Official Transcript of Proceedings

NUCLEAR REGULATORY COMMISSION

Title: Advisory Committee on Reactor Safeguard Reliability and Probabilistic Risk Assessment

Docket Number: (n/a)

Location: Rockville, Maryland

Date: Wednesday, April 7, 2010

Work Order No.: NRC-163 Pages 1-356

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UNITED STATES NUCLEAR REGULATORY COMMISSION'S
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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RELIABILITY AND PROBABILISTIC RISK ASSESSMENT

SUBCOMMITTEE

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WEDNESDAY,

APRIL 7, 2010

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ROCKVILLE, MARYLAND

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

COMMITTEE MEMBERS:

JOHN W. STETKAR, Chairman

SAID ABDEL-KHALIKJ. SAM ARMIJO

DENNIS C. BLEY

MARIO V. BONACA

CHARLES H. BROWN

COMMITTEE MEMBERS: (CONT.)

MICHAEL CORRADINI

DANA A. POWERS

HAROLD B. RAY

MICHAEL T. RYAN

WILLIAM J. SHACK

NRC STAFF PRESENT:

PETER WEN, Designated Federal Official

ERASMIA LOIS

MARY DRUIN

SONG-HUA SHEN

VAL BARNES

CHRISTIANA LUI

ALSO PRESENT:

STUART LEWIS

JOHN FORESTER

STACEY HENDRICKSON

APRIL WHALEY

ALI MOSLEH

BRUCE HALLBERT

T-A-B-L-E O-F C-O-N-T-E-N-T-S

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

8:26 a.m.

CHAIR STETKAR: The meeting will now come to order.

This is a meeting of the Reliability and PRA Subcommittee. I'm John Stetkar, Chairman of this Subcommittee meeting.

ACRS members in attendance are: Charles Brown, Harold Ray, Dennis Bley, Sam Armijo, Said Abdel-Khalik, Mike Ryan, Bill Shack and Mario Bonaca.

Peter Wen of the ACRS staff is the Designated Federal Official for this meeting.

The purpose of this meeting is to discuss the staff's activities to address differences in various human reliability models. We will hear presentations from the NRC staff and their contractors.

We have received no written comments or requests for time to make oral statements from member of the public regarding today's meeting. The entire meeting will be open to public attendance.

The Subcommittee will gather information, analyze relevant issues and facts and formulate proposed positions and actions as appropriate for deliberation by the full Committee.

The rules for participation in today meeting as part of the notice of this meeting previously published in the *Federal Register* on March 22, 2010.

A transcript of the meeting is being kept and will be made available as stated in the *Federal Register* notice. Therefore, we request the participants in this meeting use the microphones located throughout the meeting room when addressing the Subcommittee. Participants should first identify themselves and speak with sufficient clarity and volume so that they may be readily heard.

We'll now proceed with the meeting. I think, Dennis, you --

MEMBER BLEY: Yes. I need to announce that although I didn't work the specific products that are here, I was involved in some of the meetings that originally got this work started. So I'm pretty much going to be restricted to listening and questions and points of fact.

Thank you.

CHAIR STETKAR: And also before I turn it over to Erasmia, for members who are new or not familiar with why we're here, this effort grew out of a Staff Requirements Memo from the Commission to the

ACRS in response to the Committee's meeting with the Commission on October 20. 2006. So it's a little over three years old.

And particular, the direction was that the Committee, ACRS, should work with the staff and external stakeholders to evaluate the different human reliability models in an effort to propose either a single model for the agency to use or guidance on which models should be used in specific circumstances. So that's the basic context of why we're assembled here and what's been going on.

As I said, that SRM came out in November of 2006. So we're roughly three and plus years into this process.

Do we have the bridge line open to someone?

MS. LOIS: Yes, we do. Three people would like to listen to. Is Jeff Julius from Scientech.

CHAIR STETKAR: Okay.

DR. LOIS: Vinh Dang from Paul Scherer Institute who is supporting the activity, and David Kelley from Idaho National Lab who is also --

CHAIR STETKAR: Okay. Great. For those of you who are on the bridge line, I would request that you keep your phones on mute so that you don't charge in at inopportune times. And at appropriate times we'll either ask for your input, if that's appropriate, or we'll give you time probably close to the break and the end of the session, periodically to give us some input if you think that's worthwhile. And otherwise, just listen in and play around with us.

And with that, I'll turn it over to Dr. Erasmia Lois from the staff.

DR. LOIS: Thank you very much. Thank the Committee for giving us the opportunity to present to you a study from how we're to address the ancillary SRM on HRA model differences.

Chrisiana Lui was planning to be here and address the Committee at the beginning, but she is fighting a long traffic every morning. So probably she will show up later today.

CHAIR STETKAR: Be careful of that. Your papers are on the mic there.

DR. LOIS: Okay. Okay.

CHAIR STETKAR: And our reporter will become really upset.

DR. LOIS: This is the SRM that was given to the ACRS, probably the date was it October or

November 8th of 2006. And what we try to do today is to discuss the technical approach that we have taken to address the SRM, present the technical work performed to-date, obtain feedback from the Subcommittee and if needed, perform mid-course adjustments.

So this is a crucial meeting today. We're kind of eager to see and receive your feedback because we are really marching forward to address the issue and we'll appreciate your feedback here.

Just remind that actually after the SRM came to the ACRS, we met in February with the Subcommittee, and then in April with the full Committee to present our plans on how we're going to address the SRM. And it was a joint meeting with EPRI.

The ACRS wrote a letter to the Commission on April indicating that the staff and EPRI are going to work collaboratively to address the SRM. And the Office of Research initiated work in the fall of 2007.

In December of 2008 we presented a very short overview in status on the way what is the process that we have undertaking to address the SRM.

And today, we're giving you a more

detailed briefing.

What is the approach that we took to address the SRM? Actually, we used expert and user workshops. And we debated amongst ourselves shall we use a single method or more methods which we call toolbox. And as we were going, the discussion recognized that both are needed.

I call it hybrid, because this is what it's going to be to this what we're developing so far. It would be needed to address model differences within a domain. For example, for full-power internal event analysis recognizing that domain-specific hybrids would be able to be developed using the same underlying structure. However, since we're doing screening analysis, more detailed analysis, event evaluation, et cetera, a toolbox is also needed to address the specific needs.

So, the hope is that both the domain-specific hybrids and the toolbox will have the same underlying structure but will be addressing different specific needs.

What we have done so far. We are focusing on developing a hybrid for internal event analysis. However -- yes?

CHAIR STETKAR: Erasmia, let me ask you

to stop right here. You say the current focus is on developing a hybrid for internal event full power PRAs.

DR. LOIS: Yes.

CHAIR STETKAR: Why should this methodology be restricted to evaluating human performance for only internal initiating events and only full power?

DR. LOIS: The hope is --

CHAIR STETKAR: Let me ask you this: Do people behave differently because they know it's an internal event and the plant is operating at power?

DR. LOIS: You have a very good point, and we are learning that people probably do not behave differently. However, if you compare the control room UOP-driven human actions versus those human actions that are performed out in the field, the error mechanisms and the way people may make a mistake, it may be a little bit different. But we do hope that the underlying structure will be able to handle all different situations.

CHAIR STETKAR: I would hope that it's more than a hope. I would hope that the underlying structure will absolutely handle internal and external events: Internal fires, internal floods, full power and shutdown modes. If we can't do that, we have failed, period. And indeed, if the approach does not keep that focus in mind, the approach has failed.

And that's a very strong statement, and I mean it to be very strong. We need to stop this notion that we have HRA for internal events full power, we have HRA for internal fires, we have HRA for internal floods. We maybe even someday might have HRA for seismic events, but obviously they're very different and so that I must be different because it's a seismic event. And then those four different versions for shutdown. This is not responsive to the SRM which requires us to consolidate all of these into, if possible, a single human reliability evaluation technique.

DR. LOIS: Thank you very much.

CHAIR STETKAR: And kind of fostering that notion is just kind of contrary to what we're up to here.

And, by the way, I'm aware of several internal event full power PSAs -- PRAs, that's for our international listeners, that indeed do take credit for many local actions out in the plant, mechanically operating valves and whatnot that are completely analogous to local actions in the plant during fire events or flooding events. So that even if we're restricting our focus to internal events at full power, we need to be able to deal with those local perhaps less procedural driven actions more reliant on inter-communications, more reliant on access to local areas and such.

So, I'd encourage you very strongly to pull back from this focus on internal event full power and focus on HRA methods that can handle human performance under all the variety of situations that we need to look at in PRA.

MEMBER SHACK: Just following up, you know we recently got a model from, again, EPRI/NRC for fire HRA. And, you know it doesn't look as though anybody's even talking to each other. It would be one thing that there's a toolbox and it's coordinated. But this sort of looks like, you know everybody's still marching down their same path and at the end you're going to call it a toolbox because there's a whole bunch of things out there. But I'm not at all clear that people are actually talking to each other. And if you could sort of tell me if you had any interaction with this fire HRA, or they had any interaction with you, I'd be interested in knowing that.

DR. LOIS: So Susan and I are not good friends at all.

Actually, we are talking to each other and we are very cognizant of what Susan is doing for the fire work, which is on a different schedule. But we do believe that in actuality the proposed scheme here is going to do exactly what you're saying; develop a structure and an architecture for human reliability that would have the capability to address human performance in various domains. And this morning we're going to spend a lot of time, and I hope at the end will be convinced that this is exactly what we try to do.

I note here that for shutdown event evaluation, which started a little bit later, we're totally coordinated. And at the end of the meeting Dr. Shen is going to present an example of her full power in shutdown evaluations and how the same structure can be applied to both areas. But from our purposes we cannot go globally and say okay, let's built an HRA for everything. We have to bite a small piece of bite at the beginning and then in actuality most HRA methods have been developed for full power internal event analysis. So once we convince that, have it in mind and keep it mind that this may be the structure. But I hope at the end you'll be convinced and we will not have to --

CHAIR STETKAR: Erasmia, I think something that bothers me is why can't we? It is 2010. We've been nominally thinking about this problem for three years. The industry has been concerned with HRA for -- pick a number. Thirty years. Why can't we think about this problem in the context of HRA for a full scope PRA; internal, external, full power and shutdown? Why is it necessary to keep focused on internal events at full power? Because the danger in that is that you might exclude some features of a methodology that later when you look at step number 2 in, perhaps, 2012 if I believe the last bullet there, six years now after our SRM, you might discover that oh gee, we didn't really think about certain aspects of human performance back in 2009 or '10. That's my big concern about saying that, well, traditionally we've looked at concentrated on full power operation and we need to bite off a small piece of the puzzle and focus on that now and solve that piece of the puzzle and then look at the next piece of the puzzle and find out that the puzzle was different.

DR. LOIS: Okay. So we take that as a feedback?

CHAIR STETKAR: Please, yes.

DR. LOIS: And we're going to address that.

MS. DRUIN: May I say something?

CHAIR STETKAR: You may as long as you use a microphone and identify yourself.

MS. DRUIN: Mary Druin from the Office of Research.

The PRA standard does at a high level provide one methodology. I shouldn't say "methodology." You know, provides these high level requirements. It does it for the entire full scope PRA.

So, Erasmia, it is coming together. Because as she is developing her work and Susan are developing their work, which is the lower level methodology, you need to meet these high level requirements in the standard. They are tying that in together.

So if there is something that will come out, for example in fire or seismic or internal flood, when they match up their method to the standard which is happening right now, I believe those kinds of things will come out.

CHAIR STETKAR: I think, Mary, what I'm concerned about, and I think what Dr. Shack mentioned, is that it's not clear how the various pieces are focusing at a central methodology. And from what you said, it doesn't give me a lot of convince because you mentioned well some people are working on fire HRA methods and maybe we'll work on flooding and maybe we'll work on seismic and eventually they'll all somehow meet the standard. I think that we need to --

MS. DRUIN: No, no, no. I'm saying that that integration is happening now.

CHAIR STETKAR: Okay. And I think we'd be really interested to see how that integration is actually occurring.

MS. DRUIN: I was just trying to give you a little bit more warm feeling.

CHAIR STETKAR: I understand.

MS. DRUIN: And that's on now.

CHAIR STETKAR: But I think the Subcommittee is quite interested to see if that integration is in progress and happening now. How is it being done, you know in practice? How are all the little tendrils being pulled together?

DR. LOIS: Well, what I'd like to say that this is very good news, your recommendation here. That's the way, that's what we would like to do. And I do hope at the end of this morning you'll be convinced that what we propose has that capability to achieve what we recommend.

CHAIR STETKAR: Okay.

DR. LOIS: I do want to note that what we do is going to be reviewed internally and externally. And if we are successful with what we are doing, finishing up by December, then we'll start developing tools for the appropriate implementation of this hybrid method.

Probably I should not spend any time here because Dr. Mosleh is going to probably tell that, why we chose the hybrid approach. Because recognizing that different methods have different capabilities and strengths, no single method met all of the criteria that we have identified.

I omitted to say here that in order to go to develop the hybrid approach, we developed quantitative and qualitative criteria. In a way we identified the desirable attributes of an HRA method that would have the capability to address the HRA model differences. So we started without -- in a way we developed this structure.

Okay. What we should do, what the method, what are the attributes that it should have in order to not produce different results every time and different analyst is doing or the same analyst face in different circumstances. And then develop the qualitative and quantitative approach according to that criteria.

Now having criteria been established and looking at the various methods, we did not find any one that actually addresses all of the different attributes that we wanted to have, recognizing that different methods have different capabilities and strengths. So then we decided that the optimal approach is to develop a consensus approach of regulatory and industry from regulatory and industry experts. And I'm noting that EPRI is also supporting this activity.

What we do in the hybrid approach, we try to develop it based on a human performance model, and actually more than one is being encompassed at the lower level. And encompassing existing sound concepts and practices.

The key here is to be able to identify key drivers of performance that are context-specific and building on the behavioral science and psych literatures, et cetera we believe we have the capability to do that.

And then the quantitative approach really have the capability to incorporate the results of the qualitative analysis.

On the quantitative side we haven't been progressed enough. We're going to spend most of the morning on the first bullet, the qualitative analysis and what we've done. On the quantitative side, probably we'll have to come back although we have the last part of the presentation is what we plan to do on quantification. We'll have to come back and brief you in detail later. For the short term we hope that probably if we may be able to modify existing quantitative approaches, but eventually what we try to do is to be able to estimate human error probabilities on the basis of data and evidence. Probably initial may be determination of judgment and data, eventually only data.

MEMBER ARMIJO: Before you leave that, could you just give me an example of a context-specific key driver? I'm not familiar with this terminology.

DR. LOIS: Definitely. We are going to

spend the whole morning explaining these ideas. But if you think of a given initiating event, people may have to do things very quickly, time constraint: That is one context. The other is they may be in a human action that involves many, many manipulations and therefore, they will have to read different screens, understand what's going on: That's the diagnostic aspect of it.

What it drives, what we try to understand in human probability is what is the underlying reasons for which people may not accomplish a human action. And we characterize the context as the synopsis of the plant conditions, the quality of the control room in phase with humans, their capability, their training, et cetera: All of that we call it context.

MEMBER ARMIJO: Right. I understand that part. But the "driver" then, what's that?

DR. LOIS: Then the driver would be people may not be able to diagnose because the screen was not clear enough, one driver. People were not able to do it because the procedures were very difficult to understand, that's another driver.

These are the various drivers.

MEMBER ARMIJO: Okay. Thank you.

DR. LOIS: Okay?

CHAIR STETKAR: Erasmia, let me ask, you mentioned that as part of the project you developed a list of desirable attributes of a human performance evaluation model.

DR. LOIS: Yes.

CHAIR STETKAR: Are you going to discuss those in this meeting?

DR. LOIS: Yes.

CHAIR STETKAR: You are?

DR. LOIS: Yes.

CHAIR STETKAR: Okay. And your conclusion was that there was no single existing method out there satisfies all of those attributes. So indeed, the conclusion is that we don't have the solution to the problem in hand.

Would you characterize your current work as development of an entirely new modeling framework to satisfy those requirements or are you looking to take the best of the existing modeling methods and refine it or extend it appropriately such that it, indeed, satisfies the majority if not all of those attributes?

DR. LOIS: I believe that's what we do.

CHAIR STETKAR: You do?

DR. LOIS: Yes.

CHAIR STETKAR: Okay. So you think you're basically expanding on something of what we have now and trying to extend it?

DR. LOIS: Absolutely. I think ATHEANA is kind of the basis.

CHAIR STETKAR: Okay.

DR. LOIS: But it's a more structured approach, we believe. But ATHEANA has provided tremendous input in this hybrid method.

CHAIR STETKAR: Okay.

DR. LOIS: But other aspects and other methods also are characteristics of the methods that we use.

CHAIR STETKAR: Good. Okay.

It's good to hear that you're kind of building on what we have rather than launching off into new waters. Because remember, the direction in the SRM was not necessarily new research on yet another acronym human reliability analysis model. It was trying to pull together what we have in place and gain some knowledge and confidence from the best elements of, perhaps, several different methods.

MEMBER BLEY: I just wanted to ask you, when you began this slide you mentioned that the work has been guided by a human performance model but that you were actually incorporating alternative human performance models. I didn't quite --

DR. LOIS: At the high level it's one human performance model and then at lower level other human performance models also. I used that screen --

MEMBER BLEY: Is that going to be in all the talks, or is there one particular talk that's going to --

DR. LOIS: Really we have, I think each one of those elements are going to be addressed in detail --

MEMBER BLEY: Okay.

DR. LOIS: Everything is going to be explained. The space is going to --

CHAIR STETKAR: At the end of the morning we'll know whatever we want to know.

MEMBER BLEY: Thanks.

DR. LOIS: Yes.

So what we tried to do here, I believe it's according to your vision to have a single approach or architecture for all applications and eventually shift the research activities towards evidence driven HEP estimations in order to reduce analyst judgment and also in the plan is to use dynamic simulation approaches and tools to support human reliability; that's in the future.

This is the schedule which we presented in December of 2009. So I think we are right on target here unless things come up and we'll have to do mid-course correction.

And I would like to note that this is a collaborative work. Sandia has the lead for the full power work. John Forester, Stacey was here. Ron Boring that used to be with Sandia, now he's with Idaho. Dr. Mosleh, who will talk to us right away. And Vinh Dang from Paul Scherer Institute, and I think he's on the phone.

The Idaho has the lead for the shutdown work. Dana Kelly, April and Ron, again.

And then I would like to note that the Office of Research staff also are contributing to the technical work. Dr. Shen and Dr. Chang are working with the labs in the development of this effort. And also Chris Hunter and I are the Project Managers of the work.

CHAIR STETKAR: Erasmia, in your introduction you also mentioned a collaboration with EPRI. Could you explain? You don't have them listed on this slide. Could you explain how that's working or what sort of interactions you actually have in place with EPRI?

DR. LOIS: Stuart Lewis is here and he will address that part.

MR. LEWIS: I'll try to give you my perspective.

I'm Stuart Lewis from EPRI.

We were involved early, early on in the process primarily through Jeff Julius who was active on EPRI's behalf in some of the initial formulation and some of the early workshops, and that's sort of thing that led to the framework that's been developed. Over the last, I guess, six months to a year I think our participation has been somewhat uneven and there's been transitions. I've joined EPRI and have started to take on a more active role in the HRA efforts there. And we're trying to get more involved, but we haven't been directly involved very much in the development of the current framework.

CHAIR STETKAR: Oh, okay.

MR. LEWIS: And where things are headed with the quantification efforts. So I think that's--

CHAIR STETKAR: EPRI was heavily involved, though, in the work that supported the

NUREG on, I hate to say it, the fire HRA methods, isn't that correct?

MR. LEWIS: Unfortunately, that's what it says.

CHAIR STETKAR: Yes.

MR. LEWIS: That's right, EPRI and the NRC contractors have worked together quite a bit, and Susan and others at NRC on that. And I know that they talk to each other. I'm not sure at what level the integration that Erasmia referred to is occurring there.

CHAIR STETKAR: I was going to ask that. Is there a plan since EPRI and the staff worked pretty closely together, as I understand it, on the methods and examples for the -- God, I hate this term, fire HRA. Let me call it by NUREG number. NUREG-1921, that's better because I just want to do away with this notion of fire HRA or other HRA.

Since you worked together quite closely on the development of NUREG-1921, it would seem beneficial to this project to build on that experience, wouldn't it? It doesn't sound like there's a mechanism in place for active participation from the industry in this particular effort.

DR. LOIS: As you noted, we started out

with a very strong interaction and participation. For reasons that I cannot -- I mean, I don't know, EPRI, I guess, did not participate as much in the last year or so. It could be resource issues, or I cannot explain. But it seems that now we're getting back and we're going to try to do it more collaboratively, if I understand well.

CHAIR STETKAR: I would hope -- I mean, you know we can't dictate resources and time. But it's my experience that the results of efforts that come out of that type of collaboration between industry and Research oftentimes have much better chance of success in terms of practical applications and acceptance. So if there's anything that you can do to sort of foster a more active involvement, I think that we'd probably benefit collectively from that.

You know, that being said.

MEMBER SHACK: Yes, I'm less ambitious. I'd just like to make sure there's interaction between the different parts of the NRC.

CHAIR STETKAR: We'll get to that. Well, perhaps we could triangulate somehow.

DR. LOIS: So what we're going to do this morning, the overall framework is going to be presented by Professor Ali Mosleh, University of Maryland.

The Research results from behavioral science supporting the technical approach is where the different models are being used will be presented by Dr. Hendrickson, right? And April Whaley.

And then a specific example is going to be presented by Dr. Shen of the Office of Research. And that example, as I said before, is going to be for full power and shutdown. So I hope that will address most of your concerns about the capability of the method to be used in other areas.

With that, I will allow the members that are around this table to present themselves, and then we will continue with the next presentation.

Thank you very much.

DR. HENDRICKSON: I'm Stacey Hendrickson. I work at Sandia Labs. I've been there for three years now in human reliability analysis.

Before that, I got my education in quantitative psychology from the University of New Mexico. In quantitative and cognitive psychology.

MS. WHALEY: My name is April Whaley. I'm from Idaho National Lab. I've been at Idaho since 2002, I have a Master's Degree in Experimental

Research Psychology.

And at Idaho, I've been involved almost full time in HRA related projects since I started there.

PROFESSOR MOSLEH: I'm Ali Mosleh. I'm Professor at University of Maryland. And in this work, I joined this particular project about eight months ago under a contract with Sandia National Lab.

And over the past 30 years -- it's been 30 years, right? Doing mostly PRA practice or as an educator and researcher. And the past 20 years or so I've focused on developing a unified human reliability model, at least from my perspective. So I've done some HRA related work.

DR. SHEN: I am Song-hua Shen. I work for NRC Research department staff last year.

I got my Master's degree for nuclear engineering and then started working at a nuclear power station, a Westinghouse-style BWR for seven years. I finished the SRO training. I work as a SSRO for seven years. I also spend one year in the PWR PRA development.

And then I move to USA to keep going to universities, work on my Ph.D. dissertation. My

Ph.D. dissertation is working under the dynamic PRA especially for HRA. And I also after I got my degree, three years in post-doctorate but also working in HRA field to develop some new HRA methodologies. Still I'm current licensed HRA model.

And after that I start working around 1998 in the domain for more than 10 years. I also was working the PRA HRA methodology. So totally I have spent 20 years in the HRA study and another ten years in power plant operation.

CHAIR STETKAR: Thank you.

PROFESSOR MOSLEH: All right. Good morning, and thank you for giving us the opportunity to brief you on our effort on the SRM.

I must say that, John, you couldn't have actually offered a better comment than the comment you gave at the beginning. And there is two dimensions to that issue basically a coordinated and coherent directed effort toward addressing the SRM. One is the organizational and the social aspect of it. The other one is the technical.

I would say that we have been very conscious of the need and also practical and technical dimensions of the problem. And we have taken steps, many steps toward addressing the problem in an integrated and coordinated way from day one. At least, my "day one" was about eight months ago. But I sensed nothing but the desire to have a method that covers the broad range of applications. It does not make any sense to think that a human being fundamentally function differently if you find those foundational kind of basic principles. And that's why we emphasized from day one that you want to have a heavy participation by the human behavior sciences, basically. And that's why we have, like, basically we're outnumbered in this panel by such, and there's more. Dr. Ron Boring is sitting in the audience, and many other people who have directly or indirectly provided input to ensure that that perspective is actually followed.

The other comment you made was toward the end, John, was also extremely important. In our mind the projects that have been very successful in the past have had the signature of the strong and close collaboration between the industry and the regulators and, I would say, technical academy community. An example of that, I'm sure you remember, is the *Common Cause Guidebook*. Was 20 some years ago, maybe 25 years ago was developed as a result of close collaboration between EPRI and NRC and National Labs. And we can see the success of that project was because it would try to reflect in an honest and very transparent way the opinion and positions of the experts in the discipline, kind of see in the horizon what the needs might be and then put those together in the form of a set of guidelines that now de facto international standards. Of course, probably outdated in some areas.

So these have been our models. At least, you know, we have had many meetings where we actually brought up these examples; the needs, the desire and also the example of a guidebook as a success criteria.

CHAIR STETKAR: And I think, you know we have a lot more recent experience with success stories in that collaborative area. Regardless of current criticisms, NUREG/CR-6850 or whatever it is on fire analysis methods grew out of a very strong collaborative effort. The NUREG-1921 on the type of HRA that I won't mention, grew out of a collaborative effort.

And I think that's important because, you know quite honestly we need to keep focused on the users of the methodology, and the users partly within the agency, we're users of the methodology. We have to have confidence in our SPAR models, for example, that we're using a methodology that is coherent. But, indeed, the industry will be using the methods and without their input, we unfortunately have too much evidence of reluctance to accept those methods because they're not part owners of the method.

So, I'm glad to hear what you say. I hope that, indeed, we continue on that path with this particular project.

PROFESSOR MOSLEH: And I also hope that we would provide evidence today that confirms what I just said.

CHAIR STETKAR: Good.

PROFESSOR MOSLEH: So with that, the way that we have planned these presentations are reflective of basically what we have been asked to provide an example and the conceptual background and theory, and our roadmap and/or approach. And right in the middle I think an extremely important part, which is the human performance model. And that's why we have Stacey and April present at this time.

So with that, let me start with our starting point, which was effectively a survey of the user needs. Ron Boring took the lead in that and then surveyed a large spectrum of users of HRA for different applications and by different organizations and provided the basic starting point for us to see what issues we need to address with respect to application.

We're not going to be talking about that in this presentation, but there are some set of the slides and presentations that were presented in multiple gatherings that we have had on the project that kind of provided a pretty good picture of what the user needs were.

The other step we took was an expert panel consensus on desirable quality attributes of an HRA method. And in that meeting we had participation not only from the U.S., EPRI and NRC, but also international collaborators and participants in those discussions. And I will list and talk about some of the key quality attributes that came out of that particular activity.

We spent some time defining the scope. And the scope going back to your comment, John. The scope, we defined it as the entire set of applications that we identified under bullet number one. However, I think what Erasmia was I think emphasizing was the fact that due to, obviously, resource limitations and then the time scale of this particular project, we thought that we would start demonstrating the concepts and ideas in the case of power, full power application. So that we would demonstrate how we are meeting some of those desirable qualities and quality attributes and then step-by-step move toward extending the application. In fact, most recently kind of four or five month ago we started closer coordination with the shutdown event evaluation.

So the scope fundamentally is broad, but the focus currently is in power. And you'll see that at least we claim where we like to see that the approach we're taking is pretty general and then comprehensive as well. In this process, of course, with those foundations one, two, three we have to make an assessment of the gaps that existed in the state of the art and methods and tools used.

This is kind of a high level view of the expert panel consensus on quality attributes. And there are big bullets and then some sub-bullets and there's more under each sub-bullet to more precisely define what these were.

Just quickly, I'm going to go over these things quickly because I'm going to go back to this and then show or at least highlight to what extent we need these requirements.

MEMBER BLEY: Ali?

PROFESSOR MOSLEH: Yes.

MEMBER BLEY: Before you go through this list, can I ask you a question? I don't remember if you did this.

Did you play this list of what the panel developed against the good practices document?

PROFESSOR MOSLEH: Yes.

MEMBER BLEY: And how did that align?

PROFESSOR MOSLEH: It was augmented, and Stacey actually took the lead in looking at all these different kind of resources and information. I think it matches quite --

DR. HENDRICKSON: It aligned quite well. And, in fact, we used the good practices guide to kind of guide us in what to elicit as well. So we had that in mind when we had these workshops.

MEMBER BLEY: Okay.

PROFESSOR MOSLEH: Yes.

So there are big categories such as in the notion of content validity. And it says really what are the ingredients of the methodology. Does it cover all the core ingredients that we think are needed in terms of covering, for instance: Plant, crew, human cognition actions, notions such as errors of commission and omission and a wide range of terms that have been used in the practice.

Richness of context characterization. Is it covering PSFs, timing of activities; the things that are really characterizing the environment that the operators are responding to.

CHAIR STETKAR: Ali?

PROFESSOR MOSLEH: Yes.

CHAIR STETKAR: Just for the benefit, we have a pretty broad membership here today. So when you use acronyms that we in the business tend to know --

PROFESSOR MOSLEH: Yes.

CHAIR STETKAR: -- perhaps, a lot of other people. If you could just tell people what they are the first time you use them. Because EOCs and EEOs for example are not necessarily widely recognized acronyms.

PROFESSOR MOSLEH: Thank you, John. That's absolutely correct.

Errors of commission, EOCs and errors of omission, EEO. And then PSF is performance-shaping factors also known as performance influencing factors and similar terms.

So more recently, I mean I'm talking about the past ten years or so, the focus in the human reliability community has been really to really reflect the context of the operator response to events to try to understand and characterize those in more detail and rich enough such that the performance assessment could be more realistic and reflective of the types of things that humans generally respond to.

Other terms such as explanatory power, is there a causal understanding of why errors take place? What are the mechanisms that relate the context to performance, to errors? And are there any theoretical foundations in human behavioral science that we could borrow to support such causal model?

Ability to cover human failure event dependency and recovery. That's an important issue because we deal with multiple events in a given sequence in a PRA, therefore at least from a probabilistic point of view we need to consider the interdependencies of probability of multiple failures. But also from the perspective of understanding and developing mechanism or defenses against future human errors the dependencies play an important role.

Other things that the experts identified as being a source of confusion or problem or issue in the past, and we wanted to make sure that it's really clear defined in evaluation of different methods as well as any new method that is going to be developed is the notion of "unit of analysis." So you're looking at the crew, individual operators; what is the composition? What is it that you're analyzing? And when you assign the probability of error, whose error probability is it?

Empirical validity refers to really a data-based information base to support the frequency calculations, the probability calculations and enough, of course, you can extend it to empirical validity of the constructs of the methodology. If you say there is a particular human performance methodology or model that we have adopted, is there a basis in experiment and empirical evaluation that we can highlight and rely on?

The rest are essentially things that are good and kind of important, in a way I would say fundamental, in any methods development endeavor.

Reliability is are the results reproducible? Are they consistent internally and externally to the expectations and internally with respect to the different aspects of the method?

Inter and intra-rater reliability. Can different people produce the same result using the same method or the same individual using the method multiple times in different analyses?

Traceability and transparency. These are all important characteristics when people produce results and they need to be subject to review and validation. Of course, we need to be able to demonstrate that they're traceable and transparent. Can we reverse engineer a particular analysis?

It is desirable that we be able to test a method, whether it's an entire method or at least part of it, these are critical in order to establish some level of credibility or a minimum level of credibility with the technical community.

In many applications of HRA the notion that we don't want to kind of basically use a catalog version of a method. But you want to be able to have a graded approach, be able to do a screening analysis, be able to go into kind of full scale detailed analysis when it's necessary and be equipped the tools and techniques to do so.

Usability and practicality. Of course, we can develop a method that is beautiful and comprehensive and all that, but nobody can afford to touch it.

With this we are going to try to cover different aspects of our progress so far in the background of these metrics. And so I'm going to provide an overview of the methodology. And Stacey and April will cover human performance model, an example will be provided by Song-hua Shen. And then I'll come back and then make an assessment of where we are and then address the plans that we have for the near future.

I'm going to probably in the interest of time skip some viewgraphs or go faster. Just slow me down when you think that you may need clarification and then I'll refer to the main experts in the areas where I need to.

CHAIR STETKAR: Yes, we're scheduled to end at 3:30 today. There is, from my perspective, no compelling reason to necessarily do that. So don't necessarily feel too constrained by the overall time. I want to make sure that this Subcommittee hears the salient points of what you've done and then that we have ample time to ask questions and understand that.

So, you know, don't necessarily feel that 3:30 is an absolute end time for the whole presentations.

PROFESSOR MOSLEH: Okay.

CHAIR STETKAR: I don't know if anybody has travel plans, but that notwithstanding.

I know we have another informal meeting scheduled, not it is indeed an informal meeting and that can, I'm sure, be addressed.

PROFESSOR MOSLEH: Okay. Thank you, John.

Go back to my original Plan A.

CHAIR STETKAR: On the other hand, if you see us nodding off, pick up the pace.

PROFESSOR MOSLEH: Yes. Absolutely. Okay. Good.

So, a few viewgraphs on the overall framework, basically the conceptual end of it.

First, in terms of modeling the scope and unit of analysis, we recognized that we need to model and consider the plant, the crew, the individual members of the crew, organization of a nuclear installation and the environment. So that's kind of the universe that we have here.

And the key point here in this slide in terms of the notion of unit analysis is that it is a modeling choice between taking the crew as a unit or the individual operators. And both are possible, doable, feasible and then one has to provide enough flexibility to go back and forth depending on the needs or the specific application. There are, obviously, different technical complexities and issues that need to be tackled depending on whether the crew is the unit or the individual operator. But our goal is to have enough flexibility in the methodology that we can actually move back and forth between the two.

Allow me to kind of give you an overview of some of the terms and kind of concepts that we like to use, and then I'll go back and make an assessment of where we got these ideas. I think that was another issue that you raised or question that you raised, John.

We are not, certainly, developing a brand new methodology. That's a very meaningful thing to do after 30 years or 20 years of effort in the area of human reliability without a lot of good results.

So, in PRA we have very well known concepts such as event tree. And then in the event trees and in the fault trees that are attached to those, we have human failure events and system states. And what we think we need to do is to bring the level of HRA analysis to the same level of rigorous representational style of the event tree.

Now in event tree, if you look at them, it is very intuitive and conceptually simple, and most plant analysts don't even need to draw an event tree to say, you know, what can happen to a plant if you have an initiating event. But it's been a remarkable, very powerful tool over the past 30 or 40 years to do a systematic analysis, to be able to communicate results and then put things in the proper context and operational as well as from the regulatory perspective.

So we think that having something that kind of carries the same flavor that would be useful, and such concept we call a crew response tree. So you can imagine that the crew response tree is something like an enriched order or expanded, or enhanced event tree that now is human centered, human focused.

What is common between these two trees is the human failure event. In other words, one analyst should be able to find the human failure events in the CRT or crew response tree and put that in the event tree or start with the event tree, the human failure event in the event tree and try to trace it through the CRT.

Well, of course, multiple paths through the CRT, that particular style of human response modeling, could lead to multiple failures, human failure events or you could have the same human failure event being contributed to by several path or sequences, or scenarios within the CRT.

So, this is how the CRT would kind of link to the conventional event tree.

Of course, the branch points in the CRT, whereas in the event tree the branch points are essentially the human failure events or major system failures, in the CRT you may add position points, critical steps of a procedure if necessary and things that are a little bit more human centered and more detailed. But essentially these branch points are supposed to provide alternatives that could be faced in the progression of a sequence.

MEMBER ABDEL-KHALIK: In the CRT would you have to generate a branch for each possible system failure?

PROFESSOR MOSLEH: Hopefully and ideally not, although you do need to consider in the background or sometimes explicitly what the corresponding scenario in the event tree entails with respect to the system failure or component failures. In other words, when you look at the particular sequence in the CRT it has as a condition or context factor if the equipment failure that are already embedded in the event tree. You may need to add a few if the event tree and existing event tree doesn't have some key failures that are essential from a human performance point of view but are not reflected in the current structure of the event tree.

MEMBER ABDEL-KHALIK: I guess I'm not sure I see the explicit connection in a sense that human performance will depend to a large extent on what systems are available --

PROFESSOR MOSLEH: Yes. Very much so.

MEMBER ABDEL-KHALIK: -- and what systems may have failed.

PROFESSOR MOSLEH: Right.

MEMBER ABDEL-KHALIK: And if you want to make these two trees equivalent, then somehow the information contained in one should be included within the other?

PROFESSOR MOSLEH: Yes. You can do that. And I agree with you, absolutely. It can be done in two ways.

One is really, and we're not recommending that for existing kind of the applications of the PRA and HRA, but one could actually have just one tree, you know the CRT and include everything. It's possible and in principle doable.

CHAIR STETKAR: Ali, let me expand on what Said said.

As I read through this material I kept fundamentally asking myself why do we need a CRT. Why? Why do we need an entirely separate parallel construct for the event trees? So please answer that question: Why do we need this? Why can we not simply evaluate human performance in the construct of the event model?

PROFESSOR MOSLEH: If the event tree model is rich enough in terms of the human-centered sequences explicitly, and we know the level of detail we normally put in the event trees these days. And there have been two styles of modeling in event trees. You know, the extreme of having many, many branches and a detailed event tree and sometimes you have more larger fault trees. But different modeling in size. But in principle we should be able to live with one tree.

The reason for another one, and that's not kind of something that you always need to do; the need for the other one is essentially to make sure that you do a comprehensive and systematic coverage of different human interfaces and human interactions during the course of an event.

CHAIR STETKAR: Well, I certainly agree with the second part of that statement that when we develop a PRA model for integrated plant and human response to some sort of upset condition, we need to carefully think about not only hardware failures but how the human will respond to whatever the context of those scenarios are.

What bothers me is that you seem to be taking a predefined event tree logic structure as a given and creating a parallel modeling construct that somehow, and I'm not sure how, will then communicate with that model that we used to quantify the PRA.

In my experience one of the areas that's most prone to problems is, indeed, defining the human failure events in the construct of the plant response model, whether it's an event tree or fault tree or whatever logical construct. It seems that we should be working within that construct, in other words that our methodology should not be creating a parallel modeling construct that then talks to the thing that we used to quantify the PRA. Shouldn't we rather be using the principles that you elaborate in the CRT structure, but as guidance for PRA analysts on how to define those human failure events within the context of a single plant response model? Because from a purely pragmatic sense, I don't want to develop two separate logic models. I don't want to develop an event tree and a separate CRT. And I don't want to pay people who are human performance experts to develop CRTs that then I need to worry about how to integrate with my real event tree, if you will.

So, I think I was thus struggling with the notion of developing parallel logical constructs and how those would indeed finally be integrated, rather than using the basic principles that you elaborate in the CRT. You know, the thought process that you as human performance experts would use to develop the branch points and the decision criteria for human actions, how could we integrate that in the real model? And if that requires guidance on the fact that we need to expand the level of detail in a model to adequately address human performance, I think that that would be a wonderful outcome from this process rather than saying well we as human performance experts realize that your event tree models are just too simplistic and can't work.

PROFESSOR MOSLEH: Yes.

CHAIR STETKAR: So, I'd kind of encourage more of an integrated sense to use the plant event model and the level of detail in that to define human failure events and the logical construct to get to those human failure events as a starting point for the actual quantification of human failures.

MEMBER BLEY: I'm going to say, and I wasn't involved in this part of the work --

CHAIR STETKAR: So you can actually ask about this? Thank you.

MEMBER BLEY: I want to follow-up on a couple of things you said, John. Later I have a couple of simple questions about what you had up here.

But we've had parallel structures. They may have been tables cataloging how things depended on things before and on things that aren't modeled, and the system is modeled with a PRA because we didn't need to in the systems model but there are things that affect the operator. And when people have tried to do that carefully, you in fact have done this, built some very elaborate tables to track all of this. It strikes me that this CRT is kind of a different layout of those tables trying to track the things, one point.

The second point is for existing plants we've got all these PRA models in place. And if we want to do something, I think this is suggesting a way to deal with that. I would hope that what comes out of this process maybe addresses existing plants and new plants, and there are going to be a lot of new plants and they're going to have a lot of new PRAs and why not integrate it at that time.

CHAIR STETKAR: Yes.

MEMBER BLEY: And I think that would be useful.

My couple of questions are: (1) Not all systems' event trees are strictly time sequenced.

PROFESSOR MOSLEH: Yes.

MEMBER BLEY: Does that cause you any problems? As high as they are, and they just aren't.

PROFESSOR MOSLEH: Yes. Yes. It's something that we need to address in terms of procedurally how you implement this thing. Because, you know there is a temporal sequence or equivalent event tree that one can imagine that has kind of a temporal sense in it for any given event tree that is logically constructed.

When you construct a CRT you're talking

about kind of a temporally sequenced event --

MEMBER BLEY: And tracking dependencies is one of the things.

PROFESSOR MOSLEH: Yes. Yes. So you have to see how you can actually now cross-link and coordinate that with your existing event tree, as you said, for an existing PRA is not temporally sequenced.

MEMBER BLEY: And I think you guys have to address that --

PROFESSOR MOSLEH: Yes. Yes.

MEMBER BLEY: -- and acknowledge that that is a fact of life.

PROFESSOR MOSLEH: Absolutely.

MEMBER BLEY: It strikes me your introduction was these event trees have helped us a lot to structure our thinking, therefore the CRTs will do the same. That's a bit of a matter of faith, and the faith's going to be proved out in the examples. So I'm looking forward to the example presentation to see if there's a reason for that faith to hold true.

CHAIR STETKAR: I think in the sense of Said's question and something that was nagging at me is that as I read through your draft documentation there were several statements in there that said well, yes, the CRT actually does need to account for equipment failures because, obviously, equipment failures can affect the information available to the operator. They can also in many cases affect the dynamic response of the plant in terms of timing of scenarios or -

MEMBER BLEY: And the operator's situational assessment of events.

CHAIR STETKAR: That's right. So that that's where I started to feel uneasy about the fact that the CRT may contain more information about human performance then the existing the event tree, but that it probably does need to contain essentially all of that other information about system successes and failures to indeed fully assess all of the scenarios that the PRA team, if I can call it that, has determined are relevant for this particular initiating event response. And in that sense when I started to think about well if the CRT also needs all of the system failure events in it, why can't we take the added detail from the CRT and put it back in the event model?

I do recognize the fact that this should be backwardly compatible with existing models.

MEMBER BLEY: Coming up with a set of rules to decide what part of that plant model you don't need would be a waste of time. A lot of effort and a waste of time.

CHAIR STETKAR: Would be really a lot of effort and a waste of time, that's right. You don't want to tell people what they need to ignore, not think about.

PROFESSOR MOSLEH: Well, you know the backward compatibility was in our mind, basically. And we had many sessions, meetings including people with tremendous experience in conducting, you know doing PRAs and push back regarding well we really wanted these things to be backward compatible, or that's our scope.

Yes?

CHAIR STETKAR: I understand that. But recall that those of us who are getting really old now have been worrying about this stuff for 30 years. And we've had direction now for three years to try to pull everything together. This might be our only chance to develop a methodology that will be used for the next 30 years. And we need to keep that in mind. That I recognize the kind of reactionary element of folks who have already developed models and don't want to be forced into yet a new framework. But we're entering, hopefully, new plant licensing and PRA is a requirement for those new plants. And as much as people say that those plants are operator hands-off, the PRAs that I've seen have a very large number of human interactions wired into them for the new plants despite all of the passive safety features.

So I really do think that we need to be aware of the past, but not be too awfully constrained by that.

PROFESSOR MOSLEH: And the way that this thing is evolving, I believe and we can demonstrate that it's going to be both backward compatible --

CHAIR STETKAR: Okay.

PROFESSOR MOSLEH: -- and also a pretty kind of practical guidance for future.

CHAIR STETKAR: Okay.

PROFESSOR MOSLEH: And I agree with the comment, I think you offered, Dr. Abdel-Khalik, yourself John and Dennis mentioned there is a kind of a tight coupling in terms of information content between the event tree or the concepts that people have to use and the CRT. And, yes, ideally you would do a CRT or an enriched event tree and you don't need to have two parallel constructs, as Dennis said.

We do some of this thing in form of tables or stories, or scenarios. We try to kind of bring all this back into kind of a very structured formal way to the extent possible.

Now this particular slide actually highlights the point that you are making. The fact that if I look at a particular HFE that appears in the event tree and I'm going to understand how that can happen through a CRT, that part of the context is the sequence of events that I've highlighted here up to that point even from a human perspective. Part of the context is all the factors that you don't put in a model explicitly, and sometimes semi-explicit in terms of the context factors such as the performance-shaping factors that reflect organizational behavior or the crew training and things of that nature.

In addition, time, part of the time from the initiating event to the point of the arrow is part of the context in the temporal sense of things. In addition to that, the particular sequence in the event tree that you're considering as, you know a system set have failed or the extent of conditions of the plant is going to be part of the context.

So when we talk about context of a

particular branch point or an HFE or a failure event in the CRT and the event tree, we're talking about all this. And what we're trying to do is try to kind of develop a set of steps that consider all these things in a manner that is consistent with the set of criteria that we started it, the quality metrics or properties.

MEMBER BLEY: You just hit on something. John said something, two things I'm a little worried about as we go ahead.

If this evolves into something very useful, there's a tendency when you build a tree-like structure to think you've captured everything. And you mentioned the stories and the basis for all of this. It often becomes easy to forget to write down the descriptive material of that story that generates this thing and you start mechanizing it to the point that you lose that richness that gives it its value.

And John said something about I'm a little nervous about having a bunch of HRA analysts go drawing separate trees. Erasmia didn't talk about this: Who is this aimed at?

My problem is I never want a bunch of one kind of people going off and doing some analysis.

HRA is so integrated with the plant that doing this without operators involved, engineers involved who understand the whole plant, and just having them review isn't enough. And I'm just getting a little nervous that we're systematizing this to the point we think somebody can pick it up and sees it and all of a sudden we've lost that integration that's the key. And that integration generates the story, the descriptive material that pulls it altogether.

And my sense of reading the document is it looks like we're slipping that way into thinking we can build an automaton kind of thing here. And you've got to have that rich interaction of operations experience, design experience and knowledge about how people perform pulled together into a single team to make this thing work whenever you do it. And I'm losing that a little bit in the stuff I read.

CHAIR STETKAR: I'm glad you mentioned that, Dennis. I wasn't going to say it, but since you brought it up. The report, there are subtle things in the report that also troubled me. Because the report talks about event trees developed by systems analysts that are then evaluated by HRA experts.

I think that we in 2010 need to completely eliminate that notion. Event trees ought not to be developed by systems analysts because the connotation of a systems analyst is somebody who has knowledge of pumps and pipes and valves and they know that a valve can fail to open and fail to close, and spuriously open and so forth. And traditionally they've said well we don't need to think about human actions other than the fact that oh, this thing failed, the operator could push this button. Oh, that valve didn't open, the operator could run out in the plant and open that. And we let those human reliability people worry about that.

This construct seems to be developed from the perspective of the human reliability experts who say we understand everything that there is to know about human performance, but we'll take that logic model that's given to us by those systems people who really understand the plant and then develop the most appropriate methodology to evaluate human performance within that context; that context being developed by people who haven't even thought about the types of things that you folks think about.

So this notion of still an event model that's fundamentally driven by people who understand the plant and then a submodel that evaluates human performance within that context just seems to foster that separate notion that has really gotten us into a lot of problems that we have today.

So I pretty well endorse your notion to the fact that we need to have the people who understand about pumps and pipes and valves and electrons thinking in the framework of this CRT, and we need to have the human reliability people thinking the fact that they really need to understand how the plant works.

MEMBER BLEY: And it should be a team.

CHAIR STETKAR: And it should be a team.

MEMBER BLEY: The one example pops in mind was doing an HRA for a project that already had its event trees and fault trees developed. Eighty percent of the work was getting the thermal hydraulics people to do the right calculations that would analyze the situations that would be important to the operators and revamping the system's trees so that they'd make sense in the context of the operators. They all had to be done at once. They shouldn't be done from one side to the other.

CHAIR STETKAR: Well, you mentioned time. You're never going to get through all your presentation anyway, so it doesn't make any difference. Just, you know, in the breaks regroup, figure what are the pieces you need to present to us.

Thermal hydraulics, you have that wonderful green arrow time there. In picking up on what Dennis said, a lot of my experience has been also that right, wrong or indifferent the notion of time seems to be one of the few unifying elements that brings all of these different disparate entities together in developing a cohesive model. Because it's the only thing that, for example, thermal hydraulics people will grudgingly calculate for you if you tell them go run this type of scenario for me. It's the only thing that the system modelers can easily recognize and say oh gee, that's right. Under these conditions the operator would only have five minutes to respond rather than an hour and a half. So it's clear that I need at least a different definition of a human failure event. And it obviously effects the context of what's going on from the human reliability standpoint.

So it's another area where I think that we need to emphasize this integrated approach to developing that single response model for the plant. And some how we need to ensure that our guidance in a methodology emphasizes those points: That indeed the thermal hydraulics people are not separate. You know, they're not doing design basis accident analysis for this. And that the system modelers, if I can call them that, need to be aware in both directions that they need to ask the correct questions.

DR. LOIS: Can I add something here?

MEMBER BLEY: Yes. Sure.

DR. LOIS: I think you're preaching to the choir here. Everybody wants -- I mean on this table and people in the audience believe that it should be an HRA/PRA, not a different concept. But it should be an PRA where the experts from human performance are participating from day one. That will take a change in the culture of the PRA community and probably the general engineering community. Because unfortunately for 30 years the practices are to just come up with the human events and then give it to the HRA analyst. The good practices are emphasizing that practice.

So then here is a plea. You have the audience here, different activities, PRA activities come and brief you. If you could give that feedback to those PRA analysts and engineers that are working entirely separate from what we do. We do our best to integrate, but it is really a big -- it would need a big change, cultural change in the community to achieve what you recommend here.

MEMBER BLEY: Let me say two things.

One is, we'll do that.

DR. LOIS: You will, or you are doing?

MEMBER BLEY: I do it every chance I get.

CHAIR STETKAR: Every time we have.

MEMBER BLEY: Let's not put out a report from the HRA community that doesn't emphasize that from page one.

CHAIR STETKAR: Right. That's right.

MEMBER BLEY: And we've got a draft now that does not.

CHAIR STETKAR: That's right.

MEMBER BLEY: And we've got discussions right here with various of us participating and saying the wrong words about these things.

CHAIR STETKAR: If we're preaching to the choir, what we're hearing from the choir isn't necessarily what we'd like to hear. So take that as kind of a comment.

If you say we need to fundamentally change the way people think about PRA, now is the time to do it. It's late, but now's the time to do it.

And as Dennis mentioned, I know we certainly will carry that flag as best as we can here.

Sorry, Ali.

PROFESSOR MOSLEH: Yes. Okay.

CHAIR STETKAR: You can get to slide 2 now.

PROFESSOR MOSLEH: I must say that's exactly what we're trying to do. And I must admit that prior to the report, which was put together as a support to the slides and the slides are not communicating that. But that is exactly what we have in mind.

The orange line is really not only looking at what is really affecting performance, but also let me say that it also points to what type of composition of expertise and organizational involvement you need to have in order to do this type of thing.

CHAIR STETKAR: I recommend, just remember, people read reports and they read the words in those reports in the context that they want to understand the words. So if we want to present a different message, we have to be very, very sensitive to those words and in fact even in some sense, over react.

PROFESSOR MOSLEH: Yes.

CHAIR STETKAR: Just emphasize what you really want to say and be sensitive to what people might read into what you do or do not say.

PROFESSOR MOSLEH: Yes. I appreciate the comment, actually, very much.

And in our mind, and for those of you who know for the other type of research I've done over the past 15 or 20 years has been a fully integrate PRA plant system and everything called dynamic PRA. And that's where we really -- you know, essentially that's what we do. Integration. But here we're talking about the team and the coordination and the collaboration and the cross-linkages that you need in terms of reading the information and the modeling styles that need to be really a fully integrated approach. And I couldn't agree more, you know, really.

So maybe I can say just a little bit about the quantification framework, and the kind of the beginning of it at least is that if you have an event tree where we want to quantify a certain HFE that appears on the event tree and then we are doing these types of analysis, the CRT or an enriched and enhanced event tree would look at the different path that would lead to a given HFE, or to different HFEs. And the picture is very much a kind of a scenario-driven picture You're talking about human response scenarios, plant response scenarios.

So the fundamental question that is consistent with this picture is the equation that we have in there, and so that's not a new equation. It's been around for at least 10, 12 years. That HFE is a conditional probability. The probability of HFE is a conditional probability given the context and the scenario. And it's just a basic decomposition of the fact that there are different flavors of the scenario given, say, an initiating event and different contextual factors. So there is a probability for such context or situations arising, and then you have the conditional probability of a human failure event given the specific context.

So a scenario-driven picture kind of leads to the equation of this type. And in that you have the context of the scenario, which is whatever the initiating event and the system failures. You have the different path through the CRT or the corresponding event tree that can be characterized as different context. And then you have a quantification, fundamental quantification framework.

Of course, you know the main question from this point on is how do we get these numbers: The probability of the context and the probability of HFE given the context? This is something that we have some ideas, some are short-term, some are long= term. And I will wait until toward the end of the presentation and if we have time, we cover some of those ideas and points. But we haven't really focused much on the quantification as much as we have tried to kind of see how we can make the qualitative analysis more consistent with the set of criteria that we had, and then make it more practical.

So, another question you raised, John, earlier are we starting from scratch. Absolutely not. And in this slide I'm trying to kind of at least provide examples, highlight some of the things that I think are core ingredients that we now are migrating into this integrated framework, this approach at this hybrid, you can call it. The heritage and the ingredients of it is coming from, in part, the following approaches.

The feature is on the left, of course,

the rich context characterization is the hallmark and the main feature of methods such as ATHEANA. And that points and speaks to -- the rich context characterization really relates to the criteria of content validity. The characterization of different factors that need to be considered in understanding the human response, human behavior. That's coming mostly from ATHEANA.

Integrated plant crew understanding and modeling deviations in areas, ATHEANA has that very strongly. Another study I was involved many years back was errors of commission study for the Borselle Nuclear Power Plant in the Netherlands --

MEMBER BLEY: Is there a public report on that?

PROFESSOR MOSLEH: Yes. Well, public report through the utility and three papers, journal papers.

MEMBER BLEY: Okay.

PROFESSOR MOSLEH: Yes.

MEMBER BLEY: But the report is public? I didn't know that?

CHAIR STETKAR: This method been used anywhere else other than that one study?

PROFESSOR MOSLEH: No.

CHAIR STETKAR: Okay. So that's not necessarily an accepted widely used methodology?

PROFESSOR MOSLEH: It's not widely used. It my opinion, it's very much accepted.

CHAIR STETKAR: In your opinion. Now, I could also list the Stetkar methodology in here.

PROFESSOR MOSLEH: Yes.

CHAIR STETKAR: But it's not widely used. So in the sense of trying to integrate -- remember the SRM is not to look out in the fringes or develop new methods. It's to distill the elements of generally pretty well accepted applied methodologies here.

PROFESSOR MOSLEH: And to the extent that those methodologies don't provide some of the core ingredients, then you can go there.

CHAIR STETKAR: Absolutely. Absolutely.

PROFESSOR MOSLEH: That's what I was thinking.

CHAIR STETKAR: Okay. But just be careful in this forum. We're not necessarily focusing on --

MEMBER SHACK: Of course, you don't want to invent any new methods, but you want to remember the ways PRAs are done scratch. You're kind of speaking of the two sides of the main here, John.

CHAIR STETKAR: You know, Bill, in fairness, I don't want to invent the way PRAs are done from scratch because a lot of the elements for thinking about human performance have been elaborated in the literature for 30 years. It's just in practice many of the people who develop the event models have not really paid attention to that. They've not really paid attention to the fact that under certain scenarios I need to really think about operator performance differently then I did in other scenarios. So I'm not proposing a new construct to the way we do PRA. It's kind of filling in gaps in the way that it's been done.

I agree with you, Ali, that if there are certain elements of methods out there that fill in some of those gaps that the existing methods don't address, we should certainly think about those. It's just kind of a warning that in HRA in particular you're well aware that we can very quickly get into an alphabet soup going back into 30 years of a large number of different methods that have proponents who believe address very specific gaps in human reliability. And I'd hate to get this effort bogged down too much in that type of activity.

MEMBER SHACK: Yes.

CHAIR STETKAR: So, you know, I see ATHEANA there quite a bit. I see CBDT.

PROFESSOR MOSLEH: Another unknown method, you know was IDAC, you know.

Reasons for the list, it says a list of examples of where we got some ideas and then concepts. And it's not a comprehensive list. And it's not to imply any weight or with respect to, you know credibility and use. But it is really from a pure technical perspective where are we getting the ingredients and these are examples.

CHAIR STETKAR: By the way, in the introduction you mentioned the exercise that you went through to delineate the desirable attributes of a human reliability analysis method. Has any work been done to evaluate, I don't want to say the available human reliability methods, but a large number of those methods relative to those attributes and essentially develop a check list to say well this particular method satisfies 80 percent of these criteria? So perhaps, you know in the sense of understanding which methods we should be thinking about expanding?

Stacey is shaking her head like yes.

DR. HENDRICKSON: So we did start that effort.

CHAIR STETKAR: Okay.

DR. HENDRICKSON: And we went through a number of well known methods, such as ATHEANA and CBDT. Also did some of the older methods, THERP and ASEP. Did SPAR-H. And so we did start going through and look at which of these methods, and did they address the criteria. If they did address a certain criteria, how well did they do it?

CHAIR STETKAR: Good.

DR. HENDRICKSON: And what fashion did they do it? So, yes.

CHAIR STETKAR: Are we going to hear about that today?

DR. HENDRICKSON: We do not have that planned for today.

CHAIR STETKAR: That would be good.

MEMBER BLEY: There was also, Erasmia, a follow-up to the good practices document that laid the good practices against half a dozen methods, right? And that's a NUREG.

CHAIR STETKAR: That's a NUREG. Yes. I'm aware of that NUREG, yes.

DR. LOIS: That was to evaluate the

various methods against the good practices. And that was a basis for the evaluation Stacey is talking, but then went a little bit farther using the criteria in evaluating the various methods.

MEMBER BLEY: Is that to be a product of this work, the thing you're --

DR. LOIS: It's going to be a part of the report eventually.

CHAIR STETKAR: Okay.

PROFESSOR MOSLEH: One of our kind of the starting points, I didn't list them probably here explicitly. And a number of other efforts or studies that highlight kind of the weaknesses or strengths of different methods indirectly were kind of the basis for some of our decisions. The empirical study highlights the strengths and weaknesses of some of the existing methods. So these are all background information.

So, here is just a partial listing of bits and pieces that were kind of being integrated into the framework. So we really, that didn't start from scratch.

The last one. IDAC, as you'll see in the next presentation, is really trying to bring a little bit more theoretical foundation from behavioral sciences into the framework and make such links explicit. I think the word "explicit" is important because pretty much all human reliability methods do have a certain basis in human sciences. Here we're talking about explicit link. And I have a set of criteria for that.

Let me --

CHAIR STETKAR: Ali, in time --

PROFESSOR MOSLEH: Yes. Yes.

CHAIR STETKAR: -- you're going to get into the crew performance model, IDAC. How much time do you estimate? I mean, we can take a break now if it's an appropriate time.

PROFESSOR MOSLEH: Probably a good time to take a break.

CHAIR STETKAR: Okay. Let's do that. Because I don't want to rush you too much or I don't want to separate your presentation.

So I think what we'll do is recess for a break, a 15 minute break until 10:25 and you can come back.

(Whereupon, at 10:07 a.m. off the record until 10:24 a.m.)

CHAIR STETKAR: We are back in session.

Before we start, let me mention a little bit of process here. We have another meeting scheduled at 12:00, from 12:00 to 1:00, that it would be good if we can actually break for that meeting. So what I'd like to do in our schedule, if that's possible, is to continue this session until 12:00 and reorganize the lunch instead of 12:30 to 1:30, if we can break at 12:00 and then come back from lunch at 1:00 and then continue on.

3:30 we do have an informal meeting scheduled. Let's see where we are at 3:30. I don't want to artificially constrain the presentation or the discussion because of that 3:30 time frame. If some members need to leave for that other meeting, that's fine. But when you're thinking about organizing your presentations, don't necessarily feel constrained by that 3:30, although we may lose some of the members from the Subcommittee for some period of time there. I don't want to necessarily adjourn the meeting at 3:30 simply because of that other constraint, but I do want to see if we can hold to the 12:00 to 1:00.

So let's see what we can fit in between now and noon and then break at noon and come back at 1:00. Okay?

Sorry about this, but you guys can figure out what to do on the fly.

PROFESSOR MOSLEH: Okay. So with that, may I start?

CHAIR STETKAR: Yes. Certainly. Yes.

PROFESSOR MOSLEH: Okay. So, one of the requirements was really that we want to have a better understanding of the fundamentals and how a particular context leads to a particular observable human performance error. And for that, really that points to having some form of a causal model that provides the link between the input being environment and the output being the human action.

We listed a number of features that we would like to have for the model, an underlying model or set of models. You will see a lot more on that. Is that really the model or the kind of framework really needs to go beyond just a conceptual framework. That it really should provide a clearer map between the context characteristics and HFEs. If we don't use it for that, it remains as maybe something that may not even be consistent with some of the assumptions that we make and some of the outputs that we get from the methodology. So a clear explicit kind of link that the model would provide between the context and performance.

It also should be an integrator of the engineering and relevant human sciences. So you should be able to kind of see these different perspectives through the same modeling umbrella.

And as a minimum it should provide an ability to say what performance-shaping factors are relevant, if that is an ingredient of the qualitative and quantitative analysis. Describe relation between the PSFs and the HFEs, and with a set of failure mechanisms that really describe the underlying process.

MEMBER BROWN: Do you have an example of a performance-shaping factor?

PROFESSOR MOSLEH: A good example is like a constraint that the operators may have in terms of time. They need to take an action within a certain time window.

MEMBER BROWN: Okay.

PROFESSOR MOSLEH: And that time may result in pressure and stress on the part of an operator.

MEMBER SHACK: You mean causal or special?

CHAIR STETKAR: Give a more esoteric one, just so that some of the members understand what we're talking about. Because time is too easy to construct.

PROFESSOR MOSLEH: But I understand, you're right.

CHAIR STETKAR: I'm streaming through here, you don't have you list of PSFs.

PROFESSOR MOSLEH: We do. I guess an initial list, we do have that.

CHAIR STETKAR: And you're going to talk about that?

PROFESSOR MOSLEH: Yes, in the next presentation.

CHAIR STETKAR: Okay. Good.

MEMBER BROWN: That will be fine.

CHAIR STETKAR: It's an important concept and I want to make sure that people understand --

PROFESSOR MOSLEH: Absolutely.

CHAIR STETKAR: -- that construct.

PROFESSOR MOSLEH: There are many. There's 32 other examples.

And the last bullet is also important in a sense that whatever method or model we pick, we need to have enough detail and connection to reality and metrics and measureables such that they will be subject to empirical validation, at least on an elemental level.

With that, let me kind of walk you through very quickly, I hope, and then we'll leave most of the detailed discussions to the rest of the team, is that we recognize we have a number of actors, elements, that we need to tackle. Let's not focus too much on the details and the lines. But basically what we have here is acknowledgement of the fact that we have a system and we're looking at an operating crew, we have individual crews. So if I look at an operator's behavior, that operator's behavior is influenced and is influencing other operators' behavior. And then we have a set of organizational and environmental factors, many of those are listed normally as PSFs or performance-shaping factors. And there are lines of communication in input and output from these different elements.

The thing in the yellow here is the beginning of our kind of sense of the kind of a human performance model. And what you see here is the basic information processing human as an information processor where you have input, information and something happens in the head, in the mind in terms of actions and the decisions and cognitive activities towards solving complex problems or simple problems. And then decision to take an action and then taking that action action.

Internally how this model works, I will kind of leave that to the main experts. But the idea is to have something that looks like the cognitive activities as well as other types of, you know the physical, emotional and then cognitive response of the operators in the context of the system, factors that effect the performance externally and the fact that you're doing this in the presence of a crew or as part of a crew. So, we want to consider these actors or elements.

The modeling framework, as mentioned earlier, that we pick is something that has deep roots in psychology, direct and indirect, implicit or explicit. Most cognitive models and concepts really have some sense of this framework where you see a person as an information processor with input being information and then some processing that we characterize that as D for decision making and problem solving and then actions.

So when we say IDA or IDAC, we really mean the information processing as the underlying method.

This being an underlying method is not sufficient to look at all the different activities or specific aspects. For instance, one would need to now understand specifically how a person processes information, how do they make decision and how do they formulate or plan on taking actions. So there are other modeling layers underneath the I,D,A principle that we call mid layer model or sub-models. And Stacey and April will discuss those as to what we mean by that. But the common thread among all these is really the I,D,A as the information process.

In relation to the crew response scenario modeling if I look at the entire kind of response spectrum, one can divide it into phases that would be very much like in an I,D,A set of sequence of activities. Initially the operators are trying to figure what is going on and perceive the information and understand what the plant is telling them in terms of alarms and signals and information. And then the next phase of it could be an effort on their part to assess the situation and plan a response. And the next phase is in an action.

So if I look at this spectrum one could in principle divide it into these phases. But, of course, we need to go further down in order to be understanding each segment, what are the specific activities.

Yes?

CHAIR STETKAR: Ali, just for clarity for, perhaps, my benefit. You have kind of as a background there that CRT construction. And what you're talking about here is actually the elements of human performance within the context of one specific plant state scenario out of the whole PRA, is that correct? I mean, these are general principles but --

PROFESSOR MOSLEH: General principles. So if you look at and pick one scenario, you go through these phases.

CHAIR STETKAR: Right. Okay. So this thought process is not for that whole tree? It's evaluated for each scenario through that tree?

PROFESSOR MOSLEH: Yes. Yes.

CHAIR STETKAR: I just wanted to make sure for people --

PROFESSOR MOSLEH: Yes. Absolutely.

CHAIR STETKAR: -- who aren't fully familiar with these model constructs that that's pretty clear. Thanks.

PROFESSOR MOSLEH: So different methods or approaches label these things differently from the sense you can look at methods such as, I think SPAR-H will look at cognition and action as the two phases, two D phases. There's other subdivisions of this thing. Again, Stacey and April will discuss this in a little bit more detail. But the idea here is that starting kind of looking at the scenario trying to characterize what is happening. And then in that characterization, of course, you can look at the phase where the operators are essentially gathering information into also separate individual activities, ingredients. Because you know in a major event or accident there are a lot of interactions, even in the phase that you're gathering the information and there are many decisions and actions that you take.

For instance, such as walking toward kind of a panel to see more closely what the kind of the dial is reading: That's an action. But it is in the phase of information gathering your perception. And then you can subdivide the other phases. And then you can further subdivide that into smaller elements to go to some more fundamental segments of information gathering decision making and taking action. And that immediately tells you that we need to develop a set of stopping rules. You know, you can go through this kind of a decomposition to an infinitely detailed level, and that thing is very much on our mind. And we have devised a certain set of stopping rules to make this thing a little bit more practical.

CHAIR STETKAR: I would be interested to hear about that. Because I think one of the dangers that we've seen is that there's sort of a delusion that simply by subdividing the cells in a spreadsheet into more cells we suddenly understand the fundamental problem more completely and delude ourselves that we now precisely understand the problem and know precisely the solution to that problem. So those stopping rules are somewhat interesting. You know, it would be interesting to see that. Because --

PROFESSOR MOSLEH: That's one of the most difficult things in any modeling including this.

CHAIR STETKAR: Are you going to talk a little bit about that, the concept of about it?

PROFESSOR MOSLEH: We'll give you examples.

CHAIR STETKAR: Good.

PROFESSOR MOSLEH: I'm not sure if we have the complete set to present to you. It's an evolving thing.

CHAIR STETKAR: That's one of the dangers of doing this.

PROFESSOR MOSLEH: Right.

MEMBER BLEY: Is that suddenly you delve down 37 levels and have such a large construct with so many small elements that now you know you're absolutely complete, and you're not.

PROFESSOR MOSLEH: I agree with you a 100 percent. And we're going to actually demonstrate that. We haven't really fully decided because what you see in April and Stacey's presentation is one layer decomposition. What you see in Song Shen's presentation is a two layer.

CHAIR STETKAR: Okay.

PROFESSOR MOSLEH: Because the example was developed before further development in the area of modeling.

We'll settle at some point where we have to go through the process of exercising, practicing this thing and see what would be the, in my word, "optimum" level of decomposition. And that's an art a little bit.

So these are examples of the sublevel decomposition. It's on your viewgraphs as example, so let me not kind of spend too much time on this as examples of how you can actually further subdivide things.

The other thing that one has to consider is what is the definition of an action that is now in your system model or your plant model or event tree? And that also is the subject of kind of basically a modeling stopping rule and model level of detail.

If I look at, for instance, a steam generator tube rupture event in there where you have to isolate and then cool down and pressurize a steam generator, you see that the HFE could be the combination of these two or further subdivision. And those are also kind of something that the modeling team need to decide as to what would make sense. And our kind of concept is that we want to subdivide these things to a level where we see, obviously, a clear impact on the plant and the scenario that you're analyzing from a functional point of view and also detailed enough so that we can link into failure mechanisms that we recognize from human sciences. So that was kind of basically our decision groups' process.

Further, in this framework we recognize that if I,D,A, this process, is what is really taking place by the operators and in the minds of the operators as well as the operating crew, then where are the failure points? Well, it's a serious system, in a way if you think about it.

We have external input from the plant where the information is perceived by the operator. And then based on that information you try to assess the situation and make some decisions. And then they try to take actions or plan the actions.

So failures can happen in any of these cells, so to speak, and in the interface between the cells. And then where do we observe failures? Normally the HFE is essentially a case where the action taken by the operators is inconsistent with the plant's need. And that inconsistency could be kind of a physical inconsistency or legal and procedural inconsistency. But fundamentally, any inconsistency you see between the plant and performance requirements and the actual actions such as skipping a step, delaying an action, premature action and the normal things that we consider in human reliability, acting on a wrong option. These are inconsistent with the plant.

So this is how we try to kind of see and view error from the perspective of this model. A break in the link between I,D,A in any of those boxes leading to the observable failure being an inconsistency of the action and the plant need.

MEMBER RAY: Just a second.

PROFESSOR MOSLEH: Yes.

MEMBER RAY: I thought I understood this earlier, but I'm not sure I do now.

Backing up to the external input, does that include for example the conditions of system load? For instance, the likelihood of a blackout as a result of shutting the plant down, is that included in the --

PROFESSOR MOSLEH: Yes.

MEMBER RAY: It is?

PROFESSOR MOSLEH: Any external physical condition of the plant and the information that is provided by the plant.

MEMBER RAY: Well, that's why I raised the question. Because it sounded like you're talking about the plant. I'm not talking about the plant. I'm talking about the role that the plant plays in the larger context. In other words, the biggest changes I ever saw as a plant operator, and I did it for a long time, was conditions when shutting the plant down would cause the County of San Diego to go black, for example. Now do you have a way to include that in there or are you just assuming a normative condition where the only consequence of action that may be taken to shut the plant down would be to the plant itself?

PROFESSOR MOSLEH: In the decision making, and then maybe April and Stacey can comment on that further, in the decision making model that we have some of the considerations are the consequences of actions that the operators actively could consider. And in principle the broad range of consequences could be considered.

I must say that in the examples we've been developing we've been very much focusing on the consequences to the plant and obviously from a risk perspective. But --

MEMBER RAY: Well, I'll just tell you for what it's worth that the biggest factors, and then John can speak to this having operated a plant as well, the biggest thing that varies day-to-day or even hour-to-hour isn't the effect on the plant of the actions you take. It's the effect on the service that the plant is providing to the grid of the actions that you take that will most heavily influence the response of the operators.

PROFESSOR MOSLEH: To an accident condition?

MEMBER RAY: Well, to any condition that requires them to take action.

PROFESSOR MOSLEH: Well, I would say that, and I think your comment is something that we need to actively consider. April, do you want to --

MS. WHALEY: Yes. The I,D,A model is a very generic model of human performance, and its meant to be broader than just a specific plant focus. And from our perspective the inputs coming into the operators is basically anything external to them. It could be plants, alarms or indications, or changes in indications of communication from some unknown crew member, a telephone call. And it certainly would include the risks that when they're operating under concerns about the risk to the grid or the risk to a certain city for blackout; that would all be considered very generally the external inputs.

MEMBER RAY: Well, I would just tell you that, you know, I guess to say it's being considered very generally, you get directives from the grid operator for example what's called hands-off, which means don't touch the plant no matter what. And this will go for six or eight hours a day during summer peak load conditions, for example. Well, that's a pretty heavy external influence, but I don't hear you talking about it at all. And yet to me it would have a much bigger effect on operator response than anything else I can think of. And it happens regularly.

PROFESSOR MOSLEH: Song?

DR. SHEN: As to these measures, because we are talking about this was applied to PRA model. PRA model usually assume initial event occurred. So that means focus on initial event occurred, we base that point of view of the story to build up all the contexts and the mental state of operator to see the inference. Just like you say, just you know general operation and then here, Washington, D.C. there's a power station they want to shutdown just because, you know, maybe Virginia because of grid problem. And the whole system got problem. That is beyond this scope because in that case we don't have internal event occurring in this power station. So that may be like D.C. problem, it's not a risk problem.

MEMBER RAY: Well now, wait a minute. You guys have talked about context and we've gone on and on and on here about stuff that to me is relevant, but not all that significant to what the operators do. I'm just telling you that what they do is heavily affected by what the consequences of the action that they take are likely to be: That's all.

DR. SHEN: Yes.

MR. FORESTER: John Forester, Sandia Labs.

Yes, I would say that that is taken into account and consideration of the performance-shaping factors in the context when you go to quantify. I don't think there's been a heavy emphasis on that in terms of the PSFs. But certainly we've talked about organizational factors in the sense the plant wouldn't want you burning up these pumps so that's going to influence your performance. And certainly looking at it more broadly in terms of the impact of the consequences on power for everyone, that's certainly going to affect their judgment in terms of how they respond to a particular event. And that should be addressed through the performance-shaping factors or the context --

MEMBER RAY: Yes. Well, that's why I said I thought I understood this before. But when he started this explanation, it sounded to me like the only inputs had to do with the plant itself. And like I say, take it or leave it. But my point is that the thing that will most, and the things that I had the most problems with were operators unwilling to do things because if they did them, it would cause the plant to reduce power or shutdown at a time that they'd been told don't touch it by the grid operator, not by anybody else.

CHAIR STETKAR: John, something you brought up reminded me of something, and it is in this context of operator performance reluctance, perhaps, to perform a particular action because of the operator's concerns about the consequences of that action. Let me just bring up an example within the context of a post-initiating event operator performance. And it comes from the not-to-be-named NUREG-1921 fire HRA stuff.

And that is, there are some plants that have procedures that instruct the operators to initiate a station blackout in response to certain fires. Now if I was an operator, there might be some reluctance on my part to, for example, put the plant in a station blackout condition or at least certainly consider in time thinking about other options rather than simply following those instructions. So there's another example where the operator's concerns about the affect of their instructions and their training, their actions could in fact influence their behavior or delay it long enough so that it becomes ineffective.

So, I would certainly hope that the constructs of these models, the performance-shaping factors that you've evaluated, would adequately handle those types of situations. And those in general would also extend back to some of Harold's concerns about actively taking a plant off line under some conditions that might have different consequences then we might necessarily think of.

MEMBER BLEY: And a factual comment going back to the ATHEANA methodology, you'll find in there a fairly lengthy discussion about things such as informal procedures and administrative procedures and site requirements that I'm assuming will get factored into this as it goes along. But I think they're still at a structural stage in what they're doing.

MS. WHALEY: Yes. We're not going to go into the PSFs in too much detail at this point because we're still getting into that work. That work is still preliminary. But we do have a slide where we talk about the PSFs.

And one of the PSFs is perceived decision responsibility, perceived consequences. So those are accounted for in our PSFs.

CHAIR STETKAR: Good.

Ali?

PROFESSOR MOSLEH: So in each of these kind of a failure opportunities or failure points between the I,D,A, there are recovery opportunities. And the HRA method needs to consider those and factor them in developing the, say for instance, CRT scenarios.

One thing that this perspective actually is probably an obvious point also, is that really it points to a logical failure or something of that nature, that it is really if you think about it the I,D,A become the minimal cutsets of a failure event. And, of course, you know you have a lot more detail behind each of these ingredients, but that's a gateway to understanding or accounting for points of failure in a particular human response. And we're going to use this kind of a so called minimal cutset approach in developing extracting information from different scenarios in the CRT.

I mentioned that the CRT or the scenario kind of structure is laid out such that you can actually put -- you know, segmented in terms of types of activities and phases of activity. And that forms the top layer of the model.

And then we have two other layers. These layers are there to provide an explanatory power to the approach, to identify and be able to characterize the failure mechanisms or reasons behind the actions that go on on the CRT. So nature of the activity, failure modes and failure mechanisms would be identified through this so called mid layer. And you'll see in the presentation by April and Stacey if I ever finish mine, that we do have several different methods and concepts that feed the development, help with the development of the mid layer model.

Now in any modeling we also need to have some stopping rule. Because you can model this thing to sub-atomic levels. Where do we stop? Where is the fundamental particle of our framework?

In causal modeling we think, and we kind of decided, that the last layer of model that we want to have is really the so called PSFs, or performance-shaping factors or influencing factors. Whatever we do not want to analyze further, whatever we think would be able to characterize the context without further modeling, we will put this in this bottom layer. And they are mostly performance-shaping factors and performance influencing factors.

So you can think of the entire modeling approach being composed of PSFs, the mid layer causal model and linked to the I,D,A level of decomposition and to the HFEs. And we're going to talk about the mid layer after my talk.

The idea in why we need the mid layer model is in this slide.

So if I have an HFE in an event tree or as part of my CRT, and I have a framework where I try to use to understand how the operator's response and this would be the I,D,A --

MEMBER ABDEL-KHALIK: Going back to the previous slide, if you would. Shouldn't this subdivision be consistent with the level of detail in the procedures?

PROFESSOR MOSLEH: Yes, to a large extent. But not necessary.

MEMBER ABDEL-KHALIK: If I give sort of big picture instructions to the operators, say identify the failed steam generator, isolate the failed steam generator, establish whatever, et cetera; doesn't that result in a different subdivision versus if I were the case where I would give the operator a detailed instruction as to step-by-step actions to take?

PROFESSOR MOSLEH: Yes, you would. Yes.

MEMBER ABDEL-KHALIK: So this is not necessarily generic?

PROFESSOR MOSLEH: Under either kind of regime of instructions or style of response, the decomposition still applies. Because, you know, they are talking about the structure of how you would take an operator response, whether the response is to specific instructions of a procedure or whether knowledge-driven response, we ought to be able to decompose it in terms of the I,D,A and then further the failure mechanisms that apply.

MEMBER ABDEL-KHALIK: But my concern is about this three layer or two layer plus the bottom layer subdivision. But that is not necessarily true for all situations, regardless of the level of detail of the procedural guidance that the operators have.

PROFESSOR MOSLEH: The level of detail would be reflected in the level of detail in the top and the mid layer. At least according to this style of modeling, you would still first consider the scenario, namely what is it that needs to be done whether it's the steps of a procedure or a functional response. And then try to understand it through a set of causal mechanisms. And that's the basic decomposition I'm talking about.

What is it that they need to do or they are doing and what are the reasons? The top layer and the mid layer.

The bottom layer is trying to bring more of an explanatory kind of factors into the picture to cover different aspects of the context; consequences, specific constraints that they might have. But the two layers is really pointing to understanding functionally what it is that they're responding to and then the causes.

MEMBER ABDEL-KHALIK: I'll have to think through this. Thank you.

PROFESSOR MOSLEH: Yes. We'll have a couple of examples and maybe further in -- you want to --

MS. WHALEY: It seems to me that your question about the level of decomposition in the instructions, that would be reflected in the CRT. The mid layer is once you've identified a particular HFE that we want to model, then what are the mechanisms for failure at that level.

So, yes, depending on the type of procedures that you're working with, how detailed they are, in the top layer there is going to varying levels of details or specificity. So, yes, it can accommodate multiple levels of procedural guidance, if that helps.

MEMBER ABDEL-KHALIK: Okay.

PROFESSOR MOSLEH: Okay. So, let me go back to where I was, basically the fact that, say, if I have HFE and then I have my response model and then that is modeled through the I,D,A kind of decomposition of the process modeling, then the mid layer is going to help us kind of identify failure mechanisms for each of these phases or segments. I'm going to take like information perception as one of those. And you can see that we can start kind of having different layers of further characterization of what that kind of activity looks like.

For instance, one subdivision or characterization could be based on whether the information it is actively pursued or passively received. And depending on whether you're actually asking or looking for the information or you're bombarded with the information, the types of mechanisms, human response mechanisms might be different.

So taking this subdivision one could kind of consider, hopefully supported by behavioral sciences, a process that takes place in terms of how a human responds to a piece of information. And I'm not going through the detail of this thing. This is just an example, a schematic and representation of that. That process may involve different types of memory, different types of filters, cognitive and external filters that affect the perception of the information. And if you have a process model, then we might be able to identify the points at which that process may fail.

So for instance if, say, it is an internal filter such as the operators being preoccupied with something, therefore they're not paying attention to the information they're receiving, therefore they label this internal filter, then what are the set of PSFs or performance-shaping factors that are relevant that are flawed, or what are the PSFs and failure mechanisms that apply to failure of the activation of the internal filter?

So by mid layer model we mean model that is informed and, to large extent, based on the cognitive sciences, the psychology and human factors to provide a roadmap from where we see a failure in human response to the causes that are characterized through failure mechanisms as well as performance-shaping factors. And you'll see two or three or a fair number of slides actually on that.

And if they changed a lot, you know the piece that is affecting the performance, the failure in the process, there will be a separate set of failure mechanisms.

What we are pursuing at the moment is to represent the mid layer through a fault tree representation, which so far we have found it to be effective although some of us at least are thinking of augmenting this kind of a representation with another representation called BBM, Bayesian Belief Metrics. And there are many reasons for that, but for now let me stay with just what we have now which is really a series of fault trees that describe or collect the set of failure mechanisms that apply to I,D,A part of the process. And we'll have a set that will be discussed by April and Stacey as well as Song-hua who is going to use an older set to provide you an example.

MEMBER BLEY: Ali, let me ask you a practical question about this. I'm just thinking back to some of the stuff we'd done before.

Is this a fault tree in the sense that we do in systems analysis of a deductive analysis or is this a fault tree that you might have a catalog of these to present to the analyst to help them look for situations under which this might apply?

PROFESSOR MOSLEH: More of the latter, actually.

MEMBER BLEY: Okay. Because what I'm looking at is this mid layer going to do the kind of thing that the tables in the ATHEANA did.

PROFESSOR MOSLEH: Yes.

MEMBER BLEY: Helping you figure out what might have gotten us into a situation--

PROFESSOR MOSLEH: Very much so, yes.

MEMBER BLEY: So this is as much guidance as analysis, and it turns into analysis as you pick your way through it?

PROFESSOR MOSLEH: Yes. Yes. In tailoring, for instance, we started with a set of generic fault trees, you know six or seven of those, that have essentially catalogs of failure mechanisms, very much like what we have in ATHEANA. And it can be used in two ways.

One is as a guidance, purely guidance. If somebody wants nothing to do with the CRT, I don't want to even though that, just tell me what the failure mechanisms are. You have those tables, those fault trees.

The other thing is to actually to fully integrate that as part of the analysis into the CRT and say well these are your fault trees generically, modify and tailor them as you will see examples of. And then put them in the CRT and then analyze the total model to identify the scenarios, the sub-scenarios and of the cutsets that apply and lead to these.

So far we have approached that the building of these trees, which are catalogs of things, you know try to have a logical constructing of the type -- kind of shows the logic of how they are decomposed from the top kind of a failure mode to failure mechanisms, we approach it kind of a top down and bottom up.

Top down has been what Song-hua has been doing basically from a functional perspective; what are the failure points in operator response to the situation and our human factors and human psychology theme have been looking at them from bottom up kind of perspective to see what kind of failure mechanisms and causes can be collected and assembled into a countable set that could be integrated with this top down. And ultimately we're going to have one mid layer that kind of integrates these two perspectives.

MEMBER BLEY: Okay. And something I was seeing in the slide before this, I think, but don't go back to it, there's in the information in the information perception analysis layout, you're actually picking up pieces of the D in IDA that are dealing with situation assessment and maybe mental models and seeing how those could be influencing the perception. So this layer is linking those things together or showing you how they might link? Am I picking that up right?

PROFESSOR MOSLEH: Yes. And I think probably should leave the discussion to the next presentation, yes.

MEMBER BLEY: Okay.

PROFESSOR MOSLEH: That be, you know there are certain things, modeling decisions that we need to take that affects the way this thing looks like ultimately. And there's no one kind of a unique and one and only one solution that one can kind of converge to. There are many different ways of capturing the same information. But the idea is to really look at however many phases of response we have, the I,D,A or some segments of those to support those with a list of failure mechanisms that are embodied in these fault trees.

PSFs, we do have a set of principles and fundamentals based on which we will pick, define and develop the performance-shaping factors. These principles will be discussed further, so I'm going to skip this one. But the list of PSF, we have a list of PSF that we are looking into as our prime candidate. Ultimately what we will settle on is unknown to me. Ultimately what we will settle on is unknown to me. But it will have many of what you recognize in many of the HRA techniques today, but they're included in our PSFs. So there's not much new in that. It's a reorganization applying some of these principles that I've outlined here, one of which is actually, I must say, the fact that the PSFs need to be definitionally orthogonal. That's a combination of math and psychology.

In the past, many problems with the PSFs, list of PSFs, has been that they overlap in definition, they overlap in the meaning and application. We've tried to come up having an orthogonal set that would perform a fundamental building block for characterizing context.

MEMBER ARMIJO: Maybe this is out of sequence or something, but how do you use a PSF in a quantitative way in the analysis? You know, pick one and just kind of walk me through how that results in a number.

PROFESSOR MOSLEH: Can I defer that to a set of slides that I have on quantification?

MEMBER ARMIJO: You're going to get there?

PROFESSOR MOSLEH: Yes. Yes. I have that.

MEMBER ARMIJO: Okay.

PROFESSOR MOSLEH: Yes.

So how is this going to look like? The process, at least conceptually, is as follows.

You have a CRT which looks like the sequence of events or human system interactions. And each of these sequences points it or branch points in these sequences. So if I take the yellow one, for instance, each of these branches are supported by a set of causal trees, basically fault trees, that provide the explanatory part. And the next logical step if you want to kind of systematize this and borrow some concepts from the standard PRA is to link these trees. And in the language of PRA methodology, solve it with the integrated model. And by "solving," we mean extracting the information on the nature of the sequences. What set of causes and actions and activities and context factors contributed to this particular yellow scenario that went from the initiating event to the action of the operator?

Those causal kind of explanations are extracted from solving the combined tree in some actually pretty standard fashion, if that's something that one needs to do.

Often an experienced analyst would be able to see the connection of the combination of causal factors. Just visually inspect the tree and then identify those. But one could also envision an automated tool, an environment very much like what we have in standard PRAs, to process this information and provide the detail information in form of cutsets. And I use "cutsets" for lack of a better term. Really we're talking about the chain of causes and influencing factors that lead to a particular HFE to a particular sequence of the CRT.

So if that's the perspective, this perspective, then one issue that is quite important in HRA, that is the core question of dependence, it becomes a little bit clearer as to how one should approach it.

So if I have two HFEs, normally what we're interested in is probability if these two HFEs appear in the same sequence, and take this particular sequence.

The probability of HFE 1 and HFE 2, would be the probability HFE 2 given 1 times probability of four. That's a standard decomposition of probability of two dependent events.

What we want to do in HRA is really to capture this. Make sure that we understand how probability of E2 changes when E1 has happened. So we're talking about quantifying this sequence.

Now the causal perspective you're talking about if I take the first HFE and go through my decomposition through the CRT in terms of the failure mechanisms that relate to I, D or A and do the same thing for the second one, now it's part of the same CRT sequence. And I go further and identify, I have my list of PSFs, that's this box, and say what happens under I under HFE 1. Well there's these factors that are influencing the process; three performane-shaping factors.

Time pressure, F1.

I go to the next one to HFE 2 and I see the same factors, identical or slightly different, or maybe even new factors that affect the process.

The fact that these context factors are common is the root of dependency. So if you have a way of identifying these explicitly through this causal decomposition, we know where to look for for the mechanism of dependency and then build the quantification based on the presence, degree, intensity of these factors. And now when I talk about the quantification in terms of as a function of PSF, well we can see how something like this works. Of course, you know a vast major of HRA methods do apply the same set of principles in terms of relating probabilities of errors to PSFs.

MR. BAYSAH: Ali?

PROFESSOR MOSLEH: But here we're talking about using the PSFs as common links of two different actions.

Yes?

MEMBER BLEY: Something about the way you've just presented this sits wrong with me. And I guess the problem is the way you described it is kind the way in fault trees we find that for system A we've got some components that are replicated in system B and we found out by doing a detailed deductive analysis. Here I would think we're starting at the beginning of the scenario, going through it thinking about human reliability and about the context. And we ought to be carrying that context through from one to the next unless something breaks it. It's not that we discover these are common events under two different HFEs. We should have built it that way unless there was a reason they wouldn't be common.

PROFESSOR MOSLEH: Yes.

MEMBER BLEY: It seems inverted in the way you're talking about it.

PROFESSOR MOSLEH: Yes, I know. It is not really, it's not discovering it, you're building it that way. But I'm talking now about really highlighting the fact that the --

MEMBER BLEY: If you're going to come back and try to solve it?

PROFESSOR MOSLEH: Yes. And also, you know basically you're describing the common context, kind of the string of things that lead from one to another one are identified explicitly to the process of just pointing to the fact that in the process you're explaining the dependence through what is common between the HFE 1 and the HFE 2, which is the story up to that point, for the first one and the second. So you're building it that way.

And if you run down to -- sorry.

MEMBER BLEY: Yes, I agree. And it didn't sound that way before.

PROFESSOR MOSLEH: Yes, but I mean it that way. Maybe these lines provide kind of a little better linkage that it is really the commonality through everything that I highlighted as a context in the second slide or third one that you're really looking at scanning the scenario from one HFE to another from the beginning to the end. And what I was trying to say was that the reason that the two HFEs become interdependent is because of the commonalities, which is an obvious point, right? And if you specify those clearly, then you have at least a very explicit way of factoring those into the quantification if the quantification allows that, you know, and if you have the mechanism, the formulation for that.

All right. So we said okay, well these are concepts and ideas, let's see if we can build up. And Song Shen developed a CRT for steam generator tube rupture of a particular plant and color coded and then branch points that converge, merge and then diverge, and then you have pinch points and branch points. It's a tree, forward branching tree. And I think we have an Excel file that shows the big one, that this big we can actually navigate it through when San Shen talks.

CHAIR STETKAR: It's always good to have really big, really detailed Excel files. That gives me confidence that we really know this. Be careful.

PROFESSOR MOSLEH: Well, John, hopefully this is knowledge-driven as opposed to graphics-driven.

CHAIR STETKAR: Okay. I hope so.

PROFESSOR MOSLEH: Yes. Now the same kind of environment, you can start with something big and through merging and converging and then pinch points of these things you can actually simplify it. And once you have simplified this and then in your mind it characterizes that particular steam generator tube rupture, you can start attaching these causal models, causal trees to the branches, the important branches in the CRT.

I have a few points to make regarding the practical implications and practical considerations. So I don't know whether it's in part of this set or the last set, but we will get to it.

CHAIR STETKAR: I hope so because when

all is said and done, real analysts developing real models for real nuclear power plants which may entail tens of different initiating events each of which may have N operator actions where N can be up to ten, we're talking about a catalog of perhaps a 100 or more distinct human failure events. This has to be implemented in practice.

PROFESSOR MOSLEH: Yes.

CHAIR STETKAR: You know, in a real time within a real budget.

PROFESSOR MOSLEH: Right.

CHAIR STETKAR: So I'm really interested in hearing and eventually getting to that practical consideration.

PROFESSOR MOSLEH: We definitely are mindful. I have been a PRA analyst, as you know, John. So I know the constraints, practical constraints. And so are the colleagues on the team.

Do we have the optimum level of modeling and the right tools to do this? We have some ideas, but not the total solution. But we will have failed if we didn't come up at the end with something that's practical. It will be practical, otherwise there is no point in doing this. Because you wouldn't be able to implement.

CHAIR STETKAR: Well, and the reason I come back to the practicality, you mentioned it, and the reason I come back to the practicality is, indeed, I'll come back we're three years now into this respond to the SRM. And in some real time frame we should be focusing on real practical applications of this. This should not, in my mind anyway, develop into a decade research program. You know, the direction is not to evaluate the most complete methodology possible. The direction is to take the best elements of what we know today and distill some type of methodology that indeed we can have some confidence in in terms of consistency and reproducibility and so forth. That's why I keep focusing back on this practicality --

PROFESSOR MOSLEH: No, I --

CHAIR STETKAR: -- and the desire to see real applications for real models is very high.

PROFESSOR MOSLEH: And if I can say, you know, I would count at least 30 percent of our energy has been debates on the practicality ends of it. But we are not --

CHAIR STETKAR: And perhaps about 80 percent should be is my focus.

MEMBER BLEY: And some well done

applications.

CHAIR STETKAR: Some well done applications. The examples -- and I think, by the way, examples would help, and I see we're going to get to an example.

PROFESSOR MOSLEH: Yes.

CHAIR STETKAR: I kind of forewarn you. I didn't want to interrupt too much, but this forewarning. I think it's really important that we get to the example before 3:30 when we may lose some of the members. If we need to continue into some of the more theoretical bases for some of the things after 3:30. So kind of keep that in mind because I think it would help several of the other members understand a little bit better what you're up to in terms of seeing that example.

PROFESSOR MOSLEH: Okay. I don't know how many more I have, but let me see if I can actually -- so this slide shows basically the core ingredients of a qualitative analysis. Our focus has been on qualitative analysis, not the quantification yet. And it shows kind of the phases of activity, the steps and products. And, obviously, you can see that the first phase of it building and reviewing or reviewing any entry for the initiating event is really part of the standard practice in PRA. We're either going to build together or start with one if it's an existing PRA. But it is an integral part of this process.

And then it goes from really building the model, identification of HFEs, all the way to writing narratives and qualitative insights that one can get from these types of process.

The rest are tools or tricks in the process. The rest are there to provide consistency, coverage and a way of meeting the quality criteria in terms of reproduce ability, scalability and then graded methods, if that's the right word, the correct word.

So let me say a few things about practical issues.

Managing the size and the complexity of CRT or any logic model that you have, it's obviously it can get out of hand very quickly.

Practical guidelines for consistency of whatever structure you have, if it's integrated from day one, it's integrated. If not and if you're really backfitting an existing PRA, all the assumptions and the ingredients need to be fully consistent.

The other thing is really the extent to which one needs to introduce tools or tricks to make this thing practical. So what are the tools and techniques, what do we need in order to make this thing practical? So we at least put a partial list of solutions that we've been thinking about. Not discussed extensively, but take this as kind of an easy list.

One approach that is very appealing is to have template models for this CRT.

CHAIR STETKAR: Appealing to whom?

PROFESSOR MOSLEH: To, I would say, the analyst. Because I think --

CHAIR STETKAR: Haven't we learned lessons that having predefined logic structures for things have gotten us into trouble before?

PROFESSOR MOSLEH: Yes. There is trade-off. Sure. I agree with you. I mean, there is trade-off. I must say that between -- a little bit of history that you and I could share.

John, if you don't know, is the only one I know and many people acknowledge and know, is a person who can look at a fault tree and write the cutsets of that fault tree without going to any code. He intuitively understands the cutsets.

And for years we were trying to see if we could capture his knowledge and make it into a computer code that would automatically generate the cutsets and solve, you know, take the schematics, develop the fault tree. Ideally, we have many people like you, John, right? But, at the same time, we have people who don't have the same knowledge base, for instance in their domain, and they're in practice applying. So where is the balance between developing procedures, processes that can be followed in a generic way, subject to tailoring and modifications, and relying totally on domain experts to do the analysis?

CHAIR STETKAR: Yes. It's just a distinct caution against the concept of cookie- cutter PRAs. Because we've suffered from that sort of idea that we want to make the process as simple as possible so it's that the least educated analyst can use it without thinking has created many, many problems in the past. Because especially if it's something, quite honestly, that comes from the staff. Because it's then viewed as the accepted practice.

PROFESSOR MOSLEH: Yes.

CHAIR STETKAR: And therefore even though I might know better, I will follow the accepted practice because it's the path of least resistance.

PROFESSOR MOSLEH: Yes.

CHAIR STETKAR: So let's just caution with this notion of -- I understand the desire, but it's a distinct caution when you start talking about predefined templates, everyone by definition will use them, and probably use them wrongly.

PROFESSOR MOSLEH: We have to look at kind of the pros and the cons and then see what would be kind of a right mix of generic models and additions, instructions of when to stop using those. I know the phenomena, and I agree with you. We don't have that set of procedures or practice. But I think so far based on the experience of one CRT fault tree, I think the idea of a template as a pretty good starting point for any analysis is very appealing to me. Now I shouldn't say the analyst.

CHAIR STETKAR: Okay.

PROFESSOR MOSLEH: The other thing is, and I think somebody mentioned on the Committee, of how much detail do we put in the CRT in terms of the understanding of the reasons and the sequence of things leading to a particular human action if the procedures or detailed or less details or more detail? And the other kind of level of modeling or detail that one has to really consider is when you can actually put things on the CRT or put it in the fault trees or the causal model. Very much like what we do in the PRA, division of modeling between event tree and the fault tree. And the right balance in terms of detail, where the details go is something that we have to find what might kind of what would be an optimum level and that there's no, again, standard solution or answer to the question. One has to try different levels and then see what would be the most flexible at the same time meaning practical.

So that's another thing that we need to do. And then we have done some of it. We think we have settled on not making the CRTs too complex and then relying mostly on more generic fault trees to support some of the details.

The other thing that kind of would be necessary, and I think is essential for this type of modeling that can get quite complex, is guidelines for tailoring and controlling the size through things such as:

Screening rules, qualitative and quantitative;

Guidelines for plant-specific

applications;

What branches to consider, what branches to cut or add, and how to to the CRT, and;

Usual tricks such as probability truncation to cut down on the sequences that you're looking at do sort of a qualitative screening ahead of time.

CHAIR STETKAR: Ali, how much have you thought about that process, that screening and pruning? It's one of the areas where many of the existing -- I don't want to call it methods. Much of the existing guidance falls quite short in a sense that, again, you're deluded by the nature that you've subdivided a particular scenario into, let's say, six human actions, HFEs, and have applied a nominal conservative .1 failure and not recognized that they're all fully linked but have screened out that scenario because it's insignificant because .1 to the sixth is 10 to the minus six multiplied by a couple of hardware failures, it's irrelevant?

PROFESSOR MOSLEH: Yes.

CHAIR STETKAR: Or that even if you presumed that it is relevant, might lead directly to a large release in the level 2 model that you haven't even thought about yet?

A lot of the problems that we tend to see are due to misapplications, if you will, of that type of quantitative -- qualitative screening is a different issue as long as you're following the fundamental guidelines about thinking about human performance. But this quantitative screening bothers me a bit. So I was curious how much you've thought about that process.

PROFESSOR MOSLEH: Notmuch, John, in terms of the specifics.

CHAIR STETKAR: Okay.

PROFESSOR MOSLEH: It's a principle that I think is quite powerful if applied properly.

CHAIR STETKAR: It is, and a lot of people like to use it.

PROFESSOR MOSLEH: Yes.

CHAIR STETKAR: But it's a caution.

PROFESSOR MOSLEH: Yes. Obviously that's where the PRAs, they quickly use credibility by pruning scenarios because the assumption --

CHAIR STETKAR: Right, right, right. It's just I was curious. Continue on. I was just curious how much you've really thought about that.

PROFESSOR MOSLEH: I really do need to work on that.

Automation is another thing. You know, it's along the lines of like templates and then making tools that make the analysis easy to be conducted. Because we're carrying a lot of information. We are looking at possibly combining and linking models. So we've been thinking about proper computational environment or modeling environment to support the analysis. And we have some ideas. But as a class this automation is in our minds to try to supplement the analysis procedures with tools.

The use of generic models is really what we're talking about. Select a generic template for, say, an initiating event. Modify as needed based on the functional design and operational differences for the plants to the generic plant. Then you do a qualitative or semi-quantitative pruning to eliminate the unlikely scenarios. Then you attach the fault trees or causal models, link them. And it's hard to separate that step from the previous step because part of the story is what's in the fault trees. So maybe they're done at the same time.

MEMBER BLEY: I'm kind of hanging on something John talked about before. My worry, of course, is once we have something like this people take the generic template and don't do much with it and say I've gotten an analysis.

The language is kind of we'll start with this and we'll do semi-quantitative pruning, maybe additions, too.

If you're really thinking about automation tools, I would hope the thoughts come along of automation tools maybe working like websites do to force you to think about things rather than select and clean out and be left with something that's missing holes, but things that say before you do this think about the following ten things, and say you have to address them all?

CHAIR STETKAR: That's precisely the problem.

MEMBER BLEY: If it doesn't have that kind of stuff, you know what a lot of people are going to do with it.

PROFESSOR MOSLEH: Yes.

MS. WHALEY: One of the ideas we've been talking about as we've been discussing the idea of templates is that well you're not going to come to the template for a shutdown event because they're so unique. So we're talking about well then we need a template of the things you need to consider and the questions you need to ask. That's kind of where we're going.

CHAIR STETKAR: That's, I think, the important issue rather than a picture of a logic diagram. Because regardless of what you say about shutdown events being unique, I'll tell you that no matter what you think about plant response to an initiating event at full power, you haven't thought about everything. Because you've not thought about every single plant out there. And you've certainly not thought about any of the new designs of the plants which might have initiating events that sound like the things we modeled in the past. But you haven't even seen any of those models yet.

MEMBER BLEY: And you've even from the real events you've looked at, you've seen lots of unique aspects to them. So to me the idea of guidance rather than templates might be a way to focus. And the things people do with website constructions can led you to ways to get people to think about the right things and maybe get some assistance in building a model, rather than having the template --

CHAIR STETKAR: Yes, that's right.

MEMBER BLEY: -- that you cut pieces out

of and use.

CHAIR STETKAR: Because the natural tendency is to take the template, recognize again the practicality that eventually this method will be published in something called a NUREG that has a stamp that says United States Nuclear Regulatory Commission on it. The implication is that the templates in there are: (a) endorsed; (b) approved, and; (c) complete. And there isn't anything more that I need to do other than to take those and make my life simpler by throwing out the stuff that I don't think is important; that's the way people use these things in practice. And they're not going to change their behavior simply because we talk around the table here saying well of course they need to think about other things.

PROFESSOR MOSLEH: We saw that in the common cause database.

CHAIR STETKAR: There are infinite just it will be used that way.

PROFESSOR MOSLEH: Yes. All of these are good points. And Dennis' idea is an excellent one we can use.

I think John --

CHAIR STETKAR: John?

MR. FORESTER: I just wanted to make one comment. This is very complicated.

I think part of the reason you make the assumption that you can do a generic template for the CRTs is that they are based on procedures. So any plant, like Westinghouse plants for example, if you do CRTs for those procedures, those should generalize to all the plants that use those procedures.

So that's the hope, I think, of being able to do a template is because they are based on the procedures and deviations through the procedures.

I don't know whether that was clear to everybody or not, but it does --

CHAIR STETKAR: But it hasn't come in, I am glad you brought that up. But again, I'll pull you back to the fact that this methodology should apply to internal/external events, low power, shutdown and full power. And I will tell you that even though I have a four-loop Westinghouse 1000 megawatt electric plant my procedures, if there are any for response to fire events, if I have ten plants there are probably ten different procedures. So any methodology that we use we're not going to propose a 104 different generic templates for 38 different fire scenarios. Any methodology should be able to handle the fact that we have variations among procedures plant-to-plant, even though they're nominally the same category of plant.

They'll also handle some of the shutdown stuff that you're talking about.

MEMBER BLEY: Even so, some of our friends who helped develop the current procedures some think very broadly and understand their limitations and how they work. Others think they've solved the problem once and for and all. And if we build templates out of those procedures, the tendency will be that they'll solve everything because you're not looking for the places where it diverges. And all of the incident reports you read dwell in the areas where it wasn't a perfect overlay. And that's what we need to care about.

CHAIR STETKAR: Right. We found many instances where the question you raise in, let's say, a fairly comprehensive PRA evaluation do indeed identify places where those procedures indeed -- the presumption behind the procedure is not valid. So therefore models constructed only from those procedures by definition will not catch those issues.

MR. LEWIS: Could I ask one question or make one comment?

CHAIR STETKAR: You have to identify yourself, Stuart.

MR. LEWIS: I'm sorry. I will. I'm Stuart Lewis from EPRI.

One thing that makes this even a little bit more complicated in my mind from a practical standpoint is what John alluded to, something like a 100 or more human failure events than may be in a PRA, a large fraction of those are not events that represent actions that are in the Emergency Operating Procedures. They're abnormal operating procedures or other lower levels and at the same time these are things that are not reflected in event trees. A very, very small fraction of that 100 events, if any in some PRAs, are included as top events in event trees.

So this idea of how the CRTs are structured and how they interact with the scenarios to me becomes extremely complicated.

And I asked this in October when we met. And the practical considerations that come into play in implementing that to me are mind-boggling.

CHAIR STETKAR: Thanks. Yes. I think you're hearing a few concerns about that type of issue.

Remember we need to stop at 12:00, so see what you can do to keep us at least somewhere on that schedule.

PROFESSOR MOSLEH: Right. Well, let me then share with you some preliminary ideas and thoughts of quantification and then since this is really not something that we have really focused on, we'd like to really cover this as quickly as possible.

This is the slide I showed earlier. Basically we have multiple path through a CRT type analysis that identify same or different HFEs. And these are scenarios. So an equation, or probability equation that really captures the nature of the event being a scenario is the most appropriate quantification framework from a kind of a conceptual level.

Now the context factors that you have embedded in the CRT and the rest of the context and the plant state, and the PSFs and the time and everything else really are all there. And you can see that I can look at different scenarios and quantify them based on their specific context. Then add all multiple scenarios that lead to the same HFE, add their probabilities. That's what this equation says.

And I mentioned the fact that this equation is not new. In fact, if you look at ATHEANA-type analysis, you can see that the same equation applies and there are things in there, the ATHEANA methodology called unsafe acts that could be really the same or similar to some of the key things that happen in a given scenario leading to HFE. And if you make a few assumptions such as, for instance, a given unsafe act, the probability of HFE is 1, then you can simplify the equation even further.

So whether this is an exact replica of the ATHEANA equations or not is less important than saying that conceptually they're related because they're both scenarioed in this approach under ATHEANA and similar approaches in the past if they're scenario driven, really start with the same concept that you calculate the probability of the sequences and you add them up.

Now going beyond this, ideally then we'll be able to quantify these equations, the elements of these equations. So what this equation has in it, the context factors and the probability of context given for a given scenario or situation, and a conditional probability of HFE given the context, the context can be written in terms of a set of factors. In some style of analysis the context is translated or reduced to or summarized in terms of the PSFs. If you look at, for instance, the SPAR-H has a quantification method, the score, you see that you have a base probability and then you adjust the probabilities based on the PSFs that represent the context or the situation. But you can generalize the notion and say well we're going to take the scenario and then identify its distinct elements, and call them factors. And those factors could be the fact that this one crew, a specific crew, a factor could be elapsed time, could be a specific PSF, could be a specific operator action that preceded the one that you are quantifying. All of these are part of, obviously, the context.

So you write the equation further as something that has a probability of these factors kind of connected together or the joint probability of these factors for the same area and then try to see if the same equation. Short term what we have in mind is, you know we recognize that there are different formulations, mathematical formulations beyond this point, beyond the point of this particular equation. You can modify it and change it to speak and link to some of the existing quantification methods.

So in short, short kind of a term we're thinking that maybe -- I'm going to this slide now. That we could rely on existing frameworks, quantification frameworks, provide the technical justification in how and why they fit within the qualitative framework that we have, and leverage those methods as a basis for quantification.

And then maybe instead of one method we end with a set of methods or quantification frameworks that would be consistent with this framework. And as a minimum we'll be able to kind of basically describe where the differences are. Where do they deviate or depart from the equation that is consistent with the scenario model?

MEMBER ABDEL-KHALIK: Would the safety culture of a utility be a context factor?

PROFESSOR MOSLEH: Yes, in the general sense we talk about. Yes, it is.

MEMBER ABDEL-KHALIK: But how would you quantify that in this framework?

PROFESSOR MOSLEH: I should not try to attempt to answer the question even though I can offer some ideas. But this is not what we have discussed within the team. We're not at that phase where we actually have devised or developed techniques to capture or quantify and develop metrics for things such as safety culture. But personally I've been researching that area and I have some ideas.

MEMBER ABDEL-KHALIK: But it would seem to me that this is a very important --

PROFESSOR MOSLEH: And a very difficult one, actually.

MEMBER ABDEL-KHALIK: --context factor that's a lot of it.

PROFESSOR MOSLEH: Yes. Yes. You're right there.

MEMBER ABDEL-KHALIK: Whatever quantification you're going to do.

PROFESSOR MOSLEH: You're absolutely right,

MEMBER BONACA: Well, you can quantify the different levels.

MEMBER RAY: Well that is similar to what I was saying, Said, that the safety culture may be affected by some external direction. For example, hands-off from the grid operator.

PROFESSOR MOSLEH: In fact, if you look

at our PSFs we have explicit PSFs that point to different aspects of a safety culture organization factors. But I do not want to say that we know how to or we have a consensus on how to quantify those.

MEMBER BLEY: Said, your question was a very general one, Said. And there's probably no general answer. But there are many specific answers for specific aspects of safety culture. Some of them are already incorporated. Some of safety culture, of course, shows up in terms of the training people get and in terms of the way of administrative procedures are written, and in terms of the way -- you know, it's kind of under administrative procedures a given utility deals with demands and requests from the people they're supplying. And some of those in fact, are built into the model.

So you need a big catalog. And if you go through that catalog, I think you'll find some things are done pretty well, others are going to be the focus of research for a while.

PROFESSOR MOSLEH: And maybe when we get to the list you can kind of go back to your comment and see if that --

MEMBER BLEY: But it would be great if somebody built that list.

MEMBER BONACA: The worst part is the quantification. That's where the most difficult part is going to be, the quantification. You can find links to actions. But quantifying, it is such a subjective --

MEMBER BLEY: I'm not sure. A good first step, though, would be to try to build this list of all the things we mean when we say "safety culture" as a catalog. And some of those I think won't be that hard, others will be, some won't matter so much and others we'll think matter a lot. But without the catalog -- and we had a meeting here on safety culture that dwelled in the big area and never got really specific on these kinds of things.

DR. LOIS: For example, the reluctance issue. If you do a human reliability and you go to the plant and you're talking to the operators and plant experts, you identify that the operators have to adhere to hands-off. That is going to be taken into consideration in your human reliability. It doesn't matter what method you are using. And it's going to be on your PSFs or causal mechanisms for not performing a human action.

So a lot of that is embedded in the qualitative analysis that we're doing and the information we're collecting from the plant.

Now the safety culture on a more global sense in the sense that if you now say that this utility, the first priority is money and not safety; that aspect I don't think we can funnel it in the PRA in general, and more important in the HRA.

So there are different aspects. At the lower level whether or not the maintenance performed is of quality or whether not the business is of quality, those aspects are part of the qualitative information we're gathering to do human reliability. And at that level I think we're addressing it, at some level.

CHAIR STETKAR: Ali, let me ask you this, the middle bullet on this slide here is somewhat intriguing to me, your vision for what's going to happen in the short term. As I understand it you're saying that perhaps you could develop guidance on how to modify existing quantitative methods. And we're well aware, there are a number out there. To tailor them to address some of these more broader issues that you're talking about. Have you thought much about that?

I again, I'm very interested in we as a group, the agency, coming to some degree of closure on this issue recognizing that indeed there's always opportunity for long term research developing longer term methods, perhaps for quantification, perhaps for treating more explicitly issues like safety culture.

How much have you thought about that second bullet? Because that leads back to this integration of how do we take this framework and integrate it with, at least in this sense, existing quantitative methods? And have you thought about which of those methods are better -- I don't want to put you on the spot for that. But how far have you gone along that line?

PROFESSOR MOSLEH: Yes. Well, I give you two samples, you know what appeals to me and what I think we an link to this, but they're not going to be a consistent model. Let me just give an example.

If I take a SPAR-H, for instance, and saying well the structure is quite simple. You have a base probability, you adjust it by multiplying factors that are PSF, effectively. Through this kind of qualitative analysis I think what the picture that will emerge, and it's consistent with what the question that we have, is that a log-linear or linear view of how PSFs effect performance is not the right perspective. In other words, you can't just multiple that whether it's a log-scale or additive and all that it going to have the same thing, a picture. They're interdependent and the way that they influence performance, of course, would be different and their rules in that.

So one modification to a SPAR-H framework would be to have a nonlinear or a little bit more sophisticated way of adjusting the base probabilities with PSFs. That would be consistent with this scenario perspective.

And we did a version of that many years back for a utility, Song-hua and I did that. And there is that thing as a reference point. But that's the idea, kind of modifying.

CHAIR STETKAR: Ultimately we have to quantify these things. And again, you know trying to avoid the nature of yet another decade of long term research programs it's certainly an area where interaction with PRA practitioners, HRA practitioners out there who have practical experience using different types of quantification methods that may have shortcomings --

PROFESSOR MOSLEH: Right.

CHAIR STETKAR: -- could be useful.

PROFESSOR MOSLEH: Right.

CHAIR STETKAR: And I'd kind of encourage you to focus on that

PROFESSOR MOSLEH: Yes. The other example I wanted to give you was CBDT. The appeal of CBDT to me is that it's very much a cause base quantification. So we can see why it kind of matches our thinking of it. So we think if we now point people to using CBDT, for instance, for some applications, then how do you make that consistent with this whole scenario.

MEMBER BLEY: I guess there's one I keep hanging on, we tried it a lot and the ATHEANA worked, which originally the same -- had severe context situations. And that is the idea of a base failure rate gets modified seems to me not always the right model. There are situations in which you see people failing multiple times in recognizing even the information coming to them because the situation has reached a very difficult spot. And there must be cases you'll find where the context is such that it doesn't really matter how easy something was in its natural base state. What really matters is the context has reached a point it's very difficult to do anything right.

PROFESSOR MOSLEH: Right.

MEMBER BLEY: And somehow that dichotomy is --

CHAIR STETKAR: But I think that is, in a sense, my interest is how much effort in this project is being focused on that second bullet evaluating, for example, does that construct of a base human error probability with modifiers really work.

PROFESSOR MOSLEH: Right.

CHAIR STETKAR: Or is that something that indeed should be relegated to something that we tried and doesn't really work that well. I mean, we don't need to force fit this construct to methodologies that have been used in the past that are perhaps second-tier methodologies. You know, providing that the evaluation of the available methodologies is uniform and that if there are one theoretically, one or two that have a large number of very desirable attributes, you know focus in on those and have a bases for why that is.

Dennis, I think some of your concerns would fall out of that evaluation process.

MEMBER BLEY: I think that's true. Maybe before you finish today when you get toward the wrap-up, some understanding of how much effort is being allocated to all these different pieces of the puzzle would be of real help to us.

DR. LOIS: I would like to clarify. Actually, our house is in the long term. Beyond that takes that conditional probability expression and has the capability to quantify human error probabilities on the basis of the causes of errors and then associated PSFs, et cetera. And I'm not quite sure that we need to focus on what we call short term. However, we have a practical need here, especially for SPAR-H. It's been used widely for event evaluation. And we're going to explore the possibility of not improving SPAR-H, but we may have to because our colleagues at the regions and NRR, et cetera are using SPAR-H everyday for event evaluation.

So that practical consideration is going to take some kind of thinking here. But if we could, we don't have to go that route really. If we could use the anchor values and the data we have right now, or expert judgment and go ahead and use the appropriate traditional probability expression, that's what we should do. And we may put more time into that.

CHAIR STETKAR: Thanks.

We do have to keep to our schedule here.

So what I think we'll do now is recess until 1:00, come back.

If you folks could over lunch think about your presentations after lunch, one of the things I would emphasize again is I really would like to have the opportunity to hear about that practical example while we have the largest attendance among Subcommittee members. So if you can think about fitting that in and recognize there probably will be some discussion about that. So think about that.

And we'll recess until 1:00.

(Whereupon, at 11:58 a.m., the Subcommittee was adjourned, to reconvene this same day at 1:00 p.m.)

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

1:00 p.m.

CHAIR STETKAR: We are back in session.

Give us a little bit, before you start, just if you could, give us just a one-minute roadmap of how we are going to organize this afternoon, so that we have a little bit of an idea where we are headed.

MR. MOSLEH: So, following your recommendation to make sure that we cover the example before we end by 3:30, we decided to change the order of presentations, have Song-hua present the example, and then we move to the mid-layer modeling. So, that is a change in order. I had a short piece that they reserved for the last kind of after all the presentations, kind of plans ahead and a summary of what we have said. If we get to that, that would be good.

CHAIR STETKAR: Yes, I think it is important to get to that, Ali, even if the number of remaining members dwindles to me.

(Laughter.)

I think it is important to sort of review that because I would at least like a decent idea of where we are headed and rough schedule, if you have that. We will sort of play that by ear. If that happens after 3:30, that is fine.

MS. LOIS: So, then, if we go until 3:30 on the --

CHAIR STETKAR: I would like to get as much of the technical information to the maximum number of Subcommittee members as possible. Then, if members need to leave at 3:30, that's fine. We will carry on from there with whatever we have.

MR. SHEN: Okay. Now we start with an example to describe. Dr. Mosleh has presented a high-level message how to go through these.

Currently, I tried two examples. One that is for using a plant operation model of a steam generator rupture. Another is for low power and shutdown, the loss-of-inventory scenario.

Before the example, I just try to show what is the steps we try to use for constructing a CRT. So, this morning John suggests, let's say, if we already have an existing PRA model, do you already have inventory, how to incorporate this one into the current inventory? Essentially, it is not very big, you can see from this these are constructed structures.

The first one we start will identify the initiating event. The second one does define the safety functions. The third one, that is to build up the story, to link, line up with the accident sequences. I think all these three steps that are similar, we can say, exactly the same as eventually how to build up the inventory.

And the fourth one is to constructing the CRT. I will use, because the whole CRT may be too complicated, too big, I just choose one of the points to show up how to do it.

MEMBER BLEY: I am sorry to slow you down right away.

I am surprised on that first slide not to see identification of the HFEs or sub-elements of the HFEs.

MR. SHEN: Basically, we don't want to say the HFEs. Essentially, in this CRT, there are ones, they not only HFE. We also identify success paths because later you will see. Even though it is a success, but for this action it makes sense, but the next action may be affected by the previous one.

So, in CRT, we don't limit it under the --

MEMBER BLEY: Although you didn't say it, you are identifying all the human actions along the path?

MR. SHEN: Yes. Yes, all kind of human action as possible, not only the fatal event.

This is a graphic model to say the process. The first one, where it builds off this process, the first one we identify the initiating event. Then, we try to say the safety function. Like this is a reactor trip of one of the safety functions, and then we try to build up a different branch under this safety function. Then, we try to show up all the safety functions necessary for this scenario. If any of these safety functions fail, they may lead to core damage.

So, essentially, this process is similar to the event tree, but the only thing that we focus on is both hardware failure and the human error together. Because for some human behavior, it is conditionally your status of the plant station, not only the human itself.

And I also want to say one thing for this SRM. This one is not very important because in the nuclear power station usually any human failure is not an isolated event, but it is highly dynamic, a highly strong effect by previous actions and previous conditions. So, most of the current existing SRM methodology, we just treat the human failure as an isolated event. We just do this one without conditions, detail it conditionally to say how it is in these cases.

Just like this one, we say reactor trip. We made reactor trip automatically a reactor trip or mainly to trip the reactor. For the last action, it may have a different impact because always they may tripped reactor or the reactor trips by itself. The mental state of the operator may be different. So, that may be important. So, we have more detailed instruction how to build up this one.

The example of the branch points in constructing the CRT, because in trying to construct the CRT it is very importantly we need to identify the safety function. After we identify the safety function, we need to decide how many branch points inside or where is the branch point. So, we try to identify the branch point. You can see each branch point in the traditional way, that may be a one human failure event in this branch point.

That branch point just means that they may go right or they may go wrong or they may go another direction or a multiple choice. But, for each one, you can simplify the status of the human failure event which is one human activity there.

The first one, we try to say because, as I said, the prior conditions is very important for human mental status. Under this prior condition, another condition may be different. So, a prior condition is nicer to decide where is the branch point that we need to have.

So, like I said, not only human failure even we are interested, we are also interested in the success path, including all the behavior. So, we need to put the plant conditions and success paths and failure paths, and we also need to provide some branch. For example, just like Westinghouse-style procedures, you enter E0. If this is a U-tube rupture event, you need to go to E3 because there is a lot of trip. We can say that the branch point, before you go to the steps, go to E3. It is a simple step. Maybe you will go to the E1 or E2, that that is a wrong procedure. So, all that also is the criteria to select the branch point.

CHAIR STETKAR: Song-hua, back to the earlier slide, I think Dennis mentioned this morning that -- is the fundamental basis for this CRT a replication of the plant emergency operating procedures or is a depiction of plant response to various hardware successes and failures and human successes and failures, regardless of what the procedures may tell you? Which of those two?

MR. SHEN: Yes, essentially, I will answer that both are interesting and both are important because usually, essentially, a procedure is just a guidance. Under this condition, what is the best way to treat this prior condition? So, usually, even though you are aware that they didn't follow the right written procedure, I can say they are following some remembered, memorized procedure based on their training for the U-tube rupture. Even though they don't have a procedure, they will isolate the broken steam generator; they will cool down the RCS as soon as possible. So, it is like this kind of principle now means that you have procedures or don't you have procedures, and you are always to do it in this way.

So, following procedure, that it is really easy and simple way to say, what is the scenario in the operator's mind to go through the whole scenario? But it is not a nice scenario.

In the beginning, we have this caution, you know, to connect this CRT exactly with that procedure. But in this way we have limited your application. The first one for low power and shutdown, usually, we don't have an EOP-styled procedure. And also, for some plants, you know, it is not a --

CHAIR STETKAR: Okay. Let me slow you down a minute. Let me ask the question a little bit differently.

You have personally constructed the CRTs for this example of the methodology.

MR. SHEN: Yes.

CHAIR STETKAR: Did you construct them to replicate the procedures or did you construct them --

MR. SHEN: Based on the functions. Because I say the first thing is to identify the safety function. Yes, it doesn't try to do that safety function; we still need to call that procedure. So, it is very difficult to say where to start this kind of procedure completely.

So, the next step, you will see what is procedurally in this CRT construction. So, essentially, this page just tries to say how do we identify, after we have the safety function identified, we just try to say why this safety function failed. How many tests for this fatal situation. We just used all of this one to be a branch point.

This is an example, just like a steam generator trip rupture. One function does say you need to isolate the broken steam generator, but how you isolate this broken steam generator may have a lot different result.

The first one, they finished isolation already. They finished isolation late. I just said early and late. Both are a success. But you know for this action both are a success. But we know for the next action we need to cool down this RCS. If you finish earlier, the cooldown to the job may be easier. If you are just allowed 60 minutes, and you finish in 59 minutes, for this action it is a success, but for the next action the likelihood to be a failure will be increased.

So, if you are near this last detail, say both are success paths, but they may have different impacts for the next one. We just put that in a different branch.

And also, they may be too late, so this action failed. Also, for this failed, we have some different situations. For example, the operators never have any action, they never diagnose that this U-tube ruptured. They never do the isolation. But they want to do it, but maybe the hardware failed. They wanted to, but maybe there was a hardware failure. They cannot do it.

Or they tried to identify that they need to do it, but they do it in the wrong order. For this isolation, it may not be important, but for some other action -- for example, if you try to start a pump, and that pump you need to open the suction valve first. If you are early, you start the pump first without opening the suction valve, you may destroy your pump. So, for some actions, the ordering also is important. But, for some actions that are like this one, this is not important. Maybe it is not important here. I just tried to list as completed, can branch over here.

MEMBER ABDEL-KHALIK: My understanding is that procedure adherence is a fundamental tenet of plant operations.

MR. SHEN: Yes.

MEMBER ABDEL-KHALIK: So, for you to develop a structure that is not anchored in following procedures, and the operator may make a mistake in following, but to do this independent of the plant procedures just doesn't make much sense.

MR. SHEN: You can see later we still use that procedure. Essentially, all this says, we just try to say, if we assume the operator is following procedures exactly, then no human error. We just try to say in what condition they have procedures, they still do something not made by the procedures.

So, I think that the major thing is human failure, but --

MEMBER ABDEL-KHALIK: Well, I understand, but that is not the point.

MEMBER BLEY: Let me try something.

MEMBER ABDEL-KHALIK: Go ahead. Sorry.

MEMBER BLEY: Well, I suspect we should hold that and come back to it because what they are doing here is laying all the "what can happens". I assume we are going to have an overlay of the procedures onto this later. So, it seems a very reasonable approach to me, but let's wait until they get to the procedure and then come back to it, if that is okay.

MEMBER ABDEL-KHALIK: All right.

MR. SHEN: Okay. While you are talking about procedures, I just would say one more thing. Essentially, this is an isolated broken steam generator, maybe only one sub-step in that procedure. So, under this step, what is the likely result we may get there, result in this condition?

MEMBER BLEY: Before you pass that slide, I just have to say, if you are going to show these slides around, there is a real careful distinction made in those procedures you are talking about between a ruptured and a faulted steam generator and "broken" is not used anywhere. I think you can get yourself in trouble by inventing new language here --

MR. SHEN: Okay.

MEMBER BLEY: -- and not defining it.

MR. SHEN: You know, just like I said, you will finish earlier or you will finish a late; there may be no difference in impact to the next step. The wrong order maybe not be the important. So, that means that this is just trying to say all kinds of combinations.

But in the practical way, you will want to get a simplified version. You don't need to have all of that stuff over here. So, that means, for example, for your purpose, since this already ended late, they both are a success. The result, the consequence is exactly the same. Then, we can merge to be one branch.

For example, that wrong order also is not important. Maybe we say for this action the wrong order and you isolate a valve. Which one first, which one later? There's no difference. So, this one can merge to a success path as well. So, in this case, this way you can merge a less complicated branch to be some simple branch.

Here, we show that under this branch

point you have this history of results. When we build up this CRT, we also try to say what resources we have. Currently, we know there are several tools that can handle an event tree. We just try to use that one to handle CRT. But for some of the tools, they cannot handle much for the branch. They just can handle binary points. So, we also can restructure this one to be a binary branch, just like all kinds of stuff to build up your CRT.

Here, we try to build up a complete steam generator rupture with the CRT trees. The first one, we have a steam generator rupture start from this branch. Then, we say the reactor needs to trip. Usually, eventually we cannot see a SI signal separately, but for human purpose --

CHAIR STETKAR: You know, in perhaps the event trees that you have looked at it might not appear, but certainly it appears someplace in the event model. It might in a fault tree someplace, but it is there. So, don't presume about what is in an event tree or what is in a model simply because you have only looked at one or two.

MR. SHEN: Yes, okay.

CHAIR STETKAR: So, don't say that this is more complete than an existing PRA model because it is not. I see no difference in any of this from any integrated event and fault tree model yet. So, I am still looking for what is different about this, what I am learning about this process compared to what I do already have in hand in my PRA model.

MR. SHEN: Yes. Usually, I just say, for example, SI signal, automatic start or the manual start. Usually, with a with a different model, eventually --

CHAIR STETKAR: Perhaps you didn't in the models that you have looked at.

MR. SHEN: Yes.

CHAIR STETKAR: I will say I have looked at probably more models than you have, and I have sometimes seen people never put manual SI, but usually that is in there, too.

MR. SHEN: Yes.

CHAIR STETKAR: So, be careful. Be careful. I have not yet seen anything in this structure that is not already in a reasonable PRA model. I am looking for what is different. I need to learn what this resource-intensive exercise is helping me as PRA modeler learn about evaluating human performance. I haven't seen anything yet.

MR. SHEN: Yes, okay. Until now, that is

the extent, but because I just say that the first three steps, the consecutive steps must eventually model/develop the place where we identify the initiating event. Then, we identify the safety function. Then, we line up the scenario. That is exactly the same as the event tree models are doing. Later, we just try to put more human action in these CRT trees.

I just tried to use this to show up how do we build up the sub-CRT trees for this scenario with a U-tube rupture and their AFW problem, to see what may happen to fail, to get the core damage.

So, this sub-CRT is done for secondary heat removal function, based on this condition. The first one, SGTR occurred, and then the reactor tripped automatically. Then, automatically the SIS signal generated. Then, HPSI functions successfully.

That is just based on we have all these functions successfully, and then we are talking about what is the AFW, the secondary heat sink removal. This function failed.

Now we go back to the procedures and try to review our procedures before we build up the CRT. We go by the procedures, but the procedures usually are two procedures to handle this kind of situation.

Usually, your Westinghouse-style procedure, in E0, they will ask the operator to check the AFW flow rate. If they don't that AFW flow rate, they may need to start it or they may need to transfer to a safety function through FR.H-1 to restore the AFW function.

So, essentially, there are two procedures related. One is E0; one is FR.H-1 in Westinghouse style. So, this is a nicer action. They need to do this job.

MEMBER ABDEL-KHALIK: You would never enter FR.H-1 in this process. I mean you have to lose wide-range level in the steam generator to enter FR.H-1.

MR. SHEN: Yes. So, if you don't have AFW, you may have loss of AFW flow.

CHAIR STETKAR: Let him continue.

MEMBER ABDEL-KHALIK: Okay.

CHAIR STETKAR: I think he's got all this stuff.

MR. SHEN: Okay. The first step, which tries to identify CRT branch points, the first one we need to say the plant conditions and to synchronize likely operator actions for these functions.

This just tries to list the likely

process for the secondary heat sink removal. After we have this situation, the first one we need to ask, how about the AFW system? After the SI signal occurs, usually we need to have an AFW signal automatically created, to generate an AFW signal.

The first one, we will ask you, do we have this AFW signal start? This will be the first branch. The second branch, then, it is after the function is not working. It still the due to it physically failed or not physically failed. So, tried to build up this sub-CRT for these special process.

The first one is branch point 1. The first one was just to examine is the AFW automatic start, yes or no? If no, the second point that we will ask, is this an AFW hardware failure or not failed? They physically fail or not fail.

If the AFW physically failed, then what is the next step? If now we have a fail, we can restore it. It may be a job very simple to push a button to start your AFW system from here. You hardly failed in this function. We need to go through the next step. We may need to use the main feed or we want to use the feed-and-bleed. These functions will remove heat, release your heat.

This is, if the AFW signal does not automatically generate, your AFW system does not automatically start, it will go through these paths. If this starts, we also try to catch this so-called EOC, error of commission. If this AFW signal starts, the AFW function automatically starts, but the operator may think about this flow may make the steam generator start again, and we don't want to have this function. They may manually trip this AFW system.

In this case, then this is the main event, and they will go to another path. If they didn't, so that means all the way the AFW function is not a problem, then we will go back to CRT. We will go to the next safety function to see what has happened.

If this one failed, because the main AFW system, and then -- so, like I say, the FR.H-1, that procedure will ask the operator to restore the AFW back. FR.H-1 has two entering points.

CHAIR STETKAR: Wait, wait, wait, Song-hua. Can you go back to that event tree, please? I know you are going to proceed on for your simplified example on the top sequence, which I think is a really interesting sequence.

What I would like to ask you, though, is if I go over to the bleed-and-feed action and look at your event model construct, I see the number 8 circled. In fact, eight 8s.

Could you elaborate a bit on what this model construct tells me about those 8s, and do I need eight of them?

MR. SHEN: Yes.

CHAIR STETKAR: Do I need 32 of them? Do I need three of them?

MR. SHEN: So, I said we need to investigate what is the context in this branch. So, for example, I think for this one --

CHAIR STETKAR: I don't necessarily want you to do it in real-time here. I want to know whether you have thought about that part of the problem. That is a very important part of the problem.

MR. SHEN: Yes.

CHAIR STETKAR: It is structuring the model and how we think about human --

MR. SHEN: We think about just like --

CHAIR STETKAR: Because your example is going to focus on the simplest path through this event tree possible, a different action than we typically think about an error of commission. But, indeed, the vast majority of the time and money we have spent building risk models in the past have focused in the black part of your model down there, where we have an ever-expanding number of different potential scenarios that would affect human performance at that circled 8.

MR. SHEN: Yes.

CHAIR STETKAR: So, I am curious how much you have thought about that so far.

MR. SHEN: Yes, I will try to answer your question and say how many in these 8 points we need. Actually, these top two are different because the top one, the first one that is under operator, the main feed system isn't available. The operator failed to restore it. And the second one just tries to say maybe this is physically not available.

So, in the operator's mental status, there is an absolute difference. So, for the first one and the second one, they are two different stories. We have to analyze them separately.

But, currently, usually, if you don't want to do it sometimes for most of the current PRA, the measures have one action to replace feed and bleed. They didn't represent where you use this feed and bleed.

My point, I developed this one I think the mental state is an absolute difference. Then, the result comes from the absolute difference where it does nicer to model separately under different situations.

CHAIR STETKAR: I think I would really like to see an example that takes this model out to those points and tells me how many different flavors, if you will, of number 8 I really need to think about, because that is one of the real powers, I think, of perhaps this logical construct. I just haven't seen any evidence of how it would be implemented or whether I need, in addition to eight branches, I might need 32 or whether I can get away with three or something like that.

MEMBER BLEY: If I can make a comment on this, not from work here, but from related work in the second Halden study, we looked at this. Or maybe it was the first one. One of them, we looked at something like this where at first we laid out multiple -- and I forget how many -- there were a dozen or more possibly distinct states.

As we went through clarifying them and talking it through, they condensed to sometimes one, sometimes two or three, but always a great simplification. But you had to think it through to get there. You couldn't a priori determine that. You saw there could be influences and you just had to look at them and see if they were significant or not.

CHAIR STETKAR: And that's why I think, in the sense of an example, that type of an example within this construct would be really useful to see how this process will actually be implemented, what we learn from this. Because, in fact, you probably are not necessarily organized around the procedures, but, indeed, there are models out there that theoretically identify all of those logical different conditions. They may overly simplify the human failure event by defining a single basic event and putting in one number for it, but, indeed, the logical constructs of those models would, indeed, capture perhaps all eight of those number 8 different conditions.

MR. SHEN: Right.

MEMBER BLEY: If I can sneak in a little question here, we are looking at the sub-CRT dealing with aux feedwater. But the previous thing that got this all started, in your first event you identified that there were possible places in the zero one might have branched instead of coming right here.

Those branches themselves, which don't show up on this sub-CRT, will certainly affect the timing, but on the particular event you are talking about, 8 could have a major impact on whether you make it or not.

CHAIR STETKAR: Absolutely.

MEMBER BLEY: So, when we look at the sub-CRT, we have kind of lost that connection to those --

CHAIR STETKAR: It is a bit of a problem with the modularized thing that we were talking about earlier.

MEMBER BLEY: I don't know if that is just the example you are showing us or if you have got a way to not lose that conditionality when you get to a --

MR. SHEN: Essentially, what you are talking about, I think the context of each branch point is very important. Here we have a context of branch point 9 and the context of branch 11. But you can see this is actually context. Oh, the context in 9 also is put into context 11 because context 11 is your next step of this branch.

So, this condition here will bring it to the next one. And you see the previous one in the

CRT, of course, we need to bring to here. That is a part of the context of this one.

When you try to use this one, you need to bring every information necessary from the first point all the way down to here. We don't want to give up anything.

Just like I said, for a certain precision, even on the success paths, we try to identify the success earlier, success early or success late, because success early/success late, the timing will strongly affect your next step. So, that means other steps, success early or success late, for the next action, the likelihood will be different. We tried to bring up all the --

MEMBER BLEY: Let me suggest something here. You are laying out binary switches in this kind of model. But it might be -- timing is a nice one to talk about this -- it might be that you could make a probabilistic time estimate instead of doing early and late, and having a time distribution might well be the right way to condition the things that are coming later, rather than picking early and late on a basis before just what it is.

MR. SHEN: Yes. Yes, that's good as a suggestion. We saw it before, but the practical part may be difficult because maybe only the other time, now the PRA can handle it, because the consequence carries a lot of difference.

MEMBER BLEY: Maybe, but I don't think so.

(Laughter.)

MR. SHEN: Yes. Yes. So, I don't know how many in that timeframe --

MS. LOIS: We will consider the suggestion, right?

MR. SHEN: Yes, we can consider this one.

MEMBER ABDEL-KHALIK: I guess I am trying to understand the discussion that happened earlier about point 8 in that diagram. Your point is that not all of these point 8s are the same because they will have a different context?

CHAIR STETKAR: Yes, that's right. And the question is, are the eight number 8s that are delineated in this particular model enough to capture the differences in the context or are they too much? Do the perceived differences make any difference? And the methodology should be able to answer both of those questions. Have we captured all of the appropriate scenario-specific contextual factors that we need to understand to define a number 8 with a circle around it?

MEMBER ABDEL-KHALIK: I mean, if you go through this whole process and find out that the human error probability in all of these various number 8s ranges from 10 percent to 11 percent, then I think we are pounding sand.

CHAIR STETKAR: Yes. On the other hand, if you have missed one where it ought to be 1, that is important.

MR. SHEN: Yes. I think this morning Dr. Mosleh suggested we will provide a template. The template, essentially, which is just to put together a single complete one. So, that means it is not necessary to have that. But we shall provide a template to be as complete as possible. Then, we provide some rules to merge, to simplify. This is just my personal idea.

Just like this branch, this is under the branch. They entered FR.H-1 for Step 14. This one is the operator didn't enter Step 14. They may enter the FR.H-12 for this STA. The safety function trees are mandatory. So, this one and this one are both in the FR.H-1. So, in this 8 and this 8, I think there is no difference. So, maybe we can merge to be one.

But in the beginning, we just tried to

ask how we can be as complete as we can. Then, look, this is one is a template. Then, you use this template for your situation. We provide a simplified rule how to merge this together, simplify the CRT. That is the original idea.

MR. MOSLEH: And also, each sub-tree is connected. Whenever they are connected, they carry the context of that particular point that they are connected. So, even though structurally they may be identical, they take different color and flavor, depending on where they are connected to the main CRT.

MEMBER ABDEL-KHALIK: I mean it would take an incredibly long time during a steam generator tube rupture to ever get to FR.H-1. And therefore, all the concerns that were raised earlier about time sequence, all the things that happened up to that point, to me, it would be far more critical than this just simplified set of conditions.

MEMBER BLEY: That is true if aux feedwater --

MEMBER ABDEL-KHALIK: The problem in this case, you have too much water in the steam generator.

CHAIR STETKAR: No, no, no. Be careful. Not necessarily.

MR. SHEN: This is safety function 3. You can see this is really the red path. There are two paths that go to the red path. We can go through this condition to go here or we can go through here to go through the red path.

So, this is very simple. If your AFW flow rate is less than 340 gpm, you can enter the FR.H-1.

CHAIR STETKAR: Go ahead. I'm sorry.

MR. SHEN: So, this is the actual Westinghouse style, the safety function 3. And to answer, if you have ample flow rate less than 340 gpm, you can go through this red path and then go to the FR.H-1 directly.

Okay. I just try to say how do we view the construct of this sub-CRT. After we filled out every single sub-CRT, we linked together to be a big CRT to be complete.

This is the place where we say how to identify this one. So, this we also try to say this CRT we try to handle the commission error as well. So, that means even if you have automatically started the AFW system, the operator may still come over here. And if they didn't go to FR.H-1, they may still get trouble here.

CHAIR STETKAR: They, obviously, can't turn it off after they decided to turn it on?

MR. SHEN: So, that means we only have these ways under automatic start. So, we don't have a manual start to have these --

CHAIR STETKAR: They can only decide they have too much feedwater if it started automatically?

MR. SHEN: Yes.

CHAIR STETKAR: Okay.

MR. SHEN: Because just maybe the steam generator may be starting soon, and then they don't want to get the steam line to fill with water because steam lines decide by steam, not water.

Just let's say there's a --

CHAIR STETKAR: My point is that it doesn't seem to make any difference to me whether an automatic signal started auxiliary feedwater or whether I ran up to the board, pushed the button, and it came on, and I verified I had flow. Later I might be concerned that I am overfeeding steam generators. Why can't your universally-applicable template acknowledge the fact that I might later turn it off because I have misrepresented the condition that I have too much feedwater?

The basic problem with having a

universally-applicable template, if it is not universally-applicable or complete, it is not universally-applicable or complete.

MR. SHEN: I think that problem we need to leave for the human psychology people to investigate what is the PSF --

CHAIR STETKAR: But this is a logical construct that you, as an expert, are proposing to handle any particular scenario that later the human psychology experts, if I can call you that, should be able to help you quantify.

MR. SHEN: Yes. Essentially, I think we can see this scenario from the actual event. I think in one licensee event report they got some problem and --

CHAIR STETKAR: So, your universe of possibilities is governed by the things that you have read?

MR. SHEN: It is not an AFW system. I think that is a HPSI system, a HPSI system working. We can see a lot of it before they find out what happened, what is the root cause to make HPSI happen. They manually --

CHAIR STETKAR: Well, Three Mile Island, okay, there's an example. But my whole point is

-- I'm going to be really critical here -- you are proposing this methodology with a set of universally-applicable templates that people will use and further simplify. If those templates are not logically complete, if they do not logically account for the things that we understand can go wrong in the sense of human performance now, then those logical templates are dangerous and misleading.

MR. MOSLEH: May I?

CHAIR STETKAR: Sure. Yes, absolutely. I mean, you know, I am trying to provoke a response here, obviously.

MR. MOSLEH: A complete scenario in an absolute sense is not achievable, as I am sure you agree. But the fact that we have this discussion and you picked up on a point, and you are saying, you know, if I look at this logic, this is incomplete because I can imagine this scenario, points to the power of representation we are advocating here, because now we can all sit around the table and point to a missing scenario.

Whether that missing scenario has been identified because of your extensive knowledge or a plant procedure or experience from operating experience and actual event, and all that, it is something that we all try to capture as much as we can in a universal template. It is not going to be complete, but it provides a lot of pointers and then natural ways or entry points to ask these sorts of questions and make them as complete as possible.

The idea, also, for the generic template is not to really -- we are not suggesting that that is the only way we are going to propose that this thing may be done or the most effective way. It is one of the ways we thought that we could make this a little bit more practical. Because if you don't provide a layout and map initially, it may be too difficult for people to consider at least the base scenarios.

We provide that, and then, by additional guidance, we can probably help people add, delete, and modify, and for the community to in time actually enhance this, based on either more knowledge, better experience, more events that we have observed. So, I think the framework is helpful in achieving some of those goals.

CHAIR STETKAR: All right. I hear what you are saying, Ali. I will grant you that striving for completeness, you are never going to be 100 percent complete. On the other hand, the reason that

I like these examples is not so much for the example itself, as to understand what the basic fundamental science behind this methodology is.

And I'll leave it at that. We can go on from there.

MR. MOSLEH: And one point I might add is that, if I look at the graph, it is a graph; it is a diagram. It is not knowledge. It is representation of knowledge, right? But it is helpful in reminding people to see what's missing or the gap.

So, I wouldn't call the CRT as a new idea or a methodology or something that we look to kind of to find answers through. It is more like, is it helpful in capturing knowledge and then making an analysis more systematic?

CHAIR STETKAR: I think it is a wonderful construct from a thought perspective because you can, indeed, now ask questions about, is eight number 8's enough? Should I have more or less? You can ask, should I have a branch point under No. 9 on sequence whatever the heck it is?

The only concern is that, if you then take the next step and say this is the NRC-endorsed CRT for this portion of a steam generator tube rupture event in a Westinghouse-type plant, and develop a methodology for then feeding numbers into those branch points through some sort of automated process, you have stepped well past what you just said, using it as a tool for thinking, rather than a direct quantification tool.

MS. LOIS: But one of the issues that we are dealing in human reliability is the fact that HRA analysts do make different assumptions and do identify different aspects of the human failure event, I think that being the more comprehensive approach and others being not as comprehensive.

So, we are trying to address the HR model differences, and we believe that a representation of the structure could help us to ensure ourselves about -- what is it? -- the adequacy and the completeness of the event being analyzed. But the suggestion that Dennis had before to eventually create a web-based construct that would help the analyst to provide inputs to the right questions may be a way of creating the kind of constructs that would be more complete and address those kinds of limitations.

MEMBER BLEY: You know, part of this jumps off the page here. If this were your template, and for reasons John indicated earlier, I would hope it wouldn't be, it ought to have -- you ought to be able to go to any node on here and either have a cross-reference or click on it, if you have automated yourself, and get a real explanation of why it branches, why it doesn't branch.

Come over here at 8; it ought to ask all those questions about 8, and did you come into this sub-tree under multiple conditions that you ought to look at? Why didn't it branch at operator turns it off? Over here, he started it automatically because it didn't start, and that is the first thing you do, is if it didn't start, you start it. You don't think about how much feed I need. So, it is pretty much the same situation.

But everywhere you go in here, you ought to be able to get a little story that tells you why it is the way it is. I am assuming your idea is, if you had this template, that even though you have picked up physical modeling things at a high level from some PRA, the people who are using it would have to find out their representation of that part of the hardware.

I wonder how, just off the top, I wonder how general these can be. Because even if you go Westinghouse plant to Westinghouse plant, you get to a few that will have motor-driven main feedwater pumps, and things are a little different, if you have that, and the reasoning is a little different. So, it is worth thinking about --

MR. MOSLEH: Then, it is a general model. It could be general at some level of abstraction that would cover, for instance, if you look at the master logic diagram that we used for identifying initiating events for a PWR, at the highest level of abstraction it is very complete because it looks like the physical universal physics that apply to a nuclear power plant. And it tries to kind of identify the sub-events or sub-classes that contribute to those states of the plant.

MEMBER BLEY: When I do that for a specific plant, I build that model, kind of, okay, I still ought to describe all those things we are talking about. But if I propose that as the general one for everybody to use, then it needs a lot more guidance embedded into it.

MR. MOSLEH: So, the point that we were trying to make was that the art or the science of this thing, if successful, is to find the right level of abstraction where the generality is there. Yet, it actually provides room for people to add the specifics. If you make this too prescriptive, if you try to cover general modeling in the sense that every plant that you see, all their details are in the model, that is neither the objective here nor is it very meaningful or practical.

We want to drop this down to some level of abstraction and generalization, so that the plant-specific differences fit those. Like, for instance, if you look at the functional decomposition of a plant, and, okay, for a Westinghouse four-loop, and this is kind of a general function step they have, use that. Maybe you stop at that level, as opposed to going to kind of the last level of details in terms of what pumps or valves are involved.

We haven't really found exactly what we mean or what we see, actually, as the right level of modeling for this generic template. But I think I agree with you, I think everybody agrees with you, that the intent is not to cover every difference that you could see in any given plant that you pick at random to analyze. It is to provide coverage and completeness, comprehensiveness, at a high level, drop it down to a level, and you stop at that level. Then, with guidance, we are going to help the analysts to fill the gaps or the plant-specific differences.

Also, as an example of kind of the dropdown menu, like these boxes that Song-hua has here, kind of a in a sense, it is kind of the dropdown boxes that you can see in a software, that it provides the context and the information per path, with starting with the generic list, and then modify as necessary. You know, remove or add material to it. So, that concept I think is very much what I think would work here, as I think you suggest.

MS. LOIS: But the recommendation, they worry that, what we hear is, to create constructs that people will take for granted and apply without thinking. We take that as a suggestion.

CHAIR STETKAR: That is exactly right.

MS. LOIS: And we are going to address that.

CHAIR STETKAR: I think we hear you kind of feeding back the right things that we hope to hear, but there is the concern that, if you just see what's on paper and read what's in the report, it seems to be leading strongly in that direction that we are cautioning about.

MS. LOIS: Absolutely. That is a lesson that we heard --

CHAIR STETKAR: I'm glad you --

MS. LOIS: -- loud enough.

(Laughter.)

CHAIR STETKAR: Good. Okay, let's continue with this example because I know it is important to see how we eventually get to throwing numbers into that box there.

MR. SHEN: Yes. Okay. These several pages just try to say how do we, after we have identified the safety function, then how do we break it down to different paths or just try to catch all kinds of -- we can think what these may, a combination of the results.

After that one, this is a really important step. Just for any identified branch, we need to address the context of the branch.

I think there is one job that is underdeveloped, but it is, basically, all the context for any branch point that we will convert to a PSF status. According to the context for a certain branch point, we need to identify what is the PSF status for this point. And then, based on that one, to decide what is the fatal mechanism that may get a higher chance to get a fail. Now, also, conversely, what is the SCP for the human failure events already at that point?

Here, let's try to say, after we identify the first is very important, just try to address all the context in this branch point. This context is in the branch point, usually incurs two things.

The first is the prior condition. The second one is what the operator has done before this branch point. Now this plant condition is also what the operators have done that we need to bring up from the very beginning.

I also tried to put what is the information for this space, for example, in this point, that we need to do some actions. What is the information that is needed for them to make a decision to take these actions? That also is part of this context over here.

This I just tried to use one example. After we build up this context for each branch point, the next step, we just try to connect this one to the so-called mid-layer, the fault tree model, and then to break it down to the fatal mechanism. Then, from fatal mechanism, to break it down to the PSF, to see what is the story at this branch point.

For the first one, I chose this sequence. If the AFW automatically starts, but the operator manually turns it over. Then, we enter the FR.H-1, Step 1. We ask them to check the plant conditions. If the condition is they think this is not necessary for the AFW, they may still jump out. So, this scenario could replace one of the fatal paths. They didn't do anything for AFW and may go to core damage.

So, this is including two different human actions. The first one, they turn off the AFW system. Then, they entered the FR.H-1, Step 1. They evaluate the plant condition. They still say we don't need the AFW once the generator is almost started. So, they jump out.

We just try to see, to build up the fault tree model, and then from this fault tree model, we can create the likely cutsets. But these cutsets are for fatal mechanisms. But these cutsets, we just try to tell people what it is the story out of the possible combination, to go through these failure paths.

This is the context I suggest to for this other branch sub-sequence 1.

CHAIR STETKAR: Let me stop you on this because -- go back. I read this one in your report. I'm just a poor systems analyst, and I don't really understand cognitive psychology, but I am curious why, on a tube rupture event, we get a high steam generator-level turbine trip. How does main feedwater flow control work in a real nuclear power plant?

MR. SHEN: Usually, I think a narrow range to the --

CHAIR STETKAR: How does main feedwater flow control work in a nuclear power plant? What happens when steam generator level starts to increase to -- what does the main feedwater flow control valve to that steam generator do?

MR. SHEN: Yes, the steam generator level controls for three different, usually, that is the loop that has three different --

CHAIR STETKAR: This is a three-loop-specific one plant in the world?

MR. SHEN: All four-loop. They usually control that, all the ones, but for this one, for this regular trip, they just need the one --

CHAIR STETKAR: What does main feedwater flow control do to a steam generator if its level is increasing?

MR. SHEN: It will reduce the flow rate.

CHAIR STETKAR: Okay, it will reduce the flow rate.

MR. SHEN: Yes.

CHAIR STETKAR: Does that mean the level is going to go high or just does it mean that main feedwater flow to that steam generator will be reduced so imperceptibly that an operator won't notice it?

MR. SHEN: Essentially, I can tell you --

CHAIR STETKAR: He has got primary feed. The level is increasing. There's a three-point control. You are managing feedwater flow and steam flow with a level override. If level increases, you reduce the feedwater flow, so you get lower feedwater flow to that steam generator. The level doesn't go up.

MEMBER BLEY: And the bias is on mass flows.

CHAIR STETKAR: There is an override usually on the level.

MR. SHEN: There is one swelling because you know the RCS --

CHAIR STETKAR: The water flow will go down to that steam generator.

My point is that in many, many plants you will not trip on high level in a steam generator.

MR. SHEN: You know, the essential --

CHAIR STETKAR: You will trip on low pressurizer pressure or low pressurizer level after the VCT goes down. It is a long-developing -- unless you have the biggest steam generator tube rupture I have ever seen in my life.

Now why is that context important? The context is important that, if I'm an operator, and I saw the plant trip on high steam generator level, I am now focused on the fact that, oh, my God, something is going on, that I've got too much stuff going into my steam generators, and I had better be careful about that.

If I saw a plant trip on low pressurizer pressure or low pressurizer level, I am not so concerned about steam generator levels, am I?

MR. SHEN: There's one thing here, because the steam generators, a phenomenon we call the swelling, yes, because the RCS --

CHAIR STETKAR: It's called the shrink, too.

(Laughter.)

MR. SHEN: Yes. It is very high-temperature water. If the high-temperature water goes there, there's more bubble. Even though you have a control in the feedwater flow rate, the swelling can be suddenly to get a high level to touch --

CHAIR STETKAR: What happens to steam generator levels when you trip the reactor and turbine? Which way do they go?

MR. SHEN: They will go down. But for this RCS, for this one steam generator, they may keep going up because it depends on what is the -- more important, if you have full open AFW, the AFW will not be stopped. So, the AFW keeps --

CHAIR STETKAR: Does the plant have AFW flow control, like a lot of plants do?

MR. SHEN: No. AFW flow will not be controlled by the level. Those are controlled by manual. Usually, you've got an AFW signal --

CHAIR STETKAR: Now wait a minute. I know many plants that have automatic AFW flow control.

MR. SHEN: That's true?

CHAIR STETKAR: Yes. Certainly, most of the newer plants that are coming online do. So, be careful.

I am trying to provoke a response, but the point here is that, if we are developing examples, this comes back to something that Erasmia mentioned earlier, the integrated understanding of the plant response context, Point No. 1. Human reliability experts ought not to develop examples of models out of the context of people who understand how plants work, and people who only understand pumps and pipes and valves ought not to be developing models for human response, just because I can think of pushing a button, you know, to solve any problem.

So, be really careful when you are developing these examples to make sure you consider that integrated plant response and, more importantly, to emphasize the fact that the people who develop these models need to have both of those skill sets.

MR. SHEN: Yes. But I think this is not wrong because this is our trust in the procedure. EOP, there is one signal for you to rupture. You need to check if the main steam generator level uncontrolled increasing. That is a simple thing to identify that is due to rupture.

So, I think after due to rupture, even though you say you have to a flow control, but your level still is increasing because in Westinghouse, if for something like --

CHAIR STETKAR: Be careful. You are generically calling all Westinghouse plants plain vanilla. And I will tell you all Westinghouse plants are not plain vanilla. Be careful.

MS. LOIS: Point well-taken.

CHAIR STETKAR: Just be careful.

MS. LOIS: Sure.

CHAIR STETKAR: Indeed, if you have no automatic auxiliary feedwater control, level in the ruptured steam generator will, indeed, continue to increase. Now why is this important? You happened to have selected a very, very interesting operator action for your example, and that operator action depends on the context.

The way I, as an operator, think about that context is, if I am predispositioned now that I went out on high level initially, and auxiliary feedwater has come on, and I have an uncontrolled increase in level, I would certainly be somewhat more predisposed to take perhaps untoward actions to turn off auxiliary feedwater.

But another plain vanilla Westinghouse plant that has main feedwater flow control that, indeed, limits the amount of level increase and automatic auxiliary feedwater flow control, would predisposition me completely different to the sense that I have problems with too much water going into my steam generators.

That type of thought process needs to come out of your guidance on how to think about these scenarios because that is all part of that context.

MEMBER ABDEL-KHALIK: I have a big-picture question. Ultimately, this entire effort is going to be anchored into empirical validation of the human error probabilities, and those will come from operational data. Hopefully, you are not going to find a whole lot there. They are going to be anchored primarily in simulator experiments.

The whole sort of underlying basis here is that these probabilities are dependent on the context in which the operator is taking that action. You may be able to duplicate the context in appearance, that this thing has failed, that thing has failed, this thing is available, this thing is not available. You may be able to do that in the simulator. But the operator knows that. He knows he is working in a simulator, right?

So, this just doesn't make any sense.

MR. MOSLEH: You mean modeling?

MEMBER ABDEL-KHALIK: No, in terms of being able to get real data that would allow you, real simulator data that would allow you to duplicate the context for which you can get the data and compare to validate the model. Because you are not going to get these contexts generated randomly during the simulator experiments. Otherwise, you will be waiting forever, right?

So, in order for you to duplicate the context, the operator has to know that, okay, we are in this situation. The reactor didn't automatically trip. You had to manually trip it. Aux feedwater didn't come on automatically. You had to initiate it manually. And we are now in this situation, in this step of the procedure, and you are entering FR.H-1. Well, gee, that is totally different than reality.

MS. LOIS: Which reality is?

MEMBER ABDEL-KHALIK: The reality of ever being in that scenario under real conditions vis-a-vis the sort of simulator sort of scenario that you have forced the operator to enter into.

So, I am just wondering, how realistic are these data that you are going to get, and whether or not you really are going to be able to empirically validate whatever model you are going to come up with.

CHAIR STETKAR: Ali, do you want to say something?

MR. MOSLEH: Yes, I think let John.

CHAIR STETKAR: John?

MR. MOSLEH: John, and then I will respond.

MR. FORESTER: I guess two things.

CHAIR STETKAR: Just identify yourself.

MR. FORESTER: Oh, I'm sorry. John Forester, Sandia Labs.

I don't think the claim has ever been that we would have empirical data from simulator runs for all conditions. There's always going to be an expert judgment process. Maybe you run some similar kinds of scenarios. And there are certain scenarios you are not going to be able to simulate. You can't run them because it required the operator to know something that you can't tell them. So, there are some limitations of what you can do there.

But, generally speaking, again, the notion is that you find some basic data about some relative kinds of scenarios, and you are going to have to use expert judgment or some other technique to come up with a quantification approach.

MEMBER ABDEL-KHALIK: But we were talking about this chart and different number 8s. The heart of this effort is to distinguish between these different points by saying that the error probability depends on the context. And if you are telling me you're not going to be able to generate simulator data that would allow you to validate whatever differences you are going to get, then how do I believe whatever you come up with?

MR. FORESTER: We don't have that information now, and we are doing it.

MS. LOIS: We have an answer in the back?

MS. BARNES: Well, I don't know if I have answer.

(Laughter.)

I'm Val Barnes. Is this on (referring to the microphone)?

Okay. I'm Val Barnes. I'm the SL in Human Factors in the Office of Research.

I just wanted to respond to this comment. If I understood it correctly, I would want to say that in most studies that are done with regard to human performance, there's typically a good relationship between the kind of phenomena that we are able to produce in a laboratory or simulator setting versus what we might observe in the real world through naturalistic observation. By designing your simulator scenarios to account for as much of the real-world variability as you are able to identify going in, it increases the fidelity of your laboratory situation for reality. So, that the relationship between what you see in the lab does have a good, is predictive of what you will see in the real world.

And my second point is our entire operator licensing process is based on operator performance in simulators. If we didn't have good confidence that what occurs in a simulator is predictive of behavior in the real world, then we have an issue as an agency in terms of our licensing process because we have already accepted that, if our crews are able to perform in the licensing examination situation, then we will have confidence that they will be able to perform in circumstances that they might have to deal with in the real world.

MEMBER ABDEL-KHALIK: I guess I think you missed the point.

MS. BARNES: Did I misunderstand your --

MEMBER ABDEL-KHALIK: I think you missed the point.

MS. LOIS: Can I try and answer it?

MEMBER ABDEL-KHALIK: Yes, please.

MS. LOIS: I believe, if you move on to

the second page, to the other page where the context has been created, what we tried to do is the combinations of hardware failures and potential misleading steps in the procedures, et cetera, all of those combinations lead or we believe that we can characterize the context presented to the operator on the basis of these combinations of failures in more generic terms, in the sense that the operator does not have the information, adequate information, regardless of the reason, that reason, or is not trained enough, or whatever.

But the bottom line is all of that we are getting through a detailed example which eventually would lead the characterization of the context in more generic terms. That generic context, if you wish, is going to be through some simulator exercises or examining the historical events, et cetera, to give us a basis, an empirical basis.

But there's no way you can empirically validate each of those paths. Absolutely, we can't do that.

MEMBER ABDEL-KHALIK: Right. If you go back to that slide that shows the multiple number 8s, I mean that is -- I am sorry to take so much time, John.

CHAIR STETKAR: No, that is okay. Go on.

MEMBER ABDEL-KHALIK: Okay. Again, we are trying to distinguish between these points, right?

MS. LOIS: Yes.

MEMBER ABDEL-KHALIK: As I sort of indicated before, if you go through the whole process and you come up with probabilities of 10 percent, that range between 10 percent and 11 percent, then we are just spending a lot of effort on something that is not really worthwhile.

But the question is, let's say we come up with numbers that vary between 10 percent and 100 percent amongst these different number 8s. How would I know whether or not that is something to believe?

MS. LOIS: And what I am saying is that the difference from 10 percent to 100 percent would be based on some context characteristics that are in a way possible to validate empirically through simulator experience, because those differences are not going to be associated so much with the individual plant equipment failures or procedures, but are going to be characterized more generically. If you have lack of information or lack of training or lack of procedures, the combination of that would give you one aspect of the failure event, and a different combination will give a different aspect of the failure event. That is where we are leading here. That could be validated at a certain level.

MEMBER ABDEL-KHALIK: So, really, the context is going to be sort of put forth in more sort of generic terms --

MS. LOIS: Absolutely.

MEMBER ABDEL-KHALIK: -- rather than specific terms, and in a few categories?

MS. LOIS: Yes.

MEMBER BLEY: I think they don't know for sure how that is going to shake out.

There's a parallel project going on that James Chung is running over here that is trying to go through real events, real-world events, and identify the same kind of characteristics. So, the more of that information that is developed, and the more simulator data, and like the things they have been doing at Halden in the last few years, they are trying to exercise those parts of this model that people think are most important, and then looking and seeing if it really has an impact on the operators.

So, the combination of seeing what's coming out of Halden and the work on looking at real events with an overlay of these same kinds of performance-saving factors and the -- what did we call it? -- the mid-level structure that underlies it, will give us much more confidence, I think.

MEMBER ABDEL-KHALIK: But that is the point I am trying to make, John. If you force the simulator scenario -- I'm sorry, Dennis --

MEMBER BLEY: It happens all the time.

(Laughter.)

CHAIR STETKAR: No, it doesn't that way.

(Laughter.)

MEMBER ABDEL-KHALIK: If you force the scenario to get to a specific point, that is not the same as the operator getting to that point through a sequence of errors.

MEMBER BLEY: Well, that's true, but that is not the only point involved in all this work now.

MEMBER RAY: Yes, it is the trouble of getting enough data, I think that Said is talking about. The performance-shaping factors, take operator -- I've not got the right -- fatigue. That is a performance-shaping factor, right? Okay.

So, if you want to try to assess what the effect of operator fatigue is on performance, it takes a lot of data to do that. It just seems sort of like something that is beyond imagining how on earth you would gather all that data.

So, the alternative is to just use expert judgment, I guess, and attempt to derive performance-shaping factors that reflect expert judgment. Trying to get it empirically seems beyond the pale.

CHAIR STETKAR: Let me see if I can pull back a little bit. The availability of empirical data to benchmark human performance is common to every human reliability analysis method in existence today. It is not unique to this proposed methodology. It is not unique to any other methodology. That is a universal concern that everyone expresses. So, that is not necessarily a problem that this particular methodology proposes to solve any differently than anybody else has not been able to solve it. And it's always going to be a problem. It is for a variety of the reasons.

It is important -- and Erasmia mentioned it earlier, and we've all touched on it -- it is important to have a methodology that forces the analyst to think about these different contextual contexts. In other words, to think about, gee, there may be a difference between No. 8 sub-7 compared to No. 8 sub-3. Perhaps the methodologies in existence don't adequate force the analyst to at least acknowledge that that difference exists, to at least put in the model that there is an 8 sub-3 and an 8 sub-7, and there's enough difference about the context that it is worth acknowledging that those are different.

Now what actual number to put in there, and how relevant that is to actual human performance, is a different issue. First, you have to structure the model and acknowledge the fact that you need to account for the fact that there are differences.

But if we try to solve all of the problems of fidelity of every number that goes into one of these models as the goal of this project, of the SRM, we are not going to get there.

MEMBER RAY: Well, John, granted, what you just said is true. We do live in an environment here that is a regulatory environment. I think all that is being said is that there's a danger of overdriving the conclusion that one would potentially draw here; that is to say, to forget the qualifications and the limitations that you just recited. Right? I mean that is the way we tend to do business.

CHAIR STETKAR: On the other hand, some

of the things that Dennis mentioned, without thinking about simulators in the context of collecting countable data, numbers of failures and numbers of attempts, but using the experience from simulators and reviews of actual operating performance to say that, oh, now that I've identified 8 sub-7, that there's some experience that, under those particular conditions, the operators are quite likely to fail. We don't know whether it is .6 or .7 likelihood of failure, but under those particular conditions, we have evidence that there is a high likelihood of failure.

You can't quantify precisely to seven significant figures what that likelihood is. There's obviously uncertainty, but it is more likely to be in the .6 to .7 range than 10 to the minus 4.

MEMBER RAY: I don't know. Maybe so. I guess enough has been said, at least in my thinking.

The main thing is just that, are there insights that we can gain here? Of course, there are. Is it worth doing? Yes. Is it possible it can get overdriven to reach conclusions that aren't justified? That's true as well.

MS. LOIS: I do want to make a statement here, with all due respect to ATHEANA developers that are here, Dennis and Susan and John, the concepts of the various deviations has been an ATHEANA concept, a very strong one.

What we tried to do here is to make it more explicit and more -- what is it? -- presentable. Probably we were successful or not successful. But it isn't something that it has been invented by this group. Okay?

CHAIR STETKAR: Let me ask just a short procedural question here. It is 2:23. At 3:30, we are going to lose -- how many members are we going to lose?

MEMBER ARMIJO: The meeting?

CHAIR STETKAR: Yes.

MEMBER ARMIJO: There's that ABWR.

CHAIR STETKAR: ABWR. Dennis?

MEMBER ABDEL-KHALIK: Half an hour.

CHAIR STETKAR: The question that I have is we didn't have a break scheduled this afternoon. We are supposed to end at 3:30. I don't think we are going to end at 3:30.

Should we take a break? Should we push until 3:30 and take a break at that time and reconvene?

MEMBER RYAN: Let's give everybody a bio

break for 10 minutes.

CHAIR STETKAR: In 10 minutes?

MEMBER RYAN: No, for 10 minutes.

CHAIR STETKAR: For 10 minutes now?

MEMBER RYAN: Now.

CHAIR STETKAR: Let's do that and sort of rethink things because it is pretty clear that we are going to continue past 3:30.

MEMBER BLEY: Before you bang your gavel --

CHAIR STETKAR: Okay.

MEMBER BLEY: -- and we take that break, I am going to miss part of this, obviously. I am disappointed to do that.

The piece we haven't heard yet, and I don't know much time we will have for it, is really the glue that ties together some things that have been very loosely coupled before.

A quick question, in case I don't have time later. We've got the slides. Is there a report ready now or is there one in the foreseeable future that will explain the -- I forget the buzzwords you guys used -- the mid-layer model?

MS. HENDRICKSON: So, the only written work that has been out now is the paper that will be presented at PSAM.

MEMBER BLEY: Okay. That is really short.

MS. HENDRICKSON: Exactly. It's very short. It's very short.

MEMBER BLEY: That's of high interest.

CHAIR STETKAR: Let's see if we can figure out, if this meeting -- well, let me first -- (bangs the gavel). We're off the record now.

(Whereupon, the foregoing matter went off the record at 2:22 p.m. and went back on the record at 2:35 p.m.)

CHAIR STETKAR: Okay, we're back in session.

And again, I apologize for all of this confusion. You came with an awful lot of material. Obviously, there's quite a bit of interest about it. So, we just have to work with these constraints. And I apologize.

What I think we should plan to do, just to have some sort of closure, is not go any later than 5:00. I mean I think by that time we will be exhausted anyway. But I think we should probably plan to go that long. I think there's enough -- I would really like to hear about that middle level part of the model because I think that is a real key element. I think it is important to hear what's going on in the area of empirical information, anyway, because that tends to -- I don't think it will answer all of Said's questions, but at least provide some information about what's going on in that area.

With that being said, let's see if we can continue on with the example here.

MR. SHEN: Okay. This example goes through Steps 1 through 3 to build the CRT and sub-CRT tree, and then review the procedure, to write down the context for this branch point that we are interested in. Usually, for this CRT, we can find any sequence we are interested. You may go to the core damage.

So, here we just try to use one sequence like this one, how to reconnect the mid-layer fault tree. For each branch point, we need to build up the context for this branch. This context usually will tell you the story, before this condition of this branch point, how do we get to this point. What is the plant condition and what operators have done before this branch point. And based on this information, we try to build out the mid-layer fault tree.

Because this is two branch points tied together to go to this sequence S1, so that means we have one of the mid-layer fault trees for this branch, another for this one. We try to build up the generic mid-layer fault tree for any branch point. But different ones, for each fault tree, it will be decided by that context and, then, to decide which failed mechanism is there.

Based on this one, we go back to Dr. Mosleh who described in the morning, let's see we have an IDA model. You said your IDA model, we just try to base it on this decision tree. Usually, for one human action, you may fail because of the information collection failure. You didn't collect the correct information. So, this is one failure path.

And even with your correct information, necessary information, you still may make a wrong decision to make this actually fail. Then, even if you make a correct decision, you still to perform these actions still may make something wrong, push a wrong button or anything. So, either way may fail your actions. So, this is the base idea with IDA. You may fail the "I" and the "D" and the "A".

For each branch point that we just say this branch point may fail the "I", "D", or "A". So, we just fill out this sequence of failing branch point 9 and branch point 11, and branch 9 does it in this branch. Here is another branch. This is where you fail the "I", "D", and the "A".

In the morning, I said Dr. Mosleh has to say "IDA", maybe have some sub-loop. I developed these ways in parallel of a psychology person who is developing in parallel.

In my version of this development, because I just simply, by "D" and "A", without any sub-loop, teaches the "A", just "A", but under "I" we have another loop IDA. Because the reason for this one is I found out there are two kinds of "I".

The first one I called a "cue". The cue is a starting point. You start your cognitive process for any kind of human failure event or any human activity. You start with this "I". But, usually, that starting point is not all the information, just like you could rupture your radiation alarm. That is a cue point. You start cognitively; you know something is wrong. You need to collect information, to make decisions. But, therefore, that cue is not all of the information.

After you've got the cue, you need to decide what information you need to make a diagnosis, to make a decision. So, the first cue of these usually call them the passive information, even though they don't have an intention to do it, because a lot of times they ask you to take your attention; you have to do it.

The second one we call data for analysis. That is based on your cue. Then, you base on your knowledge your procedure. You need to collect more information. That information starts from your intention. So, that we call the active information because you need to be active to collect it.

This, too, has two fatal mechanisms. The decision, then, for the data, the second "I", you want the decision. You need to decide which information you need, and you also need to go there to check the indicator or to check the panel. So, also, you want the action. Of course, there we have reading arrows or kind of correct information, but the action arrow. So, I just put another layer of IDA under this "I".

So, this "I', this is the big fault tree we start from, where B9 and B11, and here B9 may fail in the "I", fail in the "D", and fail in the "A".

Failing in the "I", we can see to another. Because they are too big, we just use a different connection to connect together.

Here I used these gray highlights. These gray highlights are the pure as for judgment, just try to say, for this branch, which one is the dominant failure move for this one? Just recall what we say in B9. B9 is the commission arrow. "Operator turn of the AFW" system by themselves. Usually, we see the information is passing wrong. Usually, they make a wrong decision. So, we are focusing in this decision part.

And the second one is after they enter the FR.H-1, they may still jump out of FR.H-1 because here we just say they make use of the information. Because here you will go to FR.H-1, Step 1. We ask the operator to check the current plant condition, if this is necessary or not necessary. So, you have included the information and check it. They may check some wrong information, and, then, with this wrong information, they make the wrong decision. So, here the information and the decision both are important.

Now, basically, what you saw on this one should not decide by here, should be decided by PSF, which has the PSF go back to the context. The context tells us what is the operator's mental status. And based on that mental status, what is the PSF status? And the PSF status is to decide which fatal mechanism is it actually.

Here the basic idea we have developed is mid-layer fault tree, just say, based on IDA, we just try to simplify the cognition process. We just say you have "I" stage, "D" stage, and then "A" stage. In each stage, you may have a different fatal mechanism. We just try to break it down to more detail.

This is transfer to 2. I would just say here that this is the fault tree, and here is the 2. That is the decision arrow. I think maybe we can go to here, then the information arrow.

Here that is the scenario of the fault tree we developed for information failure. For information failure, because usually the cue we also separate, have two different kinds. It is why we call it rule-based cue, and not a technology-based cue. Rule-based cue is more like a procedural step. The procedure asks you to check something, and that step we are easy to link to a rule. That means we have got a procedure.

Another especially if there is some low-point shutdown, for some situations they don't have a very clear cue for this information to connect to your situation. So, like a loss of inventory, loss of inventory there's not a lot there. Then, they just have some RCS level is slowly decreasing. So, that is not very strong evidence to link to some rule. The rule here, that means some procedure, has to rely on our prepared procedure.

CHAIR STETKAR: Can I ask you just kind of a pragmatic question? Why do I need those flags here if this is a thought process and not a push-a-button, quantification tool?

MR. SHEN: This flag here, this is for modeling purpose. Because sometimes we think this whole branch is not likely for this situation. We can use this flag to --

CHAIR STETKAR: Well, I understand that in the traditional sense of hardware fault trees. I'm asking you whether this is the tool that I'm going to push a button and plug numbers into and quantify my model.

MR. SHEN: Yes, here there is one reason. For some situations, just like later we will see an example of a low power and shutdown. For low power and shutdown, in the beginning your loss of inventory, you don't have any around. You don't have anything to clearly to tell you what happened.

So, that means that this branch is completely not necessary. In this situation, we just use this flag, say this branch, this is your best cue; it does not exist here. So, we just try to use this flag to say it is not there.

And also, here, this is for knowledge-based. We just try for the conservative purpose. For example, for a U-tube rupture, you have very clearly simple radiation alarm. Then, you say you don't want to use this radiation alone. You can take some credit for some not directly information, say you were a success. We see that is not likely.

So, in this case, we just force the people to say denied this power. We don't want to get credit from here. Just directly say this branch will be failed; just use one branch to do it.

MS. LOIS: So, the attempt here is to have a representation in this fault tree structure of the different kinds of information arrows or for information, for example, it may be this fault tree or another fault tree, but this construct here would help you, when you are dealing with an information type of error, to identify potential failures that are associated with information type of error.

So, in a way, we are looking at generic inventories. Am I right?

MR. SHEN: Yes.

MR. MOSLEH: And also, I think John's point is, do we envision that at some point, once you have done your analysis, that this will actually be kind of a push-button? Actually, that is an option we are looking at.   Once you have put all the knowledge and information, it would be nice to be able to dedicate some of the effort to a computer to sort out the differences.

So, we are using language where it gives us the option to actually do --

CHAIR STETKAR: You know, I can see that, obviously. What I am looking for here is the logical constructs so far are identical on each side of that top or gate. So, since we have now defined that something is either rule-based or knowledge-based, and it apparently can't be both, I need to understand what differences there are down below that make a difference in putting us into either Bucket A or Bucket B.

MS. HENDRICKSON: So, one of the things

that is missing here, where you see the little circles down at the bottom, that will eventually be where the PSFs are.

CHAIR STETKAR: That's what I was hoping to hear.

MS. HENDRICKSON: So, what you are going to see is the difference in the PSFs primarily.

CHAIR STETKAR: Okay.

MR. MOSLEH: The mechanisms are different, and therefore, you have --

CHAIR STETKAR: Good. Okay.

MR. SHEN: One major reason I put this flag here, just to try, you know, this branch we know does not exist here. Only this branch is working for this situation. We don't want too much burden to go every single past event here. So, we provide just the number, and later we say, oh, it does not exist here. So, that is easier to deny this one. Also, I think that we also have another flag.

MEMBER BLEY: Before you leave that last one, if we could go back to it, there's one I was looking for. I might have found a home for it, but it has troubled me. Well, I mean in a lot of nasty events it seems to happen.

That is something about the context leads people to see what you are calling a cue here, but not recognize it as a cue for the situation that is going on here, to dismiss it: "Well, the high level in the sump is because somebody was washing down sump screens." Well, the meter on the peg at Chernobyl was because they didn't -- you guys didn't know how to set up the instruments. An explanation to quickly dismiss, so that you don't even catch them as cues.

Where does that fit here?

MR. SHEN: This cue, essentially, the cue here, we come down here. Essentially, they fail the information correction. I just described before, you know, this is a failure. I still have an information arrow and a decision arrow in information collection, and there is an action arrow in information collection.

Yes, so here we just say information arrows and focus on the source arrow. For example, instrumentation failure or --

MEMBER BLEY: Well, the case I was talking about isn't an information arrow.

MR. SHEN: Yes.

MEMBER BLEY: You have information coming to you. You interpret it wrong.

MR. SHEN: Yes. So, that is under here.

That is under "D". We just try to say this is --

MEMBER BLEY: No, that's action. I guess it would really belong in "E", but we don't see what's under "E". That is a situation that occurs an awful lot.

MR. MOSLEH: It is either under "E" or "D", but it is there. You know, this missing --

MR. SHEN: Yes, this is a decision arrow in information collection. So, what you see in Chernobyl, I don't think that this would work as the cue. That should be a knowledge-based cue.

MEMBER BLEY: Now the other thing I was going to ask you about, and we will look for your presentation, but I don't know if we will get to it, but we will look for that. I know a number of people who do this kind of work who say emergency operating procedures are an encoding of knowledge and using them as actually a knowledge-based procedure, rather than a rule-based thing.

It seems as if you have categorized following EOPs as rule-based. Is that right?

MR. SHEN: Yes. Yes.

MR. MOSLEH: However, I think the label is maybe misleading. Because if you look at what we consider in the mechanisms, they do not kind of stay limited to strictly rule-based in a literal sense.

We have to label these things to generally say, well, are they following procedures or are they thinking about the problems because they don't have a procedure?

MEMBER BLEY: So, on this chart, the flag of rule-based cue is really saying they are following procedures? I wouldn't have guessed that, but --

MR. MOSLEH: Yes. Well, in the decision like this -- go back to this one. This is like in a rule-based cue; it is really instructions or things that are coming from procedures or a set of memorized procedures.

MEMBER BLEY: Okay, and figuring out whether the procedure is applicable right now is mixing the two sides again, I suppose, which is something people need to do all the time while they're using the procedures.

CHAIR STETKAR: That goes back to my, why must I be either --

MEMBER BLEY: How does it help?

CHAIR STETKAR: -- 1.0 on the left side and 0.0 on the right side, or vice versa? In the real world, you tend to be in both halves of that little model simultaneously for essentially any scenario that develops in your plant.

MR. MOSLEH: Let me address this now. In the mid-layer modeling, one critical part, of course, is the "D" side, the decisionmaking. It really covers two things. One is the process that you are digesting the information and understanding the situation. Then, based on that, you make decisions. You know, you make choices between alternatives.

Now in there, if I now am going to the IDA or IDAC kind of approach that we developed some time back, we say this process has a few characteristics. Often, if not always, the operators are goal-oriented, and then the goals are created or provided to them through the procedures. Then, to address those goals, they have a set of strategies or approaches to follow.

One is procedure-driven, say purely. The other one is purely knowledge-driven, and there's more. And one of those strategies, the hybrid, the mix, which is the most common mode of response. Operators think and read the procedures and follow.

In the work I have done using this IDAC model, IDA model, in simulation, that is what we implement actively. Here we have been debating whether we have the mixed mode separately.

So, we have a procedure. We have a knowledge-driven and the mixed mode. And we haven't really quite settled as to what would be kind of the best, whether we need three branches or two branches, and then how to allocate and pick.

CHAIR STETKAR: I guess I am asking, why three or two? Why not just one and evaluate within the context of the scenario what type of information is available to the operator? When I say, "information", guidance is available to the operator.

MR. MOSLEH: The reason for two or three is that what kind of the failure mechanisms or the underlying PSFs may be different.

CHAIR STETKAR: Yes.

MR. MOSLEH: That's it. They really become two different things.

CHAIR STETKAR: I will wait to hear about that part. Okay.

MR. SHEN: Okay. Go back to this fault tree. We say, out of this "I", we have a rule-based cue and a knowledge-based cue. Each side, we have information source failed. Then, we also have where they make the wrong decision, to collect the wrong information, or they just simply read the indicator wrong to get the wrong information. So, this is another layer of IDA under this "I".

Go back to here. This is a decision arrow. Originally, we just say that this, the simple fact is it is a problem. Sometimes we don't know what is the decision arrow, what is the information arrow for this modeling purpose, to simplify this problem. Just like a lot of people say, during the instrumentation failure, for example, loss of heat sink, the operator doesn't have -- it is just like the Halden project. They have some complicated tests. They don't have the information. So, in this case, that is a decision arrow or an information arrow. We just try to say it because it is an instrumentation failure, they don't get current information. So, it is not a decision arrow.

We refer to this decision arrow just simply for to say you've got the necessary information and still make a wrong decision. So, if you didn't get correct information, we still call this the information arrow, based on this concept, to bring it down to here.

Finally, we just try to break it down to what we call these failure mechanism or failure mode. Essentially, we just try to develop this general fault tree to break it down, to limit here numbers of the failure mechanism. All these failure mechanisms who come in different combinations to make your human failure event. That goes through this one. We just try to anticipate a mechanism, a cutset to tell you the story of why the operator under what conditions to make a wrong decision.

This one I tried to build up in the staff 8.0. In that one, we can load this one together, minimal cutset. Like the cutset before, to get this cutset, I just used my personal judgment to say I've got this situation. Some failure mechanism does not exist here for this one. So, we just say that into zero.

Now all other failure mechanisms, I say it is likely to get this kind of failure mode. I just used 10 to the minus three. The major purpose is not to create the failure probability. The major purpose is just to try to see under what kind of combination to get this failure path. So, it is possible to use current tools to get this one.

This is causal No. 1, causal No. 2, causal No. 3. If we have all the causal list here, from here we just say this combination together does fail or pass. Then, we can see what is in the branch point 1 and what is in the branch point 2.

Also, currently, we don't have that version yet. But, later, all these base events still can break down to the PSF label. Then, we can represent this minimal cutset to be a cutset of the PSF. And it goes through the PSF. We just say, what factor to affect this current situation, to get this failure mechanism combination together? And that goes through the PSF. We just say, if there were two PSFs identically to fail in the first and the second one, we can see that there may be a common-cause failure. That dependent failure is over there. It just goes through here, and more easily to understand the whole story.

This is I just tried to run that cutset for this Branch Point 9 and Branch Point 11 to come back together, to go through this one together.

The next one, I just tried to use the same SRM principle in low power and shutdown situations. This low-power and shutdown situation I chose from one STP report. These STP reports is in one of power stations. Currently, they are doing some testing during the low power and shutdown. Just before they enter the mid-loop operation of the power plant station, they try to do things that trace the test. Trace the test to make some general trends together, the temporary loss of electricity.

After the loss of the electricity, temporarily they have got some pump that will pop open and cannot close again. So, that is one is a path to lose their RCS inventory. The RCS inventory goes through there to losses. So, this page just tries to say the current condition before this event occurred.

Fortunately, you know, this event is before they enter mid-loop operation. If they are doing something in the mid-loop operation, then they get more problems there.

This sequence that I have described, as I mentioned, there is a lot of signals because we are doing some testing in turbine building. Then, there is a temporary loss of power. The temporary loss of power, they lost the SDC pump. But after the power is back, the SDC pump is on again. This is not really a problem.

The main problem is when the temporary power loss, because the design deficiency to make some RCS goes through a pump to keep the leaks from the RCS, the loss of inventory.

This is simply the background for that event. So, here does the valve pop open and cannot close automatically.

The first thing after we identify this story, first we need to review the procedure. Reviewing the procedure just tells us what the operator is likely to do and what exactly makes their action in this procedure.

In this one, AP-26, loss of decay heat removal, that is the correct procedure they need to handle waste.

In this procedure Step 4-12, it may lead the operator to jump to Step 4-18. This one will terminate this procedure, and they will not keep going.

Step 4-17, that is a correct step. The operator will transfer to 4-C, and 4-C will tell them how to isolate the leakage. Then, this also is a time-dependent action. If they found this leak earlier, then they don't need to make up this inventory. If they found this too late, and they lost too much inventory, then they have to make up to get successful.

This is the CRT we tried to construct. This is the initial event, loss of inventory. The loss of inventory, we just need to say they enter AP-26 before loss of SDC or they enter AP-26 after loss of SDC. These are two different timings. Because if they enter here, they don't need to do the makeup action. If they enter here, they have to do that makeup.

Here they have a longer time to do it, but the problem is in this point I think they don't have a best cue because there is none along there.

And here, because there is already loss of shutdown cooling, with the loss of shutdown cooling, the pump will get a problem. At this point, they will have a lot of alarms which generally is related to this loss-of-inventory event.

The context here and here is different, and the timing also is different. So, I feel that this one, they enter here or they enter here. If they enter here, we still need to say, the first one, you isolate this decay. The second one, you need to make up.

But in the first one, they enter here earlier. They just need to isolate. They don't need to have a makeup.

The next step after we identify this one, we just try to build up the context for each branch point. Just like I say, in the first point they don't have any direct alarm. Now they only have some interacting information there; for example, RCS inventories is slowly, it leaks, and then they just get some PRA label or some label. It decreases slowly.

Here, after the loss of the shutdown cooling pump, a lot of our alarms will be occurring. So, you asked me why we have two branches here. I just say, for the first branch, for the first point, before the loss of shutdown coolant, this one is the dominant part. This part is not the dominant part because they don't have any direct information to lead them to go to the loss of inventory. So, I called it a knowledge-based cue.

For the second point, because of the loss of shutdown coolant pump, and they have a lot of clearly alarms, but the alarm, it goes through the alarm procedure to link to this loss of shutdown coolant procedures. So, then I called that a rule-based cue.

So, that means in the first branch point, this part will be dominant. For the second one, this part will be dominant.

Anyway, these two branches need to be in together. This is an integrated. The first one, the end of the AP-26 earlier, and this is end of the

AP-26 later. So, these both fail together; this fails to pass.

Then, I just tried to say this fault tree is set up before the fault tree. We also tried to use this fault tree, which this morning John asked, we tried to use this one to try to handle for the fire assessment, if we have a complete failure mechanism that has been identified in this fault tree. But this one will be generic for any kind of human analysis.

I also want to say for current, existing PRA, you have identified human failure even already, and you don't want to go through a CRE. You can directly put your condition for your identified human failure event that goes through this mid-layer. It actually goes through here to find out what is your failure mechanism over there, to get a combination, and also, it is easier for you to identify what is the dependent action.

For this one, that is not only for that current, existing power operation. It also can be for some not existing PRA model. We can go through CRE to develop that.

Another potential application is for event evaluation. Event evaluation, usually, there's a limited scope. We can just, for that to analyze, we just to need to choose the CRE path we are interested in. That means this STP is different, this condition. This condition has already been in the path, under this path, what is lack of a human action over there. Then, we can use this one just to get what we are interested in there.

Also, we can just actually use the mid-layer to evaluate and identify human failure event.

MEMBER BLEY: You were just talking about event evaluation at the end. In your earlier slides, you have very strongly the bias of somebody who knows how the scenario is going to end up when you say "wrong decision" and this sort of thing. I guess I would caution going into looking at a real event with an idea of how it ends up, rather than an idea of what the operator knows at the instant they are making decisions, can lead you very much astray, and there's a pretty big literature on that. So, I would be really careful with that.

But back up two slides to 32. I kind of followed everything you said about this, but when I look at this one, after the loss of SDC, you don't have any more branches. Yet, you're analyzing what happens after that. So, I am very confused.

MR. SHEN: This one?

MEMBER BLEY: Yes.

MR. SHEN: I just said this is a fatal task because you never end the AP-26. You have two chances to end the AP-26. Now one is earlier. Earlier, then they don't have --

MEMBER BLEY: So, on that path, if you go back to 34, two slides further on, you don't need a fault tree for what happens after --

MR. SHEN: That is true for this side and this side. This diagram is to represent, one is here; one is here. So, the lefthand side, unfortunately, that represent, yes.

MEMBER BLEY: That's what you're talking about?

MR. SHEN: Yes. So, you didn't enter it earlier. The second, the righthand side is you didn't enter later. So, those are two points to go to these fatal paths.

MEMBER BLEY: And that path has no recovery for --

MR. SHEN: No recovery. We just say you failed.

MEMBER BLEY: Okay.

MS. LOIS: What was your point before

that, Denny?

MEMBER BLEY: My point before was, if you are going to use something like the structure to evaluate real events that have happened, you have to beware of evaluating the events based on knowing how they turned out. The operator doesn't know this thing ended up in a core melt or whatever happened at the end of it. The operator knows what they see in front of them at the time they act. And if you are evaluating them based on your idea of what is a bad decision, based on knowing how the sequence turned out, you're not getting all the information you can about what the operator was doing.

MS. HENDRICKSON: That is a valid point about event evaluation in general.

MEMBER BLEY: Yes. So, I was a little troubled by seeing this applied that way. Once you've got that biased built into these templates, or whatever we're calling them --

MR. SHEN: Yes. Yes, we are trying to do more exercise. I think Jim has mentioned to me NRR is interested in the variation. I just try to say give me more STP events occurring, a report. I just try to use that your event report to create a CRT, and then to compare it with your evaluation to see what is the --

MEMBER ABDEL-KHALIK: I am trying to understand the point that you are making. Success and failure should be defined locally.

MEMBER BLEY: Yes. You can't really understand what the operator did if you already know how the sequence turned out.

MEMBER ABDEL-KHALIK: Well, but you can define success and failure locally still.

MEMBER BLEY: You can. You can, but you really want to understand what led the operator to do what they did. Decisions aren't always failed and success. Decisions are decisions, and then you carry on from that point forward. If you are doing your event review based on your knowledge of how things came out in the end, you really get biased results almost every time you do it.

You have to put yourself in the operator's place and understand what they saw at that time --

MEMBER ABDEL-KHALIK: Right.

MEMBER BLEY: -- not saying, well, if they had turned left instead of right here, they would have been okay. How do we know that?

MR. SHEN: Excuse me. I want to clear up

one point. This event evaluation, what I am talking about is not to say what human being. For example, this example here, regardless of the human event, the focus is not on what the operator did in this event. Honestly, the point for this event, in honesty, is that they have some design wrong, that they have some design wrong to make the temporary electricity power loss, and then get pop of the valve.

This design, if they don't have a deficiency, the valve should close automatically. But if this condition is designed wrong, then it will pop open. So, we just try to say, because you don't have it this way, what is the core damage frequency?

So, all this analysis here is not related to anything what they did in their call station. We are just saying all kinds of combination, under this design deficiency, that's one STP. So, under this condition, what is the likely fatal path? And it is essential that they didn't get the core damage because we know there's no core damage, but we just say, what is likely?

We try to review now what you are doing. We just try to say, under these design deficiencies, what is the likely result? We have different paths that go to core damage. So, still, it is kind of a

PRA application, but just limited scope under some condition existing, not trying to reproduce what the operator did during this event.

MR. MOSLEH: It is essentially a conditional assessment, obviously, and the CRT that is built tries to cover a different spectrum, given the starting point. But I think your point is well-taken, a sense that once you have a structure that is based on a certain set of mindsets that goes into how these generic trees are built, you are kind of boxed into that in a way and saying, well, these are the scenarios, the likely scenarios, and then, as such, it carries a certain bias. But it is not the same bias in kind of putting yourself beyond the point where the operator was. You're starting that way with that, going forward with the structure that you --

MEMBER BLEY: Okay. I didn't understand that is what you were talking about at the beginning.

MEMBER ABDEL-KHALIK: I still don't understand the issue. I mean, to me, what we are trying to do, we are trying to get a failure probability at a given context, right? Therefore, at each point, at each branching point, we need to be able to define what success and failure are, regardless of what happened before and what happened after.

MEMBER BLEY: I would say you can't always do that.

CHAIR STETKAR: Dennis' point is --

MEMBER BLEY: You can succeed out of whatever decision you make quite often. In fact, our current emergency procedures are built to help you do that by checking alternatives and by checking back as you do it, and seeing if the plant is doing what you expected it to do. So, yes, we can't really put success and failure on these operator decisions at every point. Some places you can. Some places it's easy. Other places you can't.

But if you're going back to look at a real event, to learn something from it, that is a little different than laying out a model of how things might turn out ahead of time, a PRA kind of model. So, you need to look at it differently and you will learn different things in a retrospective analysis of a real event, depending on the real event.

We can talk about that some more offline. That's not really what this is all about. It is just I heard those words and I keyed on them.

CHAIR STETKAR: Let's see, it sounds like you are done with this part. Let me ask, I haven't yet heard -- I've seen pictures of those intermediate trees, and I have heard that somehow they are linked somewhere down below to performance-shaping factors somewhere, and that it is important that we have a left side of the tree that we switch on differently from a right side of the tree that we switch on because somehow those performance-shaping factors way down in the bottom would be different for that.

Are we going to hear anything about what they are and how they would be different within the context of, let's say, the tube rupture example today?

MS. WHALEY: Yes. I mean in our presentation we are going to be speaking about how the fault trees connect to the PSFs. So, I don't think we are doing it in that specific example.

CHAIR STETKAR: No? Okay. That's basically what I was going to ask because I think it is important for us to hear about your story about the PSFs. If they did connect to the sample, the specific example, I would need to think a little bit differently how we are going to organize this then, given the 10-minute evaporation time here.

MS. WHALEY: They don't connect to that same example.

CHAIR STETKAR: Okay. Okay. That's, I guess, unfortunate because it doesn't really answer some of our questions about kind of seeing an example of how this process really works to quantify some number somewhere.

MR. MOSLEH: John, we have not completed the development, even the first round of the development.

CHAIR STETKAR: That's pretty clear.

MR. MOSLEH: Yes. We have proposed an approach, an architecture, and that we think the different elements, in answer to some of your questions or concerns, are going to fit under that, including why you have different branches and how they are different with respect to the PSFs.

We have either placeholders for those because we have anticipated those to be kind of important or we have actually taken the steps, but they are not at the stage where we have even communicated specifically how they relate to a specific example or whether those are proceduralizing a form that is practical that we can implement. So, we still have work to do.

CHAIR STETKAR: Let me, in seven minutes, before we lose three or four people here, because I think at 3:30 we will go into the empirical data, you know, empirical evidence stuff. Hopefully, at about four o'clock everybody will be reconvened because I think there's some interest in hearing the little story about the PSFs.

Let me ask you, just back to the leading question, at one level I see what you're up to here with these intermediate trees, in a sense of trying to enforce at least a consistent thought process for the different types of contributors.

I will go back to the SRM. The SRM says we should try to consolidate existing human reliability analysis methods to avoid this concept of 25 different methods implemented by 50 different analysts will get us, you know, whatever the product. Those things are number of different estimates for human performance in a particular scenario.

How do you answer the question of, how does this formalism integrate with the existing methods? This looks different to me. And because it looks different, it starts to sound like a new methodology, which is fine in an absolute research sense. But if it is not directly addressing the needs of the SRM, I now have a question about where are we heading in this whole process.

If you are saying, absolutely, we need a completely different new methodology, that nothing out there, we can't rework something that is out there to fit our needs, I think that is a very, very important conclusion. If this really isn't different, I guess I still don't see how it is not different.

MS. LOIS: I will take some of that, and then I will let other people.

I think, to begin with, when we started out addressing the SRM, as I said at the beginning, we tried to identify desirable attributes of human reliability. When given the variety of views, and some of that is the consistency and the reproducibility and the capability of one analyst to produce the results or different analysts, then if you look at the various methods, none of those methods had that capability.

And we felt that, given the knowledge we have and the tremendous experience, if we could attempt a process of adopting what we say, the information processes model, which in a way helps structure the thought process of the analyst, then building on the experience we have, that achieves the SRM objective, which is not to have so many methods, and each method giving a different result.

So, that is at least our interpretation. It would be a more structured approach, and none of the thought, none of what we know in human reliability is missed here. It is the structured approach.

CHAIR STETKAR: Let me try this: I understand that sort of thought process, but when you went through the exercise and evaluated each of the current methodologies against these attributes, if you had identified a particular methodology that satisfied 80 percent of the attributes, was there any notion of saying, what can we do to that methodology? This is the best of the lot that we can identify. It satisfies 80 percent. Perhaps there is another one that satisfies 70 percent. So, maybe we ought to look at those, too. The next best one only satisfies 30 percent of the attributes. So, clearly, we have done some vetting of this process.

What could we do to those one or two methods to bring them up to 100 percent, not a different method, but what could we do to those one or two? What are they missing in the context of --

did any of that process go through your --

MR. MOSLEH: Absolutely, John. Absolutely.

CHAIR STETKAR: Okay, good.

MR. MOSLEH: And I tried to summarize the answer to some of your questions earlier in some of the viewgraphs. This is not a new method in a sense of starting from scratch, absolutely not.

And I tried to identify areas where the existing methods have provided fundamental input to this.

CHAIR STETKAR: Okay.

MR. MOSLEH: Having said that, let me also share with you some of the challenges which are existing. If you look at existing methods, there are two parts to all these methods. One is the qualitative part. The other one is the quantitative part.

Unfortunately, the picture is kind of a mixed bag. Some methods that are very good qualitatively are not as good quantitatively, and vice versa. Some are kind of reasonable. You know, they are different in terms of their strength.

And some of those that provided very good contextual kind of analysis method lack some of the key attributes that we think are important for quality HRA, and we listed those, reproducibility and then consistency, and a number of other ones.

We are very good in providing contextual analysis, but lack in those scores. I think qualitatively you could easily see significant analyst-to-analyst variability.

So, in my assessment at least, I think we are building on ATHEANA to a large extent, to a very large extent, that it is an integrated, context-driven, scenario-driven approach to analyzing what can happen during the course of an accident. But we also try to fill or address the shortcomings of those, one of which resulted in actually trying to see if there is a representational scheme, so to speak, that can highlight or enhance the reproducibility, consistency, transparency of an analysis.

To me, if you ask me, CRT, we all know -- I mean you said that, in fact -- you know, a good plant analyst, a good PRA analyst would do the CRT in his or her hat or --

CHAIR STETKAR: But be careful. The fact of the matter is they don't, by and large. That is a huge source of variability.

MR. MOSLEH: Yes. Yes. A good analyst would have the knowledge base to do so, right? But we see the variability and say, how can we now control this, minimize it. That I think was at the core of the SRM, plus a few other things. This is, how do we control the variability?

If you look at the empirical study, it shows that one major source of variability is the shortcomings of the qualitative analysis or instructions for qualitative analysis. Even though they may be really fundamentally sound in every other score, when it comes to, well, you know, how do I do this and then keep the inter- and intra-reliability, I'm asking the expert. We see that there are shortcomings.

We thought that we could actually address them. So, if we say, well, are we enhancing -- or no. Why don't we enhance an existing model? My answer would be we are enhancing ATHEANA on the qualitative side.

On the quantitative side, my personal opinion is ATHEANA has always been weak, although the fundamental equation is sound. It is perfect. And I show that.

But we want to be able to go beyond that.

How do we do that? There I thought that personally, and then we discussed it, that this idea of a cause-based approach, where you kind of try to decompose the question and delineate kind of the specifics of the causes that are supported by experiment, experience, and literature, and all that, can we capture that and bring it into the quantification framework?

And since the quantification framework and the qualitative framework need to be consistent, so, then, we said, okay, well, then, our quantification and the qualitative part need to be cause-based.

CHAIR STETKAR: Yes.

MR. MOSLEH: And for that, we needed a model. Okay, well, where do we go for a model? The underlying model of a vast majority of HRA methods are IDA type, implicit or explicit. So, we are not doing anything new there in a way.

What we are doing is we are putting more structure on it, and then show, if method A has a list of eight PSFs, why those eight? Why not 30? So, we try to consolidate the differences and understand them based on bringing a little bit of more kind of this causal understanding.

So, we are not developing a new one. It is a hybrid. It is a phoenix of methods or a mixture of methods, but with a few new flavors.

CHAIR STETKAR: Yes. Okay. I still feel a little bit uneasy, but I think we have kind of transmitted our concerns in that area without trying to endorse specific models in this forum.

A question would arise, for example, if you feel the qualitative part of ATHEANA is really good, but it is weak quantitatively, but perhaps there are other existing quantitative models that, indeed, embody the basic concepts of IDA. There are a number.

Was there any attempt to try to merge those two? So, you take the front end of ATHEANA and the back end of model methodology X, for example?

MR. MOSLEH: The merger is, obviously, non-trivial.

CHAIR STETKAR: Well, but my question is, is it less trivial than this? You have to admit that you're still at a fairly high level, and there's a lot of discussion about, well, we need to develop this a little bit more; we need to think about that a little bit more.

I am a bit concerned about how deeply we get enmeshed in a particular structure that perhaps may be in some senses duplicating an awful lot of what has already been done in other methods.

MR. MOSLEH: On that point, instead of duplicating, we have read, studied, and we then copied what is in those methods actively. We have, in fact -- well, I can go on for a long time to give you specific examples.

The idea was not to duplicate, reinvent the wheel. It is just we don't have the time, the energy, or the --

CHAIR STETKAR: Well, that is one of my concerns, is that a lot of this, some of it sounds very familiar. Some of it sounds a little bit different.

MR. MOSLEH: Correct.

CHAIR STETKAR: Anyway, I think we have discussed that enough.

MS. LOIS: To add one point here, it is one of the reasons that ATHEANA hasn't been adopted is because people shy away from the level of effort --

CHAIR STETKAR: Yes.

MS. LOIS: -- that it will need to use it. So, we believe that by structuring the concept of identification of the connection of context and failure, the potential failure paths, structuring that, we make it more transparent and easier to follow, assuming that it would be procedures and guidance on how to construct those trees.

In addition, I don't know if you agree, but by getting down to very few specific types of failure mechanisms, I believe that, at least in my mind, it is a contribution to human reliability. Because although you may start with potential vast failure paths, recognizing that you can consolidate the various types of failure paths in a few kinds of human error mechanisms and associated PSFs, that is on its own a help to the HRA analyst because now you have collapsed the PRA HRA through process with the psychology and human behavior thought process, and you have linked that to very specific structures and very concrete failure mechanisms.

CHAIR STETKAR: Okay. John, did you want to say something?

MR. FORESTER: John Forester from Sandia Labs.

I think this follows what Erasmia is saying. I think it should be noted that the notion of using the failure mechanisms and the way they get tied to PSF is perfectly consistent with CBDT.

CHAIR STETKAR: Sure.

MR. FORESTER: And even some of the failure mechanisms that are in CBDT are included in the models.

CHAIR STETKAR: But because of that, does the formalism of the CBDT approach, would it be better to adopt that formalism rather than this type of formalism? Or is that too subtle?

MR. FORESTER: I'm not sure I recognize the difference.

CHAIR STETKAR: Okay.

MR. FORESTER: The failure mechanisms are listed in -- you know, there's a set of them there. Maybe there's more than what's in CBDT.

CHAIR STETKAR: Yes.

MR. FORESTER: For particular failure mechanisms, there's going to be a set of factors, causal factors, that influence the likelihood of that failure mechanism, which is what CBDT does. That is what we will do also. Now whether we exactly use the decision tree framework that CBDT uses, I don't think we have decided that yet. But we are doing is certainly consistent with that.

Now whether you just take the whole

decision tree approach and add in some extra failure mechanisms, and maybe change the performance-shaping factors that feed into those failure mechanisms because we recognize some potential shortcomings there, that's a possibility. But I think we are trying to do this, following that same model, make sure we have everything that should be there.

CHAIR STETKAR: Okay.

MR. FORESTER: Maybe that was a little random, but --

CHAIR STETKAR: Okay.

MR. MOSLEH: And, John, there are multiple criteria in that. It is not just the causal perspective or the quantification. We had like a list of 10-12 items that we kind of checked against them to make sure that we meet the quality criteria. Then, CBDT lacks in some areas, yes.

CHAIR STETKAR: Okay, but they all lack in some areas.

MR. MOSLEH: Yes. So, the integrated approach is, we hope -- and I have one slide on our assessment of where we are with that. I will be covering that.

CHAIR STETKAR: Okay. Let's try to keep things moving here while we are missing two or three people.

Let's hear about the empirical work that has been done, only because I know Dennis would have to keep exceedingly quiet in this area anyway. I know he is really interested in the middle part of the modeling.

MS. LOIS: Very quickly, I will remind the Committee why we have these activities. We do have another SRM.

Okay. Starting with what we call International HRA Empirical Study, where we used Halden simulators to test various kinds of HRA methods using crews that perform different scenarios at the simulator, the Commission became aware of it, and the question came up: well, you test methods using non-U.S. crews and non-U.S. facilities, and therefore, we should focus on -- we have the SRM, which was in February of 2009 -- to pursue testing of U.S. nuclear power plant operating crews' performance in a variety of situations. Use U.S. facilities to do similar testing, similar empirical studies that you did at Halden.

And also, the SRM included to really look into the possibility of creating a data collection through the simulators in U.S. facilities.

So, because of this SRM, we -- I'm sorry, the slides are messed up.

The NRC has an MOU with a U.S. reference plant. The MOU states that we are going to use their simulators and crews to do run some scenarios, to test methods, HRA methods, through those simulator runs and, also, to examine the use of U.S. simulator data produced through a variety of HRA activities.

So, in actuality, what we have here, collecting data in the reference plant, we have two different activities. One is the one that John Forester is going to talk about, what we call a U.S. empirical study. Then, we have another HRA data collection which I don't know if we will get to the point to talk about it today.

CHAIR STETKAR: Erasmia --

MS. LOIS: Yes?

CHAIR STETKAR: I know you've got the slide orders messed up.

MS. LOIS: Yes, yes.

CHAIR STETKAR: Right now, is the primary emphasis on the first of those sub-bullets in terms of looking at the testing of various HRA methods to evaluate, observe human performance? You know, you mentioned that there is sort of two purposes of that.

MS. LOIS: Yes. Actually, we use the same data, the same scenarios for both purposes. So, we do have both activities going on parallel. Sandia is going the empirical study. Idaho is doing the data collection and examination of how we could use log data, simulator data for the purposes of collecting information more routinely, simulator data more routinely to support human reliability and human performance in general.

CHAIR STETKAR: Okay.

MS. LOIS: So, if we get to the point, Bruce Hallbert from Idaho is ready to give us an idea about that activity.

CHAIR STETKAR: Okay.

MS. LOIS: Okay? So, John is going to talk about it. What we tried to do is to address some issues, open issues that were identified in the Halden study. The HRA teams will get to go to the plant that they didn't have the chance to go before.

So, we would like, within those activities, to address issues related to the need and the amount of data to be collected, how the various methods are collecting the data, and how they use it, and how could we optimize the data collection process.

And also, here we are going to use three teams per method. So, we are going to examine the analyst-to-analyst variability and to better understand how the analysts are applying their methods.

And the result of this study will feed what we do overall in improving robustness of HRA methodology. I would like to note that the methodology that was just presented as an SRM concept is going also to be tested through this --

CHAIR STETKAR: I was going to ask you.

MS. LOIS: Yes.

CHAIR STETKAR: It is?

MS. LOIS: Yes.

CHAIR STETKAR: Okay.

MS. LOIS: So, it is going to be part of it.

CHAIR STETKAR: What's the timing of all this right now? I mean, obviously, the methodology that we are learning about today has a bit of a ways to go before it becomes as mature as a lot of other methodologies in terms of evaluating --

MS. LOIS: The data collection has been planned for June, for the HRA analysts to go and visit the plant and collect information. So, although we haven't completed the development of the analysis, we know that we are going to learn a lot by testing at least the parts of the methods that we have.

CHAIR STETKAR: Okay.

MS. LOIS: Eventually, we may need to do more testing when we have a complete product.

CHAIR STETKAR: Okay. Okay. Thanks.

MS. LOIS: So, for the other aspect, which is the data collection, I mentioned, as a matter of fact, the ACRS, Mario Bonaca, et cetera, had many, many times in the past recommended to us: why you don't use log data; why you don't use the exam data? We are going to examine how we could use that kind of data.

In addition, too, there is an international activity, a desire to exchange data at the international level, human performance data. So, within that umbrella, we are looking at the log data from the specific plant simulator.

It is a collaborative work, all of this. I would like to note that Halden is supporting the empirical study. They are providing the same support, although it is a U.S. study, if you wish. So, we have our experts who came, helped us with the scenario, design, et cetera. They are going to do the analysis like they did before for the existing empirical study. At the same time, we have Idaho National Laboratory that is supporting the same data collection effort.

I don't think I should spend any more time. These are the methods that we tried to address.

I think we should move ahead.

CHAIR STETKAR: When you say, "the methods", under methods, it would include this one that we are hearing about today?

MS. LOIS: Yes.

MR. FORESTER: Yes, I'm going to go over it. I will talk about it.

CHAIR STETKAR: Okay. Okay.

John, do we have copies of these slides? We do.

MR. WEN: We don't have this one.

CHAIR STETKAR: Okay.

MS. LOIS: These are in the box.

CHAIR STETKAR: Okay.

MR. FORESTER: So, you will have copies.

CHAIR STETKAR: In principle, we do.

(Laughter.)

MR. FORESTER: Okay. Conceptual copies.

CHAIR STETKAR: Yes. Here they are.

MR. FORESTER: Okay. Well, as Erasmia said, I am just going to try to give you an overview of what we are referring to as the U.S. empirical study.

CHAIR STETKAR: Go on. We can listen to you and look at the board.

MR. FORESTER: Okay. So, first, I will just talk about, just give you an outline here. I will give you a little bit of background about the International Empirical Study, for those that may not have that. Erasmia has already done that to some extent.

CHAIR STETKAR: Yes, and we have, by the way, had a presentation on that also, as you probably recall.

MR. FORESTER: Right. That's right. Sure. But I will make sure everybody --

CHAIR STETKAR: Okay.

MR. FORESTER: Anyway, I will try to move through that quickly.

CHAIR STETKAR: Yes.

MR. FORESTER: Because that sort of serves as the basis for what we are doing now. So, that leads to the U.S. study objectives, and I wanted to quickly cover the basic experimental design that we are using. Then, I do have some examples of the scenarios that we are going to try to quantify, and the HFEs are going to try to quantify. I don't know whether you are going to have time for that today or not because Bruce might have a chance to cover his stuff, too. So, we will see what you are interested in.

CHAIR STETKAR: See how far we get, yes.

MR. FORESTER: See how we get going, okay.

CHAIR STETKAR: Be careful with your paper.

MEMBER RYAN: Don't whack the microphone.

CHAIR STETKAR: Don't whack the microphone in front of you.

MEMBER RYAN: It's the black thing right in front of you.

CHAIR STETKAR: The black thing with the little green dot. They are really sensitive, so you can push it away from you.

MR. FORESTER: So, for the international study, as you may recall, we had 13 HRA teams that they were using that they were using 13 HRA methods.

They would predict performance in operating crews in the Halden simulator. So, there were 14 crews involved in that, and the HRA teams would try to predict performance of what the crews would do in a particular set of scenarios.

What we asked them for there was we had asked them to predict the human error probabilities and what factors they thought would be driving performance. Traditionally, in HRA you are looking at the performance-shaping factors, and different methods have different factors. So, we are asking them to tell us, in the context of your method, what are going to be the important drivers here.

Then, we had also asked for operational stories for all the HFEs in the scenarios that were run. By operational stories, we mean essentially a description of what they thought would be occurring in the simulator. What would the crews be doing? What would be causing the crews problems? How would they be using their procedures? What would go smoothly? So, just a little story, a description of what they thought would be occurring.

So, those are essentially the measures that we had. We would compare these aspects from the HRA teams with what happened with the actual crew data. So, we collected similar things from the crew data. Again, we couldn't have error probabilities in all cases. Where there was multiple failures, then you could have some estimate to work with. If you had all the crews failed, you would have a pretty good notion it is pretty tough.

Where we didn't have that data, the analysts would make judgments about how difficult the particular HFEs were, using the data that was there and also observations about what the crews were doing. So, again, we would have the HRA team predictions to compare with the actual data.

MEMBER SHACK: Just on a particular scenario, I mean what were the number of failures? Where you had 13 crews, how many of them actually failed the scenario?

MR. FORESTER: There was at least one HFE, I think, where we had almost all the teams, all the crews failed. It was difficult enough --

MEMBER SHACK: And did you get some where half failed?

MR. FORESTER: We did.

MEMBER SHACK: Okay. It wasn't zero/one kind of an arrangement?

MR. FORESTER: No, no. There were some

where you had a few fail, and, yes, particularly we had both SGTR scenarios and a loss-of-feedwater scenarios. And, yes, we would have like three teams were successful, seven failed, and then later on down the road, those seven would recover. So, there was an interesting combination of lots of failures, no failures, and one or two failures.

It was harder to know what to do with the one or two failures out of 14 crews, for example. Because in some cases, they almost seemed sort of circumstantial or serendipitous, or something like that. So, I mean, it was useful information, but, again, it is hard to know what to do with that.

MEMBER SHACK: Okay.

MR. FORESTER: So, anyway, this overall approach, then, allowed us to assess the strengths and weaknesses of the methods to some extent and also get some idea about their predictive power. But what we found was, similar to the earlier benchmarking study, the main one being the ESPR study, where there was an attempt to assess a lot of different HRE methods. What was found there, there's a lot of variability in the predictive results. So, the predictions of the HEPs for various HFEs were a broad range.

We found something like that also -- it wasn't as bad as what was seen in that study -- but we still found predictive variability. So, what we identified, and this has been mentioned earlier today, is that there appeared to be some general problems with the qualitative analysis that the HRA teams were performing. So, they were all using different methods, and depending on the method, they would do a particular kind of qualitative analysis. It appeared to be, to some extent, that regardless of which methods you were using, most of them had shortcomings in some ways in terms of how that qualitative analysis had performed.

But based on the experimental design we had, where we had, essentially, one team per method with one exception, we really couldn't separate method effects from team effects. So, that is an important aspect of what we do in the follow-on study. And Erasmia mentioned now we are going to have several teams for each HRA method.

Another thing the design didn't allow us to do was to get a good understanding of the qualitative analyses that were being performed. You know, you see the information we asked for, asked from them. They had to document their HRA as they normally would. But unless there is a specific guidance for doing qualitative analysis, you know, the teams go out, they took the information we gave them, they tried to understand what would be going on. They looked at the procedures. But they don't necessarily document all that.

So, we weren't able to really get a clearer understanding of what qualitative analysis they were performing. It looks like there were some shortcomings there, but we couldn't be for sure. So, this time around, we want to try to get a good handle on how they perform their qualitative analysis. I will talk a little bit about that.

Then, finally, this design that we had before, you know, it was in Norway. The timing on things didn't work out in a lot of ways. But, essentially, the HRA teams were not allowed to go up to Norway and talk to the operators, the operating crews.

That is a key part of a lot of HRA methods. Particularly, the ATHEANA methodology puts a lot of weight on being able to interview the crews, talk to the operators, not necessarily see every particular scenario or anything like that, but they could talk to the crews about some of the important scenarios. So, that aspect was not included in the initial study. So, we want to respond to that.

Again, what we are doing here is extending what we did before. We did the design. It is hard to control for all variables in every experimental design. So, you do an initial study and you control for certain things. Then, you begin to move away from that by manipulating other factors. So, that is the goal of the follow-up study.

CHAIR STETKAR: Be careful about the paper. Just move the microphone away from you. It is sensitive. So, they will pick up your voice.

MR. FORESTER: Okay. So, then, the study objectives, again, we want to test the consistency of the HRA predictions across the same method, and we can do that across different methods, too. So, we will have several teams for each method, and we will look to see if there's some sort of large team effect here. In other words, if you look at the same method with different teams, do we get consistency in their predictions or do we find a lot of variability as a function of the analysis team?

CHAIR STETKAR: Since you are going to be using different teams for each method, I am assuming you are selecting your teams as people who are experienced using those methods.

MR. FORESTER: Absolutely. We want a very experienced person on every team. That doesn't mean they won't have some less experienced supporting them.

CHAIR STETKAR: But you have, essentially, an expert --

MR. FORESTER: Exactly.

CHAIR STETKAR: -- three experts in each of the methods?

MR. FORESTER: Exactly.

CHAIR STETKAR: Okay.

MR. FORESTER: We are not looking at, we don't want to look at novice performance here.

CHAIR STETKAR: Yes. No, that's --

MR. FORESTER: We are interested in expert performance at this point.

CHAIR STETKAR: I am trying to find, have you identified the teams already?

MR. FORESTER: Pretty close.

CHAIR STETKAR: You have? Okay.

MR. FORESTER: We've got an awful lot of them, yes.

CHAIR STETKAR: Good, good, good.

MR. FORESTER: We are getting pretty

close to having them all set.

CHAIR STETKAR: We're talking about a fairly large number of --

MR. FORESTER: It is. It hasn't been easy finding the people.

CHAIR STETKAR: -- 12 or 15.

MR. FORESTER: But we have had a lot of cooperation from EPRI and the NRC.

CHAIR STETKAR: Good.

MR. FORESTER: So, there's a pretty good set of teams put together. I can talk about that a little bit, too.

So, as I mentioned, we want to examine the qualitative analysis this time. So, we are going to try to build in ways. We are going to provide questionnaires or forms that the HRA teams can fill out that sort of document their qualitative analysis. And when they do actually go to the plant to interview plant staff about the scenarios, hopefully, we will have observers. At a minimum, we will audiotape the sessions. So that, again, we can see what questions they are asking and what their approach was for collecting information for the method they are using.

CHAIR STETKAR: Have you thought pretty

carefully about -- you said you are going to now try to develop more consistent or better documentation of the qualitative analyses that the teams do perform.

MR. FORESTER: Right. We are going to have to ask them to do that to some extent.

CHAIR STETKAR: Yes, because the problem is you can enforce consistency among those qualitative analyses just by asking, did you think about this; did you think about that?

MR. FORESTER: That's true. We will have to keep it -- one idea is we are going to ask for a diary that sort of lets them describe to us --

CHAIR STETKAR: Okay, good.

MR. FORESTER: -- without asking the leading questions. You are right, that is a very good point. We need to keep that in mind. Just that, yes, we don't want to set it up too tightly, right.

CHAIR STETKAR: That's right.

MR. FORESTER: Exactly. So, we will leave it to them to tell us.

Well, then, Erasmia mentioned that before we were looking at, in a lot of cases, we had U.S. teams predicting international crew performance. So, we wanted to sort of see if we could -- and in some cases, since those teams didn't get to interview the HRA, the operating crews, they could have fallen back on assumptions about what U.S. crews could do. There may be some. We don't know that there's necessarily differences, but in this case at least we will have mostly U.S. HRA teams. However, they will have some international teams. We are using mostly U.S. methods. So, we will begin to see if maybe there will be less variability this time around.

And we talked about let the teams perform more realistic HRA by visiting the plant and being able to interview, ask questions about the scenarios.

So, here's the methods we are going to use. Three teams for each method. The EPRI Calculator, ATHEANA, SPAR-H, and ASEP/THERP. We will have an NRC team performing the Calculator. So, it will be a non-industry team, and then we will have industry teams using the HRA Calculator. Then, we have an industry team, at least one, performing the ATHEANA analysis, too. So, we do have that. It is one thing we were encouraged to do. The SPAR-H are mainly going to be Idaho and NRC teams doing the SPAR-H application.

Then, we had mentioned, you had asked about the model differences, the SRM project. They will do an initial test of the hybrid method wherever they are at on that. We hope to send out the information package that the HRE teams will use to perform their analysis at the 1st of May, essentially. So, then, they will have a month to look at the materials before they go to the plant to do the interviews.

CHAIR STETKAR: That's only three weeks from now.

MR. FORESTER: I understand.

CHAIR STETKAR: So, we're --

MR. FORESTER: No, we are pretty good.

CHAIR STETKAR: We're pretty close on this.

MR. FORESTER: Yes. We've got the HFE definitions. We've got the scenarios all done, obviously. So, it is just a matter of tweaking a few things. We've got to get the procedures out to them. But it is mainly a distribution issue at this point. We've got a month to do that. So, I think we're in pretty good shape on that.

As I said, there were two international teams that followed on that wanted to participate. Also, the plant team, the plant itself may want to participate and apply the Calculator to the scenarios, too. So, anyway, experienced HRA people.

Am I using up too much time here?

CHAIR STETKAR: Yes, if you can, I would like to see if we can stop around 5:00-ish.

MR. FORESTER: Okay.

CHAIR STETKAR: And I would like to leave enough time for the mid-layer part. So, can you see if you can finish up in 15 minutes or so --

MR. FORESTER: I can stop at any time really.

CHAIR STETKAR: -- the salient features of what we have?

MR. FORESTER: I go into the experimental design more specifically, into how we collect the data, what information we are collecting. So, it is details about the study, which maybe you don't need right now.

CHAIR STETKAR: Yes. I think, actually, quite honestly, and I have had some discussions with other Subcommittee members, and I think, Erasmia, what we would like to discuss at the end of this session is we will probably request another presentation sometime in the relatively-near future. We will have to discuss what "relative" and "near" means. By that time, you will have a little bit more stuff underway on that part of the project. So, we can perhaps postpone some of that.

I don't know. What's your timescale for actually finishing this exercise? You're starting imminently.

MR. FORESTER: Right. Yes, the HRA teams will start the 1st of May doing their analyses. They will go to the plants in June. Then, once they have collected that data, we will give them two to three months to finish their HRA analyses.

CHAIR STETKAR: So, you are looking September/Octoberish timeframe?

MR. FORESTER: Right, for them to get their data back to us. By then, the Halden folks will have summarized the outcome from the crew data. Then, we can begin the comparison, so that, then, we will carry that into 2011 in terms coming up with the results of the study.

CHAIR STETKAR: Okay.

MR. FORESTER: You know, the initial results.

MS. LOIS: By the way, I would like to acknowledge Christiana Lui, our Division Director, who is the decisionmaker. She has been here. She hasn't had the opportunity to address the Committee today.

CHAIR STETKAR: Hi, Christiana. Thank you for being quiet.

(Laughter.)

MS. LUI: I figure there is enough action on the floor.

(Laughter.)

CHAIR STETKAR: Yes, that's good.

So, yes, let's at least get some input from Bruce on what you are planning in the sense of data collection from this exercise.

We also don't have these, conceptually we don't.

MR. HALLBERT: Okay. Well, I am happy to be here today and have the opportunity to talk about some of the work that we are doing in support of the SRM. I think Erasmia is handing you the copies of the presentation.

I am Bruce Hallbert from the Idaho National Laboratory.

For the purposes of this presentation, we will be talking about collection of empirical human performance data. I am going to talk about what that means first, and then give you a little bit of background of sort of the theoretical framework that we are using to inform our perspective for data collection and how we think that ties to human reliability research and HRA method needs.

So, in this context, what we are talking about is data obtained from simulators, nuclear power plant simulators, quite simply. The things that we are looking at in terms of data are objective performance measures in terms of what the operating crew does in the plant in response to certain events, how those affect plant parameters, descriptions about performance, and then subjective measures as well, too. I will describe in a bit more detail what these are and provide some illustrations of them.

What we are trying to do is to understand the relationship between human performance and human reliability. By human reliability, we are talking about the limits of reliable human performance, the distinction between successful human performance and meeting some sort of system criteria and unsuccessful and not meeting some system criteria.

We want to identify ways that we could collect this data in a standard manner and in a portable manner, and in a way that is not highly labor-intensive, so that there would be, you could say, more interest in doing that.

And also, there's a number of data collection efforts going on in a number of countries. It would nice for us to come up with a common approach for doing that that would support international exchange discussion on some level.

MEMBER RAY: Let me interrupt for just a second.

John, can you help me here? I tend to think that what we are interested in are what I would call tail events, low-probability, high-consequence. So, I listened to all the presentations here trying to figure out how on earth you get those data. I guess I am not connecting because it seems to me likely the criteria for performance that we are talking about measure how well we do in what I would call the broad middle distribution of human performance. It would take forever to observe one of these tail events, a TMI kind of event.

So, am I thinking about this the wrong way?

CHAIR STETKAR: No, I don't think you are, Harold. I think that you are thinking about it in the traditional sense of data exactly the right way. It has been a problem traditionally in terms of the ability to use simulator information to directly predict human error probabilities in the 1-in-1,000-per-demand type.

MEMBER RAY: One in 10,000.

CHAIR STETKAR: You have to run many thousands of the same experiments under very, very controlled situations to have any confidence in those numbers. That is one of the reasons why I am interested to hear exactly what the goals of this so-called data collection and, indeed, what types of data will be collected. Are we actually looking at estimates of human failure probabilities or are we looking for a different set of information that just happens to be called data for the current audience?

MR. HALLBERT: We will talk about that as we go through. I want to mention that, while we are using a lot of data and providing a lot of data in this presentation, none of this is from some of the current studies that you are hearing about today. So, I have made a number of notations throughout.

I want to call your attention to one thing on this slide. That is that we are restricting our focus in these data collection efforts to PRA context. We are trying to look at those, look at operator performance under those conditions that PRA essentially is concerned with, meaning in response to some sort of initiating event.

So, you're right, there are lots and lots of contexts out there that could be of potential interest, including pre-initiator conditions and things. We may not be looking at those in great detail. But I hope that I will be talking about these tail conditions a little bit in a few slides.

MEMBER RAY: Okay. Well, that is what I am mostly interested in, is how you get empirical data for rare events.

MR. HALLBERT: Okay. Well, this slide didn't come out exactly the way that it looks on my laptop, but let's see how good you are at filling in blanks here.

A couple of slides on the theoretical framework for this, and I might just stand up.

CHAIR STETKAR: Just as long as we can pick you up on the microphone, that is the important thing.

MR. HALLBERT: Okay. You let me know if I start becoming too quiet. I've never been accused of that before.

The idea here, for the background, is that essentially these PRA scenarios, initiating events and associated post-initiator conditions, establish some demands that the operating crews need to respond to, things such as the pace of the event. You heard them talk a little bit this morning about the pace at which things occur, creating time demands for a response. The severity.

In other words, if it is an event that affects a number of plant systems or a common support system, electrical systems that influence many systems in the plant can certainly increase the demand, and the complexity of the event. How easy is it to discern what is happening? How easy is it to respond to what is happening? So, a lot of these factors.

In addition to that, there are external performance-shaping factors that come along with the design of the systems, such as the human/machine interface, procedures, the way that they are written, and things like that. So, these provide some sort of demand conditions.

And in response to that, the crews have certain capabilities, which we might refer to here as capacity. That includes their experience in training, how they function and work as teams. That is very important. How well prepared they are for using their procedures and operating with these types of scenarios in the past. Then, their own abilities, which we heard them talk about this morning in terms of cognitive resources, memory, information processing capacity. Those certainly become important in the context of a PRA event.

The alarms that occur will very quickly exceed the processing capacity of any individual human, when you look at the pace and rate at which they come in. They have to work as a team, and how they divide up the work is very important.

So, in principle, here, then, we know that by increasing demand, that we are sort of eking over into the capacity of the crew. And the greater the demand increase, the more overlap with the capacity and the higher likelihood for failure. And ultimately, this leads to what we refer to as the limit state in reliability engineering, which means there's a delineation here between success and failure. If you increase demand enough or if you diminish capacity enough, or some combination dynamically, you reach this limit state. This is where you observe failures and failure modes.

In terms of data collection, we would like to collect data and provide observations that sample performance conditions from a PRA-relevant context. We also want to sample data from those conditions that HRA methods make predictions about, including the performance-shaping factors that are assumed or predicted to drive performance, and see what they actually do to human behavior.

What we want to do, when we do that -- so, the first two bullets there really talk about the kinds of simulator conditions that we want to create. If we create them, then, what do we want to do? We want to collect data that says what the operators did and when they did it, and provide some insights into the how's and why's, especially when those how's and why's may be important in terms of successful and unsuccessful performance.

You asked a question earlier about the tails. How many crews do we have to run through, how many variants, and how many scenarios to know whether or not something is error-likely or not? How long could this take to figure out?

Well, the graph you see here is something that we have attempted to conceptualize, and it is really saying that, if you have an operational context such as a PRA context, and if you understand the types of performance-shaping factors that drive performance, then by selectively sampling around different instantiations of the performance-shaping factors and giving context, you might be able to identify, well, when the performance-shaping factors were in certain types of situations, we observed failure, but down here we observed success.

MEMBER ARMIJO: What are the axes S and R?

MR. HALLBERT: These would be some combination of performance-shaping factors or contextual factors. It is a theoretical type of --

MEMBER ARMIJO: Okay. So, one axis is performance-shaping; the other one is context, or are they both --

MR. HALLBERT: Or they could both be performance-shaping for a given context. So, think of something like HMI interface deterioration as a function of loss of indicators, or something like that, or electrical failures, and this being some sort of time-stress demand. When you start ratcheting these things up in a negative way, then you might start to see systematically failures.

The question is, where do those occur? And if I can observe those intentionally, then I can start to say, well, hmmm, it appears that there's something in here. Now how do I relate that back to the HRA method? I don't know. But now I have failures to work with.

MEMBER ABDEL-KHALIK: But these are many-dimensional plots in principle.

MR. HALLBERT: Well, you know, it all depends. I mean that would be an interesting discussion. That might depend upon how you conceptualize the performance-shaping factor space. You know, for the most part, most performance-shaping factors are consistent or held as constant as possible, and only a few really significantly vary. Then, I guess we could say that we probably have some good, useful data of the kind that I am talking about here. So, the question, then, might be, can you design scenarios to do this?

CHAIR STETKAR: Bruce, I hate to -- we're, obviously, way out of time. I mean the meeting is out of control. I run a terrible meeting, and I need to take notes from people who do this better.

(Laughter.)

But let me just ask you one thing, and then we will get to Mario. It sounds like, I had thought initially that this exercise would benefit very largely from the scenarios that you are going to run at plant X in whatever, June, May or June. It sounds like you might derive a bit of information from those, but this sounds like to me a much longer, broader-term project than the immediate concerns. Is that right?

MR. HALLBERT: Well, it is, but we actually designed the scenarios for what they are using in June.

CHAIR STETKAR: Good. So, at least you have some control points --

MR. HALLBERT: We absolutely do.

CHAIR STETKAR: -- to start to think about this concept.

MR. HALLBERT: And for our part, we have collected the data that we are going to use to benchmark against the --

MEMBER BLEY: Are you getting into anything --

MR. HALLBERT: I'm not going to relate any of that information because there are potential --

MEMBER BLEY: Okay, good.

(Laughter.)

I was about to leave.

MR. HALLBERT: What we are talking about

here --

CHAIR STETKAR: Oh, that's right, because you can't --

MR. HALLBERT: So, what we are talking about here in a way has been done.

CHAIR STETKAR: Okay.

MR. HALLBERT: Okay. I'm jumping ahead here, just to give you some sort of flavor of where we are going with this.

CHAIR STETKAR: Okay.

MR. HALLBERT: But earlier today, we heard questions about time, thermohydraulics. How do you relate all these things in a framework that is sort of method-neutral? In other words, data are data. They tell us what operators did and didn't do.

I can lay out on this in a way that is understandable to people who operate PWRs in any number of countries about what initiated, what operators did, what became the time window for their response, when they performed it. If I start amassing quantities of data like this, and I start observing the variation there and collecting information about the PSFs as the crews perceive them, then I can start ascertaining what effect these kinds of things have with regard to that PRA limit state.

So, you know, in theory, that is how we bridge between human performance, the plant, the plant systems, and human reliability.

CHAIR STETKAR: Okay. Thanks. I have to apologize. I think I'm going to cut you off here. This is really interesting.

MR. HALLBERT: I jumped to this because --

CHAIR STETKAR: Yes. I think we would be interested to see a lot more about this because we, as a Subcommittee and a full Committee, for many years have thought that there's a lot of benefit from using simulator experience. I wanted to get you to this because it starts to answer Harold's question about the concept of collecting data and how that information will be used.

MEMBER RAY: No, I understand that. My point is that you can combine factors in an appropriate model that are very hard to combine just by waiting for them to happen.

CHAIR STETKAR: That's right.

MEMBER RAY: So, I understand.

MR. HALLBERT: And it sort of goes back to a question that was voiced earlier this morning, which was, is human performance different in this context than this context? And the question here would be to say, well, if you can put things on the right axis, if you can characterize them in such a way that it is not so context-dependent, then you can talk about the things that really do drive human performance irrespective of that context.

MEMBER RAY: I am interested to hear that.

MEMBER BONACA: The only comment I was going to make is that, you know, looking at the presentation today in a context, one of the things, that you would spend an infinite amount of time to human reliability analysis for a PRA. What you do, up to a certain point, however, what I am trying to say is that there are sequences where you know that the operator action is critical. And you find it by doing your PRA.

I mean, from my experience, I don't think that there are many actions that are so critical. That is really where you focus most of your research, understanding how you do. I mean, if you think an old PWR, going to bleed and feed and being successful is a challenge. It is a unique challenge. But, you know, that is a decision point where you add a system or you fail to add other systems to the plant. So, it makes a hell of a difference.

I think it would be good to give a sense at some point of how much of this effort is focused, and then give some of the perspective about the fact that so many of the actions are not so relevant because, whether there is failure or not, something else is going to happen.

Anyway, that kind of perspective I think is important.

MR. HALLBERT: Yes.

MEMBER ARMIJO: I just wanted to ask a question about the internal PSFs. To me, that is your biggest variable, some of which you may know something about, what's visible.

But I wanted to ask you, how do you deal with the issue of variability in the emotional state of a key person in the crew? A divorce, health problems, financial problems, in dealing with a severe accident? Is there any way? Do you just put a fudge factor and say, hey, look --

MR. HALLBERT: We don't. We don't treat that in any way right now. I mean, there's no really, I don't think there's a good way to account for that, unless you start thinking about individual differences. Once you start getting down -- this is just my opinion now -- but once you start getting down to the level of individual differences, then you have defeated the purpose of sort of the PRA in a way.

MEMBER ARMIJO: It is a variable. It is a big variable that humans have that machines don't.

MR. HALLBERT: You're right.

MEMBER ARMIJO: And I'm just wondering how you do that. Is your assumption that maybe, well, one member of an operating crew may have such problems, but all of them won't at the same time? And that will level things out? I don't know. This is not my field. So, I just wanted to ask.

MR. HALLBERT: Not treated explicitly.

CHAIR STETKAR: I think in some sense, you know, a careful thought about uncertainty helps in that area. I think in a PRA sense we are never going to have precise estimates of human performance. So, there will always be uncertainty. Certainly, your issue is a contributor to uncertainty, as are a lot of other issues.

The question is, though, in a PRA sense, does Joe having a bad day because he had an error on his bank statement affect his performance uniquely --

MEMBER ARMIJO: Or he has had a foreclosure, his wife is leaving him, and he is not in very good health.

CHAIR STETKAR: But does that affect his performance uniquely for scenario X versus scenario Y versus scenario Z in a PRA? Or is that a uniform contributor to the uncertainty in his performance for any scenario on that day?

MEMBER ARMIJO: I'm only worried about the scenario that Mario talked about, the critical ones. Those are stressful, and he's already under stress. Do you just use a fudge factor, say, okay, whatever I measure with normal, healthy, happy people --

MEMBER BONACA: But I thought that the way that the operators in the control room operate, or the numbers of people and the repetition, in part, does tie to the kind of event, to cope with a weak performer for a day, because you do have a supervisor person there in the control that repeats statements, repeats actions, follows up on what you are doing.

MEMBER ARMIJO: But you have dominant personalities. You have senior people. If they are the weak link, you've got a big problem.

MR. HALLBERT: Your question to me sort

of lies in the margins of a discussion around fitness for duty and the importance of individual crew variability, which ultimately do end up in the area of uncertainty analysis.

MEMBER BROWN: But fitness for duty doesn't come down to the operator --

MEMBER BLEY: Not the alpha operator, but if you were here for the discussion on that several months back, it does come down to questioning people and seeing if they have problems going on at home, and that sort of thing. Actually, that is enough to remove a person from duty.

MEMBER BROWN: Yes, but I was thinking more of the dominant personality, the guy they perceive as being smarter, having a better feel for the plant, and they follow him along. They are -- I don't want to call it "intimated", but they don't question his judgment or her judgment, whoever it may be. So, I think that is a bigger, to me, that is a bigger issue of dominant personalities from a bias standpoint than the other factors.

CHAIR STETKAR: We can discuss many of these points for hours and have already. I think what I would like to do, I do want to at least get some input from those infamous middle-level folks who are going to tell us everything we need to know about performance-shaping factors and how they are relevant to the world, in at least a half hour's worth, recognizing that we are only go skim the surface, but at least to give the Subcommittee a sense of what you are doing.

And again, as I mentioned earlier, I think that at 5:00 we need to think about probably scheduling another meeting to revisit several of these issues in the relatively-near future and have a better opportunity to delve into some more of the details on some of these topics.

MEMBER BLEY: While they are setting up, I would just say I look forward to when they can tell us more because, if there's a glue that holds this whole thing together and ties together the pieces, it has got to be here.

MEMBER SHACK: We are not putting you under any pressure or anything.

(Laughter.)

CHAIR STETKAR: Don't start at the beginning and march as far as you can in 30 minutes. We are fully capable of skipping if you have some really important, salient points.

I think what Dennis mentioned is, in

fact, true. We would like to at least get some confidence from your presentation on how your work stitches all of this together. Because, ultimately, what we are hearing is it is one of the bases for a quantitative evaluation, and that being said, it is also the fundamental basis for how we think about human performance, which feeds back into the basic elements of that qualitative structure we spent most of today talking about.

So, you can kind of think about those.

MS. WHALEY: All right. Well, other than go through the purpose of this presentation, I am just going to talk real briefly about what we are trying to accomplish with what we are calling the "mid-layer".

Basically, in this project we are focused on explicitly grounding this hybrid method in cognitive science and psychology in order to have a complete characterization of the human performance in the model. So, we set out to really look at a very kind of bottom-up approach, see what the psychological literature could tell us about human performance and how could we incorporate that knowledge into this very practical applied HRA methodology.

So, basically, the benefit of this is that it gives us a more complete list of failure mechanisms, allows us to use these empirically-supported models to connect the performance-shaping factors to the human failure events that have been identified in the CRT, in the event tree. And it reduces human judgment, and it provides more increased traceability.

So, basically, what we had planned on talking about is our literature review, identification of failure mechanisms, construction of mid-layer fault trees, and then mapping to the PSFs. I am going to just, rather than talk about the literature review in-depth, I am just going to kind of highlight that.

But, basically, we have spoken about IDA a number of times today. We used the IDA in our literature review as a starting point. Basically, it is a three-stage model of human cognition that, basically, any model out there will agree on these three fundamental aspects. And it includes all the relevant areas of human performance that we are interested in.

So, we used this as a starting point. Then, we did a literature review. Basically, we said

"I" encompasses information-gathering and detection, and "D" encompasses understanding the situation and making a decision, and "A" is implementing the action. So, what models do we need to look at that will address all of those parts of the IDA structure?

This was a very bottom-up approach. Other than using IDA kind of as a starting point, we didn't impose any sort of top-down structure at all. We wanted to see what the psychological literature would tell us.

Then, we took what we found and started trying to turn it into failure mechanisms. Essentially, what we are doing by turning something into failure mechanisms, we are trying to identify how this process may fail. We are trying to identify the ways in which any particular model or cognitive theory, what are the ways in which an error can occur in this?

And we were trying to look for things that are pretty much guaranteed failures. We kind of had a criteria that we would use to say, okay, this feels more like a PSF. There is something that pushes you one way or the other, but it doesn't guarantee failure.

This review produced over 130 separate

types of errors. Then, all of us psychologists got together and we condensed those down into about less than 30 error categories. These have become our list of failure mechanisms.

This is just an example. We take a couple of sentences out of an article and we would say, okay, well, this article states that people sample information sources as they are perceiving elements of information. One way that situation awareness may fail is if the information-sampling strategy isn't correct. So, what's the end result of this?

We kind of went through all of our literature. What is the end result of this error and this error? Well, it is the cues aren't perceived or they are not attended to or they are misread. These became our failure mechanisms.

What we have that we are working on is that we have what we are calling a master table. It is over 130 items long. So, I am not going to go into any of those in any great detail. But we are breaking it up by the IDA stage, and we are identifying the failure mechanism, and then the psychological support for each failure mechanism. There is often more than one instance of support from different models. We are identifying the model, if the model contains stages or steps, an explanation of that model and a description, a reference.

We are coming up with examples. Currently, we are trying to make sure that we have examples that are relevant for this domain, rather than just general psychology.

Then, we are just really getting started on connecting the failure mechanisms to the PSFs, but I have some examples that I am going to show you.

These are meant to be illustrative. We don't need to get into the nitty-gritty of these details. But this is an example of an "I" phase failure mechanism, cues are not perceived, that is explained by two separate cognitive models. We've got filter theory, which basically says that we have sensory bottlenecks, and we are able to look at that and say, okay, it looks like task-load could affect this, you know, the amount of information that is going on. So, this task-load is a PSF that we could put in our PSF structure.

Or situation awareness specifically states distractions can lead to a failure in perception of relevant information. Some of the literature specifically says that this error is particularly a problem when you are having issues with attention. So, this is an example of how the psychological literature can tell us something about the PSFs for a particular failure mechanism.

We have similar examples for the "D" phase and the "A" phase of IDA. Here we are looking at one failure mechanism of data being misinterpreted. That error can occur, according to situation awareness, basically --

MEMBER BLEY: Situation awareness level 2 --

MS. WHALEY: Yes.

MEMBER BLEY: -- is that a reference to your tree structure?

MS. WHALEY: No, that is a specific stage in the model of situation awareness.

MEMBER BLEY: Oh, okay.

MS. WHALEY: As structured by Mike Endsley, the author of that particular model.

MEMBER BLEY: Okay. So, that's where it comes from. Okay.

MS. WHALEY: Yes. Basically, level 2 of situation awareness is where you integrate all your perceived information into some sort of understanding. This can fail due to an inaccurate knowledge of what the perceived elements mean. This is particularly vulnerable to training knowledge and experience. So, here the literature is telling us this is a PSF for this particular error type.

Similar thing for recognition-primed decisionmaking. You can misclassify the situation due to attending to the wrong cues. So, this process would be vulnerable to attention, which is one of the personal PSFs in our PSF structure, which Stacey will be talking about shortly.

And a similar process for some of the "A" mechanisms. These are just excerpts. Our list is much bigger than this.

But you can skip a step. This can apply just in like a task sequence or it can also apply in following a procedure step. But it is kind of meant as a task sequence.

And interruptions or distractions can lead to placekeeping errors. This is a contextual error identified by James Reason. So, that would be vulnerable to task-load and attention.

Or you can omit a step due to the location of the step in the task sequence. One of the most classic examples of this is the post-completion error of leaving the original in the copier machine. You're done; you leave the original, and you walk away and you don't get your original back.

An example that is kind of more relevant to this domain is leaving a tool in the equipment, post-maintenance reassembly, forgetting to remove a lockout/tag-out, you know, these kinds of things. The last step in the action sequence is vulnerable to omitting.

So, now that we have got this large list of failure mechanisms, supported by the cognitive models and the psych logical literature, the next step that we have been working on is to organize these failure mechanisms into fault trees that will connect to the CRT.

As Song-hua said earlier, his fault trees were developed independently of our fault trees. We are in the process right now of bringing them together and seeing how we need to combine them, merge them, change them.

MEMBER ARMIJO: April, these are the 30 categories of similar failure mechanisms?

MS. WHALEY: Yes.

MEMBER ARMIJO: Is that your -- okay.

MS. WHALEY: Yes. Okay. So, Stacey has been the one working on the fault trees. So, she will talk about those.

MS. HENDRICKSON: You can stay there. I will just go from here.

MS. WHALEY: Okay.

MS. HENDRICKSON: So, April said and we said earlier, these were developed parallel to what Song-hua has been working on, but the structure is the same.

So, what we have done is tried to break down -- you start with HFE, and then you try to break down and find the source of the error. What has been directing, then, it is the I, D, and A structure.

I am going to go through these fairly quickly, since we have already hit on the structure of fault trees, we have already talked a lot about this, so that I can get into the PSF structure a little bit.

In general, the way we have set it up, the fault trees that we have been working with do not have a nested level. So, we just went with here's your general fault tree for the "I" phase. We have still maintained the rule- versus knowledge-based cues. Underneath each of those, then, are the list of relevant failure mechanisms. Then, under each one of the failure mechanisms will be the PSFs eventually. That is what we are working on currently, is coming up with these PSFs.

Now it is possible that, in coming up with the relevant PSFs driving these failure mechanisms, that these fault trees could change some, in that earlier we talked about that currently this division between rule-base and knowledge-based seems to make sense. But the reason why we are going with that is because we are assuming that the rule-based cues and the knowledge-based cues, that when we break it down into the failure mechanisms and the PSFs, that we will find differences.

If when we get down to this level we do not find those differences, and if it makes more sense to either merge them or to come up with a different distinction, then we'll go --

CHAIR STETKAR: But you haven't gotten that far yet?

MS. HENDRICKSON: That's right.

CHAIR STETKAR: Okay.

MS. HENDRICKSON: Exactly.

MEMBER ARMIJO: Why do you have instrumentation failure in that lower box, since that is equipment, not people?

MS. HENDRICKSON: Right. So, what we are saying here is the rule-based cue was to follow the procedures, and the procedures told them to look in instrument. There was instrumentation failure that, then, drove the person to do something incorrectly. So, you're right that the preliminary --

MEMBER ARMIJO: I could see them not having confidence in an instrument, and even though it is right, he just ignores it.

MEMBER RYAN: Or vice versa, you could have kind of the reading error problem of --

MEMBER ARMIJO: I see reading error, that is a different thing.

MEMBER RYAN: Well, but that can be related. He might read it incorrectly, and it also might be reading incorrectly.

MS. HENDRICKSON: Yes, you can have different drivers towards the mistake made by the person as well. So, the error could be driven by their own interpretation, meaning like a reading error, or it could be driven by what has been presented to them.

MEMBER ARMIJO: Okay.

MS. HENDRICKSON: Or has not been presented to them.

MEMBER RYAN: I guess maybe interpreting it incorrectly, based on it's reading low, let's say, and he knows it should be high, and he interprets that. He is actually making an interpretation of the correctness of the reading --

MS. HENDRICKSON: Yes, exactly.

MEMBER RYAN: -- as well as reading it.

MS. HENDRICKSON: Exactly, and you also have that they have collected it and they have dismissed it. That is related.

MEMBER BLEY: To keep this along the human side down here, if you had misinterpretation of instrumentation failure, that would get your point across, I think.

MS. HENDRICKSON: Yes.

MEMBER BLEY: It wouldn't just have a hardware thing.

MS. HENDRICKSON: That is a good point.

MEMBER BLEY: Yes.

MR. MOSLEH: Now recall that I think initially we are trying to kind of see what fails the "I", and then that is an input from the plant as well as the mechanisms that are internal or human in nature.

MEMBER BLEY: Or unrecognized.

MR. MOSLEH: Unrecognized, yes. So, I think we may at the end really separate these things clearly and say, you know, external to the person or as a result of kind of a human failure or some human decision. At this level, it is recognizing that the failure in "I" could be due to the failure in source, namely, instrumentation failure, or failure mechanisms in general. Separating that is something that can --

MS. HENDRICKSON: Absolutely.

So, this is the rule-based cue branch. The knowledge-based cue is than covered here. And you will notice that a lot of these are very similar. In fact, only two of them change, just intentionally ignore the alarms and cues, and there's a second one that has changed here as well. But, in general, six of the eight have stayed the same. Just getting down to that, we were thinking the PSFs would probably be different for the two.

Similarly, then, there is a "D" phase, where we break down -- we have kept the rule-based versus knowledge-based decision strategy. Again, for "D", realizing perhaps that the procedure-driven decision strategy is going to be different or lead to different types of errors, then what a person who is following their own knowledge or experience is going to lead them to make.

For instance, one of the primary blocks that is under the knowledge-based decision strategy is errors in situational assessment. This came up earlier, asking if we had -- I don't remember exactly the wording, but it was related to the state of misinterpreted. This is where it would be included here.

Earlier the conversation was, has this been included? Would it be under an "I" or a "D"? We have chosen at this point to put it under "D", which is that, once information has already been gathered by the operator, and now he has it in his head, what kind of decisions will he make with this information and the interpretation of the data?

Dennis?

MEMBER BLEY: Just one jumps off the page to me there that worries me. Errors in situation assessment can be these misinterpretation things. They can also be what some people call a mental model.

MS. HENDRICKSON: Yes.

MEMBER BLEY: My picture of the plant isn't correct.

MS. HENDRICKSON: Yes.

MEMBER BLEY: Under my picture of the plant, I'm interpreting things correctly, but it's wrong.

MS. HENDRICKSON: Yes, yes. Right.

MEMBER BLEY: And I don't see that falling in somewhere here. I hope that gets picked up somewhere.

MS. HENDRICKSON: It has. So, what we have tried to do, and we have kind of gone back and forth on some of these mental model pictures, is, can we boil it down to when the error is actually realized or how it manifests itself or how it is observed? Can we boil it down to one of these two simpler forms of either data misinterpreted or data misprioritized? Or do we need to keep it as a separate level, being a mental model?

One of the things we have tried to keep with these failure mechanisms is that they are observable and that they are predictable. So, one of the things we have struggled with in that very thing of either goal selection, forming of the mental model or of the scheme they are working with, is there a way to phrase it such that it is observable?

MS. WHALEY: And under the data

misinterpreted failure mechanism, we have a large number of instances of psychological support, some of which are we have the wrong mental model. And others are misread the data. So, that is kind of encompassed in the justification for a data misinterpreted failure mechanism.

MEMBER ABDEL-KHALIK: Is navigating through the procedures a part of the "D" phase?

MS. WHALEY: Yes, it can be.

MS. HENDRICKSON: It can be. It can also be part of the "I" phase and it can be part of the "A" phase.

MR. MOSLEH: It changes back and forth, you know. You go from "I" to "D" and then "A" in a procedure. Because you read and then interpret and then take action, and you go to the next step. So, the cycle is --

MEMBER ABDEL-KHALIK: Well, no, what I meant by navigating is jumping, for example, from E0 to E3.

MS. WHALEY: Yes, that would be in the "D".

MR. MOSLEH: "D", yes.

MEMBER ABDEL-KHALIK: Okay.

MS. HENDRICKSON: Because in that case,

you have to, well, one, you are assessing the situation, and then you are making the decision of how to react to that situation of deciding, then, to leave to go to the other procedure.

MEMBER ABDEL-KHALIK: Okay.

MS. HENDRICKSON: And the final one that we have come up with is the "A" phase, which is really, I guess, maybe the most cut-and-dried. Right now, we have boiled it down to just the five failure mechanisms that you see here.

When you are in the action phase, what we decided at this point was to get rid of the rule-based versus knowledge-based because now they have decided to take the action. Whether it is driven by procedures or whether it is driven by their own knowledge and experience, we haven't seen the need to maintain that difference.

So, I will give you a minute to look through these, if you have any questions.

MEMBER ABDEL-KHALIK: But that is perhaps where safety culture comes in, right?

MS. HENDRICKSON: Yes.

MEMBER ABDEL-KHALIK: I mean there are some utilities, if somebody goes knowledge-based, they would be terribly upset about it.

MS. HENDRICKSON: Well, and you can also see that certainly the safety culture, delaying execution of the action, so earlier we are talking about station blackout and initiating station blackout, and you could see definitely an argument for either the organizational culture or the safety culture driving the crew in contemplating the delay here.

So, certainly, I see those playing a part in coming up with these decisions, the decisions to make these actions, I should say.

MEMBER RAY: I apply the pretty well-publicized Copenhagen experience to this, as you were talking about it. At this step, for example, it was really not selecting the wrong component; it was taking the opposite action to what should have been taken. It was pulling back on the stick instead of pushing forward on the stick, for example. I think there are analogous things in the --

CHAIR STETKAR: That is what I was going to ask. I had another example, but that is a good one.

MEMBER RAY: Yes. Well, Copenhagen had a lot of things. It had fatigue. It had training. It had on and on. Situational awareness was screwed up.

CHAIR STETKAR: How do you account for those types of behaviors that have been observed? I was going to ask you. Practical experience, an excellent operator, well-trained, had interpreted the available information that, indeed, he was cooling down too fast and walked up to a valve and closed the valve because he knew that, by closing that valve, it would slow the rate of cooldown. And indeed, he increased the rate of cooldown by closing down on said valve and continued to do so until he called for help because he needed to go have the valve repaired because it wasn't operating correctly.

(Laughter.)

How do you account for that? That is precisely the opposite. He knew what he wanted to do. He had the information. He was interpreting the information correctly. He was following what he thought his training told him to do. And yet, the outcome was precisely -- he didn't not do something. What he did was precisely opposite to what he should have been doing and had no mental mechanism to recognize the fact that maybe I ought to undo what I'm doing.

MS. HENDRICKSON: That would be a problem with his mental model of what his action --

CHAIR STETKAR: But where does that come into --

MS. HENDRICKSON: That would be in --

MEMBER BLEY: And he proved that is a hard one to overcome.

CHAIR STETKAR: And he proved it was a hard one to overcome.

MS. HENDRICKSON: Yes. I would definitely put it in "D" and under knowledge-based.

CHAIR STETKAR: But he didn't misinterpret the data.

MEMBER RAY: I think sometimes you take the opposite action for some reason that is not --

CHAIR STETKAR: He had a perfectly good reason.

MEMBER BLEY: Harold's is he meant to close it; he opened it. That is a different one.

CHAIR STETKAR: Okay. That's right.

MEMBER ARMIJO: Your guy meant to close it.

MEMBER BLEY: It was all consistent with what he expected, and he ignored it.

MEMBER ARMIJO: And he ignored that. He didn't say, "I must be wrong." because he knew he was right.

MS. HENDRICKSON: These are two different things. In the one where he meant to close it but he opened, it would be an "A" phase error because that is just a slip or a mistake in an action.

The one, however, where he took the action that he meant to take would be under "D" phase. It is a misinterpretation of the situation.

So, I don't know that it would necessarily be data misinterpreted. It may be under data --

MEMBER BLEY: That's why I had trouble fitting it in there.

CHAIR STETKAR: That's right. When you brought that up, I thought of my example.

MEMBER BLEY: I've got other examples just like that.

MS. HENDRICKSON: There is a difference between those two.

MS. WHALEY: So, we may be needing to pull the wrong mental model out as a separate failure mechanism rather than --

MEMBER BLEY: Or redefine it. That means things to different people. But come up with something that has if is the wrong picture.

On your other picture --

MS. HENDRICKSON: Which one?

MEMBER BLEY: Where Harold asked about the "A" phase, it does seem you are missing some of the slip kind of things.

MS. HENDRICKSON: Yes, I know that we talked about that.

MR. MOSLEH: There is a kind of a long list. That is a fairly good one that will appear in some of the HRA matters. I like that. In fact, we put it in a table. We haven't really closed this particular item yet.

That is, you know, you can look at the action failure in a number of dimensions, in the time dimension, in terms of the force and momentum, and other things, because physical action, you are talking about whether you are delaying yet or acting in time, whether you are applying too much force in the right direction, in the wrong direction. All those things are specific categories of failure.

So, as a minimum, one could actually list those, the way a particular action is incorrectly implemented. That is kind of the type of list that you have seen as a setting in some HRA methods. You could use that.

In fact, that was what we discussed

there, yes.

MEMBER BLEY: Or something to pick those up. You know, it doesn't quite fit in these boxes.

MS. HENDRICKSON: Yes. Yes, we are missing one, I think.

Do you want me to jump to PSFs?

CHAIR STETKAR: Yes. Yes, let's hear about five minutes on everything you wanted to know about PSFs.

(Laughter.)

MS. HENDRICKSON: What I am going to do is jump from -- I am going to cover this, the graphic, real quick, and then jump ahead.

What we are trying to do, then, is we have a failure mechanism that, through the cognitive models that we have discovered through the literature review or through experience, then can break it down into what the performance-shaping factors are. What we are using is a grouping of -- it is called the kind of six-bubble model, I think.

This comes from Katrina Goff's University of Maryland dissertation, where she went through and did a factor analysis and came up with these definitionally-orthogonal bubbles. So, what that means is that these six high-level groupings are definitionally-orthogonal.

Under each one, then, are the PSFs that we are, then, thinking of using for describing these failure mechanisms. So, this is what we are trying to now go back and group these into those relevant failure mechanisms.

For example, here we have one failure mechanism, unintentionally ignored alarms. We have picked situational awareness could be one of the cognitive models which would explain the unintentionally ignored alarms.

Then, breaking that out into what really is it that has caused or has driven the operator to unintentionally ignore the alarms, it could be a narrowing of attention. And all three of these could, then, be explained by the model of situational awareness.

So, we have the narrowing of attention, which would be explained by the PSF of workload; the premature closing of the search for information, which is failure to consider all the information presented due to high stress. So, therefore, the PSF is stressors. Or in sufficient expertise to understand, to make those fine classifications of the information that is coming into the operator, which would be due to experience and training.

So, this is just an example breakout of how we would go from one failure mechanism and then, based on the cognitive model, on which the cognitive model would be driven, the relevant cognitive would be driven by the context leading up to this, then would explain what PSFs are relevant in this situation, what PSFs were really driving this failure mechanism.

MEMBER RAY: Can you back up one slide?

MS. HENDRICKSON: Yes. To the list of the PSFs?

MEMBER RAY: Yes. I was trying to read the top right one there for a second and see if fatigue was in there somewhere.

CHAIR STETKAR: It is. The second sub-bullet under 3B.

MEMBER RAY: Here is it, yes. Okay.

MEMBER ARMIJO: I am wondering, what do you mean by psych abilities under "physical and psych abilities"? What is it?

MS. WHALEY: Those would be the individual differences, you know, that we were talking about earlier. Basically, it is the psychological characteristics of the individual operator, of which alertness and fatigue are subcategories.

So, in there, you would also probably include kind of -- in the personal box, I mean this is kind of a high level. If you look at her dissertation, there is a breakdown of a lot more specific items. But included in the personal box would be things like attitude. You know, so the dominant personality would fit in here.

MEMBER RAY: Yes, but something that is a lot more practical or down-to-earth that I have been involved in, for example, is the debate over 5/8s versus 4/10s. What effect does that have, when you add overtime, then, to either one of those? Well, I mean, that is an important thing to try to know about. You can have endless arguments, and I have, with unions, because the operators they love 4/10s; they could go for 3/12s, if you would let them, things like that.

And it has a heck of an effect, but most of the time the shift is boring, and the fewer of them you have to put up with, the better, from their standpoint. So, there's always a tendency to say, "I'm just fine. I can respond to any emergency that arises." But having some better measure of the reality of that is valuable, I think, as we go about trying to do our job.

MEMBER BLEY: You know, one of the things that jumps off the page here for me is this catalog. I'm not sure how you are going to end using all of this, but some of the things in this catalog are a good source of things to consider when you address uncertainty.

CHAIR STETKAR: Yes. Well, that is what I was going to ask. How far along are you in terms of linking this catalog to an actual computational model, which is what we eventually will need? We need to know how variability within, theoretically, all of these factors will be measured in some sort of quantitative sense, and then how those quantitative elements will be combined through some type of cognitive, you know, some type of model, some type of logic model, to ultimately influence what our predicted human error probabilities will be.

In fact, as Dennis said, are the effects primarily in terms of uncertainty or are they effects in terms of an absolute estimate, in terms of human error probability? How far are you? I see the smiles.

(Laughter.)

But I need an answer. How far along are you in that?

MS. HENDRICKSON: That is a good point. So, at this point, we are really just getting started.

MS. WHALEY: Well, I would say we are still assigning the PSFs to the failure mechanisms, so getting to the point of quantification, we are not there.

CHAIR STETKAR: You are doing a catalog? You are still in the cataloging stage?

MS. HENDRICKSON: Yes.

MS. WHALEY: Exactly.

CHAIR STETKAR: Okay.

MEMBER BLEY: Go to that next --

MEMBER ABDEL-KHALIK: Before that, can I just ask a question about one of these? The situation PSF grouping, when we talk about urgency, I guess the tendency is for people to think that, if something is really urgent, then there is a higher likelihood that people would make a mistake.

But there is also the other side of it. If people perceive that something, hey, it's no big deal, they often make mistakes.

MS. HENDRICKSON: Yes, that's right.

MEMBER ABDEL-KHALIK: Now does your model allow that?

MS. HENDRICKSON: Yes.

MEMBER ABDEL-KHALIK: Or are these sort of monotonic functions?

MS. HENDRICKSON: No, it does allow that. Because you are absolutely right, that if there is not the appropriate level of urgency, or we could fit it under a broader term of stress, then you face boredom.

MEMBER RYAN: Isn't that complacency then?

MS. HENDRICKSON: Exactly.

MEMBER RYAN: So, it's a view. It is complacency goes to urgency point of view, right?

CHAIR STETKAR: Yes, it is. No, there is --

MS. HENDRICKSON: There is a U-curve. Absolutely.

CHAIR STETKAR: There is an optimal stress.

MS. HENDRICKSON: There's an optimal level --

MEMBER RYAN: Okay.

MS. HENDRICKSON: So, this would account

for that.

MEMBER RYAN: Thanks. Sorry, Dennis.

MS. WHALEY: This particular categorization of PSFs is value-neutral in the sense that it talks about training not as a poor training or good training, but what is quality of training. It allows you to move in either direction.

MEMBER BLEY: Would you go to the one you had up there before, the next one?

MS. WHALEY: Which one? This one?

MEMBER BLEY: Yes. A nice thing about this picture, I think, is if you are actually doing an analysis, you have somewhere identified that unintentional ignored alarm might be troublesome for a situation in you are in.

In a lot of methods, you might say workloads are three, something else is a six, or something. But this gets you down to the point to think about, what are the things that could affect me here? Does this particular scenario and context make them more likely? And how do they affect the uncertainty overall? So, it gives you a nice structure for thinking about things.

This is the first time I have seen this. So, this is kind of nice.

MR. MOSLEH: And I would like to add something to the discussion on the PSF. There are a number of issues that we will need to tackle. One is we can list the number of things, factors, that you consider to be influencing behavior, but these are factors that could also be, should also be definitionally-orthogonal, meaning really they should not have any overlap. That doesn't mean that they are not independent.

CHAIR STETKAR: That's right.

MR. MOSLEH: So, there is a structure of interdependency among them. Safety culture from this penetrates through all the layers. Some factors such as workload affects other things.

So, one of the things that Katrina did was she was trying to use a limited database we have to try to see the structure of interdependency among the PSFs, and to see if we can actually develop a model of the PSFs collectively. That is one dimension of the problem we are trying to tackle.

I am not sure to what extent this project will be able to deliver such a structure because it also requires additional data and information, but in terms of kind of the path forward and roadmap, that is the direction we would like to take.

CHAIR STETKAR: I think that is one of the reasons for my question earlier. Although this project, I guess a little bit of my unease is, when you say this project may not be able to develop that structure, almost by definition it needs to because, if you are developing the PSFs and proposing methodology of how to use those to quantify with some degree of confidence and reproducibility human error probabilities, you almost need to tackle that internal logical construct, don't you?

MR. MOSLEH: John, it depends very much on the extent to which such model would be made to be subject to validation and then testing of the type that is possible within the realm of --

CHAIR STETKAR: But, remember, the SRM is to try to reduce variability in estimates that come out of different models. So, if you are saying that, well, we are going by definition to have a large variability because we can't validate our internal models here, that strikes me as --

MR. MOSLEH: Well, you just propose a model, and then say that there won't be any variability. But the question is, do we have the knowledge base and the support, the supporting evidence, to say, well, here is the structure of interdependency?

If you ask me personally, I have proposed two. One is through Katrina's work, which is interdependence. The other one is through the IDAC model. We have actually a causal model there.

But this really needs to be subject to kind of a broader review and validation and testing in order to get to a point to put the stamp of an agency like this.

CHAIR STETKAR: Let's see, it is seven after 5:00. Everybody is getting pretty exhausted, I think.

Can you, in five minutes, give us a picture of where you are headed and an estimate of schedule for where you are headed? And if the answer is no, that's okay.

MR. MOSLEH: I'll try two minutes, and I will leave the other three minutes for John and Erasmia.

So, we are in the process of bringing the pieces of the qualitative analysis together and then develop a set of procedures and the necessary at least minimum set of test cases to demonstrate or test some of the things that we haven't been able to test. For instance, is this going to improve inter-and intra-reliability? Then, we are going to participate in a benchmark and then going to test that.

So, some of these things are in kind of the near future. In the next three or four months, we will be in a position to integrate all of these things into a framework with procedures.

At the same time, in parallel we are starting, quite actively, in two weeks from now, to have our first serious meeting on quantification. Even though there have been a lot of ideas on the table, we are going to kind of look into the quantification. So, that is going to be a parallel activity now that we know more or less generally what the architecture of kind of the qualitative approach looks like.

So, the two key components, kind of wrapping up and integrating the quantitative approach, and starting ramping up the quantitative approach, are the things that are kind of basically in the near future.

By the end of the year, we hope that we will be able to address and kind of cover the qualitative and the short-term quantitative approach. The long-term quantitative approach that included kind of an outline of a data-driven or data-based quantification is something that we will probably formulate, but, obviously, not implement because that requires database development.

So, that is kind of the short-term horizon, basically, between now and the end of the year. I think the following year is really --

MS. LOIS: The tool development and guidance.

So, at the beginning, I indicated that this is kind of a decisionmaking for us. If you have real concerns and you would rather us let this go and go back and take a couple of methods and kind of try to measure them, we should know that now as opposed to later.

We believe that what we do here, we provide a structure and more explicit representation of what an HRA analyst is doing through a thought process. By doing that, we are embracing a lot of the variability aspects.

For example, even the same analyst, if it doesn't have these structures, probably will miss some aspects of the scenario being analyzed if today he talks to these three experts and tomorrow talks to some other three experts. So, we try to create that structure and framework that provides the pathway of not missing a lot of things, recognizing that you can never be complete.

But my desire is to hear that, in general, you agree, and if you don't agree, then what we should do.

CHAIR STETKAR: Yes.

MS. LOIS: I don't want to come back in six months from now and you say, why you didn't do ATHEANA and CBDT together --

CHAIR STETKAR: Right.

MS. LOIS: -- and why you did that. We did it because, on the basis of the empirical study we saw and the lessons learned from the various methods, we felt that this what we call model-based HRA approach that uses that structure, the "I", the "D", and "A", is a way of helping and formulating, formalizing the process.

If that is okay with you, recognizing that there are a lot of things that should work, we are working on, I believe that at least we could have a good draft representation of the method, including the quantification, by the end of 2010. Is it a big rush to do that? I believe that there was a rush before, and, also, another driver here is the fact that we may do a new 1150 study, and we wanted to have a methodology that would be ready and probably be applied, and then learn from the experience.

CHAIR STETKAR: And I think if people are crafting PRAs for the new reactors coming online --

MS. LOIS: Exactly.

CHAIR STETKAR: -- they are still in the design phase, but as we get closer to COL stages and fuel loads, those PRAs will be refined and need a human reliability aspect to them. So, there is some time pressure.

And thanks for your feedback.

First of all, the Subcommittee can't give you guidance about whether or not we think that this is good, bad, or indifferent. That is something that is going to have to come from the full Committee. I think this is an important enough issue that it would merit a full Committee letter.

But we will go around the table at the end of the meeting, but my initial reaction is that, although we have good attendance today, we don't have the full Committee and we haven't had the benefit of internally discussing good points, bad points, and whatever.

I think another problem is that,

obviously, there's a lot of discussion about this topic. I don't think we have had the full benefit of hearing all of the different pieces, even from what you have presented. Just time constraints.

What I have thought about is perhaps having another Subcommittee meeting in the near future to sort of catch up on some of the areas that we glossed over, and perhaps try to push a little bit more toward a real example. Although you had an example, it was still a relatively high-level example of a fairly-contrived type of action. I am more interested in seeing a rather more thought-out example of perhaps some more of those difficult typical actions down into the structure of your little logic model, getting through to some different flavors of bleed-and-feed cooling to see how your method would, indeed, address some of those issues.

So, I think I would like to explore getting another Subcommittee meeting. The question is when, trying to be responsive to your need for some feedback from both the Subcommittee -- I mean you get the technical feedback in the Subcommittee meetings, but from the full Committee in terms of concerns about proceeding in the direction that you are headed now, or should there be some thought about a different direction? I do feel pretty strongly that that should come from the full Committee because it is an SRM task collectively.

I guess, Peter, we need to work with Erasmia and decide when we can schedule --

MEMBER SHACK: You need a full Committee meeting, too.

CHAIR STETKAR: We will need a full Committee meeting, but my sense is we need another Subcommittee meeting on this topic before we get to the full Committee meeting because I am not quite sure what we would present to the full Committee. That is just my thought right now.

The question of timing of that Subcommittee meeting is going to be a bit difficult, just because of our schedules. So, we need to think about that.

It's late. Let me go around the table and ask each of the members present whether, No. 1, you have any specific comments that you would like to make, sort of from what you have heard today, that would be useful to the staff in terms of where they are going, what they have done.

And No. 2, some feedback on what I just discussed. Should we have another Subcommittee meeting before we go to the full Committee? And do you think that a letter from the full Committee regarding the direction of this is worthwhile?

So, the first is sort of technical comments, if you have any. The second is more of a procedural where do we go from here internally.

Charlie, since you are sitting over there and still awake --

MEMBER BROWN: My eyes are open.

CHAIR STETKAR: And your eyes are open.

(Laughter.)

MEMBER BROWN: On the technical side, I won't add anything. I did come to the conclusion we, obviously, have to have some full Committee. Yes, I totally agree with your assessment of that.

But, right now, I don't see a product that you can lay your hands on, based on what we have done today, that you could write a letter that would say, hey, we want to go this, that. I mean there's many wiggles and weaves and some uncertainties in terms of direction. That is my personal opinion from listening to it, and the other issues where we have laid out a letter that said, hey, this is the direction, we had a product that we were looking at.

It could be a game plan. It could be,

say, we need to do this and put these things in place and go forward, and here's a schedule, something like that. I'm not saying you have to have everything, all the "i's" dotted and "t's" crossed, but you need to know where you are going. What are you actually -- a crisp, one-page statement, what are we trying to do that you can get across to somebody, not 50 pages or 50 slides and have somebody deduce what it is.

With you and Dennis and some others, I was able to divine a few things. I am, obviously, not an expert on this stuff, and I am also a skeptic.

(Laughter.)

So, that is my thought. I agree with another letter. I think you probably need another meeting. I think you need to have a little bit more of a structured product of some type, if you are going to recommend stuff that you are going to write a letter on.

CHAIR STETKAR: Okay. Harold?

MEMBER RAY: Well, I think this is important, John. I've got more questions than I have opinions at this point. I would certainly benefit from another Subcommittee meeting.

I think I detected a desire for some

feedback that I think you would understand at this point better than I would as to what the letter would be addressing. I think there's more of an affirmation that we could provide than I could articulate right now. In other words, I think there's some value probably in us providing feedback, but you and Dennis would have to decide if we are ready for that.

In any case, I do think this is important, as I have tried to suggest at various points. I think there may be limits on what is achievable, and that may be as important input from us as anything else is. Okay?

MEMBER BROWN: That is my skepticism, also, that there are limits on the thing, not that it is not worthwhile looking at.

MEMBER RAY: So, I do think we should see if we can have another Subcommittee meeting, certainly the full Committee, and a letter I think is appropriate, but that is your judgment, not mine. It is really uninformed on my part.

CHAIR STETKAR: Dennis?

MEMBER BLEY: Yes, and I will stay away from the things I worked on, which wasn't a whole lot of what we have seen today.

(Laughter.)

As it says in the introduction to the paper, one of the key observations was in proving the qualitative aspects of the HRA methods as important. The story I have heard in the presentations and discussions indicate that is really a high principle here. The materials, however, focused on other things. So, to accomplish that goal, there needs to be the structure that talks about how that qualitative information gets generated and incorporated.

I have worried that IDA has kind of filled this whole piece, and I will acknowledge there's no information processing model that everybody would agree to, and maybe some don't agree with any of them. In some places, it seems to de-emphasize things that seemed important to me, but the mid-layer model seems to be the place where that sort of thing is picked up.

For me, getting a more complete picture of that mid-level model and how it works and ties everything together is kind of a key to seeing if we are really on our way to having a hybrid that is addressing the best aspects of various methods. Our quantification hasn't quite hit the streets yet here.

So, I don't think there is anything to say about that.

I haven't quite got the true response tree picture and what is new there and what is different from the event trees. And in fact, the example we went through looked to me like, if we actually implement it, we are only teasing people saying we're not redoing the PRA. We actually are, is what it looks like, not that that is a bad thing, but it looks like that is what it is about. So, we need to see more to get a real confident picture.

I really did like the stuff we saw in the last half-hour and think there's some new ways to look at things that are showing up there that will be really helpful. I look forward to seeing more of that.

I can't say anything here isn't workable, but it isn't clearly the next step, I guess, to me. It's en route.

And there are other parallel projects going on that would feed this, and the Subcommittee hasn't heard about those much at all.

CHAIR STETKAR: Sam?

MEMBER ARMIJO: Okay. Well, I am far from an expert on human reliability analysis. So, I will speak with confidence.

(Laughter.)

I think the staff did ask for feedback, and I think it would be a shame if six months from now they have a full Committee presentation for the first time and get negative feedback. I think, from what I saw, there was enough, more than enough, information to show the key parts of their approach and what they are trying to do.

I think it would be a good idea if they could get some feedback from the full Committee as soon as possible. You might consider reversing that Subcommittee and full Committee. You guys are the experts of whether you think that you would want to advise them to change direction in a radical way or just finetune it, but I wouldn't hold back on a full Committee briefing in the near-term.

I learned a lot. I thought it was very informative. I think, to me, the most important output of all this work is not necessarily going to be the reliability analysis itself, but it is in the identification of these performance-shaping factors on human error probability, and then feeding that into all the things that the plant can do to affect safety. That is in the selection and retention of the right kind of people with the right kind of intelligence, the right kind of emotional stability, health, financial situation, a lot of these things that are very difficult to assess, making sure that the operators have confidence in their emergency operating procedures, so that they can just use their knowledge to confirm where they are in any event and stick to their procedures. I think that is important.

Also, in feeding back into the training, as much as possible into the training under realistic conditions, taking into account these performance-shaping factors.

And of course, the other factor is the favorable work environment, everything from safety culture to hardware, work environment, pay, all of these things that affect human variability. I think that is where all of this issue is.

I think Harold is right, we are dealing with the tail-end, you know, the tail of a distribution, and the most variable piece of that tail and the hardest to measure is the human being. So, I think you are on the right track as far as the assessment, but I would hope that the information you get is feeding back into the operations people, so that they can really look at what they have done so far and see if we are doing all the right things to really get the reliability up, rather than just assessing where it is.

That's all I've got.

CHAIR STETKAR: Okay. Thanks.

Said?

MEMBER ABDEL-KHALIK: I think the question really that stands out is whether or not this effort is responsive to the SRM. What you would like is feedback from the full Committee as to whether or not you should remain on this track or you should change course. Therefore, I would agree with Sam that I think we have enough information for the full Committee to make that assessment without another Subcommittee meeting. That doesn't mean that we don't need another Subcommittee meeting, but we need perhaps to answer that question. I believe we have enough information to answer that question.

I can't tell you how the answer for the full Committee will be, but my own sort of personal bias is that I don't think this is responsive to the SRM. It may be just a matter of presentation.

In a sense, you indicated that a lot of the effort really is improvements to ATHEANA. You have identified a set of attributes that you would like to have in the model. You didn't find any model out there that meets all attributes. Perhaps the implication is ATHEANA is as close to that ideal model that has all these attributes as you can get, and therefore, your modification.

But I think I would have felt a lot better if, after going through that exercise, you said, okay, we will start with ATHEANA and we will modify it to get it to the point where it meets all the ideal attributes that we had identified.

Because all along this process, we would have a gradually-improving model towards the ideal model that meets all the attributes; whereas, the way this is presented, this is just another new model. I don't think, from that perspective, this would be responsive to the SRM.

Now the other issues, in my mind, creating a very complicated structure to answer a set of specific questions is theoretically wonderful, but unless you have meaningful data to validate it, then I think we are just plowing the ocean.

Those are probably the main comments that I can offer at this stage. There are specific comments about the use of templates, overconfidence in the model, how you integrate safety culture issues or concerns, et cetera. But the big thing is deciding whether or not you are on the right track.

CHAIR STETKAR: Yes. Thanks.

Bill?

MEMBER SHACK: I guess I don't know enough to know whether you are being responsive to the SRM. I was very impressed by the work today. I mean, to a certain extent, I am kind of with Dennis that the tree thing looks like, you know, you are redoing the event tree with sort of more attention on human response. That is probably a good thing. I kind of like the way you roll up the context as you go along to the decision points. That seemed a useful thing.

The mid-level model I thought was a very interesting way to do it. How you are ever going to get to a quantification process from this, you know, I look at ATHEANA on the one hand and SPAR-H on the other. We take a PSF modifier and multiply our SPAR-H probabilities. You know, that is a great ideal. Just how you are going to get there from here isn't at all clear.

I think that is where my question into the responsiveness of the SRM is. Have we created a wonderful qualitative picture, but can it be brought to a quantitative model that people will actually use? I mean, you created ATHEANA, which was never used by anybody. Are we going to come up -- well, I'm sorry, Dennis.

(Laughter.)

MEMBER BLEY: That is not true.

MEMBER SHACK: When EPR comes in and uses SPAR-H, when we have two NRC-approved models out there, I will give you a wild guess as to which one they are going to pick. So, that is sort of my qualm here.

But I'm of the school that we give them enough rope and let them hang themselves, would be sort of my --

(Laughter.)

You know, they are out there. They are on the --

CHAIR STETKAR: Well, wait. This is the first SRM that is written too fast.

(Laughter.)

It says, you know, "To: Tom Larkins, Executive Directors, ACRS".

(Laughter.)

MEMBER SHACK: You know, they are out

there on, I would say, the cutting-edge here. So, you know, that, again --

CHAIR STETKAR: They go down; we're down with them.

(Laughter.)

No, not on this one.

(Laughter.)

They win; we win. They lose; we lose.

MEMBER SHACK: Anyway, that is where I am at.

CHAIR STETKAR: Okay. Mario?

MEMBER BONACA: Yes, I must say I was equally impressed by the presentations. I think that there are still a lot of questions about where this ends and where it goes. But having been part of this Subcommittee for a long time, I have never seen before this jump in progress. So, we will call them the quantum jump. I mean there is a lot of information that you have got.

I think my main question is, are we ready for going to the full Committee? My sense is it will be different from Said. I think that probably you should answer that question, but maybe you need to do some more work before you get there.

MEMBER SHACK: Well, they want to know

what the full Committee is going to say.

(Laughter.)

MEMBER BONACA: But if you bring the amount of information we got today to the full Committee on a two-hour presentation, you know, it is not going to work. I think there has to be a better product in the direction of the SRM before we get to the full Committee. Anyway, that is my impression.

Beyond that, I agree that ATHEANA is the horse which has to run here, but we beat around the bush on ATHEANA for really a number of years, discussing. And now I see some progress taking place. So, anyway, my sense is I have a positive feedback to your presentation.

MS. LOIS: Can I mention something?

CHAIR STETKAR: Sure.

MS. LOIS: It seems, though, one lingering concern is the quantification. So, it seems that, unless we have a better proposal for how we are going to address the quantification aspect of it, it may be premature to go to the full Committee, I guess.

CHAIR STETKAR: I don't know. I mean I think that, my opinion, I think that from my perspective, for the full Committee to answer the question, is this project as it is organized and headed at the moment responsive to the SRM, No. 1? Forget all of the little technical details and all of those nuances. Is it responsive to the SRM?

One of the things that I would like to hear is, for example, I will now come back to that NUREG because the staff, research, and industry have spent a reasonable amount of time addressing the inability of current human reliability analysis methods to address some specific concerns that appear during the evaluation of internal fires. And that produced a NUREG that addresses qualitative descriptions of scenarios that address integration of scenarios into event models and, to a lesser extent, quantification, although it does address quantification.

So, my question, then, would be, well, how has your effort taken this into consideration as a potential building block? How has it taken into consideration other possible avenues that we broached during this meeting, meaning if you have evaluated several other methods relative to those attributes, desirable attributes of any HRA methodology, have you considered fluffing up the remaining 20 percent of the top one, rather than embarking on this methodology?

Or, as you have said, if this methodology, indeed, does build on the attributes of the best-available method, I think the full Committee would need to hear pretty succinctly how it does that. In other words, what is the selling point, so that we are convinced, indeed, you have taken that into consideration in how you have done it? Not at this level of detail, but at a much higher level of detail.

I think, without that information, you may be running the risk of a not-too-encouraging Committee letter. With that information, I think if you can build that case, if you listen to the discussion around the table, it might go the other way.

So, maybe I like Mario's idea. Throw it back at you. Do you feel that -- I understand your desire. In fact, I think it is time for the Committee to weigh-in. We haven't weighed-in on this one in quite a while. I think it probably is time for the full Committee to weigh-in on the direction on this program.

So, I do think that a full Committee letter is warranted. The question is, then, are you ready to come to the full Committee or do you feel you would like another Subcommittee meeting prior to that? You don't need to necessarily answer that question today, obviously, but think about that because we would like to accommodate you.

MS. LOIS: But to the extent that the quantification part of the analysis may not be part of the full Committee consideration, I mean if the full Committee could sustain the lack of complete quantification proposal and look at it only on the qualitative analysis, I believe that we can address what we heard from you, the concerns about the incorporation of existing methods, and how we did that, how we accomplished that, et cetera, and the building blocks. I believe that is doable.

But the quantification aspect is lingering. It is out there.

MEMBER ARMIJO: But that problem is for any model.

MS. LOIS: Yes.

MEMBER ARMIJO: Quantification is common to any model that you choose to work on.

MS. LOIS: Yes.

MEMBER ARMIJO: So, I don't see where that is a particular problem with your approach. I mean nobody has a quantification, do they?

CHAIR STETKAR: Yes. Oh, yes. Yes, I mean everybody does.

MEMBER ARMIJO: On human reliability?

CHAIR STETKAR: Absolutely. Oh, yes.

MEMBER ARMIJO: Then, I misunderstood it.

CHAIR STETKAR: It is the problem with --

MEMBER ARMIJO: Nobody believes it then.

(Laughter.)

CHAIR STETKAR: Well, no, wait.

MEMBER ARMIJO: Tell me.

CHAIR STETKAR: I used to use my hand. For the purposes of the record, let it be shown that my hand is up in the air.

We are talking in some sense of anchoring different estimates of human performance to actual experience. That is credibility of the numbers. That is one of your concerns, Sam.

MEMBER ARMIJO: Right.

CHAIR STETKAR: For many, many years, we have been developing estimates of human performance and at least proposing methods that will relatively rank those different human actions, such that we have reasonable confidence that it is much more likely that people will fail during this particular condition than another condition, without a lot of real evidence of what those absolute human error rates will be.

So, I think we need to be careful in terms of distinguishing between the validation, if you will, of specific estimates for specific human error rates, probabilities, and no methodology does that, versus the ability of a methodology to develop internally-consistent estimates for human error probabilities, and all methodologies claim that they do that, through a variety of different logical modeling constructs.

MEMBER BONACA: Well, what troubles me is that, even when they compared different methods, they, again, got different results. You know, that is, for example, one attribute of a decision that says I'm not going to have only one model because I cannot trust it.

That is the kind of information you like to have when you have the full Committee.

CHAIR STETKAR: And that is why I think that, Erasmia, for a full Committee, my opinion is you do need to address that quantification aspect because it is ultimately the end product of the whole analysis, is the estimation of a human error probability with some uncertainty that will coherently fit into a model for human performance, and that model being the PRA model.

So, I think, honestly, if you came to the full Committee and said, "Well, we have this wonderful methodology, but we haven't worked out the quantification," the full Committee is going to say, "We don't know what you're doing."

So, I do think that the quantification, you do needs to address that.

MS. LOIS: Therefore, probably what we should do is have another Subcommittee meeting where the quantification will be part of the presentation. Also, we will have addressed your comments about how we built on existing methods and how we interface with the different activities. These are some of the main concerns that you have. Then, presenting the short-term or long-term, or both, quantification approaches, that may be, I don't know, at least three or four more months before we can --

CHAIR STETKAR: We can work out the schedule, but I think --

MS. LOIS: Okay. Let's do that.

CHAIR STETKAR: I think that is worthwhile. We should talk over the next few weeks or so and figure out what makes the most sense in terms of scheduling.

MEMBER SHACK: I think, otherwise, the best they could hope for would be a letter that said, well, you know --

CHAIR STETKAR: "Come back in four months."

MEMBER SHACK: Yes, yes. "Come back when you tell us about the full methodology."

CHAIR STETKAR: Which doesn't help you at all. I mean, you know, it probably would be a non-committal letter saying, "We can't draw a conclusion about the direction of this effort without that information."

Because, ultimately, we come down to the numbers. You have to come down to the numbers.

Anything else?

(No response.)

I would thank you. You know, with all of the discussion and all of the criticism and things, I thought the presentation was really good. It is just too bad we had so much information to try to go through in a one-day Subcommittee meeting because there's a heck of lot of stuff that has been done here.

I am really happy from the last briefing we had, whenever it was, over a year ago I think, to where you are now. There's been an awful lot of work done, an awful lot of progress made.

But thank you, and I apologize for just not having enough time to do that.

MS. LOIS: Well, we thank you very much. We appreciate the feedback. We have a sense of reality of where we are, and we are pleased to get all of your comments.

(Laughter.)

CHAIR STETKAR: And thanks a lot for your stamina.

(Laughter.)

At 5:45, you're real troopers.

With that, we will adjourn.

(Whereupon, at 5:43 p.m., the proceedings in the above-entitled matter were adjourned.)

Status Report on Addressing SRM-M061020 on HRA Model Differences

Erasmia Lois, RES

ACRS Subcommittee on
Reliability and PRA Meeting
April 7, 2010

SRM-M061020

- The Commission directed the ACRS to "...work with staff and external stakeholders to evaluate the different Human Reliability models in an effort to propose either a single model for the agency or guidance on which models should be used in specific circumstances." Nov 8, 2006

Objective of Today's Briefing

- Discuss the technical approach taken to address the SRM
- Present the technical work performed to-date
- Obtain feedback from the subcommittee
- Perform mid-course adjustments as needed.

Previous Interactions

- February 2007-Subcomitte Meeting to discuss the SRM
- April 2007 Full Committee Meeting to discuss the SRM
  - ACRS letter to the Commission, April 23, 2007
  - RES initiated work in Fall 2007
- December 5, 2008—status/overview of addressing SRM-M061020
- April 2010—Subcommittee Meeting

Approach/Status

- Determine path to address the SRM--completed
  - Expert/user workshops
  - Hybrid vs. Toolbox ➔ Both selected
  - Hybrid to address **model differences within a domain** (e.g., full power internal events)
    - Domain specific hybrids use the same basic structure
  - Toolbox to address different applications (e.g., screening analysis, detailed analysis, significance determination process)

Current activities

- Develop & Test Approach—Dec 2010
  - Current focus on developing hybrid for internal event full power PRAs
    - Establish qualitative and quantitative criteria
    - Identify and develop both qualitative and quantitative approach according to criteria
  - Recently initiated work for LPSD event analysis totally coordinated/integrated with the hybrid method development
  - Hybrid method to be reviewed and tested
- Guidance and training—Dec 2011
  - Training and guidance materials and other tools will be developed to address inter-analyst variability

Justification for a Hybrid Approach

- No single method met all criteria
  - Theoretical foundation and coverage
  - Reliability
  - Practicality
  - Application scope coverage
- Merits in various methods' elements
- Optimal approach
  - A consensus approach of regulatory and industry
  - EPRI is also supporting the effort

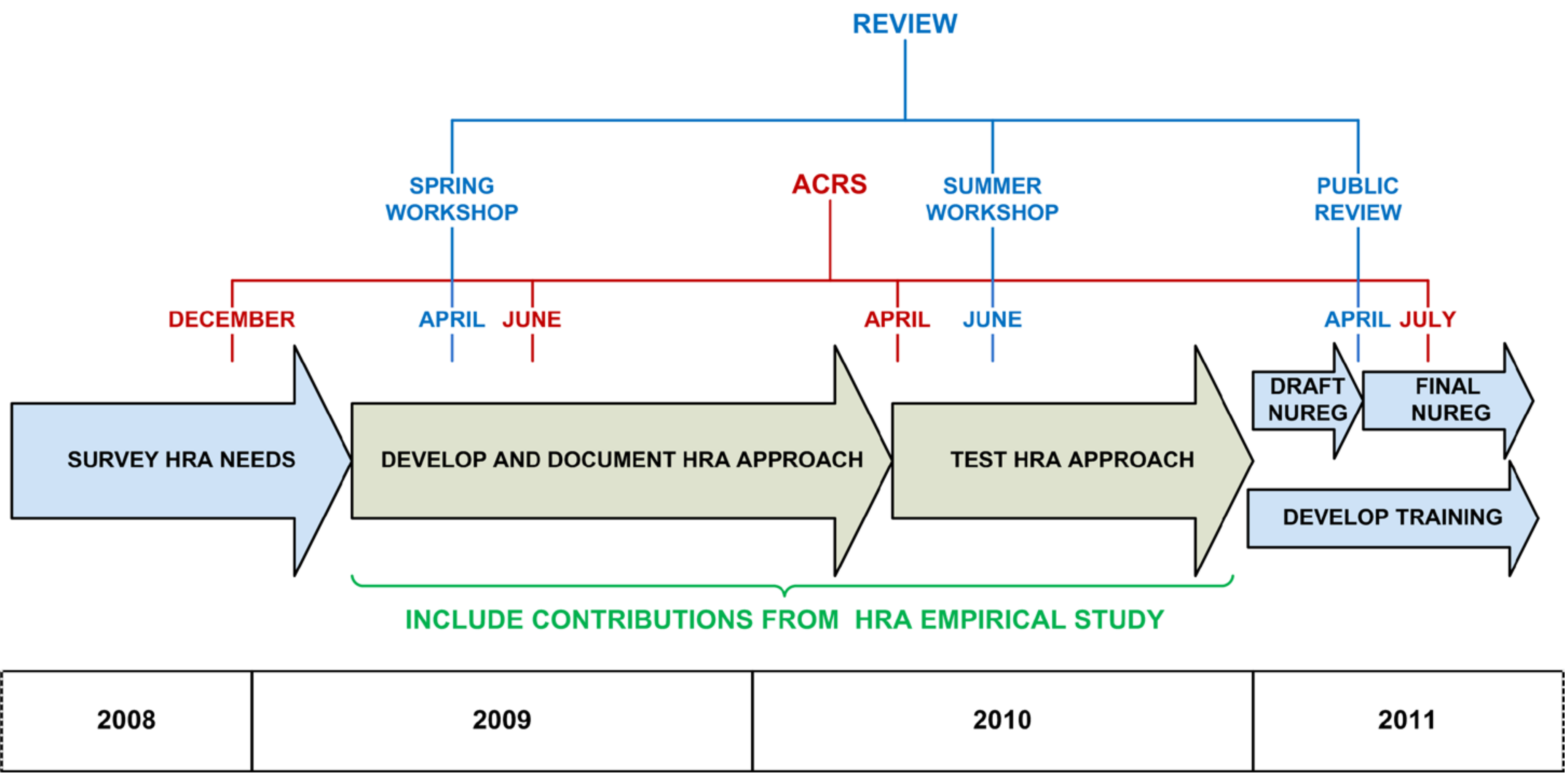
The Hybrid Approach

- Develop qualitative analysis approach guided by a human performance model
  - Encompass existing sound concepts and practices
  - Identify context-specific key drivers to performance
- Develop quantitative approach capable to incorporate the results of qualitative analysis
  - **Short term**: Modify existing quantitative approach(es) or make recommendations for how they should change to meet qualitative analysis
  - **Long Term:** Develop anchored values to estimate HEPs
    - Initially combination of judgment and data (i.e., simulator and historical experience)
    - Eventually data

Research Vision & Trend

- Single approach/architecture for all applications
- Gradually, shift research activities toward
  - Evidence driven HEP predictions
    - As more experience from events/experiments is accumulated and better understanding of human performance becomes available
  - Reduced analyst judgment
  - Dynamic simulation approaches

Project Timeline
Internal events/Full power



Organizations Involved

- Sandia/UMd have the lead for the full power work
  - John Forester
  - Stacey Hendrickson,
  - Ron Boring—now at Idaho
  - Ali Mosleh
  - Vinh Dang, PSI
- Idaho Nat. Lab. has the lead for the LPSD work
  - Dana Kelly
  - April Whaley
  - Ron Boring
- RES
  - Song-hua Shen
  - James Chang
  - Chris Hunter
  - Erasmia Lois

Structure of Presentations

- Overall framework and basic structure
  - Prof Ali Mosleh, UMD
- Research results from behavioral science supporting the technical approach
  - Stacey Hendrickson, PhD, Sandia
  - April Whaley, INL
- A specific example
  - Song-hua Shen, PhD, RES

Model-Based HRA Framework

Ali Mosleh
University of Maryland
(Sandia National Laboratories)

Presented to
ACRS
Nuclear Regulatory Commission
April 7, 2010
Rockville, MD

Starting Point

- Survey of User Needs and Field Applications
- Identification of Desirable Quality Attributes
- Scope Definition
- Assessment of Gaps

Expert Panel Consensus on Quality Attributes

- Content Validity
  - Coverage (plant, crew, cognition, action, EOC, EEO, etc)
  - Richness of context characterization, PSFs, timing)
  - Explanatory power, “causal model” for error mechanisms and relation to context, theoretical foundations
  - Ability to cover HFE dependency and recovery
  - Clear definition of “unit of analysis” and level of detail for various applications
- Empirical Validity (of HEPs)
  - Operational Data, Simulator Experiments, Other Industries

Expert Panel Consensus on Quality Attributes (cont)

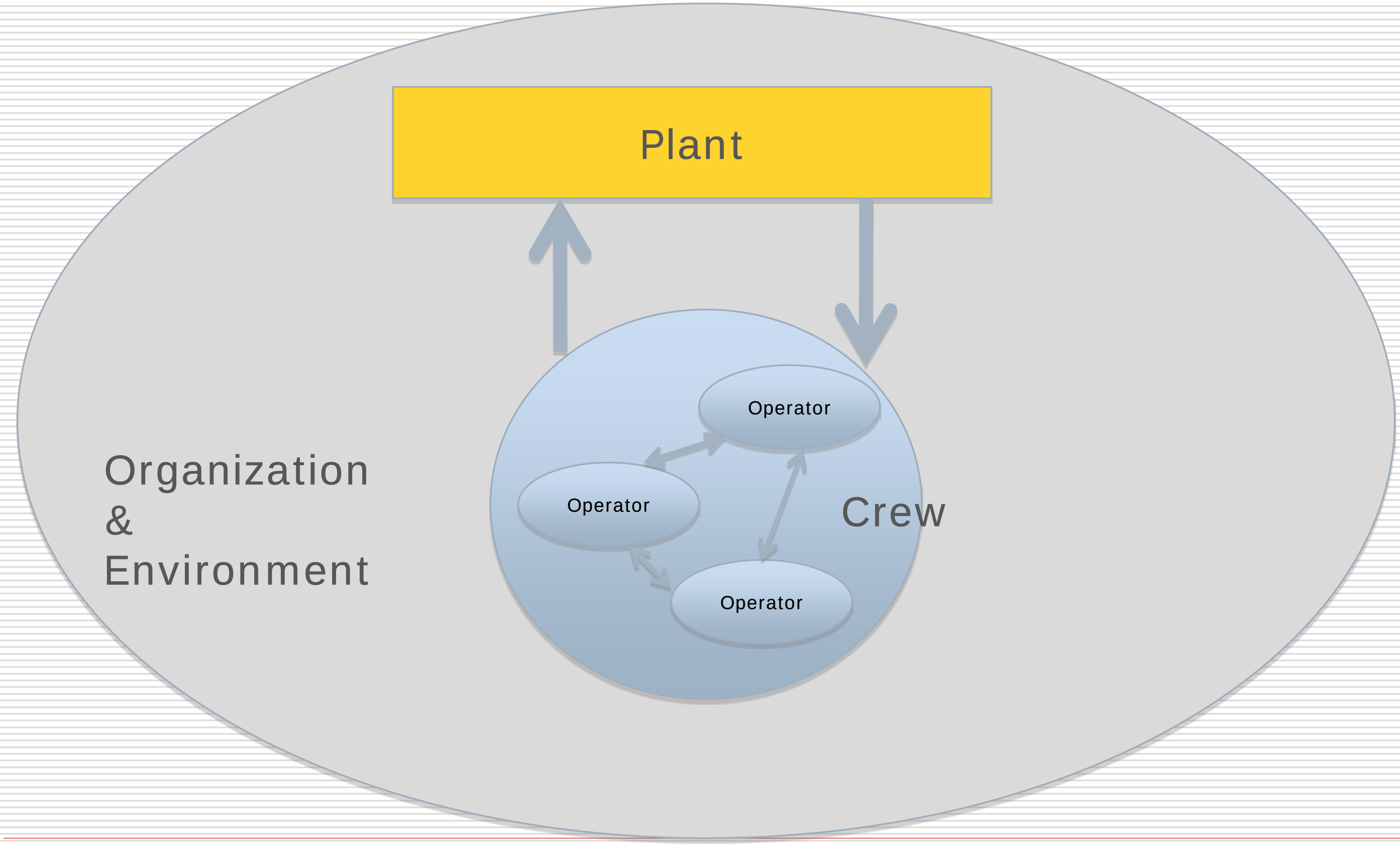
- Reliability
  - Reproducibly
  - Consistency
  - Inter- and Intra-rater Reliability
- Traceability/Transparency
  - Ability to reverse engineer analysis
- Testability
  - Part or the entire model and analysis
- Capability for Graded Analysis
  - Screening, scoping, detailed analysis
- Usability/Practicality

Presentations

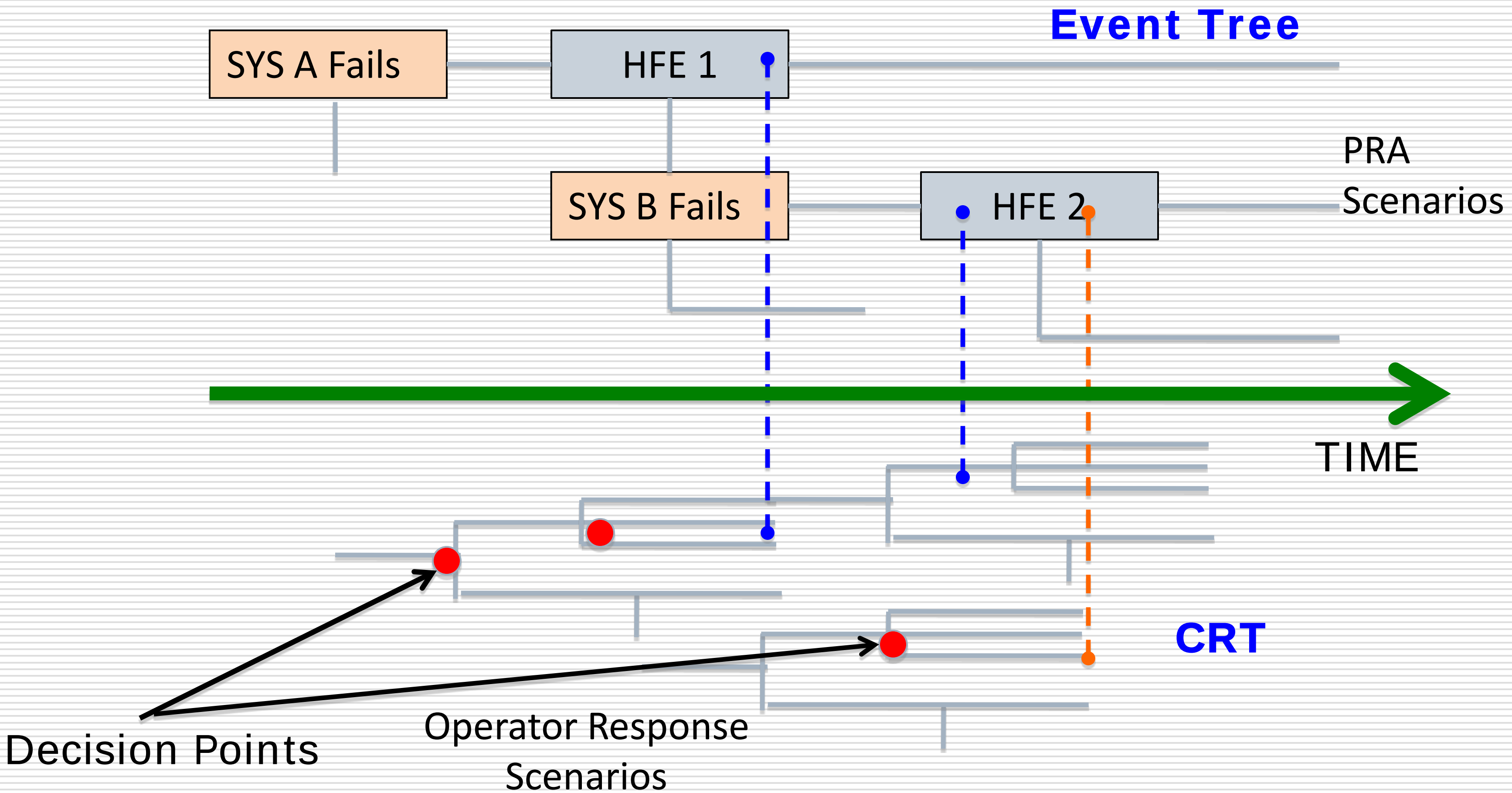
- Methodology Overview
  - *A. Mosleh*
- Human Performance Model
  - *S. Hendrickson, A. Whaley, R. Boring*
- Example
  - *S. Shen*
- Status and Future Plans
  - *A. Mosleh*

Overall Framework

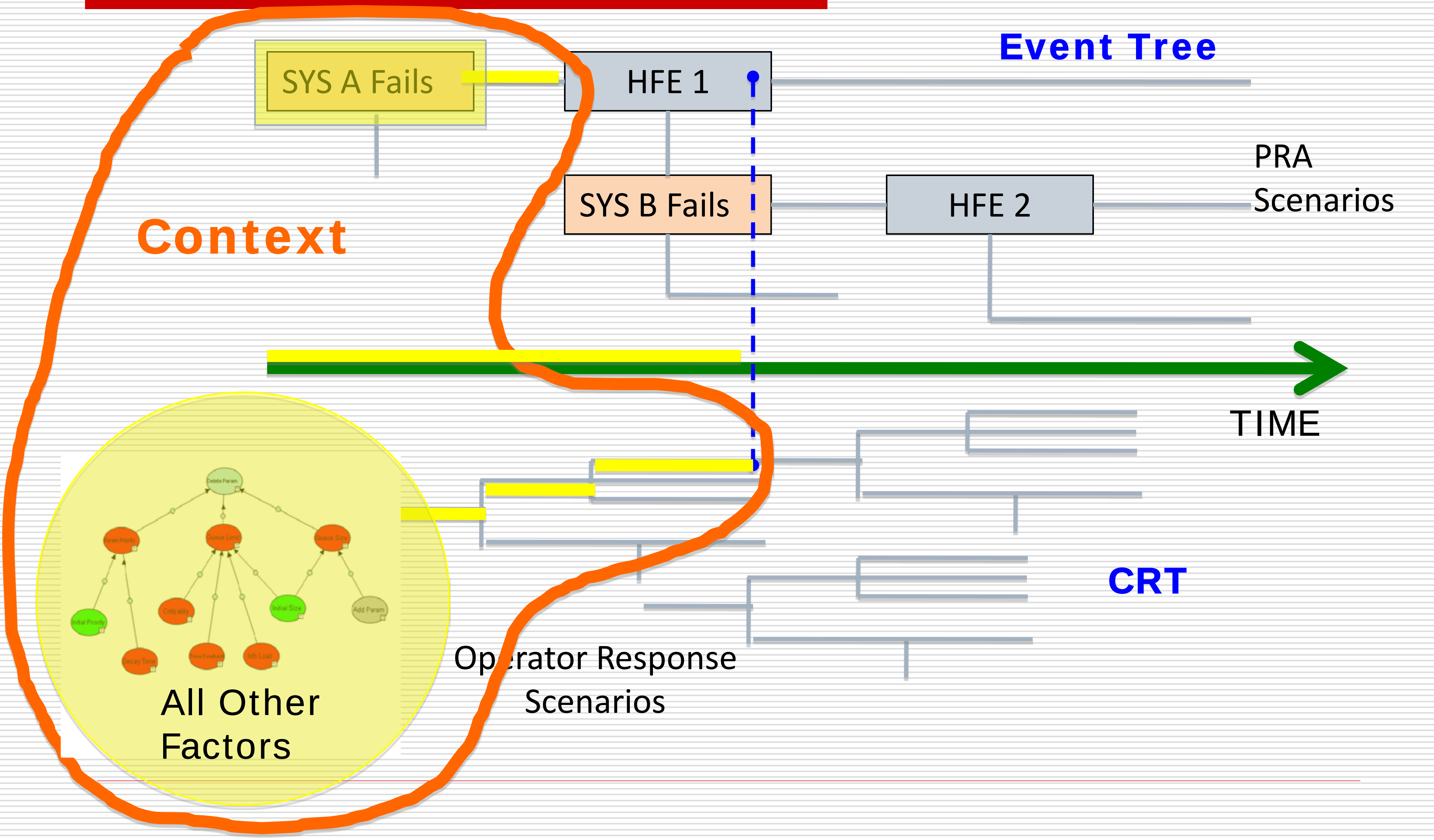
Modeling Scope and Units of Analysis



Two Track Cross-Linked Scenario Modeling

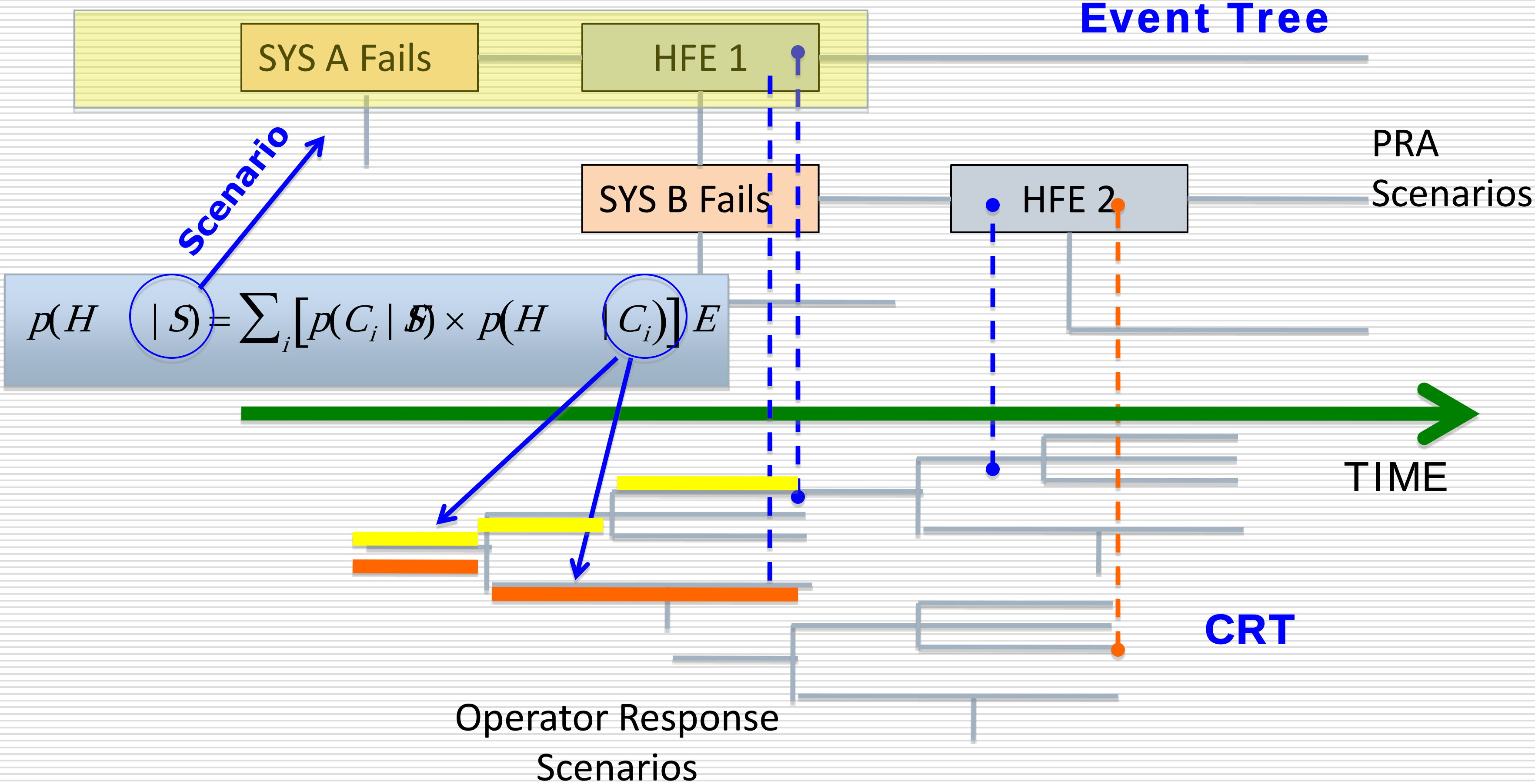


“Context” according to the proposed framework



HEP Quantification Framework

(Consistent with Two Track Cross-Linked Scenario Modeling)



Heritage of the Approach

Feature	Reference Method (examples)	Quality Attribute
Rich Context Characterization	ATHEANA	Content Validity
Integrated Plant-Crew (deviation) Scenario Analysis	ATHEANA, BEOC*	Content Validity
"Standardized" Cause-Based Analysis Process	CBDT	Reliability (Reproducibility) Traceability Usability (Practicality)
Explicit Link to Human Behavioral Sciences	IDAC	Theoretical Foundations

*Borselle NPP Error of Commission Study, NUS/UMD, 1998

Crew Performance Model

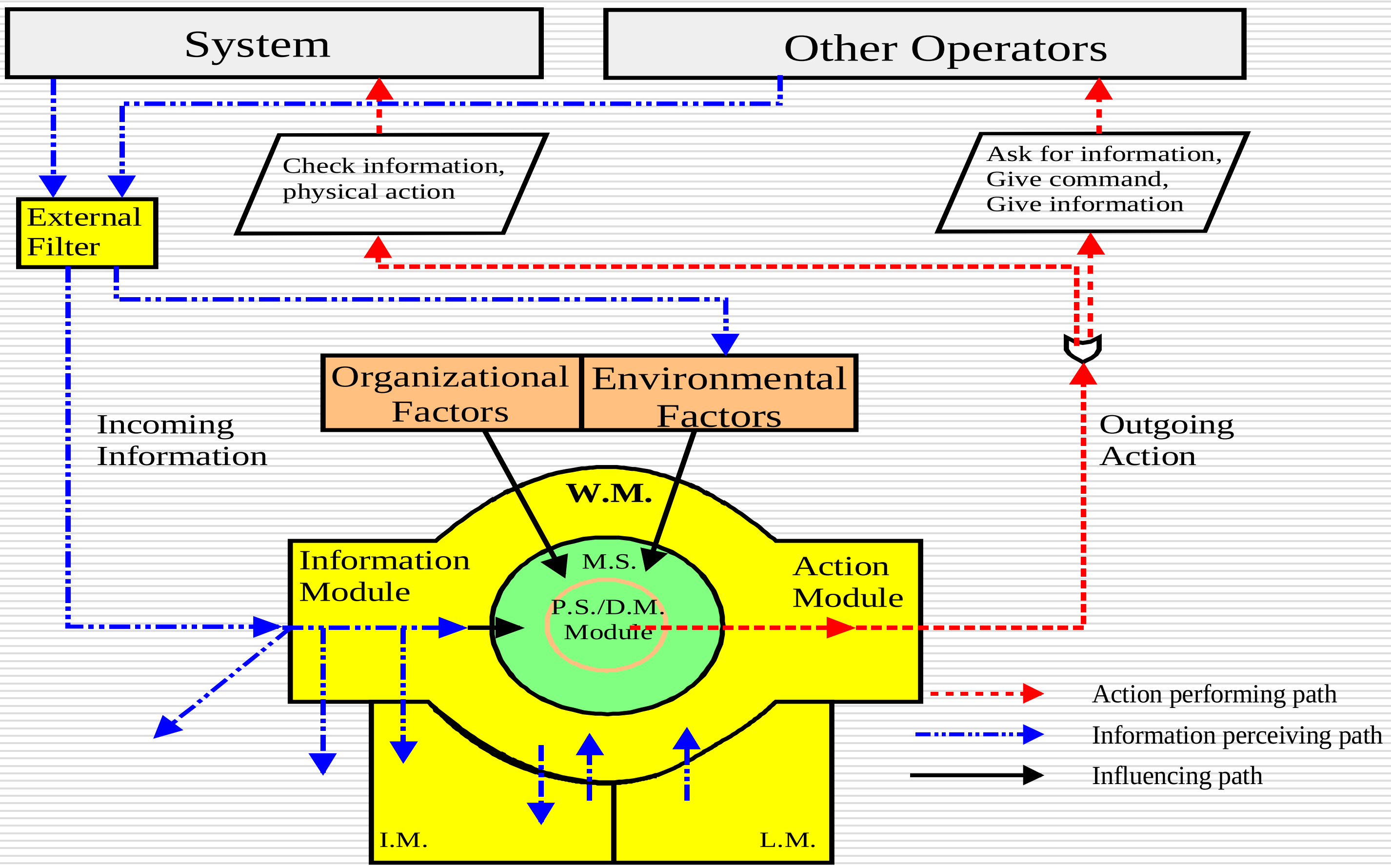
Partial List of Model Requirements

- Needs to go beyond a high level conceptual framework
- Should provide a clear map between context characteristics and HFE as well as HEP
- Provide a clear and explicit link between engineering and relevant human sciences

Partial List of Model Requirements

- At a minimum the model should help
  - identify PSFs that need to be included
  - describe relation between PSFs and HFEs , as part of a casual explanation of failure mechanisms leading to HFEs
- Detailed enough to support data collection and empirical validation at elemental levels

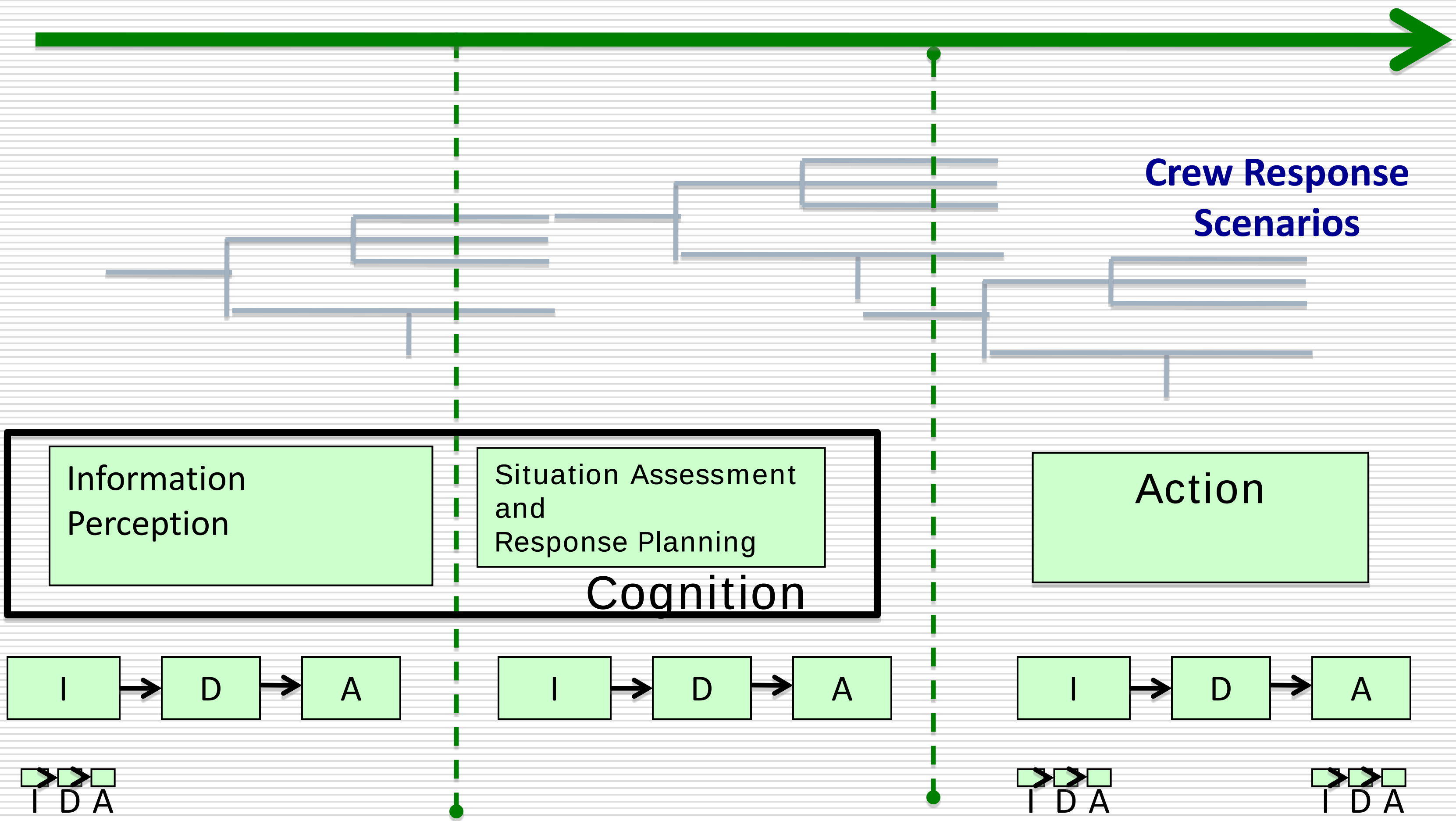
IDAC High Level Architecture
Actors, Information and Action Flow



Modeling Framework

- Human Response Framework: “Information Processing Model”: I*D*A
  - I: Information Perception/ Pre-Processing
  - D: Problem Solving *and* Decision Making
  - A: Action Execution
- I*D*A is only one layer of modeling
- Additional layers also needed cover for example
  - Each of the IDA elements (I, D, and A),
  - Failure Mechanisms,
  - Dynamics, error recovery, and HFE dependencies
  - Impact of context

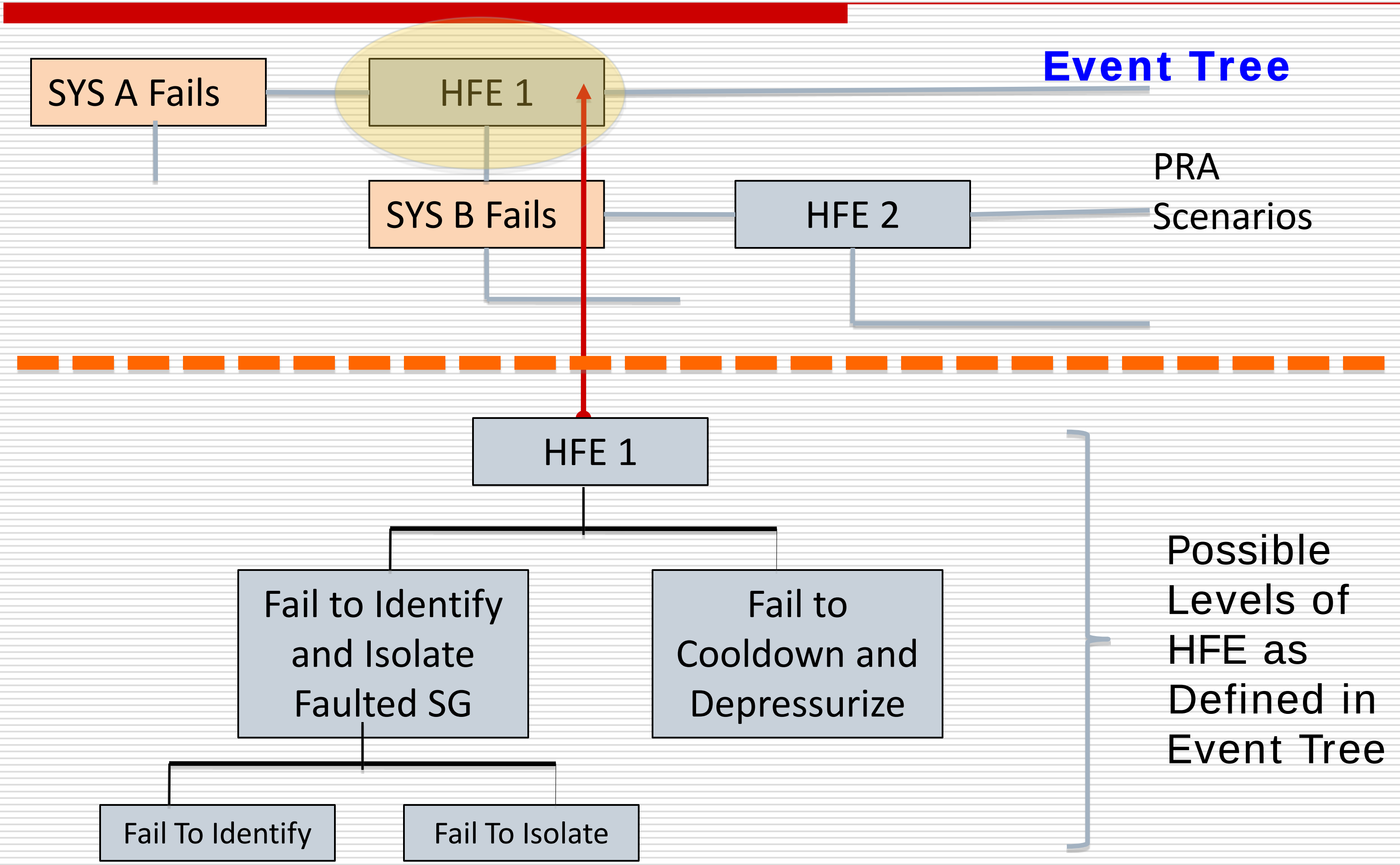
Hierarchical "Information Processing Model" , ***Nested IDA*** Modeling Framework



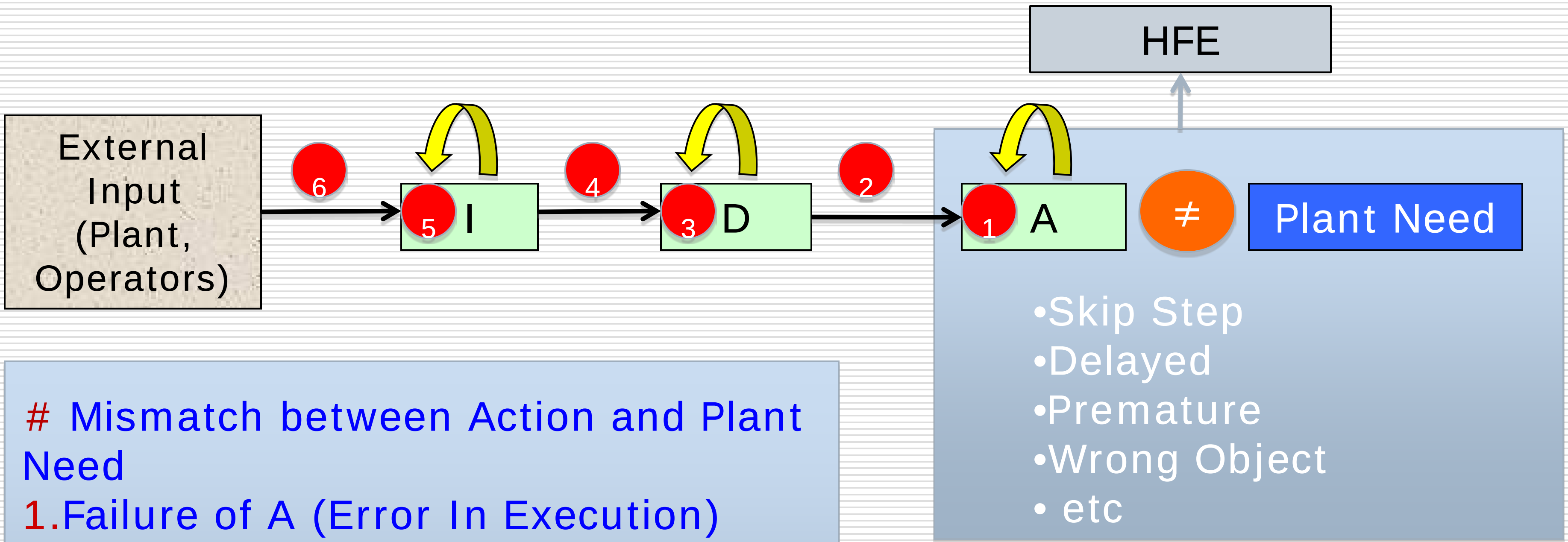
Nested IDA: Examples

- I: Information Perception (via Alarms, Displays)
  - (I) Perception
  - (D) Filtering, Grouping, Prioritization, Importance Assessment, Interpretation
  - (A) Monitoring
- D: Situation Assessment/Response Planning
  - (D) Diagnosis
  - (I) Verification
  - (D) Procedure Selection
- A: Action
  - (I) Reading, Comprehension
  - (A) Execution
  - (I) Verification

HFE Definition and Decomposition

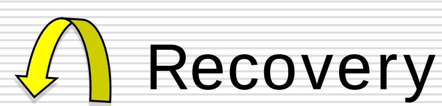


Human Error in IDA Framework

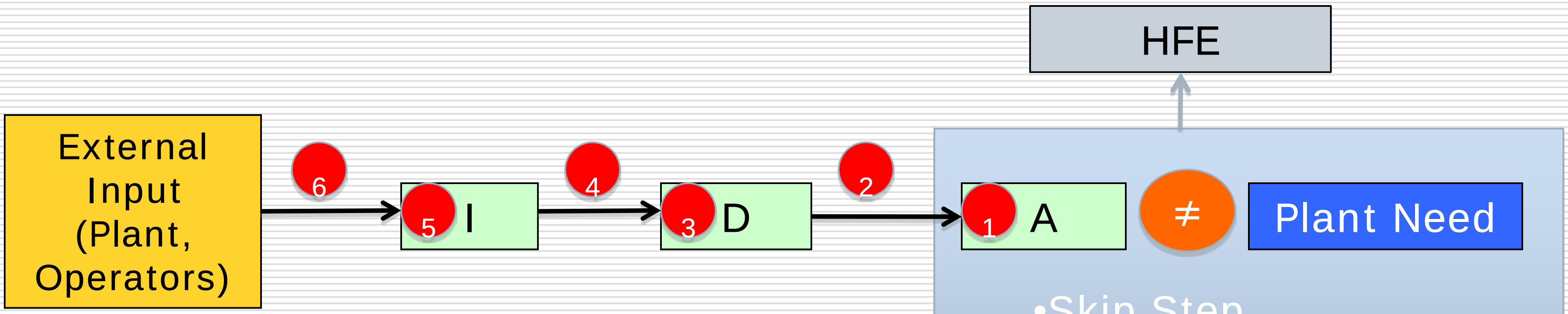


\# Mismatch between Action and Plant Need

1. Failure of A (Error In Execution)
2. Failure of A due to Error in D
3. Failure in D
4. Failure of D due to failure of I
5. Failure in I
6. Incorrect I from External Source



“Logic of Failure”

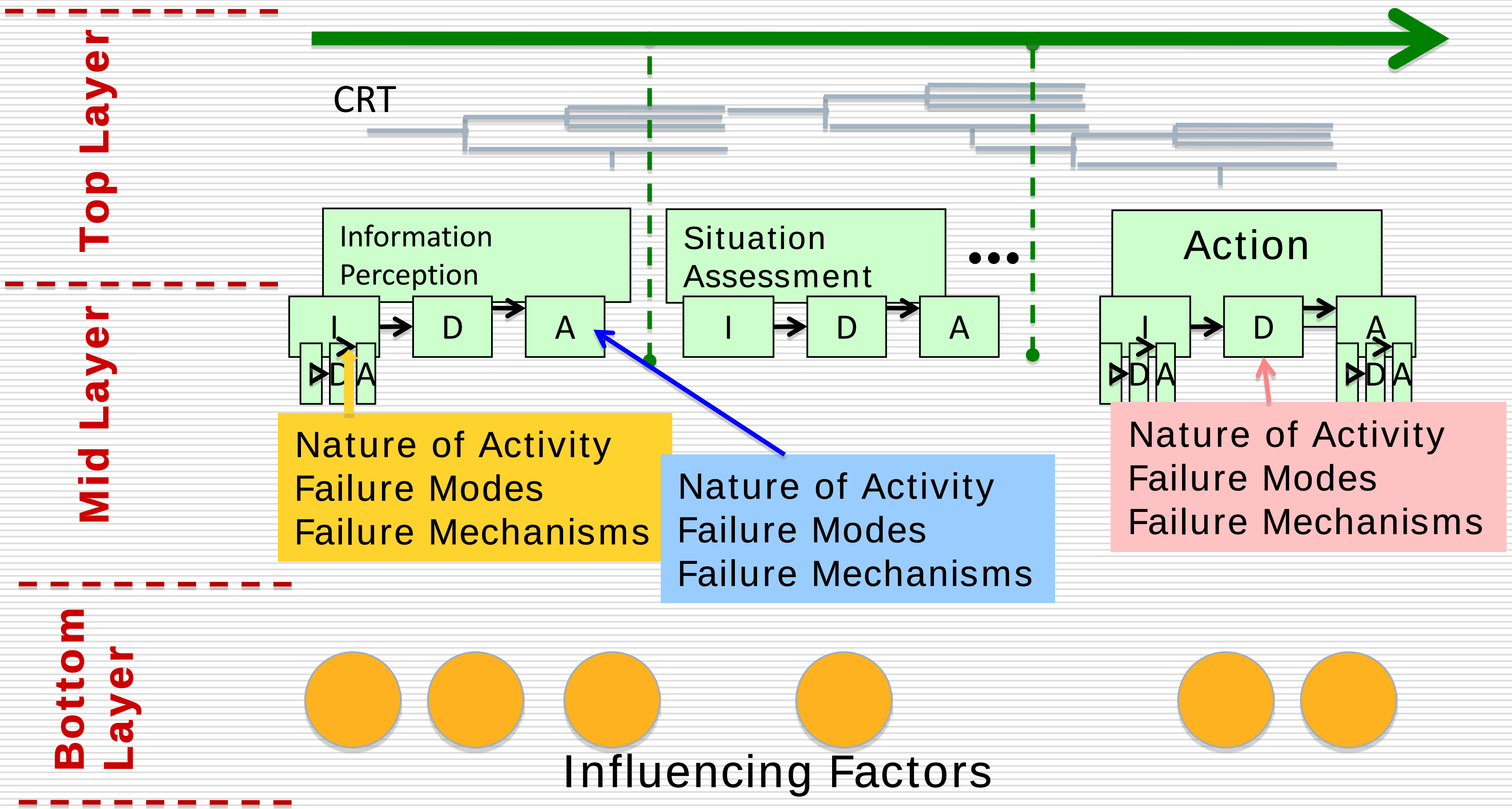


- •Skip Step
- •Delayed
- •Premature
- •Wrong Object
- • etc

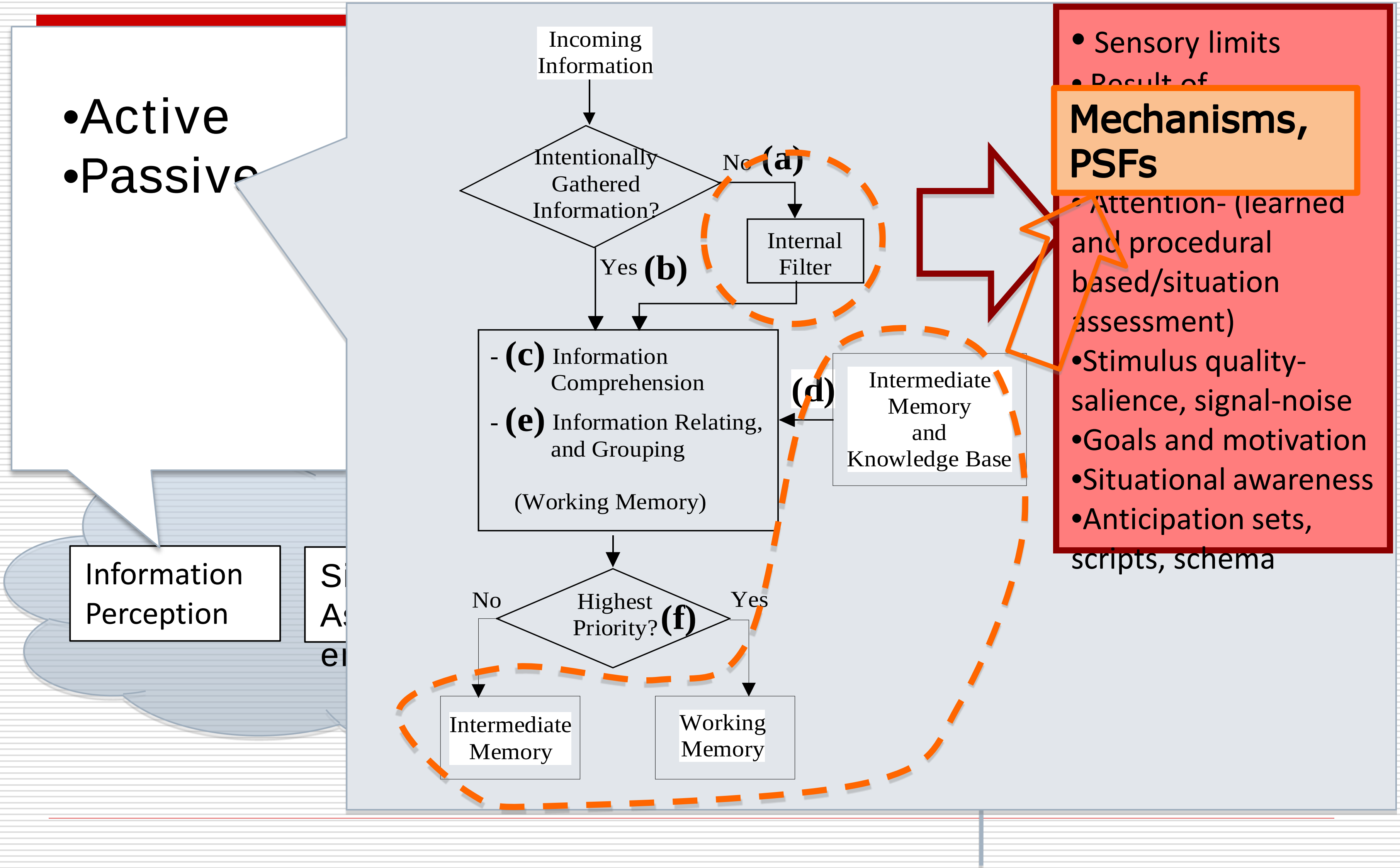
HFE = I+D+A (logical OR)

This means I, D, A are “minimal cutsets” of HFE

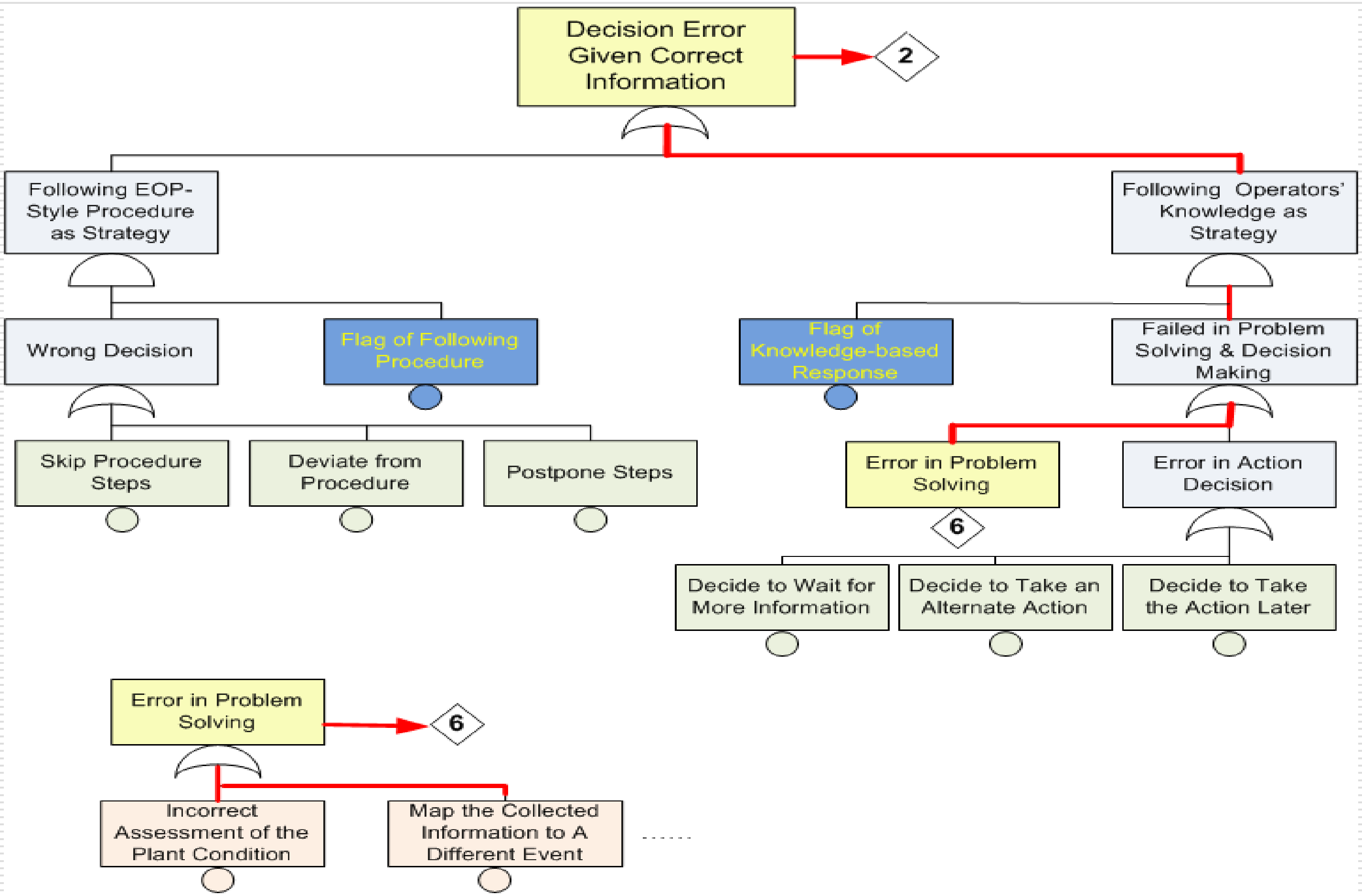
Adding Causal Depth



Midlayer Models: (I) Perception, Pre-Processing, Error Mechanisms and PSFs



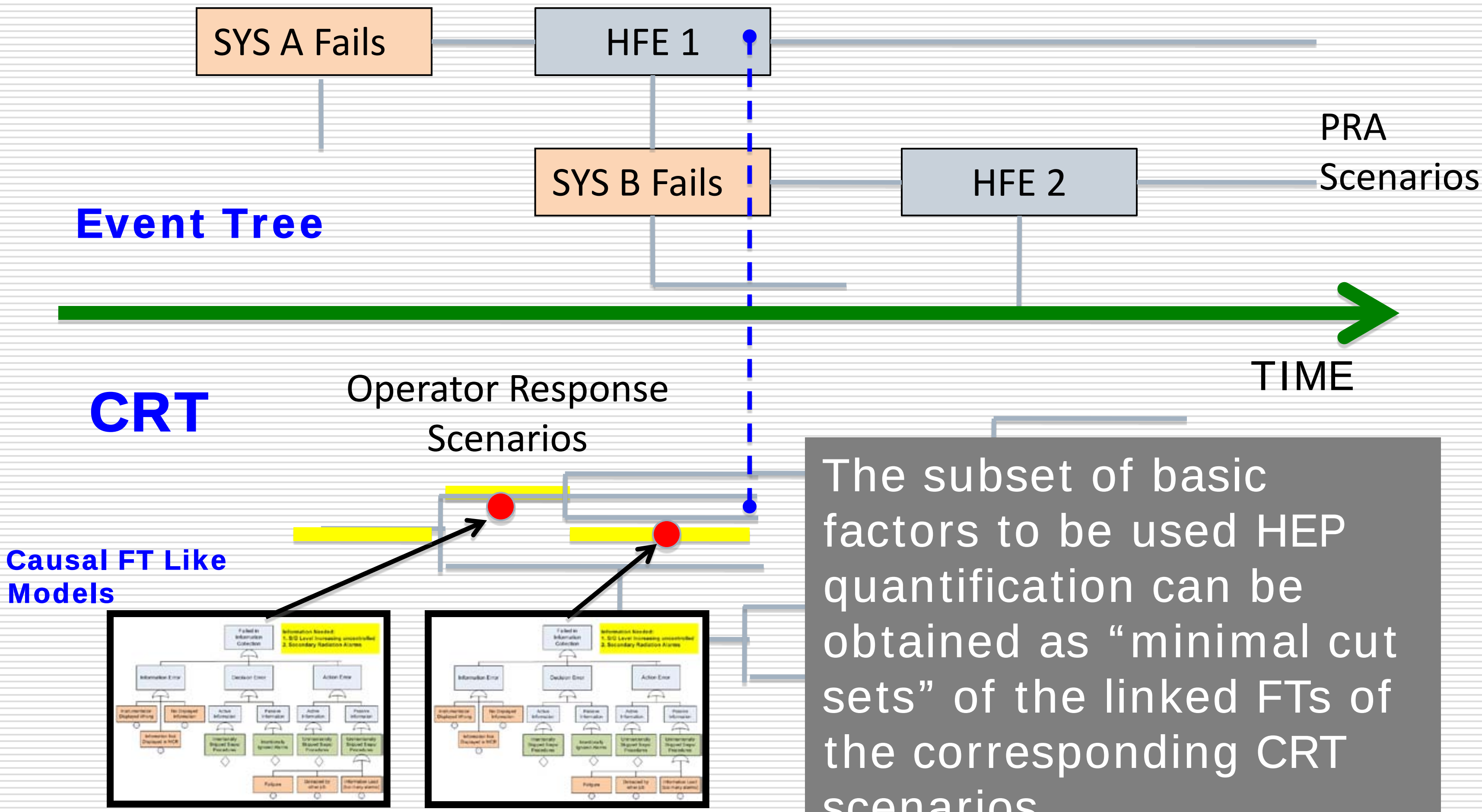
Identification of Failure Mechanisms



PSF Essential Properties

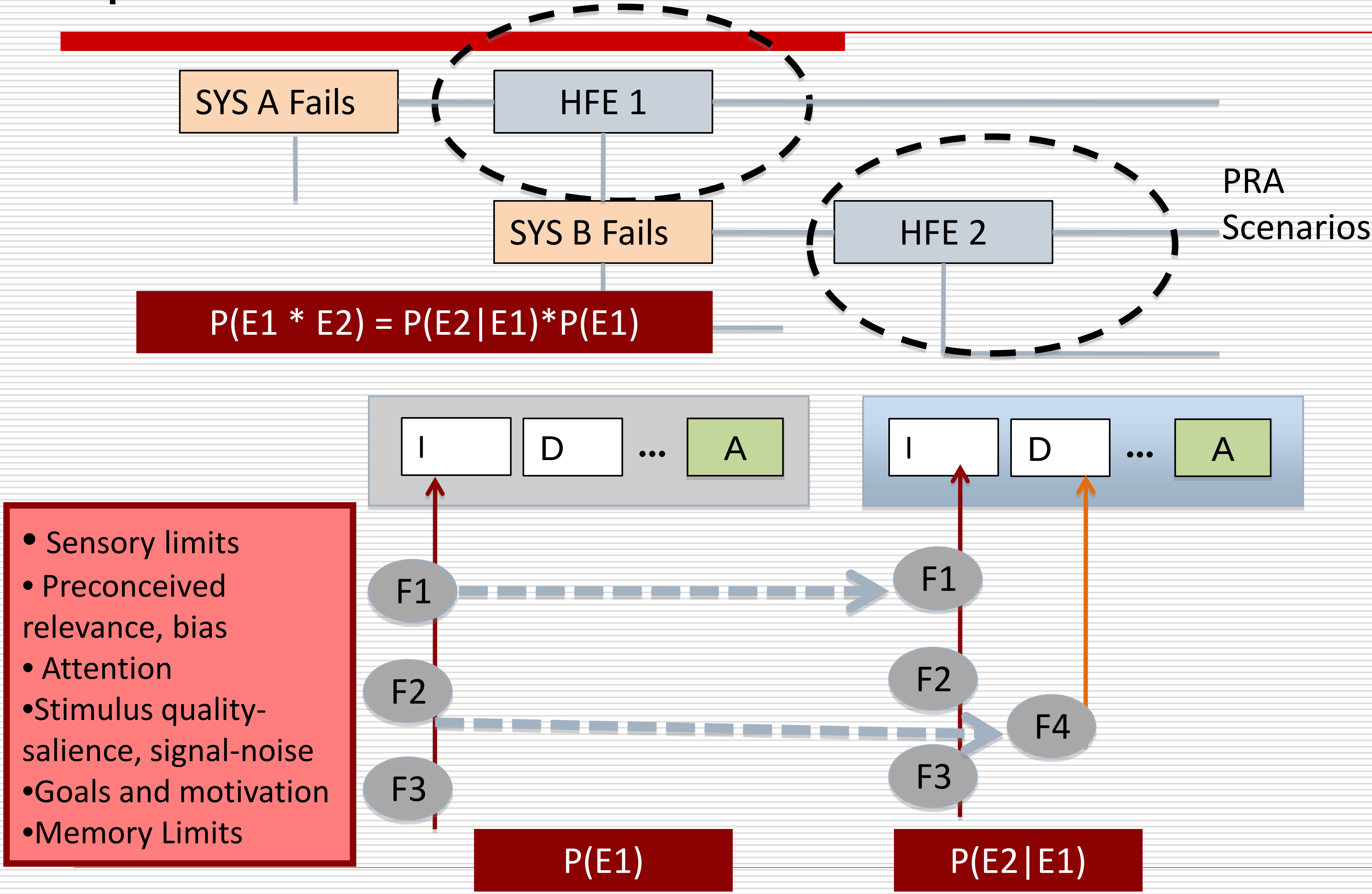
- Hierarchical structure
  - Can be expanded for qualitative analysis or collapsed for quantitative analysis and link to data
- Definitionally Orthogonal
- Value neutrality
  - "Procedural adequacy" vs. "Procedures Less Than Adequate"
- Behavioral metrics
  - Consistency in data collection

Model Assembly --HFE “Causal Cutset”

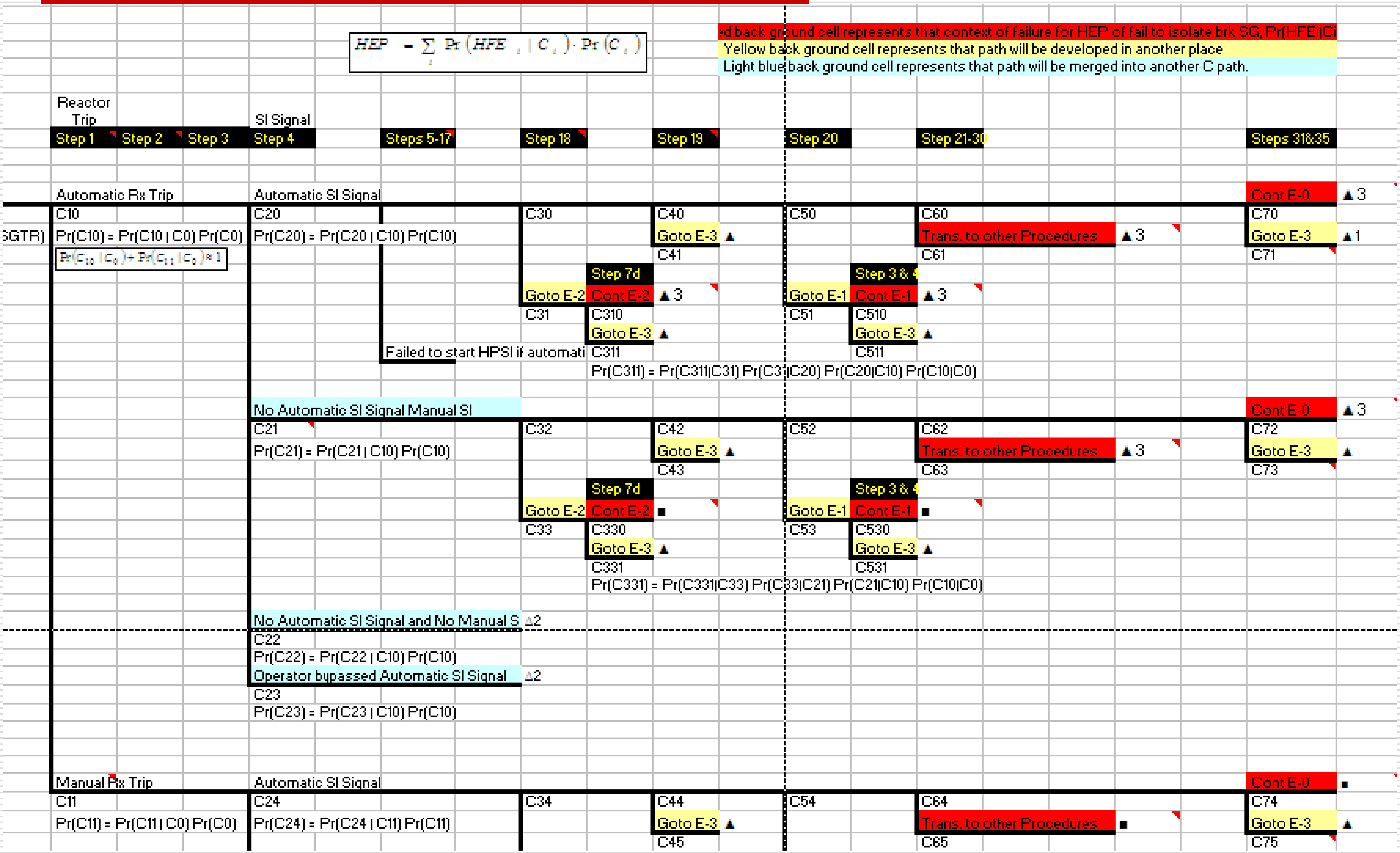


The subset of basic factors to be used HEP quantification can be obtained as “minimal cut sets” of the linked FTs of the corresponding CRT scenarios

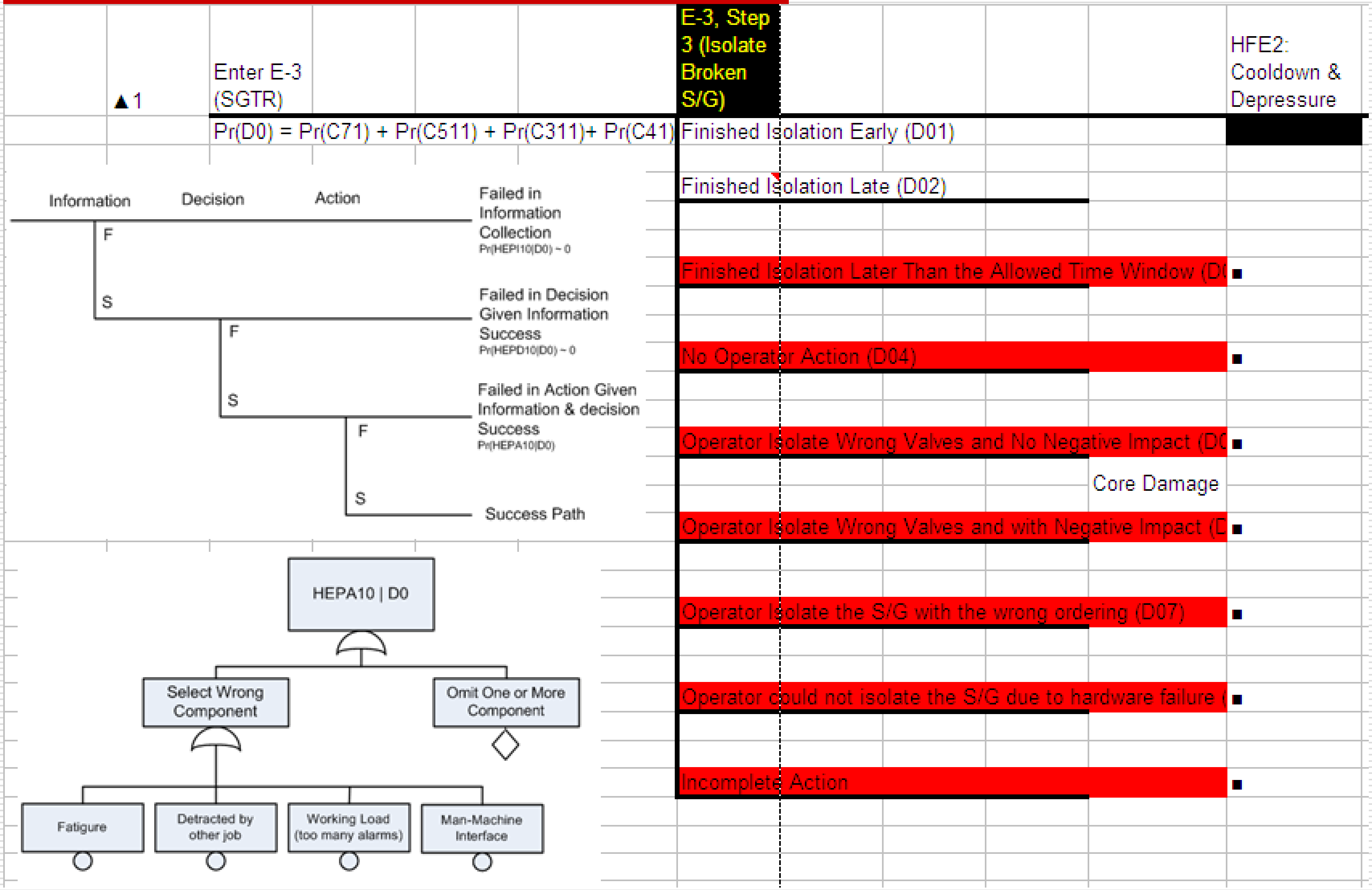
Identification and Quantification of Dependencies



A Portion of CRT for STGR E0



Example CRT Pinch Point: Combining CRT HFEs into the HFE as defined in ET



Summary of Qualitative Analysis Process

Phase	Steps	Product
Build/Review ET for the IE	Standard PRA Steps	• ET, • Plant Scenario Context Factors
Develop CRT (or Modify Generic CRT)	•Functional Scenario •Task Analysis (procedure Review) •Construct Sub-CRT •Prune/Simplify	• CRT • HFEs
Attach Causal Models (FTs) to Sub-CRT Branches		• Linked Model
Solve Linked Model (CRT/FT) Scenario	• Insert FT-Sub-CRTs models into CRT • Solve Linked Model (perhaps using a software tool)	• CRT Scenario Cutsets
Analyze Scenarios, Write Narrative, Trace Dependencies		• Narratives • Qualitative Insights • Input to Quantification

Practical Issues

- Managing size and complexity of CRTs
- Practical guidelines for consistency of PRA ET/FT scenarios and CRT scenarios
- Availability of Needed Tools

Solutions

- Use of Template CRT/FTs
- Proper allocation of modeling between CRT and FTs (and if needed BBNs)
- Guidelines for tailoring CRT/FT for plant-specific applications
- Model pruning & screening
  - Qualitative
  - Probability truncation (with conservative values)
- Automation with simple user interface

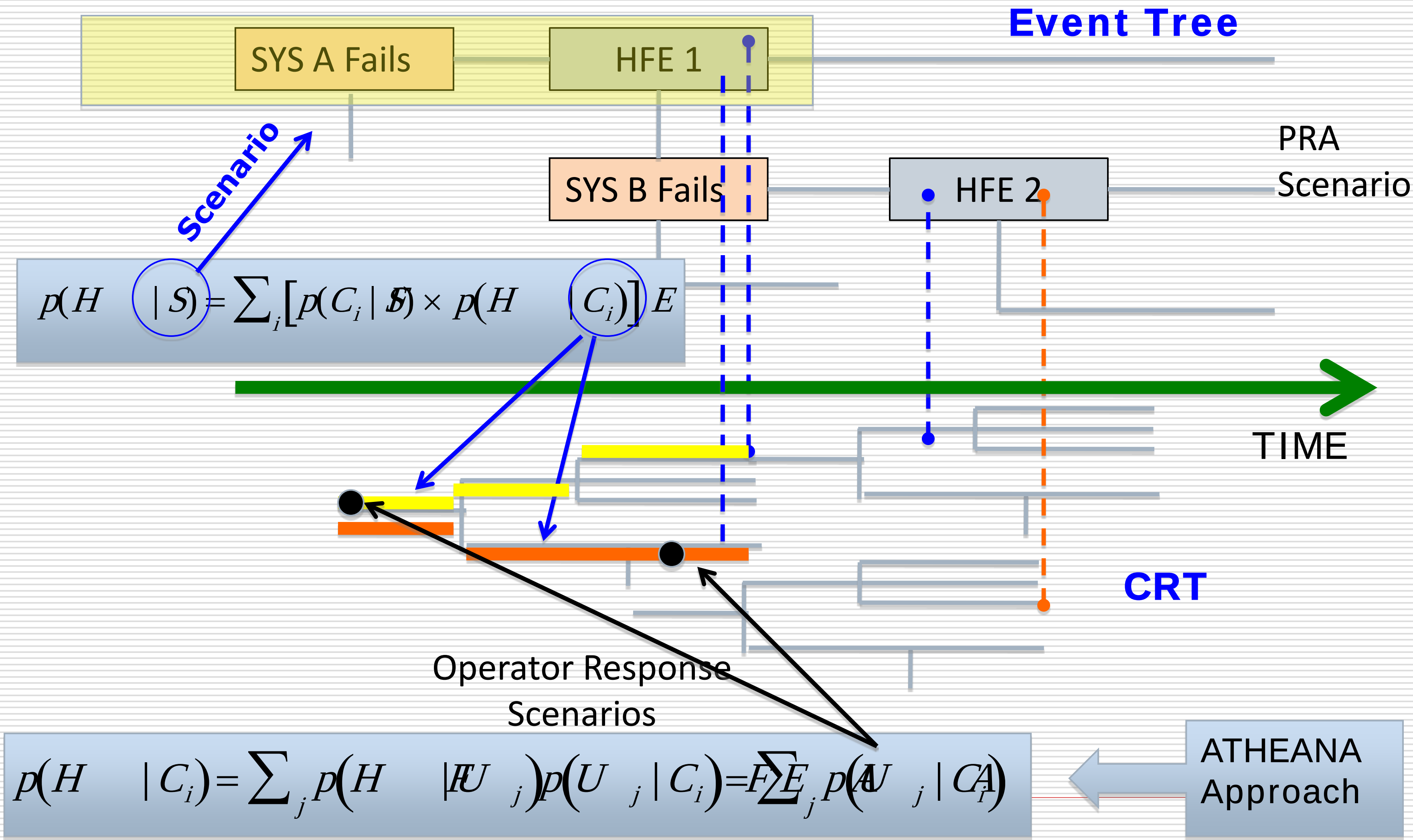
Use of Generic Models

- Select a generic template CRT
- Modify as needed
  - Functional, design, and operational differences
- Perform a semi-quantitative pruning to eliminate unlikely CRT scenarios
- Modify attached Fault Trees as needed
- Solve the linked trees to get the causal paths details for scenarios leading to HFEs

Preliminary Thoughts on Quantification

HEP Quantification Framework

(Consistent with Two Track Cross-Linked Scenario Modeling)



Quantification Framework

- Main Equation for a given HFE as define in the Event Tree:

$$p(HFE \mid S) = \sum_i \left[p(HFE \mid C_i) \times p(C_i \mid S) \right]$$

  - S= PRA Scenario (essentially the initiator)
  - Ci= Specific “context” i (as defined earlier in CRT)- each CRT sequence leading to an HFE represents a unique Ci
  - Different Ci’s often have common elements (e.g., common human actions, plant events, and PSFs) as represented by common segments of CRT scenarios

Quantification Framework

- Under some modeling assumptions and abstractions, each Ci can be described via a set of context factors

$$C_i \equiv \{ F_{i1}, F_{i2}, \ldots.., F_{in} \}$$

  - F_{ij} = context factor j for context i
  - Examples
    - A specific crew
    - Elapsed time in scenario
    - A specific PSF
    - A specific operator action

Quantification Framework

- In this case HEP equation can be written as

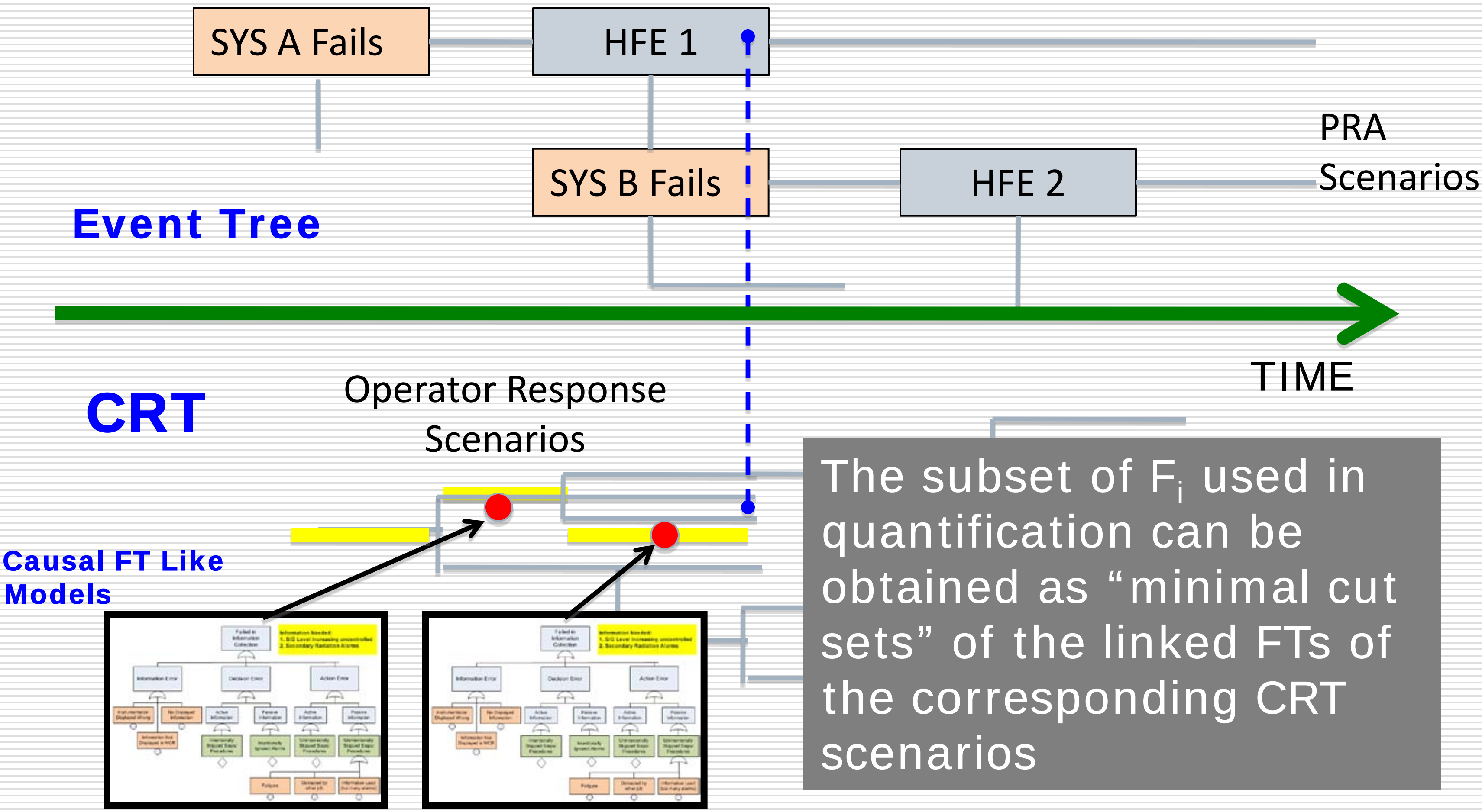
$$p(HFE \mid S) = \sum_{i=1}^{I} p(\ HFE \mid \mathrm{F}_{i1},\ \mathrm{F}_{i2},\ \ldots..,\ \mathrm{F}_{in}) \times p(\mathrm{F}_{i1},\ \mathrm{F}_{i2},\ \ldots..,\ \mathrm{F}_{in} \mid S)$$

- Note that often $F_{ij} = F_j$ for several i
  - Examples
    - Same Time Pressure
    - Same crew

More on the equations

- Different formulations of the equation are needed depending on, for example,
  - Level of HFE decomposition
  - Whether we characterize context and in terms of a set of factors, “proximate cause” , “story”, “scenario” etc.
- These equations are useful in providing a **conceptual** link between qualitative and quantitative parts of HRA
- We may be able to explain relation between these equations and some of the HRA methods such as SPARH

HFE "Causal Cutset"



The subset of F_i used in quantification can be obtained as "minimal cut sets" of the linked FTs of the corresponding CRT scenarios

Roadmap to Qunatification

- Refine

$$p(HFE \mid S) = \sum_i \left[p(HFE \mid C_i) \times p(C_i \mid S) \right]$$

  to reflect qualitative analysis

- **Short term**: Modify existing quantitative approach(es) or make recommendations for how they should change to meet qualitative analysis

- **Long Term:** Develop anchored values to estimate HEPs using above expression
  - Initially combination of judgment and data (i.e., simulator and historical experience)
  - Eventually data

Status and Plans

Preliminary Assessment

Attribute Category	Attribute
Content Validity	☑ Coverage (plant, crew, cognition, action, EOC, EEO, etc) ☑ Richness of context characterization (PSFs, timing) ☑ Explanatory power, “causal model” for error mechanisms and relation to context, theoretical foundations ☑ Ability to cover HFE dependency and recovery ☐ Clear definition of “unit of analysis” and level of detail for various applications
HEP Empirical Validity	☐ Operational Data, Simulator Experiments, Other Industries

Preliminary Assessment (cont)

Attribute Category	Attribute
Reliability	☑ Reproducibly ☑ Consistency ☐ Inter-rater Reliability ☐ Intra-rater Reliability
Traceability/Transparency	☑
Testability	☐ Entire Model/Methodology ☑ Parts/Constructs
Capability for Graded Analysis	☑ Screening analysis ☑ Detailed analysis
Usability/Practicality	☐

Ongoing Efforts

- Develop a complete generic template CRT/FT for at least one initiating event (SGTR)
- Complete human performance model including
  - Adding fundamental failure mechanisms
  - Linking orthogonal set of PSFs to
    - failure mechanisms
    - CRT sequences
  - Explore use of BBNs to represent PSF interdependencies
- Review operating events and simulator data to find any other human failure modes and mechanisms which are not modeled.

Next

- Develop qualitative analysis procedure
- Participate in US Empirical Study (early summer)
- Conduct Multi-disciplinary Peer Review
- Develop Quantification Methodology
  - Use of existing approaches
  - Possible hybrid of existing approaches
  - Longer term methodology for data-informed quantification
    - Mathematical formalism
    - Data source characterization and identification
    - Data collection and HEP estimation

Next

- Develop specifications for analyst software tool
  - Potential use of FAA code (IRIS)
  - New version of SAPHIRE
- Test the Approach
- Conduct Multi-disciplinary Peer Review
- Develop User Guide

Examples of
CRT and Mid-layer Fault Tree

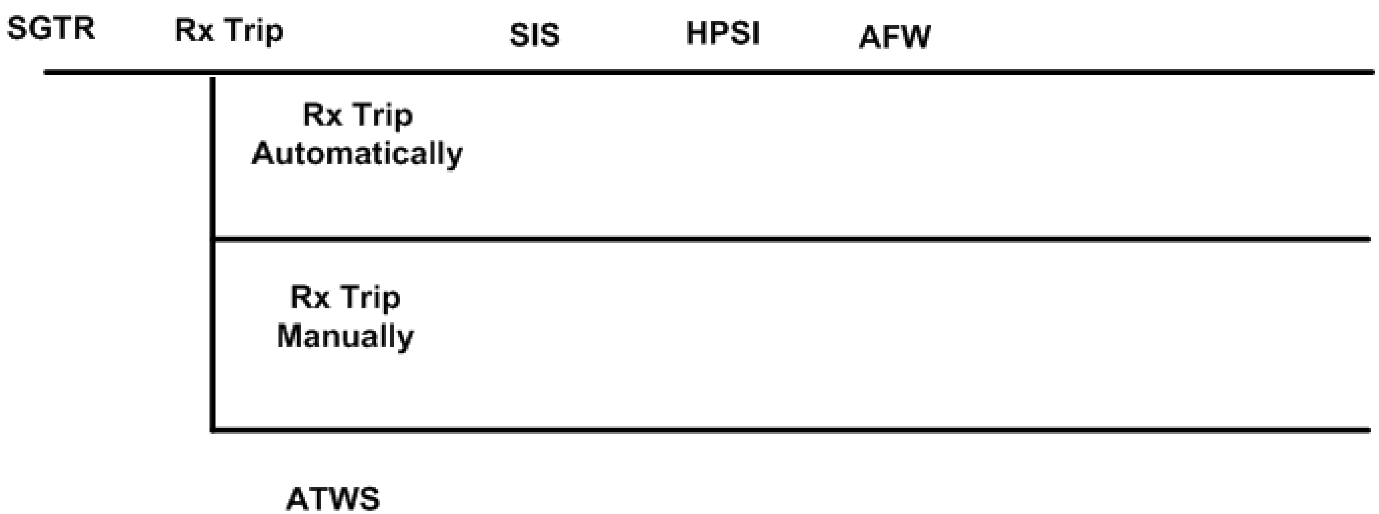
Song-Hua Shen, RES

Presented to ACRS
Subcommittee on
Reliability and PRA
April 7, 2010

Key Steps of Constructing a CRT

1. Identification of the Initiating Events
2. Define the Safety Functions
3. Delineation of Accident Sequences
4. Constructing the CRT (Using sub-CRTs for each identified function)

Example: Highly Abstracted CRT for SGTR



Example Branch Points in Constructing the CRT

1. *Plant Conditions*

   e.g., Hardware Failure, Automatic Function Failure

2. *Success Path*

   may include Success Early, Success Late

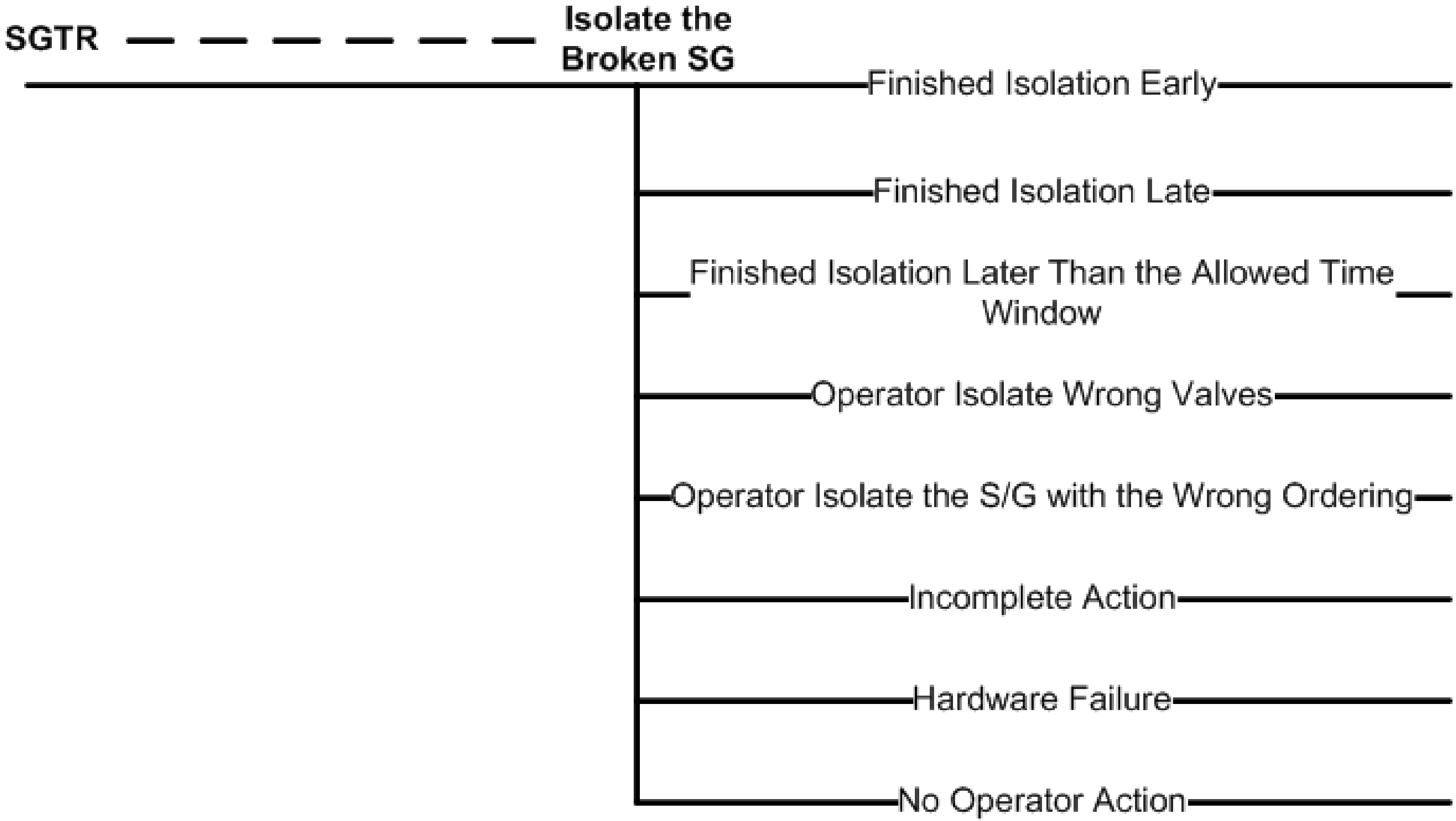
3. *Failure Path*

   e.g., Incomplete Action, Too Late, Wrong Ordering, No Action, Acting on Wrong Component

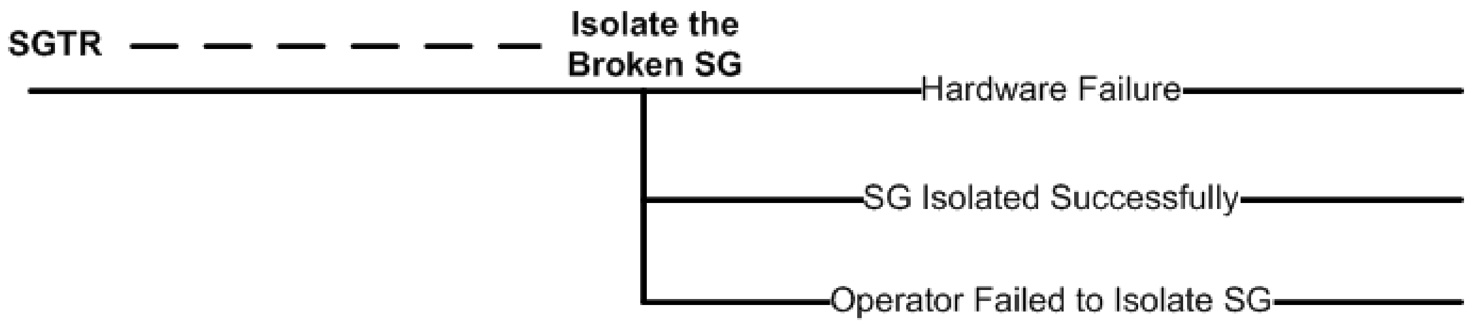
4. *Opportunities to Branch to Another Procedure*

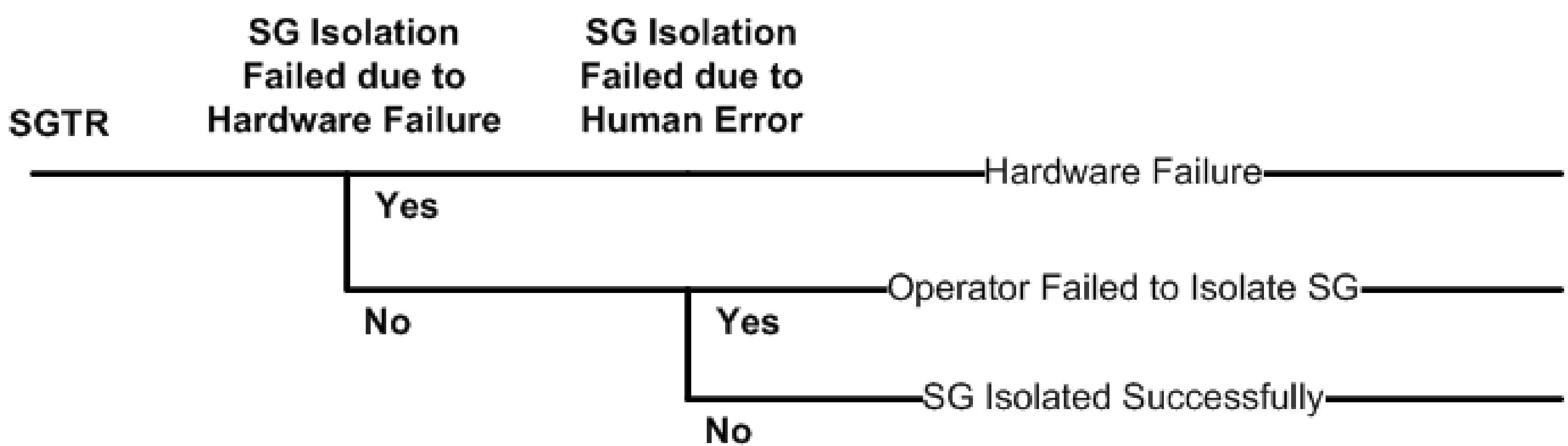
5. *Other paths observed in operating experience*

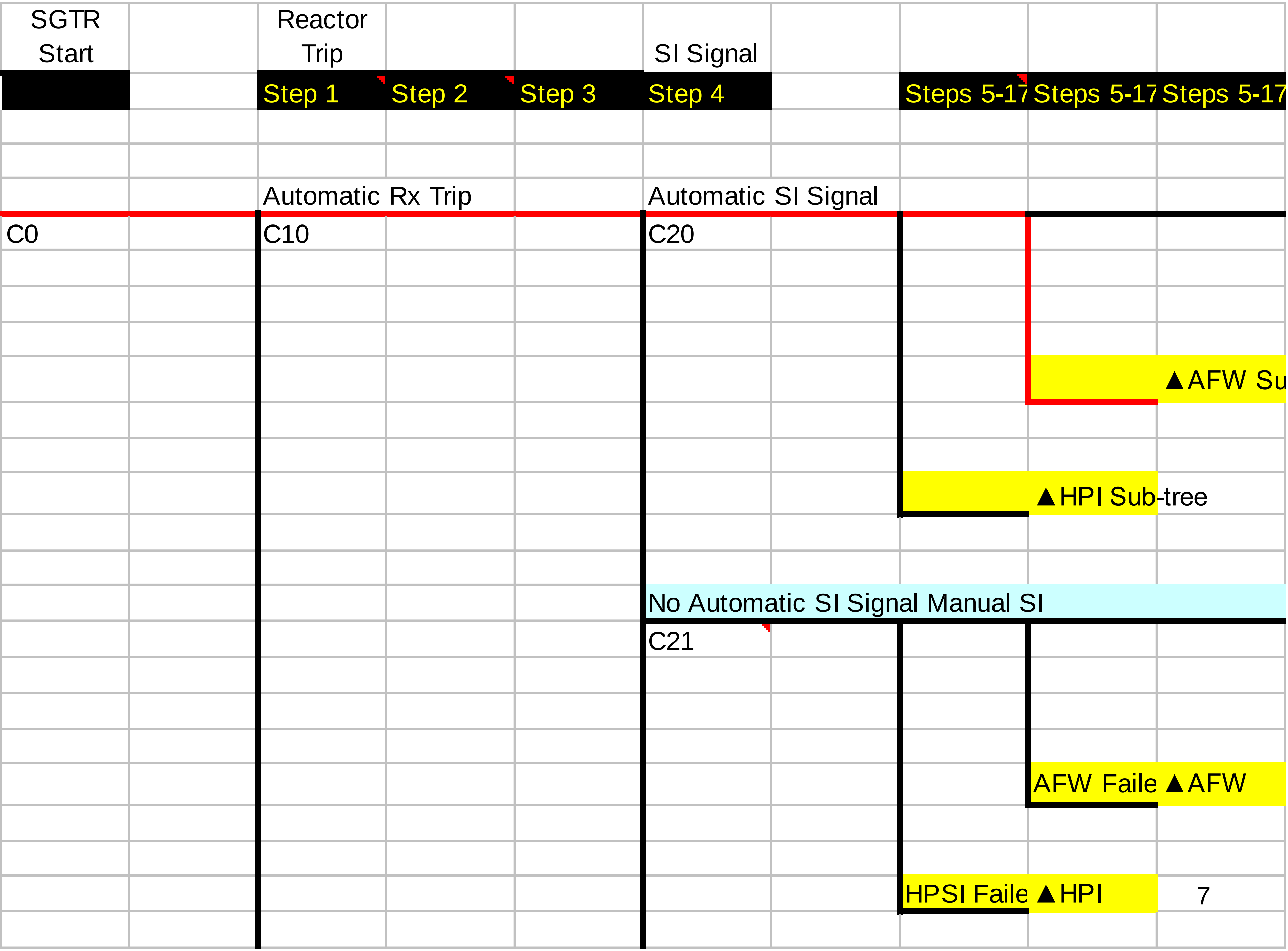
Example


SGTR
Isolate the Broken SG
Finished Isolation Early
Finished Isolation Late
Finished Isolation Later Than the Allowed Time Window
Operator Isolate Wrong Valves
Operator Isolate the S/G with the Wrong Ordering
Incomplete Action
Hardware Failure
No Operator Action

Simplification of CRT (cont)






SGTR Start
Reactor Trip
SI Signal
Step 1
Step 2
Step 3
Step 4
Steps 5-17
Steps 5-17
Steps 5-17
Automatic Rx Trip
Automatic SI Signal
C0
C10
C20
▲AFW Su
▲HPI Sub-tree
No Automatic SI Signal Manual SI
C21
AFW Faile ▲AFW
HPSI Faile ▲HPI
7

Example
Sub-CRT for Secondary Heat Removal Function

The sub-CRT is developed for the following scenario:

1. SGTR
2. Rx Trips Automatically
3. Automatic SIS
4. HPSI Functions Successfully

Step 1: Review Operating Procedures

(Typical Westinghouse Procedure)

1. E-0 step 14 - check the AFW flow rate. Manually restore AFW system.
2. FR.H-1 two entry points: E-0 step 14 or the red path condition of safety function tree met.
3. FR.H-1 step 1 - assessed the plant condition.
4. FR.H-1 step 2 - establish AFW flow.
5. FR.H-1 step 3 - establish MFW flow.
6. FR.H-1 step 5 – feed and bleed.

Step 2: Identify CRT Branch Points

Consider :

- Plant Conditions

  e.g., SIS Automatically Initiated, Hardware Failure, ..

- Likely Operator Actions

  e.g., Operator Restores the AFW System, ..

Example Branch Points (Sub-CRT)

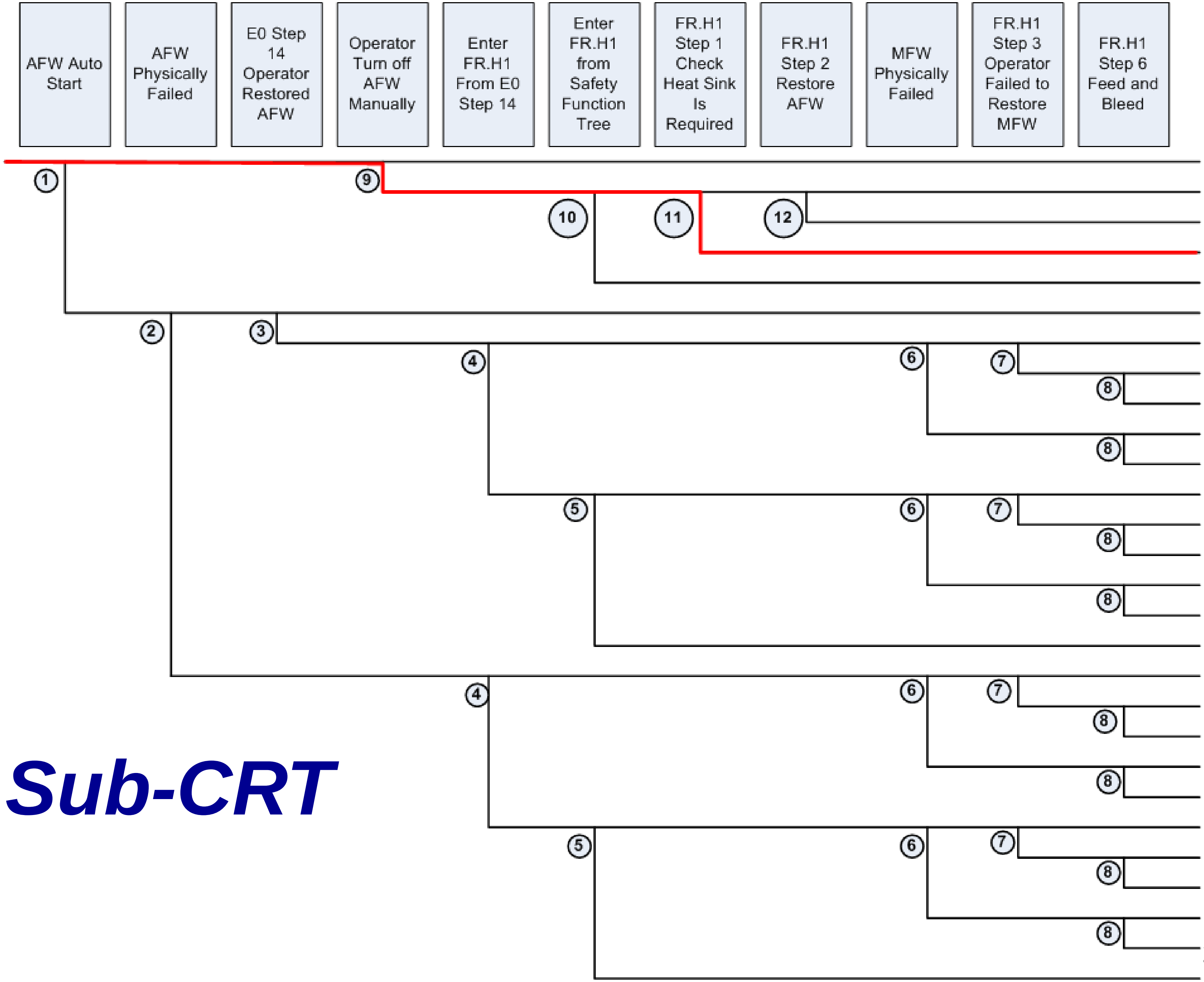
Following an SI signal, the AFW system may automatically activate. However, there is a certain probability that the AFW automatic start function may fail.

Branch Point 1: **AFW Auto Start**

Given the AFW System Automatically Start Failed, the failure may be caused by a start signal problem (*the operator may start it manually*), or the AFW may fail physically (*the operator can not start it manually*)

Branch Point Point 2: **AFW Physically Failed**

Sub-CRT



AFW Auto Start
AFW Physically Failed
E0 Step 14 Operator Restored AFW
Operator Turn off AFW Manually
Enter FR.H1 From E0 Step 14
Enter FR.H1 from Safety Function Tree
FR.H1 Step 1 Check Heat Sink Is Required
FR.H1 Step 2 Restore AFW
MFW Physically Failed
FR.H1 Step 3 Operator Failed to Restore MFW
FR.H1 Step 6 Feed and Bleed
1
9
10
11
12
2
3
4
6
7
8
8
5
6
7
8
8
4
6
7
8
8
5
6
7
8
8

Sub-CRT Branch Points (cont.)

Given the AFW system automatically start successfully, Operator may turn off the AFW system. For example, operator may turn off the AFW to prevent the S/G and steam line solid when the S/G level increased fast.

Branch Point 9: Operator Turns off AFW Manually

Sub-CRT Branch Points (cont.)

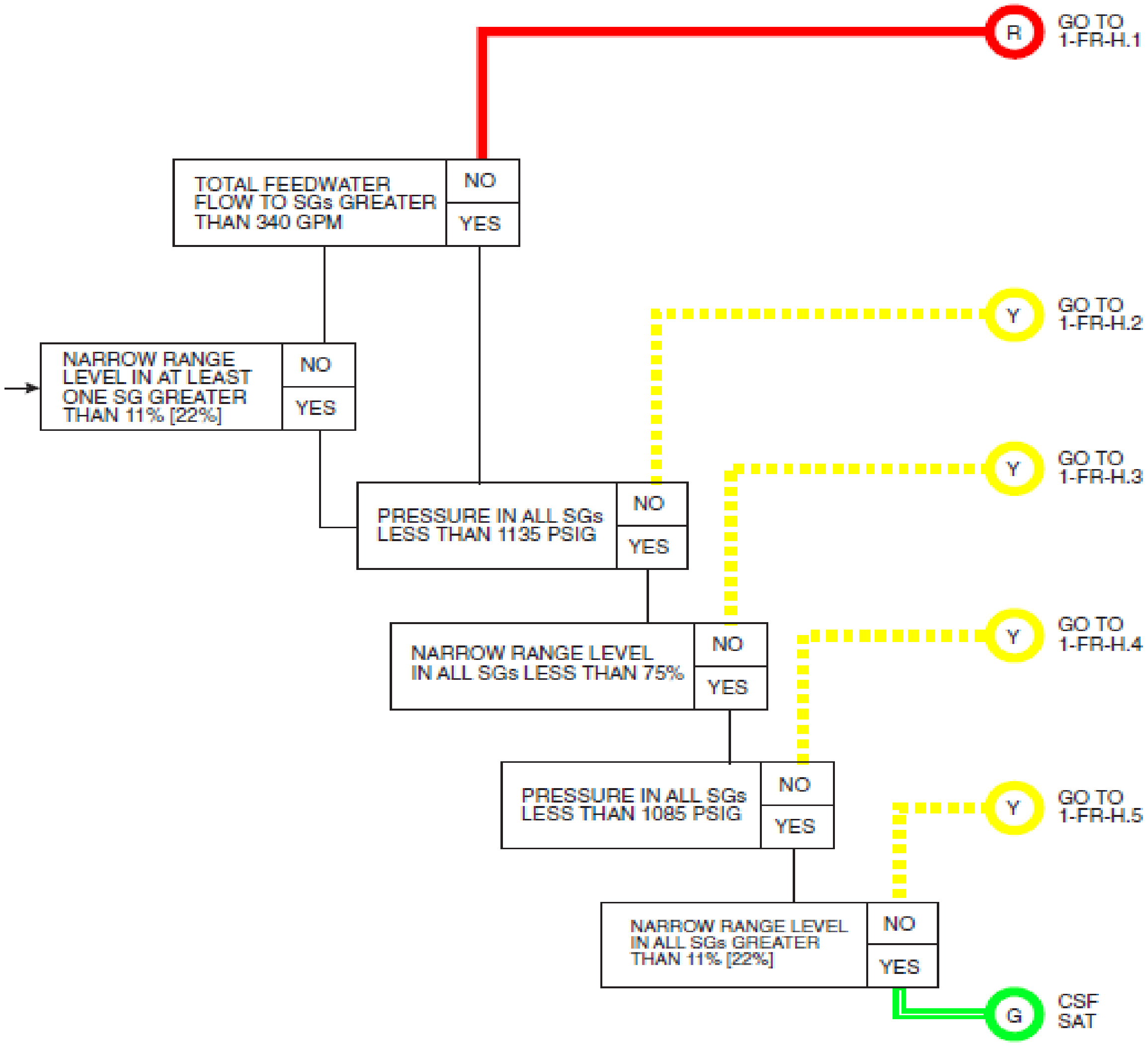
Given the operator turn off the AFW manually, once the condition of the red path of the safety function tree is met, the STA may inform the operator to enter FR.H-1

Branch Point 10: Enter FR.H1 from SFT

Once the operator enters FR.H-1, Step 1 leads the operator to check the plant conditions. He may think that AFW is not needed and go back to the previous procedure

Branch Point 11: Check Heat Sink Is Required

Typical Westinghouse Safety Function Tree for Secondary Heat Sink

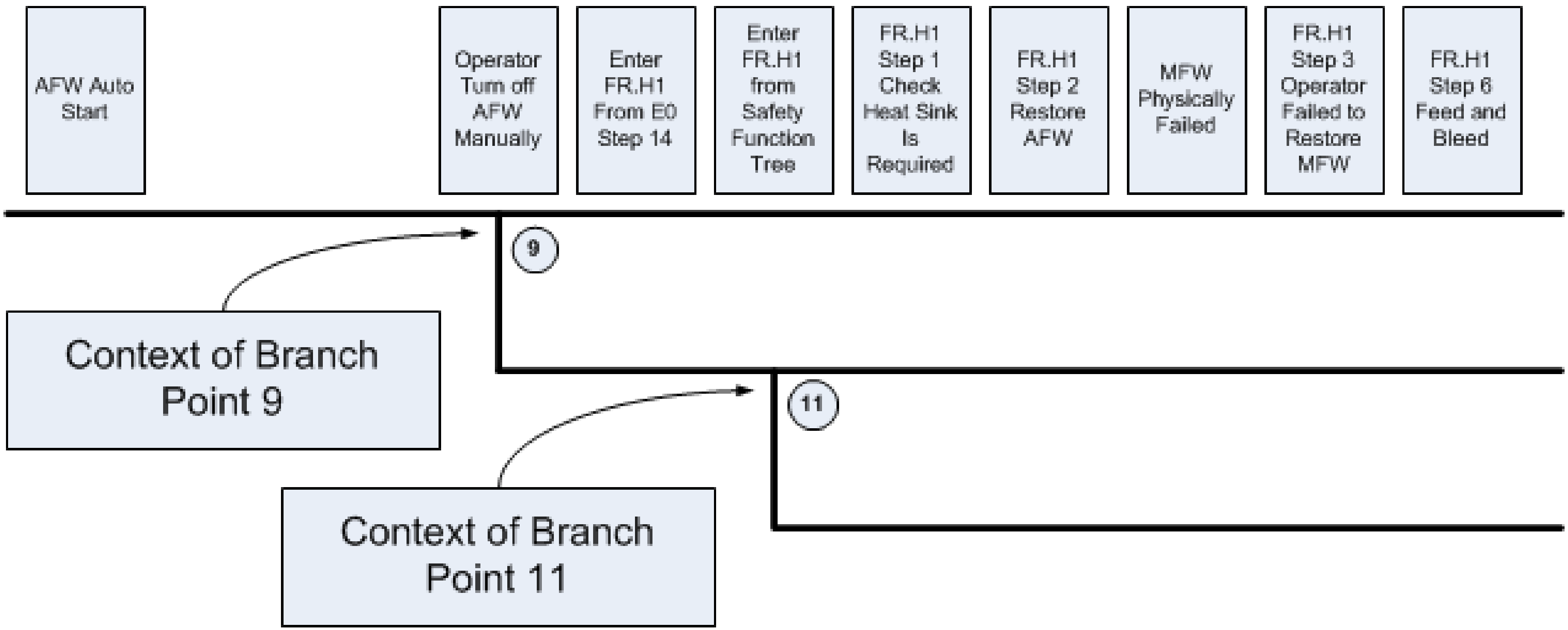


Step 3: Characterize Context for the Identified Branch Points

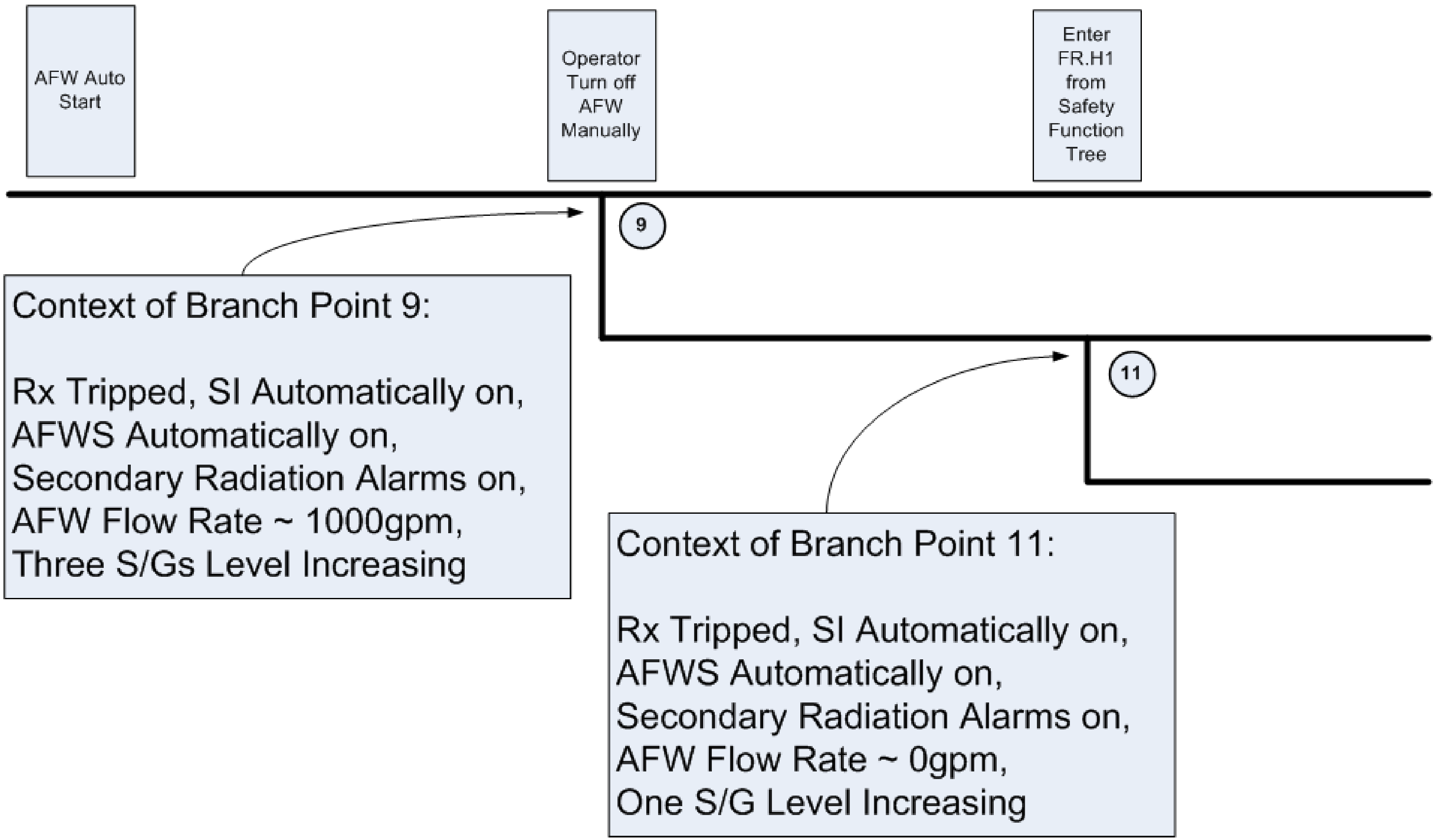
The context for the identified branch point includes:

- The relevant plant conditions (system state and physical parameters) for branch point.
- The previous operator actions that may affect the operator's behavior in this point.
- Man-machine interface.
- Other influences characterized as PSFs.

Step 3: Characterize Context for the Identified Branch Points (cont)



Step 3: Characterize Context for the Identified Branch Points (cont)

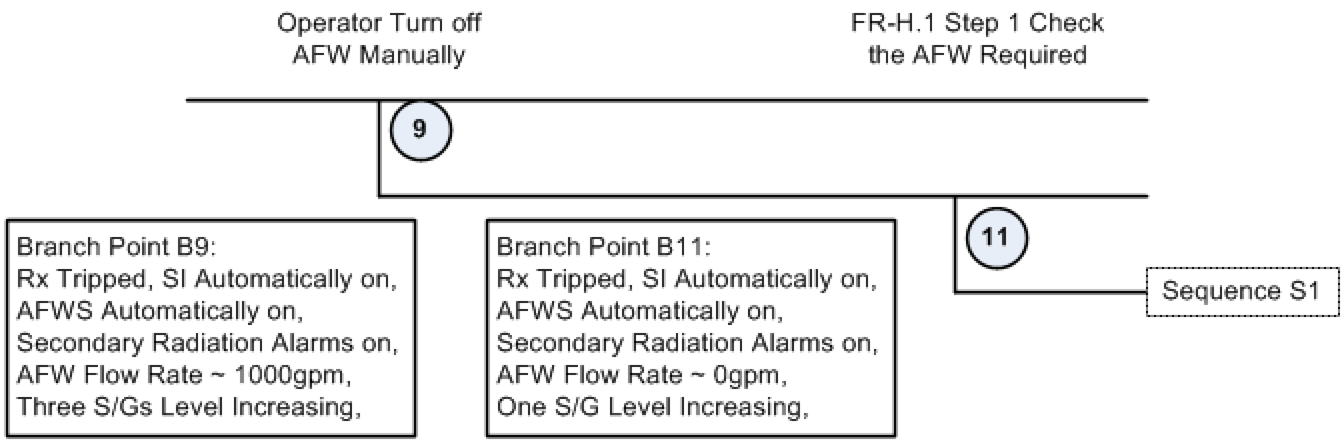


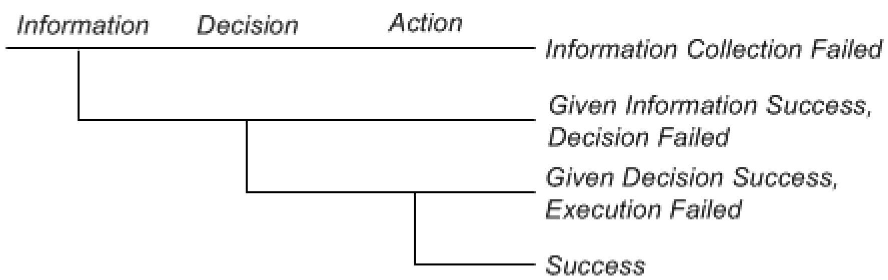
Underlying Plant Scenario of Sequence S1

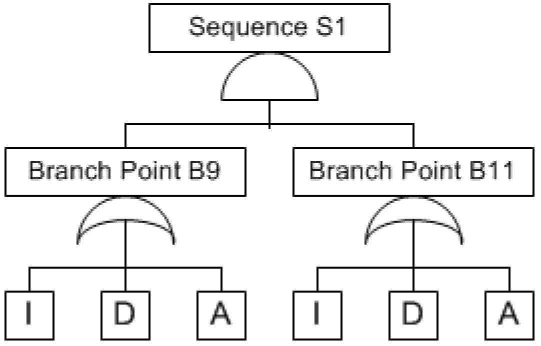
- S/G U-tube Ruptured
- Secondary Radiation Alarms on
- One S/G level increasing
- S/G High Level Tripped Turbine, and then Rx automatically Tripped, SI Automatically on
- AFWS Automatically on
- AFW Flow Rate ~ 1000 gpm
- Three S/Gs Level Increasing

- In Branch Point 9, the operator manually trips the AFW system.
- STA is monitoring the critical function tree.
- When the Critical Function Tree red path condition is met, STA instructs the operator to enter FR-H.1 procedure.
- The operator enters FR-H.1, Step 1 to check whether the secondary heat sink is required.
- If the operator determines that the secondary heat sink is not necessary, he transfers back to E-0, and the path leads to core damage because of the lack of the secondary heat sink. (Branch Point 11)

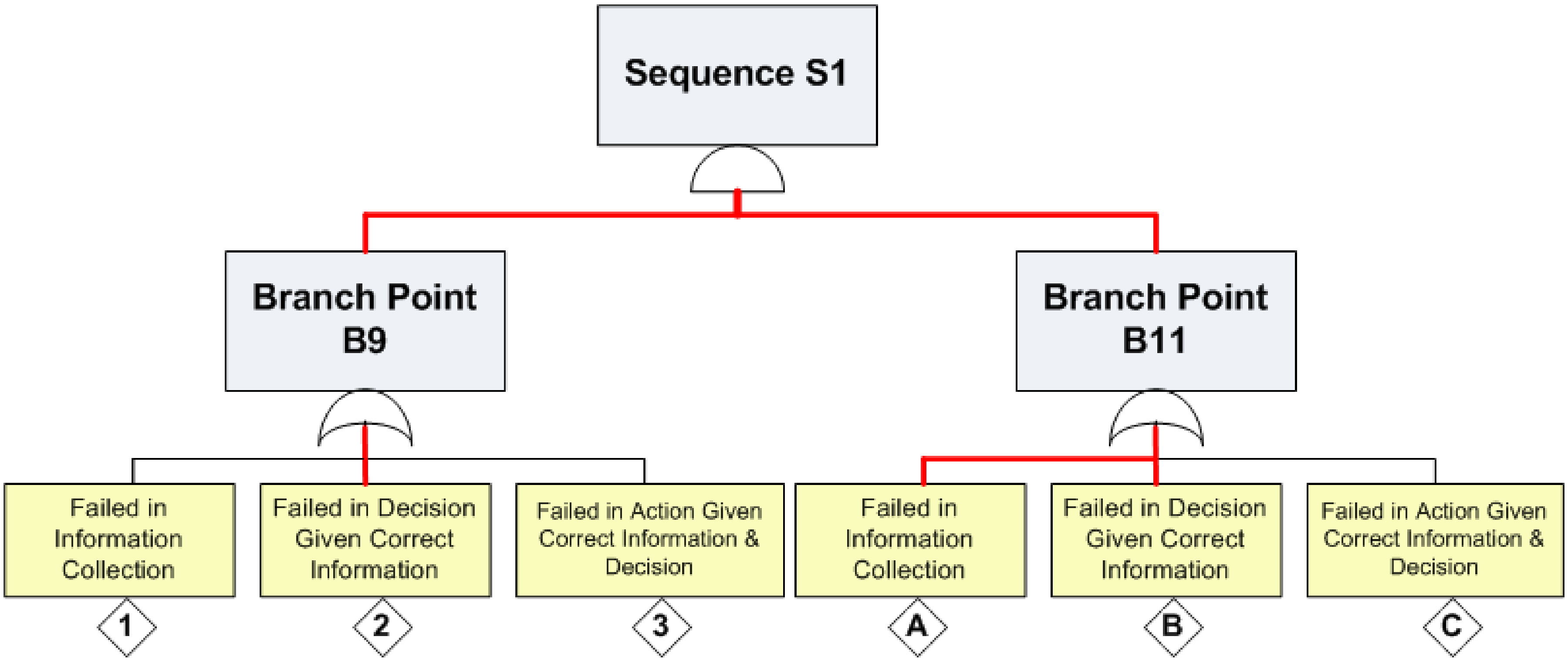
Step 4: Build and Link Mid-layer Fault Trees for the Identified Branch Points



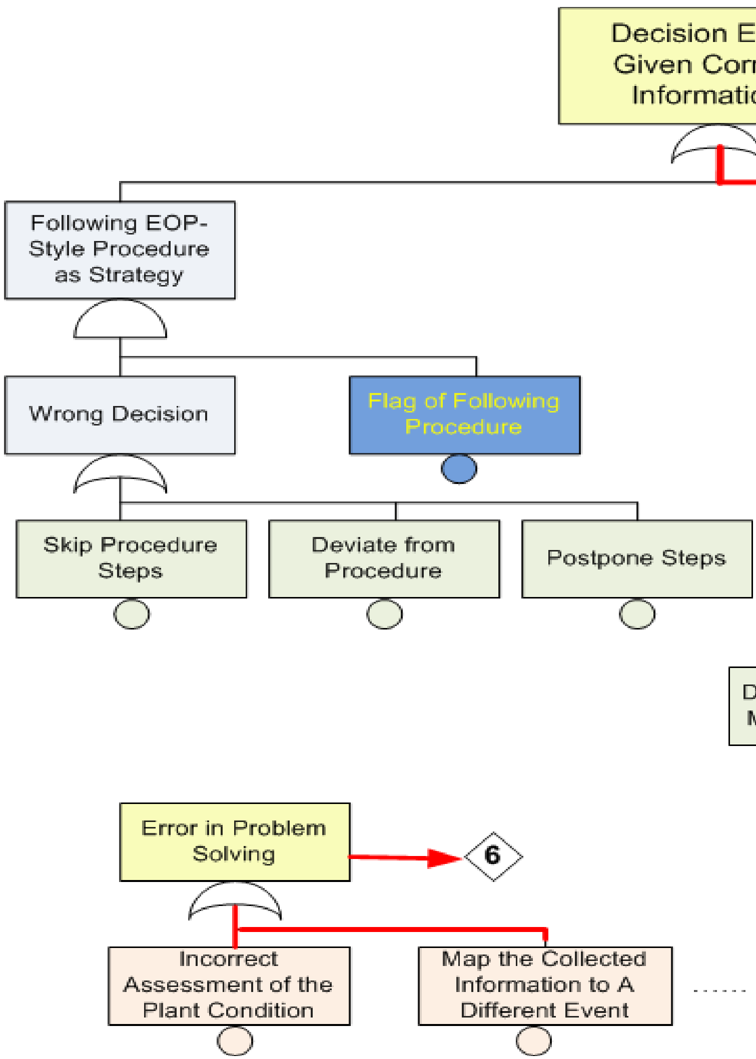


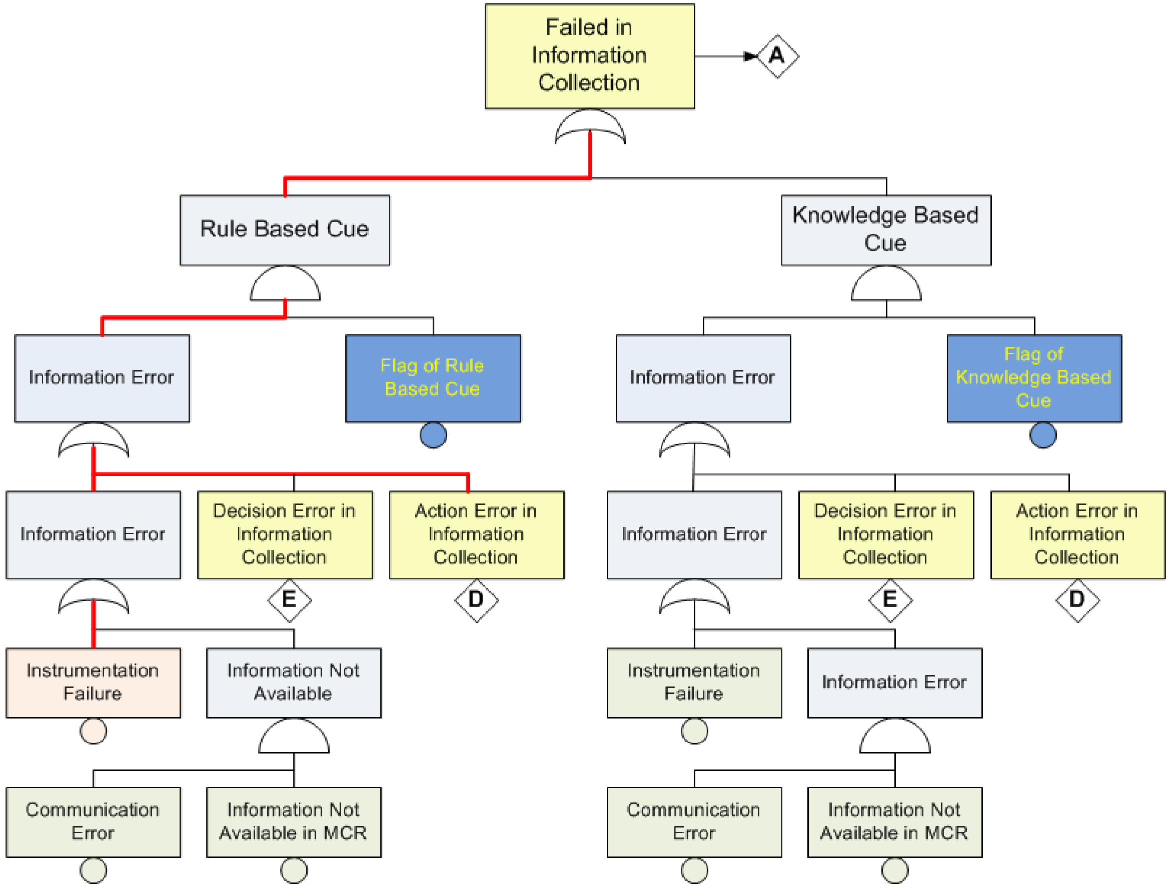


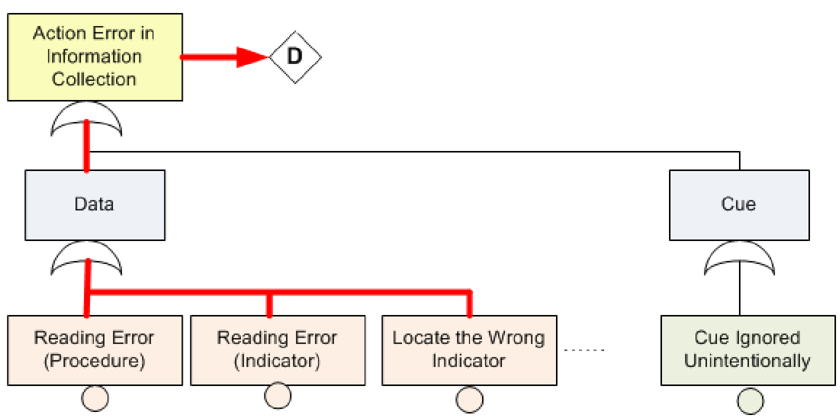
Step 4: Build and Link Mid-layer Fault Trees for the Identified Branch Points

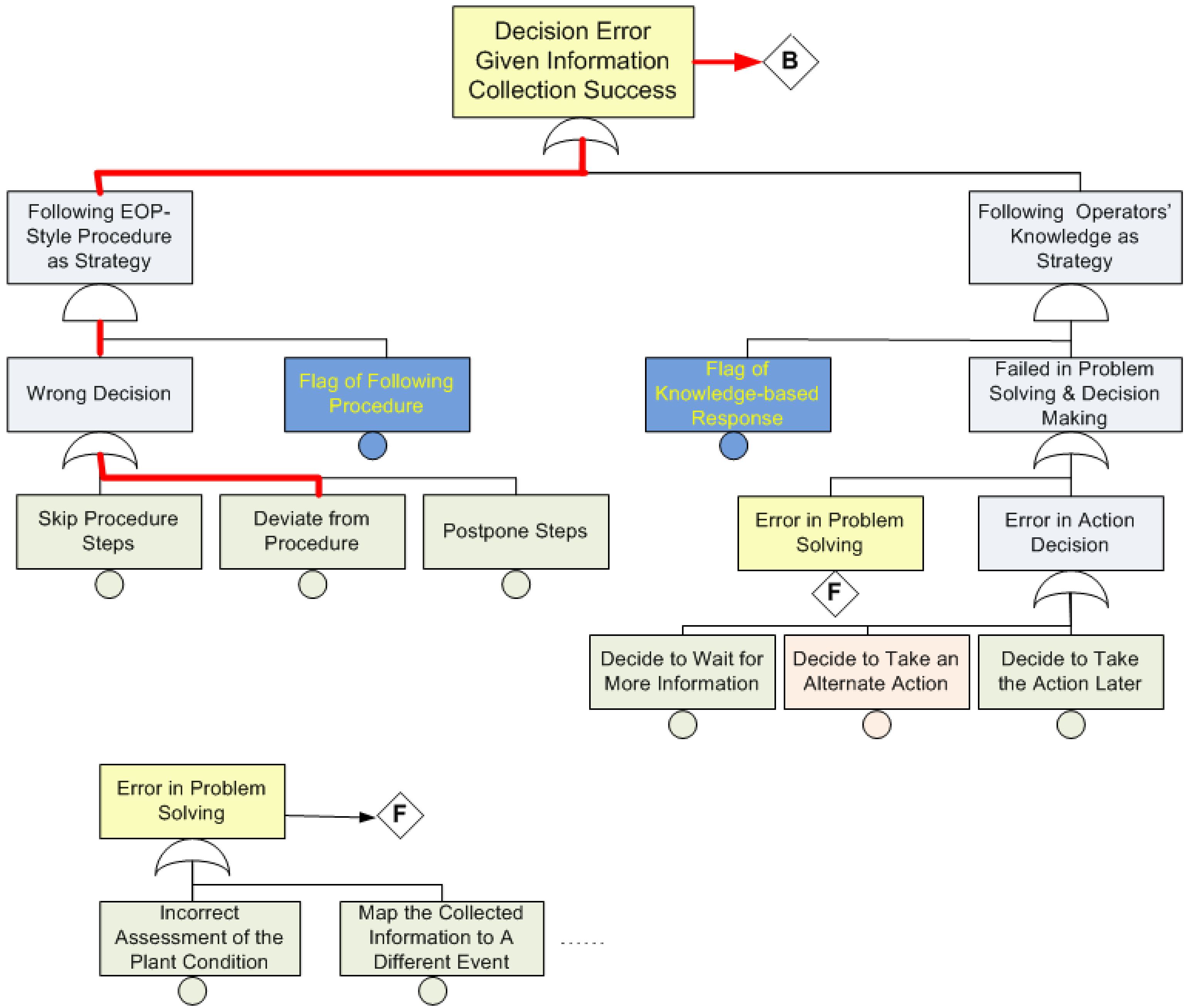


Step 4: Build and Link Mid-layer Fault Trees for the Identified Branch Points




Failed in Information Collection
A
Rule Based Cue
Knowledge Based Cue
Information Error
Flag of Rule Based Cue
Information Error
Flag of Knowledge Based Cue
Information Error
Decision Error in Information Collection
Action Error in Information Collection
Information Error
Decision Error in Information Collection
Action Error in Information Collection
E
D
E
D
Instrumentation Failure
Information Not Available
Instrumentation Failure
Information Error
Communication Error
Information Not Available in MCR
Communication Error
Information Not Available in MCR


Action Error in Information Collection
D
Data
Cue
Reading Error (Procedure)
Reading Error (Indicator)
Locate the Wrong Indicator
......
Cue Ignored Unintentionally



Decision Error Given Information Collection Success
B
Following EOP-Style Procedure as Strategy
Following Operators' Knowledge as Strategy
Wrong Decision
Flag of Following Procedure
Flag of Knowledge-based Response
Failed in Problem Solving & Decision Making
Skip Procedure Steps
Deviate from Procedure
Postpone Steps
Error in Problem Solving
Error in Action Decision
F
Decide to Wait for More Information
Decide to Take an Alternate Action
Decide to Take the Action Later
Error in Problem Solving
F
Incorrect Assessment of the Plant Condition
Map the Collected Information to A Different Event
......

Scenario 1 Causal Cut Sets

#	Prob/Freq	Cut Set	Description
1	1.00E-03	B1_D_KATPCW	Assess the Plant Condition Wrong
	1.00E-03	B2_R_CTWI	Choose the Wrong Indicator
2	1.00E-03	B1_D_KATPCW	Assess the Plant Condition Wrong
	1.00E-03	B2_R_REP	Reading Error (Procedure)
3	1.00E-03	B1_D_KATPCW	Assess the Plant Condition Wrong
	1.00E-03	B2_R_REI	Reading Error (Indicator)
4	1.00E-03	B1_D_KATPCW	Assess the Plant Condition Wrong
	1.00E-03	B2_R_IF	Instrumentation Failure
5	1.00E-03	B1_D_KATPCW	Assess the Plant Condition Wrong
	1.00E-03	B2_D_P_DFP	Deviate from Procedure
6	1.00E-03	B1_D_K_MTCITADE	Map the Collected Information to A Different Event
	1.00E-03	B2_R_CTWI	Choose the Wrong Indicator
7	1.00E-03	B1_D_K_MTCITADE	Map the Collected Information to A Different Event
	1.00E-03	B2_R_REI	Reading Error (Indicator)
8	1.00E-03	B1_D_K_MTCITADE	Map the Collected Information to A Different Event
	1.00E-03	B2_R_REP	Reading Error (Procedure)
9	1.00E-03	B1_D_K_MTCITADE	Map the Collected Information to A Different Event
	1.00E-03	B2_R_IF	Instrumentation Failure
10	1.00E-03	B1_D_K_MTCITADE	Map the Collected Information to A Different Event
	1.00E-03	B2_D_P_DFP	Deviate from Procedure

Example for LPSD PRA Applications (SDP)

Loss of Inventory Event at PWR Power Station

Plant Condition Before the Event:

- The RCS level had restored from a midloop operation to below the reactor vessel flange.
- The reactor vessel head was detensioned in preparation for removal.
- The switchyard was back-feeding all Unit 1 electrical loads through the main transformer and the associated auxiliary transformer.

Event Sequence

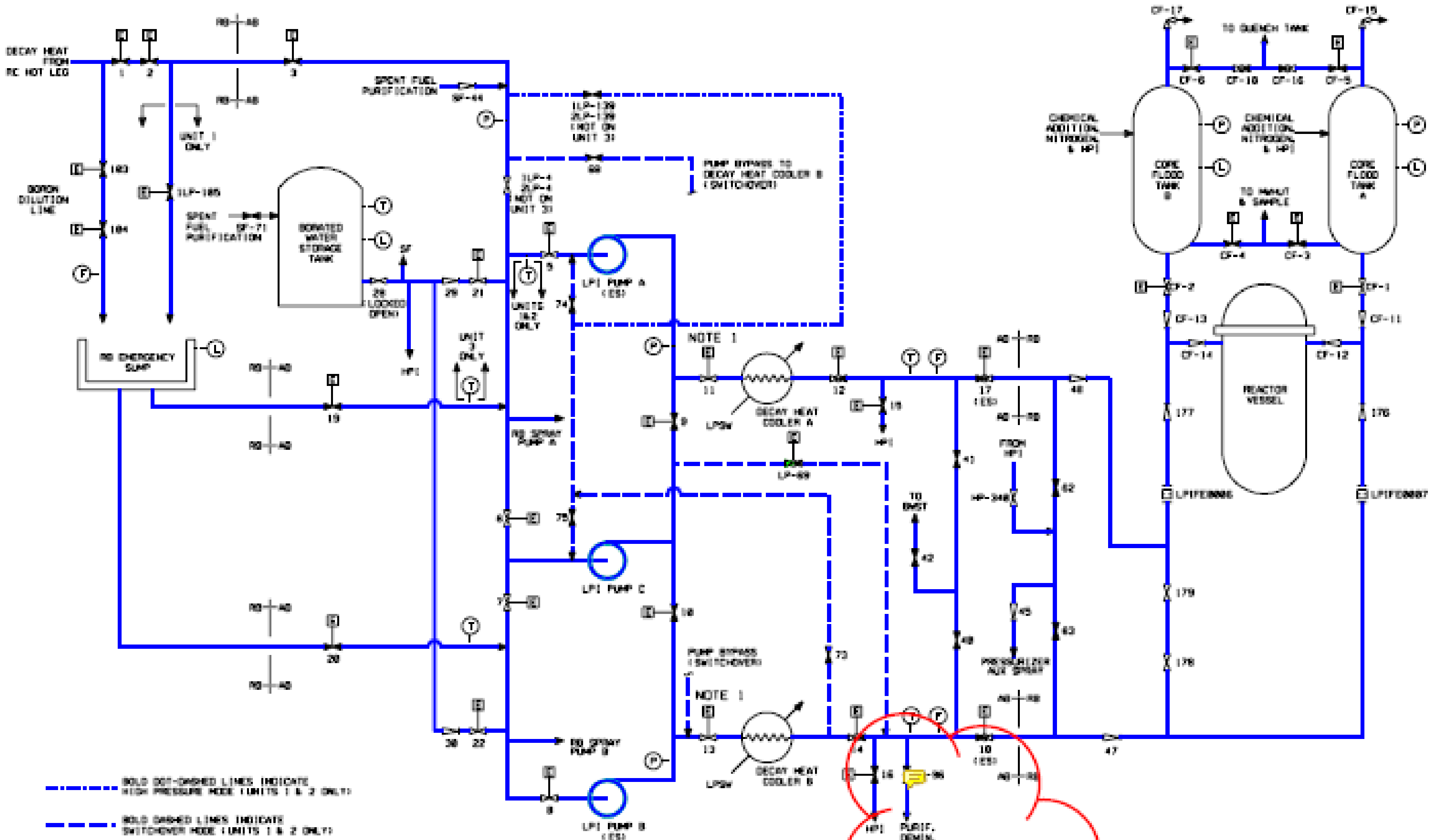
- A main generator lockout signal was generated during main generator voltage regulator modification testing.

- The lockout signal caused a slow transfer from the aux transformer to backup transformer (CT1) from the switchyard.

Event Sequence (cont)

- The resulting electrical transient caused a momentary loss of power to the running pumps performing shutdown cooling (SDC) and due to one complication a relief valve in the letdown purification system opened and remained open as designed.

- This transient caused a loss of inventory (LOI) from the reactor coolant system (RCS) to the miscellaneous waste holdup tank (MWHUT).



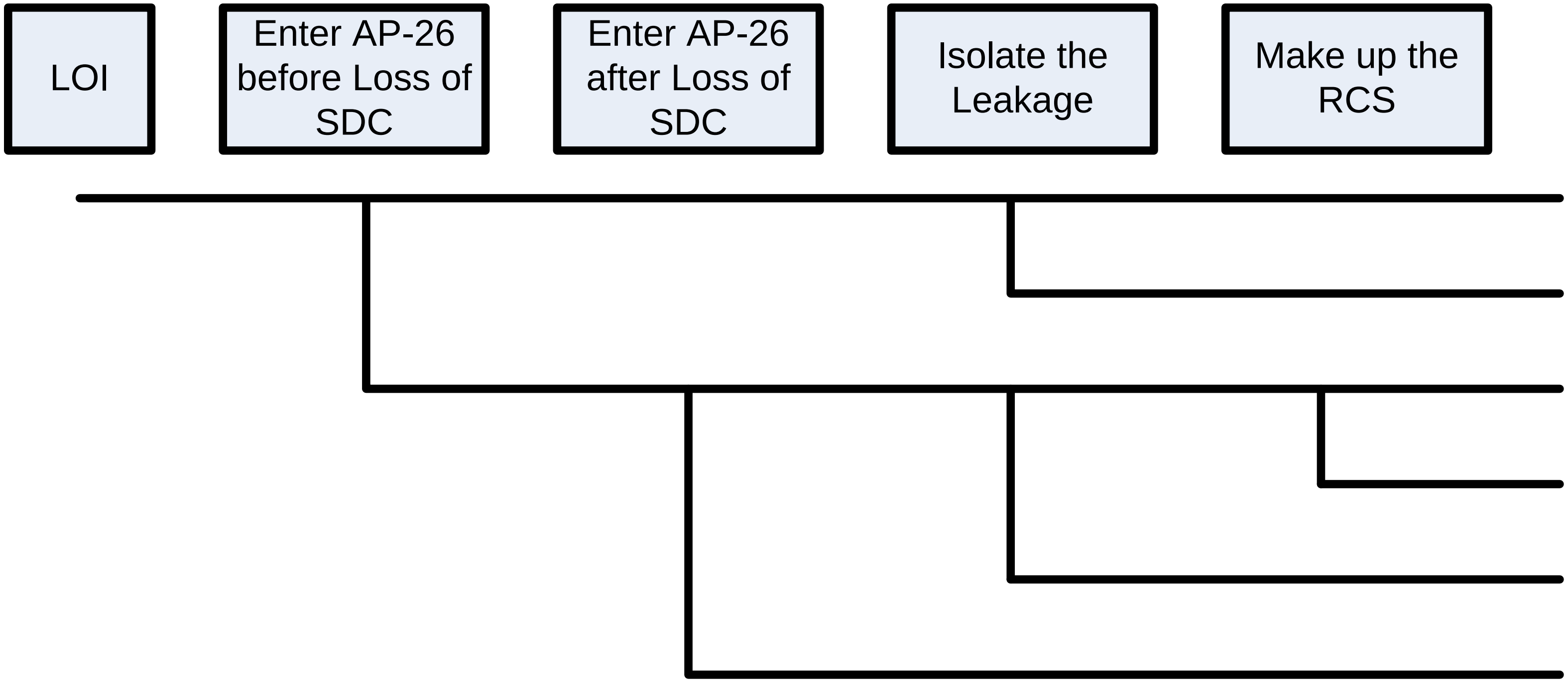
NOTES:

1. LP-11 & LP-13 ARE MANUAL ON UNIT # 3.

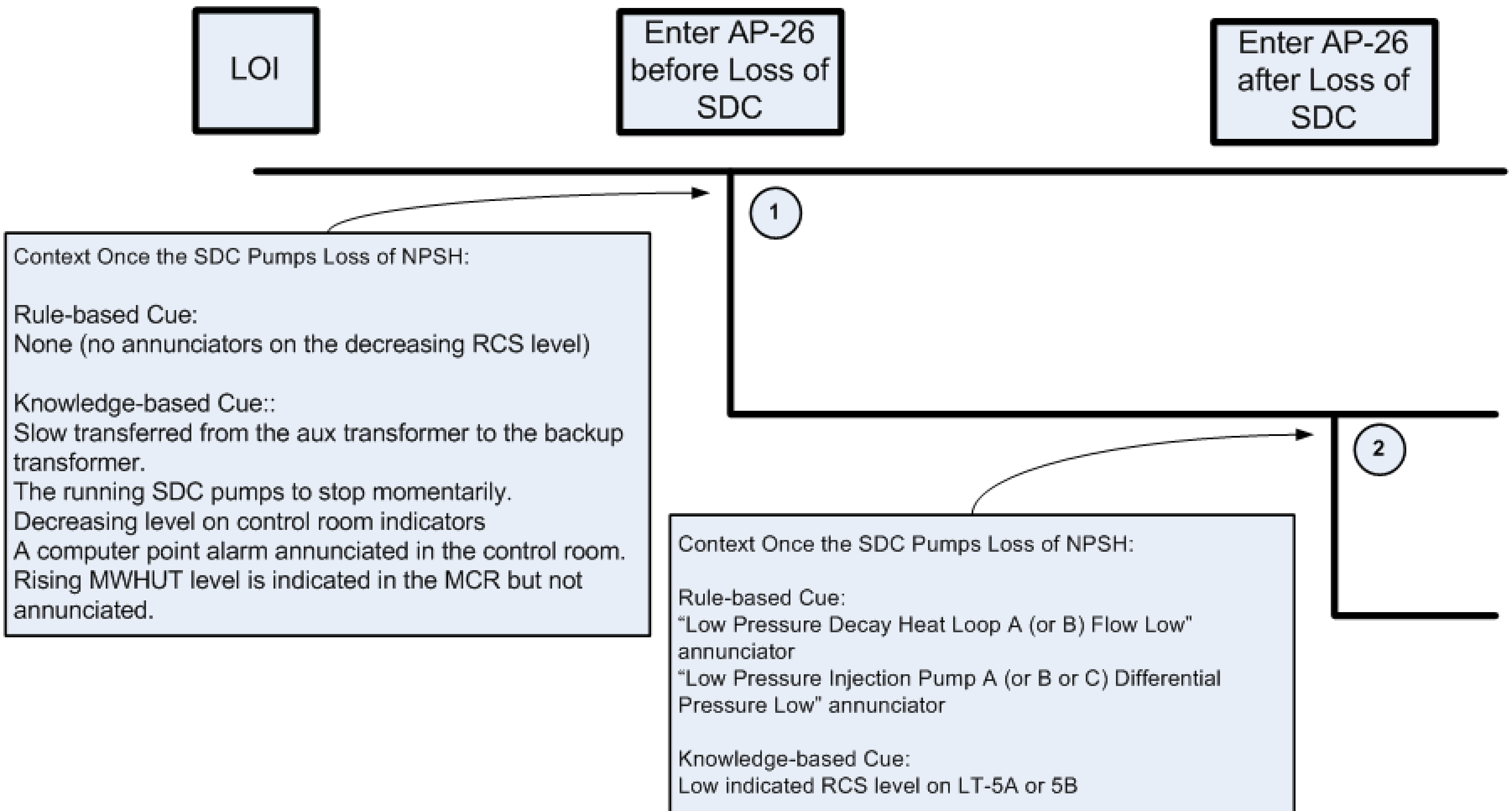
Procedure Review

- The operator must recognize the abnormal event and start implementation of Procedure AP-26 “Loss of Decay Heat Removal.”
- Step 4-12 may lead operator to jump to Step 4-18 and exit the procedure.
- Step 4-17 leads operator to transfer to Section 4-C.
- Step 3 of Section 4C directs operator to isolate the leakage.
- Step 4 leads the operator to got to step 187 to make up the RCS inventory.

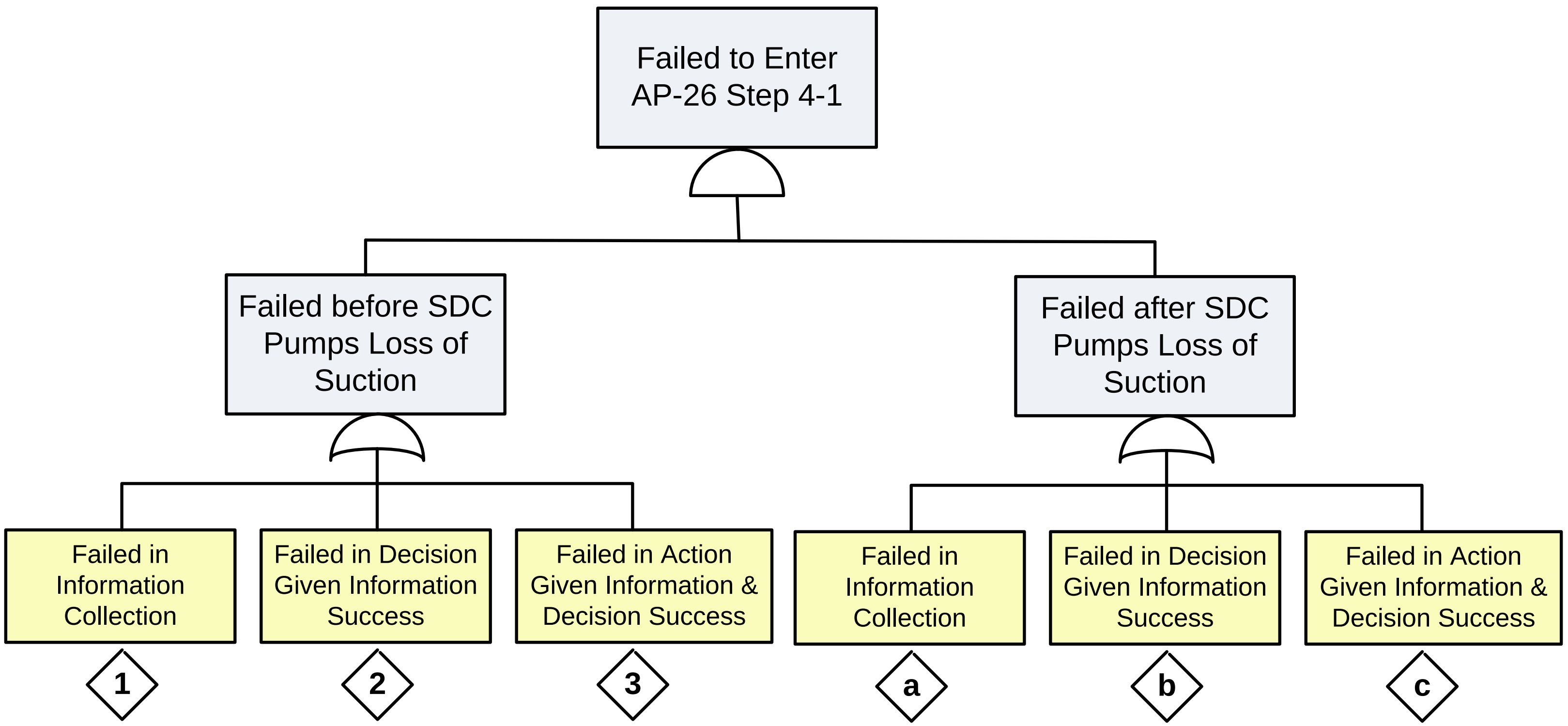
Constructing the Event CRT



Characterize the Context for the Identified Branch Points



Build and Link the Mid-layer Fault Trees for the Identified Branch Points



Addressing SRM-M090204B: Use US Plant Experience for HRA Method Testing and Data Collection

Erasmia Lois, RES

ACRS Subcommittee on

Reliability and PRA Meeting

April 7, 2010

Presentation Outline

- Background
- Objectives
- Organizations involved
- Status

Background

- The International HRA Empirical Study
  - Assessed HRA methods using Halden Reactor Project simulator facilities and European crews
    - Analyst did not have the opportunity to visit the reference plant
    - Ensure that the lessons learned are applicable to US applications
  - Performed mainly method-to-data comparisons
    - No analyst-to-analyst variability
  - Recognized benefit from additional empirical studies
- SRM-M090204B – February 2009
    - Pursue testing U.S. nuclear plant operating crews' performance in a variety of situations
    - Keep the Commission informed on the HRA database and benchmarking projects

Background (cont.)

- NRC MOU with a US reference plant to use its simulators for data collection activities for both objectives:
  - Test methods thru US simulator runs
  - Examine the use of US simulator data produced thru a variety of activities for HRA
- Therefore, there are two activities
  - HRA method testing—the US HRA Empirical Study
  - HRA data collection

The US HRA Empirical Study Objectives

- Address open issues identified in the International HRA Empirical Study
- Visit the plant to collect information for HRA
  - HRA teams will visit the reference plant
    - Address issues related to the need and amount of plant specific information
    - Assess method specific needs for plant specific information
    - How could we optimize the process
- Address analyst-to analyst variability
  - Have more than one team per method
  - Better understanding of how analysts apply methods
  - Identify variability drivers
- Develop tools as needed to improve the robustness of HRA

US Simulator Data Collection Objectives

- Examine how simulator runs produced thru training could be utilized to support HRA
  - Collection of simulator runs has been repeatedly recommended by many, including the ACRS
  - NRC/Industry benefits
- Potential for an data exchange at an international level
  - Support the NEA/CSNI/WGRisk plans for an international data exchange activity

Who is involved?

- Collaborative work
  - Sandia National Labs has the lead of the empirical study
  - Halden supports the data collection/interpretation
  - Idaho National Lab collaborates to establish a formalized process
  - NRC staff extremely involved
    - RES/NRO staff in the design of the study
    - RES/NRR/NRO teams will conduct analysis
  - HRA teams are also comprised by national lab and commercial experts
  - EPRI also supports the study
    - Offers teams to perform analyses and assessment team support
  - University of Mexico
  - Finland and Czech Republic
- Methods to be applied
  - ATHEANA
  - EPRI's calculator/CBTD
  - SPAR-H
  - THERP/ASEP
- Idaho National lab has the lead for the training simulator data collection

Status

- The HRA Empirical Study
  - Design completed—October 2009
  - Simulator runs performed, January 2009
  - HRA teams receive information and visit the plant, June 2010
  - HRA teams submit analysis, September 2010
  - Simulator data are interpreted, August 2010
  - Predictions-to data-comparisons, May 2011
  - Draft Documentation of results/publication, Sept 2011
  - Final NUREG, June 2012
- The simulator training data collection study
  - Involved in the design and simulator run execution steps
  - In process of establishing an approach, December 2010
  - Establish data collection practices, September 2011

Overview of HRA Empirical Study Using US Simulators

ACRS PRA Subcommittee Meeting

April 7, 2010

Presented by
John Forester

Sandia National Laboratories

UNITED STATES NUCLEAR REGULATORY COMMISSION

Outline

- Background from International Empirical Study
- US study objectives
- Basic experimental design
- Summary of simulated scenarios and HFEs
- Study team members

Background

International Empirical Study

- 13 HRA teams using 13 HRA methods predicted crew performance in accident scenarios run in the Halden Reactor Project (HRP) simulator
- Predicted human error probabilities (HEPs), factors driving performance (e.g., PSFs), and operational stories for multiple human failure events (HFEs)
- Allowed assessment of strengths and weaknesses and the general predictive power of the methods
  - Similar to earlier benchmarking study (ISPRA), found variability in predictive results
  - Identified apparent limitations in the qualitative analysis prescribed by essentially all methods
- Experimental design did not allow:
  - Clear separation of method from team effects
  - Good understanding of the process the teams used for performing qualitative analysis
  - HRA teams to visit plant or interview plant staff

Study Objectives

- Test the consistency of HRA predictions across the same method and different methods using different HRA teams
  - Several teams for each method
  - Is there a large team effect?
- Examine qualitative analysis performed by the different methods and teams
  - Identify any particular shortcomings that contribute to inaccuracy and inconsistency
- Further examine strengths and weaknesses and predictive power of the methods
  - Confirm results using US crews and (mostly) US methods
- Allow teams to perform more realistic HRA – plant visit
- Identify ways to improve the robustness of HRA methods

HRA Methods

(Current Plans)

- At least 3 teams for each of the following methods:
  - EPRI HRA Calculator
  - ATHEANA
  - SPAR-H
  - ASEP/THERP
- Initial test of hybrid method from the Model Differences Project (SRM)
- 2 international teams want to participate – method TBD
- Plant team may apply EPRI Calculator
- Experienced HRA people for each team

Experimental Treatment of HRA Teams

(Current Plans)

- Information package
  - Scenario descriptions
  - HFE definitions
  - Procedures
  - Crew descriptions etc.
- Plant visit
  - Each HRA team will have two hour interview with unique plant SRO and Instructor team (different plant team for each HRA team)
  - Group tour of simulator and generic question/answer
  - Group observation of regular training run
  - Follow-up session with different Instructor to ask additional questions, confirm information obtained
    - Reduce impact of idiosyncratic plant interview team
  - Plan to audio record interview sessions to support assessment of qualitative analysis and assess whether all teams are getting similar information

HRA Method Information Collected

(Current Plans)

- As in international study:
  - Driving factors for each HFE
  - Operational story for each HFE
  - HEPs
- Documentation on how they perform their qualitative analysis
  - Provide guidance/questionnaire for the process they follow and information they collect
  - Observe/record interviews they conduct with plant SRO and trainer at the plant
- Traditional documented HRA analysis

Simulator Data Collection

- 4 crews
  - Shift Manager (SM)
  - Unit Supervisor (US)
  - Shift Technical Advisor (STA)
  - 2 Reactor Operators (RO)
- 3 scenarios
  - LOFW and SGTR with complications
  - Loss of CCW and RCP Sealwater
  - SGTR without complications

Simulator Data Collection

(Continued)

<u>During simulator session</u>

- Observers from the experimental team
  - 2 observers in the control room
  - 4 observers in the back of the control room and in the simulator booth
- Observers from the plant
  - Timeline and comments
  - Predefined actions
  - 2 trainers in the control room
  - 1 trainer in the simulator booth
- Simulator logs
  - Alarms
  - Process parameters (selected)
  - Simulator actions
- Audio/ video recording
  - To be kept at the plant, available to the experimental team if needed

<u>After simulator session</u>

- Critical Decision Interview
  - 2 Halden observers and 1 NRC observer
  - Crew decision makers (SM and US)
  - 2 plant trainers
  - Chronological story of scenario
  - Focus on understanding decisions and main actions
  - Trainers' assessment of performance
  - Decision makers' rating of difficulty of scenarios
- Crew Member Interview
  - 2 INL observers and 1 NRC observer
  - STA and ROs
  - 1 plant trainer
  - Focus on experienced difficulties in the scenario and communication
- Performance Shaping Factors questionnaires
  - All crew members

Simulator Data Collection

(Continued)

- Combine information from previous slide with expert judgment to obtain:
  - Determination of driving factors for each HFE
  - Operational story/description of crew response with respect to the HFE
  - Assessment of difficulty of each HFE for comparisons with HRA team HEPs

Scenario 1- LOFW and SGTR

LOFW

- Plant technical information
  - Three main feedwater pumps: 11, 12 and 13.
  - Four auxiliary feedwater pumps: 11, 12, 13 and 14. AFW pump 14 is turbine-driven and the other three motor-driven.
- Loss of main feedwater pump 11, and subsequent trip of feedwater pump 12 and 13 within the next 10 seconds.
- All main feedwater pumps are tripped, and if the crew doesn't trip manually the reactor will trip on low SG level (20%). (The start up feedpump cannot be started.)
- At autostart, Auxiliary feedwater (AFW) pump 14 will overspeed and cause damage that cannot be repaired. AFW pump 11 will have a seized shaft and trip and will not be available. AFW pump 13 will start but the shaft will shear and no flow will be indicated.

Scenario 1- LOFW and SGTR

(Continued)

- AFW pump 12 will start and indicate full flow, but will not be feeding the steam generator because of a recirculation valve being mispositioned open. There is no indication of the valve's position in the control room.
- No AFW flow to the SGs, and SG levels go down. In reality, criteria to start FR-H1 (Loss of Secondary Heatsink) are met.
  - But because of the indicated flow from AFW pump 12, the plant computer will not show a red path on heatsink.
- According to procedure FR-H.1, Bleed and Feed (B&F) shall be established when the WR level on any two SGs are less than 50%.

Scenario 1- LOFW and SGTR

(Continued)

- To establish AFW to SGs the crews can:
  - Dispatch a plant operator (PO) to check and close the open recirculation valve (feed SG B)
  - Cross-connect AFW flow from pump 12 to SG A, C or D
- If the crew sends a PO to the recirculation valve before start of Bleed and Feed, the PO (simulated by us) will delay closing the valve until B&F is established
- If the crew tries cross-connecting before B&F, the valve breaker would open (spurious component failure) and the valve remains closed. After B&F the valve breaker would be reclosed by a PO (part of the simulation). If the crew tries cross-connecting after B&F, the valve would open.

Scenario 1- LOFW and SGTR

(Continued)

SGTR

- After B&F has been established, the crew will be able to establish AFW flow to one or several SGs.
- A tube rupture occurs in the first SG that is fed.
- The crew will want to fill a SG to be able to exit FR-H1, and the tube rupture may be masked by AFW flow to the SG, as long as it is being fed. The leak size of the ruptured tube is about 500 GPM at 100% power, but the flow will depend on the differential pressure between the RCS and the ruptured SG.
- There is initially no secondary radiation because there is a minimum steam flow. The BD and sampling is secured because of the SI.
- The crew is working in FR-H1, and may have criteria for FR-P1 as a consequence of the B&F.

HFEs for Scenario 1

LOFW

- Time at which the reactor is tripped will impact the time available to initiate B&F before CD.
- Trip within approximately 30 - 45 seconds of the loss of feed water - approximately 45 minutes before CD.
- If do not manually trip, plant will trip automatically on low-low SG NR level (20%) approximately 50-60 seconds after the loss of feed water.
- If the plant trips on low-low SG level – approximately 13 minutes to initiate B&F to avoid CD.
- According to FR-H.1, B&F shall be established when WR level on any two SGs are less than 50%. This criterion should be reached approximately 2 to 2.5 minutes after the LOFW.

HFEs for Scenario 1

(Continued)

- HFE 1A: The probability of failing to initiate feed and bleed within 45 minutes, given that the crews initiate a manual reactor trip before an automatic reactor trip.

- HFE 1B: The probability of failing to initiate feed and bleed within 13 minutes, given that the crews do not manually trip the reactor before an automatic reactor trip occurs.

HFEs for Scenario 1

(Continued)

SGTR

- Per the description of Scenario 1, if the crews successfully initiate B&F, they will be able to establish AFW to one or several SGs.
  - If they do so, an SGTR will occur in the first SG that is fed.
- Assume that crews are successful in establishing F&B.
  - **HFE 1C: Failure of crew to isolate the faulted SGTR and control pressure below the SG PORV setpoint before SG PORV opening**.
    - Time window to perform required actions is estimated to be approximately 40 minutes.
- The actions include:
  - Isolate the ruptured SG (feedwater and main stream isolation valves closed)
  - Maintain SG pressure below the setpoint by cooling down the RCS (cooling the secondary by dumping steam and depressurizing the RCS).

Scenario 2 - Loss of CCW and Sealwater

- On RX trip - Bus E1C will have bus lockout due to a bus fault. (The busbar is de-energized and the DG breaker cannot be closed.)
- On RX trip - CCW pump 1A breaker will trip due to failed/ seized shaft.
- There are no CCW pumps in service (B pump out of service, A pump tripped, C pump de-energized), and no charging pump running (A pump de-energized). If charging pump 1B is started, it will trip 2 minutes after reactor trip.

- If the crew does not stop all RCPs and start the positive displacement pump (PDP), all RCP seals will fail 15 minutes after reactor trip (Seal LOCA).

HFEs for Scenario 2

- HFE 2A: Failure of the crews to trip the RCPs and start the Positive Displacement Pump (PDP) to prevent RCP seal LOCA

- Success requires that the crew:
  - Trip the RCPs after the loss of CCW and start the PDP to provide seal injection before seal water inlet or lower seal water bearing temperatures are greater than 230 degrees to avoid potential (not necessarily immediate) RCP seal LOCA.
  - Time to reach 230 degrees is about 7-9 minutes from loss of CCW.

Study Team Members

- Scenario design
  - Plant staff
  - Helena Broberg, Michael Hildebrandt - Halden Reactor Project (HRP)
  - Bruce Hallbert, Tommy Morgan – INL
  - Erasmia Lois, Amy D'Agostino – NRC
  - John Forester - SNL
- Crew data collection and analysis
  - Helena Broberg, Michael Hildebrandt – HRP
  - Bruce Hallbert, Tommy Morgan – INL
  - Erasmia Lois, Amy D'Agostino – NRC
- Assessment team
  - John Forester - SNL
  - Vinh Dang – PSI
  - Susan Cooper – NRC
  - Stuart Lewis – EPRI
  - Andreas Bye - HRP
  - With contributions from all of the above

Human Performance Data Collection in Support of Human Reliability Analysis Programs

Bruce Hallbert, Director
Nuclear Safety & Regulatory Research

U.S. NRC Advisory Committee on Reactor Safeguards
Washington, D.C.
April 7, 2010

www.inl.gov

INL
Idaho National Laboratory

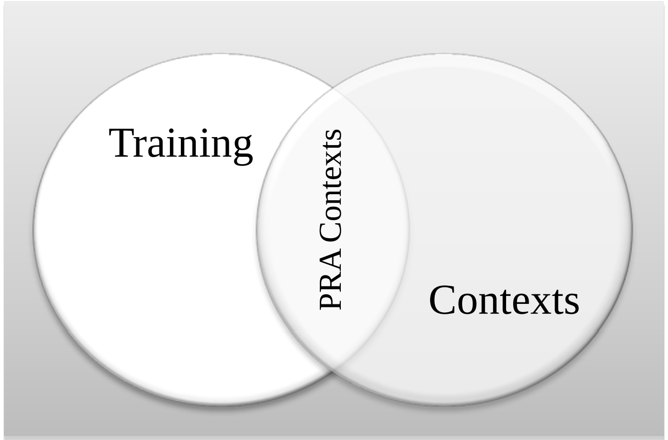
Empirical Human Performance Data

- Refers to human performance data obtained from high fidelity simulated work performance environments.
- Includes, potentially
  - Objective performance measures (control actions)
  - Plant Parameters
  - Descriptions and qualitative analyses of performance
  - Subjective performance measures
- Need: consider the relationship between human performance and human reliability and identify how the context of simulator-based data can be used to inform and improve methods and assessments of human reliability for PRA.
- Goals:
  - Identify objectives and standards for data collection that can be used to readily obtain a sufficient volume of human performance data to strengthen the technical bases of HRA.
  - Establish a simulator data and information collection and exchange program.

Human Performance and Human Reliability

- Data on human performance are readily available in the records of training and qualification routinely conducted in simulators.
- Training is conducted to ensure that team and individual performance meets standards for foreseeable situations, including those described in the PRA.
- How can these data be used to support HRA?
- Human Reliability aims to predict:
  - Conditions
  - Feasibility
  - Probability

  …of human failure



- Training includes conditions of interest
- This project seeks to develop measures, methods and standards for data collection and exchange to support the use of simulator data in HRA.
  - In this context HRA is defined broadly to include aspects of ongoing HRA programs being carried out by Office of Regulatory Research.

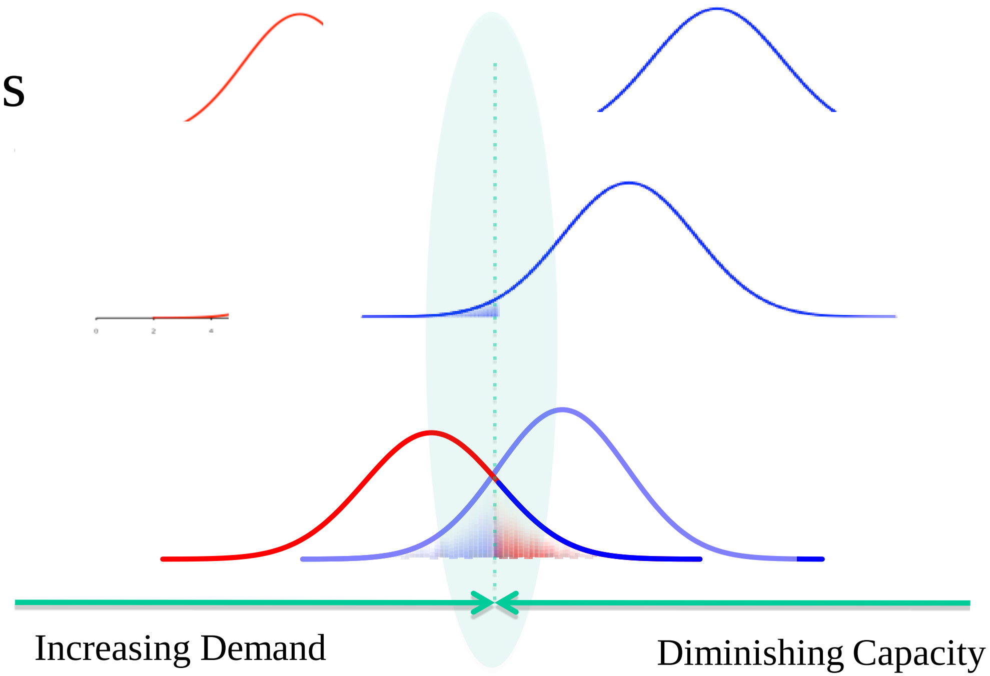
Human Reliability Data Collection Framework

Demand

Capacity

Scenario Features
•Pace
•Severity
•Complexity

'External' PSFs
•Human Machine Interface
•Procedural Guidance



Capabilities
•Experience & training
•Teamwork

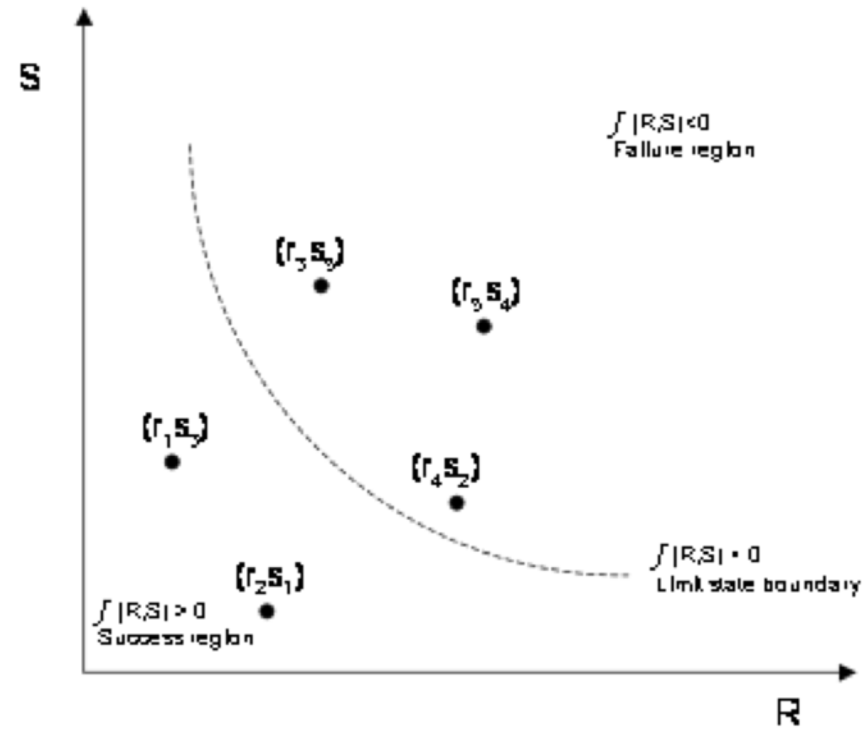
'Internal' PSFs
•Memory, perception, information processing
•Workload
•Situation Awareness

LIMIT STATE

(Failures & Failure Modes)

Data are desired…

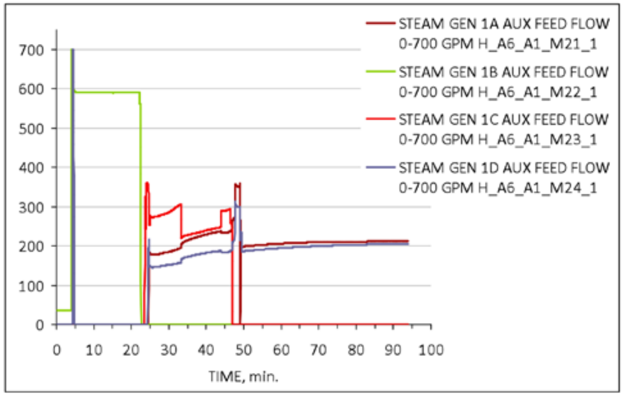
- …from PRA-relevant contexts that:
- …sample performance conditions that theory predict drive performance reliability (e.g., PSFs, PIFs, CPCs)
- …include one or more HFEs of interest
- …describe objective performance (what/when)
- …provide insights into crew behaviors (why/how)
- …show sensitivity of plant response to human performance
- Can be used to empirically derive limit state descriptions for different PRA contexts.

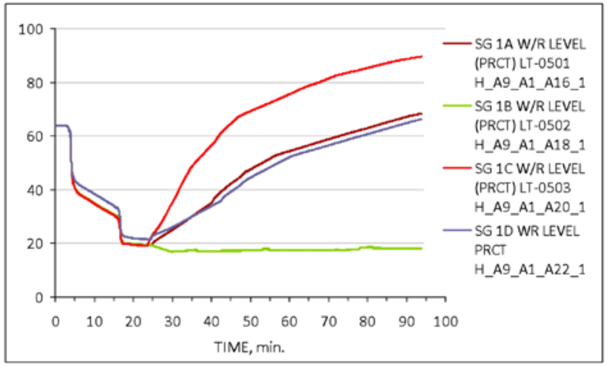


A theoretical limit state and an experimental sampling strategy

Performance Measures

- Plant Parameters:
  - Sensitive to actions that are themselves or in part constitute the HFE
  - Illustrate the base or nominal case expected actions – "What is normal for this plant?"
  - Sensitivity runs:
    - Effects on plant parameters from the human failure event
    - Timing
    - Additional contexts and cues provided by the HFE
    - Degraded PSFs of relevance





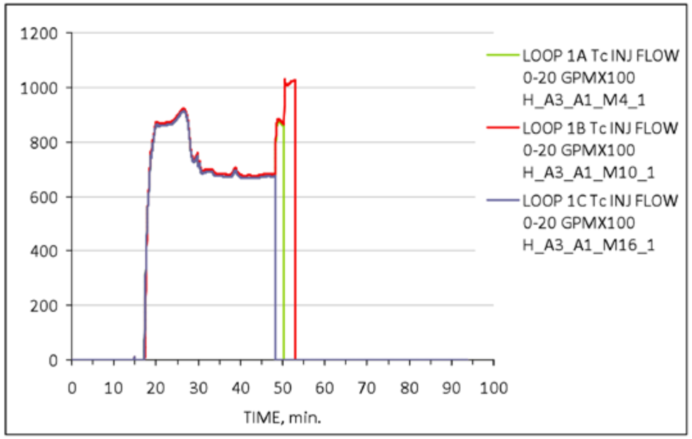
*(Note: graphs are examples and used for illustration only)

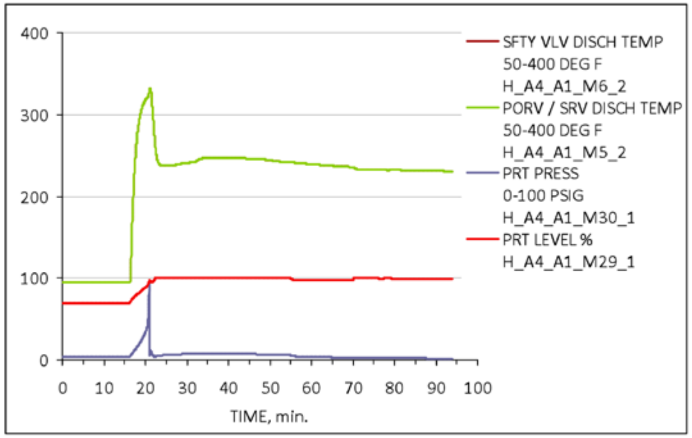
Performance Measures

- Objective Measures
  - Control actions that were performed
  - Acknowledgements
  - Procedures entered and in effect
  - Decision points and solution path

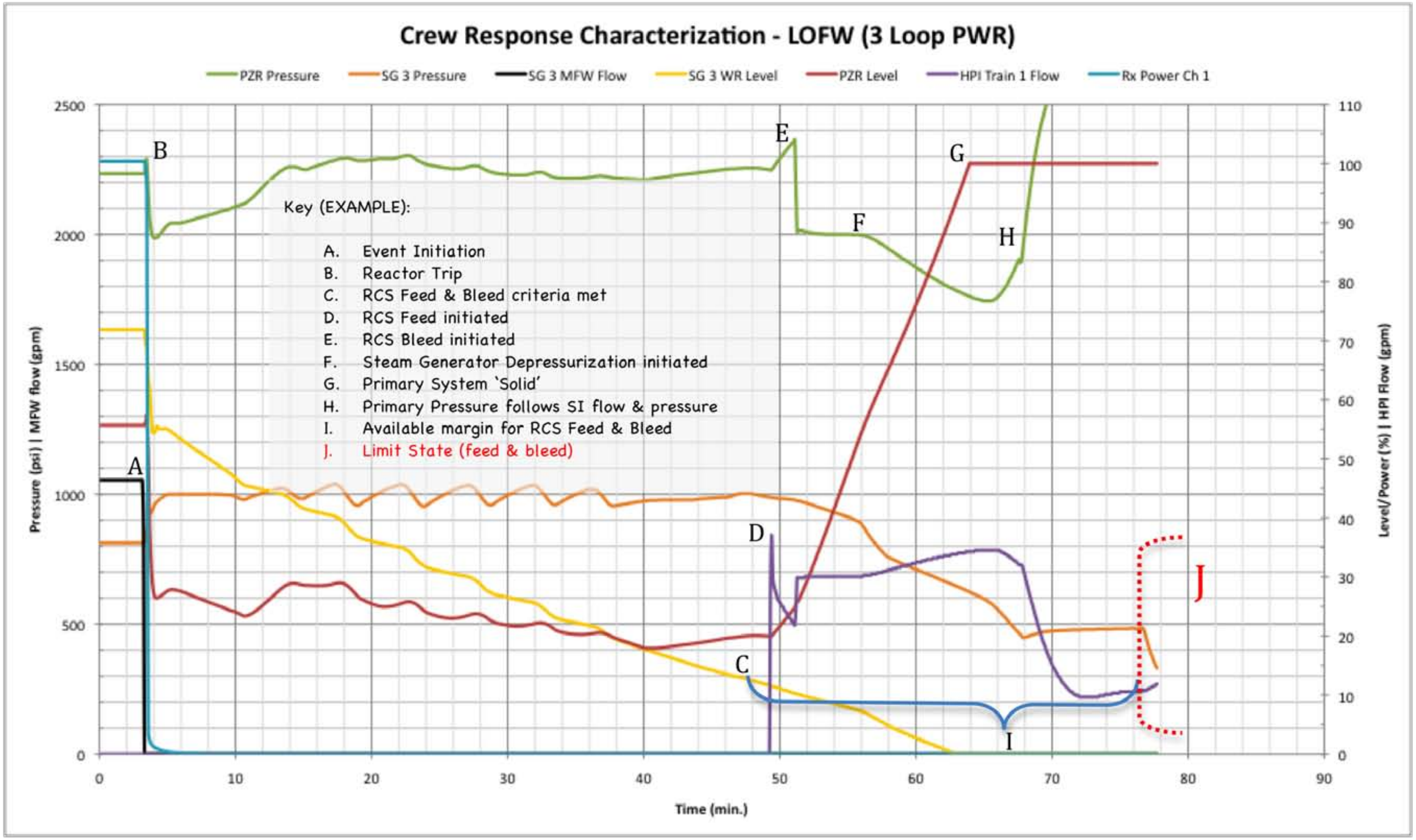
- Corroborated by event log data
- Correspond to groups of plant parameters
- Require modest interpretation

*(Note: graphs are examples and used for illustration only)





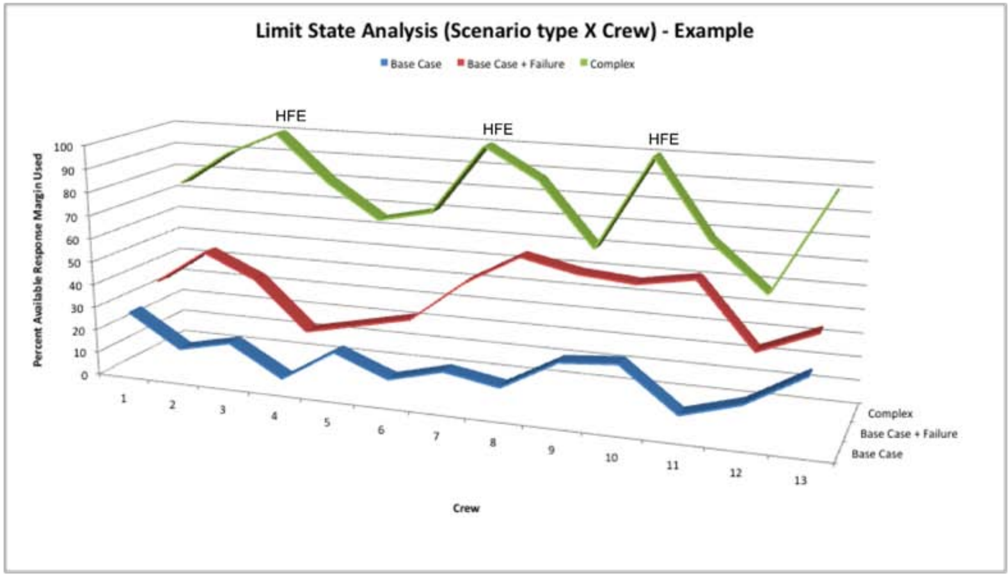
Objective Performance Measures - Example



*(Note: Graph generated from previous study data and used for illustration purposes)

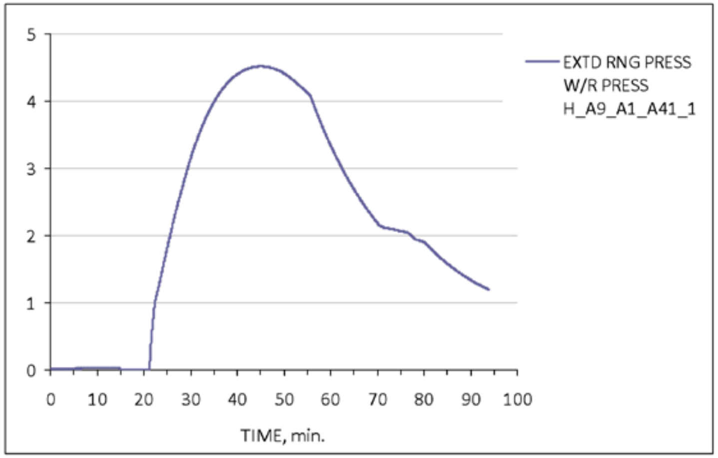
Improving the technical basis

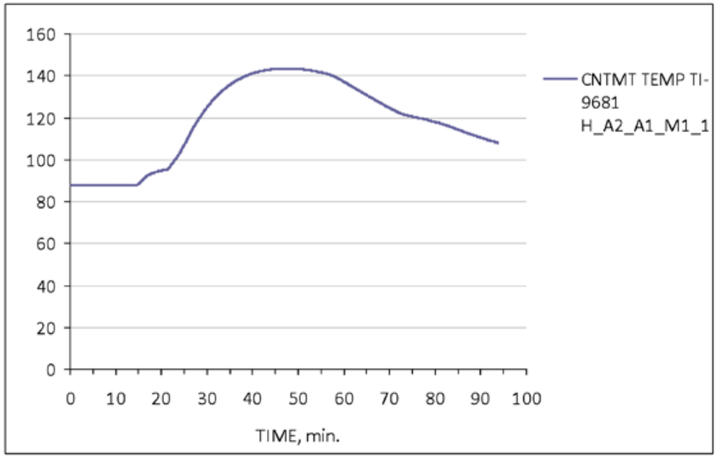
- For critical actions from a variety of common initiating events (e.g., limit states for loss of feed water events)
- Showing differences in performance that relates back to contexts and PSFs
- Differentiates successful from unsuccessful performance (e.g., HFEs from errors and variability)
- Can be used to substantiate assumptions about human performance in HRA (e.g., demands and capacities, effects of PSFs, etc.)
- Support the development and validation of crew response trees



Performance Measures

- Descriptions of performance
  - Could be based on performance criteria reflected in the boundary conditions of the given scenario.
  - Should be related to the HFE of interest
  - Constitution of 'failures' critical
    - Not deviations
    - Not artifact of experiment
    - Differentiates recovered from unrecovered
  - Resulting analysis should relate back to the 'limit state'



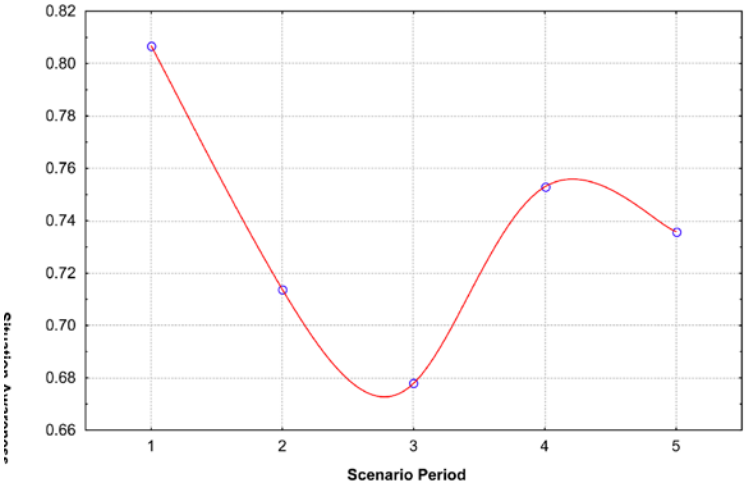


*(Note: graphs are examples and used for illustration only)

Performance Measures

- Subjective Measures
  - Explain performance in terms of the cognition, dynamics, demonstrated abilities, and limitations of crew members.
  - Relate back to important cognitive features of the hybrid model.
  - Can be validated via other performance measures and self report.
  - Demonstrate psychometric properties such as reliability and validity.

*(Note: graphs taken from actual crew response data reported in NUREG-IA-0135)



Applications

- Testing qualitative and quantitative aspects of HRA methods
  - Do HRA methods demonstrate reliability
    - Comparisons of different HRA teams applying the same method to an HFE to demonstrate convergence in their estimates of likelihood.
    - Depict the same kinds of failures and driving mechanisms.
  - Do HRA methods demonstrate sensitivity
    - Do they scale to the expected complexity and difficulty of the postulated HFEs?
    - Do some methods demonstrate better sensitivity to some plant conditions and human performance than others?
- Developing empirical crew response trees
  - The hybrid method and model require data to verify and validate key assumptions
- More thorough exploration of specific initiation conditions and PRA contexts to study factors driving human performance reliability

Longer term perspective

- Interest in establishing an international working group focusing on methods and activities to support data exchange.
- Emphasis on data from relevant performance contexts that are collected according to open standards.
- Support collaborative R&D and longer-term resolution of HRA issues related to
  - Validity of underlying human performance models used in HRA
  - Improving guidance and training for HRA practitioners
  - Developing consensus regarding performance measures
  - Sustainability and advancement of PRA technologies.