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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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SUBCOMMITTEE ON ADVANCED REACTORS

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TUESDAY,

JUNE 5, 2001

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Auditorium, Nuclear Regulatory Commission, Two White Flint North, 11545 Rockville Pike, Rockville, Maryland, at 8:30 a.m., Thomas S. Kress, Chairman, presiding.

COMMITTEE MEMBERS PRESENT:

THOMAS S. KRESS, Subcommittee Chairman

GEORGE APOSTOLAKIS, ACRS Chairman

MARIO V. BONACA, ACRS Member

F. PETER FORD, ACRS Member

GRAHAM M. LEITCH, ACRS Member

DANA A. POWERS, ACRS Member

WILLIAM J. SHACK, ACRS Member

COMMITTEE MEMBERS PRESENT (Continued):

JOHN D. SIEBER, ACRS Member

ROBERT E. UHRIG, ACRS Member

GRAHAM B. WALLIS, ACRS Member

B. JOHN GARRICK, ACNW Chairman

C-O-N-T-E-N-T-S

PAGE

Introduction, Chairman Thomas Kress 340

Presentation by Ron Simard 346

Presentation of Dr. Neil Todreas 368

Presentation by Dr. Andrew Kadak 422

Presentation of George Davis 469

Presentation of Dr. Michael Golay 480

Presentation of Dr. Charles Forsberg 533

Presentation of Adrian Heymer 580

Commission Discussion 627

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

(8:31 a.m.)

CHAIRMAN KRESS: Will the meeting please come to order?

I have to read this mandatory statement. This is the second day of the meeting of the ACRS Subcommittee on Advanced Reactors.

I'm Thomas Kress, Chairman of the Subcommittee.

Subcommittee members in attendance are ACRS Chairman George Apostolakis. That's him right there.

DR. APOSTOLAKIS: On time, as usual.

CHAIRMAN KRESS: On time and under budget.

Mario Bonaca. I almost missed that one.

Peter Ford.

Graham Leitch.

Dana Powers.

William Shack.

Jack Sieber.

Robert Uhrig.

And Graham Wallis.

Also attending is the Honorable ACNW Chairman John Garrick.

The purpose of this meeting is to continue our discussions of the regulatory challenges for future nuclear power plants. The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions as appropriate for deliberation by the full committee.

Michael T. Markley is the cognizant ACRS Staff Engineer for this meeting.

The rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the Federal Register on May 10th, 2001.

A transcript of the meeting is being kept and will be made available as stated in the Federal Register notice.

It is requested that speakers first identify themselves and speak with sufficient clarity and volume so they can be heard. If the people from the audience wish to make comments, ask questions, and so forth, please use these microphones on either side and also identify yourself and speak with sufficient clarity.

We have received on written comments or request for time to make oral statements from members of the public regarding today's meeting.

The morning session up until lunchtime

will be here in this auditorium. The afternoon session, we lose this auditorium, and we have to move. The afternoon session will be in the ACRS Conference Room, T2B-3 on the second floor. I think everybody knows where that is.

I don't have any additional comments. Do any of the members, co-chair have any comments?

(No response.)

CHAIRMAN KRESS: Seeing none, we will now proceed with the meeting and call on Ron Simard of NEI to start us off this morning.

MR. SIMARD: Thank you.

Dr. Kress and I were just reminiscing. When we first met each other 30 years ago, he was working on Generation IV concepts down at Oak Ridge.

This is probably not the most interesting title for this talk. Sometimes I've taken to giving this talk and calling it "The Future Isn't What It Used to Be," because -- Jenny, would you go to the first?

Just a reminder as to what's changed, and today let's try to understand why it's changed and changing so rapidly, and then I'll try to tie that back to what it means in terms of challenges to the NRC in being able to respond to those changes.

But just to summarize what's different about out view of the future now is it's clear that we'll need more electricity. This has been coming for a while as demand has grown, as we've eaten into our reserve margins. We've seen it in the annual projections by DOE, the Energy Information Administration, and now we have the National Energy Policy out, which makes it pretty clear.

And the problem we have with that is that we are looking at -- even at the lower end of DOE's estimates, we're looking at increasing our generating capacity by almost 50 percent. Fifty percent of a big number is a very big number, and it's not going to be possible to meet it entirely with fossil fuels, whether it's natural gas or coal.

It's becoming increasingly clear that there are long-term concerns about the price of the fuel, as well as the physical inability to add that many more megawatts solely of fossil fired generation without violating clean air constraints.

And, on the other hand, we're seeing an increased prospects for nuclear energy partly because their economics are being perceived as potentially better in the future and partly because with restructuring in the industry and consolidation, we're moving toward a situation where a number of large generating companies, a small number, are increasingly moving towards operating the majority of our plants.

Now, I think that this is partly contributing to the increase we're seeing in the performance of the plants, this consolidation of expertise, but it also means looking forward that these folks have the capital to consider adding more nuclear plants to the fleet.

We're also seeing a significant change in public support and certainly political support. I think Thursday of this week, for example, you'll see Senator Bingaman's bill introduced, which will help expand the nuclear work force not only for the industry, but for the NRC, the full range of the work force, and the public support has completely reversed itself even in California where now 60 percent of Californians tell the field poll -- this is not an NEI sponsored survey. This is an independent poll -- that more nuclear energy is going to needed.

And finally, and this is what we're here to talk about today, that last bullet, the potential is there for increased certainty in the licensing process, and this is important because it's a new business environment, and we have to be able to have certainty with respect to what it's going to take to bring these new plants to market now in a restructured environment.

Remember that 60 percent of our nuclear plants today, 60 out of 103 units, are operating in states where electricity restructuring has occurred. So there is a fair amount of effort underway, which I'll try to summarize for you, to prepare for what we know are near term business decisions.

We know that several companies are beginning today to make their business plans and their decisions about whether to add more nuclear to their fleet, and, Jenny, let's go to the next slide. I think the next slide might be even better to show you the scope of activities underway.

You have a copy of this in your handouts, and what it does is it tries to tie together the activities I just showed you on that previous slide and show you how they all come together in an integrated way.

Up at the top of the slide there, we need to change the very top of that slide. The very top box refers to a seminal document that we've been working from for the last few years. It's a document that sets the direction for nuclear energy going forward. There's a new document. As of last month we have something called "Vision 2020," which I'll talk about a little bit toward the end here, but what I'd like to show you here on this slide is that from that "Vision 2020," or from that statement, which by the way has been bought into by the NEI board of directors, that means the chief executives of all the generating companies and a fair mix of the other companies across the industry that belong to NEI.

At that level of industry leadership they have bought into this, and in fact, what you'll see is that the NEI business plan, our whole plan for next year and our budget, will, in fact, mirror this "Vision 2020." It will conform with the objectives that we're going to be talking about today.

And under that we have a plan, and this plan assigns work in four areas, and the intent of this work is to take on as many of the open issues as we can in the next couple of years roughly and provide that certainty that the executives are going to need in their business decisions.

I might just point out on the extreme right-hand side, I think one of the most challenging things for us is the infrastructure, and I'm talking here about not only the people, but also the manufacturing capabilities, the equipment suppliers, the engineering services.

We had a kickoff meeting of a task force. It's the second one in from the right, the work force issues task force, at NEI yesterday, which has representatives from the generating companies, the labor unions, the contractors who supply contract personnel to our plants, NRC and DOE, and the purpose of that is to identify the manpower needs for the entire industry, all aspects of running this operation in the future, and then to identify where the gaps are, and finally to lay out actions, how we're going to fill those gaps.

Now, going back to the licensing area, that box in the middle, you're going to hear about that later today, the new plant regulatory framework. That's the subject of a separate presentation this afternoon.

Let's focus on the other boxes over there. Jenny, would you please? Let's go to the next slide.

And let's talk about licensing, and in three areas in particular. We're talking about the licensing needs in the very near term with respect to working out the Part 52 implementation details. Also, with respect to not only assuring the safety, but how other types of NRC regulations will apply to these new types of designs, the kind of designs you heard about yesterday afternoon.

And finally, reflecting the fact that the next group of plants that's going to be brought to market may not be brought to market by regulated utilities in a cost and service environment. Rather, they will be merchant nuclear power plants competing on their own merits. They're going to sell all or part of their electricity to the market, and they're going to be run by some new approach to the ownership and risk sharing in these projects.

So let's talk about those three areas. With respect to Part 52, let's go to the next slide, Jenny. Maybe it's even better to look at this in a picture.

Compare the top and bottom here. What we have on the bottom is an efficient new approach to licensing future plants, and what's relevant to our theme today, talking about the uncertainties in cost and schedule, is the fact that this framework holds the promise for being able to bring these plants to market with a certainty we've never had before.

On the lower left-hand side, with design certification, which the NRC has now certified three advanced designs; with design certification, we also have this concept of ITAAC, inspections, tests and analyses, that you can perform and then acceptance criteria that show that, in fact, you've built the design that was certified.

That's key because at the end, the bottom right-hand side here, the focus in post construction hearings is on whether or not those acceptance criteria have been met.

So with design certification and the fact that it's been applied now three times, I think we've made tremendous progress. What still has to be tested though are the other two key pieces of Part 52.

On the bottom left, early site permitting. So one of the things that we currently have underway are interactions among the industry and between the industry and NRC and public meetings to work out exactly how early site permitting will apply.

For example, if we're going to add additional reactors to sites that already have reactors up and running, sites that have already been reviewed by the NRC, the environmental characteristics are know, for example.

But then the other key and the other challenge to the NRC now is working out the rest of that line along the bottom. Once the construction permit and operating license has been granted and once the licensee has this extremely effective construction schedule now, which is capable of bringing these plants to fuel loading in three years or less, how can the NRC superimpose its inspection process, and especially how will they, beginning for the first time, use this -- verify that, in fact, the ITAAC had been met?

So I think one of the larger challenges that we're working on today is construction inspection and ITAAC verification, and that's key. It's key not only to being able to meet the licensee's construction schedule, but, again, it's key to that arrow on the bottom right, to being able to demonstrate to all of the stakeholders here, the licensee, the NRC, the public, all of the stakeholders, the key to being able to demonstrate clearly and unambiguously that the acceptance criteria have been met.

This is the second area we talked about. Not only are these designs likely not going to be brought to market by regulated utilities who are going to put them in a rate base, get a guaranteed rate of return, but we're now, as you saw yesterday, talking about different designs. They are not necessarily light water reactors anymore.

Some are. We have three advanced light water reactors that are certified. They're on the shelf. They're ready to go, but other designs, like the ones you heard yesterday are modular, for example, and there's a list of four questions you need to ask.

If it's not a single reactor unit anymore but a series of modules, well, then how do some of these NRC regulations apply? For example, you need to bring clarity to whether or not you can issue one license for five, six, seven, ten modules at the site.

You also have to clarify the requirements under Part 140 or Price Anderson.

That third bullet is key. What about the annual fees, which is on a per reactor basis?

And then finally, the NRC regulations are quit specific as to the number and qualifications of people in the control room.

Similarly, in the second bullet, if there are gas cooled designs, the regulations, for example 5075, currently give estimates for how much money you'll need to set aside over time to decommission a PWR or BWR. What about a gas cooled reactor? What about the generic environmental impacts which are in Part 51, those two tables that you see there?

And finally, what about the fact that you're going to have to redefine what are the appropriate actions to take as part of your emergency plan?

On the next slide, here's the third example now. Here's yet a third example of a number of issues that need clarification by NRC, given the fact that, again, these are not necessarily regulated utilities applying for a license.

So if it's a merchant plant, for example, some of the issues that you see currently being discussed and need near term resolution are the previous requirements for an anti-trust review, the requirements for NRC to determine the financial qualifications, and finally what mechanisms are appropriate in terms of setting aside that money we talked about a minute ago for decommissioning of the plant.

So those give you examples, I hope, of the types of challenges that are before us. Now, let's just remind ourselves of the urgency. If you believe DOE projections, and, by the way, you shouldn't because they've been consistently low. For the past ten years, their annual projections have been on the low side, but let's take them at face value.

At their low end of their projections, we would need to add 400,000 megawatts of new capacity to the grid by 2020. Now, today 30 percent of our generating capacity is non-emitting. It's nuclear; it's hydro and some renewables.

Now, if all you wanted to do was maintain that 30 percent contribution to avoid getting into even more problems with clean air, you'd actually have to add 60,000 megawatts of new nuclear, 60,000 assuming you can get maybe another 10,000 megawatts out of up rates, 50,000 new.

That's the basis for "Vision 2020." That's what the industry announced last month at the Nuclear Energy Assembly. That's what's going to drive us to the future.

Could you raise it a little bit, Jenny? Are you able to?

DR. POWERS: There seems to be a body of opinion that takes issue with this though. I can't reproduce their arguments, but they seem to think that maybe we don't need that much electrical energy, and that we, in fact, can achieve the necessary energy supplied by conservation.

MR. SIMARD: No question that conservation and efficiency are important, but it's folly to think that you're going to conserve your way out of having to add almost a 50 percent increase.

I mean the gains that we have made in conservation have been impressive, you know, at times, and efficiency has really helped quite a bit, but there's no way that you're going to conserve your way out of the low end of this projection without disruptive impacts on the economy.

So, you know, take issue. You don't believe we need 400,000 megawatts? Okay, fine. Cut it in half. Let's suppose that we're able to bring the sort of passion to this that we brought to the Manhattan Project, and we're able to achieve unprecedented levels of conservation and efficiency and shave that in half.

DR. POWERS: You don't look like you're intimately familiar with the passion of the Manhattan Project.

MR. SIMARD: Well, seriously, I think that what you find now across -- yes, it's true. There are still some people who will question that, the need to have that much electricity and they might even go so far as to say that we can keep our current demand steady. I don't know.

But you don't find them having prominent roles in policy making anymore. What you find among the policy makers, whether you read the administration's national energy policy or whether you look at the Nuclear Caucus in the Senate or the House Nuclear Issues Working Group, when you look at the bills that are currently out there from Senator Dominici, Bingaman, Murkowski, Mr. Gramm, you see a growing consensus, I think, among the policy makers that this sort of aggressive action is going to be needed.

I mean this is what we could do. To maintain that 30 percent, as you work your way up the bottom here, there's a small yellow band, which actually it's small on the scale, but 10,000 megawatts from power upgrades is actually pretty substantial.

And then you see what would have to be added, some 50,000 megawatts, and again, that's just to maintain the brackets there. That's just to maintain the current contribution and to avoid getting into even more trouble with clean air.

So let me just summarize then over the next couple of slides. The future isn't what it used to be because I think the consensus is here now that the demand will grow, and we used to talk about the nuclear option. It's not an option anymore. It's an imperative.

The business case for new plants is pretty clear, but we have to have cost and schedules known to a greater degree of certainty than we ever had before, which leads us into the challenge for the NRC because, as you saw a minute ago, the ability to bring this plant to make depends upon being able to work out these Part 52 implementation issues in a timely manner, and having in place efficient and, Commissioner Diaz's word, "scrutable" processes for early siting and licensing and construction inspection.

And I think what's emerging here from this day and a half is the challenge for NRC to be able to respond to this with a whole new focus and discipline and efficiency.

Thank you.

DR. POWERS: One of the persistent problems that we encounter when new things are brought to this particular body is the documentation is incomplete, documentation is not rigorous. Those kinds of things slow the process substantially.

Is the industry doing anything to try to address those kinds of questions?

MR. SIMARD: I think the challenge on our side is to bring in an unprecedented quality of application. On our side, we need to bring the NRC the highest quality information and application.

And I think what you're seeing both with the Westinghouse and PBMR North America International with NRC now is an effort early on to really clearly identify exactly what the staff needs are going to be to be able to do their review.

So I think that's encouraging, but you're right.

DR. POWERS: For heaven's sake, solve the momentum equation properly.

MR. SIMARD: You're right. We need to do better, too, on our side.

CHAIRMAN KRESS: Ron, one of your slides pointed out some of the regulatory challenges associated with multiple modules on a given site, how you deal with that with respect to site permitting and certain financial issues associated with that. It seems obvious to me that what you should do is get a site permit for the maximum number of modules you expect to put on that and call it one facility.

Is that something your guys are proposing or is that --

MR. SIMARD: Yeah, and maybe -- in that

area maybe "challenge" is too wrong a word here. Maybe we're getting carried away by the theme of the workshop here. Some of these things ought to be fairly straight.

CHAIRMAN KRESS: Yeah, that one looks pretty clear to me.

MR. SIMARD: But the point is they do though require either a clarification or a change to the current NRC implementation requirements. So, no, I think that's a good point.

Some of these shouldn't be challenges. They're pretty straightforward.

DR. APOSTOLAKIS: In one of your earlier slides on new licensing process significantly reduces project risk where you have the chart, maybe we can go back to it. They're not numbered, but, the heading is "new licensing process significantly reduces project risk."

MR. SIMARD: Yeah, it reduces the perceived business risk on the part of the licensee, and it certainly provides for earlier and more meaning parts of --

DR. APOSTOLAKIS: It's the fifth or sixth from --

MR. SIMARD: Yeah, she's got it now.

DR. APOSTOLAKIS: Oh, yeah, that is the one.

When you say at the bottom here "acceptance criteria met," I guess the acceptance criteria, do we have those now or --

MR. SIMARD: Yes, in the three designs that have been certified, a key feature and a high level of detail in those certifications are the ITAAC. So they're clearly specified. In the ABWR, for example, the high pressure core flooder system, I understand there were 31 separate ITAAC that clearly focus on the performance of a pump, for example.

What inspections or tests will be done on that pump and what acceptance criteria will be necessary to show that, in fact, that pump is going to deliver the amount of water you need at the time you need it?

So in the design certification, a key feature of them has been these ITAAC. We need to add a few more that are site specific when the licensee brings you the application, but --

DR. APOSTOLAKIS: So in terms of Part 52, which you cited as one of the major challenges, the implementation of Part 52, and if I look at this particular chart, where does the implementation of

Part 52 come into the picture? Just the whole sequence?

MR. SIMARD: Well, there are actually three pieces to Part 52. The bottom left there, there's one that outlines design certification. Then there's one that outlines early site permitting, and then in the middle there on the bottom, there's one that talks about the conditions on granting a construction permit and operating license.

And then finally it also covers at the end of construction and prior to start-up the basis for the NRC determination that the plant is ready to go.

DR. APOSTOLAKIS: Well, yesterday there was a lot of discussion of using risk information in all of this. So if I were to choose one of the designs that have not been certified yet, then the potential for using risk information is on the left where it says "design certification"?

MR. SIMARD: Oh, no, certainly. But what about all the way across?

DR. APOSTOLAKIS: All the way.

MR. SIMARD: Yeah, when the NRC has to dust off its construction inspection and program and apply it now to these new designs, this new environment, but with the knowledge that we've gained over, you know, the past 30 or 40 years, it certainly would make sense to focus on the aspects of construction and the completion of SSCs that are most important to safety, and I think in our interactions with interactions with NRC on this subject, which are about to begin this month, we'll certainly be looking at it from our point of view.

DR. APOSTOLAKIS: So we'll hear more about this this afternoon, I understand, right?

MR. SIMARD: I don't know that you will. You know, from Adrian Heymer you're certainly hear about the proposal that we have in mind for the overall regulatory framework, but in terms of the specifics of how NRC might modify the inspection manual --

DR. APOSTOLAKIS: No, no, no, no.

MR. SIMARD: No, that's still something that needs to be worked out.

DR. APOSTOLAKIS: Sure.

CHAIRMAN KRESS: Any other questions from the audience or other members?

DR. APOSTOLAKIS: There is one here.

CHAIRMAN KRESS: Ah, good.

MR. ALLEY: Neil Alley.

In your projections for energy demands

looking forward, what assumptions did you make about plan life extension?

MR. SIMARD: You know, i'm not sure. If you're asking specifically about "Vision 2020" and how we're going to meet the need for 60,000 new megawatts, I think that we assumed almost all the plants are going to go in for license renewal. I can't tell you for sure though whether it was 100 percent or, you know, maybe we drop back a bit, but certainly the feeling in the industry is that all or almost all of the plants are candidates for renewal rate.

But also remember -- I'm sorry. The real answer to your question is this is 2020. All right? So you wouldn't see a significant number of today's plants reaching the end of their life anyway before 2020.

DR. POWERS: Yeah, there are a bunch of them. Without license renewal, there are a bunch of them that are out by 2014, some by 2007. Yeah, license renewal is very important.

MR. SIMARD: But anyway, the answer is at this point it looks like all, if not -- it looks like all or almost all of the plants are candidates.

DR. POWERS: About 80 percent.

MR. QUINN: Dr. Kress, it's Ted Quinn.

Ron, good morning. The reason for success in the license renewal process to a large extent was the project management role that was put in place with a lot of work by NEI with a lot of work by the NRC, and a suite of documents that became part of the process, the GALL report, the NEI guideline.

Have you considered working with NRC on a similar type of suite of documents to help us make this a more stable framework?

MR. SIMARD: Yeah, I think you're right, Ted. That's been a good model in the past. By bringing to bear the range of industry resources and expertise on an area and combining that with the NRC, I think we've wound up with a better quality product in the end and improved the efficiency of the process.

So building on our success with license renewal, maintenance rule or other things like that, yeah, it's our intent to put a lot of thought from our side into how -- for example, the format of an early site permit application, and that's something we actually have underway, or with respect to construction inspection at ITAAC verification, it's our intent to bring together the folks who still have construction experience in the industry, if we can find them, and again, drawing upon their expertise and our knowledge of how Part 52 -- the basic principles of Part 52.

Again, it would be our intent in cases like that to bring in a document and ask the NRC for, you know, its review and reactions and use that as the framework for these productive discussions.

CHAIRMAN KRESS: Well, thank you very much, Ron, for this very informative and interesting talk.

Then we will turn to the next item, safety goals for future nuclear power plants, and I'm certainly looking forward to hearing this one.

By the way, Neil, I know that you don't need any introduction, but the fact is I don't have any introductory material so you have to introduce yourself at this particular meeting.

DR. POWERS: I'm dying to know what a KEPCO is.

DR. TODREAS: KEPCO in the title speaks basically to the success of the Asian countries in developing nuclear power and up till now the lack of success in the U.S. So the Korea Electric Power Company gave a chair to MIT in nuclear engineering, which I hold, and the Tokyo Electric Power Company gave a chair to nuclear engineering that Mughid

Khazzami (phonetic) holds, and we're still waiting perhaps nationally for one of the U.S. utilities to step in.

(Laughter.)

DR. TODREAS: Okay. What I'm going to do is stand here. My intention is to address you guys relative to this question of future nuclear plants and also bring the audience up to speed in terms of our activities.

Yesterday, the DOE folks were here, and they talked about the program, and it's called really a Generation IV reactor development program, and it covers the near term, which is zero to ten years; deployment, in that period; and then from 2010 to 2030 the development of what's called Generation IV plants.

So the word "future" here means a lot to different people. What Ron just spoke about in terms of my focus was the near term deployment, mainly zero to ten years. So you have to switch horses now in terms of the safety goals that I'm talking about relative to future plants are aimed at the 2010 to 2030 developments.

You can take these goals, focus them back and ask what about the near term deployment plants, but in a sense that isn't fair because you know some of them are already certified. If they're not certified like the ESBWR, they've been under development for years, and so they've been aimed differently.

There are also nuclear power plants in terms of near term deployment, and you'll see that although I was given this title, our goals are on nuclear energy systems, the difference. Nuclear energy systems brings in the whole fuel cycle. In terms of our activities, we put the whole fuel cycle on the spectrum.

So with those introductory remarks, I just want to conclude by saying John Garrick is on the group with Saul and I, Saul Levy and I leading it, and we have five, six rather, other people on the review committee overseeing the DOE activity and offering comments, and John is a valued member of that activity.

So if I could start, having talked to the people in front of me before at times, I thought I'd start off and tell you how not to construe this talk or how to misconstrue it to try to get you on the right approach.

So first, it's the talk and then the goals, and then we'll get into it.

So the way you follow this slide is four points here, is really what I'm talking about down below. So I'm not talking about the NRC safety goals. That's the first thing that probably jumps to your mind when I say safety goals.

We're generating what we call technology goals. These are goals to drive new reactor systems development.

DR. WALLIS: Are you going to mention the word "risk"?

DR. TODREAS: Risk? Maybe at the very end, but actually Graham, that is one of the themes. What I want to do or what we want to promote through this program is technological innovation and development, and we want to structure things so that we can promote that and not clamp down too early.

Of course, risk has to be mentioned from the beginning.

We are not suggesting regulatory requirements for future plants. These goals are formulated to stimulate innovation, as I've already said, and the goals, of course, as you're going to see, are general, and there's a group that's following up to put specific metrics on each of the goals so that we can use those.

We also use those to sort out concepts from among -- we've gotten effectively almost 100 concepts or pieces of concepts submitted into the program, and these have to be sorted out, selected, and areas of R&D picked out either generic along a -- if a set of concepts come together in a technological direction, will pick out the R&D that's relevant to this set, and push ahead.

And so we're going to need to make some selection, and the selection will be based on metrics which are derived from the goals which are now being worked on. That's what the word "metric" means here.

I mention the point we're not talking solely about power reactors. We're talking about fuel cycles, and the power reactor is part of this. We started this before the national energy policy was announced. It's interesting that there's some consistency there, but it wasn't a grand plot.

And then finally, I'm not talking about goals for near term deployment plants. I mention that point. We're talking in the range 2011, 2030 or 2010, 2030.

We go to the next slide.

I've got a few points to mention on how not to misconstrue the goals. One way to misconstrue them is to assume that future plants must meet every goal or must even exceed every goal, and what you're going to see is these goals are fairly encompassing. Just immediately, to put some meat on those bones, we've got issues of fuel utilization, nonproliferation, and waste, and through the fuel cycle there's obviously got to be a tradeoff among those areas, and the tradeoff -- there's multiple tradeoff solutions available and some of them will favor one of those factors. Some of them will favor another factor.

I'm almost convinced that you won't be able to come up with some scheme that will uniformly meet and exceed all of these goals. So --

DR. POWERS: I'm glad that you mentioned the word "tradeoff." One of the questions that comes to mind, especially after the previous speaker portrayed something of a crisis appearing, I wonder if in looking at these goals and looking at new systems that you compare the more modern or the existing plants against him to see if we really need all new concepts, and the 94 new concepts that were portrayed to us yesterday or, in fact, how well do the existing plants meet these various goals that you've laid out?

DR. TODREAS: The answer to that is on the metrics that we're going to develop to assess these new concepts. We've picked a standard, and the evaluation process will measure these new concepts against the standard. Is it better, much better, et cetera, worse, much worse, and the standard we picked is the advanced LWR with once through fuel cycle.

The rest of your question asked me what's the answer going to be, and I don't know that yet.

DR. POWERS: I find that a peculiar standard to pick because we don't have a whole lot of experience with advanced LWR, or if we do with existing machines, we have a lot of experience, and that experience, at least my friends at NEI certainly provide metrics that suggest that experience is outstanding right now.

DR. TODREAS: And is the implication that the advanced LWRs will be less --

DR. POWERS: I have no idea what they are.

DR. TODREAS: -- performers than --

DR. POWERS: I have no idea how they'll do. I certainly have opinions on a couple of them, but I have no proof. Whereas with some of the existing machines, I know exactly what they're doing. I've got data I can point to.

DR. TODREAS: I can see thinking about

that, but if we're going to develop advanced systems, I would say from the vendor community and the development community, we've got ABWR experience to an extent, and we have some degree of real respect for what the designs have accomplished in the ALWR.

And I would say as a minimum you'd include both, but I certainly wouldn't go back just to the operating reactors as the standard for the future. I wouldn't ignore the 15 years of ALWR development.

CHAIRMAN KRESS: Well, you probably have three criteria. You want them to be safe, and you want them to be economic, and you want them to be acceptable to the public and other people.

I would say the current place is certainly safe enough if you compare them to certain safety standards, but I would guess economics might be a big driver, especially the capital cost. I'm not sure.

DR. POWERS: The numbers I see suggest that they're producing power as cheaply as anybody.

CHAIRMAN KRESS: I know. That's because they've already gotten rid of their capital costs, and they're just talking about operating costs, but I would suspect these new designs are much cheaper to build.

DR. POWERS: Well, I wonder how much it

would cost to build a plant today, a current plant today?

CHAIRMAN KRESS: Well, that's a good question, and I'm not sure I know the answer to that.

DR. POWERS: I don't know the answer either.

CHAIRMAN KRESS: My guess would be the new designs would be cheaper to build, but then there's that third attribute, and that's acceptability, and I suspect newer, safer, inherently -- plant that has these attributes that we're looking at might be more acceptable from the standpoint of the public.

DR. POWERS: Yeah, I don't know.

CHAIRMAN KRESS: I don't know.

DR. POWERS: You're giving up 3,000 reactor years of operational experience when you make those statements, and --

CHAIRMAN KRESS: Well, maybe.

DR. POWERS: -- I don't think we've begun to discover all of the ways that you can run afoul on some of these modern control systems.

CHAIRMAN KRESS: Yeah, you have a good point there.

DR. TODREAS: Okay. Well, I think you guys will have plenty of time to focus on that one actually when you get your next certification application as well, but let's say that point's on the board. We can chew it further later if we desire.

I'll carry on on these goals down at this point. The desirable outcome from this program and effectively the goals which are going to drive this program I believe is a spectrum of designs, each of which best meet possible future market conditions.

For example, we don't know, although we think uranium will be cheap in the future, in fact, as cheap as it's been in the past, but we don't know that for sure. So it would be nice to have advanced designs on the table as the output which could respond in either direction.

If you want to have designs which would respond in either direction, then these alternate designs effectively would be aimed at optimizing and exceeding certain goals in one direction and then meeting, but exceeding other goals in the other direction.

So you want a spectrum of results, and therefore, different goals will drive you in these different directions.

the next point is some of the goals, in fact, one presently appears unattainable.

CHAIRMAN KRESS: That one really surprises me.

DR. TODREAS: Well, why don't we wait for the full discussion when I get there?

CHAIRMAN KRESS: Okay.

DR. TODREAS: But the point I want to make is don't jump on it now. We want a goal that will drive design and innovation. We can't meet it no, but does that mean we shouldn't write it in?

That's the question. I know you've read ahead. We'll get to it where we cover S&R3, Safety and Reliability 3.

And then finally, as I mentioned, the goals in terms of their specificity purposely have a little generality to them because we are talking about reactor systems that we want to bring on in this time frame, 2010 to 2030, which gives us an opportunity to innovate. So we don't want to squeeze down too early on that.

DR. WALLIS: And, Neil, we're still not on the subject of misconstruing goals, are we?

DR. TODREAS: Yeah, I am.

DR. WALLIS: You are? Okay.

DR. TODREAS: Yeah. The point of misconstruing there is why are they general. They're general to open the door.

Next point.

The next point is that one can misconstrue these goals by assuming that all the safety considerations are under the title of the grouping "safety and reliability goals."

To go ahead, we have sustainability goals, three of those; safety and reliability goals, three of those; and economic goals, two of those. So a quick reading would say, hey, let's just look at the safety and reliability goals for safety implications.

Now, we should be all smarter than that to realize that future designs are going to involve new cycles and a broader range of energy products. So we're going to get into new fuel materials, higher burn-ups, longer operating cycles, higher temperature operation, and all those design directions bring in safety considerations as part of it. They have all been reduced specifically to risk criteria, but there's tremendous safety opportunities and safety factors that one must consider as part of the sustainability and, in fact, the direction that the economic goals will drive us to. That's the point of this figure.

Now, with that, we can go to the next one and start on the goals. the logic in framing these goals cycled many times because obviously there was a large community involved in deriving these goals.

What we finally felt was it would be desirable to group them and then have these subcategories, and the first grouping that we picked was sustainability with the idea that if nuclear power was going to stand head and shoulders strong relative to alternate energy generation approaches into the future. we had to address and label part of the goals through the sustainability label and really place or position nuclear power and the product that came out of this product as a sustainable product.

You can get into arguments on this in the sense that sustainability if you go through the formal definition kind of projects it out without any time bound, and yet nuclear power in terms of fuel that we're going to use has a long time horizon, but it's finite.

There we didn't basically accept that point and, therefore, say nuclear power will no be sustainable, but we really took the bit and through the first goal effectively positioned nuclear power product as a sustainable product.

This, I've given you the words, but the

words in red are the words that we got into the most discussion about because this went through the NERAC process, and NERAC is -- let me call it a balanced committee. So there's viewpoints on all sides of the drivability and the effectiveness of nuclear power.

If you've been in the business a longer time and you're a nuclear engineer, when you think of fuel utilization, the word "high fuel utilization" jumps to your mind. This word that's here, which is "effective," is a long, negotiated word. It doesn't say we've got to go toward high fuel utilization because if you say you've got to go toward high fuel utilization, you immediately prejudice the outcome, so it is viewed, and with some justification. You prejudice it toward the fact that you definitely need a breeder, and also that fuel economics are going to come and constrain you in this 20-year time frame.

And that definitely is a view that definitely is not held throughout the review structure. So the word "effective" here means that you balance fuel cycle economics with environmental considerations and with nonproliferation considerations.

So effective fuel utilization implies that a tradeoff is going to be made between those factors because when I said fuel cycle economics, if, in fact, we have uranium constraints, that will drive up the price, and that will be reflected in fuel cycle economics.

In terms of Sustainability 2, that issue comes down to saying something about nuclear waste. We have got two key words here, minimize and manager. Manager is not controversial, but the word "minimize nuclear waste" was very controversial, and it was controversial in the sense that the other viewpoint was that minimization isn't really what you're after. What you're after is even beyond toxicity. It's ultimately burden to public health and safety, and there's a lot of different factors and a lot of different streams that finally get you down to that.

We effectively pick that up through reduced long-term stewardship burden, but we -- and now I'm talking about our review committee and the DOE whole project -- we still felt that there's great advantage going into the future with systems that minimized the waste generation because if you minimize the waste generation, you at least tend to reduce pressure which comes from the pile-up of large amounts of waste, and the question of what do you do after Yucca Mountain.

And I was going to say hopefully. What do you do hopefully after Yucca Mountain, with the "hopefully" being hoping Yucca Mountain gets moving?

On the third one on Sustainability 3, this has to do with nonproliferation, and there was a special group that was run by John Taylor called TOPS on nonproliferation where that issue was debated, and they effectively came up with these words: very unattractive and least desirable group.

And that comes from the view that we're going to have intrinsic and extrinsic barriers to proliferation. Hopefully they're mutually supportive in that you can do something intrinsically that may have a positive effect on external barriers and vice versa, but the view is that there's no silver bullet here. We're not going to come up with a fuel cycle that from an intrinsic point of view puts the nonproliferation issue to bed.

And therefore, we're going to come up with schemes that are very unattractive and are the least desirable group. That's how those words came about and why they're important.

We go to the next slide. Here we have the safety and reliability slides. They're set up in the logic of maintaining excellence in safety and reliability. Here we're really focusing on accident initiators, reliability of operation of plant.

Actually it stimulates a point relative to what Dana Powers mentioned. We do want to capture all the lessons, all of the positive lessons from operating plants and put those into these Generation 4 systems relative to their ability to operate with safety and reliability.

This goal, when you're working on advanced plants, you really at least in the conceptual stage, you really always focus down on the second two goals, and what we wanted to do was actually put something right up front that reminded all of the designers, all of the conceptual innovators that fundamentally the plant operating through steady state and through transience had to capture this base.

Now, when we come to the second goal, then we get into the traditional language, dialogue that we're all used to about low likelihood and degree of core damage. So we, of course, want to emphasize that.

DR. POWERS: One of the ways of assuring that you have minimal --

DR. TODREAS: What was the verb you used? One of the ways of?

DR. POWERS: Assuring --

DR. TODREAS: Assuring.

DR. POWERS: -- that you have minimal core damage would be to release all of the fission products so that you have no decay heat. Release them as they're generated. That would meet this goal.

DR. TODREAS: You would have to release them and sequester them because we're talking about systems, but along the line you're talking about, we get them out of reactor core system where we might have less control into a system that wasn't operating. Not a bad --

DR. POWERS: My point really is that I think this goal is perplexing in the context of the kinds of designs that people are coming up with where classical core damage doesn't really occur, but you still worry about fission product releases.

And why not cast the goal in terms of release of radioactivity?

DR. TODREAS: Oh. It's -- maybe, maybe. That effectively leads to number three, where we're talking about the need for off-site emergency response, various ways to do that and fission products.

Fission products actually could be the

whole story down here, and you might think about writing it that way. I'm not sure, Dana, whether just off the top, whether writing it that way would capture the end product or not, but it's simulating --

DR. WALLIS: I think that while you're being innovative, you should not use -- you seem to be here really talking about core damage frequency, and that just may get you in a box, and I think to be innovative, to follow up with Dana, you really ought to get away from these terms of the past and be more general.

CHAIRMAN KRESS: And after all, I think it is fission products we're worried about.

DR. TODREAS: I think that's a reasonable point. If I've got you guys or if you've got me saying that we ought to get away from terms of the past which will lock us into certain design directions and means of dialogue, that is really my whole message, too.

And if you're offering me a suggestion that says, hey, what you wrote doesn't go that way; you should go a different way, then I'd perfectly accept it.

DR. GARRICK: I think we have to be a little careful to unduly focus on fission products because for many of the most important scenarios it is not the fission products that's driving the long-term performance of Yucca Mountain. It's mainly -- well, technetium and Iodine 129 certainly are in there, but depending on the scenario and depending on how you look at it, Neptunium 237 is the principal driver.

And also, in most low level waste situations, you find that much to our surprise most of the low level waste is uranium contaminated. So, again, the fission products are not driving the long-term stewardship or management of a lot of the low level waste, but rather it's actinides.

The same thing is true in WIP for transuranic waste. Again, it's not fission products, but it's plutonium. So --

DR. POWERS: The distinction between captured products and fission products I'm not sure I would draw.

DR. GARRICK: Well, it sounded like you were drawing that. It sounded like you were drawing that.

DR. POWERS: I wouldn't do that. I would call them radionuclides maybe.

CHAIRMAN KRESS: We put quotes around the words "fission products" at ACRS. When we say that, we mean all of those things that you talked about.

DR. GARRICK: Well, then I think we need to be more precise.

CHAIRMAN KRESS: Yeah, precision would have helped there.

DR. TODREAS: But that also refers back to the sustainability goal. It really doesn't obviate the suggestion relative to S&R 2 here relative to core damage. I say that because what Garrick's comment really impacts on is the waste issue, not effectively the immediate release through core damage. Okay.

CHAIRMAN KRESS: I'm intrigued by that third bullet. Are you going to talk about it some more?

DR. TODREAS: Yeah.

CHAIRMAN KRESS: In particular, do you have some sort of criteria on what it would take to eliminate this need?

And if so, does that criteria encompass some sort of measure of defense and depth also?

DR. POWERS: I would go even farther and say that what more tangible proof of the concern over the public do you have than an emergency preparedness zone, and what are you going to replace that tangible proof with?

CHAIRMAN KRESS: That's another way to view it, yeah.

DR. TODREAS: Yeah, but that's how you guys ought to look at it.

Will you skip to S&R 3? It's the third viewgraph after this.

CHAIRMAN KRESS: Number nine.

DR. POWERS: Number nine.

DR. TODREAS: Yeah, page number 9.

From the point of view of a regulator or a group advising a regulator, and we got into this discussion immediately, the immediate question comes to mind. Okay. It's find that you guys got this goal, but what are we going to do about it?

And this goal doesn't say at all that in the first instance you people need to back off about planning for emergency response. This is about the misconstruing right at the beginning.

These are technology goals. These are goals we want to drive the designers into thinking about.

CHAIRMAN KRESS: How would you know if you met that goal? That was my question. What is the measure that you're going to use to say, "Okay. The technology we have here meets that goal." Whether or not it actually comes about or not is another thing.

DR. TODREAS: The measure has got to be release of I'd say fission products or radioactivity of a certain amount past the boundary.

DR. POWERS: I can always find a way to get that many fission products out. There's no conceivable design; I can't imagine a scenario that will result in release of excessive amounts of fission products.

DR. TODREAS: That would prevent it or that would --

DR. POWERS: Any design you come up with I can find a mechanism to get the fission products out; the point that it violates some emergency planning guide.

CHAIRMAN KRESS: Yeah, there has to be a frequency involved there is what he's saying partly, and my question is: is that value of fission products a value that you would meet, for example, the early fatality safety goal without evacuation? That's one possibility.

DR. TODREAS: That's one possibility. What I did here is, well, we have written a discussion under each goal. I worked hard on Paragraph 1.

The debate was effectively you write down something now that you don't have a way in your own mind of achieving or do you come short of that and, you know, put some numerical or put something that kind of reflects current technology?

So in the interest of intellectual honesty, we wrote in its demonstration may prove to be unachievable, and this is what Dana Powers basically just said. He's saying as he sits on this group, and I presume and I hope he'll sit on it for a number of years, all of these designs which come through which claim that they can meet it, he's going to shoot the hole in them. Quite possible.

But --

DR. APOSTOLAKIS: Dana would never do that.

(Laughter.)

DR. TODREAS: But that is a reason to write this goal down, because if you're really talking about future systems and vulnerabilities of future systems, it's this whole -- and ultimately public acceptance, it's this whole idea of off-site response that's a very, very significant issue.

DR. WALLIS: Now, this includes you started your talk saying you were looking at the whole fuel cycle. So presumably this includes fuel fabrication, transportation, any kind of reprocessing.

DR. TODREAS: Yes.

DR. WALLIS: You seem to have focused, again, on the reactor in this discussion, and --

DR. TODREAS: In the discussion below, not in the goal above. I'm just scanning it.

DR. WALLIS: Off site radiation then means in the fuel fabrication facility as well, for instance?

DR. TODREAS: What was the word you --

DR. WALLIS: Well, you're looking at the whole fuel cycle you said in the beginning of your talk.

DR. TODREAS: yeah.

DR. WALLIS: And now I got the impression in talking about these goals you were focusing once again on the reactor itself.

DR. TODREAS: Yeah. It may be true that in the oral persona that I'm putting across my years as a reactor designer come through, and I should be pulling back, being consistent with nuclear systems, and as I read this discussion here, there's nothing here that's focused on the reactor. It's general to all of the facility.

So it's --

DR. WALLIS: Well, it talks about off site. I mean off site presumably in transportation includes off the truck or something.

DR. TODREAS: Yeah, okay. Off site, of course, carries with it, yeah, we have to -- we have to go through and scrub it. I agree.

CHAIRMAN KRESS: But I would love for someone to tell me exactly what it takes to meet this goal. I personally think I know, and I'd like to have some corroboration of that some time.

DR. TODREAS: Okay.

DR. POWERS: And I'd like to know why you'd want to.

CHAIRMAN KRESS: Well, that's another issue, yeah.

DR. APOSTOLAKIS: I'd like to come back to the safety and reliability, goal number two.

DR. TODREAS: Could you flip back the slide?

DR. APOSTOLAKIS: Page 6.

DR. TODREAS: Go to page 8. It gives you more.

DR. APOSTOLAKIS: Yeah. In fact, I was looking at page 8.

It seems to me that when the discussion a few minutes earlier brought up the issue of fission product releases and as a possible candidate for replacing this, it focused too much on the safety, and here it says safety and reliability, and if you go to page 8, it says this goal is vital to achieve investment protection.

So it seems to me that I can have serious damage even with the new designs to my investment, and still I don't release anything. So the words "reactor core damage," I think, were a little bit provocative here because yesterday we heard speaker after speaker saying this is something of the past, and you know, this core cannot be damaged.

But I'm sure that one can define what we call plan damage states in PRAs, where you are not really releasing anything outside anyway, but your investment has been, you know, severely hurt, and the NRC is up in arms.

So the challenge will be to define those states, but I think by taking the words out, "reactor core damage," and finding some other words, not going all the way to fission product release, this goal will serve safety and reliability. You may need a fourth goal regarding fission product release. I don't know, but that, again, as you say, these are technology goals. They are not regulatory goals.

We will definitely have to look at fission product release. I mean there's no question about it.

(Laughter.)

DR. POWERS: You think?

DR. TODREAS: Yeah, let me pick up on that. This is on page 8, if you back into that.

We very much had investment protection on our mind as well, and in fact, that's why on the second line I've got that highlighted. Originally, or through a large part of this dialogue, in that goal we had the additional statement about preserving the plant's ability actually to return to power I won't say promptly, but to return to power over a period of, let's say, months, with the idea that we wanted to preserve the investment by having a design that actually could come back.

So that's what was in the second line. That one in the discussion, the comments actually came back as in the third one as to how would you ever do it. If you got core damage, it's just so much based on our experience that core damage, even to a minor degree, is going to really impact negatively the ability of the plant to return to power.

DR. WALLIS: Well, supposed you have a

core which is fluid. You just flush out the back part and start again.

DR. TODREAS: Yeah. Well, see, that's the point. If you get locked back into solid fuel pins, et cetera, you can't conceive --

DR. WALLIS: But you're being creative.

DR. TODREAS: What?

DR. WALLIS: You're being creative. You're looking at all kinds of things. There may be things where you can just flush out the damage and keep --

DR. TODREAS: Well --

DR. APOSTOLAKIS: How about if you replace, say, generation for nuclear energy systems will have a very low likelihood and degree of plan damage, period? To be determined later. At this point you're high level.

DR. TODREAS: Well, in relation to Graham's point, we kept the idea here by actually putting it in the second sentence. The --

DR. WALLIS: The second sentence is terrible. The possibility is either zero or one, and you reduce the possibility. I mean, that's crazy. You're just trying to avoid the word "probability."

How did you ever let anybody use the word "possibility" in here? That zero or one, isn't it?

DR. TODREAS: Where is "possibility"? Oh, okay.

DR. WALLIS: On three.

DR. TODREAS: The second -- yeah, the third line, "reduce the possibility."

DR. WALLIS: Well, we shouldn't pick on words, but I mean, I think --

DR. TODREAS: No, that is fair because these words in this paragraph get reduced to more specific items subsequently. So the guidance in this paragraph is aimed at developing more specific metrics, and to the degree if that occurs that these words cloud the ability of the subsequent group to develop the metrics, it's fair game. So you've made the point.

Follow up. You're shaking your head.

DR. WALLIS: Well, the word "possibility" is inappropriate.

DR. TODREAS: Oh, that's what I said. You've made your point.

DR. WALLIS: All right. Okay. So you agree.

DR. TODREAS: The other point that I wanted to make down here was there was a lot of discussion about passive safety features, and this is written basically to say evaluate them, but there is a community and a viewpoint that passive safety features compared to active safety features should be strongly encouraged.

It seemed to those of us putting these things together that that was a design tradeoff. It's not necessarily obvious that the passive safety features throughout to be preferred, to be preferred and to push out active features.

That's more of a detail, a trade-off, and while we wanted to have passive features examined, we didn't want to push them unduly. That's the significance of these words at the end.

I haven't followed all of your deliberations and views on that, but I would presume it's consistent. If not, I presume I'll hear about it.

DR. APOSTOLAKIS: I have a comment in the middle of the paragraph.

DR. TODREAS: Yeah.

DR. APOSTOLAKIS: This is a factor of about ten lower in frequency by comparison to the previous generation of LWRs. That's not quite accurate. In fact, it is inaccurate.

It is a factor of ten lower than the regulatory goal of ten to the minus four. There are many LWRs right now that have core damage frequency ten to the minus five or less. So it's less than the goal.

DR. POWERS: There is a body of opinion over here that thinks that that may be true for operational events, but not for the total core damage frequency.

DR. APOSTOLAKIS: That's right, but I don't think that's what they meant here.

DR. POWERS: Well, I think he should be looking at all of those things.

DR. APOSTOLAKIS: This is a factor of about ten lower in frequency by comparison to the previous. I don't think you have any basis for saying that it's a factor of ten lower than the current generation.

There are plants that are low even now.

DR. POWERS: Plants that certainly claim to be low. That's right.

DR. APOSTOLAKIS: That's right.

DR. GARRICK: But you do have to remember, George, that the PRAs still are limited in scope with respect to such subtle issues as modeling uncertainty.

DR. APOSTOLAKIS: Sure.

DR. GARRICK: And a real genuine treatment of uncertainty, which is still lacking in a lot of the contemporary PRAs.

DR. APOSTOLAKIS: What I'm saying is that it should not be the intent of a document like this to pass judgment on the current generator of reactors. The factual statement is that this is a factor of ten lower than the goal. Now, whether it's reality is a different story.

DR. TODREAS: Yeah, the objective of this was to report reality, not to pass judgment. I mean, certainly your statement and your point is clear and noncontroversial. If this goes over the step, then --

DR. APOSTOLAKIS: Well, then it seems to me that somewhere else you should say that these probabilistic risk -- I mean that these goals that are being stated here should be from all modes of operation, from all -- you know, to make sure that --

DR. TODREAS: That's the second sentence, an additional sentence that we could put after that.

DR. GARRICK: But the real thrust of this was the recoverability issue. If you're going to have a goal and improve on it, you'd like to, if you have another Three Mile Island, to be able to recover the plant, and that's why there was --

DR. APOSTOLAKIS: So plant damage we're talking about.

DR. GARRICK: Yeah.

DR. APOSTOLAKIS: Not core damage.

DR. GARRICK: And so the other thing that's important, too, with respect to words like "possibility" is that we were trying to be extremely sacred with respect to what's in the box. The rest of this is discussion and explanation, but it's what's in the box that we were hopeful --

DR. APOSTOLAKIS: "In the box," what do you mean by "in the box"? Which box?

DR. TODREAS: Well, in the box at the top.

DR. APOSTOLAKIS: Oh, oh, oh.

DR. TODREAS: But nevertheless, John, as I said, the follow-up does take the write-up and transfer it to metric, but what's in the box, do you see what's in the box now, George? Is the specific goal statement.

DR. APOSTOLAKIS: Yeah.

DR. TODREAS: So there you can go after core damage versus broader. That would affect the very specific goal.

DR. APOSTOLAKIS: And also I'm not sure

that you need both the likelihood and degree. A very low likelihood of plan damage, period. At this high level I think that would do it because plan damage can be anything, and then you can define plan damage as something I can recover from very easy.

DR. TODREAS: No, but see, degree is in there because degree leads to the ability to recover.

DR. APOSTOLAKIS: Yeah, but that's inherent there. I mean it's understood.

DR. TODREAS: No, I mean, you could have plant damage extent across a spectrum, and we wanted to cut that spectrum back. that's why the word "degree" --

DR. APOSTOLAKIS: I think very low likelihood and degree -- that doesn't sound good to me, but --

DR. TODREAS: Okay.

DR. APOSTOLAKIS: -- because the likelihood refers to the degree, right? It doesn't?

PARTICIPANTS: No.

DR. TODREAS: No, I don't see it that way, but --

CHAIRMAN KRESS: I think the two go together. I'm with George on this one. You have a likelihood of something. That something is a degree of core damage, and there's a spectrum, but the likelihood goes with --

DR. APOSTOLAKIS: I want to have very low probability and the non-damage states. What does that mean?

DR. TODREAS: You say likelihood of significant plant damage, but I think you have to qualify it or add something to it some way.

DR. APOSTOLAKIS: but you have to say something as to which noun the word "likelihood" refers to. Likelihood of what?

CHAIRMAN KRESS: Core damage. It's the likelihood of core damage of such a degree that it is recoverable from.

DR. APOSTOLAKIS: That's the correct -- yeah, that's the complete statement.

DR. TODREAS: Okay. Except we are not going to go in in the box statement of the recoverability from that explicitly. We just got all tied up on that.

DR. WALLIS: Now, to be general, your core damage also includes what happens to it when it is taken out of the reactor.

DR. TODREAS: Yes.

DR. WALLIS: And put in a pool, for

instance.

DR. TODREAS: The whole --

DR. WALLIS: The whole smear.

DR. TODREAS: Okay.

CHAIRMAN KRESS: Do you feel like we're picking on you, Neil?

DR. TODREAS: No, because what I was going to do, I was going to request from the Chairman that we get a letter with some suggested comments and --

PARTICIPANTS: No.

DR. TODREAS: -- and I did.

DR. POWERS: The only one that can request letters from us is the staff and the Commission.

CHAIRMAN KRESS: We only write letters to the Commissioner.

DR. POWERS: We only write reports.

DR. APOSTOLAKIS: -- write to the Commission commenting on the goal.

DR. TODREAS: We'll take your comments and suggestions and views any way we can get them, but they would be helpful.

DR. APOSTOLAKIS: By the way, in two or three days there will be a transcript available.

CHAIRMAN KRESS: Yeah, transcription.

DR. TODREAS: That's fine.

Let me go to number ten, which is the economic goal. Two points here.1 In the discussion of economics, the word "clear" is here with considerable debate. Again, there's several viewpoints.

The pragmatic and certainly the majority viewpoint was that if nuclear power of these nuclear energy systems are going to have a future, they're going to have to penetrate a market, and the only way you penetrate a market, particularly given the history of nuclear power costs, is for the new product to have a clear advantage.

The other viewpoint is that nuclear power is going to be needed in the future. There will be environmental imperatives that will promote it and draw it in, and it's unfair to require that it have a clear advantage. All it needs to do is be competitive, available, and await the demand from the evolving market, which will emphasize new environmental points of view.

DR. WALLIS: Well, presumably all you have to do is put the environmental cost into the cost and add up all of the costs and then your statement is valid.

DR. TODREAS: Yeah, well --

DR. SHACK: What as a technology goal, I don't think clear -- certainly as a goal you'd want to have a clear advantage. Now, whether you need that to be economically competitive is another question

DR. TODREAS: Going back to Graham's point, what I interpret you're saying is take all of the energy systems take all of their costs and make them internal to them.

Interestingly on the NERAC Committee where we've debated this one extensively, the non-nuclear members, and particularly the non-nuclear economic people basically say that will never happen. Don't hold that as a pipe dream. Proceed and compete on the situation as it presently exists, and effectively don't wait for the non-nuclear energy systems to actually have their extrinsic costs picked up.

So while it sounds great, we all agree it's logical.

DR. WALLIS: It's like Safety and Reliability 3. Maybe even if it seems unattainable you should try.

DR. TODREAS: But we basically didn't want to -- well, let me actually back up and ask you again. Your point I got was an observation that if other energy systems made their external costs intrinsic, then this would fall out.

DR. WALLIS: No, I think it comes out politically, too, and if the coal plants in the Middle West that claim the fish in the New England lakes, then that is a cost to somebody, and it's not a negligible thing. It figures out in the political decision somehow.

DR. TODREAS: It's a huge cost.

DR. WALLIS: Right, right.

DR. TODREAS: Well, we agree. The question will then come when you make this judgment have you brought in into the alternatives their full life cycle cost.

DR. WALLIS: Right.

DR. TODREAS: We're together on that.

And the only point I was making, the advice we got is don't hold your breath till officially those are subsumed, and in fact, those people are not pushing that these other alternative energy sources should subsume and have them made visible, which is what I think the real deficiency is.

Okay. And then finally on Economics 2, the question came up and came up fairly strongly: why have it? If you've got Economics 1, you've got the financial risk reflected already in the life cycle cost, and so Economics 1 effectively is a complete statement.

The response to that was to get nuclear energy systems going, somebody is going to have to put up the capital to start with, which is a risk capital, and although all might be balanced out, ultimately in the life cycle cost analysis, you still have to come up initially with this capital, and that is going to need to be bounded, and therefore, it needs to be focused on.

DR. WALLIS: Well, I'm not quite sure here. It seems to me that one and two go together. If the nuclear energy systems have a tremendous cost advantage and they're very profitable, people will be willing to take more risks to invest in them. So they're not independent, as you know.

DR. TODREAS: Yeah. That's what I just got finished saying. I agree with you, but at the beginning of the project, you still have to put up an investment, and it's still a risk, and if that amount is focused on minimized or comparable, then getting the ball rolling is easier.

And so Economics 2 was put in there in reflection of that view.

Okay. So then the last figure is just a

summary as to where I've been, but an important summary. So let's go to that.

I've done it in three bullets. The first bullet is to reemphasize to you that future reactors fall in three categories or more, but at least three: those that are certified or derivatives of certified designs, those designed to a reasonable extent and based on available technology, and then those in conceptual form only, with the potential to more fully satisfy the Gen. IV goals, and it's this third group that these goals are directed at.

There's a lot of activity in the second one. You'll hear about the gas reactor, IRIS, et cetera, but these goals are directed at Gen. IV plants in the 2010 to 2030.

DR. WALLIS: Well, this is true. I'm sorry, but it seems to me that a case could be made that present plants satisfy almost all of your goals, except for this off-site emergency response one; that they're becoming more economical; they're profitable; that they're safe. They have a low probability of core damage.

I mean it's all done already.

DR. TODREAS: Yeah. With some respect to you, Graham, if you go back to Sustainability 1, you will get into one hell of an argument that present plants or advanced ALWRs or anything on the once through fuel cycle is responsive to the sustainability goals, one, two and three, to enough of a degree.

That's where the argument is focused.

DR. POWERS: I mean, it seems to me then you're complaint, your argument is with Congress over the reprocessing issue.

DR. TODREAS: Or recycling, but there's no argument. What we want to do and what we've got imbedded in this program is an ability to reexamine the fuel cycle, and so my point is this.

DR. POWERS: I mean that seems like a big enough challenge that I would leave the plant alone and go reexamine the fuel cycle.

DR. TODREAS: The plant is a piece of that fuel cycle, but when you say that plants in the -- either operating plants or the first two out of the three bullets meet these goals, they don't -- the sustainability goals is a spectrum, of course, on there, and there are views that with regard to nonproliferation, with regard to waste those plants on the once through fuel cycle are good enough.

But if we're going out 30 years, we get an opportunity to do something better in that, and even if you're debating the whole spectrum of people who impinge on nuclear power decisions, they won't accept that the operating plants are good enough on those sustainability goals.

That's where it's focused.

CHAIRMAN KRESS: Actually our assumption at this meeting in general is that NRC will be faced with licensing some sort of new reactor or Gen. IV reactor or Gen. III reactor. Therefore, the question is a bit moot, I guess. What we're interested in is what are the challenges that are going to be faced through the regulatory process when and if such a design comes forth.

We know how to license the present reactors. So, you know, I think it's a different subject as to whether the present reactor ought to be the next iteration or whether or not we should focus on the advanced reactors.

This is an Advanced Reactors Subcommittee. So I'm making the assumption that there will be some sort of advanced reactor that we have to deal with in the regulatory process.

DR. TODREAS: Okay.

CHAIRMAN KRESS: That's just to put things into perspective.

DR. TODREAS: Yeah, I would just say a follow-up to this along the lines you're talking about is what I was prepared to discuss later in the afternoon, the challenges, but my challenges are going to be technological challenges coming out of the fuel cycle. That's the bottom line.

CHAIRMAN KRESS: Okay.

DR. TODREAS: Okay. Then the second bullet says we're looking for a range of design options that respond to various marketing demands, and I've got those in the four subpoints, and then the final bullet down here is I think what we started off agreeing on earlier in the discussion, that the dialogue, at least my point is the dialogue between the regulators and the designers relative to advanced plants, and I'm talking there about these Gen. IV plants has got to be framed to promote and encourage fundamental design evolution, revolution directions.

And in that sense, the interactions that come out of this I think require -- here I'll mention the word "risk" now -- require the development of a regulatory framework which is based on risk based principles.

And I think we need to move to that kind of structure and certainly that kind of dialogue as you interact and as the staff interacts with the conceptual and the development of these advanced systems.

That's the bottom line message.

CHAIRMAN KRESS: Questions or additional comments?

MR. LYMAN: Ed Lyman from Nuclear Control Institute.

I think that there are a few goals that are really missing from this whole formulation. First of all, under sustainability you refer to one that minimizes, that a goal is minimizing and managing nuclear waste, but at the same time, you really should impose a requirement that the routine emissions from the entire fuel cycle, as well as, let's say, occupational exposures are also minimized because one of the concerns with fuel cycles that involve reprocessing are these additional routine emissions, and you have to balance whether the reduced risk in a repository is justified by increased short-term emission.

So that's really something you have to keep to minimize at the same time or it doesn't make sense.

Second of all, under the financial goals issue, you didn't really dwell on the one that requires or suggests that the financial risks should be comparable to other energy projects, and I was wondering if in that context you would also have a requirement then that Price Anderson protection not be extended to Generation IV plants because other energy projects don't require that kind of protection.

DR. TODREAS: Yeah, on the first point you brought up, the specifics of that have been recognized and will come up in Safety and Reliability 1 because there we are talking about across the whole fuel cycle, and those routine emissions are picked up there. They could be picked up either place, but that's where they come up.

And on Price Anderson, we didn't get into the specific item within the structure of the goal that can be picked up and debated. It's been debated to some extent, but we didn't pin it down and resolve it specifically.

I know that's coming up legislatively.

MR. BARRETT: I'm Richard Barrett. I'm with the NRC staff.

And my question relates to the methods that we use for estimating the likelihood of core damage and the likelihood of release of radioactivity.

If NEI is correct and we have 50,000 new megawatts of capacity out there, and those are modular reactors -- that's 500 cores, and in an environment like that you find yourself striving for lower and lower core damage frequencies, and as you do that, you begin to put more and more stress on the current methods of estimating core damage frequency, and you begin to get to the point where many people think you're beyond the capability and the limitations of the method and the ability to have a complete model.

And in addition, as you move to different types of reactors, you find that you're depending less and less on highly reliable, redundant, and diverse systems and more and more on the intrinsic capability of the core itself to withstand these accidents, and to withstand them either indefinitely or for long periods of time.

And, again, the methods that we have today really don't deal very well with this kind of intrinsic, passive capability.

So my question to you is the stated purpose of your effort is to stimulate innovation in the design of the reactors, and my question is: could you also complement that with trying to stimulate innovation in the methods that we use for analyzing the risk associated with these reactors?

DR. TODREAS: Yeah, I would answer that two ways. First, it's a good suggestion and a fair suggestion. There's nothing implicit in -- what's going to come out of this fundamentally is a spectrum of concepts to focus on, but much more than that, an R&D road map of activities to flesh up those concepts and the methods associated with those concept development is certainly part and parcel of that. So we could do that.

The other thing though that I'd say implicit in a response is, you know, if the future were to evolve the way it is and even if we were to develop the methods, and we're going to have to reduce core damage frequencies further to get a desired output. So that really leads you to say that if you go with concepts now that are clones or like -- I'm talking about 20, 30 years down the road -- that are like these, you're going to reach a point where the methods can only go so far based on the existing approaches, and so that's a clarion call to change those approaches and go toward -- well, first, you go toward situations that avoid core melt, but that's very limited in a sense that what you really want to do is do what Dana Powers was talking about.

It's not core melt. It's the fission products, and it's the radioactivity in the dose from that, and that's what you've got to get after.

So I would say we certainly would accept and develop methods, but what we are trying to do is stimulate. I'm talking about real innovation, beyond that, to try to open up approaches that really change the playing field.

Larry?

MR. HOCKRITTER: Larry Hockritter, Penn State.

It's not clear to me why in your conclusions you have to have small versus large power ratings. It seems like you're biasing yourself already towards a particular class of designs.

DR. TODREAS: Yeah. Yesterday I presumed the whole layout of this program was announced or was explained as an international program with eight to nine countries now, and one of the goals of the program in all the specific directions is to come up with design solutions or concepts that meet markets internationally, and there are some international markets, and also if you listen in the United States, too, depending on the grid size, there are some markets that have a priority toward low rated systems.

And so you have some of those, and then you also have the traditional, if you talk about Asia, Japan, Korea, Taiwan, large systems.

So inherent in the whole program, since it's looking at worldwide markets, we're going to have this dichotomy, these two parts, and not one reactor thrust or direction is going to meet them. So you're going to have to come up with systems in both directions.

Now, your point may be fine, but they're not going to be sellable in the United States or the industrialized world. That's fine, but we'll have a product for that. We just may not use the other product.

MR. KHADAMI: My name is Presar Khadami. I'm with the NRC staff.

If I understand the rules by which the South Africans are trying to license their plant, one of their goals is that in the long term the concepts employed should be amenable for society to make a decision that higher levels of safety need to be obtained from these energy systems.

And therefore, one of their goals, as I read it, and if I should be corrected, I'd like somebody to point this out; one of their goals is the design should be amenable for society to demand higher levels of safety at some future time if we take, you know, these systems as operating for many decades.

Where does such a concept fit into the kinds of goals that you have articulated?

DR. TODREAS: Okay. On this let me give you a brief answer and ask for some help because I am not knowledgeable about a specific or the specific South African drive that you're talking about. I just haven't interacted with them specifically.

I would say that even though these are general, we are going to have some kind of constraint because we're going to come up with a set of specific metrics that go with each of these goals. They're going to be as we go on a year or two -- there's going to be some numbers and some specificity here . So. There's going to be a little bit of a lock-in, and that sounds to me like it's inconsistent.

The way I interpret what you're saying is you come up with a design. Society decides they want more safety, and so this design has somehow got to be expandable or have margin or a way to capture more safety. That's how I understand it.

So I don't know the answer. These goals have been pushed in through a discussion with the so-called GIF countries, of which South Africa is a part of, and we didn't get any effective comment back from them that's relevant to what you said.

But if Andy or somebody else can speak specifically to that, that would help me.

DR. SLABBER: Mr. Chairman, the South African concept, the baseline was to use existing technology as far as possible, existing technology that has been qualified and tested and proven to be acceptable for use in the PBMR&S, and with a basis that the fuel is the central point of focus.

And within that framework, we do the system design, that it fulfills the requirements that imbedded in the design without reliance on operator actions is imbedded a term, and I again say, in inverted commas, inherent safety and small units, and usable for not only producing nuclear power, but also some other usable byproducts specific for South Africa.

DR. TODREAS: Can I build on that maybe in answer to his question? You stay there because I'll need you.

I would say with that focus and the ability, as you went to successive improvements in fuel fabrication and fuel reliability, you could actually enhance your safety profile if the key focus is fuel, and that would be an answer back to how you reflect the future, the fuel.

DR. SLABBER: Yes, and I think the objective of any new innovator system should be to improve, but there is a limit because it's also costly. So improvement, the improvement for public acceptance, improvement of safety, that the boundary made improvements so that you do not have to shelter and evacuate, but these are all factored in to provide a facility which is still affordable and reliable.

CHAIRMAN KRESS: Thank you very much, Neil.

At this time I'm going to declare a 15-minute break. Be back at 20 till.

(Whereupon, the foregoing matter went off the record at 10:26 a.m. and went back on the record at 10:45 a.m.)

CHAIRMAN KRESS: Before we move on to the next speaker, I want to reiterate my announcement I made this morning, that we are changing rooms for this afternoon's session, and the room we're changing to is the usual ACRS meeting room, which is on the second floor of White Flint 2. There may have been some confusion in people's mind.

And if you're signed in this morning, we will have a -- you have to have a badge to get up there, and there will be a temporary badge available for those people who have signed in at the security desk in White Flint 2 lobby, and that will be available after lunch.

But if you haven't signed in at all or are not currently badged, you will need to go through that and get a temporary badge before going up to the second floor.

So with that little aggravation, we'll move on to the next talk, which should prove to be very interesting, and as I mentioned earlier, I have no introductory comments. So you have to introduce yourself, Andy.

DR. KADAK: Thank you.

CHAIRMAN KRESS: And then I'll turn it over to you.

DR. KADAK: My name is Andy Kadak. I'm professor of the Practice at MIT. You can ask me later what that means exactly.

I was formerly a president and CEO of Yankee Atomic Electric Company. So I've been able to see directly and experience the strengths and weaknesses of the NRC regulatory process, and I'll just leave it at that.

(Laughter.)

DR. KADAK: When I first came to MIT --

DR. POWERS: Because if you went through all of the strengths, it would take too long.

DR. KADAK: Absolutely.

DR. POWERS: I understand.

(Laughter.)

DR. KADAK: When I went to MIT in 1997 as a visiting lecturer, Professor Ballenger and I engaged about 11 students under an American Nuclear Society program called the Economic and Environmental Imperative, and it was aimed at stimulating student interest in looking at innovative, new reactor technologies, and to see how we could make nuclear plants competitive, safe, and politically acceptable.

In 1996, the students chose a pebble bed reactor as the technology to develop since it appeared to best meet our attribute.

We then convinced the Idaho National Engineering and Environmental Laboratory that, of this particular fact, and they supported much of our research for the last three years.

Overall our objective is to develop a conceptual design of a complete power plant based on the concepts and ideas that we formulated in 1998.

We're now working in the following areas, just to give you a sense of the scope of our effort. We're doing and developing a fuel performance model, which includes and will include the manufacturing aspect of it.

We're doing some experimental work on silver and palladium, effect on silicon carbide. We've got a core neutronics capability, and ultimately hope to verify and validate using MCNP, a lot of the core neutronics.

We're developing a balance of plant design and a simulation capability to assess normal operating transient.

We're also working in the area of safety, loss of coolant and air ingress analysis. We've done some work on nonproliferation, waste disposal, and we're also now engaged in what I call true modularity, namely -- and this is the innovation -- true factory manufacture of essentially the balance of plant for site assembly.

We are also working with the University of Cincinnati on developing of a burn-up monitor for these pebbles.

If we get additional funding, there will be work on advanced INC with Ohio State. We're looking at management issues and a PRA.

So ultimately, if our work is successful and we continue developing this concept, our plan is to build a combination research and demonstration facility to test the technology, help validate the technology and operation, and essentially use it as a continuous test bed for the life of the plants should they be built in the future.

This is sort of an introduction to what I'm going to talk about today, which is this license by test, which I've been thinking about for many years. I've talked to many of the NRC staff about the idea.

Now, this presentation that I'm going to make today does not claim to have all the answers about how such a process might work, but it is meant to address some of the high level issues and the approach that we might consider.

And to determine whether this concept is workable, it is recommended, and that's my bottom line recommendation, that the NRC, we and other interested parties work to see if such a process can work rather than jumping on all of the reasons that it can't.

So with that, let me just begin. Here are the challenges as I see them. The regulations, as you all know, are focused very much on water. The knowledge of the technology, particularly in new technologies -- forget the pebble bed for the moment. This is generic -- knowledge of these knew technologies is generally lacking, and the infrastructure to support some of these new technologies is also lacking.

We've heard plenty of that yesterday, regardless of whether it's gas, liquid metal, lead bismuth, whatever the technologies are.

And changes in the system, what I call the system is the regulatory system, take a very, long time.

So how do you introduce a new technology in less than a lifetime? And yesterday I heard hints of lifetime project.

We need to go back to the basic safety fundamentals. We need to work within the existing regulatory high level objective, use -- and here we go -- very early in the game, risk informed, which I define as risk based with deterministic analysis, approaches to determining safety; assess our gaps in the knowledge, especially if it's new technology to see what we understand and what we don't understand very objectively; prioritize namely what are the significant risks associated with what we don't know and what we do know; and then try to license this thing by test.

Well, here we got. Relative to establishing the safety goal, we would use a public health and safety goal, not a core damage frequency, and I think you were sort of getting at that yesterday in terms of releases.

You look at this public health and safety goal, and then you start to define your plant risks, whether they be normal operating risks, events, transience, accident scenarios, and then identify the safety margins as bets you can using deterministic analysis. Then begin or attempt to quantify the risks as you know them using a PRA, and then show defense in depth, and what I will describe later about defense in depth is how many barriers are there to prevent a release.

CHAIRMAN KRESS: Is that what you mean by defense in depth?

DR. KADAK: That's what I mean by that.

And I'm not defining the barrier, and how do I deal with the uncertainties that recognizably exist in this technology.

Next slide, please.

The risk informed approach then really attempts starting with the safety goal, and it's a public health and safety goal, by applying what we know and using the probabilistic techniques that we do know in a scoping kind of a sense. We will obviously not know the performance of helium high temperature, high temperature helium turbines or compressors because the size that we're talking about hasn't been built, but we can estimate it based on other experience.

Are these health and safety goals something different than the quantitative health objectives that we currently have?

DR. KADAK: they would be based on fatalities, ten to the minus -- pick a number -- ten to the minus six. Start at that level.

CHAIRMAN KRESS: Yeah, but do you think that those we now have are sufficient or do we need something else?

DR. KADAK: I would say at that level it's sufficient.

DR. POWERS: Why do you focus on fatalities?

DR. KADAK: It's an easy measure. You

could talk about injuries, if you like as a separate measure.

DR. POWERS: I mean if we're going to learn something out of accidents that have occurred, the most transparent consequence of Chernoble has been radiation injuries rather than fatalities.

Line contamination could arguably be the other thing that we've learned. Why not change the measures in response to things we've learned?

DR. KADAK: We could do that. I'm not limiting it. I'm just saying establish something that everybody is comfortable with, and I mean societally comfortable with. And if it talks to land, if it talks to injuries or if it talks to fatalities, fatalities is the one that we now have.

CHAIRMAN KRESS: Well, you know, part of the purpose of this meeting is to identify regulatory challenges, and my question was aimed at saying do we have appropriate let's call them safety goals now or should the Commission be thinking about something different for safety goals for the advanced reactor, and that --

DR. KADAK: My sense right now is we have already essentially established the policy that says -- we established the public health and safety goal. Let's start there. If there's more that needs to be done, add it, but I don't see that as a priority issue right now.

From what I understand of the British system, they're trying to harmonize safety goals across all technology, and perhaps we can learn something from that to be able to judge whether nuclears are in the right ballpark.

CHAIRMAN KRESS: Okay.

DR. KADAK: So we would then apply these deterministic and probabilistic techniques as best we can to see if the goal is met, and then using the risk-based techniques, identify dominant accident scenarios and what critical systems and components need to be tested as a functional system.

And in this case I'm trying to avoid the use of design basis access. I'm trying to see what really matters for safety and use the risk approaches to identify those.

The next slide gives an approach that I think has been used in the past where you go through, you know, the risk informed approach, namely, identifying on a very high level basis the issues of protection of the public, evaluate risks against the safety goals, use the PRA to quantify obviously larger uncertainties, limit core damage, mitigate releases, and then mitigate consequence.

Now, this is sort of a standard kind of approach. What I would suggest is that's where you start, and the master logic diagrams would be more or less technology specific relative to the kinds of vulnerabilities of the particular technology might have.

The next slide gets into a description of a master logic diagram, but that's for water reactors. One of our students at MIT is now attempting to try to define this better for, say, the pebble bed reactor, and we're going to start with a basically different approach at least from my perspective, and that is, you know, starting with the plant and how do I protect the public working backwards, and what events can cause release.

We're going to try to do a different master logic diagram on that basis.

Next slide, please.

This chart here, which you can't see very well, but it's in your handout, is a summary of what the South African national nuclear regulator is using for their assessment. They've got a very similar system to what I'm proposing, at least at a higher level, and they developed some requirements that starts from the public health and safety goal and establishes various safety criteria in a range of events which I think we heard about yesterday.

It's in the handout, and hopefully you can read it better, but I bring that up only to allow one to see that there is a logical frame of reference from which to proceed to establish such a process of using risk informed to establish and correlate that with the public health and safety goal.

The next slide, please.

We do have an existing regulatory structure, and I'm still trying to do this in less than a lifetime. So what we're going to try to do if we get a chance to is -- and it's already been discussed, I think, by Exelon -- and that is review the existing regulatory structure for the gaps that exist relative to that particular technology. For example, as far as I know, there's no error ingress safety criteria. We might need to have such a thing developed, but identify those kinds of issues as you look at the existing regulatory guidance.

And, in fact, look at the general design criteria and say how do we and how can we implement those, given what we think are the high level safety objectives that we've established in the previous step.

Where it gets confusing and where it will get difficult is trying to meet the general design criteria for non-standard or non-order technology, and it's in the details that you really get hung up, and that's where the whole process of show me that it doesn't require this criteria happens.

So we're trying to say by reviewing the existing structure, applying it to say the pebble bed reactor, and then being able to say on a risk based, you know, foundation what does and does not require it in terms of the fundamental design for the regulation that would apply to that.

Next slide.

So, and I use the word "design basis accidents" using risk based techniques. I really wanted to keep to the word design the dominant accident sequences using risk based technique, which you would then analyze to try to assess how much defense exists in those accident sequences.

DR. WALLIS: Can I ask you something here?

DR. KADAK: Surely.

DR. WALLIS: I mean, you seem to be applying what we do today to what we might do tomorrow, and did you question whether we really need design basis accidents in their present form?

DR. KADAK: My approach would say --

DR. WALLIS: Or would it be replaced by something else which might be less plant specific and be more effective?

DR. KADAK: The process that I would recommend is developing dominant accident sequences as part of the regulatory process, and don't call them design basis accident.

DR. WALLIS: But you just did.

DR. KADAK: Well, I made a mistake.

(Laughter.)

DR. KADAK: I was revising my slides, and I was looking for design basis accidents, hopefully not to include it, but I made a mistake. It should be establish dominant accident sequences. Okay?

CHAIRMAN KRESS: If you go back two slides to the one we couldn't read --

DR. KADAK: Yes, the big -- yes.

CHAIRMAN KRESS: It seemed to me like that's at least three points on it, a frequency consequence curve.

DR. KADAK: Right.

CHAIRMAN KRESS: It seems to me like such a curve encompasses all of the accidents, the whole spectrum.

DR. KADAK: It attempts to cover them all.

CHAIRMAN KRESS: If you meet some sort of regulatory requirement on this, and it may have to have confidence limits or something, and then encompasses the whole shebang, doesn't it?

DR. KADAK: We're trying to cover the regime of accidents possible for this technology. Okay? And looking at the categorizations placed under A, B, and C, it appears to cover logically what one would need to worry about, but I can't --

CHAIRMAN KRESS: So if you just tell the designer or the license applicant that he has to meet this curve -- I call it a curve -- at a certain confidence level, what else do you need?

DR. KADAK: I guess --

CHAIRMAN KRESS: The thing that seems to be missing to me is defense in depth. We can get into that later.

DR. KADAK: Where I get hung up is for new technologies doing that is going to be extremely difficult.

CHAIRMAN KRESS: Because it requires a pretty good PRA.

DR. KADAK: It requires a good PRA.

CHAIRMAN KRESS: And a good knowledge of the phenomena that go into the accident sequences.

DR. KADAK: Yeah, and a lot of data that supports the probability --

CHAIRMAN KRESS: Which is the part that's usually tempted to be covered when you have that situation by defense in depth. That's why I keep harping on we need a firmer definition of defense in depth and how it fits into a regular or a system like this, for example, with new technologies where you don't really have core melts, and you don't really have the standard barriers against fission products.

But, anyway, that's another subject.

DR. KADAK: Well, my sense of defense in depth is how much margin do you have to, say, core melt or in this case release.

CHAIRMAN KRESS: Yeah, that's a sort of a defense in depth.

DR. KADAK: Sort of.

CHAIRMAN KRESS: It's not my definition.

DR. KADAK: Okay.

DR. WALLIS: What's your measure of margin?

DR. KADAK: I hate to say this, but

engineering judgment.

DR. WALLIS: That to me always is an ignorance factor than --

DR. KADAK: Absolutely, and I'm just suggesting that when you introduce new technologies, there will be a lot of uncertainties which you cannot precisely calculation.

DR. WALLIS: Your engineering judgment is maybe ultimately different from somebody else's. So how do you explain or argue with that person?

DR. KADAK: It depends on the design.

DR. WALLIS: I think you have to be quantitative in some measure which you can agree upon.

DR. KADAK: If you can do deterministic analyses and show that the worst situation as was presented, I believe, yesterday is acceptable and analytically, deterministically. That's why it's not purely a probabilistic approach.

Using the best tools that you have and, in fact, being able to, as I will get to, the license by test scenario to demonstrate such things, I think your confidence levels will be greatly increased, and that's the bottom line.

What makes me very nervous is just relying on numbers with confidence levels because as we know, even with our PRAs things happen that are not in the PRA.

DR. KADAK: Okay. If I could catch up to where I was, okay, then if you'd just back up that one, I want to -- to develop the defense in depth basis using the natural physical attributes of the designs, what that basically means is if there are significant natural physical attributes and not so much reliance on active systems or passive systems that must function, you are in a much better position to develop the confidence level you need relative to defense in depth, and you can argue about how many barriers or whatever, but that is a key part of this, and that's a key direction, I believe, that the regulators ought to encourage relative to new technological develop, and that is natural physical attributes.

CHAIRMAN KRESS: I interpret that statement to mean that there's probably less uncertainty associated with determining the risk of those than when you have a complicated system with lots of barriers and lots of active --

DR. KADAK: That's the point. We want to try to limit those active --

CHAIRMAN KRESS: Therefore, since you have less uncertainty and higher confidence in the risk results, the less defense in depth might be needed?

DR. KADAK: Again, the less defense in depth is not the right term.

CHAIRMAN KRESS: Is that too big of a step to take?

DR. KADAK: Now, the point is to demonstrate the defense in depth exists and give credit to natural physical attributes, I think is the direction that I would be heading.

And then to whatever degree possible, establish confidence levels in the analysis using risk assessment method.

Next slide, please.

All right. License by test. Depending upon the technology, and in my case it would be sort of the pebble bed for an example, build a full size demonstration facility. Perform these critical tests on those components that you identified as dominant risk contributors.

DR. WALLIS: I don't quite understand that. Are you going to have a near core melt or a near containment failure in order to do a critical test?

DR. KADAK: Let's just say, for example,

if LOCA is a major accident sequence --

DR. WALLIS: Do you have a LOCA in your --

DR. KADAK: You would perform a LOCA.

DR. WALLIS: You would perform a LOCA. Okay.

DR. KADAK: Or to the degree, at least, that you can validate your computer models and methods. And that's why these physical features become very important.

DR. POWERS: Have you imagined what the environmental impact statement on this federally funded examity (phonetic) is going to look like?

(Laughter.)

DR. KADAK: Sure, and what I didn't mention and I probably should was that for the purpose of this research, combination research demo facility, we put a containment on it.

DR. POWERS: Well, I thought you just put it in Idaho and nobody would care.

(Laughter.)

DR. KADAK: For the record, Idaho is a beautiful state, has lovely people.

(Laughter.)

DR. KADAK: Nature abounds.

DR. POWERS: Probably do $10 million worth of improvements in New Mexico.

DR. KADAK: Okay. So clearly it's a research facility that needs to have a containment, but the purpose of the containment is to prove you don't need one, if that, in fact, turns out to be the result.

DR. POWERS: How would you do that? I mean, suppose you ran this test and, indeed, it did just fine, and some skeptical guy like Ed Lyman over there came along and said, "But if you'd done a different test" --

DR. KADAK: Well, that's what I want Ed Lyman to work with us. When I said all interested parties, I'd like to have Mr. Lyman, Mr. Lockbaum, and Mr. Gunther involved in this because I think that's part of the process.

DR. POWERS: And still no matter what test you did, somebody else could come along and say, "But if you'd just done this other test."

DR. KADAK: Yeah, but Mr. Lyman will be explaining to this other person why these test series are adequate, not me.

(Laughter.)

DR. WALLIS: Well, I think the problem you get into --

DR. KADAK: Sorry.

DR. WALLIS: -- is the basis of scientific testing is to try to disprove your hypothesis.

DR. KADAK: Yes, or to prove it. I think you'd like to try to prove it.

DR. WALLIS: Of course, by the very fact that you could disprove it, you would have had an unacceptable release presumably. So it's a little difficult to design that crucial test to disprove a hypothesis that it's safe.

DR. KADAK: Well, again, there's a reason for the containment, and obviously you'd be a little more creative about the type of test you run so that you understand what the possible outcomes would be, but theoretically it's conceivable, and it obviously depends on the plant and type of design.

DR. WALLIS: I guess we're asking these questions because we're kind of intrigued by the idea.

DR. KADAK: Good.

DR. WALLIS: But we're skeptical.

CHAIRMAN KRESS: Yeah, one purpose --

DR. KADAK: Wonderful, marvelous.

CHAIRMAN KRESS: -- we attribute to integral tests are to -- two purposes: one, to see if there's something going on that we hadn't thought of;

two, to validate our computerized analytical tools so that they can be used in an extrapolatory sense to cover the things we can't do inn the test.

Would that be your view of what this test might do for you?

DR. KADAK: Next slide.

The needs. Why? To validate analysis. Okay? To shorten the time for paper reviews; to try to prove in quotes what's debatable; to reduce uncertainty, and this is very important; to show the public and the NRC, and I include them as the public in this case, that the plan is, in fact, safe.

And that's what it's all about. Can we do the -- you know, can we try to melt the core? If we believe that we can do it without melting the core, yes.

DR. WALLIS: So what you should do is you should give an operator carte blanche to try to melt the core, and he or she will fail. Is that your test?

DR. KADAK: Depending upon the design, yes. I mean, theoretically that would be the test, but I would structure it more carefully than that.

(Laughter.)

DR. KADAK: See, we're going to hear about radiological sabotage in a few minutes, I'm sure, and maybe that's the test that Ed would like to run, but we don't know yet.

Yes, I'm sorry.

DR. GARRICK: Andy, we have a bit of a model for this in that we once had something called a national reactor testing station, and we once had something called the borax experiments, and we once had something called the spurt experiments, all of which have a kind of familiar ring as to what they wanted out of those experiments in terms of what you're describing.

Does that experience, just from the standpoint of answering the questions of one scenario versus another scenario, I want to test my scenario, Dana wants to test his scenario, and so forth; is that experience relevant at all in what you're proposing here?

DR. KADAK: I'm not sure, but I recall some of them actually wanted to break fuel like no fuel.

DR. GARRICK: Right, but they were talking about various degrees, and they tried very desperately to come up with an experimental program that gave them the biggest bang for the buck possible, and what they were really trying to do was get closer to a quantification of the loss of coolant accident, and better parameter information with respect to the containment and so forth.

DR. KADAK: Clearly, you know, that experience would be certainly helpful, but again, I don't have all of the answers. I'm just giving you an idea of what I think might work, but how to exactly do it and what to build on, I just am not all that familiar.

What I hope to do after this presentation is you're so excited about this concept that you'll ask the NRC staff to work with us to try to figure it out.

MR. LEITCH: Andy, I have a question about your second bullet up there, shorten the time for paper review.

DR. KADAK: Yes.

MR. LEITCH: I'm not exactly sure what you mean by that. Does that mean that the paper reviews would not be as detailed or not exist at all --

DR. KADAK: No, no.

MR. LEITCH: -- in lieu of this test?

Or talk a little bit about would the paper reviews be less detailed than they would normally be, and if not, how would the time be shortened?

DR. KADAK: See, that depends on what licensing action you have. Let's just take the most recent paper review, AP 600.

MR. LEITCH: Okay.

DR. KADAK: All right? I'm told -- I do not know -- it took roughly ten years. I'm told, but do not have the number confirmed, it cost around $249 million, which included a lot of testing as well.

And the end of that process was a certification, a piece of paper. What I'm suggesting here is for $249 million I could probably get part of a plant built that looks like a research facility that could be used to answer some of these tests, some of these questions.

In terms of submittals, I don't see much different in terms of what the design is. The submittal would largely be here's the design. Here's why we think it's comfortable and appropriate, and here's the testing program that we're planning to perform here to validate these areas that are in question or to validate some computer code.

So the approval would be more of an approval to conduct tests on a facility than to grant a license or a certification. That certification would come after the test had been completed, hopefully successfully and whatever design modifications made.

So I think in time scale, we're probably going to be about the same, say, five to ten years, you know, including the building the plant. What you will have at the end of that process not only is certification, but also a plant that theoretically is workable.

DR. WALLIS: Are you asking for a kind of full scale LOFT test?

DR. KADAK: Full scale LOFT test, I suppose in the sense of a LOCA. There will be others on a facility, and one of the things it avoids is remember the scaling issue that you've had to fight over? I mean, clearly the scaling issue sort of goes away if you do a full scale plan or a large enough scale to be able to say scaling is not a factor.

DR. POWERS: I still get hung up over these. When George does a PRA, he comes up with more sequences than I can count, and you're going to have to validate all of them?

DR. KADAK: Not all of them, no.

DR. WALLIS: Well, some significant fraction of them?

DR. KADAK: You'd validate obviously the

dominant accident sequences that are really important for public health and safety. That's the ones that --

DR. POWERS: So maybe 12, 13 major full-scale tests?

DR. KADAK: Probably.

DR. POWERS: And what happens if, I mean, just one of them kind of goes awry?

DR. KADAK: Fix it. You make the design change. That's why it's called a research facility.

DR. POWERS: Well, cleaning out a full scale facility contaminated with radionuclides does not strike me as a low cost operation.

DR. KADAK: Well, clearly you wouldn't do these if you had any question in your mind that it wouldn't work.

DR. POWERS: Oh. So there's a certain level of uncertainty that I can't have.

DR. KADAK: That's right. I mean, clearly you wouldn't build a plant that you didn't feel could withstand the test.

DR. POWERS: You're going to have a hard time buying the insurance policy.

DR. KADAK: Well, that's why we have this containment. I mean, no --

DR. SHACK: Well, somebody has got to

clean up the mess just in case it goes wrong.

DR. KADAK: Well, again, the confidence level basically is that of the designers and the engineers after a lot of review and approval to say that this thing will work.

I mean, clearly, you wouldn't do anything stupid, and that's the point. If you have confidence in the technology, you could do this. Maybe not all technologies are amenable to this kind of an approach, but those technologies that have the kind of margins that I think exist relative to the melting or fuel failure certainly could try.

But let me continue and you can get the full scope here.

MR. SIEBER: Well, who would finance the demonstration plant?

DR. KADAK: Good question. It is a research facility, bottom line, and if, in fact, it's as broad a scope as we are talking about here, I think it's a legitimate government expense.

DR. APOSTOLAKIS: I think that's the way you lose Mr. Lyman.

DR. KADAK: Well, he's going to be a player.

DR. APOSTOLAKIS: You wanted him to work

with you, but --

DR. KADAK: But he could be a player. I'm saying that, you know, there's obviously some industry money that's going to be required as well, but how much of it is research and how much of it is application and certification relative to usable technology is the matter to be discussed, but clearly, you know, this kind of facility would be, I think, a government supported --

MR. SIEBER: Well, it seems like it would be very expensive, and in a competitive environment I'm not sure that licensees would be willing to ante up a lot of money.

DR. KADAK: Well, let me just give you some rough numbers. If my numbers about AP 600 are right, that's, say, 250 million. I've done some preliminary cost estimates to engineer and design this facility would be around 500. A 50-50 split sounds fair to me. It may not be the right numbers, but that's kind of what we're talking about.

MR. SIEBER: In this facility you would have active fuel in it?

DR. KADAK: Oh, yeah.

MR. SIEBER: So you would have to license it just to have the facility, would you not?

DR. KADAK: That's, again, part of the process. The licensing basically is the thing that Graham was talking about. What is the NRC review and approval process?

So it would be licensed, if you will, as a research facility.

Okay. Let me move on. The test that I think would be required are, you know, you're never going to get away from the traditional performance of component. There will probably be some small scale, integral tests to verify so that we don't have this scenario about cleaning up fuel, but you then would use these risk based techniques to identify the kinds of accident scenarios that are important, critical systems, critical components, some integrated tests which may be in a smaller scale.

Next slide, please.

And the test that I was considering may be more. I don't know if it adds up to 13 quite, but loss of coolant, depressurization, natural circulation, see if we can get it or not. In our case we don't want it.

Rod withdrawal, reactivity shutdown mechanism, cavity heat up and heat removal, and then other key component failures that you find become dominant in the PRA.

DR. WALLIS: Now, if you just look at loss of coolant, there are all kinds of sizes of breaks in all sorts of places.

DR. KADAK: Yes.

DR. WALLIS: So what you presumably would do is you'd do a lot of analysis ahead of time and say this is the one we're really worried about?

DR. KADAK: Could do that.

DR. WALLIS: Then you're going to miss Dr. Kress' point because, you know, the whole purpose of doing the test is to find out things that gave you a surprise.

DR. KADAK: We could do it by expression. I mean, this facility, my hope would be it would be designed in a way that it is, in fact, a research facility with different abilities to blow down by size, if that's the --

DR. WALLIS: So loss of coolant might be a whole sequence of tests.

DR. KADAK: Could be, yeah. Again, I have not designed it, but in concept, yes.

So next slide, please.

Additional tests. Oh, here. I guess I put up to my 14 or 15 now. Balance of plant failures, the traditional things that we worry about in liability space, turbine over speed, failures of various components, rod ejection or rapid withdrawal. I'm not sure we want to do a rod ejection per se.

Cavity heat-up. Again, we want to validate the core physics models.

DR. POWERS: Let's look at that control rod ejection because it's a fun one to look at. The scenario that we're now worried about is one where the fuel had extremely high burn-up. How are you going to do that in your test?

DR. KADAK: That would have to be outside of the reactor. We can't do that for -- you know. There would be a whole series of fuel tests as part of this program.

Next.

DR. POWERS: Well, and the problem that plagues the right ejection accident is an argument over how it propagates within the whole course. So if you do this test at the FABRI (phonetic) facility with one rod, that doesn't answer the question. I need a whole bunch of rods.

DR. KADAK: Well, I think we could do like I said, a rapid withdrawal, and we could model it from the standpoint of what we expect as a reactivity transfer and to see whether those codes, in fact --

DR. POWERS: I mean, that's where the argument is, is whether the codes are right or not, and whether they give you the right amount of heat going into the clad and not into damaging fuel.

DR. KADAK: Well, the first is the reactivity. Then we can go to heat, right?

DR. POWERS: No. This is a time scale where those two are very coupled together.

DR. KADAK: Okay. Then xenon, we talked about xenon.

DR. WALLIS: Some would argue that the technologies are fine, and that most of the major accidents are caused by people doing something out of ignorance, stupidity, whatever.

I don't see that as part of your testing. I'm not quite sure how you would test it anyway.

DR. KADAK: Oh, we could do your earlier scenario.

DR. POWERS: Graham, I'm shocked. People don't make mistakes out of ignorance and stupidity. It's an error shaping factor.

(Laughter.)

DR. POWERS: Forcing factor. You've got to learn this language, sir.

MR. LEITCH: Andy, would you be talking about fully integrated tests here? For example, if I may ask the question this way. In the start-up of a normal power plant, there are those who would advocate walking up to the generator breaker at 100 percent power and opening it and seeing what happened. I mean, I always thought that was a little like testing para chutes, and what I'm saying --

(Laughter.)

MR. LEITCH: -- we would demonstrate that the turbine would trip and that it had contacts that would make the reactor scram, and we would demonstrate separately that the reactor would scram.

But I mean, I really think some of these integrated tests would unnecessarily put the plant through perturbations that could be demonstrated piece-wise. And I'm just wondering if you have thought about the piece-wise demonstration of this or would you be talking fully integrated tests?

DR. KADAK: I think what the final test program ends up being is that which is judged to be such that it can demonstrate where the safety concerns are. Now, if there's too much of a strain, for example, and the plant could just trip a breaker and see what happened, and people say, "Well, I can get the same information from these separate tests," I think that would be fine.

I'm not here to design the test, but I think that would be part of the process, working with the regulator to develop what evidence do they need to show the plant can do what we think it can do.

So it doesn't have to be the crazy.

Okay. The next slide, please.

Continuing on with the test so that it's more than 15, dual performance, which gets to Dana's question about, you know, high burn-up, cycling, most heat-up, most accident heat-up, ingress to validate this chimney question, and water ingress if you'd look at the reactivity effect and the possible fuel damage.

My sense is those would be done probably outside the core on varying degrees of fuel and varying size of the facility, and I think the Germans have done many such tests already.

Next slide.

Well, what I started talking about was a prototype, and as a suggesting, using the pebble bed reactor as such a prototype. It's built full sized with the containment as I mentioned.

Implement the structure test program, and as part of this process, and I call it a process, we would develop what rules might be appropriate for introducing new technologies that don't have, you know, 25 years of regulatory history.

So we would not only test the facility, but also see if this process that I've outlined can work with new non-water technologies, for example.

And if, in fact, the process works, apply it generically to other technologies. That was sort of the idea.

And then if all goes well, you have a certified design, and you have a reactor that's sort of the fleet innovator, if you will, for the next 40, 50 years, however long the fleet exists.

Next slide.

Will this answer all of the questions, categorically, no, but at least it gives us a good shot at answering hopefully the most significant ones, but in combination with all of these subtier component tests and small scale tests, we'd probably have a good, relatively high level of confidence about critical safety performance.

Next slide, please.

Will this license by test instill public confidence? I say yes, in the sense that it gives the public -- giving the public and the media an opportunity to observe these tests, hopefully the confidence in this technology will be increased so that you avoid -- and I'm sorry, George -- ten to the minus pick a number is not understandable for public communication, although it may be very well understood here, but it doesn't really work out there. They'd like to see this thing work, and if successful, the core doesn't melt --

DR. WALLIS: Do you think using words like one in a billion would be more appropriate?

DR. KADAK: You know, one in a billion people still win the lottery, you know. So what does that mean?

DR. POWERS: I think in pursuing this viewgraph, you ought to look at the experience they had at the Phoebus (phonetic) facility, which was doing an experiment, which amounted to melting down 21 fuel rods, two of which were fresh fuel and the rest of them were irradiated, and the public responds prior to the first test there, and how eager they were to watch that particular test.

DR. KADAK: I'll look it up. I'm not familiar with it.

CHAIRMAN KRESS: They had people with placards marching around.

DR. POWERS: They were invading the test site.

DR. KADAK: Well, it could happen here, too, but hopefully we will engage them long before and get them to buy into the objective of all of this, and if this approach works, I think it will encourage the development of what we would all a more naturally safe reactor.

Next slide, please.

Well, how about the traditional regulatory approach? I think we need to just ask a few people, which I've done from time to time, and maybe they can answer your questions about, you know, how well that worked for them.

As you know, with the MHPGR, Candu and Canadians, I think Westinghouse will have a nice authority to tell them, and I think the AP 1000 is still an open issue, and answers are not always possible to the extent that it can always satisfy the staff.

And I am very familiar with bring me the rock process. I don't think it's very effective, and maybe this approach is an alternative to that work.

So with that I'd like to conclude and answer any other questions in the house.

DR. POWERS: I'm intrigued by your students looking at the pebble bed reactor. Do you have any of them looking at the potential for that particular machine to be used for the fabrication of 239 plutonium?

DR. KADAK: We looked at proliferation. Yes, we did.

DR. POWERS: Find out anything?

DR. KADAK: Yeah. In a normal operating elevator reactor, the number of pebbles required to accumulate eight kilograms of plutonium at end of life is roughly 250,000, and the isotopics at that level are very uninteresting for a nuclear weapon.

If you're deciding to do that, well, let's only run the pebbles through one pass to accumulate eight kilograms. That's around 800,000, which makes it an unlikely target for delivery.

You could be clever relative to the technology, but in that case, as in all nuclear technology, you need extrinsic measures to detect -- as you recall, the system is a closed system, does not have a spent fuel pool, and so even at that point it would be very difficult to get, but we've looked at that, and we need to be real careful in that area.

At some point I hope you invite me back to talk about our work because it's really quite interesting.

CHAIRMAN KRESS: Other questions?

DR. KADAK: My new collaborator.

MR. LYMAN: Ed Lyman, NCI.

Here's a practical question. So you're proposing that the test facility go with a containment which is not the same containment that the pebble bed is planned to have?

DR. KADAK: Only because it's a research facility.

MR. LYMAN: Right. So I've heard the argument that the passive cooling of the pebble bed is incompatible with a leak tight containment and it would interfere with, for instance, the design base LOCA heat removal. So --

DR. KADAK: Well, we'd have to look at that to see whether or not and how we could make it compatible for this particular facility. We'd have to look at whether, in fact, we need to make additional modifications to the facility to accommodate the passive cooling feature.

MR. LYMAN: But if it could be done for the test, then it could also be done for the real thing, I guess, if you had to.

CHAIRMAN KRESS: Yes, ma'am. Please identify yourself.

MS. FABIAN: Hi. Teka Fabian from Nuclear Waste News.

It's not as exciting as melting down the core, but I'm wondering if as part of your conceptual design process you've done the sort of things that the fusion materials program has done, is looking forward to end of plant life and looking at lower activation materials that are easier to dispose of, possibly easier to resmelt and reuse in a nuclear facility, designing the plant for decommissioning using robotics and remote technology; if any of this has played a part in the design process.

DR. KADAK: Not at this stage, although we are following what's going on in Germany as they're decommissioning their AVR reactor.

Clearly, one of our initial objectives was to design a plant with decommissioning in mind, also having a lot of personal experience about decommissioning the Yankee Row plant. So I'm very sensitive to that issue.

But we haven't really looked at it, and we're not really at that level of detail yet.

MR. HOCKRITTER: Larry Hockritter, Penn

State.

As an AP 600 design certification survivor, I'm familiar with the testing that we had done and a number of questions that we got from the NRC, which were large.

But when you structure a test program, usually you build on separate effects tests to try to identify and create a model that you then put into an integral code, and then you use integral tests for verification of that model.

I think one of the problems that we have in the water reactor technology world is that we don't have very good integral systems tests. The loft tests, which are the largest integral systems tests, that we've all used for a code validation, there's a lot of questions on the accuracy of the instrumentation, which are really measuring versus what you think you're measuring, and so forth.

And there may be a lot of potential problems for that in this type of a program unless it's very, very structured very carefully, and then if you add the instrumentation that you want to add, you can start to distort the things that you're trying to measure.

So I think that you're -- I like the idea.

Okay? But I think that you really have a background of tests that you're going to have to provide in addition to a large, full scale test where you build the technology so that you can have confidence then in the code that you'll use to predict the test, which you'll then try to run in the facility.

Otherwise you may have some unpleasant surprises.

DR. KADAK: I think a lot of that stuff that we're talking about, some of which at least I should say has been done in Germany, we don't know. I don't know, first of all, and like it's sort of the code of record essentially is based on, which really has no experience in the United States, but we're learning how to use it, and that's got a lot of models built into it and has been benchmarked against some of the tests that they've done in Germany.

We would hopefully use that data, disrupt your test, but I think your point earlier is exactly right. This is a research facility. In order to be effective, it's got to be well instrumented, and that is going to cost much more money than just building a straight power plan.

MR. HOCKRITTER: That's right, and you'll have conflicting objectives in the design of the plant versus the measurements that you want to make. I mean, that's the problem that LOFT had.

MS. HAUTER: Wenonah Hauter, public citizen.

Who should assume liability for this test? How does Price Anderson play into this? What kind of radiation releases is it appropriate to expose the public to? And should there be a public process, public hearings and so forth to determine if this is something that the public would want to buy into?

DR. KADAK: Let me answer the last question first. I think clearly the public has to buy into this process, and relative to the public hearings, you know, I'm not all that familiar with how that would occur, but my sense is it would have a licensing proceeding, but it would be a licensing proceeding, licensed and experimental facility, and if successful, probably another licensing facility, say it's ready for operation.

The Price Anderson question, I'm not an expert on Price Anderson, but, you know, depending upon who ultimately ends up being the builder, whether it's the DOE or some private government partnership, those people would obviously have to pay the insurance costs for that.

In terms of releases, again, you would design the test such that they would be essentially over this.

DR. POWERS: On the other hand, we could test the validity of our consequence code.

DR. KADAK: That's on your nickel.

DR. SLABBER: Mr. Chairman, just Johan Slabber.

Just a comment in support. I'm not claiming and proposing that part of the PBMR demonstration unit in South Africa will be used as part supplying all of the information to Andy Kadak, but part of our objective as a demo. unit, and it's not a prototype; it's a demonstration unit; it will be instrumented to such an extent that critical parameters during transience, like load rejection, may be loss of coolant, could be measured, and this is not making an open statement.

We've got quite a good technological base for proposing something like this because in an AVR, they have done loss of coolant simulations, as well as reactivity excursion experiments. It is documented, and they found, and this is, again, coming back to the integrity and the quality of the few, that they did not observe any significant increase in releases, although the core was filled with fuel, with a variable degree of quality and burn-ups, and they've also substantiated the reactivity predictions, the temperature coefficient predictions.

So, in fact, there is a base where we can stand on to claim that some of the tests that are proposed in such a reactor has got some supporting evidence in Germany.

DR. KADAK: Just as a follow-up, to the extent that it's appropriate and doable, I think many of these tests could be done on the south African demonstration facility. So the concept is a generic concept suitable for, I believe, any type of advanced reactor that has certain characteristics.

CHAIRMAN KRESS: I'll take one more question, Larry, and then we need to move on.

MR. HOCKRITTER: One of the things that we dealt with a lot in the AP 600 was looking at uncertainty, uncertainty in the predictions, uncertainty in the analysis. Do you know if they've done that with these code for the pebble bed in Germany?

DR. KADAK: I don't know. Perhaps Johan knows better, but I have not been able to get at some of the qualifications.

MR. HOCKRITTER: I know our class also looked for that type of information, and we weren't able to find that either.

CHAIRMAN KRESS: That's a good comment, Larry, because I think having pinned down the uncertainties in, for example, you fission product release models is key to whether or not you really need a strong containment or weaker containment, and it has to do with how certain you are in your risk analysis results.

So I think it was a really good comment. So with that --

DR. KADAK: Could I just make one final comment?

CHAIRMAN KRESS: Yeah, go ahead.

DR. KADAK: I don't think we should get hung up on the fact that we're putting this containment on a research facility as implying that you need one. Again, the purpose is to show that the fuel and the performance of the plan is such that you don't need it. End the debate.

CHAIRMAN KRESS: Okay. With that, let's move on to the next part of the agenda.

DR. POWERS: Mr. Chairman.

CHAIRMAN KRESS: Yes.

DR. POWERS: I notice that Sandia National Laboratories may be some partner in this presentation. I'm not familiar with this particular work, but sometimes I associate with people from that laboratory, and so members should discount anything I have to say.

CHAIRMAN KRESS: We usually do anyway.

DR. POWERS: I noticed that.

CHAIRMAN KRESS: And I don't see why anybody would associate with people from that laboratory.

DR. APOSTOLAKIS: And, Mr. Chairman, I have a direct conflict of interest here. So you will have to do without me.

CHAIRMAN KRESS: You don't have to leave, George. You can stay.

So thank you, Andy, and I don't know who the next speaker is.

PARTICIPANT: I follow George.

CHAIRMAN KRESS: You follow George.

Okay. George, as I told everyone else, you have to introduce yourself.

MR. DAVIS: Okay. My name is George Davis with Westinghouse.

I always like to start off with saying I worked in the same place in Windsor, Connecticut for about 28 years now, and I'm on my third company. We started out as Combustion Engineering and then became part of ABB and then last year became part of Westinghouse, which is an indication of how the industry is consolidating nowadays and how much things are changing.

I'm not really going to give today's presentation. The meat of it is going to be given by Mike Golay. Mike Golay is going to talk about what we're looking at under a DOE NERI project, Nuclear Energy Research Initiative, NERI program, looking at the process for how one would go about applying risk informed insights into not only deregulation, but the design of your nuclear plants, such as Generation IV reactor.

But before Mike goes into that, I wanted to first give you a little bit of a brief overview of what we're looking at in a group of three projects that includes this one all tied together.

Basically, a couple of years ago we put together a team of industry labs and university people. Besides ourselves from Westinghouse, we have Duke Engineering from the industry side; Idaho National Lab and Sandia; labs at MIT, N.C. State. In fact, in one of the other projects we also have Penn State that should be mentioned up here.

And then as we were looking at regulatory issues, we even had a law firm, Egan & Associates, get involved so we could bring in some of the insights from Marty Mulsh to be here at the NRC.

Next slide.

What I wanted to do first is time to give you an overview of where we see these three projects that we're working on going in the long run and how they fit together, and then introduce that as a lead-in to Mike's presentation on the actual processes for design and regulation.

The driving force for what we were looking at in these projects was the issue of capital cost. Basically when we step back and look at what we see as the biggest challenges to nuclear plants being ordered in a deregulated marketplace, we keep coming back to capital cost as the big issue that we're having to address.

Production costs are looking pretty good on the operating plants today. Fuel plus operating maintenance are coming down. If you look at the best performing plants, they're getting close to that one cent per kilowatt hour production cost, and with the consolidation going on in the industry and continued improve, we don't think there's a whole lot of room for continued improvement there compared to what you can do on the capital side.

Secondly, there's the issue that with a deregulated marketplace instead of taking 30 years to pay back the mortgage on a plant, the investors in a deregulated market are going to be looking for capital costs to be paid back on a probably 20 year period or less, which creates even more pressure to reduce capital cost compared to what we saw with the old regulated utility environment.

And so basically we come to the conclusion that if we want to assure that nuclear can be competitive against other alternatives, such as large coal plants, where we see coal plant costs going, we're looking at a need to reduce capital costs on the order of about 35 percent or so below where we are with a large ALWR, our System 80 Plus design.

If we want those to truly be competitive against coal plants in the U.S. marketplace for the long term, and that means we need to be looking at overnight capital cost as a goal, somewhere around $1,000 per kilowatt electric, and being able to get these plants up and running in about a three year production period.

So what we've done in these programs is rather than tackle a particular reactor design, we decided to step back and address the processes and ask ourselves what can we do to improve the processes, the tools that would be used for designing and licensing future plants with Generation IV reactors that could help to drive down the costs and cut a lot of fat out of the process and provide designers with the flexibility they need to be able to really come up with new, innovative designs and get those licensed.

And so we have three projects that we're working on. The first is looking at risk informed assessment of regulatory and design requirements. It's basically looking to develop methodology for how designers would use PRA insights in the design process in a much more radical approach than we've done in the past and how that could also be translated into the regulatory process for getting plants improved.

Next is the area of smart equipment, and basically there we're looking at methodologies for how you could put self-diagnostic, self-monitoring features into plant equipment, such as pumps and valves, as a way to improve reliability at the component level.

All of this would obviously have some benefits from an operating standpoint. The way we think it would help on capital cost is if we can address reliability at the component level. Then that should allow us in the above-program on the risk informed design process to step back and look at simplifying on a system level.

In other words, if you can count on higher reliability of the components you're using because of these smart features built in, self-diagnostic, self-monitoring features, then you should be able to look at further simplification and not as much redundancy being required at the system level if you can encounter a more reliable components.

And in the third project we're looking at are technologies that can be used for design, fabrication, and construction of new plants, again, to reduce the cost of those processes. And there we're looking at what can be borrowed from the aerospace and automotive industries and the approaches that they've been developing over the recent years, again focusing heavily on computer based application, to do things like collaborative internet based engineering activity.

We see that as being related to design of regulatory process in the initial program, the top program up there, because if you've got designs being developed on an Internet based collaborative approach like they're doing in the automotive and aerospace industries today, then you could talk about in the future getting to the point where the NRC and even the public can have some limited degree of access.

You may have to have firewalls for proprietary information in some areas, but the point is you could have the whole design process a lot more transparent and open where it could be looked at by reviewers and the general public as the long-range goal for where you're going.

So even the tools you used in the design process could have some benefits for the regulatory approach down the road.

MR. LEITCH: George.

MR. DAVIS: Yes.

MR. LEITCH: Regarding your second project, I can see how smart equipment may improve the reliability and safety, but I don't quite see how it would improve capital costs. In fact, it would seem to me just the opposite would be the case. Could you run that past me again?

MR. DAVIS: For the individual component, it would increase the capital cost of that component. If you put in a smart valve, adding those monitoring features and the computer software to go with it, it's going to add to the cost of that valve.

However, let's say you've got in an ALWR like our System 80 Plus. You've got a four train, high pressure safety injection system. If you can show high enough improvement in reliability and individual components, you can go back and question do I really need four trains of redundancy, if I can count on the reliability of the individual components in each system.

MR. LEITCH: That would be in a future generation plant though.

MR. DAVIS: Yes, this is all looking down the road at Generation IV type reactors. I mean, none of these projects as I see it can lead to processes that are going to be immediately available and can be applied today. These are things that would be applied down the road for Generation IV.

Now, we do see some potential that there could be some spinoff applications along the way for things like the pebble bed modular reactor, things that might be developed for that, but these projects were originally set up with the goal of developing some very long range programs that would lead to design activities of Gen. IV reactors in about ten years.

This figure, it looks like the cross-section of a circular firing squad the way it's pointed in, but the point here was that in looking at how you risk inform the process, one could start out at the very left side of the figure with the deterministic requirement we have now and then looking at those case by case, individually like we're doing with the operating plants and asking where it can be risk informed, those individual deterministic criteria.

At the other extreme on the right-hand side, one could go to a more risk based approach where you design based on the PRA, but recognizing that state of the art PRAs are such that they're not perfect and there are uncertainties not only in the techniques, but in the database for PRAs, that you're going to have to back up and add some degree of deterministic requirements in to make the process work to cover those uncertainties in PRA capabilities.

We basically started out in this project thinking that we would start on the left side and work across, but we quickly got to the conclusion that the only way we're going to be able to come up with a revolutionary new approach is for designing and licensing plants that were going to allow some substantial cost savings, was if we went to something more revolutionary, where we went to a more risk based approach and then back up to decide what needs to be entered in.

And that's a good example, I think of where having labs, university, and industry working together has been a good synergy, because from an industry standpoint, we started off thinking in the box on the left side, and the input we got from the lab university people really caused us to step outside the box and think more revolutionary on how we needed to go with this, starting with the right-hand side of the figure.

Basically, as far as these projects are concerned, because they're rather limited funding, they'll wrap up next year. They're just intended to lay a framework or a foundation for where we would see these methodologies going.

The ultimate implementation of these is going to depend upon several things happening. One is we're starting to coordinate our effort with NEI. As you'll hear from Adrian Heymer later this afternoon, I believe, he's going to talk about NEI's effort, that they're cranking up a task force to look at developing a risk informed framework for further plants.

And it's our intent to coordinate what we're doing in our project with them, but we'll have a representative on their task force, and the goal would be to make sure that what we do in our project gets folded into what they're thinking about in that task force and that we come up with consistent results. They may not have to match up exactly, but we obviously would like to try and have some consistency there.

Very importantly, I think we want to wind up in a situation where the technology road map activities for the Generation IV reactors, that road map that's being developed, needs to think about not just developing new designs, but developing processes to be used in designing and licensing those Generation IV reactors, too.

So we're hoping that what we do in laying the foundation for these engineering projects get reflected in the thinking for the Gen. IV road mapping effort so that there's some consideration of processing as well.

I might also add as a final point I've

also participated in an IEA activity where they're putting out a technical document later this year on optimizing technology for water cooled reactors. Although it says water cooled reactors, it's really applicable to all three reactors, and it will embody a lot of the same philosophies that we're looking at in the engineering project.

With that I'll turn it over to Mike to go into the discussion on what we're looking at in this process.

DR. GOLAY: Thank you, George.

Could we go to the next slide, please?

I'm going to speak about the specific work that has come out of the regulatorily oriented process among the three that George described, and I'm reporting on behalf of the overall project and particularly of the team from MIT, Sandia, and Westinghouse, where the most active members are listed here. Half of that team is in the room, and so if you want to follow up after this meeting and discuss things with them, they'll be available to do it.

Go to the next slide.

The thing that we have been focusing on is really to try to create a comprehensive regulatory approach that comes up with a method which is both comprehensive and systematically consistent logically and can be expected to create incentives such that designers will naturally have reasons to do the things which regulators recognize as being important in coming up with good technologies.

So we've looked at it from the point of view of an overall system to produce electricity successfully where the designer's task is really in both areas, and today we're going to focus on the part having to do with safe production, but we recognize that the designer has to produce an economically attractive plant and hopefully corresponding to some of the goals that Neil Todreas outlined earlier in the day.

So the focus here is going to be over on safe production, but we want to have the incentives aligned so that you achieve both of these and do a good job on safety.

What I want to do is begin by posing two questions to the ACRS, and that is fundamentally the issue, I think, for the NRC is what do you do in terms of regulatory reform. The fact that this session is being held is a recognition that the current process needs improvement.

The fact that every new applicant for a

new reactor concept comes in where a part of his proposal is a new regulatory treatment is, again, a symptom of the need to improve things, and so the issue is not whether improvement is needed, but rather what should be recommended by ACRS and what role should NRC play in achieving the improvement.

My specific suggestion is that we need an effort where the overall national effort for advanced reactors includes a component of regulatory reform with the NRC being involved, but I think realistically given the funding situation that the NRC faces, it probably is not in a position to take the lead.

But that's a question I'd like to ask the ACRS to ponder, and if you feel like offering advice to do so.

And the second thing I want to do is outline then for you the kind of product that we have been able to develop so far where essentially it's a work in progress, where there are some ideas of how to attack this problem that we'd like to present so that to the degree that you accept them, they can begin to soak in, and to the degree that you think we need to reconsider things, we can get the benefit of your advice.

Some of the fundamental ideas are listed here, and they're somewhat revolutionary. The top one is that the process of regulation is guided by decisions which are made based upon the beliefs of the decision makers, that is, the regulatory personnel.

This idea of beliefs as opposed to evidence is very important because what we would like to do is find a way so that those beliefs which cumulate in the evaluation of a reactor concept and how it's operated, that one way we can state this is in a probabilistic format, essentially using for continuous variables a probability density function as a way of addressing the relative likelihoods of the range of possible values that the evaluator thinks are worth considering.

And that when we approach things in this fashion, what you're naturally led to is that when we try to formulate acceptance criteria, that we do it in terms of expected performance and also associated uncertainties.

And Tom Kress already alluded to the idea of making your acceptance decisions based at some level of confidence, which would be an example of how you might approach that.

DR. WALLIS: Your choice of words is interesting. "Belief" tends to be associated with yes/no, I believe, I don't believe, I believe in nuclear power, I'm against it sort of thing.

DR. GOLAY: No, I'm not talking about values.

DR. WALLIS: I know you're saying it has to be probabilistic. So I tend to agree with you. It's just the choice of the word "belief" is a little strange.

DR. GOLAY: Let me distinguish. I'm not trying to speak about values, which perhaps is the version of that term that you're honing in on, but rather, in terms of the conclusions that an evaluator will reach regarding the relative likelihoods of alternative answers.

CHAIRMAN KRESS: It's the Bayesian concept of probability.

DR. GOLAY: Exactly, exactly.

DR. WALLIS: A state of knowledge is usual.

DR. GOLAY: Right, exactly, and so what we're leading to is a formal statement of that in a formalism that is scrutable by everyone, and what this really flows from is a conclusion that the problem of safety regulation is not one of expected performance, but rather of treatment of uncertainties.

Now, I know this is probably not a novel concept to the folks here, but if you look at proposals that we have had for regulatory improvement, they're almost always focused on what should be the deterministic expected performance criterion, and then how the things perform in terms of that, when, in fact, the big problem is dealing with the associated uncertainties.

And what we've tried to do is turn the problem around and make sure that uncertainty is imbedded in what we do from the very beginning so that it has prominence at the same level of expectation and is handled in a formally explicit fashion.

So that's what's behind what I have there. We go to the next page.

DR. WALLIS: This is an unfortunate term. I mean, if you tell the public you're uncertain --

DR. GOLAY: Yes, and I frankly want to separate the problem of public communication from technological evaluation, and the reason is that I think that I didn't really mean to get diverted on this, but I have an answer for it, which is that I think we have made a mistake among engineerings of falling into engineer-speak where the idea in public communication is that if I communicate in the vocabulary which I feel is most valid and with which I am most familiar, I can also be most effective, and I submit that the task of public communication is not one of communicating a message concerning how hardware will perform, but it is focused on helping the public in their search for who to trust for dealing with the technology.

And so the format for what we're presenting here is not amenable to public communication, but the task that has to be accomplished in successful communication is really a different one of giving people a reason to trust that you will make good decisions.

Now, that's my answer. Other people will have other answers, but I'd like to separate the two.

Okay. On the approach which we have, we're also stating that regulatory questions, unanswered issues concerning license submittal or licensee behavior and their acceptance criteria, if we're going to use a probabilistic framework, then these questions and criteria have to be stated in that framework as well.

So what we do is really use a probabilistic treatment as the integrating and systematic basis of evaluating a submittal, but we continue to use deterministic models, data, tests, all of the tool kit of evidence that we've always used, but use it to support the probabilistic presentation and to try to incorporate all of the questions which are relevant to successful performance into what is essentially a much expanded PRA.

This would require that both the license applicant, who right now has the burden of proof in terms of evidence, and the regulatory staff in parallel justify their decisions explicitly in this probabilistic framework.

This is partly in answer to Andy Kadak's point about the bring me a rock syndrome, and that is what we would do if you accept the approach which we're suggesting is that the warm, fuzzy feeling and the bring me a rock would be translated into state your evidence in a probabilistic format that we're suggesting here just as the licensee must do.

And as part of this, you're very quickly led to the need for subjective judgment and incorporating that into the overall process, which if you think about it, we do today, but we don't do it explicitly.

And the one use of the probabilistic format is to provide a vehicle by which to state those judgments and, again, make them scrutable and to incorporate them formally into the answer upon which you base your regulatory decision.

That is a subtle thing to do, and it requires development of processes for capturing those judgments. Today what we have are informal processes, but we use them. You know, the ACRS is a good example of that.

CHAIRMAN KRESS: I'm going to ask you my standard question. In this type of regulatory framework --

DR. GOLAY: Keep going.

CHAIRMAN KRESS: -- which I'm very taken by, how do you see the words "defense in depth" fitting into that?

DR. GOLAY: Fitting indirectly. I'll come to it.

CHAIRMAN KRESS: Okay.

DR. GOLAY: Give me about five more slides, and if I haven't answered it, ask me again.

CHAIRMAN KRESS: Okay.

DR. GOLAY: Okay, and because disagreements in these evaluations are inevitable, some process of resolution will be required, just as today in the regulatory system we have an appeals process, but it's formulated more looking at things in a deterministic fashion. So we anticipate the need for that.

Okay. You see this kind of hierarchy structure going from high level safety goals down to inspection requirements and things like that. We would basically stay with this, but what we would do is try to handle things, as I say, using PRA as the integrating method and continuing to focus on the same kinds of essential safety functions that you want to achieve.

So nothing has really changed in the structure here, but the way you would go about trying to show satisfactory performance is what we would change.

Could we go on?

CHAIRMAN KRESS: How would you deal with the issue that Dana gets very concerned about, and that is the PRAs are traditionally, the ones we have now, very incomplete. They don't deal with shutdown conditions very well. They don't include fires very well, and seismic even is often not treated very well in human -- would you incorporate those kinds of missing ingredients into the uncertainty of distribution?

DR. GOLAY: Yes. Now, basically the way you would incorporate them is through a statement of the subjective judgment of those who have to assess what practices --

CHAIRMAN KRESS: That's where your subjective uncertainty comes into play.

DR. GOLAY: That's right. So where objective evidence reaches its limits, then you have to go to subjective, as we do today. We just don't spell it out.

DR. POWERS: Let me ask a question. You're going to expand the capability of PRA to carry this out. One of the areas you're going to expand it to carry it out is in the shutdown risk.

Now, I presume that you have a plant here that you say is going to have some history, and during that history it's going to have various kinds of shutdowns, those that it planned, which is going to do a variety of activities that are going to be quite different, and it's going to have an occasional unscheduled shutdown.

And you can prognosticate all of those things, all of the different configurations of the plant that go on during a shutdown, a scheduled shutdown for refueling and whatnot.

DR. GOLAY: I would say that your task in those areas has not changed from the task that people have today; that when you go to consider a license application, you try to consider the spectrum of conditions under which it will be operated, and using evidence appropriate for each condition, judge whether it will be operated successfully.

So that --

DR. POWERS: But now we don't try to quantify --

DR. GOLAY: That's right.

DR. POWERS: -- those times and configurations, and yet you want us to do that. How is this possible?

DR. GOLAY: Well, I think that the development of shutdown risk analysis provides an illustration of how you do that in, say, a non-power state, and when you're comparing operations between those states, you, as Tom just brought out, you inevitably come to situations where the available objective evidence is not sufficient for you to determine, say, which practice is better.

Do you do maintenance while you're shut down or do you do it on line, for example? And, again, subjective judgment has to come into the process.

And what I'm submitting is that we use that subjective judgment today. We simply don't spell out loud the factors the way that we're weighing the factors, and what's changed with the approach that we're suggesting is that we state it in probabilistic terms and incorporate it into the PRA.

CHAIRMAN KRESS: Let me expand on Dana's question a little. What I'm interested in is the risk associated over the full lifetime of the plant. That means shutdown number 85 is going to take place n years from now I need to incorporate into my risk assessment.

Now, since I don't know what that shutdown consists of, what planned maintenance they're going to have because it hasn't even come about yet, it may even be an unplanned shutdown. How do I know how to incorporate the short time during shutdown, short compared to other things? That risk, how do I put that risk component into my risk assessment when I don't even know what it -- we're dealing with a change, a variable configuration in time rather than a fixed configuration, which is what PRAs usually deal with.

How do I deal with that in a PRA? Is that something that needs a new PRA methodology for?

DR. GOLAY: I would submit not, but let me go to why The first question that may arise is why do you need research on regulatory reform. Why can't you just get a few people to go off and think in the corner for a time and come up with some proposals and then try them out?

My experience has been that you don't know what is a good idea until you've gone through some feasibility attempts; that there's an iterative process here, and that's the heart of doing that kind of research, to find out what's feasible and then from that find a good blend of feasible approaches consistent with an over arching logical framework.

In terms of the question you've asked, I would suspect, without having tried to do the analysis you said, that, first of all, the level of detail required is probably not necessary; that approaching it from the point of view of looking at safety during shutdown and trying to anticipate a range of conditions that you think are reasonably plausible, which is the approach we have today, I think that that will work.

And what I would try and do is turn it around and try and use a real probabilistic treatment of the safety, but not to try and anticipate the fine detail the history of a plant that might occur or might not occur.

CHAIRMAN KRESS: You could use past experience of what has occurred.

DR. GOLAY: That certainly would be part of it.

CHAIRMAN KRESS: The database maybe.

DR. GOLAY: Yes, exactly, exactly.

Does that respond to what you brought up, Dana?

DR. POWERS: Yea, I was bringing it up for Tom.

DR. GOLAY: Okay. All right. Let's move on or we're going to be here until four just on this presentation.

George showed this slide earlier, and essentially where he said that we are in our work is over on the right-hand side, which is taking a top-down and probabilistically based approach, and it's in complement to most of the other approaches that I've seen, which are really trying to find an accommodation with the existing approach, partly because they're driven by the need to get a license.

You know, as people say, you don't drain the swamp when you're to your rear in alligators, and that tends to be the situation for most of these projects, although I'm sure that many people are thinking about the whole range of this.

But our starting point is over here, and that's one way in which as far as we know, our work is somewhat different from the others.

However, the elements that go into it are the kind that you see always, which are that you want to find a way to incorporate defense in depth and safety margin. These are good design practices regardless of the regulatory approach.

And one of the things that led us to the suggestion we're making today is that we wanted a way to state the benefit that you get from these various practices.

DR. WALLIS: Do you have a good measure of safety margin in a probabilistic sense?

DR. GOLAY: Yes. If you're using margin on let us say approach to melting temperature or something of that kind, what that would translate into would be to formulate your acceptance criterion from the design point of view at a very, very high confidence level so that you insure -- and you, of course, could say that let us say your 99 percent level could be somewhat reduced from what you think is the actual failure point, would be a way that you would do that.

DR. WALLIS: But once you start saying there's a failure point, you are making things deterministic, which really are not.

DR. GOLAY: Well, I'm trying to relate it to the current design process.

DR. WALLIS: That's right, but I think it would be interesting to see what you could do with a definition of margin which got away from these ideas of having a point or --

DR. GOLAY: Right, and what you would do, as you're hinting, is really to use a distribution on all of the performance limits, and that would be a natural evolution that I think we would go to and probably quicker than I'm anticipating.

DR. WALLIS: You would look at the probabilities of all of those and the consequences of all of those.

DR. GOLAY: Right. That's right.

So what you expect is that if people are using the approach we're suggesting well, they would have natural incentives to put defense in depth into their designs partly because they could see a benefit for doing it when they go and make a regulatory submittal.

The same thing with margin.

CHAIRMAN KRESS: How do I decide what confidence level constitutes an acceptable margin?

DR. GOLAY: My short answer is you have to work on it.

(Laughter.)

DR. GOLAY: Well, it's partly a social policy and has to be worked out with --

DR. POWERS: We've been working on it, by the way --

DR. GOLAY: -- the regulator.

DR. POWERS: -- for four years that I know of.

CHAIRMAN KRESS: I'm glad you said that because that's my belief also. It involves things like the loss function, for example, in decision theory.

DR. GOLAY: Right. And so if we're successful in our work, what we will do is kind of set some directions for future work to pursue because some of these, as you know, are very subtle. But if we accept the overall approach that we're trying to lay out, that's the most important thing that we really want to get across.

And then there is a lot of research for professors to do, keeping lab personnel out of trouble.

CHAIRMAN KRESS: Yeah, we've got to keep them occupied.

DR. GOLAY: Right. There you go. Well, that's never been a problem.

Could we go to the next slide?

One of the other points that I want to make is that we tried to come up with a regulatory approach which would be useful at different conceptual stages of development.

One of the things which I've observed makes consideration of regulatory change, makes those discussions difficult is that if you don't state the level of maturity of the concept, what's approach becomes a difficult conversation because what's appropriate in one circumstance may not be in another.

But this notion that you're using a combination of probabilistic analysis and essentially your best set of probabilistic with deterministic test experience and judgment at any stage of maturity is the consistent part. And I'll come back to this in a minute.

And the idea is that as the maturity of a concept grows, that the level of detail and our ability to introduce concepts that we're familiar with from light water reactors, such as DBAs, design basis accidents, that that will also grow, but that at an early stage, some of this may not be applicable.

Can we go on?

So in this table, what we've tried to do is put together an illustration of what we're talking about in terms of different levels of maturity as we go from an initial concept to the n^{th} plant as we have with light water reactors, where there are many of them around and where we have a lot of experience accumulated.

And basically the regulatory system gets into it in the lower three rows of this figure, where you may have an initial detailed design, but where it's not feasible to do more than formulate the high level acceptance criteria, and where our level of detail in the knowledge of the system is also fairly limited.

The idea that I want to get across is that as we work our way down the figure and later into time, that the amount of detail, the number of finely crafted performance goals that you can come up with, and your ability to translate those into deterministic decision rules will tend to grow, but in the early stages, you tend to stay high level and mostly probabilistic.

DR. WALLIS: It's an interesting idea, but it seems to me that as you learn more about a plant, you might actually get less detail than any kind of plan. You might really know what you have to worry about and you don't need all of this detail.

DR. GOLAY: Conceivably, and we've seen that, for example. I would say that the evolution of the passively based water cooled reactors could be an illustration of that.

But one reason for putting this figure together is to address this question of where does the design basis accidents and general design criteria come into the picture here, and I would say it's a tentative conclusion, not a firm one, that those really play a role when you get to the detailed design and later stages of things because when you try to formulate design basis accidents, you have to have a design. You have to have a concept in which to think about and have some seasoning in terms of your understanding of its weaknesses, things of that kind.

And if you look at what we've done with

light water reactors, we've gone through the evolution shown here, but with not quite knowing it or not saying it out loud, and especially the reason I've put this up concerns general design criteria.

That is, if you look at the general design criteria that we have for light water reactors today, most of them are motherhood statements. They're essentially do good things, put in margin, put in conservatism, defense in depth, and so on.

There are a few things like have a containment, have redundant shutdown systems, which are spelled out, but most of the criteria are not, and they're formulated in a way which reflects what's feasible, mostly driven by light water reactor.

And one idea which we think is worth exploring is whether that the formulation of GDCs should be done at a concept specific basis, reflecting some accumulation of study and experience.

And it bears on the question, for example, of whether you need a containment for the gas cooled reactors, and I'm not going to offer an answer for it. I'm just suggesting that with this framework, you might delay trying to answer that question until you've gone through some evaluation in this as opposed to starting by, you know, God said you have to have containments, and then from that we go on to other things.

DR. POWERS: And He did.

DR. GOLAY: Or She.

(Laughter.)

DR. GOLAY: Okay. Can we go on?

The other point I want to make is that there's nothing in what we've prepared which is inconsistent with the cornerstones, with the approach that the NRC has been taking in terms of restructuring the emphasis in the design and regulatory concerns.

What we have focused on in our work on examples is over here in the reactor safety part of the structure, but when we've looked at it, we don't see anything that would stop you from going to the other issues. We just haven't had the resources to work on them.

Can we go on?

And in terms of setting performance goals, what we've done, this is an illustration of a master logic diagram to help you identify initiating events that would be important in your event sequences or your accident sequences, as Andy Kadak had suggested, replacing the design basis accidents by the risk dominant event sequences has some attraction.

And what we've concluded is that you really have to break this into two parts. One is a general treatment at a very high level where you have certain performance goals, and as we go down in the hierarchy here of this fault tree, going to finer and more finely defined events or the concatenation into creating a public threat, that there's a general level at which you can set performance goals and where the safety goals are examples of that, and then below that, when the details of the concept become important. The kinds of failures that you worry about and the combinations of events then will be concept specific.

And so we're seeing a two-step way of approaching the fault tree and from that the master logic diagram and eventually the initiating events, which are of primary importance.

So, for example, what's in the handout figure is kind of our first shot at how you would draw this for a gas cooled reactor. It's by no means complete or even correct in every detail, but the purpose is to illustrate how some of the initiating events and failure modes that show up are not those which show up for water cooled reactors.

For example, one of the things in here is failure of the radiative cooling path, which in the water cooled reactors we don't even worry about. I mean, when you think about it, this becomes obvious, but it's an illustration of how you would go about this.

Okay. Could we go on?

How much time do I have, Mr. Chairman?

CHAIRMAN KRESS: We are supposed to -- you have about 15 minutes more.

DR. GOLAY: Okay. Keep going. I'm going to skip over the next, I think, three. Right. Stop there, please.

Okay. The last thing that I want to move to is interaction between the applicant and the regulator, and what are the implications for the approach that we're suggesting?

And what we're really focusing on is that when you have an applicant come in with, let's say, a new reactor design application, what they do, they submit all of their documentation, of course. They go through review under the standard review plan, and all of that is preliminary to what is a negotiation between the licensee and the applicant regarding what's acceptable or unacceptable about the design, and then it's up to the applicant to find a way to satisfy the regulator.

We expect that that process would continue, but that it would be replaced. Today it is really focused around how will systems do concerning design basis events with consideration being given to evidence from things like the PRA and treatments of uncertainty and so on, but the DBA has played a central role in the way things have been structured.

What we would do is reverse that and have the probabilistic integration of the system performance be the primary vehicle used for the evaluation, but the much more comprehensive version spoken about, and that the acceptability negotiation would be conducted in the context of the RPA, where we would need consistent procedures, tools, and termination criteria for this negotiation process.

That's for reviewing new designs. We anticipate that for the regulation of construction and the regulation of operations, that formulation of a set of deterministic rules, but based upon risk based information could be done, and we think that that's desirable for practical reasons, for people in a construction site. You don't want them running PRAs all the time and making decisions.

But we're suggesting that if the review of the new design, that it is a practical thing to undertake today, particularly when you're looking at marginal changes in the performance.

Okay. Can we go on?

And so I want to give an illustration of how this negotiation or discussion might proceed, where the idea is that initially a designer would come up with a plant design satisfying the goals of that first figure that I showed, producing economical and safe electric power, and that it's his or her responsibility to come up with a design that will do that very well.

When the designer, design team, more realistically, thinks that they have satisfied the performance goals that have been formulated by the regulator, they submit their application and it's reviewed.

Presumably there will be some areas of disagreement regarding the adequacy of the submittal because that tends to be the nature of the licensing process. However, what we're expecting is that the disagreements should be in terms of the expected performance, safety features, the performance criteria that were used internally to decide that they would do well, and the methods and analysis, that is, the data and models used, and that this process be documented, again, in the probabilistic terms.

Can we go on? We seem to have lost something here. Yes.

DR. WALLIS: Let's try to think about this. The method of design and analysis is going to be in probabilistic terms. You mean that every time you put a correlation in a code, you have to do something probabilistic with it?

DR. GOLAY: Only if it propagated through into your risk evaluation.

DR. WALLIS: It probably does.

DR. GOLAY: Yeah. For example, if your new correlation had a different uncertainty treatment, you would expect that to be propagated through, yeah. That's right.

Okay. Can we go to the next one? This one isn't coming through, but what it's meant to illustrate, I'll tell you what you would be seeing if it were showing up, which is above the line showing an iterative risk based design process, and below the design, showing an iterative risk based review and feedback of that process.

So below the line we're dealing with the negotiation between the designer and the regulator.

Above the line, we're dealing with the designer trying to do a good job in the first place.

Ah, there we go. Okay.

And hopefully when they've gone through this, they will eventually reach satisfaction on the acceptance criteria and gain a license.

Okay. Let's go on. Oh, no, not another one. That's the same one. Is there any way to turn this off and move ahead?

DR. APOSTOLAKIS: It was too fancy.

DR. GOLAY: Yeah, I can see that. I can see that.

And this is what we foresee that the designer would be doing, and that is -- and I'm going to give you an illustration of this, which is start off with what we call the bare bones design, and this is only an illustration of how we think it might proceed. This isn't a requirement for anybody to do, but essentially create a design to produce electricity, and then go through and ask: well, what are initiating events which could cause a safety problem?

And it doesn't just have to be core damage. It would be in all the cornerstones.

To use a PRA to identify the dominant risk contributors, and from that to identify mitigative features and systems that could be used to alter that PRA profile and iterate on this until finally the design comes to satisfy a vector of acceptance criteria, which would be formulated at whatever is the right level for maturity.

DR. WALLIS: Couldn't there be a scaler that says that whatever your PRA produces must be less than some number?

DR. GOLAY: Within a certain area of performance, that would be the case, but we recognize that there will be many areas of performance.

For example, you may want to have the frequency of initiating events to be very low, satisfying one of the cornerstones, and you may also want to have a very low core damage frequency, as well as a very low frequency of activation of the off-site emergency plan.

So, in general, we're anticipating a vector, but each element would be stated in deterministic terms, and so this is what the designer would be going through before the submittal and then afterward, following the negotiation.

Okay. Can we go on?

One of the things which we want to get

across is, and this figure doesn't do such a great job of it, is that the formulation of the acceptance criteria, once you go below that line of concept specific performance criteria, has to be determined iteratively because how you divide what's acceptable in a high level performance goals into a set of subgoals depends on what's feasible.

And so, for example, I want to use the example of for a light water reactor LOCAs of different size.

Go on.

Where when we went through with the Westinghouse design team for the set of very small LOCAs, small LOCAs, and large LOCAs with a particular mitigative system, what we ended up with is this array of core damage frequency, where you see it's a non-uniform distribution, and that's the key point we want to get across in this illustration.

So that as you take the overall division of what's acceptable ways of having core damage, that you wouldn't necessarily divide them up uniformly among all of the categories of such events.

And that's a reflection of what we are trying to talk about when we say you have to do some work to see what is feasible to do, and the answers will be different from one concept to another.

DR. POWERS: When I look at this table, I'm not sure what numbers I'm looking at.

DR. GOLAY: Well, it's the right-most column that I really want you to --

DR. POWERS: Yeah, I know, but I want to get to that right-most column. Are these -- am I looking at products and means or something else?

DR. GOLAY: Means. These are for purposes of illustration.

DR. POWERS: So mean time a mean equals a mean? I don't think so.

DR. GOLAY: Yeah, I think for purposes of what we're talking about, but if you want to do it as the integrated result to the stated confidence level, we can do it just as well.

The key point that I really want to get across is that you can't simply sit in your office and decide, well, I'll slice up the risk pie in, let us say, a uniform way or some way that I particularly like; that it's always a compromise between what's feasible and what's desirable, where I would say what's most desirable would be to try to spread the risk among sequences as much as you can or not put your eggs in one basket, but for various physical reasons, your ability to do that may be strained.

DR. WALLIS: Why do you need subgoals? It seems to me that if you had a plant that had no LOCA probability at all because of its design, then you might trade this off and be allowed to have more probability somewhere else if something else and all you care about is the total.

DR. GOLAY: But you care about the uncertainty associated with the total as well.

DR. WALLIS: Yes, you do, but the total, the bottom line is the thing, not really how it breaks up in all these pieces.

DR. GOLAY: Yeah. Well, I would say that another reason why you want to do this is that in the long run for regulatory convenience and efficiency, you probably want to move -- try to find risk-based deterministic decision rules as you reach a high stage of maturity, and so there will be sort of natural incentives to formulate subgoals as the concept matures.

And that's the reason we have this in here, simply to illustrate that you have to go through this iterative process. It's not to carry it further than that. Okay?

CHAIRMAN KRESS: Would there be a guiding principle on how to -- this is more or less talking about rationing the risk among the various --

DR. GOLAY: Right.

CHAIRMAN KRESS: -- as a defense in depth concept. One does this because he's uncertain about each of these results.

DR. GOLAY: Right.

CHAIRMAN KRESS: And so he wants to spread that uncertainty out, but is there some guiding principle one could come up with that says that that uncertainty, overall uncertainty, ought to be either minimized by selecting these distributions to optimize the level of uncertainty of each one so that it's minimized at the end, or so that it's acceptable, or is there a guiding principle on how to make this allocation of risk?

That's what --

DR. GOLAY: I think we have to do some work on it before we really know the answer to your question. My suspicion is that we want to go in the directions that you're saying, which is to try to make the distribution reasonably uniform and the total small at whatever your stated confidence level is.

But I'm sure it's more subtle than that.

CHAIRMAN KRESS: There has to be some

other principle that tells you how to do this.

DR. GOLAY: Exactly. And what I'm suggesting is the principle is really one of trial and error to see what it is that's feasible to do.

CHAIRMAN KRESS: And, of course, that would enter into it.

DR. GOLAY: Yeah, and I'm doing this because the message I want to get across is that formulating a practical system that people can really use takes some work, takes some sustained resources and is sometimes pretty subtle.

Okay. Can we go on?

So I want to go through how we did this, our team, concerning dealing with LOCA events where we came up with an improved system over the -- this is for light water reactor system.

Started off with a bare bones system and then from that added in some mitigative active systems. So I'm not suggesting this is the best design you would want to use, but it's one that's consistent with the active light water reactors, such as we have.

And so we have two high pressure injection systems, one low pressure system. I won't read all of this to you, but essentially some of the usual candidates, passive DC power, shared chemical and volume control system.

And from this, our designers contended that they had an acceptable design.

Can we go on?

And so what we're foreseeing for this negotiation is a process outlined, is in the flow chart on the next figure, where the applicant thinks he's done an adequate job and makes the submittal. Upon review, the regulator says it's not adequate basically because of a dispute concerning modeling assumptions, which could be resolved by getting better data, and the reason is that the core damage frequency associated with the high pressure category of LOCA is seen to be too great.

One way that it could be solved is to have a research program, go out and get more data. Instead the designer decides to alter the design, and what he does is go and decide he wants to make the response to high pressure LOCA be one of depressurization, and so he does this by putting in a train of depressurization capability in his shop, not going back to the regulator.

The result is that the core damage frequency is still too high. That is, we have an acceptance criterion in terms of the core damage frequency or LOCA.

And so in the next iteration, the designer comes, and he puts in an additional train of depressurization capability, still finds that it's too high, and the reasons upon investigation are that common cause failures involving the cooling system and the emergency diesels are too high.

Could we go on?

CHAIRMAN KRESS: Now, go through this process. I have to have in mind a CDF that's acceptable for just LOCAs.

DR. GOLAY: Yes.

CHAIRMAN KRESS: Or for LOCAs of different sizes, which is kind of a tough number to come by. You know, I've got an overall CDF in mind, but I don't know how to fractionate that up among LOCAs and other things.

DR. GOLAY: Right, but what we're anticipating is --

DR. POWERS: Why don't you just do it?

DR. GOLAY: Now, we're not saying how the number was gotten at. We just want to illustrate how the process would go forward, and if such a criterion were to be formulated, this is how we would expect it to be tested on whether it's acceptable.

In the very early stages, I think you'd have trouble formulating that. In the later stages of maturity, you might be able to.

CHAIRMAN KRESS: Somewhere along the line we've got this.

DR. GOLAY: Right.

DR. POWERS: Why would you want to wring your hands over it? Why not just say, as is apparently done here, "I don't want it above two times ten to the minus sixth on a LOCA"? Which one is more capricious and arbitrary?

CHAIRMAN KRESS: It might very well be that my overall CDF goal is, say, ten to the minus five, and nothing contributes to that except the LOCA, and I might very well be willing to accept it as ten to the minus five. That's the confidence level.

DR. POWERS: You might well be willing to after the fact change things, but if you're just going through this exercise here that he's outlined, --

CHAIRMAN KRESS: You're saying you don't need the -- when you look at the whole system in total and make some judgmental --

DR. POWERS: Yeah, I think you can.

DR. GOLAY: I think that may be a

reasonable process, too.

DR. SHACK: Well, it's a question of who's setting these numbers. The designer can set it any way he wants to, and the question is whether the regulator then forces those numbers.

CHAIRMAN KRESS: Well, my point was should the regulator come in at this point and have acceptance criteria related at this low a level or should he just focus on the endpoint?

And I think, you know, that that's the whole debate.

DR. POWERS: Sure.

CHAIRMAN KRESS: Should you focus on the endpoint or should you come in at this point on the regulation?

DR. POWERS: It is what point you come into.

CHAIRMAN KRESS: Yeah.

DR. POWERS: We know that they will come in more than at the endpoint.

CHAIRMAN KRESS: And that's why I keep harping on defense in depth. this is a defense in depth concept, whereas if you just focused on the endpoint, perhaps it's not.

DR. POWERS: Right.

CHAIRMAN KRESS: And this may be a way to bring in defense of depth or it may not. I don't know.

DR. GOLAY: Well, that's actually part of why we picked this illustration, because we're anticipating that as the maturity grows, there will be a natural evolution of performance goals formulated at a lower level.

For one thing, it makes the design process more efficient and should make the review process more efficient, but that's why also I went through this business that where you set the goal depends on the maturity of the concept. There isn't just one answer.

But we're assuming that things are mature enough that we can work at the system level with system specific or relevant goals, and so the idea is that after rejection, the designer goes back and using the kind of risk information we're showing here, keeps modifying his design until he thinks that he's got something ready for another path.

Could we go to the next figure?

Upon submittal, there are two paths that we consider to be worth thinking about. One is the easy one down here, is Evaluation 2, which is that the performance goal is met.

The second may be that, let us say, when you're trying out a new lower level performance goal, you may find that satisfying it is pretty difficult in terms of cost-benefit tradeoffs, and that you might do a better job at meeting your higher level goal by some risk shifting.

So we see both approaches as being feasible, depending on the level of maturity of the concept. But for today we're going to take it that he's trying to meet the standard, and we'll talk about how to do that.

Okay. Could we go on?

Now, this is a table of how in our risk assessment the core damage due to LOCA, core damage frequency, changed, and we're listing here the median, the five percent, 95 percent, and also what we're calling the risk metric, and that is one of the ideas I want to get across in here is that we can consider uncertainty just as easily as we can expected performance.

And so we are taking the postulated situation that the NRC has said that the acceptable risk metric will be one involving 75 percent of the median core damage frequency and 25 percent of the 95 percent core damage frequency and requiring it to be less than seven times ten to the minus seven.

This is just as an illustration of how you might try to take uncertainty into account in an explicit regulatory acceptance criterion.

And the point is that if you look at the various entries here, what you see is that as we go from the initial no depressurization capability down through the different design iterations, that only until we get down to two train depressurization with an improved treatment of cooling water and diesel failure do you satisfy that acceptance criterion in terms of this risk metric.

But there's nothing harder about formulating a criterion involving uncertainty measures than formulating one which is strictly deterministic as we do today, or in terms of expected performance.

The trick is to make sure that the distributions that you're using reflect reality as well as you can, and if you do that and propagate these uncertainties, you should be able to get useful answers, just the ones we want you to think about.

CHAIRMAN KRESS: How is this, the first metric that you selected, any different than just specifying a confidence level?

DR. GOLAY: We felt we could have done it at, let us say, a 75 percent confidence level. We felt that in reality that when people think about it, what they do is think about the expected performance, and they try to put on some margin factor for uncertainty, and we thought this was a way of trying to capture that.

CHAIRMAN KRESS: It fits into that.

DR. GOLAY: But how you do it is, again, some thing that there are different approaches for it. The main thing I want to get across is that it's very easy to incorporate treatments of uncertainty, as well as expected performance here, and given that regulations about uncertainty, we think that this is a big contribution, at least potentially.

Could we go to the next figure? Other way.

Okay, and this is just a graphic of the same change in the core damage frequency at different confidence levels, including this risk metric. The blue one is the risk metric that we were using, and you see that it could play the role just the way that evaluation at a conservative confidence level could do.

So what's the best treatment would be for future work, but if you accept that the idea is worth exploring, that is a step forward.

Let's go on.

Okay. We're almost at the end. Lunch is in sight.

The point is in this example what we tried to show is how that we can have a natural way for concern about common cause failures and uncertainties to lead designers to incorporate some defense in depth, some use of safety margin, to show how we can take uncertainty into account in evaluating acceptance, and that the bottom line is really the one that is most important, and it addresses what you need to pay attention to in future research, which is that there are a lot of practical questions that need examination here, and to answer them you need trial examples, such as we just showed you.

You need some work to come up with standardized models, methods, and databases which are much more capable than those which we have today.

And one of the areas which we really haven't explored -- by "we" I mean everybody in this room -- very much, but which is quite important, is methods for treating subjective judgment, for incorporating it into the decision making process in a more formal way.

We suggest that through this process, we may be able to replace the need for general design criteria and DBAs, and we would probably have to alter the standard review plan in important ways.

So these are all practical problems that need to be investigated.

Can we go to the last slide?

So in summary, what I hope you've gotten is an understanding of a new design and regulatory process that we propose for development. It's risk based. It incorporates defense in depth and margin. We think it would provide a more rational and consistent method regarding both design and regulatory review.

It provides a method of integrated assessment which we currently lack except in the treatment probabilistically in the background of the process we have now, and it should be applicable to non-light water reactor technologies in a straightforward fashion just as to light water reactors.

So in effect, the implicit favoritism which our current process bestows upon light water concepts could be removed through this and hopefully would lead us to somewhat better technological options.

And we feel that the development of this process should be supported as part of our overall attack on developing new technology, and that's all I have to say.

CHAIRMAN KRESS: Okay. Are there questions or comments?

DR. POWERS: I guess the thing that comes most immediately to mind is actually on his first bullet there, where he says defense in depth when necessary to address model and data uncertainties. Don't we do a defense in depth for other reasons?

CHAIRMAN KRESS: Pardon?

DR. POWERS: Don't we do a defense in depth for other reasons?

CHAIRMAN KRESS: Yes, there are other reasons for it, I think. What reasons would you have in mind?

DR. POWERS: I guess two things come to mind, one of which you might put in the category of model uncertainty is, well, we don't account for sabotage in the PRAs. I'd just as soon have some protection against a plausible threat to the plan.

The other one is in your probabilistic studies you always come up with some probability of bad things happening. Just between you and me and the gate post, I'd like to have something between me and the bad stuff when those bad things happen, regardless of how infrequently they occur.

DR. GOLAY: Is that a question?

CHAIRMAN KRESS: It's a comment more than a question.

DR. POWERS: He asked for comments.

CHAIRMAN KRESS: If you want to respond, you may.

DR. GOLAY: Yeah, I will, and that is concerning your example of security, I don't know. I haven't worked on security, and I don't know how you might try to handle it here.

My first reaction is: why not try? I don't know of anything that would preclude you from being able to include that successfully, and what I would like to do is sort of turn the burden around and make a presumption that we can handle the questions in a probabilistic framework until we have clear evidence we cannot.

Fundamentally you said that reason for defense in depth was not wholly treatment of uncertainty. Yet the examples you brought up were essentially treatment of uncertainty examples, and if you think that a practice is beneficial in terms of getting a good safety result as a response to uncertainty, then you should be able to state it, state your belief concerning that fact in a probabilistic format.

So it's not disagreeing about the value of defense in depth. I'm simply saying it's worth the try to incorporate anything that you think is important to the answer in the format.

MR. HOCKRITTER: Larry Hockritter, Penn State.

On page 10, you talk about using best estimate performance, expectations and uncertainties. And you really have two kinds of uncertainties. You can have the plant uncertainties, but you can have the uncertainties in the model that you use to do the predictions, and with a light water reactor, we've got 40 years of a database, experimental database so that we can quantify the models and the model uncertainty so that we have a good handle on that.

I don't know how you address that for a new design like we've been talking about for these Gen. IV designs where you really don't have much of a database at all.

So that's one question.

DR. GOLAY: Should I answer?

MR. HOCKRITTER: That was a question.

DR. GOLAY: Yeah, with any concept, regardless of its level of maturity, I'll submit that as you try to do a risk analysis of comparing alternatives, let's say, that you ultimately end up at a point where the available objective data reach the limits, and you can find this with plenty of light water examples as well, that what you're really into is a situation where you -- I think always -- that's too strong a word because I don't have the basis for saying "always," but my experience has been so -- that you end up with a combination of objectively based evidence and you have to supplement that by your judgment.

And so the only suggestion that we're making is that you should state that in probabilistic terms and incorporate it into the PRA so that with the new concept, you reach that limit much sooner than with the mature one, but that the general structure holds up for both.

MR. HOCKRITTER: Okay. Well, I can now turn the question around and say if you would embark on this type of a licensing process, you could use this approach to structure the types of test programs that you would need --

DR. GOLAY: Absolutely.

MR. HOCKRITTER: -- for a Gen. IV type plant. So I see a real benefit in that.

And then just one other comment. The examples that you showed, the design examples, I know on the AP 600 we did use that process where we went through the PRA. We looked at the performance of the systems and the system sizes in this case changed.

DR. GOLAY: Yeah, and what was lacking in that example is the regulator being prepared to engage you in the same vocabulary for making their decision.

MR. HOCKRITTER: There was never a problem with the regulator engaging us.

(Laughter.)

CHAIRMAN KRESS: Go ahead.

MR. PARME: Larry Parme, General Atomics.

I have a question in regards to your last page or near there. You mentioned possibly replacing the DBAs with the risk dominant events, and overall I'm supportive of your approach, but in the licensing approach risk based that we did for the MHTGR, one of the -- we were looking at that sort of approach, and we immediately ran into the problem that when you go and say that the risk dominant events replace DBAs, you find that certain non-risk dominant events are the only challenges, if you will, to certain key equipment or safety functions, and the risk dominant events may not demonstrate to the regulator the various ways that your safety functions are done.

And I hope you follow what I'm saying. My question to you is: did you think about this?

We had thought about this in the '80s, found that risk dominant events weren't a true substitute for DBAs and had to also use the PRA, but had to find -- pull from our event trees events that challenged each of the safety functions regardless of their risk dominance.

DR. GOLAY: Right. Let me try and translate it though, and that is what I think you're really saying is that there's a concern about the level of uncertainty associated with your risk based analysis, such that if you went in and claimed that you were doing very, very well, it wouldn't be a credible claim, and that it was necessary to, in effect, show that you could handle something tougher is in some way a defense in depth kind of capability.

CHAIRMAN KRESS: I would have put that a little differently. I would say that there are regulatory objectives that are more than just CDF, LERF, BES (phonetic) --

DR. GOLAY: Sure.

CHAIRMAN KRESS: -- ANDERS (phonetic), and those regulatory objectives can be captured.

And you had one little box called FC curves. If you actually had acceptance criteria on those, I think it would capture these things that you're talking about that don't have much to do with LERF or probable fatalities, but how to function in being sure that you don't have smaller releases or worker exposure and that sort of stuff, which can be captured in F-C curves.

DR. GOLAY: That's a good point, and I was taking for granted that the cornerstones had all been addressed, which in that era they were not.

CHAIRMAN KRESS: Yeah. I hate to do this because I think this has been one of the most challenging and interesting presentations, but I think it's time to go eat lunch.

We can return to this maybe in the discussion. They are very provocative concepts and some very attractive thoughts.

DR. GOLAY: Our team remains eager to help.

CHAIRMAN KRESS: Remember at two o'clock

up stairs in the White Flint II Conference Room rather than here.

(Whereupon, at 12:59 p.m., the meeting was recessed for lunch, to reconvene at 2:00 p.m., in the White Flint II Conference Room.)