamic Behavior of Complex Code



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Examples of Sub-model

- Chocked Flow-Relap5
  - -Sub-cooled
    - (Code Developer Alternative Models)
      - Burnell Model
      - Moody
      - Henry Fauske
  - Two-phase
    - One-Component
    - Two-Component
    - (Code Developer Alternative Models)
      - Trap and Ransom
      - Henry Fauske
  - Single-phase-vapor
- User selected models
  - -Abrupt Area Change
  - -Smooth Area Change

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Sub-models Uncertainty Examples
(Athlet Code - GRS)

- Heat transfer: model for single phase forced convection on vapor
  - Dittus-Boelter Correlation
  - McEligot Correlation
- Heat Transfer: Model for Choked Flow
  - Minimum Value
  - Hench-Levy Correlation
  - Biasi Correlation

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UMD Bayesian Approach to Uncertainty Quantification

- Incorporates
  - Experimental data
    - o Model performance
      - Separate Effect Tests (SETs) for sub-model
      - Integral Test facilities (ITFs)
    - o Measurement of input parameters
  - Expert judgment and qualitative information on
    - o Model credibility
    - o Model applicability
- Integrates the effects of model and parameter uncertainties

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Sampling & Uncertainty Propagation
Wilks' Method

- ➢ A random sample of size N is drawn for each uncertain parameters
- ➢ Simple Random Sampling is used
- ➢ Number of samples is a function of desired confidence level and probability content

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Test- Oconcel PTS TH Uncertainty

- ➢ 100 runs using TH models of PTS for Oconee-1 NPP
- ➢ Same uncertain models and parameters as in UMD PTS TH Uncertainty Method (a total of 11)
- ➢ Same range of parameter variation
- ➢ 100 unique combinations were created to achieve 95% of probability content with 95% confidence
- ➢ Results are comparable with the result of uncertainty ranges calculated by UMD PTS in Oconee-1 PTS project

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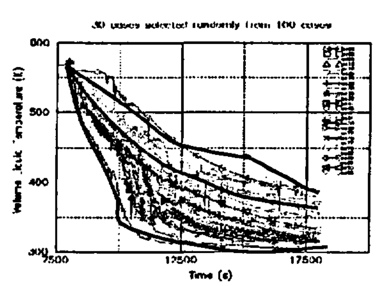
Results Compared with PTS TH Approach



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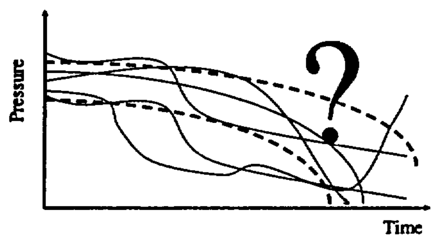
Question of Proper Uncertainty Representation



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Reactor Vessel Fracture Uncertainty Characterization

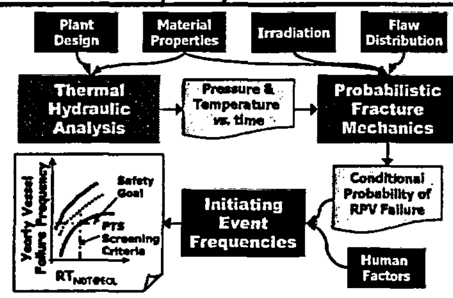
Mohammad Modarres

University of Maryland
Center for Technology Risk Studies

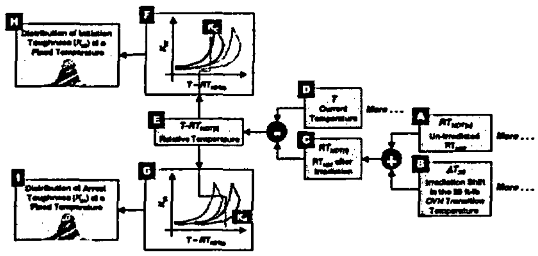
Presentation
To
Advisory Committee on Reactor Safeguards

October, 10, 2003

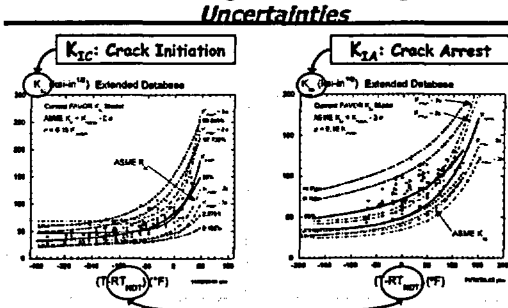
PRA-based evaluation of vessel failure frequency Due to PTS



Sources of Uncertainty

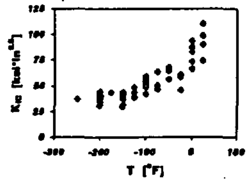


Fracture Toughness Modeling and Uncertainties



Uncertainty in Fracture Toughness

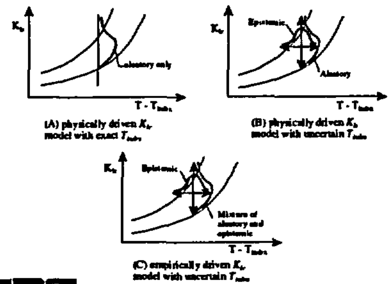
- Cleavage fracture in steels is well represented by the weakest link theory and microscopic size distribution of carbides leading to the variability in K_{Ic} at any fixed temperature
- K_{Ic} uncertainty can be assumed purely aleatory at a fixed temperature since K_{Ic} distribution is completely driven by the irreducible distribution of microscopic carbides



Indexing Temperature

- To account for heat-to-heat variability, an indexing temperature should be devised
- The indexing procedure introduces uncertainty since the indexing temperature can't be determined exactly in almost all cases
- Indexing temperature uncertainty is epistemic
- Depending on the approach used, the resulting K_{Ic} model involves added uncertainty

Recognize Three Possible Cases



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Two Possible Approaches to Account for Uncertainties in K_{Ic}

1) **Master Curve model**

- Physically-based (assumes one universal indexing exists)
- K_{Ic} *uncertainty would be a reflection of the weakest link* model (assumed purely aleatory at a fixed temperature since K_{Ic} distribution is dictated by the irreducible distribution of microscopic carbides)
- The community accepts the weakest link and carbide fracture assumptions as an accurate model of fracture

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Two Possible Approaches to Account for Uncertainties in K_{Ic}

2) Empirical Model

- ➤ K_{Ic} model is based on actual observed data
- ➤ The procedure is well understood and compatible with NRC practices
- ➤ The resulting model is not purely aleatory but use of a temperature dependent adjustment of the LEFM data to correct for indexing conservatisms make aleatory distribution assumption possible
- ➤ Extrapolation beyond data points involves epistemic modeling uncertainties

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Procedures for Computing Fracture Toughness

- **Master Curve Procedure**
  - ➤ Sample distributions of RT_{NDT}, and RT_{NDT} bias relative to T_0
  - ➤ Compute adjusted RT_{NDT}
  - ➤ Obtain the Weibull distribution corresponding to T – adjusted RT_{NDT} (aleatory uncertainty)
- **Empirical Procedure (Modified Traditional ORNL Approach)**
  - ➤ Sample RT_{NDT} and RT_{NDT} bias based on lower-bounding model
  - ➤ Adjust the LEFM data (samples) and empirically generate a new "adjusted" K_{Ic} distribution that is fit into the data
  - ➤ Compute an adjusted RT_{NDT}
  - ➤ Obtain a Weibull distribution from a sample of the adjusted K_{Ic} distributions at (T – adjusted RT_{NDT})

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Probability Distribution Of RPV Fracture/Failure

➤ The probabilistic-based method shows marginal contribution of each flaw to the *probability* of RPV fracture/failure

$$\Pr[E(t)] = 1 - \sum_{i=1}^{n} \{1 - \Pr[E_i(t)]\}$$

where, $\Pr[E(t)]$ is the total vessel fracture/failure probability at time t, and $\Pr[E_i(t)]$ is the marginal probability contribution of the i^{th} flaw at time t to RPV fracture/failure.

➤ The deterministic-based method assumes that the most susceptible flaw among all of the multiple flaws causes failure of the vessel (i.e., weakest link view)

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Probability Distribution Of RPV Fracture/Failure (cont)

➤ Deterministically, we are interested in the flaw initiation at a give time during the transient given the computed K_I value: the flaw will initiate, if $K_I > K_{IC}$. Record the time t at which the flaw initiates. If m out of n (m < n) flaws initiate at different times t_j (j = 1, 2, ..., m), according to the deterministic-based approach the time of vessel flaw initiation would be

$$t = \min(t_1, t_2, \ldots, t_m)$$

➤ Since K_{IC} value at each time is stochastic in nature it should be represented by its probability distribution (here a Weibull distribution)

➤ Use Monte Carlo simulation to randomly select a K_{IC} profile vs. time and calculate the time at which K_I exceeds

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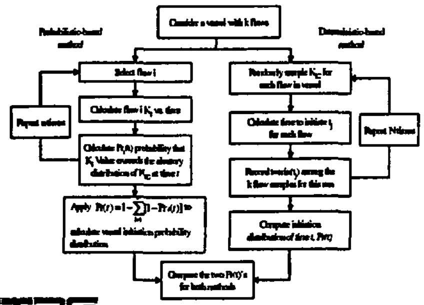
Summary Of The Approach



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Backups

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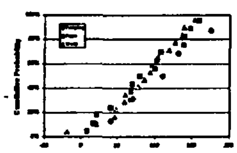
Proposed Procedure for the Use of Master Curve

1. Simulate a value of RT_{NDT} using either NB-2331, Generic, or MTEB 5.2 procedures
2. Estimate a bias correction value of RT_{NDT} - T_0 based on the CDF shown in the figure to the right
3. Estimate T_0 as RT_{NDT} - ΔRT
4. T_0 from step 3, when combined with equations to the right define the aleatory uncertainty in K_{Ic}
5. Correct for the flaw size



$$K_0 = 28.2 + 70.1 \cdot \exp[0.0106(T - T_0)]$$

$$P_f = 1 - \exp\left\{-\left(\frac{K_{Ic} - 18.2}{K_0 - 18.2}\right)^4\right\}$$

$$K_{Ic}(xT) = 18.2 + [K_{Ic}(xT) - 18.2]$$

xT = thickness of x-inches for a straight crack front

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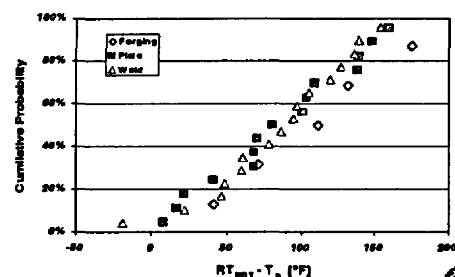
RT_{NDT} Bias Relative to T_0



CTRS

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RES/DRAA/PRAB
Low Power And Shutdown Risk Research Activities

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UNITED STATES NUCLEAR REGULATORY COMMISSION

LPSD PRA ACTIVITIES

- American Nuclear Society LPSD PRA Standard
  - Participation on the writing committee
  - Projected date for finalizing the standard is December, 2004
- Draft NUREG/CR-6595, Revision 1, "An Approach for Estimating The Frequencies of Various Containment Failure Modes and Bypass Events"
  - Provides a simplified method for estimating large early release frequency for LPSD conditions for different containment types
  - Is in public comment period

LPSD ACTIVITIES - CONTINUED

- LPSD fire analysis feasibility study
  - Determine the feasibility of expanding the scope of the "Fire Risk Re-quantification and Fire PRA Guide Upgrade Project" from full power operation to LPSD operation
- Reviewing LPSD events to obtain insights to support the worker fatigue rulemaking effort

INTERNATIONAL ACTIVITIES

- Participation in international activities on the study of LPSD risk to improve regulatory risk-informed decision making

- Cooperative PRA (COOPRA) LPSD Working Group

  - Working Group formed in 1997

- Committee on the Safety of Nuclear Installations (CSNI) LPSD Working Group

  - CSNI approved setting up a task group on LPSD PRA in 2000

COOPRA LPSD Working Group

- Initiating event topical report was written based on responses to a questionnaire
  - Objectives included an analysis of LPSD initiating events to gain insights on frequencies, data, and research needs
- Initiating event database is being developed
  - Provides a compilation of LPSD initiating events and a way to gain insights

CSNI LPSD Working Group

- Technical report on improving LPSD PRA methods and data to permit better risk comparison and trade-off decision-making is being written based on responses to a questionnaire

  - Scope of the effort includes all LPSD PRA modeling elements

  - Objectives are:

    (1) Identify differences between methods (and associated data) used in full power and LPSD PRAs that they preclude or substantially limit meaningful risk comparisons or trade-offs among these operational conditions

    (2) Define needed data collection or methods to overcome these differences