Official Transcript of Proceedings ACRST-3205

NUCLEAR REGULATORY COMMISSION

Title: Advisory Committee on Reactor Safeguards
494th Meeting

PROCESS USING ADAMS
TEMPLATE: ACRS/ACNW-005

Docket Number: (not applicable)

Location: Rockville, Maryland

Date: Thursday, July 11, 2002

ORIGINAL

Work Order No.: NRC-459 Pages 187-404

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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

494TH MEETING

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THURSDAY

JULY 11, 2002

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ROCKVILLE, MARYLAND

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The Committee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B3, 11545 Rockville Pike, at 8:31 a.m., Dr. George E. Apostolakis, Chairman, presiding.

COMMITTEE MEMBERS PRESENT:

DR. GEORGE E. APOSTOLAKIS, Chairman

DR. MARIO V. BONACA, Vice Chairman

DR. THOMAS S.KRESS, Member-at-Large

DR. F. PETER FORD, Member

DR. GRAHAM M. LEITCH, Member

DR. DANA A. POWERS, Member

DR. VICTOR H. RANSON, Member

COMMITTEE MEMBERS PRESENT: (cont.)

DR. STEPHEN L. ROSEN, Member

DR. JOHN D. SIEBER, Member

DR. WILLIAM J. SHACK, Member

DR. GRAHAM B. WALLIS, Member

ACRS STAFF PRESENT:

DR. JOHN T. LARKINS, Executive Director

SHER BAHADUR, Associate Director

HOWARD J. LARSON, Special Assistant

SAM DURAISWAMY, Technical Assistant

MEDHAT EL-ZEFTAWY, Staff Engineer

TIM KOBETZ, Staff Engineer

PAUL BOEHNERT, Staff Engineer

I-N-D-E-X

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

(8:31 a.m.)

CHAIRMAN APOSTOLAKIS: The meeting will now come to order. This is the first day of the 494th meeting of the Advisory Committee on Reactor Safeguards. During today's meeting, the Committee will consider the following:

Advanced Reactors Research Plan; Overview of NRC Research Activities in the Seismic Area; Development of Review Standard for Reviewing Core Power Uprate Applications; and Proposed ACRS Reports.

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

We have received no written comments or requests for time to make oral statements from members of the public regarding today's sessions. A transcript of a portion of the meeting is being kept, and it is requested that the speakers use one of the microphones, identify themselves, and speak with sufficient clarity and volume so that they can be readily heard.

Okay. The first item on the agenda is the

Advanced Reactors Research Plan, and Dr. Kress will lead us through this.

MEMBER KRESS: Thank you, George. Well, finally this week we had a very good all day meeting of the Future Reactors Subcommittee, where we discussed this plan. You will find it under Tab 9 of your book if you are interested and haven't already read it.

I hope that you have read it. The only members that weren't there were three, and so it is pretty much for your benefit. I don't know how they possibly condensed all that good information down to an hour-and-a-hour that they have, but we will see how they do. John, I guess I will turn it over to you.

MR. FLACK: Sure. My name is John Flack, and I am the branch chief of the Regulatory Effectiveness and Human Factors Branch, which has in it the advanced reactor group, and the focal group of advanced reactor activities in the Office of Research.

Let me introduce to you the participants and authors of the plan that are at today's meeting. To my right is Mary Druin, framework is that area of the plan that Mary will speak to today.

To her right is Don Carlson and Richard Lee, and they both are the participants and authors on the reactor systems analysis part of the plan.

To my left is Stuart Rubin, and Stu is the fuels participant and that part of the plan that has been developed for the tri-cell particle fuel. And to his left is Joe Muscara, who is a materials author and participant of the plan.

CHAIRMAN APOSTOLAKIS: John, before you start the presentation, I want to say something else.

MR. FLACK: Sure.

CHAIRMAN APOSTOLAKIS: One of our senior staff engineers is leaving the ACRS after seven years, and that is Mr. Mike Markley sitting over there. He is joining the Office of Nuclear Material Safety and Safeguard in the Division of Industrial and Medical Nuclear Safety, and he will be a project manager.

We all know Mike very well. He was one of the best engineers that we have had here, and he helped on all sorts of issues, like risk-informed and performance-based regulatory initiatives, defense in depth, revised reactor oversight process, risk-based analysis of reactor operating experience and so on.

And I worked with him very closely over the years, and I can tell you that he was really instrumental in helping me hold subcommittee meetings and writing the letters, both in substance and editorial content.

So we wish you well, Mike, and I am sure that you will do well there, just as you did here.

(Applause.)

CHAIRMAN APOSTOLAKIS: Back to you, John.

MR. FLACK: Okay. Thank you, George. Okay. For today's meeting, I will briefly go over a few points before we get started into the technical areas, but basically the agenda focuses around four technical areas; the frameworks, the fuel analysis, the material analysis, and reactor systems analysis.

And that is not to say that there is not other important issues in the other parts of the plan. But these are being presented because they are the more complicated and more complex areas, and where we see the most infrastructure needs.

Following those four presentations, I will summarize and discuss the future plan. The primary focus of today's meeting is basically on the non-light water reactor research infrastructure in the plan. Most of it surrounds that because that is where most of the needs that have been identified are.

The other piece is that we are taking advantage as you go through the plan of work going on throughout the world, and here is an area that we can significantly capitalize on that work. And so we see that as one of the more important areas in building our infrastructure.

That is not to say that the plan doesn't consider other types of reactors. So certainly IRIS and AP-1000 are included in the plan. AP-1000, of course, is built on an infrastructure that is well in place. It is light water reactor and we have been doing this business for quite a few number of years.

And so the needs are less than we see in the non-light water reactor. And IRIS as well, we have more placeholder there for IRIS as we try to understand that design better. We of course have interacted with Westinghouse and those supporting the design, but it was purely at a conceptual level and it was more on the viewgraph level.

We have not received the details that we will need to really look at in order to develop an infrastructural need to develop that plan. However, there are places in the plan that call out IRIS as being the placeholder for that work.

We are looking at the next update already. There is a number of plants on the horizon, and one is the ACR-700, which is now being discussed for pre-application review.

There is a number of challenges for that plan, and it is different than light water reactors that we are used to, and so we see that there is going to be needs in that area and we will be looking at that over the next several months as we go into this next step or phase of applying the ideas that we have in the plan and trying to understand our needs to this particular design.

The other two that are there are also light water reactors that are coming in, or at least discussing, and discussions have taken place on pre-application, and then we have the GEN-IV reactors, which we now understand there are six of them that have been chosen.

That may go down a little bit, but in any case, it is something that we need to stay engaged in. It is important for us to understand where that is going as we are developing our infrastructure so that we can not only capitalize on what other people are doing throughout the world, but stay knowledgeable of those designs and where it is heading, and what issues and challenges it represents to us as an agency.

There is always the issue about how much work we do versus the applicant. The applicant has the responsibility for making a safety case. However, it is important that us as an agency understand what the basis of that safety case is, and in some cases it actually takes doing the work ourselves to understand what that case means.

MEMBER KRESS: This comes down to mostly a judgment on your part as to what you need to do there.

MR. FLACK: As to where the line is drawn.

MEMBER KRESS: Yes.

MR. FLACK: It is more like when we see what they are going to plan to do, then we will understand what our role will actually be. But in preparing for that, I think it is more that we understand -- for example, in our interactions with PBMR and Exelon, that they would do certain work out to a certain point.

And our point would have to go beyond that and really understanding, and for example, taking things to failure. Although a licensee may come in and say, well, there is plenty of margin to failure, there is a certain point where one needs to look beyond that, and to sort of poke and probe out to the outer fringes of that knowledge, and understand where it is headed, and not leave that as a black box that we just don't understand.

So there will always be this piece that I think we are going to have to look at, but we won't know exactly how large a piece that will be until we actually get a plant in and understand what the applicant is going to do.

MR. ELJAWILA: Can I add something, Dr. Kress? I think in addition to what John has said, there will be a judgment, but there are certain activities that are fundamental to the safety of any nuclear power design.

For example, fuel research. That is fundamental for the agency to understand the fuel performance during all types of accidents, including beyond the design basis access. So even if the applicants are going to run some fuel tests, the NRC will still conduct its own independent tests.

Similarly would be the codes. As you know, the codes have a lot of uncertainty in them, and you can use the same code and get different results. So we won't have our independence capability.

So although the marcation line is really what is the responsibility of the applicant and the NRC's responsibility of the applicant to make a safety case, but we would compliment that with additional research, even if it might duplicate some of the work that the applicants are going to be doing, like for example, codes and fuel.

These are two examples, but not less comprehensive here.

MEMBER KRESS: I like that philosophy. That is a good statement.

MEMBER FORD: Could I ask a question on timing? When you say the next update, you mean the update to the current plan, the Rev-1, the plan, I'm assuming?

MR. FLACK: Yes.

MEMBER FORD: When will that next uprate date come; when will Rev-2 come?

MR. FLACK: Well, I was planning on discussing that at the very end. We plan to send the plan to the commission this fall, and we will be updating it, and it will be at that point a snapshot of where we are.

It is a living document and so we will continuously update and look for what else needs to be done as far as our infrastructure needs are concerned. But over the next few months now, we will be looking at the ACR-700 more specifically, because this is an area where we believe there will be more infrastructure needs.

And at that point, we will apply the same thinking as the plan to that particular plant, and include it as an appendix. Now, the timing on that, we would like to do that before we send it to the Commission this fall.

So we would say that the next update would include that piece, at least as far as we can take it at that time, and sort of freeze it at that point. But it will continuously grow after that. It's not where we just say that's it on the plan.

The plan will continually expand to capture whatever other needs we need and we see in the future. So a lot will be included hopefully by that time.

MEMBER FORD: And by that time, you mean the October time?

MR. FLACK: November to the Commission, and November is the due date for the SECY.

MEMBER FORD: Just glancing through your package here, there is nothing further being mentioned about prioritization, the prioritization that you mentioned the methods, but the prioritization goals; the criteria that go into those prioritization. Will they be mentioned at all today, or is that something to be decided upon later?

MR. FLACK: Well, we can discuss it. There are really two types of prioritization. One is the PIRT. As we know, that is a Phenomenon Identification Ranking Tables, and that is within the technical area where we bring in experts to look at the different sequences and data needs and so on.

Then we also have a formal process called the PBPM, with is the Planning Budget Performance Measurement -- Management process, where we look at the agency's strategic goals, and we do that every year, and plan our budget accordingly in meeting those goals that are laid out in the strategic plan.

Those are the two formal processes. Now, there is a number of forces at work all the time, where we support the user office, and what is coming in to the user office also depends on what industry's needs are, and so we have to adjust our priorities according to what is happening in industry in fact, and what NRR and other user offices see as important at the time.

And so within those two processes you have a number of forces at work, and so the priorities need to be adjusted to account for those. The plan itself was not intended to establish the priorities. The plan was to provide the insights and input into making decisions on the priorities.

So hopefully by reading the plan, and we laid it out in a way that we say, well, why is it that we need to do this work, and what is it that we need to do, and how would we use the results, will be used then in establishing those priorities.

But you are right. The plan itself does not establish the priorities, and those have a lot of different forces at work all the time in trying to establish those priorities.

One important priority is the next generation of engineers and how do we train them for these advanced reactors as we sunset ourselves over the next 5 or 10 years, and so even that piece needs to be considered in establishing these priorities.

MR. ELJAWILA: May I add one thing, too? In addition to what John said, I think the ORD and the PPM process itself is not conducive for developing a research program that is forward-looking, because it really looks at the prioritization for the issue that we have on-hand right now.

But there are management overlays on top of that. For example, it is up to the office director and the PRC, and the Commissioner to decide certain elements of the program that is going to take a long time, and we know that it is going to take a long time.

And even though the item might be low priority according to the EEPM process, we will pursue the research in this area. So it is not really cast in concrete that we are going to follow. The two methods are going to be applied, but there are other considerations that we take into account, too.

MEMBER KRESS: The plan doesn't differentiate between a user need research and a confirmatory or advanced research. Is there any need to do that at all in a plan like this, and if a research is associated with a user need, is it given priority over something that you think --

MR. FLACK: Well, I think thee is two parts there. One is having the infrastructure in place to respond to a user need office request, and then the other is the actual response to the request.

So I think what the plan is trying to do is establish that infrastructure that will allow us to respond to a user need request as it comes in; and that as it comes in, we would adjust our resources accordingly to respond to the user need.

So the purpose really is to establish that infrastructure here and to recognize what the challenges are, and the issues are, and now we are going to build the staff to be able to respond to those challenges.

MEMBER RANSOM: One part of the prioritization process that I would be interested in would be the division between the evolutionary versus the revolutionary. And if you look at the plan, it looks like it ran away with the revolutionary ideas, which are not likely to be the next generation of reactors that will be built in this country.

MR. FLACK: Well, we see the needs there the most, since it is different than our infrastructure that is in place now. So what you are seeing is saying, well, these are the areas where we need to be prepared eventually to deal with those kinds of reactors that are in a sense revolutionary.

It is a vision more than it is -- well, okay, we have an infrastructure in place that is capable. Well, capable of dealing with a lot of reactors that we see today, except for the ones that are coming in now, like the ACR-700, which we will be addressing as I said in these appendices.

But you are right. The scope really involved only four reactors when it initially had been prepared, and that was IRIS and AP-1000 as light water reactors, and of course the HTGRs, which are the non-light water, where we see most of the needs.

MEMBER RANSOM: Well, how is that balance established in the agency? You know, between the more evolutionary type systems than the revolutionary ones? If you ask an engineer, he is going to be more interested in the revolutionary ones obviously.

MR. FLACK: Well, that is more challenging.

MEMBER RANSOM: And there are more problems that exist there. But at the same time, you have to keep the basis covered in terms of what is likely to be built.

MR. FLACK: Right. And again the ones that are likely to be are the ones coming in on preapplication reviews, and will come through the user offices, and to some extent, we will be responding to those as we exercise the infrastructure, a lot of which has been established, except for some areas.

So those needs -- it is almost like you have two different domains. One is the near term, and then there is the long term, and what we see in this plan to some extent is long term.

MEMBER RANSOM: Right.

MR. FLACK: But yet I think essential to

establish our connections now for that long term, and I think a lot of that -- the plan focuses on that part of it, and being able to link into what else is going on throughout the world and these advanced reactors capitalizing on that information, and identifying where that information is.

And you see a lot of that in the plan. However, the same thinking about what we need can be applied to any plant, and now we will be doing that for these other nearer term plants coming in.

So we will be prepared for the user offices as they need to license these plants, and go through design certification, and we will be having the infrastructure to support them in that.

So, yes, it is both long and short term, and I think when we think about planning resources, we have to think of it that way, as long term needs and short term needs.

And this is again more looking at our infrastructure and our needs from an infrastructure perspective rather than the needs to exercise that infrastructure, which we need to do to deal with the short term plan. So they are both parts there.

MEMBER RANSOM: Well, I have seen the parts. It is mostly a matter of balance and I guess

I was curious as to how the agency decides on the balance. Neither can be neglected on.

MR. FLACK: That's right. Neither can be neglected and I think with a Commission directive, and basically how the Commission views it, and all we can do is provide them the tools and the basis for making decisions, but it is their decision in the end.

MR. THADANI: May I make a comment on that? I think you have raised three very significant issues, and this is Ashok Thadani from NRC Research. I am not sure that this is necessarily a revolutionary plan. If you look at it, I would say it is more of a generation four thinking rather than revolutionary designs.

If you just go back until even March of this year, there was still a great deal of pressure to move on the gas cooled technology, and move in a very rapid fashion.

So some of that thinking is certainly reflected in the plan that you have seen. We have also indicated the need that if this country is going to have gas cooled technology as a viable option, then it is going to take us several years to develop the necessary infrastructure.

We have indicated that it will take a

period of 5 to 6 years, followed by 2 years of appropriate changes to analytical tools and so on and so forth. So we are talking about a fairly long term effort.

Balancing of priorities is -- it does come about in the budget discussions, and ultimately that is what drives everything. And while final decisions have not been made, I can tell you that we have had to make adjustments to the budget to reduce the resources we are putting in gas cooled technology.

And to address what appears to be a rather fast changing environment. For example, G.E. ESBNR, and Framatome SWR-1000, and the ACL request to look at the advanced reactor design.

So those forces we have to adjust to, and what is happening now as a result of recent changes is that our emphasis has significantly changed away from gas-cooled technology to these technologies, and I can't tell you exactly, but we are moving significant resources away from gas cooled reactor work to the light water reactor and the heavy water reactor designs.

So those forces, I think, we just have to deal with, but we are not doing much of anything. I just wanted to clarify that, and so on Generation-4, other than basically monitoring what is happening out there, and to see to the extent that we need to be involved.

MEMBER RANSOM: Well, some of that I think you see, too. There is the role of DOE as an advocate, and the role of the NRC as the regulator, that how do you divide that roles.

MR. THADANI: Right. Our role in Generation-4 is mostly monitoring and where appropriate trying to push what we consider important safety issues to be thought through up front early on.

And John is a member of a working group with DOE, and I participated in discussions on Generation-4 and other initiatives. So our involvement is rather limited, but it is useful to have early dialogue at some level.

MR. FLACK: Okay. I guess we are ready for the technical areas and discussions, and the plan itself on the next viewgraph is centered on nine really technical areas.

The first seven we had our discussions in these different areas with the subcommittee. Eight, which is the nuclear materials and waste safety, we will be discussing that area with the ACNW later this month.

And nine being the safety and safeguards areas is more or less a placeholder at this point to see what work we might be involved in supporting other office needs in that area.

So I think we are pretty much on time. We were out --

MEMBER POWERS: Let me ask a question. I see tools and I see lots of specific topics, and is it within the framework of tools that you discuss the overall strategy you adopt with these new reactors?

MR. FLACK: Well, we are applying our current -- in a sense our current framework and needs within that context, and we are looking forward to whatever changes, which Mary is about to talk about, in the future.

Now, there is this gray area where we are seeing an indication of where it is headed, and we are trying to head things in that direction. But again that is a subject that you will hear about in a moment.

MEMBER POWERS: Let me ask a question that is perplexing me a little bit about -- concerning me a little bit about these new reactors, especially as we get to more and more complicated designs, in the sense with less experience with them.

It seems to me that there is a trend throughout engineering that is not peculiar to the nuclear industry to rely upon calculational results unless reliance on empirical data. And I am wondering at what point one decides that calculational results without full-scale experimental data simply are not adequate.

MR. FLACK: Well, I think that one needs to look at what the risk significance is from the area that we are questioning, and the more important that it becomes for a particular plant to demonstrate that that feature will work in reality, rather than just through the analysis, puts more of a burden on demonstrating that particular thought.

MEMBER POWERS: I think here is the problem that I would have with doing risk significance. Let's take a reactor that we are reasonably familiar with, say the AP-1000, and we know something about it because it is not a great deal different from AP-600.

No matter what component I pick in that, and I ask what the risk significance is, I come up against the fact that it has a purported CDF of around 10 to the minus 7th or something like that. So nothing ever comes up to be risk significant.

I mean, if I take one component at a time, I will never find a risk significance.

MR. FLACK: Right.

MEMBER POWERS: So using risk significance to look at things is just never going to work for me.

MR. FLACK: Not if you take one component at a time, but there may be underlying forces that could cause multiple components to fail, and then the question is what happens if those forces are at work, and how do I know that they are not going to work in the sense of common cause or demonstration that this phenomena will occur, and affect more than just a single component.

I think those are the questions that become dominant questions to ask.

MEMBER POWERS: And what I am thinking --

MR. ELJAWILA: John, Dana, fundamentally I agree with you Dana. I really think you cannot rely on any, quote, calculation without the support of a experimental program, and I want to say, although Professor Apostolakis might disagree with me, but --

MEMBER POWERS: He is a scribrant rationalist now.

MR. ELJAWILA: -- to dispel the notion that if we go into a risk-informed regulation or risk-informed principle that we need less information. The fact is that we will need more information and not less.

The design basis concept was a very good concept, you know, because you really tried to -- you know, at that time, it was a concept to vary a lot of uncertain changes and things like that. So when you talk about the risk extent to minus 5, you have to question what is the basis for coming up with this number.

And it is my firm belief that we need more information than we have right now in a lot of areas -- thermal hydraulics, neutronics, severer accident -- to be able to come to a reasonable estimation of the risk.

So one of the biggest struggles that we have in the office here with a declining budget is how to get the full-scale experimental data to validate the model that they are going to be using in the decision-making process, and that is the struggle that Ashok mentioned, that we will keep doing that through the budget process.

But principally I agree with you that we cannot rely on engineering analysis alone without the supporting data, especially for a reactor of the new design that we have not seen before, or we don't have any experience with.

CHAIRMAN APOSTOLAKIS: But Farouk, yesterday we told the Commission that we would like to see more rigor in PRA which is consistent with what you just said.

MR. ELJAWILA: Okay. Good. I am glad that you agree with me then.

MEMBER POWERS: I will tell you that he has undergone an epithony. He is going to become an experimentalist here shortly.

CHAIRMAN APOSTOLAKIS: Now, tell me why --

MEMBER POWERS: Let me just follow up a little bit on this, George.

CHAIRMAN APOSTOLAKIS: Sure.

MEMBER POWERS: Because, John, the difficulty that I face also with -- I mean, it is a mechanical difficulty that I can never get a risk number high enough to say anything is risk significant. So I must not have to investigate anything if I go that route.

The other thing is that kind of strategy puts a fair amount of burden on each of the members of your team here. I am pretty sure that Mary could do a risk assessment in her head.

But quite frankly I know that Joe knows a lot about metallurgy, but he probably can't do a risk assessment in his head. Pardon me if I am offending you. But you are asking him to do a risk assessment in his head and to be able to make a judgment, and to come to you and say that I am going to have to ask for a lot more here.

I mean, you are putting a terrible burden on him, and it is different if he had somebody he could go and ask. and say can you do this risk assessment that John is going to demand before I make a demand for more experimental data or something like that.

I mean, you are asking these guys to take on a pretty ferocious burden.

MR. FLACK: Well, I don't know if Joe will rise to the occasion for this, but --

MEMBER POWERS: I'm sure that Joe actually could. I'm sorry, Joe, but I have great confidence in him.

MR. FLACK: But behind every risk assessment, there needs to be a technical basis. When we talk about success criteria, this needs to be demonstrated. That basis on which this risk assessment is based in fact needs to be in many ways demonstrated.

If it is not demonstrated, then the rest of the analysis is different. We have to go back then and try to understand what these bases are that these risk assessments are built on. And from there decide how important that is in getting to your low number.

And to not start with the low number and work backwards, but to start from the front end, and say that these are the assumptions and these are the basis by which you get there, and then how real are these, and this is where you find the work that needs to be done.

So I think in light of that that if it becomes a material issue, and a temperature issue, then the burden is on Joe. Sorry. But that is his area.

CHAIRMAN APOSTOLAKIS: Is this framework going to be risk-informed?

MR. FLACK: Well, why don't we move to the framework.

CHAIRMAN APOSTOLAKIS: Before we do that, why isn't instrumentation and control in bold face?

MR. FLACK: The ones that are in bold face have been chosen for a number of reasons. One is that the infrastructure needs are more well-defined. It is a larger area, and it is a more complicated area, and the needs are in many ways clearer.

And in the other areas, it is not to say that they are not important. It's that we have developed a certain level of infrastructure, and now the idea is where do we go, and how much further do we go, and how do we get there.

And there are areas in all of these where we see that we need to continue to move in those areas. However, the four that have been called out, and which again we will talk about non-light water reactors primarily here, are the areas that do involve the greatest amount of work at this point anyway.

MEMBER ROSEN: let me respond to one point made by Dana about these systems being quite safe and having very low risk compared to the current version plants that we are running in some cases.

While it is true that the overall risk numbers will be lower, it is also true I think that when you do the risk analysis that you will find the sequences that are dominant, even though they remain low.

And those sequences which will be dominant, in terms of the overall, even though low risk, will be the places where you will need to focus the research.

MEMBER POWERS: The trouble that I have is that suppose I calculate with some confidence a core damage probability of 10 to the minus 7. Do I really care what the dominant sequence is in a 10 to the minus 7th plant?

MR. FLACK: Yes.

MEMBER POWERS: Why?

MR. FLACK: Because that is where you can focus your attention to further reduce the risk.

MEMBER POWERS: Is there any meaning to what safe is safe enough if we keep doing that? If I drive it to 10 to the minus 9th, and then look at the dominant sequence?

I mean, isn't there a point at which the plant is so safe that I don't care what the dominant sequences are given that I calculate them with reasonable confidence?

CHAIRMAN APOSTOLAKIS: Well, focusing attention doesn't mean doing it. You just want to know about it.

MEMBER POWERS: Necessarily I am doing something. I am focusing attention. I mean, it takes manpower and time.

MEMBER ROSEN: Well, what you are trying

to do is to make sure that there is no one sequence or set of sequences that is really dominating the entire --

MEMBER POWERS: Isn't there a point where I don't care?

MEMBER KRESS: I think there is though and that is a really good point. If you get down low enough, you are always going to have a dominant sequence of some kind, dominant being more than others.

MR. THADANI: May I make a comment on this? It seems to me that -- I mean, if anyone told me that I am calculating 10 to the minus 8 core damage frequency, I probably first of all would not believe it.

MEMBER POWERS: Well, you bite it off on AT-600.

MR. THADANI: Second of all -- well, no, no, no, no, no. What you are saying -- well, we will talk about it. Let me say that any discussion of these estimates, and in general, and in particular when you are talking about fairly low estimates, I am not sure it is meaningful unless we make sure that we know where the gaps might be and what the uncertainties are.

And again I would think that no matter what the calculational results tell you in terms of bottom line estimates, it would be important to know where the major uncertainties are to make sure that we are paying appropriate focus to try and get an understanding of whether there are any precipice or thresholds, or certain things that may be of some concern.

I don't see that you can regulate just by saying it is 10 to the minus 8 and walk away, and that you believe in these calculations to that extent.

MEMBER POWERS: Well, I hope that you are a good structionalist just like I am.

MR. THADANI: I am probably somewhere in between.

MEMBER POWERS: Oh, come on. You are a card carrying structuralist. The questions is that you --

CHAIRMAN APOSTOLAKIS: Don't insult the guy.

MEMBER POWERS: -- have outlined a fairly subtle set of analyses that have to be done. You know, look for gaps, and look for uncertainties, and things like that, and all of this burden is going to fall down Joe over here to justify some materials research that he thinks needs to be done.

it is a fairly big burden for him to carry alone, and I am asking why isn't there a component of this framework that provides that as a service? And that comes in and that Joe doesn't have to do anything.

He comes in and says I have identified this as an area that we don't know very much about. Is there a risk justification, and where I use risk, meaning uncertainties or gaps, or things like this, that can be used to support my intuitive belief -- and I will Joe will come up with them intuitively, or he will come up based on looking at the literature, or talking to consultants and things like that.

But in order to carry the day, and to get into the budget process, he is going to have to have more than his -- well, maybe not in Joe's case. He can probably persuade everybody, just because he knows so much.

But in the general researcher, is there some mechanism that allows him to develop this case for research that doesn't put all the burden on himself?

MR. THADANI: Absolutely. Absolutely. In my view the first step in the process, and I hope that this will come through during the discussion, the first step in the process is to try and make sure that we have a sense of what we understand and what it is that we don't know much about.

And identifying a set of areas where we need to get more information. The next step has to be -- and I think this was raised a little bit earlier as I walked, I heard that discussion, is what is the relative importance.

We all have an obligation at some point to make sure that we provide the necessary support to try and get the root cause; that is, how important is this issue.

Ultimately the definition of research program has to have some rational basis. One approach that we have often used and has worked fairly well has been the approach for PIRTs. And there is no reason why one can't get a group of experts together to get a sense of relative importance of various issues.

I think in the end that you have to do that. We cannot -- I mean, given the environment that we are in, we have an obligation to provide some rational basis for why we insist on whether we do some research, or the applicant does some research.

It can't just be a whole list of issues.

There has to be some mechanism for prioritizing that, and that mechanism I believe has to come from a group of experts who would support Joe in that process.

And those experts may include people who have knowledge of traditional knowledge of risk. Joe is not alone in this.

MEMBER POWERS: No, I am just taking on --

MR. THADANI: Well, I am using this as an example, and Dana, I think -- well, what sort of process should one put together. In light water reactors, I think we are in pretty good shape, and I think with some changes that we will get there.

MEMBER POWERS: Well, your fuel research is irrelevant.

MR. THADANI: But you also know that we are going forward. We think it is relevant and important.

MEMBER POWERS: Well, you are just not listening to what your brothers in the NRR say.

MR. THADANI: But again at some point I have that flexibility as leading a research program that I can put resources in areas that I think are important, and clearly we think and I think that program is very important.

MEMBER KRESS: As much as I am enjoying

this discussion, I think we need to move on.

MR. FLACK: We will move to the next topic, framework, which fits right in as a follow-on. Mary.

MS. DRUIN: let me come back to this and I am going to jump to the next one.

MR. FLACK: You want to go to the next one?

MS. DRUIN: Yes. The question is -- and Dana has led us right into this discussion here on this viewgraph, is why do we need a framework, and what are the benefits coming from it.

And the comment that I want to make up front is that when you look at research needs, and you look at the work that needs to be done in developing our risk insights, these are not done in isolation. They are done interruptively, and this is where the framework brings it together.

And so where the framework is providing this process, this approach, you know, for the licensing, what we mean by that is that it is going to help us formulate the regulations. It is going to help us provide another input to identifying what the research needs are.

It is going to help us decide where we

need risk insights, and when do we need them, and at what point do we need them, and what the scope should be, and what the level of detail is. It is hopefully going to bridge all of that together.

CHAIRMAN APOSTOLAKIS: So the risk part will be an integral part of this?

MS. DRUIN: Yes.

CHAIRMAN APOSTOLAKIS: It will not be optional? Will it be optional?

MS. DRUIN: I'm sorry?

CHAIRMAN APOSTOLAKIS: Will it be optional? Can someone come and submit an application for certification without a risk assessment?

MS. DRUIN: My understanding is no. That the PRA is going to be an integral part of the licensing process here.

CHAIRMAN APOSTOLAKIS: Right. Now, one other thing. I have noticed -- and I am beginning to get -- I don't think we should use the word PRA in sites anymore. It is a license for people to be arbitrary. I think you should demand rigor in the PRA results, which is what I think John was saying earlier.

If you question all this stuff about their assumptions and so on, that is what rigor is all about. The problem with insights is that anything is an insight. So I can give you a risk insight, and I can do a much better job, but I don't want to do that. I just will give you an insight, and people will say, okay, we will use the PRA insights.

And I think that unfortunately I know what you mean, but unfortunately in practice the concept of an insight has been abused. So I don't think we should use insights anymore. Either you use rigorous PRA results or you don't.

MS. DRUIN: You do use rigorous PRA results, but your interpretation of those results --

CHAIRMAN APOSTOLAKIS: I understand where you are coming from.

MS. DRUIN: I mean, if you can come up with another word in the English language than insight, I would be more than glad to hear about it.

CHAIRMAN APOSTOLAKIS: Belief and insights; incorporate PRA results and make requirements more realistic. Thank you very much. We are all learning from experience, and some of the experiences recently with power uprates is not very good. okay.

MS. DRUIN: But that was the main point that I wanted to make with this slide, is that the framework is in a sense providing this cohesiveness. Joe is not going to be out there by himself.

MEMBER POWERS: I bet you he is. I bet you he is hung out there all by himself, and I bet he is running around saying, oh, god, there is no research that has to be done.

CHAIRMAN APOSTOLAKIS: I should get to know this gentleman better, because everybody seems to be concerned about your well-being.

MS. DRUIN: Now, it may appear right now that he does it by himself, because we haven't accomplished a lot on -- and now I will go back to the preview. We have not accomplished a lot on the framework, but unfortunately that was because our hands were tied.

We had limited work that we could do due to Commission direction, and so we have been working on it in terms of formulating a plan, but with Fiscal Year '03, we do have funding and the Commission approval to move forward.

So what I am going to try and do in just the next couple of slides is give you an idea of the limited work that we have done, but I don't want to undersell ourselves, because that limited work has been a lot of good thinking behind it, I think.

We have started with the current framework on risk-informing Part 50, and what I mean by that is at a conceptual level. If you take the concept that is there, and where we have the goal, the cornerstones, strategies, and tactics, that same hierarchial approach we feel is still applicable to advanced reactors.

But from that part, we deviate, and we want to make sure that we take a fresh look, because when you start thinking about the unique design and operational things associated with advanced reactors, you don't want to go down a pathway that I think can be very dangerous.

And if you just take the current structure and all of its detail, and then start trying to modify it, I think you are in a mind-set where you could very easily overlook things, and that is not what we want to do.

So even though we are going to start with this concept of what is in the framework, from then on we want to take this fresh approach. So we will still have qualitative and quantitative aspects, and have a top-down hierarchial structure.

We still plan to integrate hopefully defense in depth at the two levels, and come up with quantitative guidelines in helping us to find --

CHAIRMAN APOSTOLAKIS: What do you mean by two levels?

MS. DRUIN: The two levels? If you remember with the -- and that is bringing in both the structuralists and the rationalists perspective. The current framework, we had the defense in depth, where we had both accident prevention and accident mitigation strategies. So at that high level.

CHAIRMAN APOSTOLAKIS: Let me focus a little bit on the second bullet. If I look at the experience with light water reactors, I think I would be hard pressed to find a major incident in which the operators did not play, or the organization, did not play a major role.

What do I do with that insight? Is there anything that I can do in the advanced reactor licensing area to address that issue, or is it something that I have to live with; that the organization and the people, you know, will always be the weak spot?

MS. DRUIN: No, I think that as you look at the structure and start looking at -- well, I think in different places you can deal with it. You can either deal with it implicitly or explicitly.

CHAIRMAN APOSTOLAKIS: But human factors were not in bold face in John's --

MR. FLACK: Well, there is a couple of things. I think the point that you are making has been made to industry, and I think that is one of the reasons why we see advanced designs evolving to less and less dependency on the human factors piece.

INC, of course is then becoming more and more important.

CHAIRMAN APOSTOLAKIS: Sure. That was not bold-faced either.

MR. FLACK: Well, you can only go so far. We were putting it in the plan with hopefully the right kinds of questions that we are asking ourselves, but until an actual plant comes in, we won't know to what extent human error is going to be important.

CHAIRMAN APOSTOLAKIS: Let's go back to what Mr. Rosen said earlier, and Mr. Thadani. I do want to know what dominates risk, and it seems to me that these would be very likely contributors.

MR. FLACK: Well, they may, or they may not.

CHAIRMAN APOSTOLAKIS: And we are still doing work on thermal hydraulics.

MR. FLACK: Well, no, the plan addresses

these issues as far as we can go with them. I think it is an important point; in knowing what the role of the operator is going to be in these advanced designs with multi --

CHAIRMAN APOSTOLAKIS: Well, it is not just understanding the role. I mean, is there anything that we can do about it, rather than receiving the applicant's PRA and some numbers using some HRA model, and then say, well, gee, that's okay.

Is there anything we can do to encourage people to do a better job there, or do I have to resign to the fact that I can have the best design in the world, but if it is in the hands of mediocre people, I am going to have a problem. I mean, I don't know.

MS. DRUIN: I think that there is a place to deal with it. It depends on whether you want to deal with it implicitly or explicitly, and when I say implicitly, for example, we talked about one of the tactics that we employ is defense in depth.

And then you go into the principles of defense in depth, and right there at an implicit level, you can bring that in.

CHAIRMAN APOSTOLAKIS: Well, that would be one approach, but I would rather see an explicit handling, if there is one.

MS. DRUIN: That would be one approach.

CHAIRMAN APOSTOLAKIS: If there is one, and I don't know if there is one.

MR. FLACK: It is a question, and we are asking ourselves the same questions as we move forward.

CHAIRMAN APOSTOLAKIS: But this seems to me that if we indeed want to take advantage of the lessons learned over the last 40 years --

MEMBER ROSEN: George, I think it would be an immense folly to believe that we could design and built systems that are both sailor proof and management proof. That simply is not going to happen.

CHAIRMAN APOSTOLAKIS: And I agree with you, and the fact that I cannot have such a situation, should that discourage me from trying to do something about it? That's really what I am asking.

And especially in light of the fact that they were not bold-faced.

MR. THADANI: George, if I may just comment. I don't have a good answer to the issue you raised, but two-fold. You are correct. I think the organization issues based on operating experience seem to be quite important. When we look at some of the more significant recent events, the root cause appears to be organizational attitudes.

So I think fundamentally it is clear that is a lesson learned from experience and it is an important issue. One way the designers are I think maybe helping, and clearly not fully addressing the issue, but helping is by trying to make sure that whatever might happen with these new designs --- there is a very large time constant involved.

And they have established some requirements for operator interaction with the machine, and that allows for longer time periods to deal with any developing issues, which I think is a very important and significant safety improvement.

Because if you look at today's reactors, by and large there are other deterministic approaches to operator interaction and following procedures, and in some cases they had to take action in a matter of minutes, and in other cases maybe tenths of minutes or half-an-hour.

So there is that improvement. The real issue in my mind actually is if the organizational implications are significant, then should we be increasing reliance on programmatic issues; that is, when we go to reduce margins and designs, ultimately that means that with a reduction in margin and design, in some cases that would place increased reliance on programmatic issues. Is that the right direction to go.

CHAIRMAN APOSTOLAKIS: But you see that is exactly the issue that I am raising, and that somebody has to be thinking about that.

MR. THADANI: That's an issue, yes. Yes, I agree.

CHAIRMAN APOSTOLAKIS: I am not naive to believe that we were going to eliminate the human from the loop, but just as the designers have come up with this fix so to speak, which I think is very good, maybe we can come up with something, and saying that a combination of these things will help us reduce the likelihood that we will eventually be --

MR. THADANI: And I think it is a very good point. We need to take a hard look at this.

CHAIRMAN APOSTOLAKIS: And I think also Mary's point about defense in depth is a good one. I mean, defense in depth can help you. By the way, just as a passing comment, on page 16 of this document, you say that defense in depth licensing can lead to unnecessary regulatory burden.

Well, it can also miss accident sequences can't it? Let's not forget that. It is not just a regulatory burden.

MS. DRUIN: Yes.

CHAIRMAN APOSTOLAKIS: It is on the top of page 16.

MR. THADANI: One last note regarding your comment, George, which is well taken. In many ways the experience of the 40 years of licensing that we have had -- and for instance, some designers in Germany have gone in the direction of having much more automatic action for certain systems.

Even before TMI, they had installed automatic reset to the blocked valves on the PRBs because they had foreseen the possibility of a transient that took place on Three Mile Island.

Now there was a significant debate of design level in fact at that time, and the level of automation, and in the U.S., for example, the level of automation is much less than it is in many other countries, including Germany.

So the reason that there is some precedence here regarding the experience of the past 40 years and what has been done with that. A tremendous amount of work was done there, and there was a significant debate for the manufacturers who were building the same design in the U.S. and in Germany, for example, about what had to be added to in fact prevent operator failure.

So there is a history there now. It didn't make many changes here in the U.S., but certainly I think we have to be looking for the new generation of plants, and there is an additional expectation.

And in those we should compare what is being done in other countries on similar designs. But you have a good point there.

CHAIRMAN APOSTOLAKIS: I think the answer to most of these is yes.

MS. DRUIN: Okay. I'm done.

MEMBER WALLIS: Tom, we asked these people to squeeze their presentation into an hour-and-a-half and now they have half-an-hour. Can we help them somehow?

MEMBER KRESS: Yes, we can help them by keeping on the subject as much as possible.

MS. DRUIN: I am not going to go through these. This is just to show you that there is a lot of issues, both policy and technical, that we are going to have to deal with in the development of this framework.

This is just a sampling and they are not in any kind of priority order, and so necessarily see the first one and think that is the most important one and the last one as the least important. They are just examples or samples.

CHAIRMAN APOSTOLAKIS: So these are issues needing resolution, and who is going to resolve them, the Commission? Because they sound like policy issues.

MS. DRUIN: Some of them are policy and some of them are technical. It is a mixture her. I do want to say that we do have a paper that has already gone forward, where a lot of these issues have already been covered in a paper that just went forward about a week ago.

CHAIRMAN APOSTOLAKIS: We have not seen this. Well, have we seen this paper?

MR. FLACK: Yes, there was a presentation on it earlier by Farouk, about a month before it went out.

CHAIRMAN APOSTOLAKIS: Okay.

MS. DRUIN: And the plan that we hope to have early this fall on the framework, we will identify the bulk of the issues, and what our approach is for resolution, and that is all I have to say on the framework.

MEMBER WALLIS: I think in the present context that what we really need to know is how does this framework help you to decide what research to do, because this is a discussion about research is it not?

MS. DRUIN: Yes.

MEMBER WALLIS: Have we made that link or are we in two worlds here, where the framework is out addressing one set of issues, and the research is somewhere else?

MS. DRUIN: No, it is integrated.

MEMBER WALLIS: I hope it is.

MS. DRUIN: Yes. Thank you.

MR. FLACK: Moving right along to fuel.

MEMBER LEITCH: Just before that, I had a question about the AP-1000. I noticed that on these presentations that the AP-1000 was on the list, and I see here that it is not on the list and I wondered if that just got eliminated in the condensation, or -- well, in other words, if an AP-1000 comes in and someone wants to build it, does it go through this advanced reactor framework or through the existing framework?

MR. LEE: I think the AP-1000 is a user needs within the research and there is a licensing certification schedule that is already established in the Office of Research supporting the NRR on thermal hydraulics, as well as severe accident --

MR. ELJAWILA: Richard, let me try to answer the question directly. The AP-1000 is going to be license based on the existing framework, which is 10 CFR Part 52.

So all of the regulatory framework and the structure are in place to address all the issues. As far as the research to support that, Richard is correct. We are on our way, and we have identified what is needed to be done, and we are running our tests, and we have our test run program to support that.

So all the necessary infrastructure that is needed to support the licensing decision on AP-1000 is in place right now.

MEMBER LEITCH: Okay. Thank you.

MR. FLACK: Okay. We will move right ahead to fuels.

MR. RUBIN: Yes. I am Stuart Rubin --

MR. ELJAWILA: If I may say that every remaining speaker, everyone has no more than about 10 minutes. So pick and choose from your slides what you want to cover.

MEMBER KRESS: Thank you, Farouk.

MEMBER POWERS: On the theory that it might be useful just to assume that the members can read. I know that it is open to question, but as a working assumption, it might work. So I am going to jump right ahead. Why do we care about the behavior of TRIDO fuel under design basis accident conditions?

MR. RUBIN: Okay. I would like to answer that with the first thing that I was going to say, and the first thing that I was going to say is that safety research in the fuels area is extremely important for two reasons.

One reason is because of its safety importance in the safety case of an HTGR, and the second reason is because of the uncertainties, whether uncertainties related to the role in satisfying the safety role in HTGR because of uncertainties surrounding the condition of -- the operating conditions and accident conditions that could occur in an HTGR as evidenced by the AVR.

MEMBER POWERS: I am at a lost at how that answers my question about the design basis accident conditions?

MR. RUBIN: Okay. Let me give you an example. Two things, one of which came to light this week. The first thing which we knew about for some time was the so-called melt wire experiments that were done at AVR that pointed out that the temperatures in the core were several hundred degrees higher than had been calculated at the plant.

The second thing that came to light this week was the fact that about 200 pebbles were observed to be stuck and embedded into the flow slots at the bottom of the core.

In my mind those two things perhaps go together very nicely and that the blockages that were caused by the pebbles in the flow slots reduced flow through the core, leading to the higher temperatures in the core.

Well, it would be useful to know what were the actual safety margins of the fuel to be able to stay intact at the higher temperatures, and what would be the effects of those higher temperatures were an accident to occur.

And it is for reasons like that that there may be uncertainties even in the new plant designs, that we think we need to understand the performance limitations of fuel.

MEMBER POWERS: I don't doubt that we need to know the performance limitations of the fuel, but what I doubt is the utility or the concept of design basis accidents.

MR. ELJAWILA: It is not the design basis accidents, per se. It is, for example, the event when the -- well, let's talk about the PPMR, and when we talk about that it won't keep the temperature to about 1600 degrees C.

And we are talking about billions and billions of these TRISO fuel particles in the core, and the statistical variation in the manufacturing process itself can lend to put some of these kinds of particles that you don't know if they are a hundred percent and made the qualification.

And we don't know at this time the effect of radiation, and the effect of temperature, and so on. So they might as a result of transient -- what you call design basis transients, which might need into further formation of this particle and the release of fission product that is following that if you have a depressurization accident or something like that, can result in a larger release, and whatever release it is going to be.

MEMBER POWERS: All those things I am willing to concede, but I think they emerge when you do your accident analysis. This idea of a design basis accident, some prescribed accident, and we will establish some threshold -- and say 2200 degrees fahrenheit -- and say that you are okay at 2198, but got help you if you go to 2201, is just a failed concept.

MR. ELJAWILA: Oh, I think we may be -- and Stu will correct me if I am wrong here, but I think the idea that we have a limited number of pebbles, for example, or the size of particles that we are going to be testing.

We are going to heed them, for example, to a different temperature and look at their behavior, but we will continue until the melting of this fuel. So we are going to maybe stop during the heating process and take some measurements, and continue with the heating, and take another measurement, until you fill them, and get the final conclusion.

But it is not going to be focused completely on the design basis concept. That is a part of the licensee or the applicant's submittals.

MR. RUBIN: I think you just heard two issues there. One is the uncertainty regarding the operating conditions and that the fuel could play a role in actual fuel performance, and how that would play out during an accident.

The other that Farouk mentioned was uncertainties regarding the fuel fabrication, and how that could lead to differences in physical properties and characteristics which fuel plays out in operation.

MEMBER POWERS: Again, all these things I am willing to stipulate, but ---

MR. RUBIN: And that eventually connects to the source term, which eventually connects to the decisions on containment versus confinement. And if we are going to be able to make a decision on containment versus confinement, we really need to understand what a high level of uncertainty and what the performance capabilities are of all of those.

MEMBER POWERS: And those things I am willing to concede. What I am asking about is what role does design basis accident play in this? And I think they should play none. You are making a criterion based on risk, and you should look at the entire panoply of accidents that are possible at this plant, and not pick out some that are of some specialized thing.

MR. RUBIN: The intent is that the fuel needs to perform over the spectrum of accidents, starting from normal operation and all the way through what are traditionally called design basis accidents, and those that are beyond.

MEMBER ROSEN: That sounds suspiciously like a rationalist's point of view.

CHAIRMAN APOSTOLAKIS: And you have to point that out.

MR. FLACK: Do you want to go through the viewgraphs, or would you prefer to just leave it open for questions, and then we will move on if there are no further questions?

MEMBER KRESS: I think that is a good suggestion, and just to leave it open for questions, and most of the members have already had benefit. Now that sort of leaves the audience out a little bit, but sometimes we have to do what we have to do.

So why don't we let the members thumb through and see if they have any questions.

MEMBER POWERS: Good. Let me ask a question. How do you do accelerated testing of critical particle fuel?

MR. RUBIN: Well, accelerated testing is basically the rate of burn-up.

MEMBER POWERS: No, it's not.

MR. RUBIN: Well, if you burn up the fuel within the time scale that it would see in a reactor, which is real time irradiation, or do you burn it up at a rate, and we achieve the end of life burn-up in a much shorter time.

MEMBER POWERS: You are assuming that there is no dynamic chemical process taking place in that coating.

MR. RUBIN: No, I am just describing what a definition of accelerated testing is. I am not saying that is what you should do.

MEMBER POWERS: Well, that is not a definition of accelerated testing. I mean, there you are just focusing on burn-up, and how much fission products you build into it.

MR. RUBIN: Well, don't get me wrong.

MEMBER POWERS: There is chemical processes taking place, and now you have got some real headaches.

MR. RUBIN: And you are absolutely right, and you have jumped to one of the things that we wanted to do in the radiation testing is actually run some pebbles, and accelerated versus real time irradiation testing, where we would do it both ways.

We would do the traditional radiation in the accelerated way, which is what is used in most fuel qualification programs, but we would also set aside some pebbles and do it in a real time irradiation, and then compare the results in terms of fission gas release and accident performance.

MR. FLACK: Okay. Anything else?

MEMBER POWERS: Well, it sounds to me then that fuels, and especially with coated particle fuels, we have got a tremendous problem, and what constitutes testing.

And it is some of your statistical problem, but I think in this context that it is even worse, because what you have is a bunch of little particles within a great big ball, which itself has a temperature grade across it.

So no one of those little particles is representative of any other particle. And so how do you do testing, because each ball is itself in a different thermal grade end. I mean, this is a lot of testing here that we are talking about.

MEMBER KRESS: You can run tests with balls in a uniform temperature if you irradiate first and then test later.

MEMBER POWERS: But why is that useful to me?

MEMBER KRESS: Well, that is the way that most of the LWR fission product release tests were run.

MEMBER POWERS: Well, I would still ask, why is that useful to me? It seems to me --

MEMBER KRESS: Well, it gets rid of this issue of temperature differences between them.

MEMBER POWERS: Yes, but if that term is comparable to the chemical -- if the thermal diffusion term is comparable to the chemical diffusion term, that better have it hadn't it?

MEMBER KRESS: Yes, but I don't think this is a thermal diffusion issue. I think it is a fuel failure, particle failure issue in my mind.

MEMBER POWERS: The thermal gradient is enough to cause the core of these coated particle fuels to move across and impact the silicon carbide layer. So thermal gradients to me seem to be fairly important here.

MR. RUBIN: Well, there are two gradients. One is a gross gradient through the pebble, or the element let's say, in a pebble bed core. And then there is the gradient across the fuel particle, and any particular particle will have to look at both of those to know exactly what the temperature, the absolute temperatures are.

And those calculations are done as part of doing a fuel irradiation test to understand what those temperature distributions are in the particles, as well as across the pebble, and the objective is to be somewhat conservative, but knowing what that level of conservatism is.

And when you have a real time irradiation are you going to be running -- excuse me, where there is an accelerator radiation, you are going to be running at a higher particle power, and you are going to be increasing the temperatures across the particles. So that will certainly drive the thermal mechanical failure mechanisms.

But because you end the irradiation sooner, the chemical effects may not have a chance to play out over that shorter time, and so that gets back to one of the reasons why you are doing real time irradiations as well.

MEMBER KRESS: Well, regardless of how you do the test, it is still a small sample, and you have to assume that the sample is representative of a huge number of particles, and you have to convert it into some sort of fission product release model.

I do think that you have a substantial research problem on your hands there, and part of it is to assure yourself that what you determine from this small sample is going to be representative of what you have loaded into the core.

And I don't know how you do that. I guess this is a statement or a question. How do you assure yourself that this small sample of testing, where you develop your fission product release behavior of a number of small kernels, how do you assure yourself that what you loaded into the core will behave the same way?

MR. RUBIN: This is a particular question for fuel qualification programs, because in fuel qualification programs, you generally take early production from the production facility, and you don't take the production from a large number of batches. You take it from the first several batches that meet the specifications.

So the variability in that particular batch that is used to make your qualification fuel may not be representative of fuel that is coming off the assembly line years later, where many batches and a different kind of variability goes into production fuel.

My understanding is that some of that variability differences between qualification fuel and production fuel is accounted for in factors that are applied in the licensing application of failure rates that are seen in the qualification tests.

And typically in Europe, they would apply a factor of 10 to the particle failure rate that came out of the qualification test and say that is the number that we are going to use if we have 10 to the minus 5th particle failure rate, and qualification test, and we will use a failure rate of 10 to the minus 4th for licensing purposes to account for things like that.

MEMBER POWERS: I guess the question really is, is okay, a rate of 10 sounds great, but is it?

MEMBER KRESS: Is it big?

MR. RUBIN: Well, then you have to take a look at what are the variations that one saw in the run for the fuel qualification, and look at the variations that are associated with production, and use some of your analytical tools that account for variations in property's thicknesses, strength, density, and so forth that play out in terms of failure performance and through Monte Carlo analysis, which are part of the codes which I didn't get to.

And you can understand how the differences in the qualification test variabilities compare to the variability in the production fuel and if that would have made some differences from an analytical point of view in the number of particle failures.

So you can kind of get your arms around those differences through the analytical codes that use Monte Carlo techniques.

MEMBER KRESS: Yes, this is statistical inference, a classical statistical inference problem, and you just have to ask yourself how many samples of a test and compare it to how many I am putting in, and use your classical statistics I guess, to determine the uncertainty or the ranges, and the confidence that you have in the results.

MR. RUBIN: And how that translates into fuel failure, you need an analytical tool to see how that might differ there.

MEMBER WALLIS: At this subcommittee meeting, I was impressed with the immense amount of scientific information that you wish to gather. I think at some point you are going to have to decide what is the minimum information you have to have before licensing decisions can be made.

And someone is going to have to say you are going to stand firm and say that unless you have that information, you cannot make licensing decisions. I don't know what that is, but within this huge program that you could embark upon, what is the structure which enables you to say this must be done, or you cannot make licensing decisions.

Therefore, we have to do it and how do we do it efficiently. And I have not seen that, and I think you are going to have to do that at some time.

MR. ELJAWILA: I think we have done that, and what you see in the plant is the minimum information that the agency needs to make its decision, and whether this information is going to be provided by the applicant or the NRC is what is missing at this time. But we will have to have this information to make the decision.

MR. RUBIN: Yes. I think I gave an example of conducting accident simulation tests that followed the traditional wrap up quickly and hold it constant temperature of the maximum accident temperature, versus an accident simulation temperature profile that actually tracks the predicted temperature of the fuel during a heat up accident.

And the applicant and the pre-applicant I should say had indicated in their qualification program plans that they might do that. So they do that and I think we would have liked them to do that, and then we would not do that.

But they recognized that is an issue and we recognize that is an issue.

MR. ELJAWILA: As we indicated, we need to move on, but as we indicated, this is a gap analysis, per se, about the information that the agency needs to acquire to be able to make its decision.

MEMBER KRESS: I have a couple of more questions. In the -- I looked through your plan, and there is a lot of stuff in it, but I didn't see any mention of the potential utilization of what Andy Kadack calls his licensing by test, particularly for the gas cooled reactor concepts.

Is that a research issue as to how you would you -- or what that would consist of, and how you would utilize it, and how you would participate in it, and things of that nature? Is that a research issue?

MR. WILSON: Jerry Wilson from NRR. I have heard a little bit about Mr. Kadack's proposal, but not a lot of details. As you know in Part 52, we require tests that demonstrate the performance of new safety features.

So the test is a part of our normal licensing process. I think that Mr. Kadack is envisioning more testing and perhaps less review and the details of how that would work out we have not really looked into.

MEMBER KRESS: Well, I guess my question is should that be part of your research plan, to be thinking about that, or is that too premature?

MR. FLACK: Well, I think it is there, but it's just how you go about getting the information you need. I mean, the research plan is to identify the information you need. Now, there may be ways of getting it.

One might be through the test program that Andy Kadack is proposing, and others may be laboratory and so on, but the plan wasn't to say this is the way to go get the information. It's really to say this is the information we need.

CHAIRMAN APOSTOLAKIS: I think there is a big difference though. The information that we need to review a license application, and plus all the other disciplines that you have mentioned.

And I think what Dr. Kadack is proposing is different. He is saying build the prototype and try to melt it. Now, how am I going to do that, and how am I going to gain enough confidence from my exercises there that I can convince a regulator that I don't need the extensive review that I normally get.

And I think that is different from the information that you are collecting now. I mean, it is very different. It is not even clear that it can be done.

MEMBER ROSEN: It implies that if at first you don't succeed --

CHAIRMAN APOSTOLAKIS: Try, try, try again.

MEMBER ROSEN: Yes. You keep trying to melt it, right until you do, right?

CHAIRMAN APOSTOLAKIS: Yes, but what does it mean to try? What am I going to do? Am I going to put a bomb in there? So you have to tell me what is acceptable to do. I need an envelope.

MEMBER KRESS: You need to run it through the design basis accident.

CHAIRMAN APOSTOLAKIS: Exactly. I need an envelope of accident sequences that I am going to try. It is not obvious, and this is not a standard experiment, and when you go and you have controlled conditions, and you want to do something.

He says allow me to build it and then I will demonstrate to you that it cannot melt. Well, I don't know how you demonstrate that. So I think that Tom is right. I mean, somebody ought to be thinking about it. It is not just a matter of collecting information.

MEMBER KRESS: I guess the other question that I might have is I presume one of your tools that you are going to use to analyze the safety status of things like the gas cooled reactors, and maybe later on the GEN-4 types, will require the use of some sort of updated version of MELCOR, I guess.

MR. ELJAWILA: That's correct, yes.

MEMBER KRESS: So I guess my question involves the fission product release models that are in MELCOR, or almost irrelevant to the ones that are in there now to the gas cooled reactors.

So I guess the intention of the resources is to develop enough database on fission product release, and chemical species, and transport behavior, to replace those MELCOR models with more relevant ones or gas cooled reactors. It sounds like a daunting --

MR. LEE: Yes, it is. In the gas cooled reactor, if you look at the -- for the prismatic one and the traditional reactor has these cladding materials that are associated with those type of reactors.

So that models closer I guess to what MELCOR is doing now with LWR fuel, and it is not clear at this time how we are going to do the pebbles yet, because you have a TRISO fuel --

MEMBER KRESS: For the heat up phase of the accident.

MR. LEE: Throughout the whole accident and every aspect of it. You have the TRISO fuel and then you have the big pellets, and so we have to think more about how to model it.

MEMBER KRESS: Yes, I think it is going to take a lot more than modeling. You have to have the database.

MR. LEE: And also the database, of course, and also in the fission product transport aspect, is that there is a lot of graphites now. If the fission products get out into the graphites, what are the interactions between the graphites and fission products. Those are the areas that we are reviewing to see how we can model those.

MEMBER KRESS: That seems to be one of the areas where you are going to have difficulty deciding what NRC does and what the licensee must do.

MR. LEE: And we are at the very beginning phase of literature review to see what has been done.

MEMBER KRESS: That is a good start.

MR. LEE: In both areas, in pebbles, as

well as in the prismatic areas.

MEMBER KRESS: Are there other questions that the members have?

MEMBER POWERS: I would appreciate going on and hearing about the materials program.

MEMBER KRESS: Yes, why don't we spend time on the materials program while we are at it with what time we have left.

MR. MUSCARA: It is clear that we want to maintain the integrity of pressure boundary components and internal components and possibly I should move up the third slide from the bottom to the top. We do depend a great deal these days on PRAs, both for the design and for the licensing of these plants.

For new plants, there is very limited, if any, data on the behavior of materials and components. We do not have any data on the actual on the actual failure of abilities.

And one good reason for conducting the materials research work is to identify potential degradation methods and the environments of interest, to quantify these, and then be able to use information from fracture mechanics to determine failure of probabilities for the different important components.

And that information then could go into

the PRA and reduce the uncertainty in the values that are selected for the failure of probabilities of passing components.

And since there was some discussion as I said, I thought that I might bring this up to the top, but Dr. Powers is quite right. Very often in trying to do materials work the answer comes back, well, it is low risk, and why bother doing this. You don't to do an inspection.

It is okay if a material fails and the risk is low. Well, in this case, we have very little information on how to even -- on what data to provide to the PRA on the probability of failure.

So a good reason for doing work in the materials area is just to get that information on probabilities of failure.

MEMBER POWERS: Which of these advanced reactors involve graphite as a moderator material? And we have at least some experience in this country with graphite as a material in a reactor.

And that experience is kind of uniformly bad. I see lots of discussion of alloys here, but I don't see graphite expertise.

MR. MUSCARA: I had divided this up into two areas; the high temperature models and then graphite. Clearly, there is not a great deal of expertise in graphite, but a key point in the graphite area is that the information that was developed on graphite is based on the old graphites.

And we know that the properties of graphite, both the initial properties and the irradiated properties, are heavily dependent on the makeup of the graphite, as there are materials in the processing.

So there is some data for the old graphites, but those graphites cannot even be produced these days because raw materials have disappeared and those specific mines are closed down. Some of the manufacturers are no longer around.

So we have new graphites and the attempt is to make the new graphites like the old graphites, and to use the data from the old graphite to make decisions today.

And that is a key area where we need to develop the new data on the current graphites. In addition, you need data on the irradiation of graphites. This kind of data is quite expensive to obtain and time consuming.

In my view, what we also need is to develop correlations between the irradiated graphite properties and the radiated graphite properties. And this way, whenever we have a small change in the graphite manufacturing, we have to be able to establish or estimate what the irradiated properties should be.

So there is a need for a great deal of information on graphite and the irradiation properties, strength properties, oxidation properties. Some data is available, but none of it with the current graphites.

MEMBER POWERS: There is a whole series of progress documents called progress in graphite, and research, and it is a huge body of work developed over the years, and essentially you are saying that it is the wrong material, the wrong conditions. I can't use the stuff. So you have to regenerate all of that.

MR. MUSCARA: Yes, that is correct. In fact, some of the data that is available is what we call the thin graphite, the graphite sleeves that are used in the U.K. plants.

And in trying to apply that data to the large raw graphite, again there is a problem because the properties change through the thickness, and therefore the irradiating properties also will change through the thickness.

MEMBER POWERS: My recollection -- and I know nothing about the U.K. graphites, but my recollection is that when they tried to measure properties on the materials, they looked like materials property data. In other words, a shotgun blast at a target might give you a tighter pattern.

And correlating that is in the eyes of the beholder, and property data is just tough to get.

MR. MUSCARA: And there is also a lack of standards, both in the graphite itself and on how to design with graphite.

MEMBER POWERS: So you are pretty much where you were in the '60s when we started on the current generation.

MR. MUSCARA: And one thing that we have done is identified a number of issues in both metals and graphite. We have shared this information with the international community. For example, the European communities.

They have looked at our plan and they have decided that it is quite an interesting and good plan and what needs to be done, and in fact the EC is willing to pick up quite a bit of the work that we have defined.

And hopefully we can cooperate with them by providing some recent results from our work.

MEMBER POWERS: Well, if we are going to go to these graphite type fuels and moderators in the Western World, and these things with graphites, what you say here about the codes and standards comes through screamingly.

We all ought to be working on the same graphite at the same place and at the same time, because it is a formidable amount of data. You are going to become an international traveler here, Joe, and you are not going to have time to do risk assessments.

MR. MUSCARA: Well, talking about the graphite area, we recognize that there is a great deal of lack of experience within the agency and in the States. We have two new people in the branch. One person will just be handling graphite issues; and the other high temperature materials.

And that is Dr. Charles Green on the metals and Dr. Srinivasan, who was here earlier, on the graphite. We have developed an assignment, a three month assignment in the U.K., for Dr. Srinivasan to learn from the experts in the U.K. and to start developing some outlines for the codes and standards that are required.

MEMBER POWERS: Again, I will point out to you that we did operate a huge graphite moderated reactor in this country for a long, long time, and there were a substantial body of modeling and information generated in connection with that reactor.

And I doubt that it is large compared to what the U.K. has, but it is a non-trivial database.

MEMBER KRESS: Is any of that graphite still available in case they wanted to have any?

MEMBER POWERS: You would have to ask the guys at Hanford. I just don't know. I have really lost touch with them over the last 10 years, Tom. Ten years ago, I was into that big time, and quite frankly I found some of the modeling they had done, for instance, on graphite oxidation of channels and the catalytic effect of fission products and impurities on graphite oxidation to be pretty impressive stuff.

And then they got into their growth problems, and between themselves and the Canadians, they collected a huge amount of data about how graphite grows and how defects are built into the material and things like that.

But it is going to be the same problem. Whatever graphite they had, and if that isn't the graphite that you have got, I don't know of anybody who has ever found a way to take data from one type of graphite and translate it over and say that tells me what that other graphite is going to do.

MR. MUSCARA: The European community is planning or has already decided and selected five different graphites to conduct experimental work on; irradiations, and fracture, and so on. My recommendation was that we could use that as a base program to build upon and conduct some parametric studies to go along with that testing to try and start developing some of the correlations.

And I suggested that we get together an international group of experts to define what those parametric tests are to be in conjunction with the tests that they are already planning. It should help in at least trying to get a correlation.

MEMBER WALLIS: I am puzzled here. I mean, the agency is expecting to receive applications for licensing of reactors, which graphite plays a major role, and presumably the designers knew something when they designed those.

And yet the impression you give is that very little is know about this stuff. I am astonished that anyone would then submit a design based on something where so little is known, or is it simply that the agency doesn't know it?

MR. MUSCARA: I don't think so. They knew a great deal with the old graphites, and now they are planning on using that same old data from the new graphites and that is where the problem is. Graphite is not a very nice uniform material. It really varies from batch to batch and from source to source.

MEMBER POWERS: And then you make the argument that the equivalent of core damage frequency is 10 to the minus 8th and so it doesn't make any difference.

MEMBER WALLIS: Like these mysterious heats that we get with --

MEMBER KRESS: John, do you have any wrap-up comments you want to make?

MR. FLACK: Yes, I guess it is about that time. So I guess I will move to the last viewgraph if there are no other questions in any of the areas. This is a summary. I think we have probably discussed the most important items already.

MEMBER WALLIS: So we will assume that the thermal hydraulic program is in great shape because we didn't hear anything bad.

MR. FLACK: Well, here are a lot of needs, and we talked about the research and about how much we need to do with the applicant, versus our purpose in trying to establish a technical basis for decision making, which affect a lot of things as to how much defense in depth we might need and so on.

Again, we are considering these new designs as they come in, the pre-applications, and we will be expanding to try to accommodate those and so on. We will have official stakeholder meetings with the ACNW later this month, and we plan to transmit the plans to the Commission this fall, 2002.

And certainly seeking their support, and continuing with non-light water advanced reactor research activities, and not to become overwhelmed by something else. So with that, I will conclude the presentation.

MR. ELJAWILA: Tom, if I may, as you heard, we are faced with the charge to continuously reprogram our resources and we have drastically reduced the gas core reactor sources to address the emerging issue of ESBWR and the CANDU, and would like to hear from the committee, although that plan is going to the Commission in the fall, we would like to hear from the Committee what you think about gas core reactors and whether we should pursue a research program in this area or not.

I am not telling you what to say, but I think we would like to hear from you. So that will help us in determining how to allocate resources in the future.

MEMBER KRESS: We will take that on as an objective.

MEMBER FORD: I just want to be sure that the deliverable in October, the fall, will be the updated plan that you have there, and it will not include any actions on prioritization or outcomes from the prioritization.

MR. FLACK: The plan hopefully will establish what those prioritizations ultimately are by what it says about the need to do this research, and why we need to do it, and what it is, and how it relates.

To that extent, it will play a role certainly in how the prioritization takes place, but the prioritization would not be taking place within the context of the plan. The prioritization process is a separate process, and where certainly this will support it.

And in transmitting the plan to the Commission, we will describe to them the prioritization process and our views on that. But it would not be as part of the plan itself, at least at this point.

MEMBER RANSOM: I have one general comment that I see missing, not only from this plan, but also in research in general, and that has to do that as we move towards this probablistic risk evaluation sort of framework, how uncertainly has evaluated with regard to thermal hydraulic models of the ones that I am most familiar with.

CSAU methodology really wasn't an end-all. It was a first attempt at trying to establish or incorporate uncertainty into these kinds of calculations. But I don't see any continued efforts to try to refine that.

And certainly in trying to deal with -- we have been writing a paper on uncertainty and thermal hydraulic code calculations. There is a lot of uncertainty in how you go about doing that.

MR. FLACK: Yes, sure, and I guess that it is sort of intrinsic to the way we do business in trying to understand the uncertainty as you develop or try to understand the phenomena.

And not as a separate entity, but as an integrated part of the whole. So I guess that you are saying that while in the plan itself it is not called out specifically, but it certainly has the attention of the people doing the work as to what the role uncertainty plays within its context.

So it is something that one actually lives with in developing these models and using these models, and not apart from what we are going to use the results are.

I mean, I think it is intrinsic to a decision that is made, and as was pointed out, uncertainty always plays a role in these decisions, and that has to be determined, since it will play an important role, and especially in our concepts of defense in depth and so on.

CHAIRMAN APOSTOLAKIS: I guess the question though is really is there a formal way of assessing uncertainty, which in this case is really model uncertainty, and that is the question. We know that it is a part of the decision making process.

MEMBER RANSOM: I have always been amazed at how much experimental data there is around, but how little of it is actually utilized.

CHAIRMAN APOSTOLAKIS: Right. We are talking about it, but we are doing very little about it.

MEMBER WALLIS: And in the Baysian, every time you get a data point, it tells you something about the uncertainty.

CHAIRMAN APOSTOLAKIS: Sure.

MEMBER WALLIS: But we don't know how to quantify it.

CHAIRMAN APOSTOLAKIS: That's right. That's right. Anything else? If not, thank you very much, lady and gentlemen. We will recess until 10:30.

(Whereupon, the meeting was recessed at 10:09 a.m., and resumed at 10:30 a.m.)

CHAIRMAN APOSTOLAKIS: The next item is the overview of the NRC Research Activities in the Seismic area. Dr. Powers, please chair this particular session.

MEMBER POWERS: About 6 or 7 months ago, we got a document in for possible review in the area of some of the esoterics of seismic fragility analysis, and it occurred to me that the committee had never had what I would call a comprehensive examination of our research programs and studies in the area of seismology.

And despite the fact that was an area that constituted kind of a baseline and risk that is kind of difficult to get plants below a fairly significant area, and over the course of the last 9 months, questions have arisen in connection with seismic effects that made it even more important to ask for what I would call a tutorial about earth sciences and earthquake engineering at the NRC.

So I asked particularly Andy Murphy if he could put together something for us to kind of educate us in this area. I originally viewed this as primarily an information briefing to the committee, but as things have progressed, it became obvious that it would also be an excellent basis for preparing a report on the research program in seismology at the NRC as well.

And so I think it serves two functions, but I think the members would be best served by looking upon it as a chance for them to get a glimpse of earth sciences and earthquake engineering at the NRC, and what is going on, and what is needed, and what needs are being met, and what needs are not being met.

Because quite frankly this area has shown a slow degradation in the funding area over the course of time, to the point that one even begins to ask the question of whether the appropriate level of technical expertise can be maintained at the agency.

It is particularly poignant, because it is an active area of research, particularly in Japan, and so having enough funding to cooperate in that research is probably something the agency seriously wants to consider.

So with that introduction, I will turn it over to the speakers. I am not exactly sure who is going to lead the pack here. I hope that Mike Mayfield is going to lead it so I can beat on him a little over his heavy section steel program, but he seems to have had the good sense to leave the field.

MR. DORMAN: Thank you, Dr. Powers. I am Stan Dorman, and I am Chief of the Engineering Research Applications Branch, which includes the Seismic and Earthquake Engineering Program. And we appreciate the opportunity to come down and share with you the work that -- well, some background on the work that has been done over an extended period in this area.

As Dr. Powers noted, there was a fairly substantial program in this area in the '80s, and we will talk to you a little bit about that. We will also share with you the work that is going on now, as well as what we see as some of the current issues to be concerned about in the area of earthquake engineering and seismic program.

And we will talk to you a little bit about what the resources that we currently have and what the implications of those may be. So with that, I will turn it over to Andy to give the presentation.

MR. MURPHY: Okay. Thank you. Dr. Powers asked me to put together this tutorial that explains where the earth science and earthquake engineering program has been in the past, and what it has gone through in the last few years, and what it has accomplished, and what it is trying to accomplish in the future.

I have got the outline of the presentation here, and one thing to understand at this stage is that while I will be talking about the earth sciences and the earthquake engineering, sort of as separate entities, it is important to notice and to know that there is considerable interaction and cross-tripping between these two programs, to the two parts of this program.

I will be talking about the past activities as I said in both areas, and then move on to the current activities, and then talk about future activities that have been funded or proposed to be funded, and then some of the open issues that we are facing at this time.

It is important as I said to note that the interaction between the organizations are extremely involved as you will see as I begin talking about some of these things in particular.

I have got the next two viewgraphs to show the budget from '79 until the present, and as Dr. Powers indicated, that in the past there had been a considerable budget, and it has been somewhat reduced to the present.

This is done in actual dollars rather than in constant dollars or anything nice like that. So that the decrease that you do see is the one that is actually in place.

The budget shown here amounts to something like about $70 million over the 25 years or so that we have had this program. The next one shows the budget that we have had for the earthquake engineering from '85 to the present.

It only goes back as far as '85 because of the way the budget numbers were kept, and it became extremely difficult to sort things out between structural engineering and earthquake engineering prior to '85.

And this program here represents a budget over about 25 years, going back to '75, where I have some summary numbers of about 40 to 45 million dollars.

MEMBER FORD: Why was there a peak in funding in the '95 to '97 region, or a relative peak? What propagated that? What forced that?

MR. MURPHY: Just simply a matter of the topics that were of interest at that particular time, and the prioritization that they were given. It was an ongoing annual prioritization business system.

So that if you want the arguments and the issues that were present during that time were of higher priority than they had been in the past.

MEMBER FORD: Okay.

MR. MURPHY: We will start the discussion with the earth sciences, and I note that this is the solid earth sciences, seismology and geology, and we have had a program in meteorology in the past.

That was ended in about the early '90s, and there have been a few topics since then, but basically it has been a solid earth science program.

The principal interest in the earth sciences has been seismicity. Where do the earthquakes occur, and where have they occurred, and where will they occur i the future.

This term of paleoseismicity is a term

referring to old or ancient seismicity, and this is the historic and prehistoric records that provides us an indication of the structures that exist, the geological structures, and how they interact.

Again, this is sort of an outline, and I will be talking about the seismicity, and talking about geology and its contribution. I will talk about the seismographic networks, which in my mind as a seismologist were the background of a lot of the program.

It provided the basic information that we used to develop the seismic source zones and the ground motion propagation. All of these nicely fed into the probabilistic seismic hazard assessment and the guidance that we have developed over the years for that.

The geological studies that the NRC has sponsored over the years have been quite extensive. We made a significant effort to work with the State geological surveys and U.S. geological survey to improve the cost benefit from the programs that we were studying, and also to get the people that were actually involved and knew their States, and knew their regions, involved in the program.

We had established basically three

regional programs; one in New England, which looked particularly along the East Coast and in the St. Lawrence River Valley; the New Madrid, I think, is an obvious issue.

The three largest earthquakes that have occurred in the Continental United States could be argued to have been the ones in New Madrid in 1811 and 1812.

MEMBER WALLIS: It rang the bells in Boston.

MR. MURPHY: Yes.

CHAIRMAN APOSTOLAKIS: What?

MEMBER WALLIS: It rang the bells in Boston and it is called Madrid isn't it?

CHAIRMAN APOSTOLAKIS: Madrid, yes.

MR. MURPHY: Well, it depends upon the influence of your geological or geographic upbringing.

MEMBER WALLIS: The locals call it Madrid don't they?

MR. MURPHY: Yes. I went to St. Louis University and was well indoctrinated in my mispronunciation of the term, but had not been thoroughly educated on that yet.

Charleston -- and I can get that one right -- and there we had quite an extensive program over the years using principally the U.S. Geological Survey, because they had provided us in part with the basis that we had used for a long time in citing questions in the Southeast United States.

There was an opinion that principally the Charleston earthquake was likely to have occurred and repeat itself in the Charleston area, rather than in other places up and down the East Coast with similar geology.

Now, after many years of proper geological studies, the basic conclusion that came from that program was that there is a low correlation between the seismicity that we are interested in and the science geology.

That we had a number of statistical studies and that probably happen before we knew about probability, and that if you looked at what was on the surface, it did not provide a good indication -- it definitely did not provide a good indication as to what was going to happen beneath the surface, and where the earthquakes were occurring.

And in the Eastern United States, typically the earthquakes are occurring between 5 and about 20 kilometers, with the majority of them being below 10 kilometers.

It turns out that the surface geology, while informative and interesting, did not provide a strong correlation or an indication of when the next big earthquake, or where the next big earthquake was going to occur.

As I indicated, in my mind the seismographic networks were the Basica background of the data gathering for the seismicity questions for the central and eastern United States. At one time the NRC was sponsoring and funding about 18 or 19 regional microearthquake networks.

Typically these data were recorded by single component vertical high frequency, and we call them weak motion instruments, with telephone telemetry back to a analog central recording place, and generally these were in cooperative programs with the universities, such as Columbia University, or Boston College, MIT, Georgia Tech, St. Louis University.

And then there were some in the northwest as well. We had the University of Washington working with us. The second big bullet down there, telephone divestiture, and why did that pop up in a briefing for the ACRS?

Well, it turns out that the regional networks were significantly dependent upon the telephone system in order to get the information back. These networks involved well over 300 stations and all of these had constant 24-7 as they say telephone lines back to the home institutions to record this.

So when the divesture hit, it increased the telephone bills, prospective telephone bills, from less than a half-a-million dollars a year, to a projected 4 to 5 million dollars a year.

And the bottom line was that was just an unacceptable increase in expenses. So at that time, we got together with the U.S. Geological Survey and said is there something that we can do that is better than this.

Can we improve the information that we are gathering from these instruments, because at that time we were simply getting analog records, and so there was no opportunity and there was no real opportunity to analyze the wave forms that came in.

And there is considerable information that is involved and packed into that wave form information. So getting together with the U.S. Geological Survey at that stage, and also satellite telemetry was becoming a very popular thing, and a cost effective item.

So what happened was that in the early --

call it the early '90s, we got together with them and the NRC basically bankrolled the capital equipment for a national network, with primary coverage for our concerns in the central and eastern United States.

We bankrolled the purchase of the equipment, and the Geological Survey designed the system, and installed the system, and the important thing now is that they are maintaining the system as a national resource or national facility.

There have been a number of upgrade in that system since then so that recordings of earthquakes in the United States probably above magnitude 3-1/2 anywhere in the States, and in many places above magnitude 2-1/2, are recorded at a central place in Palo Alto, and Golden, Colorado, where the Geologic Survey is.

And that information is put very rapidly on to the internet and you have access to information, wave form information, about earthquakes probably within 2 hours, and often with a half-an-hour of its occurrence.

As a backup the NRC still has its satellite link to Golden, Colorado, and so that if there is something that happens to the internet in any sense, we have backup information and backup access to that data.

MEMBER LEITCH: Is that system then redundant to the data that is corrected at each nuclear power plant?

MR. MURPHY: Yes, sir. It is redundant in the sense that -- well, no, let me back up. It is not redundant because the data that is principally collected at the nuclear power plants is strong ground motion records for events that are fairly close to the facility and that have strong ground motion in the vicinity of the facility.

The national network will pick up most earthquakes that occur in the United States above magnitude 3-1/2. So virtually all earthquakes above magnitude 3-1/2. And it provides a different set of information.

The two sets are complimentary, but they are distinct.

MEMBER LEITCH: I guess I don't understand the emphasis on speed that you mentioned. I mean, how important is it that this data be available within a half-an-hour? I don't understand that.

MR. MURPHY: It is important so that if it is necessary for there to be some sort of an emergency response, and let's say it turns out, heaven forbid, that there is a large earthquake near a facility, it is important for us to know how large that earthquake was, and where it was, and have an understanding of what may have happened to the facility.

And what may have happened to the access to the facility, and to the potential egress of the residents within a particular distance from the facility. So that information is back here and is available to us to make decisions about what we should be doing to aid that power plant or those power plants in this kind of an event.

MEMBER LEITCH: Okay. I was not aware of that. So there is a location here then? Is it in this building around here where this information is collected?

MR. MURPHY: The information comes to me and several others on a daily basis, and an hourly basis over the internet, and as an event occurs, we will get a notice on the e-mail system that notifies us about the preliminaries of an earthquake.

I mean, there were some records on my computer this morning for events that had occurred off the Pacific Northwest, off the coast of Oregon yesterday.

MEMBER LEITCH: And then there is actually a feedback mechanism then? In other words, is there is a severe enough earthquake in the location of one of the nuclear power plants, that the NRC could notify that plant and get involved in that situation?

MR. MURPHY: If there is a severe earthquake near the plant, the NRC will not have to worry about notifying them. They will already know. But it will be a matter of -- and realistically, if there has not been significant damage, and in some sense incapacitate the communications system from the power plant, we would have that information probably from the power plant directly to the operations center.

The helpfulness of the Geological Survey's information is to know the extent, because the power plant will have only a single observation point on that earthquake.

They will know how severe the ground shaking was at the power plant, but to a large extent will not have had a clue from how far away that earthquake occurred, and what it may have done to other things in the vicinity of the power plant.

Okay. And this will be one of the places that we will begin to see some of that synergism, and that the --

MEMBER POWERS: Let me just ask a question. Can you give me some idea of what our state of the art is in predicting earthquakes at locations nowadays?

MR. MURPHY: It is probably some place like the Weather Service was in the early 1900s.

MEMBER ROSEN: Which was to go outside and see if it was raining.

MR. MURPHY: Pretty much.

MEMBER POWERS: I suspect it's still like that.

MR. MURPHY: A lot of the -- I will say seismologists are going a little bit away from the talking about predictions at the moment. It would be a wonderful thing to happen and a wonderful thing to do.

What the concentration today is on what we are calling forecasting. That if we take a look at California, and we take a look at the San Andreas Fault, and say, okay, fine. From the statistics of what has happened in the past, and what has happened internationally on similar faults, we can say, okay, fine.

And because of the information on how this fault is acting, there will be forecasts of particular areas that may have a greater potential of a moderate to large earthquake in the next 5 to 10 years.

Later on in this presentation I will talk about a program that is ongoing in California. We are sponsoring a vertical array of seismograph to look at ground motion, and probably the Asian problem.

That particular site was picked because the Geological Survey had forecast that that section of the San Andreas Fault was likely to have a magnitude of 6-1/2 to 7-1/2 in the next 20 years.

Now, we started a program about 10 years ago and so it is down to the next 10 years, right?

MEMBER POWERS: I expect that it is still 20 years.

MR. MURPHY: Yes, that is what it is, and we are interested in that because we are looking for non-linear effects in the ground motion.

MEMBER FORD: What is the state of the knowledge that would indicate that the speed of creation of prediction technology is increasing? For instance, in 5 years time, will we have the technology to predict, or the monitoring capabilities to predict, that an earthquake is imminent by within the next day? Are we even close to doing that?

MR. MURPHY: I will say it depends on who you talk to. There are some individuals who think that they have achieved a level of success in forecasting and predicting earthquakes in the past.

The proof comes in actually being able to do it again, and in a number of cases, it has not been done. I had a colleague, a classmate, while I was at Columbia that forecast or predicted actually a magnitude 3 earthquake in Upstate New York.

He did, and no question about it, and he knew that it was coming and that was based upon dilatency in the rocks in the area, and in the S&P wave velocity in the rocks, and there is no question about it. He predicted that earthquake and has he been able to do it again the last 25 years?

MEMBER WALLIS: One just happened didn't it?

MR. MURPHY: Nope. But nobody predicted it. Nobody forecasted it to the best of my knowledge either. There was an experiment that was described in the <u>Civil Engineering Journal</u> this month about drilling a well into the San Andreas fault to get additional information about how the rocks actually in the fault zone at depths greater than 5 kilometers behave.

Information like that will very definitely help the forecasting abilities understanding how the faults behave, but will it lead to prediction? Probably not. There is so many things that go into Mother Earth, and how it behaves that prediction is not on the horizon yet.

It probably is not on the horizon for our children and maybe even our grandchildren to give real time predictions. Can we do forecasting, and can we do probablistic hazard analysis and understand much better where the risks are? Very definitely. No question about that.

We do have an awful lot better understanding, and we can do some things like these probable seismic hazard assessments, and actually believe that they have provided us, and are providing us, good information, from which we can make critical decisions about sizing facilities.

And dropping back to the viewgraph for the moment, this is where we begin go see some of the feedback between engineering and earth sciences. That in the early to late '70s there was the systematic evaluation of power plants, where we took a look at the 11 oldest facilities, and there were a number of issues that were identified out of that program.

And the probablistic analysis, and coupled with the Geological Survey telling us that they would no longer support a position that the Charleston earthquake had only occurred in the Charleston area, they told us in '82 that their position now was that they had not been able to identify the structure in which the Charleston earthquake would occur.

And so they were unable to then correlate that with other similar structures on the East Coast. So they changed their position to say that the Charleston earthquake was likely to occur in the Charleston area, and repeated in the Charleston area.

But there was at least a low probability that that event could occur elsewhere. We decided -- the seismologists took on the challenge of answering the question for the SEP as to which sites, which power plants ought to be looked at next, and how to resolve the Charleston issue that was sprung upon us by the Geological Survey.

And that was a probablistic seismic hazard assessment, and we drew that from a program that is called the SSMRP, the Seismic Safety Margins Program, which at Livermore developed the first probablistic technique.

We got together funding to use that probablistic system, analysis system, to select the next SEP sites, and we also set up a fund, and can that help us out with the Charleston earthquake issue, and we decided that it could provide us with a better understanding and a probablistic look at the chances of that earthquake occurring.

So the original Livermore and EPRI methodologies were developed, and I will say that one of my colleagues here at the NRC maybe made the mistake of saying, okay, fine. Wouldn't it be wonderful if we are able to challenge industry, and industry went out and looked at this with us so that we had two hazard results that we could look at and be better informed?

I will say that was a decision that has haunted us for at least 15 years, and you could say it is probably still haunting us today. Those results were very beneficial to us. We have used them in any number of things, which I will talk about in the next viewgraph or the one after.

But out of that problem or the issue of having the two results, and not a technically viable way of picking between the two of them, we put together a senior seismic hazard analysis committee, and it is an analysis committee, and not an advisory committee for obvious reasons.

And they provided us with guidance, particularly on how to go about collecting the information that was used in the analysis techniques. That study was published in about '97, and we had Lawrence Livermore do a trial application of that for us with two sites in the Southeastern United States, one at Watts Bar, and the other one at Vogel.

And based upon that trial implementation, we have come to a better understanding of some of the pitfalls that were involved, and a question of how the information is solicited from the experts, and then again how much feedback is appropriate between the calculators and the experts.

At this time, we are planning on some sort of a full implementation of the senior seismic hazard analysis committee guidance, and exactly how we are going to do that is uncertain at the moment.

And an item that does not or did not appear on the Earth Science viewgraph, much like the viewgraph that I showed you a few minutes ago, is funding under the advanced reactor program to do a 10 year plus update of the probablistic hazard assessments for the Central and the Eastern United States.

MEMBER FORD: Now, will that focus on the plant sites for which there are ESPs coming?

MR. MURPHY: No. The methodology is in effect site independent. The methodology and the database are not gathered to support a particular site. It is gathered to support a hazard analysis for any position in the Central and Eastern United States, and it is actually for the whole of the United States now.

So that nominally you could put the coordinates of any site into the methodology into the computer code, and turn the crank, and come up with an estimate of the hazard at that particular geographical location.

MEMBER POWERS: Give me an idea of what that result -- you know, you put the information into the code and you turn the crank, and what is it that you actually get?

MR. MURPHY: You get a seismic hazard curve, of course.

CHAIRMAN APOSTOLAKIS: A family of curves?

MR. MURPHY: Well, you get at least a family of curves, depending upon what you ask for out of the code, and you get a full sweep of the statistical information from one sigma, to two sigma, media, mean, the whole routine.

You can look at it for the distribution and the sensitivity to various inputs. During the initial Livermore, there was a particular expert, Expert 5, who provided a particular ground motion model that was extremely influential in some of the initial numbers, which were high.

The probablistic recurrence rates, if you want, were on the high side, and you could trace that back down to the input from this particular individual. You could also take a look at -- and it is an important thing to do -- the East Tennessee seismic zone, which probably nobody has ever heard of, around the Oak Ridge area of Tennessee and what not.

MEMBER POWERS: Is Tom going to die?

MEMBER KRESS: No, it just wakes me up in the middle of the night.

MR. MURPHY: Well, not so that we have to worry today I hope.

CHAIRMAN APOSTOLAKIS: Wait a minute. I thought you said to Dana that what you get is seismic hazard curves.

MR. MURPHY: Yes.

CHAIRMAN APOSTOLAKIS: But the infamous expert 5 gave ground motion models?

MR. MURPHY: Right.

CHAIRMAN APOSTOLAKIS: Which come after the seismic hazard curves, right, in the model?

MR. MURPHY: There is two basis inputs to the two sets of data that go into coming up with the hazard curves. The first is source information, and where the earthquakes are occurring and how large are they. And then the other part of it is, okay, fine, after you --

CHAIRMAN APOSTOLAKIS: Are the hazard curves frequency versus peak horizontal spectral acceleration still, or are they something else now?

MR. MURPHY: They are basically frequency of occurrence versus acceleration usually. You can do it in --

CHAIRMAN APOSTOLAKIS: What kind of acceleration?

MR. MURPHY: It doesn't matter. You can do it either spectral acceleration or acceleration with no adjective. You can do it for the other ground motion parameters, velocity, or displacement. All those permutations are available in the code.

CHAIRMAN APOSTOLAKIS: So I can pick now a plant, like Seabrook, and if I have this code, it will tell me what seismic hazards are out there?

MR. MURPHY: Yes, sir.

CHAIRMAN APOSTOLAKIS: You have all the data into the codes and everything?

CHAIRMAN APOSTOLAKIS: At this time, basically what you are talking about is the Livermore data that was last fully exercised in '93, and where Philip Sobel developed the NUREG 14.88, I believe, that lists all of those for the plants in the Eastern United States.

CHAIRMAN APOSTOLAKIS: So you have not exercised the SHHAC methodology for oversight?

MR. MURPHY: No. We have exercised the SHHAC methodology in a trial at Watts Bar and Vogel.

CHAIRMAN APOSTOLAKIS: Okay. So the other information is based on the Livermore stuff?

MR. MURPHY: The earlier Livermore stuff. This is still Livermore doing the work.

MEMBER WALLIS: How about these seismic hazards and these acceleration curves? The uncertainties would seem to be greatest at the tail, and we are talking about small probability of large acceleration.

MR. MURPHY: Yes.

MEMBER WALLIS: Do you think that is where you would be most uncertain, where the projections would differ depending on how you reduced your information and so on? Is there a lot of uncertainty about those tails?

MR. MURPHY: I think the answer is yes, but I won't try to quantify what a lot means.

MEMBER WALLIS: Well, that tail could wag the dog if you are not careful, in terms of seismic hazard. Does it do it?

MR. MURPHY: The tail very definitely has importance when you are talking about the occurrence of earthquakes with accelerations that are 3 to 4 times the SSE of the facility, and that is where the PRA information tells us the accelerations are important at 3 or 4 times the SSE.

And, yes, there is a level, an important level of uncertainty in those tales. Now whether the tail is creates by EPRI or the tail is created by Livermore, or whether now the tail is created by the Geological Survey, and there is very definitely uncertainty.

And I say -- I will call it an important level of uncertainty there. Now I will switch gears considerably and talk about some of the earthquake engineering things that have been going on in that 25 year time period.

The viewgraph here in front of us is sort of an outline of some of the things that we have taken a look at, and an important part of this has been to gather information on the fragility of structures and components, or actually structures, systems, and components.

And to provide an input to answer one of Dave Oakran's favorite questions, is okay, fine. You are telling me that this piece of equipment is good to an acceleration of .5. Okay. How much margin do you have beyond that.

This information is basic information about the fragility, and where does this stuff, where do these structures where do these components, actually break. A lot of this was gathered via shake table information, and some of it also gathered by actual occurrences, and equipment that had been exposed to earthquakes, and some of it in power plants, and some of it in -- well, similar equipment other facilities, whether they are fossil plants, chemical plants, or just simply manufacturing facilities.

One of the other things that we did was then take that information and develop the margins methodologies for looking at this. As Nilesh pointed out to me when I showed him these, he said, okay, fine, be sure when you start talking about the margins, make sure they understand that this stuff was before the margins program was used for the PRAs, for the seismic PRAs.

So that we had an understanding of how we can put this information together with a seismic hazard curve and come up with estimates so as if earthquakes are 3 and 4 times the SSE that are important to the core damage frequency for a nuclear power plant.

One of the other areas that we are very active, and that is in soil structure interaction, and we have done a good bit of work there in the past, and are continuing to.

Another item that we have looked at is the response of age structured systems and components, and what happens to these facilities if there has been some level of degradation, such as the corrosion that was shown in the intake structures at Calvert Cliffs.

Was it that level of corrosion, and how was that detected, and were there better ways for detecting it, and what significance did that have to the overall capacity of that facility.

MEMBER POWERS: If I had a containment maybe made out of steel, and I had a large water tank on top of it for some strange reason, do we have the capability to analyze that to tell me how that responds under an earthquake?

MR. MURPHY: Yes. Can I do it myself? No. But there are some people out in the audience here that can, and we have contractors that can work for us and provide a detailed analysis, depending on the level of instrumentation.

MEMBER POWERS: And give results that we are reasonably confident of?

MR. MURPHY: Yes, sir.

MEMBER WALLIS: Do they analyze the motion of the water, as well as the structure?

MR. MURPHY: I presume that they would have to.

MEMBER WALLIS: Well, if they are focused on structures, they may just lump it as a mass.

MR. MURPHY: They shouldn't. It must be to get a real response of the system, you need to see what the response of that water is, and how much sloshing is going on up there, because that definitely has to be important.

MEMBER ROSEN: And the mass distribution changes is a function of time.

MR. RUBIN: Yes.

MEMBER ROSEN: And you have to account for that.

MR. MURPHY: Yes, particularly if the water is draining out and is not being used for another purpose while the earthquake is going on, which we know is an extremely low probability of that.

What we have got here is a list of some of the programs that we have had over the years to look at; the fragility, and the SSMRP, the Seismic Safety Margins Research Program, like I said started about '75 or so, and finished its last reports in '81 or '82, provided us with a lot of good information about how these things behave and how they interact.

And what kinds of margins do we have associated with them. The next one, which is a mouthful if you want to try to say it, but it is something like Aldo Walsh Alphabet (phonetic); the piping, fitting, dynamic reliability research program, which was a significant effort between the NRC and EPRI to basic information about the seismic frigidity of different piping systems and components.

MEMBER POWERS: That work was done in or finished out I would say basically by the mid-1980s, and provided the basis for the recent work at ASME and the piping program and changing the Section 3 requirement, which obviously led to considerable controversy as to how much margin was actually there, and how much of it we could take advantage of.

Another significant element of this program was to get the fragility of electrical components, relays, racks, cabinets, switch gear, again a very significant program and provided significant input to things like the individual plant examination for external events.

MEMBER WALLIS: How about the effect on people?

MR. MURPHY: We really have not taken --

MEMBER WALLIS: How about on operators during an earthquake?

MR. MURPHY: That we have not gone into, and I will say specifically haven't gone into it in this program. I know that some work has been done in other parts of the NRC, looking at human response to off-standard events, and I have to say to some extent I am a little ignorant exactly what we have.

I know that the Japanese have done considerable work in this area as well, even to the point of putting operators on shake tables and seeing how well they can respond to simulated emergencies. I think they have actually put something like a simulator, although not like what we have at Chattanooga on a shake table, and try to understand how well the operators could then carry out emergency response.

MEMBER WALLIS: How about they might be if they have to move around and operate switches and stuff.

MR. MURPHY: The videos that made it into the popular press and that we saw at some stages, yes, it was more a matter that these four guys were just simply trying to hold on to the table, or the desk, while all the lights in the panels in front of them popped on and the alarms went off and that sort of thing.

But the bottom line results and the feedback through our system, I am just not that familiar with that. I will say that a lot of that information we became aware of throughout the cooperative program with NPECJ, which is the Nuclear Power Engineering Corporation of Japan.

It is there and if you want national laboratory operating for their regulator, MEDY, and we have had a very good cooperative program with them since about the early '80s, when we did an experiment with them on their large shake table.

And we have had an extremely good interaction with them over the years, and I think we can reasonably take credit for them going from proving tests to actual fragility tests.

In the past, they would take a piece of equipment, and let's say it was used in a facility, in a power plant, and it was designed for an SSE of .5, and they would basically test their equipment up to .5 and say, okay, we proved that it would handle an earthquake that it was designed for, and then they would stop the experiment at that sage.

And through our interactions, and I think we can take credit for this, they have gone from doing proving tests so much as in doing fragility tests. They will take that same piece of equipment and run it up to a half-a-g, and say, okay, fine, it didn't break.

Now they will continue running it up to 2 to 3g and maybe where it breaks. I was in Japan earlier in June, and they were doing some shake table tests on sheer wall models. The model was expected to break at about 1.4g, and the day that I was there, they ran the shake table test at the 1.4g and lo and behold it didn't break, and they recycled the system and ran it at 1.7g and it still didn't break.

And then they ran it up to almost 2g before the model collapsed. So it has been a very productive program I think for both of us to understand the fragility of some of these equipment, and to understand that it is important to understand what the margins are within the program.

MEMBER LEITCH: Could you say a word about the concrete anchorage, particularly the aging effect. Is there an aging effect?

MR. MURPHY: I have got to say to some extent that I don't know yet. One of the things that is ongoing today is a program in Brookhaven to look at five particular structures or components within a nuclear power plant; reinforced concrete walls, buried piping, tanks, concrete anchorages, and masonry walls.

The work has been completed on the reinforced concrete structures, and two steps down the list in things that will be done is to look at the capacity of degraded anchors.

We have a program that was completed about 2-1/2 years ago on developing basic information on how concrete anchors behave, particularly multiple anchors, where you may have 4 or 5 anchors in the concrete of a single type working together to hold a piece of equipment, or to hold up a series of pipe anchors.

That was some very -- I will say pioneering and very important work to develop basic capacity of these anchors multiplying in concrete, and that work has gone into at least a draft regulatory guide. Well, it is still a draft.

So the work is going from research to the regulation, and like I said, we are going back the extra step to look at how the aged anchors will perform.

MEMBER LEITCH: And that information, although not available on anchors yet, did I understand you to say that there is some information available on reinforced concrete walls?

MR. MURPHY: Yes.

MEMBER LEITCH: And do you see a significant aging effect there?

MR. MURPHY: There is an important phenomena happening there. What we have done was look at the degradation in the capacity of a concrete wall when it has been subjected to a particular level of degradation, and how much corrosion or a wastage of the concrete has happened.

And what we were doing was developing a tool so that the NRR, when a degradation phenomena has been identified, and a degradation site has been identified, we can take a look at it, and see how severe is this degradation.

And in effect put it into a code, and look at this to see what response, or how the response of that structure may have been changed. You may have a very large, ugly looking, falling wastage of the concrete in a rebar, but depending on where it has happened and how much is actually there, it may not be a significant phenomena as far as the safety of the facility is concerned.

So what we have done in effect is develop a tool with which we as the agency can evaluate a degradation, and what it means to the safety of the facility.

There was a program -- I will call it a companion program --at Oak Ridge, where Dan Knox, the investigator down there, evaluated for us different repair techniques, and what could be done, and how much recovery of the initial strength you could get by repair and replacement.

MEMBER LEITCH: We are obviously concerned about in the license renewal process as to how these passive structures behave after 40 years, between 40 years and 60 years. Is there any light being shed on that matter?

MR. MURPHY: I think the answer is yes, and there is light being shed, but I am not sure exactly how to respond to the form of the question. The information has been gathered from these programs has provided the agency to work in the evaluation.

I mentioned earlier the corrosion degradation that happened at the intake structures at Calvert Cliffs. There I think everybody is aware that the utilities decided that the easiest way to solve that problem was to do a repair and replacement of the structure, rather than try to argue how much capacity was there.

Like I said, the work that we have been doing provides us or the agency with the tools to do that evaluation, both as a structure has degraded, and potentially as the structure is repaired or replaced.

MEMBER ROSEN: I have one question about concrete anchorages. What is so different about nuclear plant concrete anchorages that we feel like we have to research those kinds of components?

Aren't concrete anchorages used in other structures where it would seem to me that the building codes and constructions would know how they work?

MR. MURPHY: Yes, and there is no doubt

that we do have an idea of how they work, and it is a question of how much capacity is there beyond the actual design levels of them.

There are at least, if they are not unique, there are different ways that the nuclear industry uses the anchorages that are not typical of commercial structures.

Like I said, we had a significant program to look at the capacity of multiple anchorage systems, and basically that information was not previously available.

It was not something that industry in one form or another thought was worth the effort to find out in detail what the fragility and what the margins of these systems were. And I will say that we got involved with what I believe was the University of Texas doing a specific program to look at these things in detail.

Okay. I will go on. So, basically after we had the seismic PRAs, we were interested, and industry was interested, in a methodology that could provide us information about the capacity of nuclear power plants without having to go through the extreme efforts that are associated with doing a seismic PRA.

On that basis, a couple of margins

programs, one at the NRC and one at EPRI, came into existence and were carried to fruition, where the NRC developed a Fault Tree-Event Tree type of approach to the system, and EPRI had what they called a success path, which identified basically what they called a hardened path that would tell us the facility could show down, safely shut down after the occurrence of an earthquake.

We made use of these techniques in the individual plant examination for external events, which was a very significant use of post-techniques.

MEMBER POWERS: Do the two methods, the NRC Fault Tree-Event Tree approach, and the EPRI success path approach, yield commensurate results?

MR. MURPHY: Well, when they have been tested against each other, and compared against each other, yes. Basically, it was one of those questions of, well, we invented it and so we will use ours.

But to the best of my knowledge, I think it was just one of the facilities that was examined under the IPEEE program that made use of the NRC fault tree method.

All others that made use of the margins methods used the EPRI methodology, and then obviously the others went to the seismic PRA, and I don't remember the statistics, but they were sort of on the order of 1-to-1; one PRA and one margins approach to it.

And I had mentioned umpteen pages back the SEP program, and that program identified about 27, I think, is the number, of major issues associated with seismic capacity of things within the nuclear power plant.

Many of those items were what we called the grand subsumption, where it subsumed into the IPEEE program and were resolved based upon the results of those studies for each of the facilities.

Let me speed up a little bit. One of the important issues is the soils structure interaction. Not only does the earthquake come along and shake the nuclear power plant, or the other pieces of the system, they in-turn shake back.

After they have been excited, there is a feedback system, and that feedback can be an extremely important component of the challenge to the nuclear power plant. So we have been involved for a long time, and up until today actually with programs to better understand the soil structure interaction, the SSI.

One of our initial efforts was with

Brookhaven and the development of the CARES code, which is a soil structure interaction code. It is also a general class of seismic ground motion response. We have been involved in two major international efforts to gain soil structure interaction information.

These two were the programs in Taiwan, one at Lotung, and the other later on at Hua Lien, where scale model nuclear structures were built on site and subjected to actual earthquakes from Taiwan.

That information, starting with the first one at Lotung, with a very, very soft soil, and that probably would not be acceptable in the United States; to a somewhat stronger soil at Hua Lien, that provided us with a level of information, or data point on our soil structure interaction capabilities at the soft soil end of the spectra.

And some work that we had been doing and is ongoing with Japan, where they have again built buildings, scaled models, in earthquake prone areas, and have recorded the ground motions there and the interactions with the structures.

Again, we are looking to build up and strengthen our capability to make predictions and understand how the two systems interact, and how the buildings interact, and how the buildings and structures interact with the ground motion.

The Japanese have carried it a little bit further also in doing a number of shake table experiments where they have built large silicon models, rubber models if you want, of the earth, that are approximately four feet tall, and maybe 15 feet in diameter, and on these they have embedded or placed models of nuclear power plant structures, and subjected them like I said to shake table excitation, to understand and to develop computer codes to predict the behavior.

We touched on this a little bit already. We have had Brookhaven specifically looking at the five structures that I mentioned. We have completed the reinforced concrete structures, and published that report.

So basically what we are doing there is looking at methods for detecting hidden degradation, and once we have found a level of degradation, understanding what the response of the structure of the system is to that degradation.

And then on a case by case basis to provide insight into the risk significance of that level of degradation. As I also mentioned, that we have looked at through Oak Ridge different techniques, commercially available techniques for doing repair and replacement of degraded systems.

MEMBER SHACK: How successful are you in monitoring the change in properties in some remote way? This was acoustic? You sent sound waves in and then sought changes?

MR. MURPHY: At this time we do not have an on-line or a real time technique for monitoring the changes in a structure. That we are still in a position where we have to find -- well, not we, the utility owner, has to observe some indication of a degradation.

Then there are numerous techniques, including acoustics, to try to understand what has happened to the structure that is unseen. I mean, it is serious enough that in some cases the protector of last resort is a jackhammer, if indeed there are indications of potential degradation.

Sometimes you can't find enough information from remote techniques and you have to resort to a jackhammer, and going in and finding out what has happened, or if anything has happened. I have in the back of my mind that that approach has been used in a number of cases.

MR. DORMAN: Let me just clarify that the program that is going on now is not for identifying the degradation. The program that we are doing right now is to assess the margins associated with identified degraded conditions.

So we are developing methods to be used for assessing degraded conditions that have been identified.

MEMBER SHACK: No, but I am just pointing out again my license renewal thing. I come up, and I have a structure, and somehow I have to measure its state of degradation, and then I have to say what does that do.

MR. DORMAN: Right.

MEMBER SHACK: And you are telling me that we actually can do both of those steps at this point?

MR. DORMAN: The work that we are doing has looked at that and complied the LER history and the information on existing identified degradations. So we are looking at assessing degradation mechanisms that we do have the capability to identify and in fact have identified.

MR. CHOKSKI: Let me -- this is Nilesh Chokski. We had a program separate of this program, which was akin to the nuclear plant aging program, which looked at this issue of the degradation mechanic techniques, and a lot of this was pertaining to the program industry programs for looking for license renewal.

This particular program that Dan has described is to looking at what happens to the structural response, and that is going to be an issue with the new reactors. The Japanese have installed quite a few on-line monitoring for (inaudible) and rebars and things.

So we will have to be looking at those techniques for the applications. So I think all of those three pages are things that need to be looked at.

MR. MURPHY: Okay. The next --

MEMBER LEITCH: Let me ask perhaps just a very fundamental question. We have billed this as a tutorial and so it seems to me that some plants are built on rock.

MR. MURPHY: Yes.

MEMBER LEITCH: I am familiar with a plant that is built on rock, but then last year we went down to Waterford, the ACRS did, and they described this thing as being built on a big bathtub they called it.

I don't know if that is an accurate

portrayal, but that is how they described it. That as though there is no rock involved in that situation; and so how are those two different kinds of designs respond in a seismic event?

In one sense, it seems like you are trying to restrain the structure, and in another sense you are kind of letting it slosh around. Is that a correct perception? Could you discuss that issue a little bit?

MR. MURPHY: If we are a little bit careful about what this sloshing verb means --

MEMBER LEITCH: I guess that is not the right technical term.

MR. MURPHY: But if you think about sloshing in a very stiff -- well, in a medium, yes, there is some -- I will say similarities. If you are not aware, the Japanese at this stage will only build on rock. Some of their rock is a little bit softer than we would call rock.

But if you are building a structure on rock, you have got probably a direct ground motion input. The ground motion is coming to the base of the structure directly from the rock.

What happens with a facility that is built either on soft rock or on soil, is that there is an interface where the ground motions have been sufficiently transmitted through solid rock to an interface.

Now, that interface may be for soft rock or it may be soil, but the soil has the ability to basically change the frequency input of the ground motion, and it also has the ability to change the amplitude of the ground motion.

So that is one of the things that the CARES program does. It takes the information that comes from the hard rock interface, and is transmitted to the soft rock or to the soil, and then looks at the amplification, and the effect in frequency of the ground motion that comes in.

That then gives you a different earthquake spectra that is inputted through the structure, and to make a long story, we have done a lot of work and the NRC has a good program and methodology for understanding the change in the spectra that occurs, and the things that the soft rock or the soil does to the ground motion as input to the structure.

Again, this is where you are talking with a soft rock or a soil, and it turns out that the structure then is excited just as the ground motion had been excited, and feeds back into the soil or the soft rock.

So again it changes the spectra now that the facility is seeing, and you want to say in the second or two seconds of ground motion. There is a time lag and a feedback, and so that there is what can be an extremely complicated interactive system to feed in ground motion, that then has the ability to cause damage to the components and systems within the facility.

The NRC has looked at this for a long time and is still looking at it, and we probably have a very good, but somewhat conservative, system to understand that feedback process, that sloshing of the earth around the nuclear power plant.

MEMBER SIEBER: I would imagine --

MEMBER LEITCH: I guess in a general sense that you would rather see a plant built on rock than in that kind of a situation, or is it hard to generalize?

MR. CHOKSKI: Could I answer that? The basic phenomena between the rock and soil is that these are massive structures. Once you see the difference in the ground motion, filtering through soil, it will have a much more -- it will filter the high frequency components.

The second thing is that this massive structure feeds back energy, but this energy also dissipates through the soil medium. So you are going to increase the energy loss, but you are going to have rigid body motion because of the soft foundation.

So the displacements of the structures are generally higher on a soft soil, but the force is going on to the structures are smaller than on hard rock.

MEMBER LEITCH: That's helpful. I appreciate that. That's good.

MEMBER SIEBER: I could picture harmonics being developed because you are changing the frequency, and so you have the basic frequency, which is the ground motion in the rock, plus a new frequency, a higher frequency, that comes from soil structure interaction.

So if one wanted to look at acceleration from a mathematical standpoint, you would actually want to take some of the absolute values of each of these harmonic components; is that correct?

MR. CHOKSKI: Yes.

MEMBER SIEBER: And I take it that you can derive these properties just be looking at core samples from the building?

MR. CHOKSKI: Yes, there are a number of geotechnical requirements, and we have a regulatory guide on that.

MEMBER SIEBER: But that would vary depending on how deep you were in the ground, right?

MR. CHOKSKI: Yes.

MEMBER SIEBER: Thank you.

MEMBER WALLIS: And it changes if the soil is very wet, too.

MR. MURPHY: Yes, and there is a difference if you are talking about a saturated or a liquefiable soil, and you have basically got a situation where if you know that is what the case is, you are not going to build there.

MEMBER WALLIS: Or you are going to avoid it happening if you do build it there?

MR. MURPHY: That means an active system to -- if you want to say de-water or to freeze it, that is probably not practical, at all practical for a nuclear facility.

Now in the next viewgraph we will take a look at some of the regulatory products and outcomes from the research programs. As I indicated earlier, I think that the earthquake engineering and the earth science program provided the basic information data that was used in developing the seismic PRA and margins methodology.

And there we are talking about the characterization of the seismic hazard and the fragility of the components, and systems, and structures, that make up that particular nuclear power plant.

We have provided a seismic assessment methodology that has not only been used for nuclear power plants, but has also crept into Part 72 and other parts of the NMSS program where you are concerned about seismic.

A probablistic seismic hazard methodology was used in the seismic hazard assessment for Yucca Mountain.

CHAIRMAN APOSTOLAKIS: But I got the impression when SHHAC was in session that the earth breaking engineering community at large are not too excited by probablistic analysis. Is that still the case?

I mean, I was very surprised. I thought it was only in the nuclear business where we had this conflict between deterministic and probablistic analyses, and here are these guys saying, no, it is Cornell and his followers who do this, who would do something else. Is that still the case?

MR. MURPHY: Not really. There has been probably a significant growth in understanding of what probablistic hazard analysis is all about. The Geological Survey provided one of their -- I will say their first modern probablistic assessment in '96.

They have put that out for comment and used by engineers and so forth, and actually when we get a little bit further down, or have you been peaking ahead at the viewgraphs, we are talking about trying to cooperate with the Geological Survey in looking at the application of the SHHAC methodology.

They have a program where they are going to release another set of assessments probably in September of this year. We had a briefing from the project manager and a number of managers from the Geological Survey back at the end of June as to what their methodology looked like.

But your assessment -- and not to pick on you -- it probably about 5 years old. That there has been a lot going on with conventional structures taking probablistic ideas into mind.

Now there is no question that there are still folks out there that say what do we need this stuff for. It is just going to confuse us and I don't understand what boxes you are turning the crank on.

CHAIRMAN APOSTOLAKIS: It is very interesting, because the first guys to really use probablistic methods in a serious way it seems to me were the civil engineers. What was the name of this professor from Europe who came to George Washington? George --

MR. CHOKSKI: Hordenfeldt.

CHAIRMAN APOSTOLAKIS: I mean, he was already doing these things in the late '50s and early '60s, correct? And in this community there is still controversy.

So it shouldn't make us feel very bad, right? We only started in 1975. In fact, some of the better books in fact are written by civil engineers. And there are two things that you have not mentioned, and I don't know why.

The seismic contribution of risk is among the top 2 or 3 sequences for almost every fault, right?

MR. MURPHY: Right.

CHAIRMAN APOSTOLAKIS: And the other thing is that the contribution of SHHAC, and my colleagues here may not know this, but it is not just seismic. They really revisited the full issue of expert opinion and recitation and utilization, which may have other applications as well.

And they built on what had been done before by 11.50 and other studies, and they went one step beyond, or two steps, or whatever.

MEMBER POWERS: Or one step astray.

CHAIRMAN APOSTOLAKIS: Right. Right.

MR. MURPHY: Are you going to take that laying down?

MEMBER ROSEN: More like water off a duck's back.

CHAIRMAN APOSTOLAKIS: I thought that they did a hell of a job actually.

MR. MURPHY: But no bias, right?

CHAIRMAN APOSTOLAKIS: No. I mean, I have a student looking at those methodologies now, and I don't think there is anybody that could have done any better, especially with the recognition that you need with PFI, and it is really a major step forward, and somebody dare say, look, this is the way that it is, because we were trying to be too scientific before in our objective. Anyway, let's move on.

MR. CHOKSKI: That is the interpretation of the ANS standard, and the ANS standard talks about SHHAC matters.

CHAIRMAN APOSTOLAKIS: Well, the Department head is the chairman of the committee.

MEMBER POWERS: And we assume that the NRC is smart enough to take exception to that.

MR. MURPHY: All right. Where was I?

CHAIRMAN APOSTOLAKIS: Andy, you have 10 minutes.

MEMBER POWERS: I would very much like to get into the needs area.

MR. MURPHY: Okay. The bottom line is you have seen where we have contributed at the current time, and one of the batch of the new and revised reg guides that we were talking about is that associated with concrete anchorages and how to do the geotechnical work.

And we will bring you up to date based upon the work that has been done. Budget history. In the past, particularly for the earth science part of it, we made a significant contribution there.

CHAIRMAN APOSTOLAKIS: Very good.

MR. MURPHY: Current activities. Current activities are fairly limited at this moment. We have got a program in California, where we are looking at the propagation of ground motion through a shallow soil model. A lot of that is devoted to better understanding the ground motion propagation models.

And there are two specifically competing models on the source spectra for earthquakes, and one involves a single fall-off with frequency in a one corner model, and the other is a two corner model.

The next item refers to work that we are having the Geological Survey do for us on characterization of faults in the Eastern United States, and cooperative work with the Japanese is an important item being carried out for us by Brookhaven.

And we are working to get these items into regulatory products and useful things. The easiest one to take a look at, or the easiest two to take a look at are the Geological Survey work, which is telling us about the characterization of sources in the Eastern United States, and the work with the Japanese is looking at fragilities which feed directly into the probablistic hazard assessments, and the PRA work.

CHAIRMAN APOSTOLAKIS: Now, Andy, is any of this work going to reduce the uncertainties in risk assessments?

MR. MURPHY: Yes.

CHAIRMAN APOSTOLAKIS: What can you do with fragility to reduce them?

MR. MURPHY: Well, part of it is that there are different components that we are looking at, and the methods that we have available to analyze these beforehand, and go to not having to do a bunch of this strong shaking testing in the future.

And I will say that as far as reducing uncertainties with the hazards, we are having a better understanding of what the sources are, and what the sources are capable of.

CHAIRMAN APOSTOLAKIS: Okay.

MR. MURPHY: Future funded activities. Moving right along, basically that the three items that we have listed on the previous viewgraph, plus the SHHAC implementation, are the things that are currently on our plate. The next two viewgraphs provide what we have characterized as the continuing and emerging issues.

MEMBER KRESS: What is in East Tennessee?

MR. MURPHY: East Tennessee is -- well, that is where we keep Oak Ridge. The experts in the area have looked at that and they feel that there is a change in the rate os seismicity in East Tennessee over the last 20 years, compared to the previous.

And on that basis, the trial implementation that Livermore did for the SHHAC methodology included Watts Bar, and based upon the increased importance, and the expert interpretation that the area is capable of larger earthquakes that we had looked at or had seen there in the past, a magnitude of 7 to 7-1/2, which are very large earthquakes, and based upon the structures that they think are there, that has raised the apparent or perceived hazard for the Watts Barr facility, and led to the -- well how do you make a GSI?

The proposing of a GSI in that area, and again it is a question of new interpretation of data and the implications for Watts Barr and other facilities in the southeast.

CHAIRMAN APOSTOLAKIS: Do we know why the seismicity rate has changed?

MR. MURPHY: No.

(Discussion off the record.)

MR. MURPHY: The next interpretation, the importance of the large earthquakes and the ground motion and the large two Turkey earthquakes and the earthquakes in Taiwan.

I talked about our coordination with the Geological Survey EPRI on the updating of the probablistic sizing hazard assessments, and an ongoing program so that we can work together and maybe not necessarily come up with next time.

And we talked about putting the pebble bed reactor just below or deeply buried, and what are the implications for that as far as the ground motion input, and the soil structure interaction between the buildings and the interconnects between the buildings.

Questions again if we are doing something like the AP-600 or the AP-1000, if you put the cooling reservoir on the top of the structure, what is that going to do for us or to us as far as our ability to calculate the response.

MEMBER POWERS: You have mentioned here buried or deeply embedded and spoke of it in terms of the pebble bed reactor. In the thinking about security issues since September 11th, thoughts have come up about a very deeply buried nuclear structure. Is that something potentially on your plate?

MR. MURPHY: If you want to say it is on there, it is on our cognizant horizon. How's that for a phrase?

MEMBER POWERS: That's a good word. I like that.

MR. MURPHY: At this time, we have not proposed going further with that. I think you may be aware that there was a large program back about when

I joined the Commission in the late '70s about potentially underground facilities.

If we go to looking at deeply buried -- no, buried or deeply embedded, if we can find the results from that work, that certainly will feed into the process.

MEMBER KRESS: To follow up on that, was seismic hazard risk a consideration for Yucca Mountain?

MR. MURPHY: Yes, very definitely. Yucca Mountain is a seismically and in some minds a potentially volcanically active area. There was a magnitude of 4-1/2 or 5 at virtually Yucca Mountain within the last month.

CHAIRMAN APOSTOLAKIS: And a volcanic analysis was done using the SHHAC methodology, right?

MR. MURPHY: Yes, as well as the earthquakes.

MEMBER POWERS: Of course, the question always is if there was an earthquake or a volcano at Yucca Mountain, how much improvements would it actually do?

MR. MURPHY: Fortunately that wasn't recorded, right?

MEMBER KRESS: One of our best lakes in

Tennessee is a result of an earthquake, and it can improve things.

CHAIRMAN APOSTOLAKIS: Now, you know it is risk-informed and performance-based, you know that? We found that out yesterday.

(Discussion off the record.)

MR. MURPHY: Okay. The next to the last slide talks about the performance-based risk-informed and performance-based design items. We are looking at with a revision to Reg Guide 160, which is the design spectra, whether or not we can do something with hazard and risk, and making that hazard and risk consistent.

We have been looking at the performance based targets and using things like the (inaudible) to design facilities, and one of the things that has been on our plate is to look at the code and standards, and to see how they need to be updated to take into consideration the risk-based approach to things.

The final viewgraph sort of takes a look at what the current outlook is, and here we basically say that the earth science and engineering research programs has either fallen to or is about the level of core confidence.

That can be best understood by taking a

look at the succession planning for the contractors and the staff; that we are at a critical state where the defense in depth really doesn't exist anymore.

You have got one or two individuals that have the experience and the technical confidence at this stage to address the issues that are on our plate, or will be on our plate shortly.

That if we have a nasty car accident, let's say, and we lose some of these individuals, we are going to be in the position of needing 3 to 5 years to reestablish that. I am not saying that there are not competent people out there in universities and the laboratories, but at this stage their base of experience and interactions with the Commission and the Commission problems is extremely low or too low to be of some value to us.

MEMBER KRESS: On your early site permit sub-bullet.

MR. MURPHY: Right.

MEMBER KRESS: If you don't know what kind of plant is going to be there, and the site has already had a seismic qualification for the plants that are there, what do you do? I mean, you don't know what plants are going to be there for design, but it is just that we want to use this site, and we will tell you later what kind of plant.

MR. MURPHY: That is where you get into the certification of the facilities issue. That for a certified design, that has to be capable of -- what is the right verb -- withstanding or continue to safely operate within our criteria if the ground motion was established in the early site permit is subjected to that.

MEMBER KRESS: I see. So you take care of that with ITAC or something like that?

MR. MURPHY: Right. I believe that one of the EPRA guidelines or requirements for the advance reactor thing-of-a-jig a few years back when we went to advanced reactors once before, that the advanced reactor design was supposed to be at a minimum of a 0.3g level with a particular response factor.

So then it becomes incumbent upon the utility to select a facility or power plant type that will meet the requirements of the site.

MEMBER KRESS: Well, when they give approval for an early site permit to somebody like Exelon that comes in and says I want to use this site, does this approval say that you can use this site, but the design that you put there has to meet the seismic --