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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

SUBCOMMITTEE ON FUTURE PLANT DESIGN

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MONDAY,

JULY 8, 2002

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ROCKVILLE, MARYLAND

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

SUBCOMMITTEE MEMBERS:

THOMAS S. KRESS, Chairman

MARIO V. BONACA, Member

F. PETER FORD, Member

GRAHAM M. LEITCH, Member

VICTOR H. RANSOM, Member

STEPHEN L. ROSEN, Member

JOHN D. SIEBER, Member

GRAHAM B. WALLIS, Member

ACRS STAFF PRESENT:

MEDHAT EL-ZEFTAWY

ALSO PRESENT:

CHARLES ADER - RES

SYED A. ALI - RES

STEVEN ARNDT - RES

PEGGY BENNETT - RES

SHANA BROWDE - RES

DONALD CARLSON - RES

MARY DROUIN - RES

FAROUK ELTAWILA - RES

JOHN H. FLACK - RES

CHARLES GREENE - RES

JOEL KRAMER - RES

RICHARD Y. LEE - RES

PAUL LEWIS - RES

JOCELYN MITCHELL - RES

JOSEPH MUSCARA - RES

J. PERENSKI - RES

PHIL REED - RES

ALAN REED - RES

ALAN RUBIN - RES

STUART D. RUBIN - RES

AMY SNYDER - RES

ALSO PRESENT: (cont.)

M. SRINIVASAN - RES

EUGENE TRAGER - RES

ROY TREPATH - RES

GOUTHAM BAGEHI - NRR

A.E. BANIONI - NRR

LARRY BURKHANT - NRR

ANDRE DROID - NRR

RICHARD ECKENRODE - NRR

EDWIN F. FOXIN - NRR

STEPHEN KOENICK - NRR

EILEEN McKENNA - NRR

UNDINE SHOOP - NRR

IAN HASTINGS - AECL Technologies Inc.

JOHN LEHNER - Brookhaven National Laboratory

LUCA ORIANI - Westinghouse

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

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

8:30 a.m.

CHAIRMAN KRESS: The meeting will now please come to order. This is a meeting of the ACRS Subcommittee on Future Plant Designs. I am Thomas Kress, Chairman of the Subcommittee. Other ACRS members in attendance are Mario Bonaca, Peter Ford, Graham Leitch, Victor Ransom, Stephen Rosen, John Sieber, and Graham Wallis.

For today's meeting, the Subcommittee will review and discuss with the NRC Staff the draft Advanced Reactor Research Plan and its implications on the NRC's regulatory framework. The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee. Mr. Med El-Zeftawy 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 June 20, 2002.

A transcript of this meeting is being kept, and the transcript will be made available as stated in the Federal Register Notice. It is requested that speakers identify themselves and speak with sufficient clarity and volume so that they can be readily heard.

That really means go to a microphone and use the microphone.

We have received no written comments or requests for time to make oral statements from members of the public. The only statement I have ahead of time is that, although we have a full day's meeting, I don't see how we can do justice to this substantial report in a full day, much less in the hour and a half that we have for the full Committee. But we will give it a go anyway.

Do any of the other members have any comments before we get started? Hearing none, I will call upon John Flack to get the meeting started.

MR. FLACK: Good morning. Thank you very much for giving us this morning on the Advanced Reactor Research Plan. My name is John Flack. I am the Branch Chief of the Regulatory Effectiveness and Human Factors Branch in the Office of Research. Although the title does not have Advanced Reactors in it, my Branch has the Advanced Reactor Group. Which has the lead on the non-Light Water Reactors. Which include the Pebble Bed and GT-MHR, innovative designs such as those.

What we plan to present to you this morning is more detail on the plan. We had previously been before the full Committee in April. And we went through the plan more at the higher level, visionary level you might say, presentation that was given at that meeting.

And today we would like to get more into the detail, the actual key elements of the plan, the issues and so on. So what I'll do is I will briefly go over the purposes of the meeting, our objectives, hopefully in line with your objectives, and discuss the key technical areas, four of them in more detail.

So I will turn it over after my opening remarks to Mary Drouin who will do the framework presentation. Stu Rubin who is part of the Advanced Reactor Group will do the Fuels presentation. Joe Muscara who is our point of contact on Advanced Reactors for Material Analysis. And then Don Carlson and Richard Lee will do the Reactor Systems Analysis.

I will then come back and talk about those other technical areas that are included in the plan. And then we will discuss a little bit more about the future plans and where we are headed.

As I have mentioned, the plan itself

focuses around key technical areas. And what we'd like to do is get down to the levels of the issues and areas and contacts where we are obtaining our information. We did take quite an aggressive approach, at least from my perspective. Had gone out and held workshops, meetings with various stake holders, including the ACRS, have traveled internationally to get as much information as we could or at least, if not at that point, identify where we can get the information.

And so, it is a rather comprehensive plan. We are hoping to get feedback, both at this meeting for the record on the transcripts, as well as would support a letter at some point and time. The earlier the better, certainly. That would really focus on two pieces.

The first piece is the plan itself. How we went about identifying our needs in the Office of Research or the Regulatory needs with respect to its infrastructure, expertise, tools, data that would be needed to take on these advanced designs as we see them. So that is really one piece of the message.

The other is to what level we need to continue to pursue and at what length of time the need for these non-Light Water Reactors. We are recognizing that we are in a state of flux in some ways. The Pebble Bed, as you know, has terminated its pursuit. And we are in a mode where we are just about phasing that out at this point and time.

But what the plan really says is that there are a number of needs that we have in developing the infrastructure. We have basically a Light Water Reactor infrastructure. And it took many years to develop that infrastructure. And what we see in the plan and all the different areas is that, it is quite challenging to take on a new design, new Light Water Reactor.

And to wait until the last minute for something like that would be catastrophic in the sense that the need to get the information in, to make the regulatory decisions that would need to be made in a realistic way, would certainly be compromised if we are not ready to do that at some point and time.

And so the second piece is a little bit more difficult to take on and that is, what is the vision that we see for the future for these non-Light Water Reactor plans. And when and how to go about developing an infrastructure that we would have in place when those designs do come in. So it is really those two pieces of the presentation or of the support we are seeking and the message that we are trying to get across.

MEMBER ROSEN: John, why are you stressing non-Light Water Reactor plans. I know there are Advanced Reactors that are Light Water Reactors, like the integral systems. Aren't there research issues involved there?

MR. FLACK: There are, but let me just go through the next view graph where it talks about the scope of the plan. What it is, is the scope of the plan itself focused on four reactor types basically, at this point and time. The Pebble Bed, the GT-MHR, the IRIS, and the Westinghouse AP-1000/600.

MEMBER WALLIS: John, some time in your write up that you sent us, the words "technology neutral" or something I think appears?

MR. FLACK: Yes.

MEMBER WALLIS: That would seem to cover anything, not just these. When we look at the specifics, we always seem to be talking about four examples.

MR. FLACK: That is true. There is really two aspects to the plan itself. One is the technology neutral aspect, which says these are the technical areas. These are the kinds of questions that we need to ask ourselves in each of these areas.

MEMBER WALLIS: For any reactor.

MR. FLACK: For any reactor. This plan goes further in saying well these are the four reactors right now that we have that will apply that thinking down to the next level.

So at some point, the technology neutral leads you to something more specific. You can only take it to a certain extent. The extent that we are taking it, again, we are asking ourselves three fundamental questions in putting this together. Why we need to do the research? What is the research that we need to do? And how do we plan to use the results.

And in each of the technical areas you can ask that against any design. In this case, we have these four designs basically on the table at the time that the plan was being developed. But to get to Steve's question, we see the greatest need in our infrastructure development in the first two.

And that is why you see a lot of the discussion centered around the High Temperature Gas Cool Reactors. It is a new technology. The staff is familiar with the Light Water technology. Not to say that there is not issues in the other two, IRIS and Westinghouse. And they are mentioned in the report, in the plan itself.

IRIS, for example, fuels and the new steam generator types. But IRIS is very conceptual at this point in time even. And it is hard to flesh out all the issues that are going to stem from that particular design. But we gave it as best a shot as we could.

Of course, AP-1000 is pretty far developed and we have a lot of infrastructure in place already to deal with Light Water Reactors. There are some issues in the AP-1000 that need to be looked at a little more carefully, like in-vessel retention and so on. They are called out in the plan.

But again, the plan is to try identify gaps, you know, the delta. The kind of things that we are going to need to put in place in order to do, to support the regulatory process at a later date. That is why you see when you get down to the technical level, a lot of the need is in the Gas Cool Reactor designs.

MEMBER FORD: Just to make sure I understand. The plan that was issued, the revision one, in June?

MR. FLACK: Yes.

MEMBER FORD: Focuses as you say on the top four. And you can take out Pebble Bed.

MR. FLACK: At this point.

MEMBER FORD: Yes, at this point. It states that it is technology neutral and that you are looking for big gaps in information? For next year's research work, what actually will be done?

MR. FLACK: Well, that is part of the budget process in setting, establishing priorities on what needs to be done. I mean, a lot of facets go into that process. That is part of the question that we are asking ourselves today, given the technology gaps in a non-Light Water Reactor field and with these other designs coming our way now, which I have listed below, and these are the ESBWR, SWR-1000 and the CANDU.

The question is, is how much, when to start and to allocate it in some way based on the priorities as we see them. Part of this meeting today is to try to find out from the Committee what their views are in establishing and feeding that in to setting those priorities.

So, I don't have the explicit answer to that question since it is evolving. But I think at some level, we need to develop our long term goals in a non-Light Water Reactor field, Gas Cooled technology at a certain pace. And as these other designs come in and as we see the needs for those designs which we'll be expanding the plan scope over the next few months to capture.

How those two work out together, we will know next year. But at this point in time, we are still trying to feel that out, understanding what needs we have and how much resources we have available.

CHAIRMAN KRESS: When you get ready to do the PIRTs, would they be individual PIRTs for each reactor type or would you envision an overall PIRT?

MR. FLACK: An umbrella PIRT.

CHAIRMAN KRESS: An umbrella PIRT of sorts.

MR. FLACK: Well, we are entertaining both ideas. We have had one PIRT already in the fuels area, very specific. And we'll have those in those fields where we see the issues and the need. The question on an overall PIRT where you lay out everything. I think there is two parts to that.

One is what you are hearing today, that is an infrastructure. Being able to ask the right kinds of questions at some level. And then there is the other piece of okay, now that we know the spectrum of issues, what is it that are more important than the others, and that becomes the umbrella PIRT.

We were thinking about having one umbrella PIRT. But we haven't decided when and what that would include at this point in time. But it is certainly an idea that's, I think, important.

CHAIRMAN KRESS: On the budget issue, will the budget you get drive the kind of research you get to do or based on the priorities. Or will you somehow take what you think the needs are and priorities and develop a budget from that and try to see if you can get that kind of budget? I'm not sure which way that goes?

MR. FLACK: Well we probably --

CHAIRMAN KRESS: Probably a little of both.

MR. ELTAWILA: This is Farouk Eltawila from research. I think the budget will drive the process, there is no doubt about it. There is limited amount of money. And the indication that we are getting from the Commission right now that we are going to pursue some activity in the Gas Reactor as well as Light Water Reactors. So, but there is a limited budget and the resources will be based on the devotion of the resource or split in the resources among the activity would be based on the seriousness of the application.

You know, because since we developed that plan as John indicated, we have three additional vendors indicated that they are interested in pre-application review of their design. So we will have to go through an add/check process based on the amount of information presented and the Commission support to address these issues.

I am going to add my two cents here about the issue of technology neutral. I think the issue of technology neutral is related to the regulatory framework. What will be 10 CFR.50, you know, that we are going to try to develop that as technology neutral. But when you come to the specifics, every design will have its own technical issue and we need to address these technical issues. So we are not developing a technology neutral, for example, thermal hydraulic for all these designs. Each one will have its own issues and a plan for resolution. But the technology neutral is related to the regulatory framework which Mary is going to address.

CHAIRMAN KRESS: Thank you, that makes a lot of sense.

MEMBER ROSEN: Let me make a few comments about the scope. First off, the IRIS concept is just one of a family of integral primary system reactors that is likely to come along. So highlighting it, I think is inappropriate. It is just the integral primary system reactors at this stage, that we should be looking at.

Furthermore, your list is, I think, a little incomplete, despite the fact that it is already a daunting list. It is a little incomplete in a number of respects. There are a series of very large pressurized water reactors being considered in Europe, the APR-1400. And the APR Plus, which is a very large 1700 megawatt reactor.

Also the EPR, which has enhanced active safety systems and extensive severe accident mitigation features. There is a high conversion BWR. Very large, could be as large as 1700 megawatts, but it could be smaller in the 300 megawatt range. And also there is a second generation Advanced Boiling Water Reactor being considered, very large 1700 megawatts.

So there just in the water family, there are a number of other designs that are going to need to be considered. Now I am not sure that they will each bring up different issues from the research point of view, but I don't think you have the full list yet on just the water side.

Now you do have a note on the bottom on the expected increase and scope of Generation IV. But I don't think it gives it justice and it needs to be given justice in this plan. Because of the extraordinary differences in design that the staff would have to deal with if Generation IV goes ahead as planned.

And let me just tick off for you what is in Generation IV right now, just so nobody in the Committee is surprised. It looks like Generation IV reactors, which are down the road a bit, but they should be in the plan as well. Will be a Gas Cooled Fast Reactor, a Molten Salt Reactor, the Sodium Reactors, both oxide and metal fuel, Lead or Lead Bismuth Cooled Cartridge Reactors, a Super Critical Water Cooled System, and a very High Temperature Gas System.

So Generation IV, both in its international near term deployment phase and in the longer term phase has got to put on the table an extraordinary range of new designs. And this slide doesn't do it justice, John.

MR. FLACK: Well, yes.

CHAIRMAN KRESS: The question I would

have, I think they are right in their priority being driven by how serious a particular application is. And I don't know how serious all these Gen IV's will be when it comes up to coming before NRC and saying we want to have this thing certified. I think they can't waste the resources on things that just have limited resources. We have to wait to see how serious the different concepts are.

MEMBER ROSEN: Of course, I am not suggesting that you waste your resources. What I am suggesting is that your plan have at least initially the full scope of things that are considered. And that it should be in the plan even if Gas Cooled Fast Reactor, let's say you just note that it is out there. You say no resources will be devoted to it at this time, if it goes forward, we will look at it.

But I think to say that we are going to look at the things we can see the tops of our heads over the hill in this plan is a mistake. Since we have the information that there are lots of other things potentially coming. The plan ought to acknowledge all of them. And say, here are the ones we are actually going to work on, even though we understand that there are major efforts both in this government, the U.S. government and in many, many foreign governments working collaboratively with the U.S. through the Generation IV International Forum.

There are many, many other efforts that are underway. I think a plan would be myopic and not as good as it could be. If it didn't take into account the full range, take into account Tom Kress' comment. Obviously you are not going to put money or resources into all of them. But you should at least acknowledge them and say they are out there.

MR. FLACK: That is a good comment.

MEMBER BONACA: As a minimum, I think for the framework portion which you want to have technology neutral, you want to make sure that by the time you are done, you can accommodate any one of these additional designs. And then when it comes down to the technology specifics, then you can ignore it because of the consideration right now in the short term that they may not be in the short horizon.

But I agree with the perspective that particularly when it comes down to the framework, we want to make sure it is technology neutral and accommodates anything else that will come.

MEMBER FORD: At your presentation to the Commission a couple of months ago I think it must have been on this subject. The question came up about the chicken and egg argument. When are the utilities and the OEMs going to come forward with serious applications for these various types of design.

And that feeds into your priority and planning to come up with some of the regulatory aspects. Are there any conversations ongoing with the OEM's and utilities more than just a letter saying hey we are coming with a pre-application? Is there any idea of their timing or their strength or will to go forward with this? Or are they just putting a case folder on the mat.

MR. FLACK: I don't know if anyone from NRR is present that wants to comment on that. The Office of Research had a lead on non-Light Water Reactor. So it is primarily Pebble Bed, to some extent IRIS and a GT-MHR. So we can really only speak for those.

I know there have been interactions, there's pre-application reviews that are being planned and discussed. But to what extent those interactions have been taking place with the specific applicants, I am not as aware of as somebody else might be. But I don't see anybody coming up. So I guess the answer is no. We are just kind of in a holding mode, looking at our infrastructure and issues that might evolve from these different designs.

But I think it is a good point that Steve made and that is we will put in sort of a list of the kinds of reactors that are out there and the status of them, recognizing that they are there. Whether they actually get developed and the materials and the fuels become, get to the point where they need to get to make the designs licensable, it may or may not happen.

But at least we know there are certain plants being considered somewhere in the world and having a list like that certainly and the status of that and staying somewhat engaged in understanding what is going on there is probably an important thing to do. So, yes, I think we can add a list to the plan to accommodate that.

MEMBER FORD: Tom, I know we are spending a lot of time on this graph, but it is central to everything we do from here on in. Is there any timing aspect? I noticed in your plan you say that the specifics are the responsibility of the licensee and the OEM. And that you are just going to set the higher level requirements.

And yet you have got a plan which is going on for several years, so does that mean for several years the OEM and the licensees will not know what they have to address in their specific applications. And that takes time, and therefore it could be 2020 before we even have one of these advanced reactors in place. Is that a ridiculous statement?

MR. FLACK: Well the plan is living. So it will accommodate, or attempt to accommodate whatever new technologies come forward or whatever plans come in as far as pre-application. Certainly when a pre-application review comes in already, we will be starting to focus hard on that because we are expecting something close. And that is pretty much the purpose of a pre-application review to be prepared for the design certification or whatever it would come in, in the short term.

So that is really going to drive a lot of it. But it is a living plan, so if there are needs and I think that by licensees and applicants looking at this plan and seeing the different research that we are focusing on, recognizing that we are not going to do it all. We are going to be relying a lot on them to do a lot of the work. They will have an understanding of what it is going to take.

So I think they can get that message even if the plant isn't specifically addressed by the plan. At some level there is some generic nature to the plan and the kinds of areas and issues and questions that need to be answered and asked in any case.

CHAIRMAN KRESS: Yes, let me give my opinion. The plan, as it sits has a lot of generic nature to it. In the sense that you outline things like the neutronic needs, the thermohydraulic needs, the fission product needs, the fuel needs. And you go right down the line. And then you went specific for the different reactor types.

But I think no matter what the reactor type is, those are the generic things you are going to look at. And so I think you have a good start even now, without spelling out these particular reactors, or where the research needs are going to lie.

MEMBER WALLIS: Is this a presentation of the plan or is this a presentation of the research needs?

CHAIRMAN KRESS: It is not a plan in the sense that it has schedules and milestones and budgets. They didn't intend for it to be that yet, it is too premature.

MEMBER WALLIS: That is why I have to ask. I think we are going to hear about needs rather than a plan.

CHAIRMAN KRESS: Yes, this is research

needs I think.

MR. FLACK: It's more of a process.

MEMBER LEITCH: It seems to me the plan divides very logically depending upon, as you have already indicated, whether we are ever going to build a Gas reactor. I guess certainly the regulatory aspects would be good to have technology neutral for that eventuality. But as far as the specific research related to gas reactors, I just have a lot skepticism about whether we are really going to build a gas reactor in this country in the foreseeable future.

You know, three months ago we were all spun up about the Pebble Bed Reactor. And it looked like it might actually happen. And now it is apparently not going to happen, at least in the United States. And I don't know what the status of the GT-MHR really is and how serious that really is.

As far as I know, there is no utility that has stepped forward and expressed any interest in that. Yet we had with the Pebble Bed reactor a utilities that looked like they were going to aggressively go forward. We were all spun up and spent a quite a bit of effort and now it is, we're not, apparently.

MR. ELTAWILA: I think this is the issue

that the whole Commission is struggling with right now. And we are getting you engaged in the struggle to share the pain. Because it is really true you know that how much resources you put and how much you delay the work.

You know, if we delay the work indefinitely, we will not be prepared for the industry. So we try to have an approach to be addressing the issue, remain engaged and try to do research. Because even if it is ten, twelve years from now, it is a long time. It appears to be a long time, but it might be a short time to develop the detail that you needed.

So we are going to remain engaged. As John indicated, there are other issues that we are better prepared for. For example, ESPWR, we have the knowledge. We can start the pre-application review and support the design in this case. ACR-700, although it is Light Water-Cooled Reactor, we still don't have enough knowledge.

So the Agency is going through the process of trying again to assess the seriousness of the application. And how much resources to put on some of these activities versus the others. But as Steve indicated, we are trying to remain engaged in all of these activities and we will try to allocate resources accordingly.

MEMBER BONACA: One question I have I would like to ask your perspective on this. It seems to me there has been the discussion, the presumption that you can have a technology independent framework. And then you can have you know, specific research for technology specific work in fuels and some of the materials.

Is it correct in all cases or is the framework somewhat influenced by the particular technology you -- can you make the separation? I am trying to struggle with that because, you know, for example for the Pebble Bed, we're seeing some new challenges that came, insofar as confinement versus containment, and to what degree those challenges affect the framework.

MS. DROUIN: When we get into my presentation, that is specifically one question that we are going to ask ourselves.

MR. FLACK: Okay, so we'll be there in a minute.

MEMBER BONACA: I was making the presumption in my mind and then I began to question the fact, you know, whether it was possible --

MS. DROUIN: And that is, you will see on the slide, is it possible to do that, or to what level do you have to put your --

CHAIRMAN KRESS: Well with respect to the Gas Cooler concepts, I agree with Ruth, I don't think the Pebble Bed concept has completely gone away. Just because Exelon pulled out. There are still some activity, it may not be a Pebble Bed. It may be another prismatic form like the Gas-Cooled Thermal.

So my view that is, and I think there has been serious thought given to certifying a GT-MHR. So, I don't think you put it aside. I think you have to have it on your agenda. And my only feeling was I would focus more on the GT-MHR than the PBMR right now.

MR. FLACK: Yes, that is a good point. I mean internationally, international interest in this gas cooled technology.

CHAIRMAN KRESS: Is high.

MR. FLACK: And in fact, my assistant is now in Russia with GA and others to see what is going on over there. So, and a lot will come out of that. I think a decision of where it is going to go.

Yes I think that it is important to continue to consider this as part of the mix of energy for the future in the United States.

MEMBER ROSEN: I think the other big issue that we may have skirted on, but not addressed, is what research given that you know the scope. What research should be done by industry and what should be done by the Agency. And that issue comes down to and I am stealing some of Tom's thunder here.

The definition as I understand it of what's a design basis accident. And what is a beyond design basis accident. Because, design basis accidents would be researched, I guess, by the industry and all of the supporting data for the design basis stuff would be done by the industry.

And whatever the staff felt it needed to do on beyond design basis would be paid for by the Agency and the government. Is that correct? And if that is correct, then isn't it crucial to know where the line is in terms of developing the plan?

MR. ELTAWILA: That is a very good question. But again, if you are thinking about the old way of doing business, but if you go into the risk informed regulation, there is no distinction between design basis envelope and beyond design basis. So you have to look at the whole spectrum. And with that, it is the responsibility of the vendor and the applicant to demonstrate the safety case of their plans.

So that is the complete responsibility. So any claim an applicant has, they have to provide the data and analysis to support that. On occasion, the staff will try to develop its own independent capabilities. Not in every area, in some of these areas, and again try to push the envelope, you know. That even though that our requirement of 10 CFR, for example, again, don't quote me on that in the future.

By let's say -- air ingress in IV gas cooled reactor is a very low likely event. But we know that it is very high consequence event. And by regulation, we might not require them to do anything, but the NRC might be interested in pursuing that issue further to be able to assess the margin and so on. So these are the areas that the staff will keep pushing harder to get its own independent capability in.

MEMBER SIEBER: I think once you get beyond the framework where you are developing the regulatory concepts, that it would be important for the agency to know what the vendors are doing. And the Agency research should be sort of complimentary to what the industry is doing.

And if they aren't doing any research, that means the concept is not ready to be born yet.

And so I would encourage pretty close looks at what the various vendors are doing and what is going on here in the U.S. and internationally. Which I think is what you are doing. You may not have the resources to do a good enough job.

MR. FLACK: But that's -- yes, in fact the pre-application reviews are very important in that regards of understanding just exactly where the applicant is going. And how much more do we need to understand as a regulatory agency.

MEMBER SIEBER: That is right.

MR. FLACK: So compliments, basically the work. Doesn't duplicate, but compliments. And to some extent there will always be this confirmatory piece to it.

CHAIRMAN KRESS: I think we better --

MR. FLACK: No other questions? I'll go to my next graph which is basically the structure of the plan. The different technical areas and basically there is nine key areas that we center on.

The first is the Framework and Mary is about to present that to you in some detail. Then there is the Accident Analysis which is the PRA, human factors, instrumentation and control. We kind of lumped it up under there. We followed the cornerstone approach in the plan. So it came along these various areas and I will touch upon that later this afternoon after the presentation on the Reactor Systems Analysis.

There is also the Fuels which is important. And you will hear from Stu Rubin on that following Mary's presentation. The Materials which covers the high temperature metals and graphite will follow. And then these others, Structural Analysis, I will touch upon. And Consequence Analysis I will touch upon at the conclusion of the presentations.

Eight and nine we will not discuss today at this point. We will be returning to the ACNW to discuss eight. And nine, we just are holding off at the moment. Nine is more of a place holder for work that we could possibly do to support other activities that are ongoing.

So, if there is no further questions, I'll turn the rest of the presentation over to Mary Drouin.

CHAIRMAN KRESS: I think that is a very nice lay out and a good way to present this information. And this was, where I was saying, the areas you are dealing with are technology neutral. Those apply to any reactor type. So it is a good way to organize things.

MEMBER FORD: This is just to make sure that I am not missing something. This is exactly the same as the framework that was issued back in May, I think it was?

MR. FLACK: With respect to the planning?

MEMBER FORD: Yes.

MR. FLACK: Yes, that is right.

MEMBER FORD: There is nothing new?

MR. FLACK: No, nothing new.

MEMBER LEITCH: John, just before we move on, could you give me an estimate of the level of effort that has been involved in bringing the plan to this stage?

MR. FLACK: That is difficult to say since a lot of it is more on the day to day activities of the individual staff members. We have discussed this with, for example, the user offices. There were working groups that were set up to interact, to talk about the issues. Of course, I have put a lot of my time into it over the last six months.

It is hard to say exactly, because there's so much of it, it is not like charged to one number and we can add it all up. But I think what is important about the plan, that isn't really written here, is that it is a communication tool. It has in fact opened up channels of communication across the office as well as with user offices.

The group in my branch is really the focal point, but we used the matrix organization. We really look to the technical expertise across the office. So we meet each week to talk about the plan, the activities going on. People get together and discuss this, as well as the user office.

So it is an excellent communication tool in just developing the plan and getting people on board and thinking about the future. Where are we going. What are the issues. What's the vision. And it does a lot in that regard. It is hard to put a number on all that.

MEMBER LEITCH: Yes, particularly this summarizing the research that is going on internationally, I think is particularly valuable.

MR. FLACK: Yes, another place.

MEMBER LEITCH: It's a good reference document, if nothing else really in that regard.

MR. FLACK: Good.

MEMBER ROSEN: I think there is another important thought here that needs to be said. And that is, really you are doing more than just trying to figure out where all the birds are. And where they are flying to and from. You are not just pure observers in this process.

Because by the decisions the Agency makes, it tends to build the future. It is more than just a monitoring role and getting ready for something that might show up. To the extent that you make decisions to go ahead and research things, you actually build the future. You are taking part in making the future. So these decisions should be considered in a lot more active sense than as just trying to catch up.

MR. FLACK: Good point. Okay, if there's no other questions and comments I will turn the rest of it over to Mary.

MS. DROUIN: My name is Mary Drouin with the Office of Research. I am here to try and give a presentation on where we are in terms of the framework. And you saw in the previous slide I had the word framework in quotes.

This means we have still not decided if framework is the appropriate word to be used here. But, for the sake of discussion, that is the word I am going to use. And how we plan to develop this for advanced reactors.

I am going to go a little bit into background. What we mean by the structure of this framework. What our plan is for developing it, our approach, some of the issues that are associated with it. And finally what is our status. Where we are and where we hope to be.

It is important to go a little bit on some background here, because we do have a current regulatory structure or framework that has been developed over the past 40 years. You know, that deal with the Light Water Reactor designs. And they certainly can be used through an exemption addition process by going through the current set of regulations and deciding where they are applicable and where there may be holes.

My personal feeling is I think that is a dangerous road to just strictly go down there, because you have a danger of overlooking something. Because you are going in with the mindset of something already on the paper. And when you deal with these new advanced reactor designs, you do have some unique operational design issues that need to be considered.

So while there again is applicability, it is there, but it is limited. Further, people can discuss the various levels that certainly risk insights have been brought into our current structure. But what we want to do here differently is from the very onset is bring our PRA results and insights and integrate them at a fundamental level into our decision-making process.

CHAIRMAN KRESS: When you say PRA insights, the only insights we have for PRA are for LWRs. That doesn't tell us very much about these other reactor concepts and designs. Do you mean the insights on how useful PRAs are and where they are useful. Is that the kind of insights you are talking about?

MS. DROUIN: I think it is both. And as you go through the process, you are going to have to determine what is the scope and level of detail that you want from these risk analyses into what kind of decision you are making.

I would argue that you could do right now, some limited PRA analysis. You certainly don't have your whole design, so your scope and your level of detail broadens and goes into more depth as you get more information.

But there are some assumptions you can make right now and it is iterative.

CHAIRMAN KRESS: Okay I agree with that. But I also gather from that that the framework is going to say PBMR concept -- will have a PRA. And it will be used in an iterative fashion. Can I assume that will be part of the framework somehow?

MS. DROUIN: Yes. I think also those insights will also feed into the framework itself. And we'll get into that particularly when we start talking about the quantitative aspects.

MEMBER BONACA: Because you're going to set criteria based on risk?

MS. DROUIN: That is right.

MEMBER BONACA: So we are forcing really, I mean if you set your criteria based on risk, you are forcing the use of PRA. You have to, to assess how a design would meet those criteria.

CHAIRMAN KRESS: This is interesting because this will be the first time that PRA actually seems to have been required by regulation.

MS. DROUIN: Correct. And part of the plan, one of the technical areas is development of the PRA. And you will see for that aspect there will be at certain times you are going to have to do research and that research is going to be dependent. And I am talking about PRA.

Your particular, it might be methods, it might be development of data. And that is going to depend, to what level are you depending on that analysis to help you in your decision making.

You're going to hear a little bit, at the full committee, on the risk-informed implementation plan about coherence, and we have an SRM from the Commission. Now this was for current reactors, you know that says, provide a plan for moving forward with risk-informed regulation to address regulatory structure convergence with our risk-informed processes.

So even though that is for the current reactors, and you talked a little bit this morning about technology neutral. If you talk about technology neutral that would also bring into your Light Water Reactors, our current generation of plants. And so ultimately, you know, we would like to have a single over-arching framework, a regulatory structure that encompasses both our current and our advanced reactor designs.

So at this point, in terms of our framework, and I want to really emphasize this next bullet because this is all the way through, we just started thinking. We haven't gone very far. Today is very timely. Because I certainly welcome, you know, input in our plan.

MEMBER BONACA: Just a comment I have.

You are really coming down to the structure of approach. Where you are saying criteria are going to be risk-informed and then you are talking about how you meet them.

Are you going to say something about safety goals?

MS. DROUIN: Yes.

MEMBER BONACA: Okay, so --

MS. DROUIN: I am going to get more into that. But I am saying, our whole plan here, you know -- and what I am looking for is that we are just in our conceptual stage -- is our plan and approach reasonable? Are we identifying the key issues?

CHAIRMAN KRESS: Will we still have design basis accidents that refine the licensing basis, you think?

MS. DROUIN: Good question.

MEMBER ROSEN: Well I would think from Farouk's comment the answer is no.

CHAIRMAN KRESS: I've been assuming the answer would be yes. But the design basis accidents would somehow recognize beyond design basis.

MR. ELTAWILA: There would be a design basis envelope. I think the distinction might be in the specification what the level of safety margin and all of the stuff. But for example, if you tried to have a design basis accident, I mention one issue here is the source term? If you try to have a mechanistic source term you have to go to beyond design basis to get that source term. There is no source term during --

So that is why I mean -- so you will require an applicant or licensee to do a test to try to verify what is the source term that is going to be used. So you might have to run beyond design basis tests, be required from applicant and licensee in order to address this issue.

Based on what Exelon presented, it is called a design basis envelope. It was not a design basis accident per se. And also, this is again all issues that need to be discussed during the next couple of years when Mary develops her plan.

I just want to make one point clear at this time. This framework does not, we don't need to have that framework to address issues like AP-1000, ESPWR. These are, can be licensed right now under the existing regulation without any problem.

CHAIRMAN KRESS: And they probably will be.

MR. ELTAWILA: And they will, definitely.

MEMBER SIEBER: It would seem to me though the concept of design basis in quality requirements came about because in the early days there was not the computational PRA that defined what the risks were. And so this design basis was sort of a substitute for that. And as we move along and progress in the PRA technology, we come up with the concept of maybe some design basis quality requirements are too much or too little.

And that is the basis of the South Texas amendment. And it would seem to me that you ought to start with a clean piece of paper and decide whether you need the old style design basis, or not, or have PRA and safety goals define what the quality requirements are and what system requirements are, whether you need a containment or not and so forth.

And in this framework, that is where you would decide how you are going to apply that. That would define what the new rules look like, to me. That is one way, anyway.

MEMBER ROSEN: In effect, provide a graded approach to quality.

MEMBER SIEBER: That's right.

MEMBER ROSEN: Which by the way is not new. We never really did it, because we didn't have the tools. We had black and white. Our grading was black and white, yes or no, on or off. Now we can do much better.

MEMBER BONACA: You still have to design the ACCS System if you have the water reactor design. So still you'll have to define what are the criteria that you have to fulfill with the ACCS System. So you have to come down I think to some kind of design basis event, whatever.

CHAIRMAN KRESS: I think I agree with that. It is a very nice tool for the designer to design to. It could be risk-informed. It is also a good way to work in your concepts of defense in depth --

MEMBER BONACA: Well, I think information should reduce the burden, the unnecessary burden. That's the whole purpose of that. But in reality, ultimately the designer has to know how much water they have to provide, under what conditions and where.

CHAIRMAN KRESS: I think one of the real challenges for getting design basis accidents is going to be what are your figures of merit that you have to meet.

MEMBER SIEBER: That's right.

CHAIRMAN KRESS: For some of the concepts, you just got to have new figures of merit. You can't use the ones you have been using for LWRs.

MEMBER BONACA: True.

CHAIRMAN KRESS: I think preserving a design basis concept is probably worthwhile thinking about.

MS. DROUIN: When we look, forgive my typing there at the top. When we look at this structure and this framework, a lot of basic questions when we just start dealing with it conceptually. Where you would start putting the words to it.

But, you know, one of the basic questions that comes up first. Can it be established at various levels? Should it be established at various levels? I mean beginning at the top, should it be a generic level where it is applicable to all currently envisioned designs? Or should it be more design-specific?

And so we have multiple frameworks, one applicable to each design, or some combination of the above. Our approach right now is going to start with the Generic I High Level, or conceptually it should be technology neutral. And then as you go down in depth, but again, is this the right, you know, approach to go after?

Also another fundamental question is, should the framework have both qualitative and quantitative aspects to it, criteria?

CHAIRMAN KRESS: Well you know how this committee feels about that. The "n". We want that "n" in there. Quantitative. I think once again, you are establishing various levels depending on whether you are trying to preserve some sort of Appendix A, general design criteria.

MS. DROUIN: Yes.

CHAIRMAN KRESS: That is where it is going to get tricky.

MS. DROUIN: There is going to be difficulties and issues. Both policy and technical associated as we look at these and try and make some decisions. We kind of jumped ahead a little bit a few minutes ago, but major point.

We said that the risk insights, our PRAs are going to be an integral part from the very beginning, such that as each reactor is licensed. You are going to bring, your risk insights will be used as appropriate, you know, at each step of the process in your decision making.

And because it is going to be integral, we want the structure, this framework to be risk-informed and to be used as a key player and help focusing the regulations and where the high risk areas are. And because it is also still going to be risk-informed as with our current, and we are going to maintain the principles, you know, of defense in depth and safety margins.

And all of these have issues that are going to be associated with them. That I will touch on briefly as we go along.

MEMBER WALLIS: I don't know how you do that? How do you write these new regulations for something that doesn't exist yet, based on high risk areas when you don't have a PRA yet. You don't know what the high risk areas are?

MS. DROUIN: That is why it is iterative.

MEMBER WALLIS: Well you need a better way of designing something. Then something which is so dependent on waiting for something else to happen.

MS. DROUIN: I think you have a lot of experience. And when you talk about something that is going to be technology neutral, the issues that you are talking about can be at the next level. And what I mean by that is one approach is you write your regulations at a high level where they are technology neutral.

And then as you come to the next level, perhaps in your regulatory guide, then you start dealing with the specific issues on the specific reactor designs.

MEMBER FORD: Maybe it would help us, Mary if you, could just give us an example? I am mirroring Graham's concern, how do you apply such a -- Well, what is the frequency of an event. What is the impact going through a PRA analysis which is technology neutral. Could you give an example?

MEMBER BONACA: You could use option three as an example. Because there you have, for example, defense in depth with prevention and mitigation that you set with certain criteria. You could talk about how do you allow in this framework. Maybe, there's a portion that could take place in different ways.

MS. DROUIN: Well, I think also we are stepping way ahead than where we are even in our thinking process at this point. What we are trying to do right now is to outline an approach and a plan for getting there.

How it is all going to fall out, it is too early to say at this point. I do think that you can come in and you have enough knowledge at a high level of these reactor designs to build a high level PRA that will kind of focus you -- You know, I am not trying to get to this valve or this component, is what you have to worry about.

MEMBER FORD: Okay.

MS. DROUIN: You're not there at this point. You are at a much higher area, level. Sorry. And maybe LOCAs, I am just talking about now, conceptually. Maybe LOCAs is where you need to worry about versus maybe it is more transient. Or maybe it is some other different reactor type. But I think you do know enough about the designs to come in to help you formulate, for example, what your design basis accidents should be.

MR. ELTAWILA: I am going to go out on a limb for right now and say it is not going to look anything different from what we might -- it might slightly look different from what we have right now. But instead of having embedded in the regulation a pellet temperature and correlation for maker and just for oxidation model. You are going to make the regulation neutral.

For example say that you should not have a fuel failure for example. And it is almost written exactly like that right now. And relegate all the details about the evaluation model. About how to demonstrate that for the difference type of reactors into the regard. So that, I really, we are making it bigger than what it is. But it is going to look -- just to clean up the regulation to make it look at very high level and the rest of this stuff will be in a specific other document.

CHAIRMAN KRESS: We are not thinking exclusively of the CDF and LERF.

MS. DROUIN: And you will see that in another slide.

MEMBER WALLIS: I think it would help if we had a framework for the current regulations. If we really knew what that was, then we could perhaps duplicate it.

MS. DROUIN: And I'm going to get into that because our intent is not to re-invent, you know a lot of good work that has gone in the past. Take advantage of all the previous work. Such as the framework that we have developed for risk-informing Part 50.

CHAIRMAN KRESS: Let me ask you about that. You know when I think about that framework, I picture this table where you have various frequency events and then you have a CDF and a conditional containment failure probability for those which are acceptable levels.

That bothers me, if that is what you mean as the starting framework.

MS. DROUIN: I am going to get into that.

CHAIRMAN KRESS: Okay, but that bothers me if that is your starting framework. Because those concepts may or may not be the right ones.

MS. DROUIN: That is exactly right.

MEMBER BONACA: Although from the perspective of the way they structure the table, prevention and mitigation?

CHAIRMAN KRESS: That may even be wrong.

MEMBER BONACA: Yes, but I am saying that you could introduce flexibility in that. And how to achieve that in a way that, and I am not thinking of the Pebble Bed. I mean, where you can be able to accommodate a balance as long as you can achieve the ultimate objective which you are setting. So there are ways in which you can do flexibility with that.

CHAIRMAN KRESS: That is what I'm working toward.

MS. DROUIN: Let me skip the next slide. I am going to come back to it. But I think it would be easier if I go to the next one, slide nine. Because I wanted to go through our current framework that we're using on Part 50. And this is the start of the framework.

And that it has, our framework, our current framework that we are using on Part 50 has both qualitative and quantitative aspects. So it is not just that single figure that you are referring to that has numbers.

On the qualitative aspect we say there is two parts to it. We have one that's a hierarchal structure that starts with the goal to protect the public health and safety. That is the over-arching structure.

CHAIRMAN KRESS: Do you have a definition of what that means?

MS. DROUIN: I am going to get to that in the next slide. It starts with that goal. And then the second part of the qualitative is that it is going to be constructed in such a manner that it maintains a defense in depth philosophy. You will see that hopefully on the next couple of slides.

And then the second aspect is the quantitative part of the framework. And that is where we bring in quantitative guidelines to help us define what is meant by safe enough. And we do that with the current one by using the safety goals.

If you go to the next slide, again dealing with our current. Looking at the qualitative aspects now what we mean by the hierarchical structure. And what we are saying is that with the advanced reactors we are going to follow this same concept.

That we are going to start with this goal of protecting the public health and safety. It is going to be the top-down approach. And then how we define what that goal is, or differently, how we are going to achieve it, is identifying the cornerstones. And the cornerstones on the current framework were derived from the reactor oversight program.

And there were seven cornerstones, but we focused the cornerstones for Safe Nuclear Power Plant Operations. And you will see on the next slide that we had focused in on the reactor safety ones.

And we are going to implement those cornerstones through strategies of accident prevention and accident mitigation. And then ultimately to achieve those strategies, we are going to employ these tactics such as defense in depth, safety margins, design bases. We are going to use those to help us form the regulations and how we do oversight.

So that is the hierarchical structure of the current one and we are going to stay with that same concept. We see no reason to change it right now for the advanced reactors at that level.

On the next slide, and you will see there over to the left, the top down going from your goal to your cornerstones to your strategies to your tactics.

Is that on the corner framework, those are now defined to the next level of detail. And so if you start with your reactor safety, there were four very specific cornerstones that were identified for the reactor safety.

Your Initiating events, mitigation systems, barrier integrity and emergency preparedness. Now whether or not these will be the same. And whether we should expand, for example, over to radiation safety and security, these are all questions now that we are going to have to deal with and answer for the advanced reactors.

And the same thing when we get to the strategies. Here for the current reactors under accident prevention we said limit the initiating events, limit your core damage frequency given you have the initiating, limit your radionuclide release and limit your public health.

Whether those remain the same at that level, the same strategies, are questions that we are going to look at and answer.

CHAIRMAN KRESS: Remind me what you meant by radiation safety, the bullet called general public. Was that intended to apply to smaller releases of radioactivity? Or control of waste? Or what was that bullet for? I forgot.

MS. DROUIN: You know, to be honest, I don't remember. I would have to go back and look at the definition of that one.

CHAIRMAN KRESS: What I am trying to decide is whether or not under reactor safety you just focus on things like prong fatalities and latent fatalities. And relegate things like frequency of small releases and things of that nature to the radiation safety.

MEMBER SIEBER: I think there is two different things there. For example, if you look at the oversight program, it talks about routine releases ODCM and those kinds of things. But if you look at it from a public safety standpoint, it would have more to do with the effectiveness of evacuation plans and warning systems and potassium iodide. At least in my way of looking at it.

So, it ends up in the global sense as a combination of the two. It is either chronic or acute. And we need to limit both effects, both the chronic effect and the acute effect.

MEMBER WALLIS: Why would anything change on a new design from this framework?

MS. DROUIN: I think when you talk about at this level, the concept, the structure I don't think changes.

MEMBER SIEBER: Right.

MS. DROUIN: I think at the level of protecting the public health, reactor safety, radiation safety, security, I don't think that changes.

Accident prevention/mitigation I don't think changes. But how you define those cornerstones and how you define the strategies, that next level may change. I don't necessarily think that your tactics will change. But how you define the tactics may change.

MEMBER BONACA: Wouldn't that be very much PRA-driven. I mean how you apply defense in depth and safety margin. Although they are, we always say that PRA is subsidiary to the defense in depth. Yet you are using the PRA to make decisions about how -- the way you are going to apply it. So that is going to take you in different directions.

But insofar as the prevention and mitigation right now, you are very, in Option Three you are very prescriptive about how you go insofar as what, how much you give to prevention, how much to mitigation. Any thoughts about how far you are going to be in allowing a shift, for example, between the two? Some new designs are challenging in that particular area.

MS. DROUIN: We have not gotten there yet.

MR. FLACK: Yes, I think that is a good point. I think a lot is going to depend on how much we really know about the plant. That is where I research, I think becomes very important. Because the more confidence and the more data and the more information you have about a plan, the better decisions could be made.

Because the lapse in that is going to result in the need for more defense in depth and so on. So I think that is going to play out in kind of a --

MEMBER BONACA: The reason why I asked that question is it seems to me that in the Pebble Bed, I mean there was the challenging issue that how far are you going to allow to prevention insofar as -- and then, less, okay.

So that is really what you are going to do with those issues at that strategy level.

MEMBER SIEBER: I guess another factor in new advanced designs is that there is going to be more uncertainty than you would have with a fleet of 25 year old PWRs.

MR. FLACK: That's right.

MEMBER SIEBER: Because of that, you are going to end up initially with more defense in depth and you may ultimately accept that as being adequate.

MEMBER BONACA: That is a very good point that Jack is raising. Because so much of what we call regulatory burden today, wasn't driven by purely, simply we just slap on a requirement. It was driven by uncertainty that was inherent in the technology 30 to 40 years ago.

So the risk is that, although we want to have all the necessary and sufficient criteria here, we are going to have burden.

MR. FLACK: I don't know how we deal with that. Initially we'll have to.

MS. DROUIN: AS you can see, our approach is to go through each level here. And you know, evaluate its applicability and its appropriateness for advanced reactors. So each one is that safety goal the appropriate one. You know the current framework uses the QHOs. Are those the right ones to be used here? In defining how you are going to protect the public health and safety. Are the cornerstones appropriate? Do you need to expand it? Same thing with the strategies, both from a qualitative perspective and from a quantitative perspective.

And again, have we identified the appropriate tactics? The level of detail that we are going to go into, is that appropriate? I'm going to discuss these a little bit more on the next couple of slides where I have given some examples. It is hard sometimes to separate out policy versus technical because sometimes they feed into each other in trying to answer the policy. You might have to have more technical understanding.

And I haven't tried to list everything here, just some of the preliminary ones that we have identified and thought about. Again, I have said this one several times, should additional cornerstones, just at the high level, should we go beyond the reactor safety? Should we include radiation safety, security and safeguards? And then within the reactor safety are the four that are identified there, the appropriate ones. Should we start looking into land contamination, for example?

CHAIRMAN KRESS: You know, I don't even think you should have even asked the question. To me it was obvious, yes you should be thinking about it. It is part of your regulatory objectives to have an acceptable level of insult. And that is an insult that you have to think about. You know, we would say sure.

MS. DROUIN: Okay.

MEMBER SIEBER: Yes, but it is not in the policy now.

MR. ELTAWILA: It is a policy issue.

CHAIRMAN KRESS: There are things -- but it is dealt with in the regulations to some extent.

MEMBER ROSEN: You are not implying that all of these are new questions. I think, should the level of safety be raised for new plants, your next bullet. I thought the commission has already expressed its expectation on that subject.

CHAIRMAN KRESS: Well that was sort of ambiguous statement.

MS. DROUIN: Yes.

MEMBER SIEBER: That's right and it needs to develop into some kind of policy.

MS. DROUIN: And what it is meant by that.

MEMBER SIEBER: Right.

MEMBER ROSEN: It's not going to be less safe than the current generation.

MS. DROUIN: It will not --

CHAIRMAN KRESS: It certainly says that.

MEMBER FORD: Mary, where does early site permits come into this whole argument?

MS. DROUIN: I'm sorry?

MEMBER FORD: Where does early site permits come into this whole argument? I keep thinking about timing. We have got three applications for early site permits on the desk right now. And as I understand it from what I have seen, it may require a fair amount of additional work.

I don't know if there is any research money being allocated to it. Where does it come in on this policy issue? Is there any policy issues associated with early site permits for unspecified new reactors at those three sites?

MS. DROUIN: I don't have an answer to that.

MR. FLACK: Yes, I am not aware of any at the moment. We are actually testing the process as we go. As you know, this has not been exercised before. And a lot of the interest is in seeing how this will go.

But at the moment, there wasn't anything within the context of the plan itself that research needs in that area at the moment. Whether or not something else comes up related to the framework. Actually that may come out of this process as it is being exercised.

MEMBER FORD: So, for any one of these three sites that are being proposed, if someone came in and said we want to put in an MHR, a GT-MHR, the existing regulations would just be sufficient?

MR. FLACK: Well it would be applied.

MS. DROUIN: Yes, you wouldn't say that the existing regulations would be sufficient, but you would use the existing regulations to make your decision. And you would go through them to decide which ones were appropriate and which ones would not be appropriate. And where you may need to make some changes to the current ones to meet that reactor design.

MEMBER FORD: Okay.

MS. DROUIN: And then we get to --

CHAIRMAN KRESS: Your regulations ought to be site-related. Talking about the various site permits. When you are talking about a LERF, that is a site characteristic. That is not a plant characteristic.

MS. DROUIN: That's site.

CHAIRMAN KRESS: The LERF is a plant characteristic, the acceptable value of LERF is a site characteristic. When you are dealing with regulations you are talking about acceptable values. So, implicitly, you have to have a site in mind. And that ought to be part of the thinking when you deal with early site permits.

You have to ask how many plants are already on there? What is their collective LERF value? And am I going to put a new one on there? How much I am going to add to that LERF? That's the sort of thing you have to think about.

MEMBER FORD: I am really showing my ignorance here at this point. As soon as the different radionuclide release, which give rise to different pump fatality statistics. Would that not impact on ESP?

CHAIRMAN KRESS: Absolutely it would. If you got a different mix of isotopes for example, and different quantity of isotopes, then the definition we now have for LERF, acceptable value of LERF in terms of what it means in terms of a surrogate for prong fatality safety though, just completely wrong.

MEMBER FORD: So, that is dependent on that --

CHAIRMAN KRESS: Absolutely. On the type and the site.

MS. DROUIN: One of the reasons that when you look at the hierarchical structure of the framework and if you stay at the highest level where you are coming down you have your goal, your cornerstone, your strategies and tactics. And while conceptually, you know, I do firmly believe that that is applicable to all technologies.

The details of it that are currently there for Part 50 are there because of how you are using that framework. And that framework was being used to help look at the current set of regulations and see if they need to be revised, deleted, enhanced or whatever.

So now we are going to stay with that same concept, but how this framework is going to be used, is a critical decision in this whole process. When and how it is to be used, will be fundamental in helping you decide in determining whether at each part whether your goals, cornerstones, etc. are applicable and appropriate.

So, one of the very fundamental questions that has to be asked is how do you plan to use this? When are you going to use it? And how are you going to use it?

CHAIRMAN KRESS: I think you are going to have to back up on this LERF concept. Because it is going to be site-specific. It is going to depend on the design of your reactor. What type of reactor you have. I think you are going to have to back up to the next level again and say my goals are something else. They're prong fatalities. They're land contamination, whatever. They're frequency of release of fission products.

I think you are going to have to define the high level acceptance criteria in that. And whether you can back down to a LERF, is in my mind, questionable at this time.

MS. DROUIN: I didn't put it on the slide, but it is in my notes here. I mean I still haven't given you your quantitative health objections. Are those even the appropriate ones?

CHAIRMAN KRESS: That is questionable too in my mind, yes.

MS. DROUIN: You have to start there.

CHAIRMAN KRESS: That is a good place to

start.

MS. DROUIN: That is where you have to start. What should be that safety goal?

CHAIRMAN KRESS: Yes.

MS. DROUIN: And the safety goal that we are using right now in the current structure are the QHOs.

CHAIRMAN KRESS: Well, I think that is a good start.

MS. DROUIN: You know, should we start there and then given that, what are the appropriate surrogates? Right now we are using CDF and LERF. Are those the appropriate ones? And then given, once you determine what are your appropriate surrogates, whether they are CDF or LERF, then what are the appropriate quantitative guidelines associated with them?

CHAIRMAN KRESS: LERF may be appropriate, but the one that's in regulatory guide 1.174, I don't think is appropriate. 1 time seven minus five per year, I think you should throw that one out of your mind and start from there.

MR. CARLSON: Could I make a comment on that?

MS. DROUIN: I think you have to look at

both what it should be just qualitative, what should the surrogate be. And then what should be its quantitative value.

MEMBER SIEBER: I think that problem is pretty complicated because the source term changes with burn up, number one.

CHAIRMAN KRESS: That's right. That 1.1 times 10, to the minus 5 depends on it.

MEMBER SIEBER: That's right. And so really what you are looking at is how much uncertainty is there in defining what LERF means in terms of QHOs. And then you have to make another decision beyond that, which is how conservative do you want to be.

You may end up with LERF times some factor that you agree on envelopes the uncertainty. You know that is one way to do it. Otherwise, a computation of that gets very complicated. As you and I know.

CHAIRMAN KRESS: Yes. We have hashed that one out, haven't we.

MEMBER SIEBER: Took a long time.

MS. DROUIN: I also think another very tough one is going to be you know, the level of defense in depth and what we mean by that. Right now, under the current framework, let me say it a little differently.

I think your thought process is different when you are looking at a current set of regulations and you are risk informing them and you want to maintain the defense in depth that is built into them versus starting fresh. Where you want to build defense in depth, but you don't want to go to the extent where you are now creating undue burden from the very beginning.

So how you define defense in depth from that perspective, and safety margins so you don't go too far. I think brings different questions that need to be asked further than what we were doing on the current Part 50.

CHAIRMAN KRESS: Yes, we'll be very interested in how you come down on that eventually.

MS. DROUIN: I will be too.

MEMBER WALLIS: Well I suspect you'll find what Jack Sieber was saying. That if you go to something which you don't know much about, you are going to have to have more defense in depth to account for your uncertainty about what is going to happen. So it is not going to be a question of reducing burden.

You're going to reduce burden maybe after you have had some experience with these.

MS. DROUIN: That might have to be the way it gets. Going back to the previous slide.

MEMBER SIEBER: That's not progress.

MS. DROUIN: Yes, we want to create -- and I apologize the slide did not get changed. It is supposed to read outline a path for generating a framework. Decision-making criteria was supposed to be framework there.

You know, how do we intend to create this framework. You know, recognizing that you know, we want a framework that is going to ensure that the design and operating requirements for advanced reactors are developing in a consistent, systematic and structured manner.

I think that is very important. We want to make sure that the advanced reactor regulations, you know, are going to be directly tied to these high level safety goals and principles that we end up defining. We want to be able to show that these safety goals, however we define them, are met. Perhaps even exceeded. And that is another issue we are going to have to deal with. And ensure that the regulations, where appropriate, are performance based.

MEMBER WALLIS: So this is, again, a statement of objectives?

MS. DROUIN: Yes.

MEMBER WALLIS: There isn't much of a plan?

MS. DROUIN: We don't have a plan yet.

MEMBER WALLIS: You call it a plan, though.

MS. DROUIN: Well this is what we want our plan to do.

MEMBER WALLIS: Right, so while I am sitting here assessing the likelihood that you will ever succeed. And all you keep doing is asking questions and having objectives, and I don't know how to assess the probability that you will ever get there.

MS. DROUIN: Well I think we are going to have to come back. Because again, I wanted to put right up front here, we just started on this.

MEMBER WALLIS: You have talked to us before, so can't have just started.

MS. DROUIN: This is my first time up here.

MR. ELTAWILA: I came here, Graham you are correct, and talked about it. But again, we go through a budget process and we will try to allocate resources and all this stuff. So it is just part of the --

MEMBER WALLIS: That's the impression I get. Is that when you get the money then you will figure out what to do.

MR. ELTAWILA: That is not fair, but at --

MEMBER WALLIS: No it's realistic.

MR. ELTAWILA: I suggest you don't give credit to the staff at all --

MEMBER FORD: Jack, at the very beginning in your opening statements, you correctly said that this plan is identifying all of the issues that have to be addressed, from a framework regulatory position and the technical position. You then said the next stage would be, with our help, to come up with some sort of PERT. To prioritize all of those questions and then go and do something. When will the PERT be done?

MR. FLACK: Well, we talked about the umbrella PERT. PERTs are going on as we speak within the technical areas themselves. What are the issues and ranking those within, just for example, fuels.

Across the board again, it gets back to this question of what is it that is causing us to react now, versus what do we need to put in place for the long term and maintain that for the future, someday at a gas cooled design coming in. I mean there's two pieces to that.

The first piece is that we are reacting to pre-applications. Design certifications that are very close on the horizon that we'll need to prepare for. What are the issues? Since these are light water issues, we are more prepared to deal with those kinds of issues.

The question on how much to put into the longer term goals of establishing an infrastructure, a regulatory infrastructure that can process an advanced gas cooled design. I think that is the question. And how this trades off. Whether or not a global PERT will come to an answer on that question, I don't think so.

I think that is more of a PERT that needs the commission itself to decide where we go and set that vision. And from there and allocating what needs to be done, how much resources are to be spent in each part of this. Well then we have a plan next to say, well these are the things that are coming out to be the most important things. They are going to need a long term effort that we need to start now if we want to be prepared when the design comes in.

A lot of this plan focuses on that.

Getting the tough issues on the table. Saying are we really prepared to deal with these. And if not, when would we be needed to deal with these and try to establish some time frame and resource level to accommodate that. There is no simple process that can get us an answer. I mean everybody has their own views on this.

A lot of it will be driven by the Commission's desire to establish certain things and goals for themselves that will then be implemented by the staff. So I don't think that kind of PERT.

The PERT that we mentioned earlier, umbrella PERT. Would be okay, now, for a non-light water reactor gas cooled designs, what are the key issues. And we see that even coming as we speak from the plan itself. That is why we are going to be focusing on three of them. Basically the materials, the fuels, and the reactor system analysis.

MEMBER FORD: For gas cool reactors?

MR. FLACK: For gas cooled reactors. I mean these are the most complex issues that we are dealing with. There is a lot to them. There is a need to have people familiar with those areas that, in gaps we see more. And so, I think it is coming out at that level from laying everything out on the table, what is it that needs to be addressed in the long term that we need to start doing now. And a lot of that is from our interactions with stakeholders and the Commission.

MEMBER FORD: Are there sufficient plans, i.e., actions ongoing to address evolutionary Light Water Reactors? The ones that you, some of them that you have mentioned, which are probably much more likely to be built than a gas cooled reactor?

MR. FLACK: Well we are expanding that as we speak actually.

MR. ELTAWILA: Can I add something to what John is saying here. So Graham does not think that we are not working on any of these issues. Just for your information, for a year right now we have been modifying our thermohydraulic and severe accident core to deal with gas cooled reactor. We have been negotiating with DOE about cooperative agreement on performance testing.

But to answer Peter's question directly for advanced revolutionary light water reactor, we are right now in the process for that. That is part of the complication of the issue.

The money that was going to be spent on testing of Pebble Bed fuel, right now is going to be reprogrammed to address ESBWR issue. So we are going to delay decision about testing on gas cooled reactor. For other reason, you know that DOE is not ready. We don't have the Pebble yet. And we have the money, so we move the money to address ESBWR.

So the priority in my opinion is going to be AP-1000 which we are definitely are on top of everything. And I don't think we have any problem with the ESBWR and the ACR-700, that is the Canadian CANDU reactor.

But we will continue to work on gas cooled reactor and when we see opportunity to enter into cooperative agreement that is going to be cost effective for the government, and within our budget, we will enter into this agreement to get information from overseas.

So, the plan is being implemented in certain areas. In case of Mary, the Commission told us not to work on the framework in '02. So that was the Commission decision, so we cannot go against the Commission directions.

MEMBER FORD: You said the framework --

MEMBER SIEBER: Just once --

MEMBER FORD: You don't need to change --

MR. ELTAWILA: We don't need to change the framework for light water reactor, they are certified under --

MEMBER BONACA: I have a question that. I received in the mail, and haven't been able to review it all, but the document from NEI. I believe NEI 02-02.

MS. DROUIN: Right.

MEMBER BONACA: Where they are proposing you know, using cornerstone so that the framework. And there is a full approach that's being described there from the reactors. You are communicating with each other?

MS. DROUIN: Yes, we've had a meeting on that and we're going to continue to have meetings with them. And that is going to be one of the inputs here that we are going to take into account.

MEMBER BONACA: Okay.

MS. DROUIN: Absolutely. We have already started looking at it.

MEMBER BONACA: Is that the final document from NEI or is it a proposed document for comment or?

MS. DROUIN: No it is just --

MR. ELTAWILA: It's send as an information paper for NRC. They are not asking a formal reply from NRC. And the staff is going to take that into account in developing the framework and in the coherent.

MEMBER BONACA: Okay, so really the staff in this communication with stakeholders.

MR. ELTAWILA: That is correct.

MEMBER FORD: Can I ask a question of Tom and yourself. There is another plan? On action plan, ongoing for evolutionary light water reactor.

MR. ELTAWILA: in the ESWBR, yes.

MEMBER FORD: Those are ongoing plans. I am thinking more selfishly the research report aspect. Would it be useful that you were briefed on those plans, the evolutionary light water reactor?

CHAIRMAN KRESS: I certainly think so.

MEMBER FORD: Because the way I am seeing it is that the plans that you are talking about for gas cool reactors. By the time we are ready write a research report, are not going to be - We could say yes you hit all the right questions, but the result of those questions is not going to be identified.

MS. DROUIN: When I talk about plan here, I am talking about my piece which is the framework.

MEMBER FORD: Yes, I understand that.

MEMBER SIEBER: It would seem to me though when you consider just the elements that you are dealing with so far. You have on the one hand phenomena logical research. Which is how the systems work. How the fuel responds. And even going so far as to try and figure out what the source term is for difference between a fast reactor and a thermal reactor and fuel matrix.

Then you have on the other hand, this framework. And think the framework has to come first. I believe that there are some flaws in the current framework to be corrected. For example, the concept of LERF being a site issue. The fact that land contamination isn't in there.

And LERF may not be the right surrogate. So I think that you have to do that first before you have an idea as to how you want to structure regulations to license and advanced plans. Then on the other hand you need to know about the phenomenon, the responsive materials and the behavior systems in order to actually be able to put your arms around the specific reactor types.

So I see it as two different things. And I see the framework as probably having a greater conceptual priority than all the other stuff.

CHAIRMAN KRESS: Yeah, I guess I would disagree a little with that. I think parts of the research plan that deal with the things like neutronics and fission product release and materials. I think no, you are going to need those.

MS. DROUIN: Yes.

CHAIRMAN KRESS: Regardless of what regulatory structure you don't have. So I think they are independent. There are some things in the plan I think that will depend on what kind of framework you could have. And that has to do with what kind of PRA research you will need to do. And some things having to do with that sort of thing. To me in my mind, they are almost independent.

MR. FLACK: Yes.

MEMBER SIEBER: That's my point.

MS. DROUIN: I think there is some that are independent, but I would also say that there is some cases where you are going to need some research to answer some questions to resolve some framework.

CHAIRMAN KRESS: Yeah, I think going in that direction is definitely a positive truth.

MEMBER SIEBER: That's what ought to be identified right up front.

MS. DROUIN: And those are all the thinking things that we are going to try. In September we aren't going to have answers. But hopefully we will have identify and how the approach we are going to use.

MEMBER BONACA: So this is preliminary plan or preliminary framework? What is going to be in September.

MS. DROUIN: No, what you are going to see in September is the preliminary plan.

MEMBER ROSEN: That is our next meeting.

MEMBER FORD: The itemization of things that have to be done, will not be done I understand for Fiscal Year 2003. Sometime or other beyond 2003 to attack those actions that you are going to identify in September.

MR. ELTAWILA: Mary, can I say quick words from your mouth?

MS. DROUIN: Please.

MR. ELTAWILA: The plan that you are talking about here, so we won't start from a clean sheet of paper to develop this regulation. Which is going to build on the existing framework of 10 CFR that we are using right now to change the information 10 CFR 5046 to 4044. And you are going to look at that framework to see how it can be expanded to include advanced light water reactor in a technology neutral fashion.

If I say it correctly so we really have a start where not really starting from scratch.

MS. DROUIN: Yes. And when I say we aren't going to have answers, what I mean by that is that as we expand. And I have gone through all and showed you all the places where we are going to be looking at. Is identify what we think the issues are and how we intend to go about resolving those issues.

MEMBER WALLIS: But you're going in to build the framework. Your objective is to build the framework. And there is someone like a bridge designer coming here saying I have a plan for building this bridge. And I don't really see you building the bridge yet. Because you are so far back in your development in the plan. That is what I have been saying.

And I am not talking about the whole program. I think you have parts of the program that is needed to be done which are important. I am just suggesting this framework. I sort of suspect that Jack is right. The framework is the key. To get the framework right, then that guides everything else you do. So I really would like to see a great framework.

The only reason I am asking these questions is I think you are a long way from saying here is our plan. We can see the framework coming. I don't see the framework coming yet. And I am reassured by Farouk saying it is a perturbation of what we have already. But that is not what some of your slides seem to say.

MS. DROUIN: I thought they were clear all the way through.

MEMBER WALLIS: They seem to suggest you are going to look right back at the beginning of regulations. Rewrite everything from the beginning. But maybe --

MS. DROUIN: But all the slides are showing we are starting with, all those pictures that you see are concerning framework.

MEMBER WALLIS: Sometimes they said that. But sometimes you were reexamining the goals and the cornerstones and the strategies and everything else.

MS. DROUIN: We will have cornerstones. We will have strategies. I mean that concept, that structure --

MEMBER WALLIS: I think you might make a decision today that the existing goals, cornerstones and strategies are a good basis for developing a framework. And then move on.

MS. DROUIN: But we have made that

decision.

MEMBER WALLIS: Well that is good to know. Then we don't need to keep hearing about it then. Make that decision and move on to the next stage.

MEMBER FORD: But Mary, I can understand what you have said. You said you take the existing one down to a certain level, the tactics level. And then take it as a given, there may be some questions about LERF and things of this nature.

But you are dotting the I's and crossing the T's on that statement is what is going to be done in 2002. The actual reduction to practice, checking on the PRA associated with those things, etc. That will not be done, as I understand it in 2003. The Commissioner said you will not do work on this in 2003?

MR. ELTAWILA: In the budget --

MEMBER FORD: Okay, so there could be a fourth bullet in that saying no work in 2003 on this particular issue?

MS. DROUIN: Yes.

MEMBER FORD: Okay.

MEMBER LEITCH: Have we muddied the issue? Let's take the case of a utility who, you know, project yourself a year or two out into the future, I mean relatively short term. As a early site permit approved. It comes in and says I want to put a AP-1000 on that site.

One of the important factors in a utilities mind in coming to that point is predictability of the regulatory process. Have we made the process less predictable. Would that be different if they came in 2003 versus 2005? With this new framework?

MS. DROUIN: I am not sure I understand the question.

MEMBER LEITCH: Have we introduced some confusion into the regulatory process that is what the utilities expectation of the regulatory process might be.

MS. DROUIN: I don't think so.

MR. ELTAWILA: No, because again, as I indicated earlier for advanced light water reactor of any kind, we can go and apply for certification based on the existing regulation. We don't have to wait for it. I think that will be benefit you need a different concept like gas core reactor and things like that. Will benefit more out of that framework than the light water reactor.

MEMBER LEITCH: So once again, the prime

driver for this is gas cooled reactors?

MR. ELTAWILA: Gas cooled or the other type of reactor that I mentioned earlier today.

MEMBER LEITCH: And if we are just dealing with light water reactors this change in the framework then, would likely not be done?

MR. ELTAWILA: I think it can be done either, it is being done under the coherence program. We are looking at the existing regulations to make themselves consistent and coherent in terms of their value and preparedness for risk.

So we are doing it, but again, as I mentioned to enlarge the playing field and include non-light water reactor and that is that what is the Delta we are talking about here.

MEMBER SIEBER: from the standpoint of the licensee, saying to myself. Do I understand what the basis for the licensing of an advanced reactor is, one thing that disappears for advance reactors out of Part 50 is all of the deterministic stuff. Since this framework really is a risk based system. I would think that once a licensee understood that, then that would be just as predictable as the old deterministic system.

MEMBER BONACA: The trouble is that this

framework is just a plan. I understand that it is not going to be worked on right now.

MEMBER SIEBER: No money.

MEMBER BONACA: I understand that. It troubles me because it means that you already saw Exelon coming in with a plan. At least they were proposing a framework of some nature and we had questions about that. There were a lot of good things about it.

And now we are going to wait for another person to come in with another proposal and another attempt to framework and everybody there probably wants to proposal design is going to struggle trying to think about where are we going to go with the regulation.

And I think it would be very helpful. In fact, my thought was that I was hoping that it would be a framework at least that licensees or potential licensees would look at and see different frames of it and then apply it within their proposals whenever they want to come into the concept.

MR. FLACK: Well, we're not really waiting. I guess a month or so ago we talked about the policy issues that were coming out of the designs that we have looked at to date. We are going up on a separate track on that one. And in the fall, there will be a follow up SECY.

That will talk about these policy issues and the resolution of those issues, pathways to resolutions and options and so on. It would probably be best in that context to think about what it would mean with the sense of a new revised framework, I would think. So it is not that we are waiting, we do have these other activities going on. We'll see how they develop and come forth in the fall.

CHAIRMAN KRESS: Where is the early site permitting being dealt with. That is not being done in research?

MR. FLACK: No.

CHAIRMAN KRESS: I think we need to get involved in that. We haven't been involved in that at all.

MEMBER SIEBER: So we understand the concept.

CHAIRMAN KRESS: So we understand the concept, what the criteria are for giving -- and how they are basing it. Anyway, I think this would be a good time to have a break.

MR. FLACK: Are you ready to wrap up?

MS. DROUIN: I'm done.

CHAIRMAN KRESS: You're through. So I will declare a 15 minute break. Please be back at 10:30.

MS. DROUIN: Thank you.

(Whereupon, the foregoing matter went off the record at 10:15 a.m. and went back on the record at 10:31 a.m.)

CHAIRMAN KRESS: Let's get started again.

MR. FLACK: Okay, our next speaker is Stuart Rubin who is part of the Advanced Reactor Group in the Office of Research. And his area is Fuels Analysis. So you will hear everything you want to know about TRISO fuel particles and associated issues.

MR. RUBIN: Yes, I'm a very tiny part of the advanced reactor research plan. And I am passing around a little of what those particles are. I haven't brought my pebbles because the plan was intended to be neutral with regard to specific HTGR fuel design. Whether it be pebble or prismatic.

And so, I should mention that although the presentation is focused on HTGR fields, advanced reactor research plan does have a piece on IRIS. And I can talk about that at the end if time and interest allow.

This first slide provides an outline of

what I will be talking about this morning. I will begin by reviewing the safety performance objective for the fuel. Its paramount role in ensuring fission product containment within the reactor system.

Next I will discuss the key issues, technical and research issues that were identified by the staff as well as by experts around the world in workshops and other forum that raised questions on the ability of TRISOP particle fuels to actually meet that performance objectives.

I will summarize the purpose and focus for the identified research needs. And then I will discuss the specific scope and content of our plan research activities.

In general, the research activities involve a radiation testing as well as accident simulation testing. Developing analytical codes and methods. And also developing staff expertise and knowledge in the are of fuel fabrication and how that relates to the fuel performance.

And then I will finally mention a few research projects and outcomes that we think will stem from this work.

As far as the safety objective, and this is not something that is written down, it's something

I put together myself. To begin with the, it is probably well known here, that the safety features and design characteristics of modern modular HTGRs are quite different from current generation LWRs. And first and foremost, among those differences is the all ceramic fuel element containing those tiny coated particles of fuel that are being passed around.

And by way of a concept, each TRISOP particle is in of itself a principle safety barrier. And the primary containment function for protecting against a release of fission products to the environment from all conditions of operations is design-basis accidents and accidents beyond that.

And so the fuel performance objective is to retain and contain those vision products at the site where they are generated within the fuel. And each withing those billions of particles that comprise a reactor core, a GT-MHR, PBMR cor.

And so because of the statement and position of reactor designers of HTGR's, that containment is essentially served by the fuel itself. There is a proposal or submittal of that the requirements for the reactor containment itself can be relaxed in terms of need to retain pressure and being leak tight.

MEMBER WALLIS: It seems to me, what you have just said fits right into the framework that Mary was talking about. There is no need to develop a new vocabulary or anything to deal with this new concept. Just to make a link to what we heard before.

CHAIRMAN KRESS: Well the framework had words like prevention and mitigation.

MEMBER WALLIS: Which we have here. I am just looking at it. It says barrier integrity and limit --

CHAIRMAN KRESS: The framework viewed those as separate things, prevention and mitigation. Here we have prevention and mitigation as one thing.

MEMBER WALLIS: That is okay, just as long as you combine features. You can combine the function and design.

CHAIRMAN KRESS: When you have --

MEMBER WALLIS: I felt that the framework was important. I couldn't understand why the Commission didn't spend the money on it. I'm just trying to put all these things into conceptual framework.

CHAIRMAN KRESS: I agree. I was flabbergasted that the Commission didn't want them to work on that.

MR. ELTAWILA: Again, it is budget. I tried to allocate the budget, so it was deferred for until '03.

MR. RUBIN: This next slide is intended to by way of background, provide some of the more important issues that were identified in these workshops and discussion within the staff and external stakeholders on what are the issues related to the question of whether or not TRISOP particle fuels can in fact retain fission products within the particles itself.

Some of the issues related to the adequacy of the historical irradiation test that were performed and perhaps not covering the more challenging operating conditions that we can expect in a modular HTGR. Such as in higher core operating temperatures, and also the fact that these historical tests may not have explored fully the safety margins during normal operation.

Similarly, there are concerns about the accident simulation testing. Whether they were sufficient to fully explore the safety margins. And for conditions such as even core heat-up, reactivity events, and chemical attack events, like air ingress.

There were also concerns and issues raised regarding the differences in fuel fabrication between the fuel that was made historically in Germany and performed very well. And the fuel that is yet to be made and knowledge that even subtle changes in a process for fabrication can cause significant changes in the fuel particle characteristics. Which play out as significant performance differences in an actual reactor environment.

And so there is work being done today to try to understand those links and how they connect. Also, questions involved the conservatism of the traditional testing methods that we used to qualify this fuel. Accelerated burn-up testing is typical of this fuel testing and other to get answers more quickly. But questions could come up whether or not that is conservative for chemical reaction failure mechanisms that may require more time to actually be seen.

Also the accident simulation test typically are a constant temperature type test, as opposed to actually tracking the time versus temperature. History that one would see in an actual event.

MEMBER WALLIS: You are talking about a irradiation testing. Where does burn-up come up in this?

MR. RUBIN: Irradiation burn-up would be associated with the irradiation testing. I am drawing distinction between the behavior of the fuel and an operating environment, fast fluence, burn-up operating temperature.

MEMBER WALLIS: My radiation that it has actually undergone a lot of nuclear reaction?

MR. RUBIN: Yes.

CHAIRMAN KRESS: Normally, all you have to do is stick them in a research reactor.

MR. RUBIN: A test reactor.

MEMBER WALLIS: But just irradiating doesn't simulate burn-up.

CHAIRMAN KRESS: No, they actually stick them in a neutron for a long time.

MR. RUBIN: Right. Burn-up is implied by the radiation testing. Other concerns relate to the ability to add analytical codes to actually predict fuel performance during normal operation and the ability to actually calculate temperatures in the core during normal operation and accidents.

And also, what were the quality controls that were used in those previous tests and how they compare with what we would expect today. And so with that background, this next slide provides the overall purpose of the HTGR fuels research.

First our focus is to more fully explore the limits for TRISO particle integrity and fission product retention capability. Both during normal operation/irradiation and burn up. As well as for the ability of the particle to stay intact in accidents that go beyond the licensing basis. And so as to more fully understand the safety margins in both arenas.

MEMBER LEITCH: Stuart could you help me with a question about my knowledge on this topic? Is TRISO a process or a manufacturers name. Or what?

MR. RUBIN: Okay, I brought a few pictures to actually explain this. On the right side, the one you are looking at there is a --

MEMBER ROSEN: Could you move to the side.

MR. RUBIN: On the right side, is a huge magnification of those particles that would be passed around.

MEMBER LEITCH: Okay.

MR. RUBIN: And then the TRISO refers to three layers principality that retain fission product. Going from the outward in, you have the outer Pyrolytic Carbon layer. And then you have the most important layer the silicon carbine layer, number two.

And an import of that is an inner Pyrolytic Carbon layer. Each has a fission product retention capability.

There is a fourth layer that is not part of the TRISO terminology and this a buffer layer to absorb fission gases to accommodate pressure build up in the fuel. And each of those layers is isotropic in terms of their properties. You get the TRISO for short. Trisotropic layers.

MEMBER ROSEN: Then in the center, you took us all the way through the buffer then there is this big hole, what is in the middle?

MR. RUBIN: Okay, that is way the way pay the bills. That is where the fuel is located. That is the fuel kernel, as it is called. Where you have either UO_2 in the case of a PBMR or UCO fuel in the case of GT-MHR. And so that is where the burn up is taking place, fission gases are being --

MEMBER WALLIS: This is just conceptual.

MR. RUBIN: No, this is an actual cut away, but it has been colorized at the uranium dioxide fuel kernel. There is the buffer layer. There is the inner Pyrolytic carbon layer.

MEMBER WALLIS: What I meant is it isn't a cartoon. It doesn't show dimension. It doesn't shoe tolerances on dimensions.

(MORE THAN ONE VOICE).

MEMBER WALLIS: But these again, these are all spherical.

MEMBER ROSEN: Wait a minute. You are not getting bogged down, this is the heart of it.

MR. RUBIN: Well sure, let's get going then.

MEMBER ROSEN: I wanted to know in the other picture. Will you go back to the other picture when you get a chance there. You can answer Graham's question and go back.

MR. RUBIN: The reason why I put that up is that shows some --

MEMBER ROSEN: That looks like to be kind of squashed. Do they all come out like that?

MEMBER WALLIS: My real question was are they spherical? There must be variations of manufacturers.

MEMBER ROSEN: Is that a real particle cut in half?

MR. RUBIN: I do believe that is.

MEMBER ROSEN: Or is that broad case? That is a real particle. It is a microscopic cross section. So we can see is that there is a lot of variability. It is not circular.

MR. RUBIN: That would come up in the part of fuel fabrication. Over the years it has been understood that it is important that the inner kernel is fuel maintain a sphericity power. In other words, the largest diameter, that is controlled in the fuel fabrication process.

And then they in turn you have coatings that are applied in a chemical vapor deposition burnup environment, and that deposition process is not uniform. It will be variations of thickness of it. It may be thicker over here than it is over there.

And again there are tolerances on what are the permitted variances between the max and the min.

MEMBER ROSEN: At 90 degrees there, it is very thin. At 270, it is quite a bit all the way up to 290 to 300 is quite a bit thicker.

MR. RUBIN: That is right, the particles are not perfect in their sphericity, the thicknesses are not perfectly uniform around the particle, but through radiation testing and pure analysis, design analysis, there have been tolerances that have been developed that provide for what is an acceptable variation from perfection in the thickness of the sphericity.

But the extent of that kernel is not perfectly, a perfect sphere when the coatings take place, that will drive larger variations in the coding thickness. So that is really a base starting point it is very important to get that kernel just as right as you can get it. If you don't you will see worse case outer thickness or thickness variation particles that miss. Okay, and there is a limit and I think on this next slide, there is some indication of what the -- no this doesn't actually show the tower. This only shows the means of those thicknesses. But there are towers that are according to the manufacturers specification. And there are tests, examinations that you could do on a sampling basis from each batch of particles to see if you are in those tolerances.

If you are not in those tolerances, you basically recycle those particles and start all over again.

MEMBER BONACA: I had a question on this thing. In your objectives you stated that the objective is to contain and retain the radiologically important fission products. Is there any gases which are being released through a normal operation of this?

MR. RUBIN: Yes. I say that because there is trapped uranium outside of the fuel particles. And there is also some uranium that finds itself in the outer layer due to manufacturer. And that uranium when it fissions, will give fission gas release and the only thing that is presenting that from escaping out of the boundary of the fuel element is the matrix material. And it is rather permeable to gases, fission product transport.

Now for gases that are generated inside the kernel, the concept is that those inner/outer Pyrolytic carbide layer and silicon-carbide layer will in fact retain those gases.

MEMBER BONACA: All right, I understand. Thank you.

MEMBER LEITCH: For some reason, we know enough that the research would be done on this TRISO fuel is going to be applicable. In other words, do we know that this is the concept that would be used in any gas reactor that would come forward. I mean are we sure enough of that that we can focus our research efforts on this now. Or is that still a subsequent decision?

MR. RUBIN: That's a good question. The information we got from PBMR or Exelon during the pre-application review is their plan for fuel design and manufacturer is to duplicate essentially the German particle design and pebble element design. And manufacture process as well. So, the particle for PBMR would be what I am showing here.

In fact, the dimensions I show on the other slide. And just in the side, the dimensions of those particles thicknesses are identical to the German reference fuel design that was made toward the end of their development process. For which there is a lot of experimental data.

Now as far as the GT-MHR is concerned, the plan, we have heard from GA, is to use TRISO particle fuel design. The thicknesses of the various layers will differ somewhat because of the kernel size. And also the application. However, they have said that they plan to follow the German manufacturing process as well for the fabrication of their fuel.

The biggest difference between the two concepts is the fuel matrix itself. As I said again, PBMR will be utilizing UO_2 fuel and GT-MHR will be utilizing UCO fuel. Uranium oxycarbide fuel. But the particle coatings will be essentially the same for both applications. Environments will be different that needs to be explored.

MEMBER FORD: Wasn't there a problem with carbon dust?

MR. RUBIN: The issue of carbon dust is not focused on the fuel research plan itself. The dust issue relates to fission product transport within the reactor system. And then exiting the reactor system as dust carrying off fission products in the case of a large break. And so there is a concern for, as a source term for whether or not that dust could be, should be included in the source term calculation.

MEMBER FORD: The reason why I asked just relates to Graham's point, I'd have thought that any OEM would want to reduce that. And therefore change the design of this coated fuel pallet.

MR. RUBIN: No.

MEMBER FORD: Just to give you a higher wear resistance. However it is going to do it.

MR. RUBIN: Again, just let me go back to this slide. The focus of this presentation is on what might be viewed as generic to both designs. Which is the particle itself. I think you are referring to the fuel sphere, which is the size of a tennis ball, I'd say. And due to motion through the reactor before creation of dust particles to the grinding action on the pebbles. And then fission product transport.

So that research plan is not focused on dust generation. However, I think as part of the reactor analysis part of this presentation, that would come into play there. In terms of how do we account for the dust in the source term, reactor systems analysis.

Well let me just try to keep moving here.

MEMBER LEITCH: I guess, Stuart, my question is basically, we know enough now to proceed with meaningful research or must we wait until the further resolution of the design?

MR. RUBIN: Yes, I think it is worthwhile to proceed if we research even now. Because again, although we have yet to have in hand fuel that is made from a production for use in a GT-MHR/PBMR. The reference fuel is in hand. And again, the particle design and the particle manufacturer of what we have in hand is to be followed by the vendors for those fuel to reactor types.

So we have a way to essentially benchmarking, if you will, what would be the safety margins for this kind of fuel with the fuel we have in hand. There are more similarities than differences and we can provide a benchmark in terms of particle integrity at high temperatures, high burn up, high fluence and also accident conditions.

And it would be useful then when the fuel for the actual reactors is available to prepare that benchmark against what how that fuel would perform.

MEMBER SIEBER: Would the agency actually be conducting basic research or would you be evaluating vendor research?

For example, all of the stuff has been tested in the past to determine its basic radiological/physical characteristics of the idea is to look at the test, I would imagine. To determine that the tests were valid, were conducted properly. And gave sufficient quality and quantity of data to these statistics.

MEMBER ROSEN: I am not sure your premise is right.

MEMBER SIEBER: Well that's the question. Is my premise right?

MEMBER ROSEN: Because you have named two different kinds of fuel. You said that there was a Uranium oxide fuel and an uranium oxycarbide fuel. Those are two different kinds of fuel. They would have two different kinds of interactions with the buffer and the rest of the TRISO particle layers. Is there a solid research and basis for both of those kinds of fuel? Both of those particles?

MR. RUBIN: Well, again, the research plan is really a plan that plays out over many years. And it starts with testing a fuel that is currently available which we think is important to do the testing on. The fuel which is currently available which is UO_2 fuel, TRISO particle fuel.

But then it moves over time, presumably when fuel for those specific plant designs are available to do a complimentary testing on that fuel. Okay, so this fuel is not the be all, end all test program. It is the beginning of the test program.

In other words, if you look at the plan, you will see test matrices for the fuel that is German archived fuel. You see test matrix for the production fuel for PBMR, if and when that is available. And then you see test matrix for fuel for the other design.

So you rarely over the course of the research plan will be looking at all of --

MEMBER ROSEN: Try to answer my question. My question is, based on my understanding that there is a lot of data available for TRISO coated particle fuel performances for uranium oxide particles. And that in that sense, the staff, for that fuel, the staff would be looking the data. Now change the subject, is there a similar database for uranium oxycarbide fuel? Or is that totally new?

MR. RUBIN: No, it is not new. There were relatively few irradiation tests and accident simulation tests done on oxycarbide fuel in Germany. The database for UO_2, TRISO particle fuel is much, much larger than UCO fuel. That is a point of fact.

MEMBER SIEBER: Now, this testing involves the particle, but not the fuel elements themselves, tennis balls or whatever they turn out to be. And that testing, to me, would be important for the thermal hydraulic standpoint in predicting what the ultimate temperatures would be during accident conditions or loss of coolant accidents. That actually is related directly to the reactor concept as opposed to the individual components of the fuel. Which are releasing tiny particles. Is that correct?

MR. RUBIN: Let me say that the fuel testing in all cases, will be carried out, not as loose particles, but as particles within there specific fuel elements. Okay, so the initial testing that is envisioned for the German archive fuel will be done on TRISO particles in a pebble bed format, you might say, a fuel element.

But the primary interest is on the behavior of the particles within that fuel matrix.

So, we do in a way get the performance characteristics of the fuel by testing it that way. And we would be measuring fission product release. Or we need to measure fission product release coming off of the fuel element itself. Which is an integration of releases from particles in tact and broken as well as from the matrix.

But the plan would be to focus in on the performance limitations or integrity limits of the particles themselves within, whether it be a spherical element, a pebble or a prismatic element, a compact.

CHAIRMAN KRESS: When you have a actual rule that says that this reactor will not release so many fission products because of the site location and stuff. The rule will be backed down to certain qualities of fuel. In terms of how many of these particles not be failed in the first place. Track how much uranium is in there. And how much particle may be defective and actually release more than the standard particle.

There is so many particles in loading the fuel, that there is no way you can know ahead of time other than by looking at the process in which it was made. And looking at the batch thing to see if the tolerance is there on the dimensions. But there is no way you can really know for a batch of fuel that is coming in that meets these quality specifications. It has to meet the regulatory requirements on the release rate.

My question is, is there anything in the plan that says, okay, when we load this fuel, I am going to start looking at the build up of activity of the coolant system to see what it is in terms of rates and what the isotopic mixture is and stuff. And I am going to confer from that, whether or not I am meeting my fuel quality standards during the initial operation.

Is that in the plan anywhere or, because that is basically what we do with the fuel now. And I am wondering if we have any research plan a way to look at that as a concept to as we say, yes you have met the fuel quality that we expected you to meet?

MR. RUBIN: The research plan is not focused in on the integrated fission product release question that might be measured by a coolant activity monitoring system. But, what we are interested is in the understanding whether or not such a coolant activity monitoring system is really capable of detecting what you might call incipient or latent failures of a fuel. A weakening of the fuel.

So, certainly if one can show that the monitoring system is capable of detecting failures that actually occur in the radiation, we would want to understand how the measurements are actually taken can be back tracked into the actual fuel performance determination.

But this research plan is not focused on that kind of integrated issue. It is really focused in on can that monitoring system detect failures before they might announce themselves in an actual accident situation. That is a question.

MR. FLACK: Yeah, I think the question on the correlation between you know, vision product release for a normal operation is an indication on how the fuel performed during an accident is a good question. And we have talked about this many times. But whether there is in fact, a correlation, and how we are going to go about determining it. And it is not in the plan to say well we plan to look at normal operation and vision product behavior during that. I think that will come as part of the operation.

The question comes down to can it be predictable from the model that can be generated about the fuel fabrication. And then from that, understand how the fuel should perform during normal operation.

And then, understand whether or not from fission product release into the coolant, predict what the performance would be during an accident.

It is a very good question and it is something we have been discussing about. We don't know how far these models will ultimately take us. Bur as far as trying to understand the fuel, and what's important for fabrication, I think the best we could do now is look at what these models will tell us and predict.

CHAIRMAN KRESS: But it is in your thinking?

MR. FLACK: It is in our thinking. I constantly talk about it quite often, so.

MR. RUBIN: Okay, let me -- I don't know where we ended up, let me go back to this slide first. The objective for the -- let me back up one more time. The purpose.

Again, the purpose is to understand what the safety margins are within the fuel. Again, the testing that was done in Germany and around the world for that matter was really focused in on showing performance being acceptable within the licensing basis. That is predominately the philosophy of fuel testing that we have seen.

What we are interested in is testing outside the licensing basis to find out what the failure point of the fuel margins are. The fuel qualification testing that an applicant will submit will again focus in on fuel performance within the licensing basis and maybe a little bit beyond that.

But they are not interested in showing failure points. That is where we come in. That is where our focus is in understanding where those failure points are. And so that is one of the key aspects of the plan.

We also think that the research is by actually doing this, will enable our staff to better assess the validity of the applicants claims of fuel performance in terms of failure and fission product release. We think they will also strengthen our knowledge and information about how you actually do a radiation testing.

And let me just jump down. And finally we think the research plan includes activities that will provide the staff with, I think an essential understanding of the relationship between how fuel is made. How that process turns into actual fuel characteristics or properties that then play out in terms of actual fuel performance.

MEMBER ROSEN: Stu, hold on a minute. There seems to be a little confusion here. At least in my mind. Maybe you and Farouk can help me.

Earlier we talked about licensing basis and beyond licensing basis. Here, and I think Farouk may a very important point that in the risk informed license world, we will have a smoother continuum. We won't have this cut off point between licensing basis and what is beyond licensing basis.

Yet in this discussion, you seem to imply that there is this firm cut off date. That we want to know what is going on within the licensing basis and beyond. And so what would help me understand why one part of the discussion we hear that no black and white situation, we have a continuum. And another part we hear there is. I don't get it.

MR. RUBIN: Well, from what we have seen in terms of the proposals from Exelon and we have been told by GA that they are going to plan on following in Exelon's footsteps, is that you essentially have a frequency versus the kind of consequences type mapping.

And from that mapping there are bands which have been identified for what the frequency between, let's say once per year, to so many times per year is defined to the normal operation. Is the frequency band and they just label it as such. And there are consequences that are associated with that.

Then there is another band of less frequent events that pick up where the normal operations frequency ends. And drops it down to a lower bound of frequency if you will, that defines what they would call the design basis events. And then below that band is events that are considered for emergency planning basis beyond the design.

So I think the two kind of work together. It is just a way of labeling those bands and that is how I labeled, that is the framework that I am talking about. It is a continuum, but I am just making reference to the normal operation being in that frequency range. Design basis events being in the lower frequency range. And then the events beyond design basis, for example, air ingress events may be viewed as beyond a design basis for some plants.

But we are interested in other standards, fuel performance anyway. So we understand what margins they exist. Should that type of event occur.

MR. FLACK: From our perspective, we look at the fuel as saying, well if the temperature is below 1600 degrees, let's say. On the average, for most of the challenging events that Stu has just described. They will go as far as, and here is where the difference of philosophy comes between where the regulatory perspective comes in and an applicants perspective comes in.

The applicant will say, well we have margin even beyond 1600 degrees and go on about to demonstrate their margin up to a certain point. For us to fully understand how the fuel is going to behave, we would take the fuel to failure for example.

We wouldn't necessarily stop at 1800 we would continue to test up until the fission products came off at a certain rate. At what rate and what temperature. And in that way, understand how the fuel really will behave under maybe more severe conditions than we can ever imagine.

One of them may have been an air ingress event which licensee would consider a self low and the frequency that we no longer consider that to be a credible event. And therefore we won't look at that.

We'll only look at these events of higher frequency, which are still pretty low. And they may very well be. The question is, do you want an infrastructure in the regulatory commission that understands how this fuel performs under all conditions and is comfortable with that fuel and the point at which it will really get to unravel. What temperature, over what periods of time and so on.

So that is more of the perspective for us to take things all the way to their limits. Not to be satisfied at one particular margin limit which an applicant might demonstrate with data. Of course, we are certainly interested in that.

But there are other conditions, just from the sake of regulatory perspective, to cover our own knowledge and understanding of the fuel. And so that we are not left with, well what happens if the fuel goes higher in temperature. What is the ramification?

I a mean, I think we do need to look there. And from there, I think you start to see the difference in philosophy between a regulator in an applicant.

MR. ELTAWILA: There is no difference. I think John said most of the stuff that I would have said. However, it is not a philosophy difference between happily content NRC. That issue we raised it to the policy level issue. We are asking the commission should the NRC require a licensee to administrate fewer performance under all the spectrum of accident, including severe accident.

In the past, we did this work ourselves as John indicated. But for in the future, we are raising that question to the commission to get some guidance. You know, because if the commission says yes that would be a requirement, then the applicant and the licensee would be required to test that fuel to failure.

MEMBER BONACA: It seems to me also that it could be the critical element in support of the confinement versus containment. What I mean, is that if you could demonstrate not only the applicant says he can't get beyond 1800 degrees Centigrade for example, and under certain conditions, it excludes certain events that is possible.

And you can prove that you can go 3000 degrees to make a number. And you cannot get there in anyway, it seems to me that would be a fundamental decision point that says you have confinement. And confinement is totally adequate. So I think in this case, it seems to me like it is an issue that goes beyond just the fuel performance per se as we have seen it in the light water reactors.

It goes into the role of confinement that or containment. Really we attributing to the matrix, the fuel matrix.

MR. FLACK: That is a good point.

MEMBER BONACA: It seems to me that would fall under physical challenges that are out there was that.

MR. RUBIN: Just let me say that the way plan is put together and the way I hope to talk about it, is in terms of needs. Whether or not ultimately the commission policy will be that those needs need to be met by the applicant. They need to do this research whether or not we are not going to require that.

And we would do the research that question is part of the policy issue. But the need to explore the failure points is valid. That has not has been explored and argued sufficiently.

And so just to talk about the scope of the research, it really involves these five areas, the radiation testing, accent condition testing, development of analytical miles and methods for predicting fuel performance and fission product release. Developing knowledge of a fuel fabrication process and how they relate to particle characteristics and performance. And then generally to develop our level of knowledge across all these areas.

MEMBER FORD: Stuart, you said earlier on that this work could go on for quite a few years?

MR. RUBIN: Yes.

MR. ELTAWILA: The first two bullets, especially. They are going to be time consuming in reactor work. Is that work, is it going to be done by the NRC with contractors?

MR. RUBIN: Well I was going to get to that. The strategy for how we would do this testing. That comes up under the discussions of how we would actually implement the irradiation testing. My response to your question will just come out in the wash in the presentation.

The answer is we are going to try to enter into cooperative research and coordinated research.

MEMBER FORD: Does that mean before, several years before you come up with the criteria that the applicant has to meet. There is going to be several years before he can even start to obtain the data to resolve, to meet those criteria.

MR. RUBIN: The focus this research is not necessarily to develop the performance criteria. We expect that the applicant will propose what are the operating and safety limits of the fuel. And then to go about doing analysis and qualification testing to show that the fuel will perform in terms of very limited fuel particle failures up to those limits.

And then in turn, you take those results from the testing plan and you put it into your analysis of consequences. And ultimately the criteria is the radiological consequence levels that we have. So there is no need for an applicant to wait for our testing to be completed.

MEMBER FORD: This is where General Atomics have been doing research, which obviously you must have been. And they are coming up with defining a certain performance criteria for their fuel pellets. What happens in two years time because the regular framework aspects and then later you come up with completely different criteria. In order to meet the risk informed aspects of this design. That means you are going to start again.

MR. FLACK: Well I don't think you would have to start again. I think a lot of it goes back to the question that was raised earlier, a comment made by Jack.

And that has to do with regulatory decisions and how confident you are in making those decisions and how much defense-in-depth you will need to implement into the plan.

And the more we know about the fuel behavior, the more we know about the plan, the better informed the regulator will be in making those decisions. If we say, well wouldn't carry on a test program now, we will wait until the design comes in. And then when the design comes in, now it is like, well now these questions need to be answered.

How are we going to make decisions? Now we are left with how many years in the future are we going to have the answers to these. And then what we are going to have make decisions now based on the regulations in place and here is how we are going to do that.

I think the whole thing is in preparing ourselves now for those decisions in the future. And where we are. I mean we will always make a decision. The question is how good of a decision can we make at that time.

MEMBER FORD: The sooner the start, the better you are going to be.

MR. FLACK: Right.

MEMBER RANSOM: The question I had is does DOE have any role in the research in general. You know they have the NERI programs?

MR. RUBIN: Again, that is coming up in a slide just to mention it now. DOE has a HTGR fuels development and qualification test program that they have funding for.

And the elements of that program include developing fuel fabrication technology for the manufacturer of TRISO particle fuels and compacts or pebble format. Also for development for analytical codes for predicting particle failure and fission product release.

The last major area relates to irradiation testing and accident simulation testing of fuel. And it is that activity that the NRC is looking to enter into a cooperative irradiation testing agreement with DOE to test fuel. So, we think there is an ability to leverage our resources.

MEMBER RANSOM: So you're complimenting what they do or it is integrated, I guess?

MR. RUBIN: Well we have established our test objectives in terms of where we want to explore margins. And they have established our test objectives and we see where they might be overlapped. And we can take advantage of what they have planned, but we anticipate there is going to be stuff that we want to do that they have no interest in things that they want to do and that we are not interested in.

Because it maybe within the design basis environment.

And so, the idea would be to enter into an agreement with some cost sharing to equitably pay for the entire integrated tests together. And share all the data.

MEMBER WALLIS: How do you know what this design basis is until you have some regulation?

MR. RUBIN: Well, the -- we have in terms of PBMR, through the pre-application review, some information as to the fuel design basis. Sixteen hundred degrees, we have been told is anticipated to be the accident limit.

The burn up level for the fuel is I believe is 80,000 megawatt days per ton. We have some information on what the fast fluence is for our fuel as a design limit. The one variable that we have, we are not sure of is the maximum fuel operating temperature in the core.

And that was kind of increasing as we went through the pre-application review as they were sharpening their pencils. And taking account of issues that were identified. But now all that maybe have to be thrown out because the latest information is that they maybe going to a solid core, rather than a graphite pebble core.

What that does is it will serve to lower the operating temperatures of the hottest fuel in the core. And so, we don't know exactly where they may be on fuel operating temperature. But we will have to pin that down before we start testing.

But I will say this, that our range of testing for operating temperature in my mind should significantly exceed what they are going to come up with. We are looking at 1400 degrees C as a maximum operating temperature for irradiation. And they are likely to be below 1250. So we will have 150 perhaps more margin testing on temperature.

MEMBER SIEBER: Actually the fuel element temperature, average fuel element temperature peak is one factor, but you also have to consider the temperature of the vessel that holds all this stuff. And if you had an accident temperature that was up like 2 or 3 thousand degrees C, then one wonders how long it would take for the reactor vessel to fall apart and everything go to the floor and from the floor to wherever it goes. Which is the other half.

MR. FLACK: That's right, you will hear about the materials presentation shortly on some of them.

MEMBER SIEBER: To me that would be an

important factor. Because this fuel is pretty robust being it is a ceramic. You know, in every kind of engine you ultimately run into a materials problem that says this is as far as you can go.

MR. RUBIN: Well you mentioned that the fuel is pretty robust, I think at the April 11 ACRS meeting on the plans the statement was made the fuel never fails. This slide is intended to just dismiss that notion by providing various mechanisms that have been identified over the years for particle failure and fission product release.

I won't go through them, other than to mention, I have tried to label whether or not those mechanisms are driven by environmental that is temperature, fluence, burn up, type, processes, or whether or not they are driven by, let's say manufacturing causes.

And so you can see there is a whole host of a failure mechanisms and fission product release mechanisms that have been identified for this fuel.

MEMBER ROSEN: Wait a minute, what does Opy C mean?

MR. RUBIN: Outer Pyrolytic carbon layer. And inner Pyrolytic carbon layer.

MEMBER ROSEN: Heavy metal contamination

of the graphite matrix or outer Pyrolytic?

MR. RUBIN: Again, as I mentioned earlier that there is trapped uranium that you are going to get just by using the natural graphite in the matrix. The release of uranium in there just naturally occurring and that will be part of a source of fission products. And then there is uranium or heavy metal that will contaminate the outer layers simply by the process that is used.

The initial kernel uranium will find its way through the reuse or the multiple layer coatings in the vapor depositing furnace will show up on that outer layer. And then when that fissions that will be seen as a fission product release element.

MEMBER FORD: I noticed that environmental dominates that list. And therefore you are concerned about mass transport connections and things of this nature. I remember at the commission meeting Graham said advanced reactors are going to be a give me. Because it is going to be so easy to resolve all of these mass transport equations for a single phase system.

Is that true. Do you see any big concerns about mass transport modeling for these systems? And therefore sending a patent to an --

MR. RUBIN: Yes, the equations that have been used in Germany are fairly well recognized diffusion equations and have been best fit to the test data that has been developed from irradiations.

I am not sure we are going to push the state of the art beyond the use of those kinds of models. We would want to develop our own test data to fully understand that these models that they would be proposing are adequate.

MEMBER WALLIS: I would think there was something between the pressure induced failure and diffusion then there must be mechanisms for cracking or other things to happen to the coating by which it would loose some of its integrity.

MR. RUBIN: Yes.

MEMBER WALLIS: Which would some time be somewhat mysterious until you have done the research.

MR. RUBIN: Yes, there is a whole host of mechanisms including, by the way the comment that the failures are dominated by the environment is not necessarily to be a conclusion to be drawn from this list. Although there are a lot of environmental lines up there.

If you take a look at the radiation performance of German fuel and compare that to the irradiation performance of U.S. made fuel, you would see about two to three orders of magnitude difference between the fission product release of those two fuel types.

MEMBER ROSEN: Which is higher?

MR. RUBIN: The higher being the American made TRISO particle fuel. And in recent studies that have been conducted have concluded that the differences in the manufacturing process for the manufacturer of those particles which result in differences in the particle layer properties and the bonding between layers is a very, very important, if not dominate factor in how particles will perform in the reactor.

And so although the environment will actually push those particles to failure, it kind of begins in a way with how you made those particles. And that by the way, understanding how you make particles and achieve the necessary characteristics, is a large world wide effort that is ongoing right now. Both DOE and the European Commission and others are trying to understand how manufacturing processes give rise to particle properties which give rise to performance.

Knowing that if you just make it the way you thought they made it, it will work out. There is a lot of devil in the details of the processes that are used. And that seems to be the big issue Areas in particle performances in manufacturer.

MEMBER ROSEN: Is there also a silver migration problem here?

MR. RUBIN: The silver 110M, that is pretty much not contained within the particles. And so silver 110M will migrate out of the particles through the graphite matrix and out into the system. And ultimately will adhere to the coal surfaces principality on the balance of plant surfaces. And then that becomes a occupational dose kind of a concern as opposed to an off site radiological concern.

MEMBER ROSEN: What is it about that isotope that makes it different from the other isotopes?

MR. RUBIN: That is an area where there has been speculation as to why those particle layers are somewhat permeable to that. I don't have an answer. I don't know that anyone has an answer to that other than they measure it and it happens. There are theories, but they are just theories.

MEMBER ROSEN: Are you going to research

that?

MR. RUBIN: Are we going to research the causes?

MEMBER ROSEN: Why it happens and what can be done to prevent it?

MR. RUBIN: Well, let me say this, there are two principle ways to reduce it. It is driven by diffusion processes which is driven by temperature differences across the particle and across the pebble. And one way to reduce it is to reduce the operating temperatures of the particles.

The other way to reduce it is to thicken the silicon carbide layer. It does provide some barrier to diffusion. So those are the two principle ways to do it. However, since these are high temperature reactors and they are trying to achieve high temperature gas temperatures for various applications, including power generation, I don't think they want to reduce the temperature of the fuel necessarily to a point where a silver 110M is going to disappear.

The approaches we have seen recently is that managing the consequences in terms of how you manage the maintenance of these balance of plan equipment to deal with that. But not to reduce it by containing it within the fuel itself.

MEMBER ROSEN: Let the operators handle it.

MR. RUBIN: Well one of the plans we have seen is to have kind of a package where you pull out the turbine generator out of the plant. And you put it aside and put a new one in its place. That is uncontaminated. And then you wait for that contaminated one to kind of pull down if you will and then after a year and a half or so, you do maintenance on it. As opposed to try and do maintenance on that one turbo generator.

MEMBER SIEBER: But see, solar is only one factor. The carbon dust has got trapped uranium in it. And I am sure there is tons of crud traps in the balance in the plants where all this stuff would collect.

MR. FLACK: Yeah, but it's not a missed point. The plan does recognize if from a LARP perspective, as an issue. And then the question of how far down in detail do we need to understand this from a risk perspective, I don't know.

It is there. It is something we are going to have to look at from regulator, from a regulatory perspective. And how much effort we need to put into it is still yet to be determined.

MEMBER ROSEN: Why wouldn't you tell the vendors to come back when they know how to control the silver?

MR. FLACK: If it's from a risk perspective, that is the indication that we get. That may be a message back. But right now, I don't know if we are in a position to give that back.

MEMBER SIEBER: That sounds deterministic to me.

MEMBER ROSEN: Well we rationalists often get deterministic. We have streaks of determinism in us.

CHAIRMAN KRESS: Yellow streaks.

MEMBER ROSEN: That's right.

MR. RUBIN: Okay, just real quickly. In terms of exploring the limits. We want to push the fuel beyond the design basis certainly and these are the kind of parameters that we are looking at. Temperature to fuel during irradiation. The burn up of the fuel. Fast fluence. Power in the coated particles.

Again the testing that has been done historically, you are looking at about 80,000 megawatts days per ton, perhaps 1100 degrees C. And let's say four times ten to the 25th neutrons per meter squared of fast neutrons.

And in Germany, good fuel performance was observed with those conditions. But what we are looking at is pushing those parameters much higher. Perhaps 20% FEMA, 1250 to 1400 degrees C, and burn ups double what have been seen or tested in Germany to kind of address the gaps in safety margins.

And again these will involve coated particle powers higher than one would see in a reactor since we are going to be irradiation testing on accelerated basis in this field.

MEMBER LEITCH: Stuart, are you planning to look at fuel performance in non stress conditions. In other words, just coming out of the manufacturer shop, how good is the fuel?

I am not talking about under stress conditions. I mean, just come out of the shop, might there be imperfections in the fuel. Are you taking a look at that at all?

MR. RUBIN: In terms of looking at the fuel, we have to think in terms of what fuel that we have to look at. And the fuel that we have to look at right now, is again the German reference archive fuel and we do expect to do pre-irradiation characterizations of that fuel before we irradiate with, I think we have more fuel than we are going to irradiate and we use that fuel for pre-irradiation characterizations.

We already have, you might say the manufacturing sampling statistics on the various QA tests that are done on that fuel. So we know in general what the statistics say. But we ought to be examining the particles.

Now for the fuel that is yet to be made, there is not much we can do right now to look at that. Since that is years away. But that is part of the plan is to do pre-irradiation characterizations of all the fuel that we are testing.

MEMBER FORD: Stuart, would you mind going back to the previous graph. If you looked at those four factors there, and refer back to the previous one where you got a whole list of all the potential performance and things. You have got a huge x by x matrix of all the interactions between the previous one and those four items.

How do you prioritize as to which of these aspects you must look at in the first year? What is your prioritization strategy?

MR. RUBIN: Well, it is kind of what you

see is what you get in terms of the actual mechanisms that will play out in the environment. And although these are the drivers for seeing those mechanisms, not all mechanisms will be seen by the fuel. Because we may not get to the temperatures necessary to where some of these mechanisms are active.

MEMBER FORD: For instance, the probability of having a certain defect density in your fuel particles would impact on what the allowable highest irradiation temperature would be. And so on, you could go on first and second and third order effects.

Are there algorithms to tell you what your prioritizations should be in terms of doing these very expensive tests?

MR. RUBIN: Well, again, we are looking at specific fuel design. As specific manufacturer for that design. And then subjecting it to a particular environment. And that specific manufacturer will give rise to variations as you said.

And those will be imbedded into the actual tests due to the fact that you have perhaps 15,000 particles in each pebble I would say. What we will see, for example, under disassociation at high temperatures. I don't expect we are going to see that, because we are not going to get near the temperatures where that mechanism would show up. Certainly not during operations in the accident temperatures were envisioning of say 1800 degrees maximum. That wouldn't show up there either.

You would see that in the starting out, let's say 2200 degree C. So we wouldn't see that. We will see what failure mechanisms occurred, if any in the PIEs. That is the purpose of the PIE is doing examination to see what the condition of the fuel is and what really happened in terms of particle failures.

Were they failures where there were cracks in the outer Pyrolytic carbon layer that then progressed into cracks not the silicon carbide. That is to say a high stress region occurring in the silicon carbide. Do we see Palladium attack. We'll see that in the PIE's. I don't expect to see Palladium attack in these experiments because the amount of time and temperature involved is again, a far in excess of the licensing basis conditions for any PBMR, certainly.

The test is not designed to test fuel where every particle is identical. And then go through a variation of environmental conditions.

MEMBER FORD: That is not practical. That is not achievable. The strategy you are outlining seems to be we will take what we get. In other words, you are taking a spot stab because those happen to be the conditions you have. But you can't extract from those conditions and say look here for that reactor or that design by that manufacturer, United States manufacturer versus German manufacturer.

You can't do the extrapolation from that data point to those conditions. I think that is true.

MR. RUBIN: I think there is a truth in what you say. Certainly because of what I said before that manufacturing will drive performance in large respects. But again, the reference fuel that we are testing is the reference fuel for these new designs so it establishes a bench mark, if you will, on capability of this fuel.

MEMBER FORD: But there is no way of doing a PRA or because you just don't have the data?

MR. RUBIN: Well if we were to test --

MEMBER FORD: A lower level PRA.

MR. RUBIN: If we were to test this fuel as they have tested it historically within let's say the design envelope for the fuel. In Germany, they saw no fuel failures during irradiation testing within a design envelope. And even a little beyond that they saw no particle failures in the accident simulation testing.

I mean they are very proud of those results. We want to see if we can drive the fuel to a more challenging operating conditions and more challenging accident conditions. And to see where we start to see some statistically significant up take if you will, in the particle failure rates. But the actual mechanisms, we won't know what they are until we do the PIE.

MEMBER WALLIS: Well finding out the mechanism may not be so easy. I mean you have got all these myriads of particles in some kind of a matrix. And then you find you have got to detect some radiation somewhere.

You are going to take everything apart to figure what happened? Look at every one of those particles? What are actually going to do diagnostically?

MR. RUBIN: Well there are mechanisms to, if you will, take apart the matrix material.

MEMBER WALLIS: Then you have got 15,000 particles, all which have failed in various ways.

MR. RUBIN: Well, we don't expect that

they are going to fail in various ways.

MEMBER WALLIS: Well why not?

MR. RUBIN: Well --

MEMBER BONACA: One concern I have, by the way, is --

MR. RUBIN: We could drive through all of these failure mechanisms if we had in hand fuel that, let's say was, made by the U.S., okay with our manufacturing. And we were to drive the fuel up to places where we know it is definitely going to fail. Up to 2200, 2400 degrees C. Or if we take it out to burn up, if we could, to 200,000 megawatts days per ton. We know we will see a significant fraction of failures.

MEMBER BONACA: In manufacturing, how do you assure uniformity of distribution of the 15,000 particles in the spherical? You may sample it. But I am saying this too, you have to deal with the possibility that you may have lumping of particles in some location rather than others. Which means that in certain locations you could decouple almost a sector with a much higher density that co-responds to 30.000 particles and vice versa somewhere else. You have the equivalent of 7,000 parts.

So, I am trying to understand how you deal with those issues in this matrix because, what I am trying to say is that the matrix may be even more complicated than what you are presenting here.

MR. RUBIN: Well in any test program, you are going to be testing a sampling of the manufactured fuel. And that sampling will have had to have met the production QA requirements in terms of a sampling rate. And what the measured variance was and what the mean was in a particular parameter.

With all that, there will be some pebbles that will have initial particle defects in them. And there will be some pebbles that have no initial particle defects in them. And there will be pebbles that have perhaps more particles with thinner layers than other pebbles have.

We will be dealing with the manufacturing QA results for the batches of pebbles that these fuels came from. Beyond that, we don't have an ability to be more precise in knowing what the exact distribution was on these particular pebbles in terms of the --

MEMBER BONACA: So you are not going to attempt -- it certainly would be interesting to have some pebble that has 20,000 particles in it and some with 10,000 and see how they -- the challenges here and that would give you some idea of how this changes in distribution may affect performance.

MR. RUBIN: I don't have a, perhaps, Don can help me out there in terms of the number of particles within a pebble. Or the number of particles within the compact and how that would play out in terms of temperatures and temperatures in effecting fuel performance.

But I think our analysis of difference in the number of particles in a pebble was not a significant driver of fuel performance in reactor. And that was due in large part due to the temperatures that the individual particles would see during operation. Would not be significantly different.

If you had 15,000 or you had 17,000 particles in there. So that is not a large factor, if you will, in particle failure phenomena. Is there something you would add?

MEMBER SIEBER: That is easy to control too.

MR. RUBIN: That's easy to control. That is true.

MEMBER SIEBER: Weigh them, see how much they weigh.

MEMBER BONACA: No, I am not talking about, I am talking about only changing the number of pebbles to test the density of particles that may be higher in some location or another.

MEMBER SIEBER: You mean within the pebble itself?

MEMBER BONACA: No, no, I am talking about --

MEMBER SIEBER: From one pebble to another?

MEMBER BONACA: When you mix using the matrix, you have 15,000 particles. That is easy to control. But am saying that you are not sure how distributed they are. They may be lumped together in some area rather than other. And you know, in that particular area, you can almost conceive it as decoupled area with more density than some.

MEMBER ROSEN: I think you see that right there Mario, in the picture that is showing. There is an area where there are very few pebbles.

MEMBER BONACA: You're right.

MR. FLACK: Just to try to get us back on track a little, there is a lot of questions. And the approach of the plan is first find out what was all done world wide in all these different areas. Try to get as much information as we can. And part of it is opportune. What we can do now within our budget.

What is the best thing to do. It is an integrative process as well.

As we learn more, we will be asking ourselves more questions to try to keep it focused. But as the discussions have been, it is a complicated subject. And it is just there is not a simple answer. There is a lot of parameters that need to be controlled.

CHAIRMAN KRESS: Well one comment I might have is, I would start my thinking from a viewpoint of what analytical tool I am going to be using. And it is probably something like MELCOR. And if you looked at the fission product release models from fuel that are in MELCOR now, they are all empirically based.

They are not mechanistic at all. They are empirical.

MR. FLACK: Sure.

CHAIRMAN KRESS: So I would say now, if I want to put in a replacement model for in MELCOR for fission product release, I have my choice. Am I going to use some sort of mechanistic model that talks about mechanisms of failure of the fuel. And how that is related to temperature. I don't give much hope there.

I think you are going to be empirical again, which tells me you are going to do something like separate out the influence of tramp uranium, for example. And already failed particles. They are going to behave differently in an empirical manner than the pebble beds that are in there -- that are already good.

But what are there behavior going to be when it goes through some sort of transient nitrites that have been in a radiation field for a long time. So I would say if I was going to redo MELCORs models, I would trade tramp uranium and failed particles differently then I would intact particles. And then my experiments, my research would be empirically based and I would be looking at full fuel elements.

MR. FLACK: Right.

CHAIRMAN KRESS: And what happens to them when they go to a temperature transient and translate into a fission product release model of some kind.

MR. FLACK: Sure.

MR. RUBIN: I would say that the fission product transport and release models for fuel do account for the tramp uranium as well as release from the outer coating due to contamination of that. Possible diffusion through intact particles and release from broken particles. So there are a number of terms --

CHAIRMAN KRESS: I would accept separate terms.

MR. RUBIN: Yes, there are many separate terms that one could look at in those codes. Just very quickly, given those irradiation test conditions, we would plan to do two things basically. Monitor fission gas release as a measure of diffusion of fission products of intact particles and release from failed particles.

And also, again, we would plan on doing PIEs to better understand the fuel condition and more specifically what were the failure mechanisms that were --

MEMBER WALLIS: How do you tell the difference between fusion and failure? It gets out, but how do you know it got out?

MR. RUBIN: Well if you are looking at 15,000 particles in a pebble and each pebble is individually monitored for fission product release, what you will see in a fuel with all intact particles, is perhaps in the order of ten to the minus eighth R over B ratio of krypton release.

MEMBER ROSEN: What is R over B?

MR. RUBIN: Release to birth of a particular. In other words, the release fraction of particular radioisotope to the birth fraction. Okay. And that history over the irradiation has a signature which is so low that essentially says, you don't have a particle failure. Now when a particle failure does occur, you will see a significant --

MEMBER WALLIS: So it's all or nothing?

MR. RUBIN: Into the range of ten to the minus five.

MEMBER WALLIS: It's all or nothing. You don't get partial failure, you don't get slight weights.

MR. RUBIN: Once that particle, the first one goes, you will see the step change in the curb. And I think I might have brought --

MEMBER WALLIS: Okay --

MEMBER ROSEN: That is one of the 15,000 particles goes, you see it.

MR. RUBIN: Yeah, you'll be able to get a good handle on the numbers based on how that curve goes. I don't think I have one here that shows that, no.

CHAIRMAN KRESS: We saw a curve of a number of particles versus failure versus time at a given temperature --

MR. RUBIN: Yes and this one doesn't show it as clearly.

CHAIRMAN KRESS: It is something like that, yes.

MR. RUBIN: These curves down here would be typical of no particle failures. If you take a look at R over B from one particle failure out of let's say 15,000, you have to be up in this range up here. So around here, you would be talking about one particle failure.

MEMBER SIEBER: It would be better if you sed the microphone.

MR. RUBIN: I'm sorry. The 1700 degree family is an indicator of multiple particle failures. The 1600 family is indication of no particle failures in this fuel.

MEMBER WALLIS: That's so far. But you might get an American fuel which it is so bad that it is porous and it doesn't fail at all, but it is up at 1700.

MR. RUBIN: This by the way is for an accident simulation, but for, if you can imagine this at irradiation time and release of krypton, then you would see it. This is an R over B ratio. Such as you would see perhaps a spike going from this curve up to that level. And then if you had more particle failure, it would start to change.

MEMBER WALLIS: I don't see steps in the curves though.

MR. RUBIN: Well, again I don't have the right curve here. Maybe if you give me some time, I can --

MEMBER WALLIS: No its okay, we need to go on I think.

MR. RUBIN: This again is a heat up curve not an irradiation curve. All I will say is that if you just go through the arithmetic of when one particle in 15,000 fails, what does that turn out to be in terms of --

MEMBER WALLIS: My point simply is that because the German's had some experience, it doesn't mean to say that is the experience you are going to have?

MR. RUBIN: Absolutely not. That is why we said we want to test production fuel for the GT-MHR. Whether it becomes available --

MEMBER WALLIS: It may not be so clear, the distinction between the fusion and leaky particles and porous particles and popped particles and whatever. It is all going on together.

MR. RUBIN: Let me say this. That there

are test that we don't propose to do that are characterized in --

MEMBER ROSEN: Use the microphone.

MR. RUBIN: There are tests that we don't propose to do and that is testing on individual loose particles. When you can do testing on individual failed particles, then you can get a good measure of fission product release from failed particles. It is kind of a separate effects type of a test.

What we are doing is an integrated effects test by looking at the entire pebble. But I will say this, that you will see a step change in release to birth ratio by the gas re-monitoring when a particle fails and you can actually determine how many particles have failed just based on the mathematics.

And that particle failure will dominate the releases that are being monitored. They will just by the order of magnitude, you are picking up a particle failure and then that will basically swamp the tramp uranium of the ratio. At that point you are seeing particle releases.

MR. RUBIN: I am not sure where we are here. Okay, let me just say the other thing. In addition to pushing the margins, we do want to understand whether or not the irradiation testing itself is, that has been historical used is conservative again, accelerated testing has been done as a necessity for getting results sooner.

But there are some issue whether or not that may not be conservative for some of the failure mechanisms such as chemical attack which take more time. We also think that simply by doing these kinds of tests, we will better understand the how you can do them right and how you can do them wrong and be in a better position to evaluate fuel qualifications.

CHAIRMAN KRESS: When you say chemical attack, you are not thinking of air and water ingress? You are thinking of fission palladium attack.

MR. RUBIN: Palladium attack, that kind of chemical attack. In terms of the kinds of accident testing we would now do, moving from irradiation testing to accident simulation testing that are going to be basically three areas.

Heat up testing, reactivity type events and then the chemical attack type events. Again, these would be for conditions in each category that are beyond the design basis.

So for heat up events, we would start with fuel that was irradiated beyond the design conditions and then go through a heat up that was beyond let's say the 1600 degrees C temperature criteria that is specified typically for this fuel.

For reactivity events, we do a similar thing there. Identify what would be a bounding reactivity pulse event and then run a test of that to observe fuel behavior in terms of disassociation and gross failure of the fuel. And then we would plan on doing oxidation tests on a irradiated fuel elements to understand how fuel that has been irradiated beyond its design conditions. What the oxidation effects are in terms of particle failures.

CHAIRMAN KRESS: In the models for fission product release from LWR fuel, the testing was done by heating up slowly and holding temperatures. And heating up and holding at other temperatures. And because the release was basically at the fusion process.

I envision the release from this kind of fuel being a failure of the particle process mostly. Plus some diffusion after that. That is driven by the failure of particles. It doesn't seem to me like this slow heat up and hold is an appropriate test to look at what causes the particles to fail. It seems to me like you need to model an actual set of expected temperature ramp rates in accidents.

I am just exploring what your tests might look like -- accident heat up rates?

MR. RUBIN: That comes up in the next slide actually where we want to explore whether or not the traditional testing methods for accidents, for heat up accidents is conservative. And I could just jump to that one next.

MEMBER ROSEN: You'll have to come back, I have a question on this thing.

MR. RUBIN: Okay. I can get to it in the next slide or two. But we will be testing the ramp and hold, as I refer to it, against the actual time versus temperature that you would see in a real accident to see if you see any differences in the number of particle failures you get for that.

MEMBER ROSEN: One of the things you will have to do I think is on the reactivity events, you'll have to do that test with high burn up fuel. Because you can't choose when you are going to have the super critical reactivity event. It might just decide to happen late in the life of some of the particles.

MR. RUBIN: Yes, there is a tradeoff between the level of energy that you can put into the particles late in life, versus the pre-condition of weakened fuel, you might say, later in life. Against the newer fuel that is not weakened, if you will, by irradiation. But has a higher potential for a larger energy spike in it. And so it is not clear which is the worst.

MEMBER ROSEN: You'll have to figure out what the worst case is and test it. Otherwise you will end up where we are on light water reactor fuel.

CHAIRMAN KRESS: I think you have to test both of them.

MEMBER ROSEN: Yeah, reactivity insertion accident questions about high burn up fuel.

MR. RUBIN: Yes, I would agree with you on that. That you need to do two or even three places in the burn up history of the particle.

I will go over the next slide in terms of what we will be monitoring because it's the same for irradiation pretty much. But here is where that question came up. We also want to evaluate the test methods by this test program and so we want to do it both ways on fuel that has been irradiated to beyond the design levels to go through the traditional law of rapid temperature increase and then hold at constant temperature, let's say 1600, 1700 or 1800 for hundreds of hours as opposed to going through a heat up which tracks the predicted temperature increase in the fuel in the worst case accident.

There is some evidence that in testing of AVR fuel in Germany, that there were failures seen in fuel that was tested that way with the actual time temperature approach that we are not seeing in the ramp-up and hold approach. And there is not a good explanation for that at this point. I will say that in the pre-application review from PBMR, there was a sentence in their information on qualification testing that they may do that kind of testing themselves to see whether or not there is an unknown phenomenon that makes that kind of a more precise temperature versus time more challenging at fuel than the ramp-up and hold.

And that is a good example of who is going to do this test. Are they are going to do it? Or are we going to do it. And that can come up along the way in many of these areas. We are not sure, but somebody needs to do this.

MEMBER ROSEN: The curious statement that applicant says he may do this testing. Now, how much credit do you give them for the "may"?

MR. RUBIN: Well that kind of needs to be kind of discussed. I think what happened was, we raised this issue in one of the early meetings and the put a little place holder in their submittal.

MR. FLACK: They didn't say they won't do it.

MR. RUBIN: I think we would like to see them do that. Okay, the question came up, how the heck are we going to do all of this. And in terms of the irradiation testing, we want to enter into cooperative agreements where we can. One is with DOE. DOE has this fuel development and qualification program which involves irradiation accident simulation testing.

And we have put together a document which describes how we would cooperate in sharing of data for that kind of testing. We are not yet sure whether or not DOE plans to go forward with irradiation testing given the current situation with the pull back by Exelon.

Also, we have been in discussion with the European commission. They also have an irradiation test program, an accident simulation test program with what they call the HTRF. Which is a High Temperature Reactive Fuels working group project. That calls for irradiation testing of both Pebble fuel and compacts to burn ups which far exceed the anticipated burn ups for this next generation HTGR's.

Another opportunity for obtaining data is IAEA initiated efforts to put together a new coordinated research project, Number 6 they call it. Which will pull international data on current and previous testing, irradiation testing of TRISO particle fuel as well as many other things like model development, properties for models, manufacturing expertise and the like.

We are also in the process of putting together an agreement with the Japan Atomic Energy Research Institute for obtaining information data on what they have developed on irradiation testing of fuel compacts with TRISO fuel. And there may be some basis for actual reactivity pulse testing which they have a need actually, a licensing need to do that kind of testing on their fuel. And we might want to enter into a cooperative arrangement where we get that data and also provide some fuel compacts for fuel with TRISO particles made in this country.

And also information exchanged from I-Net. And they currently have fuel qualification program that is no ongoing and we'll soon hopefully have operational data on their fuel. And we hope to obtain data from that.

So we don't see that we are going to be

paying for everything, in fact we like to get data from other sources and share in the cost. Let me quickly go over the next part, which is to develop our analytical tools. The objective here is to provide the staff with an independent capability to analyze a TRISO particle fuel performance. In both Pebble bed reactors and reactors with prismatic fuel.

We have two kind of complimentary objectives and two kinds of analysis needs. One is codes that can predict particle failure if you will that has in it many of the models for the failure mechanism that I talked about. But then there is a traditionally a second code that actually goes through and calculates the fission product transport out of the fuel element due to diffusion mechanisms from matrix material as well as from intact particles, as well as from failed particles.

And so you are looking at the need to kind of couple those two codes and those two capabilities. With the two, we would then have an independent capability to assess an applicant's calculations and to provide input to our own source term analysis for accent consequences based on the fuel fission product release from these codes.

MEMBER RANSOM: Is that an effort starting from scratch or are you building on existing?

MR. RUBIN: Same approach. I think it is in my next slide. The strategy is again to cooperative research with organizations world wide that are working on developing such codes. And there are many choices, many organizations that are doing this. We have to place our bets soon on which one we want to support.

Let me just say though that developing these tools is a challenge. If you look back at the German codes and let's say the more recently the Japanese fuel codes. They were very specific to the properties that related to the way they made the fuel and the results of the irradiation testing to bench mark those codes. And so you don't really have a code with models which have universal applicability to fuel that we made in the future. And so you need to have enough capability build into the codes to be able to predict any kind of new manufacturer given the kind of characteristics or properties that may evolve from that manufacturer. So that is a difficulty.

The property data that exists for unirradiated, and especially for unirradiated codings is meager and wide variations. And these properties play a very large role in when particle failure might be predicted. Things like creep, irradiation induced changes in dimensions of the Pyrolytic carbon layers varies tremendously. Even thermo expansion, there are large variations one would see in the literature. And so kind of get it right, you have got to get the materials data right.

We talked about the failure mechanisms. And you can have local imperfections in the silicon carbide. You can have local tearing away or debonding of let's say the outer Pyrolytic carbon layer from the silicon carbide. And so you have localized effects and that drives a need for 3-D modeling in doing these kinds of analysis.

CHAIRMAN KRESS: The 3-D modeling, where would that come in to play? Let's talk about a local defect in one of the layers. Are you talking about 3-D modeling of how the fission products move through that, or are you talking about further expansion of the failure to make it worse?

MR. RUBIN: Well I mean what you are talking about is localized stress risers ultimately. That then are going to be controlling in terms of exceeding the ultimate strength of the silicon carbide.

CHAIRMAN KRESS: But that is normally not a 3-D concept.

MR. RUBIN: Well I mean you do have an azimuthal variance. You don't have uniformed properties in all directions. It might be a localized. So typically you use a fine net element code to try.

CHAIRMAN KRESS: Normally those properties vary the radio as compared to azimuthal. In all, azimuthal directions are doing about the same.

MR. RUBIN: Well, but I mean if --

CHAIRMAN KRESS: I'll just try to figure out what actually is a 3-D. Is it a 3-D finite element model?

MR. RUBIN: 3-D finite element is different than what it is your looking at here to get those localized effects like a local layer debonding that may ultimately cause the ultimate stress to be exceeded in a silicon carbide.

CHAIRMAN KRESS: Is the idea of these finite element to actually mechanistically predict failures of fuel. As they sit there in temperature for a long time for example?

MR. RUBIN: I mean when you do a PIE and you see a failure. And you see the failure mechanism was due to let's say a crack forming in the outer layer. And then that you will see it propagate then into the silicon carbide layer. And then you basically failed the particle. How do you model that localized phenomenon of that propagation of the crack from way or into the other.

Three D modeling is typically what is used for that. If there is a little imperfection in the silicon carbide layer to cause a stress riser, it may not be uniformed around 360, but it may be a small arch where you have a notch, shall I say, so to speak in the silicon carbide and finite element techniques are useful for that.

CHAIRMAN KRESS: Other than understanding what when on, I am trying to figure out how I use that information in a severe accident or a normal operating predictive mode.

MR. RUBIN: Well those kinds of issues, I guess in my mind would be if they were to be significantly wide spread by say the reactor reload. Where you had imperfections. This kind of a code with this capability is what you would need to kind of really understand how that defect played out in terms of the failure rates.

And so it would be useful then as a tool for understanding, agreeing that yes, that was the root cause for the failures that we saw. And we now understand the corrective actions to address that. This kind of a code may not be of importance for a source term, however.

Okay and in the case of a source term you might be able to get by with a nonfinite element, two dimensional type code. And then you could variation of properties to get some statistical results in terms of number of particles that failed due to variations.

CHAIRMAN KRESS: That was what I was envisioning.

MR. RUBIN: That kind of thing. But, if you do in fact find that you are having some defects or manufactured, the only way you can actually corroborate analytically that is what was the cause is through this kind of capability. But I am not proposing that we would need three dimensional finite element codes for source term calculations.

CHAIRMAN KRESS: I think I understand now.

MR. RUBIN: I am envisioning the time where we have an operating plant and low and behold we have hard and expected fuel failures. And we start getting information from the applicants, this is what we are seeing. And this what we think was the cause in manufacture and this what we are going to do.

Okay we are going to want to do an analysis of that to see if we would predict that kind of wide spread failure do to that cause. But that capability is not needed for a source term calculation.

MEMBER WALLIS: You have described so many things that I think you are going to be under great pressures or restrict your activities. And someone is going to say, what regulatory need does this serve. And do I need to know this now. Because your scope is getting so huge. I think you are going to be under those pressures. I think that is what the gentleman is getting at here.

Do you need to do all these things in order to serve the regulatory needs?

MR. RUBIN: Let me just say that with the computing power of modern day computing the finite element basic platform for doing failure analysis is not a costly or prohibitive approach. And many of the newest codes that are being developed for a particle performance analysis are finite element codes.

As opposed to two dimensional codes. The older codes that were developed in Germany were two dimensional codes. But to go to three dimensional codes is not a big price to pay, if you will. And we are just taking advantage of the opportunity and it gives us more flexibility in how we can apply that code.

MR. FLACK: Your point is well taken. The plan itself is to get out all the issues that we have on the table. And then we have to decide at some point what it is that we really need to do, now and what other licenses can do and that sort of thing.

MEMBER SIEBER: It sounds like one you would do later.

MR. FLACK: I am sorry?

MEMBER SIEBER: This one sounds like one you would do later.

MR. RUBIN: But again if you basically going to use the three dimensional code as your platform, it is just, it is wise to go with that platform. Because that is what they are using now. It is not a big cost in terms of running the code.

MEMBER SIEBER: By the time you will need it, they will be doing something else.

MR. RUBIN: But again, the 3-D code can be used in the two dimensional analysis to do what the old two dimensional codes have been doing.

Let me just say that probably a bigger issue is the statistical variation in properties, both dimensions and material properties of particles that can when -- goes through 15,000 particles, we win predict failure of a particle that a nominal properties and dimensions. You would start to see some small number particle failures given the variations that occurred in properties and dimensions.

And the last thing is chemical attack in the news codes are putting capability through essentially reduction in the thickness of the silicon carbide to account for chemical attack.

Again, the strategy here is the same as we were looking at on irradiation testing. There is a lot of work being done internationally. INEEL has what is called PARFUME code. It is a three dimensional code that they are continuing to develop. They brought it and developed some assessments of the differences and performance of German and U.S. fuel with that. And that may be a venue for obtaining our needs.

MIT also is working on a fuel performance code. Includes modeling of chemical affects. And we have had discussions with MIT on possibly supporting the development of their code and using their code.

The European Commission as part of our HTR-F program has an element that is to develop fuel performance modeling. And we have had discussions with them about sharing in the cost and in the use of that performance code.

So we are not going to start from scratch, we are going to try to piggy back on what others are doing.

Just real quickly, I think we talked about the applications for these kinds of code. To kind of audit the applicants integrity analysis for their fuel. To assess anomalies that may be detected in fuel performance through fission product measurements of coolant activity. And also can be used as an input into the source term analysis that the NRC would like to be able to do.

As far as fuel fabrication is concerned, we don't really plan to do any fuel fabrication development work. There are plan is to learn from what others are embarking on in terms of developing understanding of fuel fabrication.

Let me just say again, that the recent studies show a large difference in fuel performance between German and U.S. fuel, a couple orders of magnitude. Analysis of that data shows that the differences in manufacture was a big driver for those differences and so the importance of the manufacturing process on fuel performance ultimately was recognized in Germany.

In fact in their manufacturing specifications, they included a fuel process specification along with the product specifications for the finished particles which were checked by QA. The difficulty is, even today, there is not a clear understanding of how a process variation effects a change in properties and how that then plays out.

So a lot of development work that is being done worldwide, it is a very hot area. Is to understand how you make good fuel that achieves the properties that you want. And are made consistent in terms of every particle coming out the same. So our interest there is to understand the important factors of the process of fuel fabrication that gave rise to good performance.

What are the important measurable product factors that need to be controlled for a good fuel performance and what are the quality control schemes that are used to maintain both process and product within the requirements.

Again, how we are going to do this is not going to do anything ourselves, but to try through cooperative agreements with the kind of the same organizations to obtain these kind of insights and information. The EC as part of the HTR-F has also a fuel fabrication technology development component. And they are going to be trying to re-establish that or establish for the first time I should say that understanding of how fabrication causes performance.

And we want the cooperative agreement to be able to share in that insight. DOE and Oakridge are also planning to develop fabrication capability in this country. And so there might be the opportunity to obtain information from that activity.

We have information exchange from INET. And they have within the last couple of years kind of walked in the foot steps of the German fuel fabrication and now become a source or a destination for others who want to learn how to make good fuel. And so we might try to obtain data from them. And Jerry as well now has fuel operating in the HTTR.

And then the pre-application reviews themselves have provided a very good source of information for what are the key factors for fuel fabrication. So we are not really talking about doing anything ourselves, but to basically learn from the work of others.

MEMBER FORD: Stuart, do we know anything at all about the quality of work done in China? When you say you are going to be doing collaborative work and nuclear data coming from INET. For instance, do we know anything at all about the quality of the data compared to that in Europe and Japan?

MR. RUBIN: I have not personally seen any of the manufacturing QC results for the fuel they have made. I have only heard antidotal stories and statements that they achieved the level after many years that they say exceeded the German quality.

In terms of particle failure rates from manufacturer. In terms of performance in reactor, we have asked for but not yet received the results of their ongoing fuel qualification testing. So that is the proof in the pudding. So I haven't gotten that yet.

We would hope to, in discussions with them, to learn about each of those aspects, the fabrication, the quality of the product, if you will. Thicknesses, densities, and things that you can measure. As well as learn how they made it in terms of the process through discussions and technical exchange.

And then follow up and to get information on their radiation experiments. But I mean that is our picture of what we haven't implemented that yet. I would say that the European Commission had a delegation that went to China about two months ago. And the topic was fuel fabrication. And the European Commission folks who were working on this element in the HTR-F wanted to pick the brains, if you will, of the Chinese fabrication folks who develop their process to kind of learn from them. And then try to go back and try to add to it in their own program. And we would like to get involved with that.

With that, I think I am pretty much -- just in terms of how we might apply this knowledge for fabrication. We think there is a potential policy decision for the Commission to make on how the Commission would regulate fuel quality and ultimately ensuring performance in a reactor. One approach is to actually put a regulatory imprint or footprint on the fuel fabrication through technical specifications.

In other words, to monitor reactor -- excuse me, coolant activity. And another is to do testing of fuel after it comes out of a reactor.

The first one is kind of an obvious one. But it is one that I think that we have not, as an agency, gotten into on light water reactors is to actually put tech specs on manufacturing processes.

But that is where the tire hits the road in terms of assuring or resulting in good performance. So we need to make that decision on whether or not we are going to do it or not. Knowing that is where quality of performance are built in. Well let's do that.

So there is a policy issuer there, we think there is an opportunity to provide input from this into fabrication process. A risk informed, I should say performance based fuel fabrication procedures, we think there will be inspectors that will go through these plans and do some inspections. And this will provide input into what they will be looking at. Perhaps training of inspectors as well.

I am just going to jump to the last slide on summary and conclusions. Just kind of recap where we think we end up with all of this. Through this plan, we think we'll develop the infrastructure, we will effectively develop the infrastructure of analytical tools and data and know how to let the staff effectively evaluate HTG-R safety performance and also commission policy decisions.

Notably on fuel performance and quality specifications and the need for that. It is going to allow us to explore the limits and understand the limits on safety performance and safety margins of

TRISO particle fuels.

It will provide the staff with the key knowledge that is needed to understand how fuel fabrication plays into fuel performance. And therefore what we need to watch and what we need to have a regulatory oversight in the fuel fabrication areas.

It does capitalize, we think, on existing national and international activities and knowledge and experience that has been developed before in design and manufacture as well as analytical methods in testing of fuels. We think that the plan focuses on the technical issues and the research issues that have been identified at the beginning of our planning activities.

We think that the cooperative research approach that is going to be a good leverage tool to get the information that less cost and the shorter time. And we think that it is also going to put us in a position to effectively reveal a COL -- come in on either PBMR or GT-MHR.

MEMBER FORD: Do you have any idea at all of how much this all costs and are orders of magnitude away from what you might reasonably expect?

MR. FLACK: Well, you took a shot at that already.

MR. RUBIN: Well, you're in charge of the dollars. The biggest component is the irradiation testing. It is very expensive to do irradiation testing. You are in to the millions of dollars per year to do irradiation testing.

That is where we think sharing costs is going to be the only viable way to implement what we have in mind. Either through partnership with the HTR-F, the European Commission, the DOE. And that will half for lessen the cost. But it is still in the millions of dollars. The cost of developing codes is not nearly as large.

Manufacturing is virtually little cost there. Because we are not going to be doing that development, fabrication technology. We just want to have access to it through cooperative agreements.

And then the fuel, accident simulation testing, that will provide perhaps a lesser order of magnitude. Let's say in the multiple hundreds of thousands of dollars to do accident simulation testing on irradiated fuel.

But the biggest cost factor is the irradiation testing. But that is really where the biggest benefits are in terms of understanding what the limits are of this fuel.

MEMBER FORD: But even with a reasonable surety of getting some collaborative work done, you are still going to have to have a big prioritization pruning exercise. Is that right?

MR. RUBIN: I think that is true.

MEMBER FORD: And therefore prioritization approaches and methodologies are going to become paramount.

MR. RUBIN: There is a limit though. If you take a look at the test reactors that are out there. Whether you put one pebble into the reactor, you put 14 in the reactor, you pay the same. You pay for a particular slot.

It almost behooves you, if you agree that you want to do irradiation testing, is to take full advantage of all of the positions that you can put fuel in there. Because the fuel you will be getting is virtually cost free to the NRC. The money is not an issue there.

CHAIRMAN KRESS: Clearly understanding the fuel for gas cooled reactors is paramount to understanding the health and safety effects. So I would put this one high on my list of things needed to be done.

MR. FLACK: As well as how much we can capitalize on using leverage.

CHAIRMAN KRESS: And that is a timing issue also. So, you if they are going ahead with it, you need to get in there.

MR. RUBIN: Yes, that is personally a concern that if we don't sign those agreements now and have something to share with them, then we loose that collaborative possibility.

MEMBER ROSEN: At the risk of being a broken record, could you go back to the slide that has purpose of the fuel research. It was like fourth or fifth slide. If you might be able to drag that one out. Well I'll tell you what it says.

MR. RUBIN: Okay.

MEMBER ROSEN: It has five bullets, the fourth one being develop independent fuels to predict fuel fission product release and TRISO particle failure for licensing basis conditions. And I think that last phrase, for licensing basis conditions is puzzling in the light of what we said and shouldn't be in there.

You need to develop independent tools to predict fuel efficient product release and TRISO particle failure, period.

MR. FLACK: It comes down to what, the frontline office is NRR. And what they will require to license a plan and what they will put down as this is what is necessary for the applicant to achieve is one thing. And we would develop the tools that would support them in independently confirming that. Back to the point of where do we draw the line on this. Is that the issue? Like what we mean by design basis?

MEMBER ROSEN: Right, it's that issue and your apparent confusion at least on this slide that I am referring to, the fourth bullet. That you are going to only understand fuel behavior up to the licensing basis. Now, I think you need, you said you want to really understand it well beyond that. So, I think you are contradicting yourself here.

MR. FLACK: It may be that --

CHAIRMAN KRESS: It may just be a wording problem.

MR. FLACK: Yes, I think it is. I think the whole point of developing infrastructure is really to understand the fuel performance.

MEMBER ROSEN: I am trying to urge you not to say okay, some arbitrary 1600 degrees we are going to stop understanding.

CHAIRMAN KRESS: They clearly aren't going to do that.

MEMBER SIEBER: But they said they wouldn't do that.

MR. RUBIN: Yeah, I think what I had there was the thought that irradiation conditions maybe up to 1250, 80,000 megawatt days per ton, fluence of 2.5 times ten to the 25th neutrons per square centimeter. But we want a code that will take it to a higher temperature, higher fluence, higher burn up than that. Well beyond that licensing basis in terms of the operating environment.

MEMBER SIEBER: Well if I recall what you said, you said you wanted to take it to failure.

MEMBER ROSEN: Right. And that is the right answer. But not what you say on the slide.

CHAIRMAN KRESS: If there are no more questions.

MEMBER WALLIS: Well, I don't know. I am still grasping. This seems to me that this is a huge program. And it looks to me that you are searching for a level of understanding which is bigger than the applicants are going to come in with. That seems to be the philosophy.

I am not sure that should be the right philosophy. You can regulate on other bases. When you actually talk about the regulatory needs, you may find that you don't need to know all this stuff. It would be very nice to know, but you may not have to do it. I think that is the only way you can prioritize this. What you really need to know in order to regulate. And it may not have to be this tremendous knowledge base, but it would be nice to have.

MEMBER FORD: Also prioritizing would be in terms of risk. You just do work at the highest risk. Do you have enough knowledge base to come to even that criteria.

MR. RUBIN: Well again, the performance of the fuel is driven by manufacturing. And we really have to understand what are the factors there, and it is driven by the environmental conditions and the accident conditions. And they all come into play.

MEMBER WALLIS: You don't have to understand it, you just have to say to the applicant, show me.

MR. RUBIN: Well, I mean, the basic assumption in this is that the applicants are not going to be pushing their fuel to failure. They have been highly resistant of pushing it well beyond the licensing basis. They'll try to get their toes wet a hundred degrees above the maximum operating temperature. Maybe a little beyond. But they don't want to go out there and see where the failure points are.

MEMBER SIEBER: The problem is, is that it is very difficult unless you have that additional data to know what the severe accident is all about.

MR. FLACK: That's right.

MEMBER SIEBER: And then how do you do the risk. How do you make determinations like should you have containment or not.

MEMBER ROSEN: I think I respectfully disagree with my colleague. In the case of a new reactor design for this country, we should go, I mean the vendor should go as far as I would go. But if they don't, then the staff should certainly go to a level of understanding that is very deep.

MEMBER WALLIS: It's very expensive.

MEMBER ROSEN: It may very well be.

MEMBER WALLIS: You can't do it.

MEMBER ROSEN: You have to put it in context of what we are thinking about doing. Licensing, perhaps a lot of these reactors for this country. If someone ever stepped up to the bar and wanted to do that.

I would prefer not to be in the circumstance that we have found ourselves in in the light water framework where we never had quite enough knowledge. We always liked to have more. Here is a chance to get out ahead of it. Let's get out ahead of it.

MEMBER WALLIS: Do you know what it costs to do the light water.

MEMBER ROSEN: I don't know what it costs to do the light water. I imagine it was a lot. I think this would be a lot too, but in context, it ought to be done.

MEMBER BONACA: For these agreements that you are trying arrange or you have already with other programs. You probably go through some kind of, I mean, are you talking together to see that there is no duplication of testing.

MR. RUBIN: Yes.

MEMBER BONACA: Are you recording these activities?

MR. RUBIN: We have had discussions with DOE. In fact, they are coming in on Friday to give us the latest assessment of what they want to get done in terms of irradiation testing and fabrication technology development.

We have a co-operative agreement written. The signing of that agreement, I think will be contingent upon whether DOE feels they want to actually do their irradiation testing in the foreseeable future or if they want to kind of defer that.

We also have had discussion this spring with the HTR-F project leaders about what they are doing. What we would like to do. And we see a kind of synergism of between the two programs. Again, the main thing they are looking at is high burn up. Which is one of the parameters on pushing the fuel to beyond the design licensing basis.

So we would like to get that data. Some of our parameters in terms of higher temperature, higher fluence, they are not covering that. So, we could pool all this, I think our costs that we would have to kick in for could be reduced. There is overlap.

In terms of mapping out the space beyond the licensing and design basis.

MEMBER BONACA: What is the manufacturing steps? You have mentioned several times the differences in performance resulting from the manufacturing steps. Is this open information that you have available? Or much of it is proprietary and you can't get your hands on it.

MR. RUBIN: The years past, there was free sharing of this kind of information, but now organizations that are doing work and spending money see the commercial applications and the profits from all this. And so, that is the one area, irradiation testing, accident condition testing, modeling, fabrication technology. And that last one is one very few people want to share.

CHAIRMAN KRESS: In view of the time, I think I am going to call a halt to these questions and ask people to come back at 1:45 p.m. And we'll start again.

(Whereupon, the foregoing matter went off the record at 12:39 p.m. and went back on the record at 1:45 p.m.)

CHAIRMAN KRESS: Let's call the meeting back to order and we'll start right in with the materials analysis I guess?

MR. FLACK: Right, that's Joe Muscara from the Division of Engineering Technology, Office of Research.

MR. MUSCARA: Thank you. As you just mentioned, I will be discussing the materials analysis portion of the research plan.

This is essentially the outline for the discussion on the materials analysis. We are looking at background and discuss some of the metals issues and research to address these issues.

Will do the same thing for graphite. Have a little bit of a discussion on international cooperation and then finally a brief summary.

As a way of background, the behavior of metallic and graphite components is a key research area to make sure they can maintain primary system integrity. The primary system integrity is essentially a major part of defense-in-depth. And we must ensure that we maintain the integrity so that the radioactivity can be contained.

In addition, the information from the materials research is needed for conducting a PRA, especially for the advanced gas cool reactors, where there is no experience with the behavior of materials and components. We would have to essentially guess at the probability of failure for these components.

And therefore we have relatively large uncertainties in the numbers that are selected. In order to reduce those uncertainties and to get better information probability of failure, we can study different degradation mechanisms and quantify these. And then be able to use this information, probalistic fracture mechanics, to calculate failure probabilities for different components under the different conditions.

Well there are a number of issues that we have uncovered with respect to metallic components. We'll list these and then discuss each one in turn.

There are issues related to the availability and applicability of national codes and standards. This is both for metals and graphite. But there is a lack of appropriate data bases for calculating fatigue, creep and creep-fatigue lifetimes.

There are issues related to the effects of impurities. In particular, things like oxygen and chloride on degradation of components in this environment.

Issues related to the aging behavior of alloys. There is a time-temperature dependence of solid state transformation that occur in these alloys. And the concurrent -- that happens.

CHAIRMAN KRESS: Are we talking about metals and metallic components that are different than we currently have in the LWRs?

MR. MUSCARA: Yes, for the high temperature gas cooled reactors, some of the metals are different because of the higher temperature requirements. Again, depending on the design. Exelon, for example, with the pebble bed -- for the pressure vessel material, they were maintaining the same material that we are using in light water reactors.

But for example, the duct pipe which transfers the hot fluid up to the power generation units, then that is a higher temperature material not used in light water reactors. And of course, turbine blade materials would be different.

So some materials are similar to light water reactors --

CHAIRMAN KRESS: So most of this is dated for the gas cooled reactors?

MR. MUSCARA: Yes, this concept is mostly on gas cooled reactors. There are a couple of issues that are also present for advanced light water reactors and I will mention those as I go along.

But, yes, most of this is based on the gas cooled reactors.

MEMBER SIEBER: It seems to me that the, in the pebble bed the piping and the turbine casings and all that are to be designed to the same specifications as the reactor vessel itself?

MR. MUSCARA: Well, yeah that is actually one of the key issues that I'll discuss.

MEMBER SIEBER: Well that way they seem to feel that they can get rid of any kind of pipe rupture. And I would scratch my head about that.

MR. MUSCARA: Yeah, I think that is both a technical and possibly a policy issue. So we need to address that.

MEMBER SIEBER: I think so to.

MR. MUSCARA: The question comes up with respect to sensitization. And of course we are going to be talking about what we call low temperature sensitization. The sensitization during operation, not necessarily during the welding of the components.

There is a potential for the degradation by carburization, decarburization and oxidation. These are particularly interesting issues because the fix to one problem may in fact generate the other problem. So there is a very close balance in managing the composition of the effluent.

CHAIRMAN KRESS: The sensitization is sensitizing the stress corrosion?

MR. MUSCARA: Precisely. It is the same

kind of sensitization we have seen for light water reactors where the plate, the chromium at the grain boundaries and then leave the materials susceptible to subsequent tracking.

Treatment of the connecting pipe as a vessel I think is an issue. And there are some inspection issues with both the High Temperature Gas Reactor and the Advanced Light Water Reactor.

CHAIRMAN KRESS: What is the implications treating that connecting pipe as a vessel? Is that excluded from arch break LOCA?

MR. MUSCARA: Correct, yes.

MEMBER FORD: Inspection of the high temperature and ALWR, that is just to serve as a point of reference for the research. And why would you expect the advanced light water reactors to show low temperature reactors? Why are we inspecting those? In that last bullet?

MR. MUSCARA: Again, of course we inspect current reactors as defense-in-depth concept. Some of the differences with the high temperature gas cooler reactors are the long times between inspections. For example, pebble bed continuous refueling. The plants have been down every six years for a short period of time for maintenance.