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NUCLEAR REGULATORY COMMISSION

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NUCLEAR REGULATORY COMMISSION

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BRIEFING ON ACCIDENT SEQUENCE PRECURSOR PROGRAM

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PUBLIC MEETING

Nuclear Regulatory Commission
One White Flint North
Rockville, Maryland

Thursday, June 14, 1990

The Commission met in open session, pursuant to notice, at 2:00 p.m., Kenneth M. Carr, Chairman, presiding.

COMMISSIONERS PRESENT:

KENNETH M. CARR, Chairman of the Commission
KENNETH C. ROGERS, Commissioner
JAMES R. CURTISS, Commissioner
FORREST J. REMICK, Commissioner

STAFF SEATED AT THE COMMISSION TABLE:

SAMUEL J. CHILK, Secretary

WILLIAM C. PARLER, General Counsel

JAMES TAYLOR, Executive Director for Operations

DR. THOMAS MURLEY, Director, Office of Nuclear Reactor Regulation

FRANK CONGEL, Director, Division of Rad. Protection and Emergency Preparedness, NRR

EDWARD JORDAN, Director, AEOD

RICHARD BARRETT, Chief, Risk Applications Branch, NRR

DR. PETER LAM, Chief, Reactor Systems Section, AEOD

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

2:00 p.m.

CHAIRMAN CARR: Good afternoon, ladies and gentlemen.

This afternoon the NRC staff will brief the Commission on the Accident Sequence Precursor Program. This program, which was initiated in 1979, evaluates actual events at operating nuclear power plants to determine those initiating events or system configurations which significantly increase the risk of core damage.

We look forward to hearing how the program works, some of the results of this effort, and how those results are used to reduce any significantly increased risk that may be identified.

Commissioner Roberts will not be with us today.

I understand that copies of the staff's briefing slides are available at the entrance to the meeting room.

Do any of my fellow Commissioners have opening comments?

If not, Mr. Taylor, please proceed.

MR. TAYLOR: Good afternoon. With me at the table, to my left, starting at the far left, Rich

Barrett, Frank Congel and Tom Murley from NRR. To my right, Ed Jordan and Peter Lam from AEOD.

We thought that this briefing would be appropriate because of the increased use and value of the Accident Sequence Precursor Program to the staff. It's being used in AEOD case studies. We're starting to use the approach and methodology to shut down conditions. That's being worked and it provides timely assessment of the significance of important events and gives us an inference of overall safety trends.

So, with that sort of cross staff usage, we thought it would be appropriate to schedule this briefing. The briefing will be in two parts. First, the program comes under AEOD and that will be provided by Ed Jordan and Doctor Lam. Then, Tom Murley and his staff will talk about how the staff is utilizing the output from AEOD.

So, with that introduction, I'll ask Ed to begin.

MR. JORDAN: Okay. This particular program provides a method that's independent of the, I would say, deterministic reviews that we do both in the regions, NRR and AEOD to assess safety significance, try to put a number on events that

appear significant to us and we need to analyze further.

The methodology was established using generic event sequences and this then gives us, by plugging in what actually happened in this event, the conditional core damage probability given that particular set of circumstances. So, in that fashion, it is quantitative. It has some limitations. The limitations have to do with the modeling that's done. It is a generic modeling and then the values that are assigned within the generic model, those probabilities that are assigned are also treated generically.

We see the world improving in terms of our ability to do a better job with this program. There's feedback from the NUREG-1150 work that we think is going to benefit further this model, this program. And then insights from plant-specific PRAs done under the IPE Program we feel will be beneficial to us in the future in getting a better value for a particular event in terms of that particular plant's characteristics and its particular values.

(Slide) Could I have slide number 3, please, the background slide.

As the Chairman indicated, this program was established in 1979 as a response to a TMI

recommendation. Annual reports are published. The most recent report was published in February of this year for the 1988 events. That bothers us that we are lagging behind. There is a natural lag in terms of the time to analyze from the last event for a given year.

We're currently trying to improve the timeliness of those by doing more in the way of on-line type reviews. For instance, the Vogtle event, the methodology has been revised to support shutdown events and we have characterized that event by this methodology and got a value of the order of $1x10^{-3}$ core damage probability given the events that happened at Vogtle at that time. That helps calibrate us, for instance, in our actions in response to that Vogtle event, that here we can say we have a reasonable understanding, order of magnitude level, of the significance of it.

So, we're working to try to do those events that are identified through the Agency's screening on a more like real time basis within a couple of months of the event so that we will have accumulated the more important events as the year goes through. So then our publishing of the annual summaries will be more timely.

This program was initially developed under the Office of Research and then transferred to AEOD as an operational program. The methodology has been constant. Oak Ridge has been the contractor throughout this time and this constant methodology then provides now in time a basis for examining trends and Doctor Murley is going to talk about those trends.

We have done some improvements along the way by adding other sequences. For instance, I mentioned the shutdown sequences. Sealed LOCA sequences have been added and others so that we can better characterize a wider range of events. So, without taking away from Doctor Lam's presentation, I'll turn it to him to go through the further discussion.

DOCTOR LAM: Thank you, Mr. Jordan, for your introductory remarks.

May I present to the Commission the program status and program results for the past five years. Additionally, I would like to present the highlights of the lessons learned on current emphasis and future plants.

(Slide) May I have slide number 4, please.

The way the program defines a precursor is

indicated on this slide. There are three characteristics, any one of which would define a precursor. One, failure of a safety system. Two, degradation of two safety systems. Three, occurrence of an initiator such as a loss of coolant accident, a loss of off-site power, a steam line break, or any transient with complications.

This set of definitions are sufficiently broad so that it catches and has caught in the past safety important events. At the same time, it has reasonably high threshold so the true real events would not be included in the analysis. This is a set of definitions that the program has used consistently in the past ten years.

COMMISSIONER REMICK: Excuse me just a minute. In looking at the Vogtle event and to help me calibrate, would that have fit in to this definition or not? I'm just trying to see --

DOCTOR LAM: Yes. Yes, Commissioner.

COMMISSIONER REMICK: Where would it fit in?

DOCTOR LAM: It would fit into two places. One, it's a loss of off-site power or a transient with complications. So, either one of the two would fit. Furthermore, it would also fit under failure of a

safety system.

COMMISSIONER REMICK: Where would it fit under a transient? I don't follow that.

MR. JORDAN: The heat-up would be considered a transient, the loss of coolant and then a subsequent primary system heat-up.

COMMISSIONER REMICK: Pretty weakly there, I would think. That's a pretty mild transient.

MR. TAYLOR: I think the loss of off-site power is the --

COMMISSIONER REMICK: Yes. Sure. Yes. I was just curious if it would fit in.

MR. JORDAN: We do try to treat it as a matrix. So, it tumbles on a number of elements of the matrix.

DOCTOR LAM: (Slide) Let me turn to slide number 5 about the programs product. There are three major products. May I have the next slide, please?

There are three major products the program provides. One, accident scenarios. It provides a description of the likely accident scenario given the precursor occur. Specifically, it described what the system failure would be, what type of human intervention would be necessary, and how the accident may progress.

Second, it provides a quantification of the precursors. The quantification would be expressed in terms of a conditional core damage probability. I will offer more discussion on this topic later.

Third, it provides some sort of integrated risk perspectives as to identification of potential plant weaknesses in design, in operation and in human recovery.

Let me share with you --

COMMISSIONER ROGERS: Just before you move off there, on the question of finding a scenario, how unique do you think that is? Using these screening criteria, do you find several different possible scenarios or does it -- do these screening criteria tend to lead you to one?

DOCTOR LAM: Commissioner Rogers, we usually find several likely scenarios, and some of which may dominate in terms of risk, some of which may dominate in terms of likelihood.

May I move to the next slide, please?

COMMISSIONER ROGERS: Sure. Please.

COMMISSIONER REMICK: Let me ask to make sure I understand. When we talk about conditional probability, let's use Vogtle as an example. You assume that -- what, that loss of off-site power

occurred or do you assume that somebody would back into a pole and then you go from that point? Where do you draw the point that you assume that that has occurred, loss of off-site power? Is that where you begin or do you go back a step further to the possibility of somebody backing into a pole leading to a loss of off-site power?

DOCTOR LAM: For the Vogtle event, the event boundary is loss of off-site power. So, given the loss of off-site power occurred, that's a precursor, Commissioner.

COMMISSIONER REMICK: Okay. Now, let me go a step further. Then a diesel was out for maintenance. When you go through then your trees, do you assign a probability that'd be out for maintenance of one for one of those diesels or do you use industry average or --

DOCTOR LAM: To the extent feasible, Commissioner, we use plant-specific data. For Vogtle, we happened to use generic number.

COMMISSIONER REMICK: Okay. But --

DOCTOR MURLEY: Excuse me a second. But in this case, the diesels -- one was out and one didn't start.

DOCTOR LAM: Right.

DOCTOR MURLEY: So you're already into that part of the tree where you assume emergency diesel failure.

DOCTOR LAM: Okay.

DOCTOR MURLEY: So, the question really is what do you assume about recovery and how do you-- then you've got to go into various --

COMMISSIONER REMICK: Okay. So you use the actual situation on the event.

DOCTOR LAM: Yes.

COMMISSIONER REMICK: Okay.

MR. JORDAN: We plug in the failures that occurred associated with that event and then some the probabilities for recovery are --

CHAIRMAN CARR: From there on.

MR. JORDAN: -- operator action from there on, yes.

COMMISSIONER REMICK: I see. So --

DOCTOR MURLEY: And Peter will get into it, I think, but strictly speaking, you ought to draw the tree from that point on for that specific plant and for that configuration.

COMMISSIONER REMICK: And for that condition then, what actually happened? Okay.

DOCTOR MURLEY: Because we don't have PRAs

for every plant, we do have to rely on generic event trees to some extent.

COMMISSIONER REMICK: Okay. Thank you.

DOCTOR LAM: (Slide) Slide number 6, please.

Let me illustrate to the Commission the process the program has gone through. This slide indicates the amount of data and the extent of effort the staff has gone through. In the past decade, over 40,000 licensee event reports were processed and screened by the program, in which 1,500 potential precursors were identified and more than 450 precursors were quantified. The point here is the program has utilized reasonably high threshold. Only one percent of the operating experience is labeled a precursor.

(Slide) The next slide, please. Slide number 7, please.

As indicated earlier, the conditional core damage probability is a major product of the program. It is the end result of the quantification process. The term "conditional" was used to mean given the event has occurred. So, the conditional core damage probability of a precursor is the damage probability associated with the precursor, after it has occurred.

Now, this concept is further illustrated in the next slide, please.

(Slide) We offer a simplified and very simplistic example, assuming a loss of off-site power has occurred. By definition, a loss of off-site power is a precursor. If all the diesel generators were to fail and if recovery efforts were not successful, then core damage would occur. The conditional core damage probability associated with the precursor, in this case which is the loss of off-site power, would be the product of the failure probability of the diesel generator and the recovery failure probability, which is illustrated here.

The emphasis here is that the conditional core damage probability is not the frequency of the precursor. The frequency would be indicated by how often the loss of off-site power would occur.

CHAIRMAN CARR: But to take your model, you started there at Vogtle after the diesel generator failure. So, the entry was down at the bottom line on recovery failure, right?

DOCTOR LAM: That's exactly right, Chairman.

CHAIRMAN CARR: Okay.

COMMISSIONER CURTISS: For purposes of

this program, do you give credit to recovery efforts?

DOCTOR LAM: Commissioner Curtiss, we give credit to human recovery efforts to the extent feasible. And at the Vogtle analysis, we gave a great deal of credit to human recovery. As a matter of fact, the whole Vogtle analysis is hinged on recovery of off-site power or recovery of the diesel generator.

COMMISSIONER CURTISS: Okay.

DOCTOR MURLEY: I think we ought to make sure we not leave the misimpression that at Vogtle the chances of a core damage were one in ten. In fact, do you want to say --

MR. JORDAN: 10^{-3}.

DOCTOR MURLEY: Did you mention that?

MR. JORDAN: Yes.

DOCTOR LAM: Right.

DOCTOR MURLEY: The chances -- and in Vogtle's particular case, because it had been shut down for a long time and they had some options, there the chances of core damage, given the events that occurred, was one in 1,000, 10^{-3}.

DOCTOR LAM: That's exactly right, Doctor Murley. This is a highly simplistic example.

CHAIRMAN CARR: I understand.

DOCTOR LAM: (Slide) Next slide, please.

The current results, as Mr. Jordan indicated, was available in February of this year. Within another two months, we had the 1989 data available. The 1988 results, a quick summary would be there are no precursors with conditional core damage probability greater than 10^{-3}. Among the top seven precursors in the 10^{-4} range, three of which would involve surface water system failures, another three would involve emergency diesel generator problems, and another two would involve aux. feedwater system problems.

There is a double term here. One event specifically which occurred at Catawba where clam fouling of the aux. feedwater system was induced by clams' presence in the surface water system. So, there's a double term here. All these events would add up to eight.

(Slide) In the next slide, we'd like to share with you what are the staff activities taken prior to and concurrent with the precursor safety results. The staff had taken numerous activities on these three major important safety systems, as I indicated earlier, prior to the results of the precursor safety study.

On the surface water system problems, AOED

in 1988 had issued a case study on the surface water system problems and degradations, which is a study involving a comprehensive review and analysis of the system problems. As a result of the study, the EDO had forwarded the report to the Commission. Mr. Jordan has asked the program officers to take actions. In coordinating with the regions, with Office of Research and with NRR and AEOD, the staff had issued generic letter 89-13. In the generic letter, the staff had asked the licensees to look and the licensees had looked and found numerous deficiencies and problems.

So, in our humble opinion, this is a success. This is example of a success.

COMMISSIONER REMICK: Let me ask you a question. I could draw several conclusions from the fact that the staff was working in areas where the accident sequence precursor studies indicate we should be working on. Now, a brilliant staff, which of course we do have and therefore they're working on the right things, or you could argue you don't need the accident sequence precursor study because the staff already is working in those areas. I found that odd. The justification seemed to be that you were working on the right problems and I don't differ with that.

But are you able to use this in a way to investigate areas where you might not otherwise have done so? I didn't see much evidence of that, where you were using this study for purposes like that. I saw it more you were justifying what you were doing and saying --

DOCTOR MURLEY: Commissioner, this is, to me, one of our most valuable programs and I'll give a personal anecdote as to what -- how it tipped me off.

I was, at the time, Regional Administrator in Region I and I got one of the reports that I think came out of the work that was done here on the accident sequence precursor, that I think Peter did, on BWR over-pressurization events. I read about an event that happened at one of my plants that I didn't know about because the staff was not really sensitized then to the potential for over-pressurization events. The regional staff I guarantee was not.

When I read that, I got to thinking, "My gosh, if --" and I went back and looked and, sure enough, it was in a resident inspector's monthly report, but it was not highlighted or anything because there was no real damage. But it was an important precursor.

I think as a result of that, I, at least, drew the conclusion that we had to be looking more at

these early signs of things more than we were doing. So, there are some cases where that happens. I think usually our common sense and our everyday notion of what's important will get us to the same place, but there's some occasions where it won't.

CHAIRMAN CARR: How did that fit the precursor? I can't find an over-pressure fit unless it was a transient.

DOCTOR MURLEY: This happened in the early '80s and I don't know whether they're still in here or not. I presume they are.

DOCTOR LAM: Chairman Carr, Doctor Murley was referring to the event that happened in 1984 at Browns Ferry. Mr. Taylor had intimate knowledge on that event as well. The data here -- what I just shared with you was 1988. In the next couple of slides, I will share with you about a five year summary.

CHAIRMAN CARR: No, no, I meant the definitions. I'm trying to fit in the over-pressure event he's talking about that caused him to worry into the definition of how it became a precursor.

DOCTOR LAM: It would fit into the first two, Chairman Carr. It would fit into the failure of a safety system or degradation of more than two

systems because the over-pressurization event referred to is specifically the failure of the test of a check valve of General Electric design reactors and also the subsequent failure of a motor operating valve. The end result would be a major degradation of all the ECCS systems. So, it would fit into the first two definitions.

CHAIRMAN CARR: Okay.

MR. JORDAN: And maybe I'd like to take away a little bit from the rigor of the criteria on that page. What we were looking for is a way of nominating events to do an analysis --

CHAIRMAN CARR: Yes.

MR. JORDAN: -- and since then, the staff has the significant event identification that we use in the performance indicator that NRR and AEOD jointly nominate events, about 200 a year. So, we look at those as a screening tool for this as well. So, we have an overlay of the contractors in our screening process that helps reduce the likelihood that something's going to slip through.

CHAIRMAN CARR: Okay.

COMMISSIONER CURTISS: Have you had any events that didn't meet the criteria here but that you determined ought to be plugged into the system?

MR. JORDAN: Probably, but I don't know of any examples.

DOCTOR MURLEY: Oh, yes. I'll mention one in a minute. But in Vogtle, a year or two ago they had a leak of -- a fire suppression system water leak in a cable spreading room that went down and got into the control room cabinets and caused some equipment to go off. As it turned out, that particular thing was not a high-risk precursor, but it didn't show up in any PRAs or anything. That was a systems interaction that we hadn't planned on, hadn't thought about beforehand. So, that's one that comes to mind.

MR. TAYLOR: But I think the point Ed was making is this screening tries to pick up even those and get them in in a valued basis.

MR. JORDAN: Yes. It gives us a better chance of getting them, I think, by not being totally deterministic --

CHAIRMAN CARR: So, it's not an exclusive --

MR. TAYLOR: No, it isn't.

MR. JORDAN: No.

CHAIRMAN CARR: -- screen, it's a broad cut.

MR. TAYLOR: Yes.

MR. JORDAN: Yes, sir.

CHAIRMAN CARR: Okay.

DOCTOR LAM: Let me talk about diesel generator problems. The staff has long recognized diesel generator reliability as an important issue. This is explicitly recognized in the station blackout rule. This is also recognized by AEOD which is conducting a major study on diesel generator problems. Also, there have been numerous generic communications on this topic.

(Slide) The next slide, please?

As to the aux. feedwater system problems, Doctor Murley indicated to us that there is now closer resolution of generic issues 124 and 125; 124 specifically referred to aux. feedwater system reliability and 125 is a generic issue created after the Davis-Besse event in 1985.

There has been special inspections conducted by the regional staff and by Doctor Murley's staff and there has been numerous AEOD studies on the topic. Two of the highlights are the case study on aux. feedwater system steam binding and also on the turbine pump over-speeding phenomena.

(Slide) Let me now give you a summary of the five year data on the next slide.

This is the slide that shows the distribution of the precursors by their -- according to the safety significance. This slide is color coded for the safety significance. The safety significance is measured by the conditional core damage probability. The color black refers to a conditional core damage probability of 10^{-2}. That is the most safety-significant event in the past five years which occurred in 1985 at Davis-Besse, which involved the loss of main feedwater and the loss of aux. feedwater. The event was extensively investigated by the Agency's IIT and had the results of numerous regulatory and industry activities.

At the next lower level of safety significance, color red is the precursors with the conditional probability of 10^{-3}. In 1984, there was an event at La Salle in which a reactor scram was followed by the unavailability of the RHR system and the RCIC system failure.

In 1985, an event happened at Hatch in which a safety relief valve was stuck open at 100 percent power, concurrent with the failure of the HPCI and the RCIC system.

In 1986, there were two events, one happened at Catawba. At about 50 percent power, a

let-down line, which is about the size of one inch diameter, ruptured causing the loss of reactor inventory during power operation. A second event happened at Turkey Point 3. At 100 percent power, a PORV on the pressurizer spuriously opened and stuck open at 100 percent power, again leading to a loss of reactor inventory.

From this distribution, a couple of points to be made. After 1985, there are no precursors for conditional core damage probability bigger than 10^{-2}. After 1986, there are no conditional core damage probability bigger than 10^{-3}. So, these data indicate in 1987 and 1988 the industry performance has improved.

Now, I would defer to Doctor Murley to offer more interpretation on what this data would mean.

CHAIRMAN CARR: But the Vogtle comes in at 1×10^{-3} on this chart, would show up -- will show up this year?

DOCTOR LAM: That's right.

CHAIRMAN CARR: Okay.

COMMISSIONER REMICK: There's an apparent observation one can make. As the -- you have fewer in the range of 10^{-4}. You seem to have more in 10^{-5}. Is

it obvious that those things are being shoved down in probability, the type of events are occurring, but it's just that they're occurring with a less conditional probability? Is that a safe assumption or is it that could be misleading?

MR. JORDAN: I think it could be misleading because the same sieve is occurring and we're not just assessing as a set of events, a numerical set, but the ones that get caught in the sieve. And so, I don't know the significance of that larger number of lesser events.

COMMISSIONER REMICK: I see. Okay.

DOCTOR LAM: (Slide) If I may go to the next slide, this is a slide that illustrates the system problems that have been observed in all the precursors in the past five years happening at the pressurized water reactors. It shows a lessons learned about relative systems importance.

Before I get into details, may I say to you that these results offer no surprises. These results are consistent with the staff's perception about how important the safety systems are. Additionally, these results are consistent with the current staff effort in paying attention to this safety systems.

The acronym for the safety systems are offered on page 17. As we see here, the aux. feedwater system has been observed to be most frequently involved in the safety precursors in the past five years, followed by electric power systems, followed by main feedwater, main steam relief, high head injection, surface water system, instrumentation and control, turbine bypass, atmospheric dump and PORV.

Again I'd like to iterate the precursor population had relatively high threshold. It represented one percent of the operating experience.

(Slide) Similar observations may be made on the next slide about boiling water reactor system problems. We see RCIC coming in first, electric power systems second, feedwater, HPCI, LPCI, isolation condenser, steam relief valve, instrumentation and control, turbine bypass, RHR, ADS and high pressure core spray system.

CHAIRMAN CARR: Now, on that chart -- on the other chart, I recognized what we're doing in those. But on that one, reactor core isolation cooling seems to me to be something we aren't really focused on. Is that wrong or right?

DOCTOR LAM: Well, Chairman Carr, the

staff has gone through extensive efforts in prioritizing and resolving safety issues. The results are documented in NUREG-933. I think the RCIC systems written importance was recognized in NUREG-933 and also in the latest 1150 results. I think this system's contribution to reactor accident risk is well recognized.

CHAIRMAN CARR: Well, we've got a -- I mean I'm personally aware of things we've got going on in the other systems and I guess I'm kind of ignorant of what we've got going on in this system.

MR. TAYLOR: You're asking about any ongoing action?

Tom, do you have --

DOCTOR MURLEY: Yes. I don't know that we have a --

CHAIRMAN CARR: It stands out at the top of the precursor list for BWRs.

DOCTOR MURLEY: Yes. Yes. But we pay a lot of attention to RCIC. But I don't know that we have a generic issue or that it rises to that level that we single it out as a --

MR. TAYLOR: When we have a RCIC failure, it gets an awful lot of attention.

DOCTOR MURLEY: Yes. It's part of our

inspection program.

MR. JORDAN: Maybe the idea of --

CHAIRMAN CARR: There seems to be some anomaly there, I guess, in those two charts.

MR. JORDAN: But what we're maybe confusing you with is these are the numbers of cases in which RCIC was one of the elements or the dominant element, but it doesn't assign a risk value. In fact, the RCIC risk contribution is quite small. There are a lot of ways of getting water in a BWR. So, in terms of actually getting on the scale --

CHAIRMAN CARR: So, even though it's a major contributor, its effect is negligible, relative to some others, huh?

MR. JORDAN: It's small in the risk of a BWR, I would say.

DOCTOR MURLEY: It shows up frequently in events, but it's failure is not as significant as a lot of other systems.

MR. JORDAN: Right.

COMMISSIONER REMICK: Oh, I didn't understand. So, this is not that it leads to a large conditional failure problem.

DOCTOR MURLEY: No.

MR. JORDAN: No.

COMMISSIONER REMICK: I see. That's how I was interpreting it. I was surprised --

MR. JORDAN: So, we should be weighting these with, in the cases of RCIC, how much of a risk have they contributed in these. I see quantity, but I was ignoring it.

COMMISSIONER CURTISS: What do you see on that chart as the -- if this is just recounting the numbers, what are the significant BWR precursors?

CHAIRMAN CARR: Feed and blackout.

DOCTOR LAM: Right. We see electric power systems being a major contributor. Station blackout always is a risk driver as consistent with the insights in 1150. We see the availability HPCI and RCIC together would be a problem. This has been recognized by the staff as well as by the industry. EPRI and INPO has conducted extensive studies on HPCI and RCIC together being unavailable.

MR. JORDAN: And if you added ADS to that equation, then that would be a very risky event.

CHAIRMAN CARR: But it's --

MR. JORDAN: But there --

CHAIRMAN CARR: There is a message here that something is getting by us in RCIC if it's the biggest system failure that we're seeing in BWRs. I

don't understand that.

MR. JORDAN: It's a --

COMMISSIONER REMICK: Is it a turbine failure?

MR. JORDAN: -- turbine, mostly turbine.

COMMISSIONER REMICK: Turbine failure.

MR. JORDAN: Over-speed type problems.

CHAIRMAN CARR: Turbine.

DOCTOR LAM: But it is a single train system, both HPCI and RCIC. RCIC is not even labeled as ECCS. It's a single train system, tightly controlled by tech spec. But because it's a single train on a standby basis, then the steam supply would have problem, at the discharge side they have problems. So, on the system reliability basis, both HPCI and RCIC is a single train, steam-driven, standby system had low reliability.

COMMISSIONER REMICK: Am I correct the biggest risk with RCIC would be steam line break and failure to isolate? Is that the biggest risk of a failure of RCIC?

DOCTOR LAM: That would be one of the scenarios, Commissioner Remick.

DOCTOR MURLEY: Now, that's a pretty low --

COMMISSIONER REMICK: Probability?

DOCTOR MURLEY: -- probability.

DOCTOR LAM: And if I may add to what Mr. Jordan has talked about and what Doctor Murley and Mr. Taylor talk about, the insights from 1150 are consistent with these, one of which may be relevant to our discussion. It's on the boiling water reactors has significantly lower core damage probability. One of the reasons may be, in my humble opinion, it would be the availability of multiple means of injection of water. Therefore, this would develop into our discussion.

COMMISSIONER REMICK: It becomes a teapot.

MR. JORDAN: Yes.

COMMISSIONER ROGERS: In these data, is there double counting here in a sense, that some event would have more than one of these systems out?

DOCTOR LAM: Yes, Commissioner Rogers. If you add them all up, they add up more than 169.

COMMISSIONER ROGERS: Just count them all up, whatever is out?

MR. TAYLOR: This was meant to show that it showed up.

MR. JORDAN: Yes. I think as a result of our discussion though for this kind of a presentation

we'll put risk on it as well for those events. I think that might help us understand better.

MR. TAYLOR: I don't know how you'd present it, but --

MR. JORDAN: I don't either.

COMMISSIONER ROGERS: Okay. Well, it might be semi-difficult though if you are double counting because --

MR. TAYLOR: That's the point.

MR. JORDAN: Yes. Somehow we have to not --

MR. TAYLOR: I'm not sure you can graphically do it.

MR. JORDAN: -- double count that risk.

COMMISSIONER REMICK: Another somewhat surprising thing, I would have expected ADS, looking at quantity, to be increased perhaps because I thought that was a system that we worried about reliability.

DOCTOR LAM: Yes. Yes. But to our knowledge, there has not been too many ADS actuations, Commissioner.

MR. TAYLOR: That's pretty infrequent.

COMMISSIONER REMICK: Yes. Okay.

DOCTOR LAM: And as a matter of fact, the plan was designed only for one actuation per lifetime

of ADS. So, the operator would have a great deal of hesitancy pushing that button. The plant is designed for one actuation per 40 years and no more.

DOCTOR MURLEY: But it could handle more, couldn't it?

DOCTOR LAM: (Slide) The next slide would provide the recent program emphasis. As Mr. Jordan indicated to you earlier, in the past, the program provides its results on an annual basis. With the natural limitations, they are time lack. So, right now we are, on a selective basis, providing turnaround on the order of about two to four weeks. So, the Vogtle IIT event was investigated and results were available to us within three weeks.

In the new shutdown model, a new shutdown event model was developed after the Vogtle IIT. Prior to that, all the shutdown events were recognized by the program as precursors. But because of the lack of modeling, it was not quantified. But now we had to quantify them.

(Slide) In my last slide, again as Mr. Jordan indicated to you on our future activities, to the extent feasible we would recognize and hopefully incorporate NUREG-1150 insights. When the IPE findings are available, we will incorporate them into

the program.

This completes my presentation. I'd like to turn this over to Doctor Murley.

COMMISSIONER CURTISS: One question before you do that. When you take a look at calculating the CCDFs, are they figures that you come up with weighted by time so that the duration that the plant condition exists, 36 minutes at Vogtle or different numbers for different plants, is that factored into your CCDF?

DOCTOR LAM: Yes, Commissioner Curtiss. For system unavailability type of situation, the exposure of time, how long the system was unavailable was specifically included. The longer the exposure time, the higher the risk.

COMMISSIONER CURTISS: Okay.

CHAIRMAN CARR: In your use of 1150 insights, how do you see those being used? I thought that when you were talking about all those things being plant-specific or we made the comment to say, "That's all plant-specific data, don't try to extrapolate it," so you're only going to apply it to those six plants or are you going --

DOCTOR LAM: Yes, Chairman Carr. For the plants like Zion, Surry, Sequoyah, Peach Bottom, Grand Gulf, 1150 gives very specific insights. The program

model has divided up all the plants in the country into eight categories. We will try to go back in there and fit -- for example, the Grand Gulf insight would be incorporated into that particular plant type that we are dealing with to the extent feasible. It's not always possible for us to do that.

But there are other insights, if I may add, on common mode failures, on single failures, on human errors. Some of them may be generic and may be applicable to the programs.

CHAIRMAN CARR: Okay.

MR. JORDAN: I'd make a comment. When we do a change that's rather dramatic in the methodology and values we assign, we're going to introduce a discontinuity that will cause the data not to be trendable over time. So, we'll do that deliberately to make sure that the change we're making is worth it at the time.

CHAIRMAN CARR: So, you'll have to give us a pre and post --

MR. JORDAN: I would not only have to reanalyze the pre-data, right, but at least give an indication if there is a significant perturbation to the risk.

CHAIRMAN CARR: Okay.

DOCTOR MURLEY: Okay. I'll talk a bit about how we use the results from this program. I should say at the beginning, this is one of my favorite programs, relevant performance indicator information that's available, to me at least. This is the one I value the most because it's directly related to safety, mainly core damage probability and it can't be managed. It's an indicator that can't be managed like some of the others can be. So, it's directly relevant and it's a measure of what our -- I think our safety product is.

Rich Barrett's staff and Frank Congel's staff spent a lot of time analyzing these reports for insights and trends. We ask ourselves are we focusing on the right issues, is there anything that we're missing? It's only -- there are frequently events that happen that don't rise to our attention, at least at my level, because it's not recognized by the staff that sees the event, usually the inspection staff, of the risk significance of the event. And it's only after it's been analyzed and somebody says, "Hey, we came closer then than we thought," that it is of use to us. I recognized that when I was in the region, that they did not have the finely honed sense of what was risk significant that PRA analysts back here in

Headquarters had.

So that's a separate issue to get that feeling in the inspection staff. I think this is one program that will allow us to do it, to go back and relook at some of the old events.

COMMISSIONER CURTISS: Tom, is the converse of that true, that this program could tell you because of the lack of --

DOCTOR MURLEY: Yes.

COMMISSIONER CURTISS: -- significant information that we're focusing too much attention in some areas?

DOCTOR MURLEY: Yes. I think traditionally our regulatory emphasis was on large LOCAs, for example. And the whole regulatory framework in the early days was set up to prevent and mitigate the effects of a large LOCA, and of course we don't really see any precursors to the large pipe-break LOCAs. I mean, that's not to say they're not important, but I think the fact that we don't see any precursors to those tells us that we don't need to overemphasize it at least.

COMMISSIONER CURTISS: Okay.

CHAIRMAN CARR: Unless over-pressure incidents could be a precursor to those, of course.

The fact we haven't had a large LOCA may skew the data a little bit.

DOCTOR MURLEY: Yes. The over-pressure is a separate case. There it's usually the smaller lines, four, six, eight inch lines that were only designed for low pressure. And we see several cases where they have been over-pressurized, usually by human error in opening an isolation tower or something like that.

COMMISSIONER ROGERS: Yes. A question that comes to mind is, from what I'm hearing it sounds as if, you know, we're getting new insights into relative importance of various systems from doing the PRA analysis here, which is very valuable and these insights are extremely important. And a question I have is do you think that there's any way that one can, after having done a certain number of these, begin to develop a new sense of relative importance of some of these systems in a plant for which a PRA has not been done? And the reason I ask that is it would be nice to be able to use these insights as quickly as possible --

DOCTOR MURLEY: Yes.

COMMISSIONER ROGERS: -- even though the whole machinery of a full PRA has not been worked out

in every plant.

I was visiting a plant the other day and asked them if they were considering doing anything on looking at the relative risks in their maintenance scheduling, and they're just not ready to do anything like that at this point. And yet, you know, they're very conscientious about everything they do, but they don't have the mathematical tools available and they haven't gotten that deeply into their PRA yet -- their IPE yet to have any of those insights. And I was wondering if there is anything that can come out of this that would be helpful to anyone, even though they're not ready to do the mathematics of looking at the relative importances.

DOCTOR MURLEY: Yes. That's a good question, because we've -- the answer is yes we can, but we have to be careful. We've learned that the details of the design are very important in finding, say, problems and things you hadn't thought about.

On the other hand, after you've done a half a dozen or more analyses of PRAs, you realize that service water systems show up as important in many plants and so you can kind of assume it to be the case even for those plants that don't have PRAs. And in that sense, it aims us to do specific studies like

AEOD does. Or it may make us designate it as a generic safety issue, so we'll pick it out for special study. I think it's in that sense that we use this data.

COMMISSIONER ROGERS: Well, I was just thinking that, you know, sometimes we seem to be learning here that intuition is not always correct.

DOCTOR MURLEY: That's true.

COMMISSIONER ROGERS: You've got to work the numbers out. But intuition very often comes from experience.

DOCTOR MURLEY: That's true also.

COMMISSIONER ROGERS: That's how you get the intuition about things. And if one can sort of recalibrate that intuitive sense of things based on these numbers, it might be very helpful in situations such as scheduling and planning and things of this sort for a plant that has not done -- isn't able to do the calibration.

MR. TAYLOR: I just had a discussion with some licensee management as a follow-on to another utility, but as a follow-on to the Vogtle event and talking about their outage planning. And they happen to have a level 1 PRA and they have a person assigned to evaluate and is working with the outage group

already to plan outage work. So it is -- people are, I think, getting ready to do what you're driving at.

CHAIRMAN CARR: I read his question as to say can we use this data to decide which --

COMMISSIONER ROGERS: Yes, before you've done it.

CHAIRMAN CARR: -- which system we should be most careful of taking out of commission and most concerned about getting it rapidly back in.

DOCTOR MURLEY: Yes. That can be done. I mean, that's not part of this study, but you can take a PRA analysis and do a sensitivity study on each system one at a time and find out which ones are most vulnerable to being out of service. And that has been done, as a matter of fact, for some.

MR. BARRETT: We have a very active effort along the lines of what you're suggesting for internal use within NRR and in working with the regions. We've gone through a number of PRAs for both BWRs and PWRs, and we've compiled a list of generic important accident sequences, about a dozen for each type. And within each one of those sequences, we've compiled the most important systems and the most important component failure modes and human errors that have shown up in a repetitive fashion from PRA to PRA. And

over the last couple to three years, we've used these insights in a number of ways in our own activities, for instance to help in the prioritization of the efforts of team inspections such as the maintenance team inspections.

We've also used these insights to consult with the regions from time to time on decisions of the type you were talking about wherein a piece of equipment or an important system is out of service and perhaps maybe two systems are out of service and the region wants to know how risk significant this situation is and what would be an appropriate action on the part of the region or what would be an appropriate compensatory action on the part of the licensee.

CHAIRMAN CARR: Have we published that to the guys that need it, the operators and the people who are doing the maintenance? I mean, it's great for us to have it up here and second guess them, but they're the guys who need it day to day.

MR. BARRETT: I have a concern about how this type of information is used, as Doctor Murley pointed out. We think that for prioritization purposes it can be very useful, for instance for prioritization of the inspection program. We've not sure if it's ready

for use in terms of prioritizing a maintenance program.

CHAIRMAN CARR: Well, I'm just talking about giving it to them for information. It's something that --

DOCTOR MURLEY: Let us look into that. I have no objection. I mean --

CHAIRMAN CARR: Certainly, if we're walking around here with some things that they ought to be thinking of as they lay out their programs, it certainly wouldn't hurt to at least offer it to them.

DOCTOR MURLEY: We generally have documents like that that we use for guidance for our own inspectors. That's a fair way to say it. And in principle, then, it's like our inspection plan. We would not have any trouble in publishing that. It depends on what shape it's in in terms of quality, but other than that --

CHAIRMAN CARR: Okay.

DOCTOR MURLEY: (Slide) Let me move on to the next chart, the regulatory insights. There's three major areas that I could mention.

The identification of safety issues. In here Peter's mentioned issues such as station blackout, service water problems, and auxiliary

feedwater system problems. I think there's been recent events -- not just Vogtle, but mid-loop operation events -- that have caused us to put a new emphasis on looking at shutdown accidents.

And I think a third area in identifying safety issues is the one I mentioned about pointing out the significance, the risk significance of events. And I think we need to do even better than we're doing in getting this insights, these risk insights out to our inspectors, because there are events that are very sometimes complicated that get overlooked because they don't fall into one of the classic design basis accident kind of events. And I think we need to-- we're getting there. We're getting there. I see a lot better sensitivity than I --

CHAIRMAN CARR: Don't only put it out to our inspectors. Put it out to the guys who are running the plant. They need it too.

DOCTOR MURLEY: They do as well, yes.

We look for patterns in industry performance here, and there are some patterns that are kind of counter to our intuition or what our PRAs are telling us. And one is that the older plants, those 15 years old or more, contribute less per capita of the risk than the newer plants. And for example,

about one-quarter of the plants are 15 years old or more, yet they contribute less than nine percent of the cumulative core damage probability over these four year periods.

COMMISSIONER ROGERS: Why do you think that is?

DOCTOR MURLEY: Well, we think there's several reasons for it. One is, of course, the designs are simpler.

CHAIRMAN CARR: Simpler.

COMMISSIONER ROGERS: Simpler, yes.

DOCTOR MURLEY: They have simpler tech specs --

CHAIRMAN CARR: And maturer.

DOCTOR MURLEY: -- and simpler surveillance test programs. But I think another equally valid thing is that the operators have had longer experience to understand the plant and to know its idiosyncracies. That takes some time.

Again, this is kind of counter-intuitive to some extent, because our PRAs would tell us that the newer plants with all the fancier safety systems would yield fewer precursors and have a lower core damage probability. Now we haven't totally analyzed that. We're just giving you our assessment. But I

think the simplicity and the familiarity with the plant are the two major factors.

A third benefit that we see from this where we get some insights are to verify the PRA methods and the PRA studies, because after all they are just numerical studies and one can view this as a reality check on PRAs. And in general we find that the precursor events tend to verify the important sequences that have been modeled in PRAs. Another way of saying that is we see fewer and fewer new events that weren't thought of and modeled in the PRA, and that's kind of comforting.

COMMISSIONER REMICK: Yes. That was a question I was going to ask you. To what extent do we feed this back to make sure the PRAs are complete and that when we run across a new sequence or event that we see that people incorporate that.

DOCTOR MURLEY: There's a couple of areas, and then maybe Rich will want to add something when I get to that. The precursor data here confirm the PRA predictions of the high risk significance of human errors. For example, about a half of the precursors involved a human error contribution of some sort or another, and that's consistent with what the PRAs would tell us. However, there are some weaknesses

also in the PRA methodology. These are generally known by the practitioners.

The first one is that the human errors of commission are not modeled too well in the PRAs. These are human actions that can make an accident situation worse. It's hard to model those.

Also, there are some cases where system interaction has not been modeled well. And I mentioned a case in June of 1988 at Vogtle where water from the fire suppression system leaked on the control room floor via the upper cable spreading room by flowing around an unsealed cable penetration in the floor. This water dripped from the ceiling of the control room onto various process panel cabinets and it actuated various equipment, such as pressurizer backup heaters and a pressurizer PORV. So that is a thing that is very difficult to model and yet it could have led to some system interactions that no one had contemplated or planned for.

CHAIRMAN CARR: Or electrical failures, failing automatic doors where they couldn't get to things without having to go get the keys first.

DOCTOR MURLEY: I think it's highlighted the importance of shutdown, potential accidents during shutdown. And I think we've mentioned already the

modeling of service water system vulnerabilities can be improved.

Rich, do you have any other thoughts?

MR. BARRETT: Well, there is one thought that I think is important, and that is that some of the things we've learned from the precursors are limitations of PRA. And the one area where I think that the operational experience and particularly the precursors complement PRAs is insofar as it shows actual failure mechanisms.

A PRA is limited in the detail that it can go into and it can tell you that an important failure mode or risk-significant failure mode of the HPCI system, for instance, is a failure of the valves, the steam inlet valve to open. The operational experience can complement that by showing you the mechanisms which can cause that valve to fail, and that gives you something you can work with to try to fix. So I think they complement each other, PRAs and the operational experience.

DOCTOR MURLEY: With regard to the Vogtle event of systems interaction, maybe the lesson there is not to go out and try to model all kinds of places where water can leak into the control room, but to go out and fix it to make sure it doesn't happen. I

think that's the lesson there. But it tells us that we can't sometimes be too complacent just because a PRA doesn't show us an event as a high probability. Here we've seen cases where things have happened that haven't been predicted.

CHAIRMAN CARR: Take a look at where you were on the water piping, certainly.

DOCTOR MURLEY: Yes.

CHAIRMAN CARR: Have we done this kind of analysis on spent fuel pool problems? And do we do PRAs on things that might happen to spent fuel? Or should we? Seems to me I've seen a lot of spent fuel pool leaks, pumps, doors, gaskets.

DOCTOR MURLEY: We've analyzed specific postulated events like loss of water in fires and that sort of thing, but I don't know that we've done a systematic PRA. We've analyzed events.

MR. JORDAN: We haven't done an analysis of events that quantify those like these seal failure type events in this fashion.

CHAIRMAN CARR: It may not be worth it. I just --

MR. JORDAN: We would like to continue to extend the modeling, but in a wise fashion. So it's something that we haven't given up on.

DOCTOR MURLEY: Okay.

(Slide) Could we have the next chart?

And now we get into kind of what it all means, to some extent, and we have to be a little careful there. This is the same data as in Peter's chart, but here the events are weighted. They're given their estimated conditional core damage probability and they're added together.

And what one sees here then, for example, in 1985 the red bar, the dark bar, is a Davis-Besse loss of feedwater event. And it shows its major contribution in 1985 to the total cumulative conditional probability of core damage for that year.

I think we have to also recognize that there's a certain stochastic nature of these events. By that I mean if that event had happened seven months later, which it equally could have, then it would have shown up as 1986 being a very high year. So with that caveat in mind, there is a certain stochastic nature to these random events.

Nonetheless, the trends are looking very good. They're in the right direction. They're strongly decreased total cumulative conditional probability.

If one then takes these data and divides

by the number of reactor years in a given year, then you come up with a frequency which on the next chart we've called the "core damage index." And we have to be a little careful, because it's not exactly the total -- I'm sensitive. I know the Commission in the past has been interested in whether our plants meet the safety goal, and this is I think probably as close as we come to getting an indicator of how well our plants are doing at least with regard to the core damage frequency for all of our plants.

This core damage index, then, is just what we've defined. That is, the values of the conditional cumulative core damage probability divided by reactor years. It's not exactly the same thing as the core damage index, because there's several limitations and I think we need to be mindful of these.

As good as the accident sequence precursor program is, it may miss certain events. It may overlook certain events. And also, very rare events like seismic events would not get picked up at all there, and yet our plants may be vulnerable to seismic events. It's just that we don't have them frequently enough to get enough statistics on.

There are uncertainties in the methodology, because -- take the Vogtle event. They

did not have a PRA for that plant, so we had to use a generic, I presume, four loop PWR kind of PRA and use the event trees for that generic PRA. And we also had to, to some extent, use generic failure rate data. So those are caveats I think that are important that we need to bring in mind.

CHAIRMAN CARR: But the overall sum divided by the overall number of reactor years seems to me to be a fairly reasonable indicator. This chart here bothers me, because if you -- it's so affected by one particular incident, if you move that incident anywhere down you can't draw any conclusions, you know. If I put it in '88, why '88 becomes -- we're getting shakier.

DOCTOR MURLEY: That's right.

CHAIRMAN CARR: So it's --

DOCTOR MURLEY: (Slide) Could I go to the last chart? Here is where I think the strength of this comes in, because here one sees almost 20 years of data collected. And the decade before TMI, 1969 to 1979, what one sees is a core damage index of $3x10^{-3}$ per reactor year, much higher than we thought at the time. And one sees then right after TMI, in the 1980 and '81 time period, a very sharp drop of a factor of 20 in the core damage index. We believe -- we're

quite sure that that is --

CHAIRMAN CARR: TMI is not in that anywhere?

DOCTOR MURLEY: Yes, it is. It's in the 1979 data, the first --

CHAIRMAN CARR: '69 to '79 data includes TMI?

DOCTOR MURLEY: Yes. And to be fair, it tends to dominate that decade.

CHAIRMAN CARR: Yes.

DOCTOR MURLEY: There's three events that dominate: the TMI-1 core damage accident itself-- TMI-2, excuse me; the Brown's Ferry fire, 1975; and at Rancho Seco there was an over-cooling event, 1978. Even without TMI, by the way, this would still be a very high value in the 1969 and '79 period.

So we see a sharp drop and a continuing decrease in this core damage index. The data was not collected for 1982 and '83. I don't know -- I guess I don't know the reason for that. Ran out of money.

COMMISSIONER REMICK: Tom, somewhere my math has apparently failed me. If I look at your chart of the cumulative conditional probability for '88 --

DOCTOR MURLEY: Yes.

COMMISSIONER REMICK: -- I get something like 10^{-3}. Am I right? $1x10^{-3}$ is approximate for '88?

DOCTOR MURLEY: It should be --

COMMISSIONER REMICK: And then, assuming roughly 100 reactor --

DOCTOR MURLEY: Yes, that's right.

COMMISSIONER REMICK: -- 100 reactor years--

DOCTOR MURLEY: 10^{-5}.

COMMISSIONER REMICK: 10^{-5}, yes. You have 2x --

DOCTOR MURLEY: $0.2x10^{-4}$.

COMMISSIONER REMICK: Oh, 0.2. Okay, all right.

DOCTOR MURLEY: Now this is -- we've driven --

COMMISSIONER REMICK: Well, where did you get the 2? That's a minor. I'm not worried about the difference of factor 2. I thought we were off by a factor of 10.

DOCTOR MURLEY: Yes. I don't know. It's probably the graph should be .002.

COMMISSIONER REMICK: But it's on the order of 10^{-5}, is that right?

DOCTOR MURLEY: Yes.

COMMISSIONER REMICK: Okay.

DOCTOR MURLEY: Yes.

I think there are some important lessons from all this that tell us that we're really -- that we're doing the right thing. The trends are correct. One sees a sharp drop, even after 1985. You know, there's almost a factor of 10 drop after that Davis-Besse event, which dominated in 1985. And I think the NRC, of course, did start to pay more attention then to things like the auxiliary feedwater system, but more importantly maintenance and how these plants were operated.

CHAIRMAN CARR: I started to say, can you break out of those numbers from '80 on to '88 the number of personnel-generated events, i.e., personnel error started it, and the personnel that saved it? I mean, can you break those numbers out of -- can you really tell if training is making the difference is the question I'm asking.

DOCTOR MURLEY: Depends on how well the event is described in the LERs, and I guess I'll defer to AEOD as to whether -- do you think we can get like human error rate or maintenance improvements out of these data?

MR. JORDAN: Might be able to get the ones that were attributed to human error.

CHAIRMAN CARR: I guess my feeling is the major changes we've made since then have been in training and simulators, two major changes in emphasis.

MR. TAYLOR: Yes, I'm sure that must be helping.

CHAIRMAN CARR: And we've made some other changes, but whether that really had the impact that would indicate this or not -- and you say we did something in hardware that prevented those other nine years. I'd be hard put to say. It seemed to me like it must be in the operator training and simulators.

DOCTOR MURLEY: Personally, I'm quite confident it's in better training, better qualifications of the operators, more of a complement --

CHAIRMAN CARR: Awareness by the people that it could happen, you know.

MR. TAYLOR: I would think, you know, some equipment -- some changes clearly have improved the plants through the years, because it -- but I would-- intuition would say those things certainly have improved it too. Whether you can break this out or

not, it would be useful to look.

MR. JORDAN: We'll look and see if there's a --

MR. TAYLOR: I think we ought to take a look, whether you can get a percent change.

MR. JORDAN: -- a valid way of breaking it out.

CHAIRMAN CARR: Yes. I was just trying to figure out. It's a pretty dramatic impact over the last ten years compared to the previous ten years.

DOCTOR MURLEY: Yes. I think we need to mine this a little more. I think there's just lots of data.

CHAIRMAN CARR: I guess my feeling is the plants were generally designed and built already, a lot of them. And so I can't think of any major things that came out of post-TMI that would have made that drastic a thing if it had been all hardware. But it would be worth looking at just for curiosity, I guess, once you get enough money and spare time.

MR. JORDAN: Money would help.

MR. TAYLOR: Mr. Lam is going to ask for a budget increase.

DOCTOR MURLEY: I think the emphasis after the Davis-Besse event -- we came very close to a core

damage situation at Davis-Besse. I mean, within --

CHAIRMAN CARR: And that was in '85?

MR. TAYLOR: '85.

DOCTOR MURLEY: And that was well after we'd had emphasis on simulators and training. So I think this other element of proper safety awareness and proper management has also -- and proper maintenance --

CHAIRMAN CARR: But as I remember the Davis-Besse event, if the operators had been briefed and trained on that event, since it had happened other places, hadn't led to the same consequences, that might have been a failure in the training breakdown system rather than --

DOCTOR MURLEY: Actually, the operators at Davis-Besse did extremely well. They saved the plant.

MR. JORDAN: That was a heroic save.

DOCTOR MURLEY: Yes. They did things that they've not been able to duplicate in terms of getting valves changed in the auxiliary feedwater system.

There's one other point I'd like to make with regard to the level of where we're at now. You recall Ed Jordan said that the conditional core damage probability for a Vogtle event was 10^{-3}. Divide that by 100 reactors, 115 for this year. You're down in

the range of that single event contributing about $1x10^{-5}$ to this core damage index. So that one event would contribute already half of what we saw for the whole year of 1988. So I think we're down in the range where --

CHAIRMAN CARR: Since we've got a limited data base, which is what we want.

DOCTOR MURLEY: Yes, we've got a limited data base. And the question is are we going to get it much better? Are we going to push it down much further? And of course, we're going to -- where we see weaknesses like Vogtle reveals, we'll still continue to do that. But I give you my own personal view is we're down in the range where we're not going to get substantial improvements from this.

CHAIRMAN CARR: Well, you're saying we're not going to have a substantial number of incidents and I hope that's right.

DOCTOR MURLEY: Well, we're not going to drive it to zero either. I think we're approaching a limit, probably.

This concludes what I had to say on this program.

COMMISSIONER REMICK: Am I correct that-- I mean, I'm not trying to belittle the core damage

index, because I think it's important. But since we're using conditional probabilities, dividing it by reactor years, we're getting something that would be larger than a core damage frequency?

DOCTOR MURLEY: Generally, it would be larger, because there are things that we're leaving out here.

Now on the other hand, the way I've said it here, if this accident sequence program data were perfect -- namely, if there were a complete list of events -- if all the LER descriptions were accurate, you had accurate PRA models for each plant and accurate plant-specific failure data and human error rate data for each plant, if all those were -- then this core damage index would be the mean core damage frequency for all U.S. plants, except for the seismic events.

COMMISSIONER REMICK: Yes.

DOCTOR MURLEY: But those ifs, I mean, I don't know just how close this is to core damage frequency average.

COMMISSIONER REMICK: Sure.

MR. TAYLOR: Best thing is the comparison that --

COMMISSIONER REMICK: The trend you think

is valuable?

MR. JORDAN: Yes, yes.

COMMISSIONER REMICK: I'd be afraid to put any values --

MR. JORDAN: Not in absolute --

MR. TAYLOR: I'd be nervous about the value.

That concludes the staff's presentation.

CHAIRMAN CARR: Commissioner Remick?

COMMISSIONER REMICK: Well, I certainly want to commend the staff on what I think is interesting and very important insights from the program, and I want to particularly thank Doctor Lam, I think, for a very clear and precise presentation. But to all the staff, I think it's been a particularly good one. I want to applaud you for including current events when you're able to, so we get up to date information like you did on Vogtle. That's a very good comparison.

I can't read my own writing here. One question I did want to ask you, though, Tom. When you were talking about the over-pressure event, was that an interfacing system LOCA situation? And if not, I want to know is this giving us any insights on the importance of interfacing system LOCA. Have we seen

anything specifically would tell us what kind of a core damage frequency we might infer from interfacing system LOCAs? I wasn't quite sure, when you were talking about the over-pressure event, if that was.

DOCTOR MURLEY: Yes. The event that came to my mind was at Pilgrim in I think it was 1983, if you remember that event. As I said, I happened to be the Regional Administrator and nobody brought this to my attention. It was an over-pressurization of a HPCI. A pump suction line got exposed to primary system pressure and temperature, and it had some mild notoriety because the paint on the piping started to burn. It got so hot. But no one really focused on the fact that this was a potential intersystems LOCA, and so I kind of raised the sensitivity of my staff when I found out about it.

But Rich is looking particularly into this program. Maybe you can answer some of those questions. What's coming out of this program versus --

MR. BARRETT: I think one of the things to keep in mind is that we've been looking at this program in combination with a lot of other information that comes out of AEOD. There was an AEOD case study that was done back in 1984, I believe, in which they

analyzed a number of situations in which BWR low-pressure piping was exposed to high pressures from the reactor coolant system. Since that time, we've seen other events and as a result we've initiated a rather comprehensive study of the interfacing systems LOCA for the entire question of interfacing systems LOCA.

COMMISSIONER REMICK: Well, the point I was trying to get at, did this study lead you in that direction? In other words, you certainly must have looked at some interfacing LOCA situation -- not LOCAs necessarily, but where you had over-pressure due to interfacing system type arrangements. If you then looked at the conditional core damage probability, were they significant, did you find? Would they by themselves have led you into the study or were there these other observations again that --

MR. BARRETT: There is one --

CHAIRMAN CARR: Could you speak up a little, Rich?

MR. BARRETT: There is one interfacing systems LOCA type event which was the most significant event for 1986, of all event. It was a small LOCA, guillotine break in a letdown line at Catawba. And perhaps that should have, of and by itself, alerted us to this problem. But I would have to say it's more

fair to say that it was a combination of this type of information with other types of operational information that brought us to put more emphasis on this.

DOCTOR MURLEY: Including even some foreign experience.

COMMISSIONER REMICK: No, I understand. But I was wondering, if you analyzed these this way, did they show any kind of significant conditional core damage probabilities?

MR. BARRETT: A lot of the events that we look at now and regard to be significant harbingers of an IS LOCA would not necessarily trip the criteria for a precursor.

COMMISSIONER REMICK: Okay.

DOCTOR MURLEY: I think the answer from my point of view is no. I did not see in here a high core damage conditional probability. And that kind of led me to also ask why. I think I've concluded that the modeling is not good enough. The PRA modeling is not good enough to show it, even if it had shown up.

DOCTOR LAM: If I may add to the discussion, Commissioner Remick, in our assessment of operating experience, the over-pressurization ECCS study done by AEOD had found about eight operating

events, six of which were actual over-pressurization of the ECCS. As you're well aware, if an over-pressurization ECCS occurs, then the only boundary to a core damage is the system would rupture or not. Because in one stroke, one over-pressurized ECCS, if the ECCS piping were to rupture, then the reactor inventory would be lost, containment would be bypassed, safety systems required immediately, the accident would be disabled. So one stone catches three bird type of scenario.

And in the operating experience we had observed, as Doctor Murley was saying, at Pilgrim an actual over-pressurization occurred. Now the only reason the program, the precursor program, did not quantify a high core damage probability was because a critical assumption made -- the assumption was, given an over-pressurization of low-pressure piping designed for 450 pounds of pressure to 1,000 pounds, the rupture probability is 10^{-3}. Now that assumption is critical. That assumption hinges on the information we got from the plant that even though the piping label pressure is 450 pounds, they routinely use 1,000 pound of equipment. So over-pressurization induced rupture would not be likely.

COMMISSIONER REMICK: And that depends on

the ability to isolate if it does rupture.

DOCTOR LAM: Right. But in our AEOD earlier study, we sort of disagree with the program, if I may say, because of potential defects in the piping, and also because the potential does exist that the plant's people may not have substituted higher pressure piping for the piece of low pressure pipe. And General Electric has responded to our study and they always maintain 10^{-3} rupture probability would be appropriate. Really, what is the real probability remains to be seen.

DOCTOR MURLEY: And we've got a separate program, as you know, and I think we briefed the Commission, and that's looking at is that 10^{-3} failure probability really accurate and does it apply to all the plants. But also, there are other places that the low pressure system can fail, like pump seals and places like that. We want to look systematically, just because of the potential ramifications of that event.

COMMISSIONER REMICK: Yes. Just a couple more questions. Chairman Carr introduced the subject of getting this out to industry and I did want to know to what extent are we getting this information out in a usable form for industry that they might get some of

the same insights that we glean from the presentations from you.

Then the other thing, to what extent are we using these insights in our review of the advanced reactors? Are we somehow feeding that back so our reviewers are looking for things in the reviews based on those insights?

DOCTOR MURLEY: Well, with regard to the latter question, yes, we are using these insights to do several things. I think we've -- I've talked to Research to see if we can improve some of the PRA models, for example, to make sure that when PRAs are done for these next plants, and even the current plants, that they don't overlook the importance of surface water systems, that they don't overlook potential modes for intersystems LOCA and that sort of thing.

We've picked out some of these events to -- for the advanced plants, you recall the intersystem LOCA was one of the 15 items for the advanced plants that we said, "Let's just design that away. It's easy to do with a fresh design." So that's one area --

CHAIRMAN CARR: When I asked that question they said, "Well, we're not going to design it to be

high pressure piping, we're going to design to low pressure but it will stand high pressure," which is what you're bringing up.

DOCTOR MURLEY: Yes.

CHAIRMAN CARR: And that --

DOCTOR MURLEY: Yes. We didn't say --

CHAIRMAN CARR: -- worries me a little bit.

DOCTOR MURLEY: -- it must be designed for 1,000 psi or 2,000 psi. What we said is make sure you can make it so that the failure probability is low enough that you don't have to worry about this. Sometimes what they tell us -- and we're getting a little off here, but what they tell us is even though it's, say, in a BWR, it's designed for 600 psi. It's ultimate strength can easily take 1,000 psi or system pressure.

CHAIRMAN CARR: I hear you.

MR. JORDAN: Maybe I could respond to the first part of your question in terms of getting out to industry.

DOCTOR MURLEY: Yes.

MR. JORDAN: We do distribute this report widely to industry. But I think one of the points that Peter was making was that for the issues that are

these reports, we try to have them covered by some generic correspondence where they're important. For instance, out of the current 1990 issue, we feel that the Vogtle issue will have been communicated to industry before the report actually goes and we'll be able to say that that relatively high risk event has been communicated.

Surface water, for instance. Even though it shows up as being an issue in this report for 1988, it has been communicated to industry and if we had lessons out of this that we would supplement, then we would be recommending to NRR a supplement to the generic letter or some other action. So, we try to not only communicate the total document and its results, but to assure that the lessons in it have been transferred to industry in a specific fashion.

COMMISSIONER REMICK: Do our people give papers on these type of subjects and so forth as another mechanism of getting it out to peers?

MR. JORDAN: Yes.

CHAIRMAN CARR: My problem was that they've gone through the work of analyzing this and saying, "What can we look for in this and what should we look for when we go to the plants?" Certainly, if we know what we're going to go look for, we ought to

be telling them what they ought to be looking for.

COMMISSIONER REMICK: Oh, absolutely. I agree completely, yes.

CHAIRMAN CARR: And if you've distilled it, then there's no reason not to give them the benefit of our great distillery here.

COMMISSIONER REMICK: And I'm interested in the designers of the future plants being aware of it too so they incorporate it.

That's all I have, Mr. Chairman.

CHAIRMAN CARR: I realize you'll be giving the your inspection tips, but what we want them to do is operate and be better.

DOCTOR MURLEY: That doesn't bother me.

CHAIRMAN CARR: Doesn't bother me either.

DOCTOR MURLEY: We're after safety.

CHAIRMAN CARR: I don't care why they fix it as long as they look for it and correct it.

Commissioner Rogers?

COMMISSIONER ROGERS: Yes. Can you say anything about on the core damage index numbers what your thoughts are on the uncertainties of those numbers?

DOCTOR MURLEY: I really can't give a numerical uncertainty. For the large numbers in the

early years -- no, I can't even do that. I was going to say I think for those very large numbers, the core damage index is very, very close to being the same as the core damage frequency because those events are so high and there's so few of them that you cannot have missed any of them. So, I think the fact is that we know what they were, the Browns Ferry fire, the TMI accident itself, and Rancho Seco. There's very little chance you'd miss a high precursor like that.

On the other hand, the analysis of how close they would have come to core damage -- of course TMI did go to core damage -- I really wouldn't want to give an uncertainty. I'd say certainly less than a factor of ten, but I don't know.

MR. JORDAN: I would have said at least a factor of ten.

DOCTOR MURLEY: Well, let's split the difference.

MR. JORDAN: Okay.

MR. BARRETT: I think there's an additional point to be made too and I think that this should be interpreted as an experienced risk rather than as a predictor risk. I don't think --

MR. TAYLOR: That's right.

MR. BARRETT: -- these are indicative of

what you might expect next year.

DOCTOR MURLEY: That's right. We are taking action all the time --

MR. TAYLOR: If we knew it all.

DOCTOR MURLEY: -- to deal with these things.

CHAIRMAN CARR: Well, we're dividing by reactor years of operation and that's not really a correct number. I mean if you take Vogtle, it wasn't operating. So, it's a plant and it's got a license, so you're actually taking Commission licensed years, but --

DOCTOR MURLEY: That's true, but typically what people want to know is how do you compare the PRA estimates which are given in terms of reactor years versus what's really out there. So, you have to normalize these by the total number of reactor years at risk, so to speak, to compare with a PRA numerical number.

CHAIRMAN CARR: But if we figure over a 40 year life he's going to operate at 80 percent power instead of 100 as an average, I don't know whether-- I'd hesitate to put anything on those at all that I could -- the units on that number are really strange.

COMMISSIONER ROGERS: Well, it's just

that -- they look like a mix and it's true they're real events, but then there's calculations involved and analysis that each of those steps has some uncertainties involved with them, some.

MR. TAYLOR: That's right.

COMMISSIONER ROGERS: And so, you know, you could put those back in.

MR. JORDAN: The thing we can say is that the same methodology was used to cross those. So, they're comparable, but in terms of their value with reality --

CHAIRMAN CARR: Plus there's a lot of range in the PRA itself that they're using.

COMMISSIONER ROGERS: Well, you know, for instance, if we see that something has gone down by a factor of 2, is that significant or not significant? Is 0.5 and 0.2 --

CHAIRMAN CARR: I don't think it's significant at all. When you throw in one incident like Davis-Besse, if you will, you can skew that whole set of numbers.

COMMISSIONER ROGERS: Yes.

DOCTOR MURLEY: Yes. They point out in these reports that over the years they have refined their models. So, they caution everybody who reads it

that you really can't compare, strictly speaking, one year from the next because they've revised their models. On the other hand, I tend to view it as just part of all the overall uncertainties. I guess I wouldn't be surprised at a factor of ten at all, no.

CHAIRMAN CARR: Like all other indicators, if they're used with caution, they may be good for something.

COMMISSIONER ROGERS: Well, yes. It's just a question of -- it looks like a very nice trend, but then you start asking questions about uncertainties in these numbers, is there a trend there at all. You know?

DOCTOR MURLEY: Oh, yes.

CHAIRMAN CARR: Small database.

DOCTOR MURLEY: But we're just not seeing the very large near misses that we saw in those early days. I feel --

MR. BARRETT: Qualitatively, I think you can see a difference. If you look at the foremost significant events of 1985, they were all significant trips, loss of off-site power, LOCAs with complications. If you look at the most significant events of 1988, they were latent failures of safety systems due to things like Asiatic clams, fouling of

filters, a qualitatively different type of event.

COMMISSIONER ROGERS: Well, just to try to take the most extreme view of the significance of these numbers and when one has a collection of numbers that seem to show a trend, then the first thing you say is, "Well, what are the uncertainties on each of those numbers and is there really a trend there or not on the basis of the numbers?"

What you're really saying is it's something else that you're looking at, the qualitative features of the events themselves that you're folding into it in addition to just looking at the numbers themselves.

MR. BARRETT: That gives credibility to the numerical differences.

COMMISSIONER ROGERS: Right, right, right. Yes.

Well, the other thing is, what about external events? Have we had anything, any events that -- as a result of external events that I suppose in a sense focus on external events, but --

MR. JORDAN: We've had hurricanes that have gone right up the coast. They're not included in this data unless there was an event that resulted from the hurricane.

CHAIRMAN CARR: Well, trucks in a switchyard are kind of an external --

COMMISSIONER ROGERS: Well, that's what I was going to say. In a sense, Vogtle was an external event. What do you think about -- should we be thinking about external events in this --

DOCTOR MURLEY: Commissioner, the way we're handling those is that they're additive to these. It's true, Hurricane Gloria came up the coast and it affected probably a dozen plants along the East Coast, and yet we didn't go in and analyze how close it came because it didn't come very close to any damage at all. I think it might have taken out some power lines at Millstone, as I recall or something. So, it's conceivable --

CHAIRMAN CARR: Well, they shut down, didn't they?

MR. TAYLOR: Some plants in the path --

CHAIRMAN CARR: Yes.

MR. TAYLOR: I think they might have shut down.

CHAIRMAN CARR: They did.

COMMISSIONER ROGERS: A lot of them just shut down, yes, stay out of the way.

DOCTOR MURLEY: But in general, I think

it's fair to say that they're not in here and they should be added, calculated separately from other frequency data that we have and then added to this.

COMMISSIONER REMICK: But you looked at them, right? If they had occurred and tripped your system, you --

MR. JORDAN: Right. Like the Brown's Ferry fire is in the set in those early times and that would be strictly called an external event.

DOCTOR MURLEY: That's true.

COMMISSIONER ROGERS: That's all.

CHAIRMAN CARR: Commissioner Curtiss?

COMMISSIONER CURTISS: No questions.

CHAIRMAN CARR: Well, I would like to thank the staff for this informative briefing. In my view, the evaluation of actual plant events using probablistic risk assessment techniques combines plant operating experience with new methodology in a way that helps us determine and respond to those plant system configurations that pose the greatest risk to safety.

This program is valuable in our efforts to ensure the continued safety of currently operating plants, as well as for future designs, I think.

Do any of my fellow Commissioners have

additional remarks?

If not, we stand adjourned.

(Whereupon, at 3:33 p.m., the above-entitled matter was concluded.)

CERTIFICATE OF TRANSCRIBER

This is to certify that the attached events of a meeting of the United States Nuclear Regulatory Commission entitled:

TITLE OF MEETING: BRIEFING ON ACCIDENT SEQUENCE PRECURSOR PROGRAM

PLACE OF MEETING: ROCKVILLE, MARYLAND

DATE OF MEETING: JUNE 14, 1990

were transcribed by me. I further certify that said transcription is accurate and complete, to the best of my ability, and that the transcript is a true and accurate record of the foregoing events.

Carol Lynch

Reporter's name: Peter Lynch

ACCIDENT SEQUENCE PRECURSOR PROGRAM AND APPLICATIONS

June 14, 1990

Edward L. Jordan, Director
Office for Analysis and Evaluation
of Operational Data

Thomas E. Murley, Director
Office of Nuclear Reactor Regulation

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ASP PROGRAM

OBJECTIVES

- Identify safety significant events and issues
- Use systematic, consistent methods
- Provide quantitative estimates
- Present integrated risk perspectives

LIMITATIONS

- Completeness in modeling
- Uncertainties in quantification

ASP BACKGROUND

- Started in 1979 responding to a Lewis Committee recommendation

- Program managed by RES, then AEOD

- Analyses conducted by Oak Ridge National Laboratory

PRECURSOR DEFINITION

- Failure of one or more safety systems

- Degradation of two or more safety systems

- Occurrence of an Initiator such as:
  - Loss of Offsite Power
  - Loss of Coolant Accident
  - Steam Line Break
  - Transient with Complications

ASP ANALYSES PROVIDE

- Core damage accident scenarios for given plant conditions

- Estimation of core damage probability given the event

- Identification of potential plant weakness in operation, equipment reliability, or human recovery

ASP OVERVIEW

- Screened 41,000 LERs from 1969 through 1988

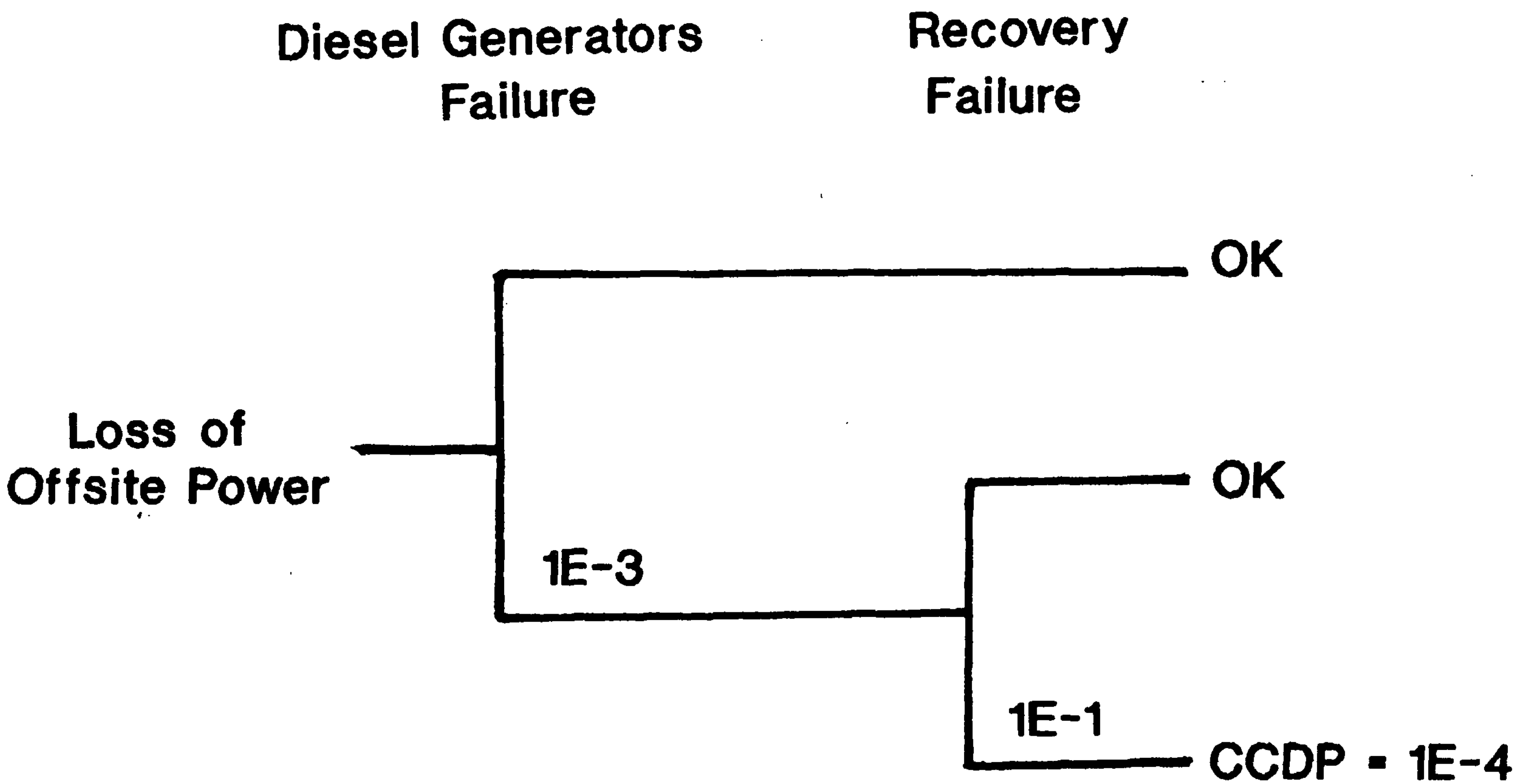
- Selected 1,500 for detailed review for precursors

- Quantified 454 precursors

CONDITIONAL CORE DAMAGE PROBABILITY (CCDP)

CCDP = The core damage probability given an event occurs

A SIMPLIFIED EXAMPLE



1988 ASP RESULTS

- No precursors with conditional core damage probability (CCDP) greater than 1E-3
- 7 precursors with CCDP in 1E-4 range
  - 3 of 7 precursors involve service water system
  - 3 of 7 precursors involve emergency diesel generators
  - 2 of 7 precursors involve auxiliary feedwater system

RELATED STAFF ACTIONS

SERVICE WATER PROBLEMS

- 1988 AEOD case study
- Generic Letter 89-13
- RES aging programs

EMERGENCY DIESEL GENERATOR PROBLEMS

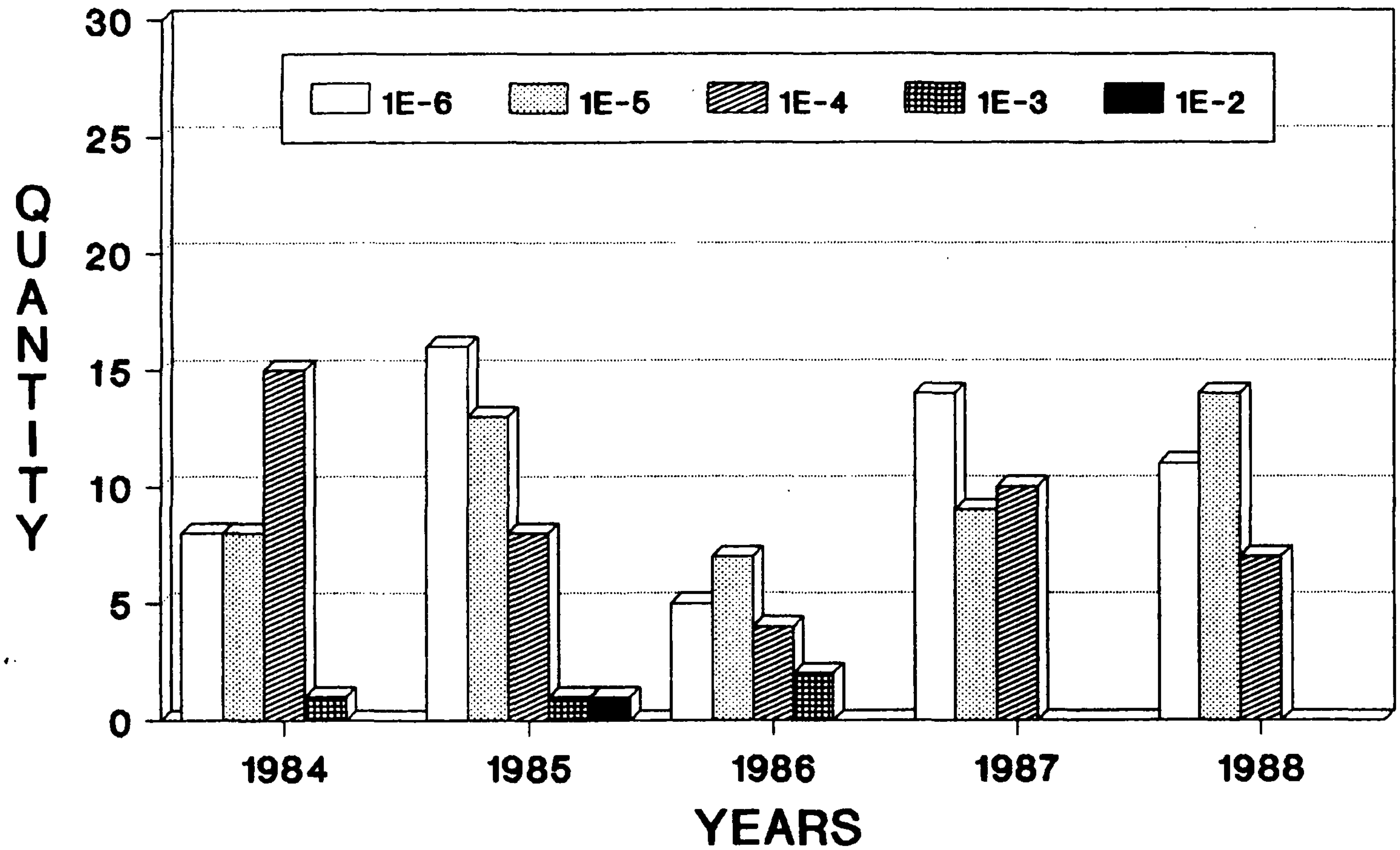
- Station blackout rule
- AEOD study of diesel generator problems

RELATED STAFF ACTIONS (CONT.)

AUXILIARY FEEDWATER SYSTEM PROBLEMS

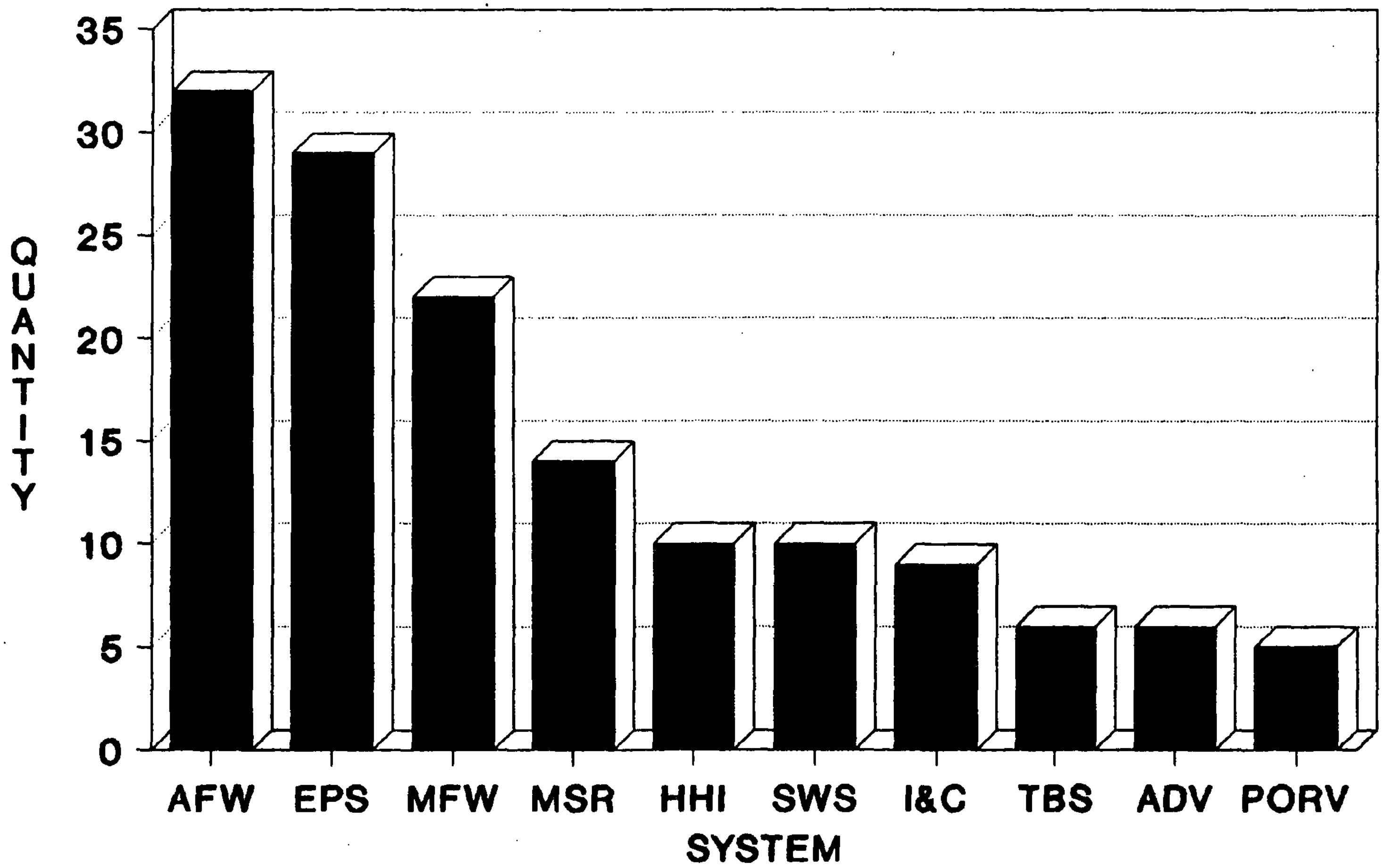
- Generic Issues 124, 125
- Special inspections
- AEOD studies

NUMBER OF PRECURSORS AND ASSOCIATED CONDITIONAL CORE DAMAGE PROBABILITIES

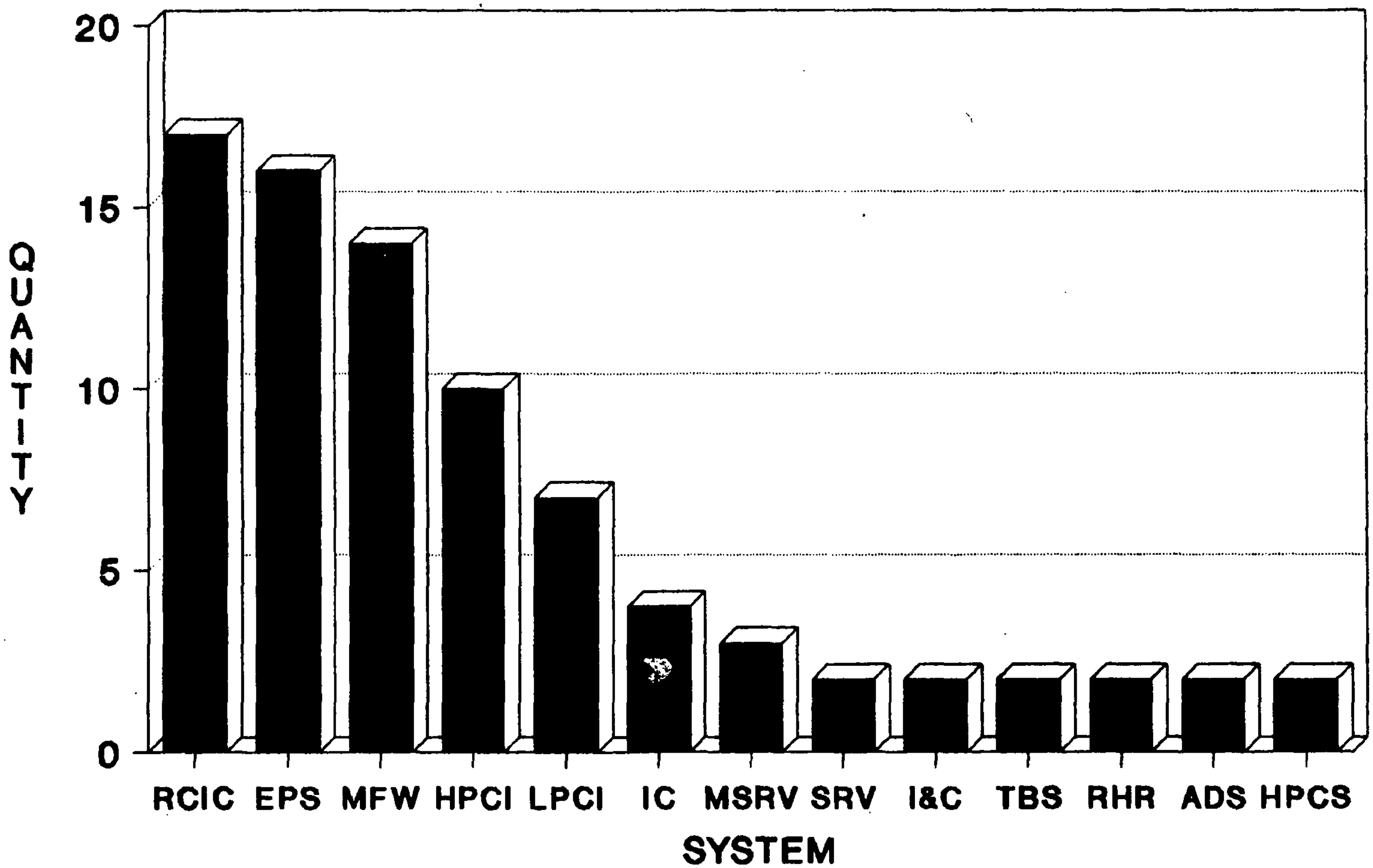


NOTE - LEGEND SHOWS CONDITIONAL CORE DAMAGE PROBABILITY

SYSTEM PROBLEMS OBSERVED IN PWR PRECURSORS (1984-1988)



SYSTEM PROBLEMS OBSERVED IN BWR PRECURSORS (1984-1988)



RECENT ASP EMPHASIS

- Timely analysis of current events

- New model on shutdown events, e.g., Vogtle IIT

FUTURE ASP ACTIVITIES

- Recognize NUREG-1150 insights
- Utilize IPE findings

SYSTEM ABBREVIATIONS

PWRs

ADV	Atmospheric Dump Valve
AFW	Auxiliary Feedwater
EPS	Electrical Power System
HHI	High Head Injection
I&C	Instrumentation & Control
MFW	Main Feedwater
MSR	Main Steam Relief
PORV	Power Operated Relief Valve
SWS	Service Water System
TBS	Turbine Bypass System

BWRs

ADS	Automatic Depressurization System
EPS	Electrical power system
HPCI	High Pressure Coolant Injection
HPCS	High Pressure Core Spray
I&C	Instrumentation and Control
IC	Isolation Condenser
LPCI	Low Pressure Coolant Injection
MFW	Main Feedwater
MSRV	Main Steam Relief Valve
RCIC	Reactor Core Isolation Cooling
RHR	Residual Heat Removal
SRV	Safety Relief Valve
TBS	Turbine Bypass System

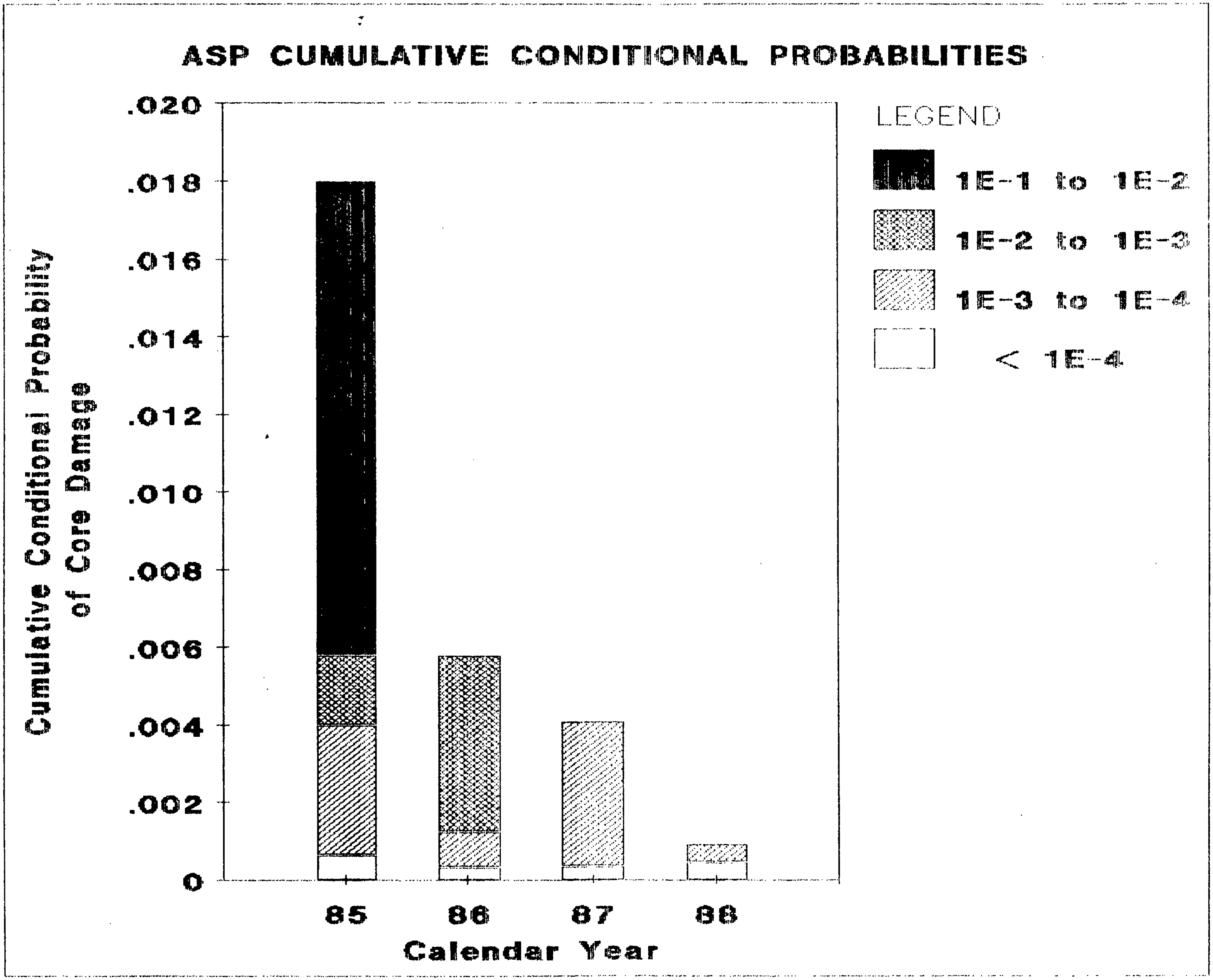
NRR USE OF ASP INFORMATION

DR. THOMAS E. MURLEY, DIRECTOR

OFFICE OF NUCLEAR REACTOR REGULATION

REGULATORY INSIGHTS FROM THE ANALYSIS OF OPERATIONAL DATA

- IDENTIFICATION OF SAFETY ISSUES
- EXAMINATIONS OF PATTERNS IN INDUSTRY PERFORMANCE
- VERIFICATION OF PRA METHODS AND RESULTS


ASP CUMULATIVE CONDITIONAL PROBABILITIES
Cumulative Conditional Probability of Core Damage
.020
.018
.016
.014
.012
.010
.008
.006
.004
.002
0
85
86
87
88
Calendar Year
LEGEND
1E-1 to 1E-2
1E-2 to 1E-3
1E-3 to 1E-4
< 1E-4

CORE DAMAGE INDEX

- FOR A GIVEN TIME PERIOD, THE CORE DAMAGE INDEX IS DEFINED AS CUMULATIVE CONDITIONAL PROBABILITY OF CORE DAMAGE DIVIDED BY REACTOR YEARS OF OPERATION
- THE CORE DAMAGE INDEX IS RELATED TO THE INDUSTRY AVERAGE CORE DAMAGE FREQUENCY FOR A GIVEN PERIOD

CORE DAMAGE INDEX
(Continued)

- USE OF THE CORE DAMAGE INDEX IN THIS WAY REQUIRES RECOGNITION OF SEVERAL LIMITATIONS:
  - NOT ALL EVENTS ARE ANALYZED, PARTICULARLY EXTERNAL EVENTS
  - THERE ARE LARGE UNCERTAINTIES IN THE SCREENING AND ANALYSIS METHODS.

CORE DAMAGE INDEX
(Continued)

- LIMITATIONS, continued:
  - CORE DAMAGE FREQUENCY IS HIGHLY PLANT SPECIFIC
  - ASP EVENTS IN A GIVEN YEAR REPRESENT A FRACTION OF OPERATING PLANTS

TRENDS FROM ASP ANALYSIS

YEAR	CORE DAMAGE INDEX
1969-79	3.1 E-3 per R-Yr
1980-83	1.6 E-4 per R-Yr
1984-85	1.4 E-4 per R-Yr
1985-87	0.5 E-4 per R-Yr
1988	0.2 E-4 per R-Yr