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UNITED STATES NUCLEAR REGULATORY COMMISSION'S

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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FUTURE PLANT DESIGNS SUBCOMMITTEE

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TUESDAY

SEPTEMBER 17, 2019

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2D10, 11545 Rockville Pike, at 8:30 a.m., Dennis Bley, Chair, presiding.

COMMITTEE MEMBERS:

DENNIS BLEY, Chair

RONALD G. BALLINGER, Member

MICHAEL L. CORRADINI, Member

CHARLES H. BROWN, JR. Member

VESNA B. DIMITRIJEVIC, Member

WALTER L. KIRCHNER, Member

DAVID PETTI, Member*

HAROLD B. RAY, Member

JOY L. REMPE, Member

PETER RICCARDELLA, Member*

MATTHEW W. SUNSERI, Member*

DESIGNATED FEDERAL OFFICIAL:

WEIDONG WANG

*Present via telephone

P R O C E E D I N G S

8:30 a.m.

CHAIR BLEY: Good morning. The meeting will now come to order. This is a meeting of the Advisory Committee on Reactor Safeguards Subcommittee on Future Plant Designs. I'm Dennis Bley, Chairman of the Future Plan Designs Subcommittee.

ACRS members in attendance are Ron Ballinger, Charlie Brown, Walt Kirchner, Harold Ray, Joy Rempe, and Mike Corradini. And on the phone we have three members, Dave Petti, Pete Riccardella, and Matt Sunseri. Weidong Wang of the ACRS Staff is the designated federal official for this meeting.

The purpose of today's meeting is to review the draft report NRC Non-Light Water Reactor Vision and Strategy, Volume 2, Fuel Performance Analysis for Non-LWRs. And a couple of months ago we had a precursor meeting where we discussed Volumes 1 and 3.

The Subcommittee will gather information, analyze relevant issues and facts, and formulate for post positions and actions, as appropriate.

This matter, along with those other two volumes in this report series, is scheduled to be addressed at the October full Committee meeting. We expect to write a letter at that time.

The ACRS was established by statute and is governed by the Federal Advisory Committee Act, FACA. The Committee can only speak through its published letter reports.

We hold meetings to gather information and perform preparatory work that will support our deliberations at a full Committee meeting.

The rules for participation in all ACRS meetings, including today's, were announced in the Federal Register on June 13, 2019.

The ACRS section of the US NRC public website provides our charter, bylaws, agenda, letter reports, and full transcripts of our meetings, including the slides presented. The meeting notice and agenda for this meeting were posted there.

As stated in the Federal Register notice and in the public meeting notice posted to the website, members of the public who desire to provide written or oral input to the Subcommittee may do so, and should contact the designated federal official five days prior to the meeting.

Today's meeting is open to public attendance and we've received no written statements or requests to make an oral statement.

We also set aside ten minutes in the agenda for the spontaneous comments from members of the public attending or listening to our meetings.

Today's meeting is being held with a telephone bridge line, allowing for participation of the public over the phone.

A transcript of today's meeting is being kept. Therefore, we request that meeting participants on the bridge line identify themselves when they speak, and to speak with sufficient clarity and volume so they can be readily heard.

Participants in the meeting should use the microphones located throughout the meeting room when addressing the Subcommittee. And we have one more member I didn't mention earlier. Vesna Dimitrijevic is with us.

At this time I ask that all attendees in the room please silence all cellphones and other devices that make noises, to minimize disruptions.

And I remind speakers at the front table to turn on the microphone. I've been chastened to tell all of the people in this room to be very careful turning the microphones on and off because we will have problems if we don't. So, be careful.

And for those of you who are new to this, the button to turn on the green light and turn it off is nearest you, where it says, push, on the microphone.

We will now proceed with the meeting. I call on Kim Webber, Deputy Director with the Division of Systems Analysis, Office of Research, to make introductory remarks. Sorry, I can't talk. Kim.

MS. WEBBER: Yes, good morning to all of you. And yeah, my name's Kim Webber. I'm the Deputy Director of the Division of Systems Analysis in our Office of Research.

Today we're here to present to you our co-development plans and strategies for Non-Light Water Reactor Fuel Performance Analysis.

In addition, we're here to also answer questions that you had for the May 1st and September 4th Subcommittee meetings.

As part of the Office of Research biannual ACRS review meeting held on September 4th, we presented an overview of our division's activities.

And one the key messages that I was trying to convey at that time, is that we're really in a position where we have to be ready to enable the regulatory offices to license advanced reactors.

And so, we believe that the introduction and the Volume 1 through 3 go a long way to helping the staff get ready to help them develop their expertise to better understand the phenomenon that are likely to be experienced in advanced reactor designs, and so we think that these reports go a long way to help achieving those goals. Let's see if I can do the next slide.

Back in May 1st, we actually presented to you information about three volumes, or three documents, I should say. One was the introduction, which is shown at the top of your slide on the left-hand side. And the introduction really laid out the approach that we're taking is, some of the considerations that we had to make in order to produce the rest of the volumes.

And then Volume 1 is on the computer codes for Non-Light Water reactor design basis analysis, and Volume 3 is on severe accident, source term, and accident progression.

At that time, Volume 2 and Volume 4 -- Volume 2 is on fuel performance -- that was a work-in-progress -- in addition to Volume 4, which, although it says radiation protection on this slide, is really licensing and citing dose assessment codes. And so, there's a fourth volume.

So, today we're here to talk about Volume 2. The fourth volume -- actually, at the September 4th meeting, I think you all requested to see Volume 4, which is the licensing and citing dose assessment codes report. And so, we're in progress, in terms of setting up a meeting on that report.

MEMBER CORRADINI: And so, can I -- I'm sorry.

MS. WEBBER: That' okay. You were first.

MEMBER CORRADINI: Since all of these advanced reactors in theory will be using higher enrichment, what about transport? What about front and back.

MS. WEBBER: Yeah. So, they're actually -- and I'm channeling Richard, who always reminds me -- there's going to be a Volume 5 that covers front-and back-end code development activities.

We have not started on that yet, but there will be one. And so, what we're looking for, as Dennis mentioned, is after the fully Committee meeting on October 3rd, we're looking for you to review the introduction, Volume 1, Volume 2 and Volume 3, and get a letter on that.

And then we'll come back with Volume 4 maybe in the spring. And then we will, at some later date, come back with Volume 5, if you're interested in that.

MEMBER CORRADINI: From the standpoint -- maybe this is the wrong time to ask it -- but from the standpoint of readiness, wouldn't the back-end and the front-end --

MS. WEBBER: Yes.

MEMBER CORRADINI: -- happen before the reactors?

MS. WEBBER: Yes. Your point is very well taken and it's something that we do think about and we're going to start working on it. I think what we wanted to do is try to get these volumes together and -- actually, that fifth volume involves the same people.

And so, we're trying to balance the workload that we have too, but your point is well-taken.

MEMBER REMPE: Let's talk about Volume 4, which we won't have before the October meeting. You said it's in progress.

MS. WEBBER: It is.

MEMBER REMPE: Can you give us a clue of what you're thinking of. I assume MACCS is involved?

MS. WEBBER: No, no. So, MACCS is covered in Volume 3. So --

MEMBER REMPE: Okay, that's true. Yeah.

MS. WEBBER: Right. So --

MEMBER REMPE: But for citing -- what are you thinking of?

MS. WEBBER: So, it codes like RASCAL, like RADTRAD. I can't think of the other codes. I'm looking to --

MEMBER REMPE: So, the reason that I'm asking this question then, is that you were at the research meeting where we talked about, think about the future and combine -- maybe have a simplified MACCS, instead of RADTRAN and RASCAL, to try and reduce some costs in the long term. Too far out for you to think about that?

MS. WEBBER: Well, I think that's something that we have talked about and we will need to have more discussions on. So, I think we met with you on September 4th and that comment was raised.

I think we still need some work internally to figure that one out, quite frankly.

MEMBER REMPE: Okay.

MS. WEBBER: And so, we'll take the comment under consideration. And when we come back to brief you on Volume 4, that will be something that we can talking about perhaps then.

MEMBER REMPE: Okay, thank you.

CHAIR BLEY: Just a reminder to everyone here and that is listening, the ACRS only speaks through its letters, so comments you've heard discussed from the research meeting and our previous meetings, really aren't suggestions of the Committee. They're comments by individual members.

MS. WEBBER: Okay. Okay, and then I give most of my -- oops, I'm pressing the wrong button. I want to give most of my time to the other presenters. So -- actually, just to follow up our Subcommittee Chairman's comment that need to combine the codes with RASCAL and MACCS was actually in our biennial letter. So, it was a little higher than our off-the-wall comments.

Okay, so I just want to introduce James Corson and Lucas Kyriazidis. They're going to be the presenters for Volume 2 and they'll discuss important scenarios and phenomenology for Non-Light Water Reactor fuels, code selection considerations, and information gaps for the major types of fuels, including TRISO metallic fuels.

And then after that, Steve Bajorek is going to respond to some of the questions that you raised at the May 1st meeting, and then also on the September 4th meeting.

And so with that, I'd like to turn the presentation over to James, unless you have any other questions. Okay, and good. We know Ron's going to take care of this.

DR. CORSON: All right. Good morning, everyone, I'm James. With Lucas, I going to be talking about our strategy for fuel performance for Non-Light Water Reactors.

And before I begin, we also have Ken Geelhood, Dr. Ken Geelhood, here from PNNL. Ken is the lead developer for the FRAPCON, FRAPTRAN and FAST codes. And he also has a lot of experience doing technical reviews for licensing topical reports for NRR. So, he'll be here to answer any more detailed questions you might have. So, next slide.

Just a quick motivation of why we're here. Kim already touched on all of this. There's a whole lot of new reactor designs out there. We need to be ready to license them. And in fact, Congress has directed us to be ready to license them.

So, part of that in the Office of Research is to work on the tools that can support licensing, that can do confirmatory analysis. So, we're specifically focused on fuel performance today. Next slide.

You can see here, there's a lot of different fuel designs out there, paired with different coolants and geometries. So, there's quite a number of different designs that have been proposed.

And this means that we need to be judicious and narrow down what we're really focusing on here, at least in the near term, based on industry priorities. So, next slide.

This just is the same thing, but not it shows that we're really prioritizing the TRISO fuel and metallic fuel, because we expect those designs to come in first.

So, if you've read the report, we do have plans for the other fuel types. But we are not really addressing them. They're not as high priority right now. Of course, as we learn more from our regulatory offices, that could change. But right now, this is our plan.

MEMBER CORRADINI: The plan looks reasonable. Explain what the lines through the other one means.

DR. CORSON: I was just getting there.

MEMBER CORRADINI: Oh, okay.

DR. CORSON: So yeah, the last thing, we had crossed out fuel salts simply because as far as fuel performance goes, we are not covering that, because we are covering fuel that's in a solid form. I mean, that's really what our fuel performance codes are designed to do.

So, fuel salts are being considered, but they're handled in Volumes 1 and Volume 3, which you've already heard about. So, those codes are going to handle the important phenomena for fuel salts. So, that's why it's crossed out here.

It's not that NRC is not considering them, it's that we, for fuel performance, are not considering them.

MEMBER PETTI: So, I have a question. How are you going to handle the fission product release in the fuel salts in Volume --

MEMBER REMPE: This is Dave Petti.

MEMBER PETTI: Yeah, sorry. Dave Petti.

DR. CORSON: So, it's covered in Volume 3. And I think part of it is going to be MELCOR. I know scale also, or -- sorry. Oak Ridge also has a Thermochimica system which will be involved. Those are both described in more detail in Volume 3.

MEMBER PETTI: Okay, thanks.

DR. CORSON: Next slide.

CHAIR BLEY: Just a matter of form in your report. They aren't crossed off in the report.

DR. CORSON: No.

CHAIR BLEY: Is there -- I don't remember a discussion. Was there a discussion that points us to Volume 3?

DR. CORSON: Yes. So, if you go to like Section 3.8 or so.

(Background interruption.)

DR. CORSON: So, I think if go to like Section 3.8, there is a brief section on molten salts that specifically says it's covered in Volumes 1 and 3. And I believe it's also covered in the Executive Summary, but I'm not positive about that.

So yeah, you do have to read through a bit I think, but it does say in Section 3.8 that this is covered elsewhere.

CHAIR BLEY: Okay, thanks.

DR. CORSON: So, just a quick overview of what we're going to be talking about for the rest of our presentation. We will begin with talking about how we do fuel performance confirmatory analysis.

So yeah, we'll talk about what we do for Light Water Reactors, and how that might apply to

Non-Light Water Reactors going forward. After that, we'll discuss the phenomenology that we need to be able to model in our codes.

We'll talk about what criteria we use to select which code we're going to use for Non-Light Water Reactor confirmatory analysis. We'll talk about its development status. Lucas will cover that. And then I'll wrap things up by briefly discussing the interface between fuel performance described in this volume, and the other volumes that cover design-basis and beyond-design-basis events.

So, for LWRs, again, just before I get into this, I will often throughout this presentation talk about Light Water Reactors first, because there are a lot of similarities in the way we intend to do things, and even in some of the phenomenology.

So, we understand there's different properties, different coolants, and so on. But a lot of the basic phenomena are similar. So, that's why I'll constantly be talking about Light Water Reactors, even though the subject of this presentation is Non-Light Water Reactors.

So, for LWRs, when NRC is performing a review we use NUREG-0800, the standard review plan for Light Water Reactors.

Section 4.2 specifically deals with the fuel design, and in there it calls out a number of the general design criteria.

And so these general design criteria guarantee that the fuel system is not damaged during normal operations and anticipated operational occurrences.

The fuel system is never damaged so severely that you can't insert control rods when you need to, to shut down the reactor, and that you don't underestimate the number of fuel failures, and that you always maintain coolability during accidents.

So, those are the criteria we use when we're reviewing Light Water Reactor designs. Next slide.

So, when staff are reviewing licensing topical reports, we try to take more of a graded approach, where we focus more on issues that are really important.

So, things that are more complex or have higher safety significance or uncertainties, that's where we really want to focus our attention.

And one of the ways that we do that is by performing confirmatory analysis. One portion of confirmatory analysis is actually doing code calculations -- independent code calculations. But there really are a number of other tools that NRR and NRO use to do these reviews, from simple back-of-the-envelope-type calculations to experimental results, and so on.

So, this is just one piece, but it's still very important a lot of times in our reviews.

MEMBER CORRADINI: Is the intent, from a validation standpoint, to take what you have from experiments to make sure that there's always a benchmark checking? I assume that's the case.

DR. CORSON: Yes. In general, we try to rely very heavily on experimental results, both when we're doing our reviews, and just for our code development as well. I mean, you know, it would be nice to be able to predict from first principles all the phenomena, and I think we're moving in that direction.

But right now, we still have to rely very heavily on experiments for all that we do.

MEMBER CORRADINI: Okay, thank you.

DR. CORSON: So, next slide. How does all this apply to Non-Light Water Reactors?

So, NRO has put together Reg Guide 1.232 that proposes advanced reactor design criteria that adapt the general design criteria to Non-Light Water Reactors. And there's a number of changes as well, but it follows the same general structure.

So, advanced reactor design criteria 10, 26 and 35 are analogous to the fuel general design criteria.

And so, this last bullet, advanced reactors may use one of two concepts to guarantee that their fuel's not going to fail during normal operations and AOOs.

MEMBER CORRADINI: Can I stop you? Because -- so why -- now I should remember this but I don't. Why is 26 replacing 27? My impression was 26 is normal operation, 27 is beyond normal operation. So, help me --

DR. CORSON: You're exactly right. So, in the general design criteria, you're right. Twenty-six deals with normal operation AOOs, 27 deals with accidents. And they're all for being able to shut the reactor down.

Twenty-six in the ARDC combines the two together. So, there's just 26 covers now, both normal operations and accidents. It's all one thing. But the language is basically the same between the two.

MEMBER CORRADINI: I forgot.

DR. CORSON: Yeah, it's -- I know. We got that same question and I probably should have clarified that point.

MEMBER KIRCHNER: And it's more comprehensive than the 26, 27 for the LWRs.

DR. CORSON: It's not identical.

MEMBER CORRADINI: It's not identical.

DR. CORSON: But the intent is similar. Very similar.

MEMBER CORRADINI: Well, I had a feeling he was going to say this. So, that's why I wanted to be clear, because I thought it was similar, as you said, but he's saying that it's -- I'll use the term more restrictive.

MEMBER KIRCHNER: More complete.

DR. CORSON: More complete. So, from your perspective, the staff help me. So, he'll check us.

MEMBER CORRADINI: I think NRO could probably -- Boyce could probably handle this a lot better than I can. Delegating responsibility.

MR. TRAVIS: Yeah, okay. So, this is Boyce Travis from NRO. So, when the ARDC were developed, this was happening around the same time as the paper that was published on GDC 26 for NuScale.

PARTICIPANT: Twenty-seven.

MR. TRAVIS: Twenty-seven. Excuse me, 27. So, the thinking behind that SECY paper was incorporated into the ARDC 26. And 26 is meant to cover the full spectrum of basically reactivity control for the full spectrum of fuel designs, operation, and conditions for the plant.

And the goal is then -- and this is enumerated on in the Reg Guide 1.232 -- is to avoid the sort of considerations that resulted in different safety significance or safety-related components being applied for 26 versus 27.

Twenty-six in the ARDC requires that you have two independent means of reactivity control, and it requires that -- and it's four different requirements that cover --

MEMBER CORRADINI: This is ARDC.

MR. TRAVIS: ARDC 26 -- has four the full spectrum, from normal operations, AOOs, and postulated accidents.

MEMBER CORRADINI: That kind of help --

MEMBER KIRCHNER: It addresses the problem that we saw with the exemption request for GDC 27. It precludes essentially a return to criticality.

MR. TRAVIS: Yeah, exactly. That's exactly right. It's specifically called out in the

Rationale and Reg Guide 1.232, that an extended return to criticality is precluded by ARDC 26.

MEMBER CORRADINI: Okay. And under current, it's unclear.

MR. TRAVIS: That is correct.

MEMBER BROWN: What do you mean by extended?

MR. TRAVIS: So, I --

MEMBER BROWN: Is that three months? Is it one week? Is it one day?

MR. TRAVIS: No, no, no. So, I guess I'm referring to something like a steam generator, like an over pooling event that results in a short power spike following the trip.

MEMBER BROWN: We're talking about minutes or so?

MR. TRAVIS: Yeah, yeah. Something on the order of seconds to minutes after the event. And then -- you have to end in a shutdown state basically, using ARDC 26.

MEMBER BROWN: But within minutes, as opposed to weeks.

MR. TRAVIS: Right. Yeah, during the course of the transient would be on the order of minutes.

MEMBER BROWN: Okay. Thank you.

MR. TRAVIS: Mm-hmm.

CHAIR BLEY: James, I'm still stuck. Two slides back when you were talking with Mike, and I certainly think anchoring to experiments -- which weren't on the slide -- you need to do. But experiments occur under very particular conditions. And the real world happens under a variety, so how do you use the experiments? Two need-to experiments can be really dangerous.

How do you use the experiments and consider the uncertainty in the way you're modeling things, and how does that get factored into the codes?

DR. CORSON: I mean, that's a really good question. So, so you say, what you do in a small scale, nice controlled experiment, may not exactly represent reality.

CHAIR BLEY: Never.

DR. CORSON: So, we do like to use a lot of sensitivity studies, where we -- so we do some uncertainty studies as well based on what we think the uncertain parameter distributions are, and we do our uncertainty studies there.

But we also do some sensitivity studies to look at maybe how close are you really to some of these limits? Or how much -- if things are just a little bit different from what we expect, or maybe a bit different from what we expect, what would happen?

So, we certainly have to be careful for that. But we really have to rely a lot on our own engineering judgment as well, and our own experience.

So, fortunately for -- I will say for some of these advanced designs, there have been operating reactors, or at least test reactors, in the past. So, we do have some indication at least of how things behave. So, we're not completely flying in the dark. But it's certainly a very difficult problem that we have to deal with.

MEMBER CORRADINI: Are you politely saying that you look for cliffs, and as long as you're far away from a cliff, a strange or very non-linear behavior, you feel comfortable?

DR. CORSON: Yes.

MEMBER CORRADINI: Okay.

MEMBER REMPE: And along those lines, I know like when we had the Volume 1 and 3 discussion, I was curious about the term design basis, because back in the old days when we started out, people didn't have a lot of experimental data, so they made conservative assumptions, or they did something like

SAFDLs. They put limits on it. But I think your proposal is to look at best-estimate based on experimental -- right? -- data and put uncertainties with your fuel modeling, is your approach here?

You're not going to try -- like in the old days, people put like factor 20 percent on the decay heat curve, and they had like design basis codes. And then we'd have best-estimate for other things. And you're going with best-estimate, but your intent is to have some uncertainties?

DR. CORSON: I mean, we're -- so I will say we'll try to be as best-estimate as we can. But at the same time, these are new designs. And our best estimate may still have very large uncertainties associated with them.

So, while yes, we may try to do like a best-estimate-type thing, the uncertainty bounds are going to be much larger than what you might expect for best-estimate plus uncertainty for LOGA, perhaps for example. Because we just don't have as much experience and as many experiments at this point.

CHAIR BLEY: As you begin to put this material together -- not just for you folks, and I liked your answers so far on uncertainty but we need to see later how it all works out -- but potential applicants really need to be reminded of this because it's real tempting to start with a few simple experiments and say I know everything there is. And you have to be careful about that.

DR. CORSON: Yeah. We do try to stress that in our vendor interactions. Certainly, NRO is much more in tune with the vendors than we are, but we also have interactions. We meet with DOE, so we certainly do try to stress that point as much as possible.

MEMBER REMPE: So, when you provide input or output that goes to the design basis codes or the -- beyond the MELCOR codes, your plan is to give them the same output results with uncertainties or whatever? I mean, you're not planning to have a conservative result you feed to the design basis codes and best-estimate that you feed to MELCOR? You know what I'm trying to get to?

DR. CORSON: Yeah. No, I mean, we would give like the same sort of information to both.

MEMBER REMPE: Okay. Mm-hmm.

DR. CORSON: So, we are going to -- so we're going to talk about this at the end. But since you bring it up, I think for design basis, I think the fuel performance aspect may be more tightly -- I guess

I could say coupled -- but it will certainly be much more involved than with beyond-design basis aspects.

So, beyond-design basis, what MELCOR is really looking for would be fuel failure rates. So, for Light Water Reactors, it has some simplified models that can handle that and we don't really use FRAPCON right now to support MELCOR.

But going forward in the future, we could provide some fuel failure rates for TRISO fuel, for example. Things that MELCOR doesn't know needs to get from somewhere, whether it's fuel performance code, or an experiment, or what have you, that's one role that a fuel performance could have in beyond-design basis.

For design basis, I think we'll do something similar to what we do now for like a MELLLA+ analysis, where yeah, we provide our input to -- she's itching to jump in here.

MEMBER REMPE: Well, finish what you're saying.

DR. CORSON: Yeah. So, where we provide input to like a neutronics code, or a thermohydraulic code, and we might have some feedback. Or, going forward, we could also have a more coupled analysis.

So, as it is right now for Light Water Reactors, we do have some of these feedbacks, but it's in a much more manual manner. That may be one approach for Non-Light Water Reactors, or we're also working to couple some of our codes together to take some of that manual difficulty out of the picture.

MEMBER CORRADINI: But before -- well, I have a feeling Dr. Petti may say the same thing I'm about to say. I'll be quiet.

MEMBER PETTI: Can I ask the question the opposite way? Why would you decide to do a more coupled and a more detailed calculation, when some of these systems have inherent safety attributes that perhaps a simpler hand calculation can get you the level of detail that you need to confirm what the vendor is saying, particularly if you're two orders of magnitude away from the dose consequence code, for instance.

It seems like it may be too much of a sledgehammer approach when you just need an elegant hammer instead.

DR. CORSON: So, I would agree with that statement. What I would say is that, while we certainly expect much larger margins and all that, we don't necessarily know at this point exactly what vendors are going to propose. So, we have to be ready.

That way we don't get stuck in a situation where vendors come in with maybe tighter margins than we were expecting and we need a more detailed analysis. So, this doesn't necessarily mean we will do this fully coupled analysis. But it makes sense to prepare for it at this point.

MEMBER PETTI: Well, I mean, it just seems to me that you should have a toolbox. The toolbox includes everything from something simple that you can learn a lot about the physics side without running detailed codes, up to the detail code, if and when you need it.

You can probably build understanding and engineering judgment pretty quickly with simpler analytical solutions. For instance, the analytical solutions for some of these fuel systems, you just got to go back a little and find them, because they were developed before we had big computers.

They capture 90 percent of what you need, and you can come up to speed pretty quickly without having the detailed code in front of you.

DR. CORSON: Yeah. Again, I fully agree. And we'll actually touch on those points a little later.

MEMBER KIRCHNER: May I ask more of a

philosophical question? So, is the expectation -- it fits in with Dave Petti's comment and Mike's -- that the applicants will come in with an NQA-1 for design basis, an AOO event?

In other words, a topical report on the code that's been reviewed and approved by the agency?

DR. CORSON: I mean, that's my understanding. If I'm wrong, NRO can contradict me.

MEMBER KIRCHNER: And then, to fit in with the comments, then is there thoughts about something like an Appendix K, which is a very conservative approach to the ECCS LOCA issues for an LWR?

Is there a thought that you would use that kind of approach, which then fits in with Dave's comments about using bounding analysis, more simplistic tools, to establish some kind of regulatory certainty, or confidence that you've got considerable margin for what in many cases will be an experimental, or first-of-a-kind prototype design?

DR. CORSON: So, I would defer to NRO for that.

MEMBER KIRCHNER: Ah. Good.

DR. CORSON: I mean, it's kind of a policy -- so, it's difficult, because it's kind of a --

MEMBER KIRCHNER: Well, you're being pretty honest. I think what my colleagues are asking you -- what I think we're all kind of getting at is, start as simple as possible, bound the calculation. If that doesn't get you there, then -- and so I'm kind of asking should you wait for the vendors to do this, or is it more cost-effective for you to start doing this now on the two fuel types that you're identifying, and just broaden it on two candidate designs for those fuel types, so that you actually get a feeling when you need to be detailed, versus assuming you have to be detailed.

DR. CORSON: Yeah. I think we -- so, internally, we do plan to do that sort of stuff. I can't speak to what would be required of an applicant, but I will say internally, we don't need the same level of detail as an applicant would in general.

We can do some of these simpler calculations. I mean, we really -- so eventually, we want to move towards as best estimate as we can, but certainly initially, as you said, we can start with simpler calculations, to give us a feel for some of these things.

And we do have some initial assessment plans to do those types of calculations.

DR. BAJOREK: Mike, I think we are thinking along those lines. This is Steve Bajorek from Office of Research.

You know, you one of the ways we would utilize something like this is a fuel performance code might go and tell us what thermal conductivity degradation is. And if we want to minimize or maximize resistance to heat flow, that's the type of information we would put in a design basis-type tool to bound it in a certain direction.

And if that's good enough, we don't have to go any further. The difficulty we have right now is that many of the applicants say there's lots and lots of margin.

We think that's right. Okay? That probably is. But the staff doesn't know that yet. And we're going to have to do some of those calculations, which may involve some of these types of details, in order to give us some of that direction.

So, we'll initially start off as simple as we can, build in those details as we need to follow those up.

MEMBER PETTI: I think it would have been helpful to have some of this discussion in the relevant chapters of the report. There's a lot of ways to attack this. Because it comes across as more, we got to get these codes ready. We got to get these codes ready. We got to put all this physics in.

And you lose a lot of this nuance that we've had in this discussion here.

MEMBER CORRADINI: I guess I'd go a little further, which is probably not in the volumes, but some sort of preliminary introduction that says, here's our attack philosophy for these things. We're going to start simple.

Now, my bias is even further. I would start and I'd reverse the problem. What is the NRC -- why do we even need NRC in all this? The answer is, source term.

I would essentially say, what do I need to do to estimate the source term? How much certainty do I need in source term before I want to say it's enough? And I can do a relatively straightforward calculation, totally -- not totally, but I'd say pretty close to totally -- based on experimental data that I can point to.

And then, Dennis' concern would be, is that data appropriately prototypical. Right? But that's -- I'd be looking for that outside of your three volumes. I'd be looking at some sort of introduction -- I'd attack it -- on how you're going to deal with all of this. Because you're never sure what's going to happen.

MS. WEBBER: And so there is the introduction, which we presented on May 1st. And we have talked about including some of this thought in that introduction.

CHAIR BLEY: I think that's important. I was about to say before Mike that the things we're talking about aren't just about Volume 2. They're probably everywhere.

MEMBER KIRCHNER: I think it would be good in the introduction to cover this. And also, working with NRO. Outline, in a general sense, what the expectations are of the applicants, because they're going to be looking at these documents as well.

I go back to my analogies. They're an Appendix K kind of approach that you would use with a novel new design to bound things, and then expect the applicant comes in with a code that's been validated within the experimental data range that they're going to try and operate within, including their design basis event.

DR. CORSON: Okay, so I'll touch on this the second half of this slide, that advance reactors may use either SAFDLs or SARRDLs. So, SAFDLs, Specified Acceptable Fuel Design Limits, deal with criteria to prevent fuel failure, which are used for LWRs and may be used for advance reactors.

And the Specified Acceptable System Radio Nuclide Release Design Limits, they limit how many radio nuclides you can release. And this is proposed for TRISO fuel.

So generally, how we do things -- again, this is generally how we do it for LWRs, but it mostly applies to non-LWRs. We're going to go over on the next few slides kind of the two ways that we do fuel performance confirmatory analysis.

So, even though, again, there's differences between LWRs and non-LWRs. The same approach, in general, should work. So, next slide.

So, the first way we it is single-element analysis. So, this would be like hottest rod-type calculations. And in this case, we'd use a standalone fuel performance code FAST, which is just the successor to the FRAPCON code.

We have some input from other codes for things like radio power profile, or axial power profile, inlet conditions, but for the most part we just run our fuel performance code and determine whether or not the limits are met. So, there's no reason why that would necessarily change for non-LWRs. So, next slide.

So, the other thing we do would be a full core analysis. And this is where the fuel performance code would fit into a design basis -- accident design basis -- event-type analysis.

So, this is kind of how we use it for MELLLA+, for example, for Light Water Reactors, where we have some information that we're passing, in this case, manually back and forth between core simulator, like PARCS, and thermal hydraulics like TRACE, and doing our fuel performance calculations.

So, as I was saying, we could take that same approach where we're manually maybe passing some simple information back and forth, or we're prepared to also do a more coupled analysis. And we'll determine what's necessary once we receive some applications, as we discussed. So, next slide.

Now, I'm going to switch gears and talk a little bit about the fuel phenomenology that we need to consider. Once again, I'm starting with LWRs because here we have the list of LWR fuel rod failures. A lot of these also apply to some of the non-LWR designs.

Of course, you have to be concerned with things like overheating, pellet-clad or kernel-layer interactions, these types of things.

So, that's why I put this up. You know, your fuel performance code, which handles these things in LWR, you can use a lot of the same infrastructure to do it for non-LWRs, of course with different properties, correlations, and so on. Next slide.

So, I talked about some of the failure modes. This just talks about the phenomena you need to consider. Basic things like heat conduction or fission gas release, stress strain, and so on.

Once again, these are generally applicable to LWRs and to most non-LWR designs. So, a little later on I'll go through TRISO and metallic, specifically to talk about some of the differences.

But in general, these are the things we need to consider. And for all these phenomena, we need to consider temperature, burn-up, the radiation effects on material properties, and also the initial manufacturing defects, which can be very important for certain fuel designs. So, next slide.

The way we determine which phenomena are really important, is generally we use the PIRT process. So, we've, way back in 2004, there was a

PIRT on TRISO fuel, which Dr. Petti was a part of -- yeah, long time ago but still applicable today -- and that's the best information we have on TRISO.

There aren't any specific liquid metal or sort of FAST reactor metallic fuel, PIRTs, but Argonne does have a series of reports on metallic fuel, which is quite useful.

So, there are PIRTs. I should clarify. There are PIRTs on SFRs, but they don't necessarily focus on fuel performance. They cover different aspects. Design-based access and so on.

MEMBER CORRADINI: So, I have two questions. One is, maybe Dr. Petti can correct me. But some of your references go back to this time. Are there not newer documents to refer to on TRISO? That's question one.

Question two is, on FAST reactors, I was under the impression that Argonne, with Sandia, did a series of five reports accumulative to one major report on metal fueled gas reactor, in terms of gaps. They didn't call it a PIRT, they called it a gap analysis. And I'm assuming you're well aware of -- okay.

DR. CORSON: Yeah. Yeah, the gap

analysis, at least in May report, doesn't specifically touch on fuel performance. I mean, aspects, of course, are important to design-based accidents and so on.

But it's not specifically a fuels PIRT like the TRISO PIRT was. As far as newer, to your first question, the best document I would say, which I don't reference on slides but is referenced in the report, is the project plan for the advanced gas reactor program.

It talks about some of the missing information. And then it talks about how the AGR program is going to deal with that. So, that might be a more up-to-date -- maybe not as comprehensive, but more up-to-date document, if you want to look at it.

MEMBER CORRADINI: Okay.

MEMBER REMPE: So, I'm not an expert on fuels, but I am aware that X-energy is trying to do some sort of manufacturing capability for all the gas reactors relying on TRISO fuel. And they realize that they're coming in and they're different than what the labs have done.

And they'll have to get a radiation data to show their capability is as good as what's been done in the DOE-funded HER program.

With sodium fuel, I think the situation's a bit different. In your report, you talk about how that there's been this FAST reactor working group report, as well as a report done by -- perhaps it was Argonne or someone in the DOE thing.

But they talk about the metal fuel. And you talk about in your report that there's data out there. But one of those reports talks about how the metal fuel has evolved over the years. And we've not had any metal fuel made and run in EBR-II in a lot of years now.

And I didn't see that clear indicator in your report that yeah, there's a lot of historical data, but whoever comes in with a new fuel capability better have some data to show that it's still valid.

I mean, I don't know if you've had time to get into the details and see if all this data, even though the later fuel from EBR-II perform the same as the earlier of the fuel, or the defects might change with the manufacturer.

And I guess I'm interesting in, do we know as much about metal fuel fabrication nowadays? I've heard over the years some saying, oh, we had two vendors make it. But jeepers, Aerojet hasn't been making fuel also for a lot of years.

And so I think there's more uncertainty with metal fuel. What's your take on it?

DR. CORSON: I mean, there's certainly some uncertainty with restarting the manufacturing process. But I think Argonne hasn't looked at this and they feel pretty good that what we've done in the past is --

MEMBER REMPE: Well, I know Argonne, and I know Gene feel very good about it. But I am concerned. And I think, again, even the Argonne folks at the MFC were not the technicians who made it years ago for EBR-II. And is there not some concern by anybody?

MEMBER PETTI: Yes, I think -- let me just add that this was a subject of big discussions at INL before I retired. And there are more than one fabrication route now for metallic fuel.

The approach that was used for EBR-1, the historic approach, is casting. And some of the newer vendors think that's not an economical process to scale for industry, with you guys not making a lot of it.

And so, if you change the fabrication route, the sessions, well, you have to re-irradiate, right? Because we know that how you make it can impact how it performs. So, I think some of the vendors that have looked at it more seriously understand that.

I don't know that it's a belief held across all the concept developers in sodium systems, but some of them understand that.

DR. BAJOREK: This is Steve Bajorek. We've recently started some work with Department of Energy to start looking at the experimental gaps that are in existence in a number of these different areas.

With respect to metallic fuel, when we met with them, they think that most of the phenomena are covered with EBR-II. However, because of the new manufacturing, swelling of these metallic fuels, that's something that has very high uncertainties. It's probably going to need more work.

The concept there is as you start to go a little bit higher burn-up, you're going to start having much more swelling in these metallic fuels and the database may not have sufficient coverage.

MEMBER REMPE: Again, X-energy folks at a meeting clearly said, even though Oak Ridge has been making this fuel, we know we've got to radiate it and we've got a plan to show we are as good as what the folks within a couple of years ago, even though we have folks from Oak Ridge coming and help us, that we could still do the same thing.

Now, I know, maybe it's harder to make TRISO fuel than metal fuel, but the folks from Argonne, they've got procedures from the old days. And I really would like to see the regulators say, well, I would like to see some radiation data to show that you had the same type of fuel that they made a decade ago, or whenever it was they last made it.

And that's what I would like to convey here today, that I think you need to check it and make sure they can still do it.

CHAIR BLEY: Amy?

MS. CUBBAGE: Do I just --

CHAIR BLEY: Introduce yourself.

MS. CUBBAGE: Hi. This is Amy Cubbage, NRO. I'd just like to make kind of a broad statement about the meeting here and the scope that we're focusing on our independent confirmatory capabilities and what data needs we see to support that. And separately from that, NROs engaging with potential applicants on what they would need to do.

So, our requirements -- they're not even requirements, they're things that we're doing because we want capability -- are separate from what applicants would need to do to demonstrate their fuel.

And at this time, the linear term applicant using metallic fuel would be the Oklo vendor, and we're dealing with them separately, outside the scope of these discussions.

MEMBER REMPE: I get that. But what I guess is that, one, even when you refer to the FAST reactor working group report as a source of data and the other places, there's been a change in the metal fuel over the years.

MS. CUBBAGE: Right.

MEMBER REMPE: And so, I'd like to see, as you --

MS. CUBBAGE: So, to the extent that the staff wants to rely on that data to validate its codes, that's a factor we should consider. But I was concerned that you were raising with regard to the applicants. We'd like to keep those discussions somewhat separate.

MEMBER REMPE: I get that. But I'd like to see if there's been a difference. And then I'd like to note that no matter what the applicant is, that even their fuel may be different than what you've had historically, is the point I'm trying to raise today.

MS. CUBBAGE: No, I understand. And I guess from a regulatory office perspective, we don't have a near-term applicant, other than Oklo, using the fuel. So, PRISM will be authorized by Department of Energy if it goes forward for the VTR reactor. They're still working on that. And so, we'll engage with those applicants as they come.

DR. CORSON: Okay, so now I'm going to go a little bit into some of the phenomenology for TRISO and metallic fuel. So, tri-isotropic fuel has been proposed for not just high-temperature gas reactors, but also for these fluoride cooled, high-temperature reactors, which have a molten salt coolant but still fixed fuel, or at least solid fuel, I should say.

So, the kernel and the codings provide barriers to fission product release. I'll show a picture of that on the next slide. And TRISO fuel has operated a number of years domestically and internationally.

Of course, the German AVR and THTR are the big examples internationally. And then, in the US we had Fort St. Vrain. So, we do have some operating experience with TRISO. Next slide.

So, this just shows what a TRISO particle looks like. So, you have a kernel which contains your uranium fuel, uranium dioxide, your uranium oxycarbide, whatever it is.

And then you have a porous buffer layer and a silicon carbide layer sandwiched between two pyrolytic carbon layers. And on the next slide I'll talk about what those different layers do.

These little particles are on the order of 1,000 microns, give or take a bit. And they're packed in a graphite matrix. Here, I'm showing a pebble design. These are some typical dimensions back when we were looking at pebble bed reactor for NGNP.

And there's quite a few of these particles per fuel compact, 1,000 to 10,000 or so. So, next slide.

So, the way this works, the kernel provides some fission product retention. It's just like the pellet in U-02. It doesn't keep everything in but retains quite a bit of the fission products.

The current plans are to use uranium oxycarbide. In the past, the reactors have used uranium dioxide, but the current irradiations that are being done for the AGR program used uranium oxycarbide.

The porous buffer layer accommodates the kernel expansion, fission gas release, and fission recoil energy, so it protects the structural layer, essentially.

The pyrolytic carbon provide fission gas retention, and also some structural support for the silicon carbide layer, which is the main structural support. It's essentially the pressure vessel for this kernel design. So, next slide.

This just goes through some of the phenomena that are important to safety. These are just the things that we need to be aware of when we're doing our fuel reviews.

So, you have to worry about fission product migration through these layers, or attack of the silicon carbide layer. So, historically, there have been large silver releases from these particles, and there's also some evidence that palladium can attack and fail the silicon carbide layer. So, these are just things we need to be aware of.

Another big thing historically that was an issue for TRISO, is oxygen and carbon monoxide release from the fuel kernel. It led to a phenomena of kernel migration, where the kernel would actually move and fail the structural layers.

But the uranium oxycarbide kernel should minimize, or pretty much eliminate, this failure mode.

So, that's one of the main reasons that we've gone to that uranium oxycarbide.

And then, of course, we need to deal with the usual suspects, like pressure buildup and mechanical stresses, strains, and so on.

MEMBER CORRADINI: So, since I don't know anything about this, I guess I can ask this question. I didn't understand the first bullet. Does that mean that it always attacks, or there's a level of burn-up above which you have to worry about this? The way you write it --

DR. CORSON: Yeah, there's -- so, for silver it just a high diffusivity through the layers. So, that's just something you have to deal with. For palladium, it's like a certain amount you need.

The exact amount and so on is being investigated. I mean, that's one of the things that the AGR program is looking at. But yeah, it's just something that has been identified as a concern. How much of a concern hasn't been quantified yet. But yeah, AGR is working on it.

MEMBER KIRCHNER: James, can I get you back one slide previous?

DR. CORSON: Sure.

MEMBER KIRCHNER: I'll just quibble a

little bit with your third bullet.

DR. CORSON: Okay.

MEMBER KIRCHNER: The pyrolytic carbon really protects the silicon carbide. That's really what it's there for.

DR. CORSON: Mm-hmm.

MEMBER KIRCHNER: But inner and outer.

DR. CORSON: Yeah.

MEMBER KIRCHNER: It doesn't provide a lot of fission gas retention at all.

MEMBER PETTI: No, that's not true, Walt. It provides a high degree of fission gas retention.

MEMBER KIRCHNER: Yes, but it's subject, Dave, to cracking and all kinds of things under irradiation and stress from heat. So, I mean, you really hang your hat on the silicon carbide. The performance.

MEMBER PETTI: But, for instance, if the silicon carbide layer failed in the particle, what is seen experimentally is cesium release but no noble gas release, because the pyrolytic carbon layers are intact and prevent the fission gas from coming out. So, it's how to interpret what you see experimentally.

MEMBER KIRCHNER: Okay, I'll yield the point, but not too much. And I would have preferred the zirc carbide. But anyway, they didn't go there.

MEMBER PETTI: Well, we can have that discussion some other time. I'm on the other side of the fence on that.

MEMBER KIRCHNER: Thank you.

DR. CORSON: So yeah, just quickly to go through metallic fuel, so next slide. So, it's specifically looking at U-10 zirc, so ten percent zirconium. That's what we expect most of -- or the initial applicants to come in with.

We're also considering a mix of uranium and plutonium, with tin-zirconium as well. But certainly initially, we expect U-10 zirc. So, this has been proposed for sodium FAST reactors and, as Amy mentioned, for some heat pipe reactors.

This fuel is typically paired with high-temperature steel cladding, HT-9 was used towards the end of the EBR program, and we expect that's what applicants would use as well.

And this fuel has years of domestic and international operating experience. Once again, EBR-II is the best example that we have.

MEMBER CORRADINI: Again, something I'm not familiar with, so I just thought I'd ask. So, FFTF I thought ran with HT-9 also?

DR. CORSON: FFTF had -- yes, but it had oxide fuel. So, FFTF had oxide driver fuel. But they did test metallic fuel. But the actual fuel in that fuel reactor was an oxide. MOX fuel. So yeah, next slide.

So, this just shows what a metallic fuel rod looked like. This is back from PRISM, which might be used -- similar design might be used for the BTR.

So, I think the big thing to note here is a very large fission gas plenum. And also, there's a very large initial gap between the fuel slugs and the cladding, which is initially filled with sodium.

As Steve had mentioned, this metallic fuel swells quite a bit. That's why you have this big gap. And you have this big plenum because you release a very large amount of fission gases. So --

MEMBER KIRCHNER: Since you brought it up, or someone did, what would they do -- if I remember it, the fuel was cast. So, is it proposed now to go to some other alloy approach or extrusion, or would it be an extrusion?

DR. CORSON: Yeah.

MEMBER KIRCHNER: Okay. And then, do we have any feeling about general dynamic behavior with regard to swelling? Because, as you point out, the large gap and the sodium is there to provide good conductivity, and so on and so forth. Do we know -- do we have any preliminary evidence about how an extruded slug would work versus the cast?

DR. CORSON: So, I have to say not that I'm aware of. I mean, certainly I agree we're going to have to deal with larger uncertainty until we have actual evidence of manufactured fuel, how it performs.

But certainly, for our purposes in research, we can get away a little bit more with larger uncertainties, just because how we do our confirmatory analysis.

MEMBER KIRCHNER: So, just sticking to what you're doing in your co-development, so when it comes to FAST, do you have confidence in the models, that they'll deal with the change in the -- what would you call it, the structural -- yeah, the fabrication technique for those slugs?

DR. CORSON: I mean, certainly we're going to rely on what our historical data. And if we have new evidence, then we will update the codes as --

MEMBER KIRCHNER: Then, you're going to have to put some uncertainty --

DR. CORSON: Yeah.

MEMBER KIRCHNER: -- kind of factor.

DR. CORSON: And that's why we do things like sensitivity studies, to see, okay, we say swelling is this much, but what if it's really a little bit greater? How would that affect things?

So yeah, that's why we really rely on sensitivity studies, to look at these cliff effects.

MEMBER BALLINGER: My understanding is that the swelling was actually intentional. In other words, once you get above about 30 percent, or 20 or 30 percent, you get interconnected porosity. And then the fission gas solutions gets easy. You got this large plenum. So, it's pretty well understood, I thought.

DR. CORSON: For the old manufacturing process. So --

MEMBER BALLINGER: But I guess -- but metallic fuel is metallic fuel. It's going to swell like a dead fish.

(Laughter.)

DR. CORSON: Yeah, so you're certainly right, it's going to swell.

MEMBER CORRADINI: I'm trying to visualize that. Say that again.

PARTICIPANT: You've seen veils flow up.

DR. CORSON: Yeah, you're right. It's

going to swell no matter what. But is it going to swell exactly the amount that we saw in the past, or are there going to be differences?

MEMBER BALLINGER: Well, when you get to 30 percent, once you get interconnected porosity, you're pretty much done. Right?

MEMBER CORRADINI: What I think Ron is saying, is if it's more, it's of no consequence. That's what I thought you were getting at.

But I know we're getting into the weeds, but I thought I remembered that we had a -- well, there was some meeting, I can't remember what meeting -- and Terra Power already had similar radiations of their extruded fuel. Am I mis-remembering?

DR. CORSON: Could be. Sorry, I'm not aware of that.

MEMBER CORRADINI: Okay.

MEMBER PETTI: There are a plan to do some irradiations on the extruded fuel, but there may --

MEMBER CORRADINI: Oh, I thought they had done the irradiations in Russia.

PARTICIPANT: M-46.

MEMBER PETTI: Yeah. Well, okay, I'm not sure at what scale that extrusion was done.

MEMBER CORRADINI: Well, I'm sure there were teeny tiny axial links. But I thought they had done extruded fuel. That's the reason I was curious.

MEMBER PETTI: There's larger scale extrusion work going on right now that's sort of at a pilot scale, I think. And the plan is to irradiate that as well.

MEMBER CORRADINI: I see. Okay.

MEMBER PETTI: I think Terra Power -- I would personally put Terra Power in the same sort of knowledge and approach as Joy described. They know they have to irradiate, and so they're working that.

MEMBER CORRADINI: So, they're aware of the need.

MEMBER PETTI: Yes.

MEMBER REMPE: In the data that you have looked at -- because again, some of those other reports emphasize how EBR-II fuel varied over its operating years -- are you seeing much variability when some of the -- I mean, have you started plotting certain performance parameters as a function of -- for different fuels, and seeing any -- or is it all just the same no matter who made it, or not even started looking at the data yet?

DR. CORSON: So, I would say EBR-II

actually used different metallic fuels throughout its lifetime. So, that could be why the performance changed. They used what, U-Fissium, I think, early on, and then they eventually went to U-10 zirc. But --

MEMBER BALLINGER: That's because of the reprocessing part.

DR. CORSON: Yeah.

MEMBER BALLINGER: Yeah.

MEMBER REMPE: So, are you seeing variation, is what I'm kind of -- I mean, have you started looking at the data and your models, or you just aren't that far yet? You just --

DR. CORSON: Yeah, not that far. I mean, we've done preliminary assessments. But we've used three test cases. I mean, there are certainly way more test cases in the database that Argonne has. So, we'll look at that going forward.

MEMBER REMPE: I'd be interested if you can see some differences in the performance for over the years of fuel.

DR. CORSON: Yeah. I mean, that's certainly something we'll need to take into consideration going forward.

So, metallic fuel performance, I already touched on the last point, the fission gas release and swelling. Of course, it's metal. It has very good thermal conductivity. But then, it also has a lower melting point. So, those are just things that you have to be aware of when you're doing your analysis. So, next slide.

Phenomena important to safety. One interesting thing that happens with these metallic fuels is that the zirconium and uranium tend to redistribute inside this fuel slugs as you go along. And this can have -- basically, they can form like local phases, which are different melting temperatures, or eutectic behavior, and so on.

So, it's something to be aware of, because it can impact fuel performance. Of course, you always have to be aware of manufacturing. And then, usual suspects, fee conduction, and so on.

MEMBER PETTI: So, I have a question. Do you guys actually plan to try to model the redistribution in the FCCI?

DR. CORSON: Yeah, that's something where it's a maybe right now. So, our plan right now is to look at whether or not we think it's necessary. So, we're going to do some preliminary assessments and determine whether or not we need the zirconium redistribution model.

I would also say that there are some models out there that we can scavenge if we feel we need to. So, to answer the question, maybe.

MEMBER PETTI: Yeah, because you'll find a lot of stuff in the literature today on FCCI and trying to understand it better. Lots of university work going on and the like. So, it's still an active area of research.

DR. CORSON: Yeah, I know. We did talk about this a little bit with DOE, like the lanthanide behavior and how that impacts fuel failure, and so on. So yeah, we're aware of it. Whether we actually model it or not is to be determined.

MEMBER PETTI: Okay.

DR. CORSON: So, right now we're going to talk a little bit about how we selected which code we're going to use going forward.

So, there's a lot more on this in the report, but I'll go through this real quickly. So, again, we need a tool that we can use.

We're going to focus on fuel performance and we're going to focus on solid fuels, so this just excludes our consideration of fuel salts for this volume, or salt fuel reactors. And then, I'm going to discuss a few of the criteria we used.

There's really two big choices. It's either FAST, NRC's code, which is a follow-on of the FRAPCON code, and then there's INL's BISON code. So, I'll just go through this fairly quickly. I talked about --

MEMBER CORRADINI: So let's stop there for a minute. But both of them rely on the same database.

DR. CORSON: Yeah. They do. So, there are --

MEMBER CORRADINI: So, is it like Chevrolet and Ford?

DR. CORSON: There are certainly a lot of --

MEMBER CORRADINI: Why do I need a Ford when I've got a Chevrolet?

DR. CORSON: So, there's a lot of similarities. I will say BISON is more detailed and it also has some interplay with the MARMOT code, which has the mesoscale-type calculation. So, it goes into a little more detail than FAST does. And it doesn't have the same assessment database, at least for Light Water Reactors, at this point.

MEMBER CORRADINI: So, you gave me some pros. So, I sense the last one was a con.

MR. GEELHOOD: Yeah, I know that's a major con was --

MEMBER CORRADINI: I think you have help from the peanut gallery. You have to identify yourself and talk into the mike.

MR. GEELHOOD: Yeah, this is Ken Geelhood.

PARTICIPANT: Is this turned on or not?

MEMBER CORRADINI: It should be on. You just got to get real close, Ken. Real close. Real close.

PARTICIPANT: Aim it straight --

MR. GEELHOOD: So, I would say the assessment database of FRAPCON and FAST is much bigger. Probably almost a factor of ten greater than what INL's used to assess BISON.

So, I would say that would be a pro of FAST, is that we have such a large assessment database, we can have higher confidence within a larger area of power and burn-up levels.

MEMBER CORRADINI: But then, let me ask a question back to James, but you have help. So, if I now take myself out of the Light Water business and I take myself into the other business of metallic fuel or TRISO fuel, both will have to take the same database and, excuse my English, tune itself to that database. Is that not true?

MR. GEELHOOD: I don't really think that tuning to a database is really what we do. So, we kind of have two levels of data. So, there's separate effects data. When you irradiate something, then you measure thermal connectivity, how much it swelled, things like that.

So, we develop models based on that. And then, we do assessments. So, when you irradiate something, maybe you've put a lot of instrumentation in, you can measure temperature in situ. You can measure straining afterward.

Then, we just compare to that. It would be tempting to go back and then try to change something to get your predictions, but that's not really our approach.

Our approach is to fit all the separate pieces, and then see how well they do.

MEMBER CORRADINI: So, the separate effects experiments lead to your model improvement, and then the assessment database with what I'll call a more integral measured test --

MR. GEELHOOD: Yes.

MEMBER CORRADINI: -- is what you compare to.

MR. GEELHOOD: Mm-hmm.

MEMBER CORRADINI: Okay, I got it.

MEMBER REMPE: But you need to say who you are too. I'm sorry.

PARTICIPANT: He did. He did.

MEMBER REMPE: You did say?

MR. GEELHOOD: Yeah, I'm Ken Geelhood from PNNL.

MEMBER REMPE: Okay, thank you. Then, I had a question to -- I mean, you made the comment about MARMOT. And in the interface between BISON and MARMOT, the explanation you gave is good in that you talk about we have separate effects for thermal conductivity degradation, and then we have an integral database.

My understand is this mesoscale MARMOT database is very, very, very, very limited, if any, especially when you get into FAST reactors. And so, that's, I think, a difference.

My understanding is the fundamental equations are a bit different in BISON. Now, you're right that they're to the same integral effects, but it's not clear to me that you have separate effects for the BISON MARMOT type of interface. Is that a true statement?

MR. GEELHOOD: I would say that's a very true statement. I would say that when we already know the answer, so to speak, in LWRs, then the proof's in the pudding. So, MARMOT could forget what we already know, fission gas release, then maybe you could have some confidence in moving it on.

But to date it hasn't been successful at predicting what we already know based on fundamental equations. And so, if it can't do that, I don't think it's ready to go to what we don't know.

MEMBER REMPE: Thank you.

MEMBER CORRADINI: Can I just ask either James or Ken just to be clear? As you would learn from what people call mesoscale, I assume grain boundary size stuff, is that what MARMOT is, grain boundary size stuff?

MR. GEELHOOD: Probably even lower than that.

MEMBER CORRADINI: Thousands of atoms stuff-ish?

MR. GEELHOOD: Probably. They call it the mesoscale. It's in between atoms --

MEMBER CORRADINI: It's not an atom and it's not a grain. It's somewhere between.

MR. GEELHOOD: Yeah.

MEMBER CORRADINI: Okay. But as you learn that, there would have to be separate effects experiments either currently in the Light Water business, or for TRISO or metal, to better improve the modeling within MARMOT.

MR. GEELHOOD: Certainly. I think that someone could use their advanced microscope skills, various spectroscopy things, to try to get some sort of data that would be used as input to MARMOT. But I think that's very difficult and I don't think it's been done successfully to date.

MEMBER CORRADINI: If I take that away and ask are there separate effects enough -- well, I guess we're getting away from why you answer --

MR. GEELHOOD: I think I know what you're answering. Like the inputs, what it means, what are its material properties? I don't think they're very easy to measure.

MEMBER CORRADINI: Oh, I was going to say something more -- I'm back to my Chevrolet and Ford question, which is, if I have an experimental database, can I not then use those separate effects data to either help in the performance of FAST or BISON?

MR. GEELHOOD: I suppose you could. But

on some level, if that's what you're doing, then would you rather have one knob to tune, or 50 knobs way down in the weeds to tune? And if ultimately you're getting the same answer, then we should go with the most simple approach.

MEMBER CORRADINI: Okay. All right, thanks. I got it.

MEMBER BALLINGER: Along the lines of what Dave Petti has been saying, we need to be careful about hitting a fly with a sledgehammer. When you have a FAST reactor fuel where you have a sodium gap, what happens to the fuel is decoupled to some extent, except for the fuel-clad chemical interaction part from the cladding. And so, from the standpoint of a source term determination --

MR. GEELHOOD: So, they're not totally decoupled. So, we --

MEMBER BALLINGER: Well, I didn't say totally decoupled. I didn't use the word totally. I said, with the exception of.

MR. GEELHOOD: Well, but we see kind of two swelling regimes. We see an unrestrained swelling, maybe of like 20 percent.

MEMBER BALLINGER: Yep.

MR. GEELHOOD: But then, once it comes in contact, certainly the swelling rate goes down quite a bit, because the cladding is pretty strong and provides quite a bit of restraint to that swelling.

And so, but when you get that restrained swelling, that is now straining the cladding, and so that is leading to damage of the cladding.

MEMBER BALLINGER: But when you have -- again, when you have 30 percent swelling, you got interconnected porosity, when you get interaction between that and the clad, the clad doesn't go out exclusively. The fuel goes in.

In other words, the fuel is able to accommodate the plastic deformation.

MR. GEELHOOD: To some degree. But it does strain somewhat --

MEMBER BALLINGER: Yeah, yeah. It does strain the cladding.

MR. GEELHOOD: -- maybe like a couple of percent. And so, that is now a damage mechanism that you want to worry about.

MS. WEBBER: Can I just make one comment? So, notwithstanding the staff's approach to selecting one code versus another, I think the other thing I think about is that some of these advanced reactor -- potential applicants, I'll call them -- may use BISON.

And so, there's active development on BISON.

And so, at the very least, the staff needs to have some level of familiarity with BISON, to be able to ask the appropriate questions during a licensing review.

And so, I think while they're considering the use of BISON, there still may be a lot of development work that needs to be undertaken. But having a familiarity with BISON will help if we have applicants who use it in the future.

MEMBER CORRADINI: So, I'm sure this is a terrible analogy. However, I look upon this as RELAP5 and TRACE.

MS. WEBBER: I don't know. I don't know that much. Personally, I don't know that much about the process.

MEMBER CORRADINI: I don't either, but I look upon these as two things that then demand an experimental database that must be fed, both, as Ken said, as separate effects and --

MS. WEBBER: I don't think we would disagree.

MR. GEELHOOD: That's a reasonable analogy. And the way we're looking at FAST and BISON is, we want the capability of using either one. Okay?

And we'll factor that in. And eventually, we'll find out which one's working better.

DR. CORSON: Next slide.

MS. WEBBER: Okay.

DR. CORSON: So yeah, we've already talked about all the phenomena we need to model. We've also touched on multi-physics, do we need to couple, or can we take a more serial approach.

Certainly, we would like a code that could do either, ideally. Next slide.

So, of course, we need to consider code development costs. We don't want to spend unnecessary money. And that means we need to consider full life cycle costs: validation, code maintenance, because we expect if applicants do come in and reactors do get built, we're going to need these codes for the long-term, because there's training, and so on. So, that's just something to consider.

Whether or not we're going to be ready to meet industry schedule, as I said, we really need to be ready and we want a code that's going to be ready on time.

Computational research requirements. So, right now we basically run on Windows, although this is changing, I will say.

While it's nice to have something that can run on Windows, we are moving to the cloud. We have a Linux instance that we've been working on. So, this isn't so prohibitive necessarily if we don't have Windows.

Impacts on staff. So, certainly, we've touched on this a little bit. But as much as possible, we would like something simpler, just if possible, because it's easier to understand.

It's not to say that we can't understand something that's complex, but certainly we have limited time, it's easier for us if we have a simpler model. And it makes sense too, because it might allow us to do our reviews much more quickly if we have something simple that we can understand, than going into a very complex code.

And then lastly, this issue of regulatory independence that comes up. We really need to understand all the assumptions that go into whatever code we use. It certainly helps if we're actively involved with code development, to really understand what the code is doing, so that we can better perform our reviews. So, based on all these criteria --

CHAIR BLEY: I like what I've read and what you've been saying here. As we went through

Volume 1 especially, I think things were a little more up in the air.

It strike me there's -- and you guys have said this a couple of times today in another way -- there's a difference between what you choose to do for confirmatory analysis, what you choose to require, or at least suggest as a good option for you to review, is very different from what a vendor decides to do.

But I think some of the concern we heard earlier at other meetings was, if we require vendors to use more complicated tools than they really need, that kind of doubles the expense of dealing with all of these issues.

So, I like the way you're talking today about what you need in-house, and I think that'll help the vendors as well.

MS. WEBBER: I mean, I just want to comment on that. So, we talk about this quite a lot, that the vendors have to design these reactors and make sure that they are designed, constructed, and operate safely.

So, they may have to have computational capabilities well beyond what our needs are. And so, that's something that we think about and talk about quite a bit. And so, the capability of those codes may be much more -- I don't know what the word is -- developed and more extensive than perhaps what our needs are. So, I just wanted to make that comment.

DR. CORSON: So yeah, based on all these criteria, we're going to work on FAST going forward. I mean, we've been actively involved with FRAPCON, FRAPTRAN, FAST code for decades. So, it makes sense to continue with this.

But as Ken said, we are still following what the BISON team are working on. And it certainly helps us to be familiar with the BISON models. So --

(Off-mic comment.)

MS. WEBBER: Protesting the question.

MEMBER CORRADINI: So, no, we're just educating ourselves.

DR. CORSON: Okay. Just making sure you didn't have a question.

MEMBER CORRADINI: No no.

DR. CORSON: So, okay.

MEMBER CORRADINI: We're not shy.

DR. CORSON: Okay. So now, Lucas is going to talk about what we're doing to get FAST ready, and what our plans are then for the future.

MS. WEBBER: Are we moving off of this?

DR. CORSON: Yeah.

MEMBER PETTI: So, just a question. Are you aware of some of the latest results in TRISO-modeling that the AGR program has done where they've done a really detailed look at every thermal mechanical material property that's needed and varied them, and figured out which are the ones that really make a difference and which of the ones don't make a difference? That might be quite helpful for you guys as you think about what you're doing for FAST.

DR. CORSON: So, yeah. That would certainly be helpful. Is that a published INL report?

MEMBER PETTI: Yeah. I was the reviewer before I retired. So, it was done in 2018.

DR. CORSON: Okay.

MS. WEBBER: Can we ask you for an action item, to give us that report?

DR. CORSON: We may have it. But I have so many INL reports that it may have gotten lost.

MEMBER PETTI: Yeah. I mean, it can really help you leapfrog. Similarly, are you aware of the four volume, comprehensive nuclear material publication that goes through all the Gen-4 systems, and there's chapters on fuels and there's chapters on the modeling of those fuels?

DR. CORSON: Yes. So, we are aware of

that.

MEMBER PETTI: Good. Good. That's scheduled for updating, actually --

DR. CORSON: Okay.

MEMBER PETTI: -- in the next year or so. So, be on the lookout.

DR. CORSON: Yeah, that would be good. If you could give us a heads-up, that would certainly be helpful as well.

MEMBER CORRADINI: So, Dave, just to close the loop, maybe you want to -- when you send it, send it to Weidong and Derrick so that they can pass it on to Kim, just so we --

MEMBER PETTI: Okay.

MS. WEBBER: Yeah, pass it along to James Corson as well.

DR. CORSON: Yeah, and thanks a lot for that. That would be really helpful.

MS. WEBBER: He'll get to it a lot faster than I will.

DR. CORSON: Maybe.

MS. WEBBER: Are we moving on?

MR. KYRIAZIDIS: All right, so good morning. So, my name is Lucas Kyriazidis. I'll be reviewing the development plans for FAST for non-LWRs.

So, as James has highlighted, the NRC has selected to pursue using FAST as its fuel performance code to further develop and use it during confirmatory calculations for non-LWRs.

Highlighting some of the reasons why we've made that selection, is just that we've been actively involved with the development of FAST, in addition to FRAPCON and FRAPTRAN, throughout its creation.

Also, as Ken has highlighted, has an extensive assessment database for LWRs. So, if you want to go on to the next slide.

I'll go over the generic non-LWR development needs, and what its current capabilities are, and then what we plan on doing to the code.

So, in its current state, FAST is limited to modeling 1.5-D cylindrical fuel rods. In here, 1.5-D cylindrical fuel rods, or 1.5-D analysis, simply refers to the fact that each radial node is calculated, and then -- well, let me -- sorry.

1.5-D simply refers to the fact that the transport equations are solved in the radial direction for each axial slice. And then, simple relations are used to handle the actual transport.

MEMBER CORRADINI: Hang on. So, that seems reasonable. So, where does that break down?

Because what you're telling me is in the world of reactor physics, that was what life was before some magical 3-D slice connection. Right?

I mean, all reactor physics are basically just 2-D analysis. And then, I connect actually by some sort of simple connection algorithm. So, what you're telling me here is I do a radial, and then I don't have any circumferential variation, but I then connect axially over some lane scale.

MR. KYRIAZIDIS: Correct.

MEMBER CORRADINI: Okay. So, why is that -- where does that break down?

MR. KYRIAZIDIS: So, the only reason that's okay is because the fuel rods are volume skinny. And so if you had a fuel rod --

MEMBER CORRADINI: A fat fuel rod.

MR. KYRIAZIDIS: A fat fuel rod, you could have some axial heat transfer.

MEMBER CORRADINI: Okay, fine.

MR. KYRIAZIDIS: But when you have a pencil, you don't really get significant heat transfer up and down.

MEMBER CORRADINI: That's what I guessed you were going to say. So, pellets, or TRISO fuel, are the issue? I'm still trying to understand where the issue lies that I might -- where I'm going with this is -- I'm sorry, I'm jumping -- I'm trying to not do 2- and 3-D because all I can see is just computers --

DR. BAJOREK: Like, I think --

MEMBER CORRADINI: Churning.

DR. BAJOREK: -- part of this might be we have seen a couple of designs. The AHTR, one of the molten assault, the fuel looks like a manhole cover.

MEMBER CORRADINI: Oh.

DR. BAJOREK: Okay, with swats through it.

MEMBER CORRADINI: Oh, I see.

DR. BAJOREK: Okay, very 3-D. And it's geometry. We've also -- we would also be using FAST for some accident-tolerant fuels. If you've seen, I think it's the light bridge design, looks kind of like a licorice stick. Okay? That one would be very difficult to handle with this, but almost everything else would be a one-and-a-half.

MEMBER CORRADINI: Okay. All right. Thank you. I appreciate it. Thank you again.

MR. KYRIAZIDIS: So, based on the currently proposed non-LWR fuel forms, FAST would be extremely limited. So, we're going to overview what we need to do to get the code ready. So, a couple of needs that we've identified is to expand the geometries that FAST can handle.

So, we want to incorporate new solvers that can handle spherical geometries, in addition to irregular geometries, and also expand the 1.5-D assumption to handle 1-D spheres, 2-D and 3-D dimensions.

And this will happen when we incorporate new solvers, so there are contracts in place and works ongoing to incorporate new finite difference and finite volume options.

And I think it was stated by Steve that 1-D will be sufficient for spherical geometries, but the 2-D and 3-D capabilities will really handle the heat pipe reactors.

So, I think James touched a little bit earlier in the presentation, but FAST is also being coupled to other neutronics and thermal hydraulic codes. So, there are ongoing work to couple FAST to TRACE through the MOOSE framework.

And this will really expand the thermal hydraulic capabilities of FAST, and possibly allow for feedback effects to be accounted for.

But another benefit of this is to allow FAST to communicate to other codes in the MOOSE framework. And then, coupling SCALE and EPIC to FAST would allow for more redefined power profile, or radio power profile.

MEMBER CORRADINI: EPIC is part of the SCALE?

MR. KYRIAZIDIS: It is. It is. And I'll give you just a brief highlight of it. But yes, SCALE and EPIC would be used to calculate the intra pen power distribution, in addition to the isotropic distribution.

And EPIC is just a simplified, faster running version of SCALE, designed for use in FAST. And yeah, like I said, it would be used to just calculate the radial power profiles. Next slide.

So, moving from the generic FAST development needs, I'm going to start focusing on TRISO, then follow that with metallic fuels.

So, in its current state, FAST can't be used to model any spherical fuel form, such as TRISO. It's restricted to 1.5-D cylindrical fuel rods. But there are features in FAST that we can recycle to model TRISO. Some of these features are calculating fission gas pressure.

And also, we have the basic infrastructure in place to incorporate new material properties,

properties such as UCO, pyrolytic carbon, and silicon carbide.

And the bottom half of the slide just highlights specific development needs for modeling TRISO in FAST.

MEMBER CORRADINI: I was going to ask about PARFUME. So, that's the basis by which --

MR. KYRIAZIDIS: That is going to be our starting point for material properties. We'll also do a code-to-code comparison between FAST and BISON, BISON AND PARFUME. Yeah, I'll get into that a little bit.

MEMBER CORRADINI: So, maybe --

(Simultaneous speaking.)

MEMBER CORRADINI: We're letting our Chairman lead the way in example. So, you're doing a -- I wanted you to repeat that so I understood.

So, PARFUME is strictly a spherical geometry modeling of TRISO fuel? Am I understanding that correctly? I know that --

MR. KYRIAZIDIS: You got to do TRISO.

MEMBER CORRADINI: -- somebody online knows this, but --

MR. KYRIAZIDIS: Yeah.

MEMBER CORRADINI: -- I wanted to task

you.

MR. KYRIAZIDIS: It does do TRISO fuel particles, but I think I read that it also does clay-type fuel. But I'm not familiar with that. But yes, it was used to do TRISO fuel particles.

MEMBER CORRADINI: And so that's why you want to do the code-to-code --

MR. KYRIAZIDIS: Yes. Yep, yep.

MEMBER PETTI: Yeah. So, Mike, the particles are spherical, but the fuel elements come in different geometries. So, it does spherical at the particle level and it does cylindrical plate at the fuel element level.

MEMBER CORRADINI: But to be politely kidding, you're on conflict since you were one of the authors of PARFUME.

MEMBER PETTI: Yeah. I'm just providing technical background.

MEMBER CORRADINI: Thank you. That's all we were -- I figured that's where we were going with this.

MR. KYRIAZIDIS: So, I just want to highlight some of the specific development needs for FAST to model TRISO. So, as we stated, the FAST needs to currently be modified to allow the model of spherical geometries, but also be able to solve the governing equation, such as heat transportation and mechanical stress through spheres. And this is ongoing right now.

But also need to expand FAST's material property library. Currently, we don't have properties that relate to TRISO in FAST. And our starting point would be just to take what PARFUME has in its material properties, and work that into FAST.

And then lastly, once these above-mentioned features are developed, we would require to do validation and assessment of whether or not we incorporated these features correctly. And this will consist of open literature benchmarks against AGR, in addition to code-to-code comparisons between BISON and PARFUME.

And here, just a note of clarification from the slides. Underdevelopment means that we are currently working on this task right now. And then under contract means that we have a contract in place but work hasn't begun yet. Next slide please.

So, moving forward, the FAST development team has identified specific data needs.

MEMBER CORRADINI: Can I stop you?

MR. KYRIAZIDIS: Yep.

MEMBER CORRADINI: So -- or maybe this slide is where I was going to go. I was going to ask, when does the use of FAST stop and the use of MELCOR begin? Or is that coming?

MR. KYRIAZIDIS: That comes towards the end of the presentation.

MEMBER CORRADINI: Okay, fine.

MR. KYRIAZIDIS: And James will cover that.

MEMBER CORRADINI: Because when we had the Volume 3 presentation, I seem to remember the MELCOR types told us that they were also using a TRISO model within MELCOR. So, I assume there's some sort of pass-off.

MR. KYRIAZIDIS: Yes.

MEMBER CORRADINI: Okay.

MEMBER KIRCHNER: So, this slide really just wants to highlight some of the specific data needs that we need to model TRISO. So, we've identified or highlighted three areas, the first being coding material properties, the second being UCO properties, and lastly, in a broader one, it's study state and transient fuel performance data.

So, coding material properties have referred to the pyrolytic carbon layers. And the AGR program, it has been cited that there are large uncertainties. This is okay, but if we want to bring down those uncertainties, we would need more data.

The second being a bigger area as UCO properties. Currently, in PARFUME it assumes that UCO properties are the same as UO2. This will be adjusted with AGR. But as for the time being, we are missing UCO properties.

And the last being study state and transient fuel performance data. This would be data that would be used to assess FAST. This also includes like the effects and interactions between the coolant and particle graphite matrix, and effects of air/water ingress.

We have used this data to determine whether or not we would need to use FAST to calculate the effects. But yeah, next slide please.

FAST assessment data for TRISO fuel. So, as stated, FAST will require integral data to perform validation. So, the current plan is to utilize data from DOE's AGR program. And based on our current understanding of AGR, AGR will provide the industry TRISO data for the development of material property models and integral assessment data.

It should be noted that AGR will focus on

UCO fuel kernels. So, that addresses the data need on the previous slide. AGR will also produce a variety of PIE data that will be used to develop material property models.

And it also performs safety tests. And this will be where we get our assessment data and code assessment -- code assessment and validation data.

MEMBER KIRCHNER: Curiosity. The AGR, is the program being run to support the BISON code at a mesoscale, or is the data being generated at a more macro level?

MR. KYRIAZIDIS: My understanding is macro scale. But if anyone wants to add to the --

MEMBER KIRCHNER: That's what I would expect.

MEMBER PETTI: That's what it is, Walt.

MEMBER KIRCHNER: Yeah. Okay.

MEMBER PETTI: Just a point that there's another benchmark you guys might be interested in besides the IAEA that Gen 4 benchmark, that focuses just on the fission particle release from the fuel.

And we can get you that. I think it's just completed. So, it'll be another one for you to compare against.

MS. WEBBER: That would be great.

MR. KYRIAZIDIS: And the last point I want to touch on this slide is, the NRC will coordinate with INL to come up with a similar and same VNV test suite between BISON and FAST. And this will be where we do our code-to-code comparisons.

So now, moving on to metallic fuel. Metallic fuel is much more developed in FAST when compared to TRISO. Modeling metallic fuel can be done, but only limited to study state and 1.5-D cylindrical fuel rods.

FAST has been implemented with material properties for U-Zr and U-Pu-Zr fuel, with H29 cladding. But as stated, it's only limited to study state calculations.

Material properties that need to be implemented for transient analysis includes heat capacities, entropies, and H29 cladding the old stress models.

I think Ken mentioned that we have done preliminary assessment on EBR-II fuel. This was a paper presented at top fuels in 2018. We'll highlight some of the results in the next couple of slides, but I'll just give you an overview of what the paper discussed.

It discussed the modeling process, the

limitations of FAST, and additional future work that FAST needs to be changed to perform, I guess, refined assessments.

Two areas of future work were noted, the first being a more refined fission gas release model, especially in the low burn-up areas. And the second was to evaluate the need to implement a zirconium redistribution model.

We'll get into the details of the results in the next couple of slides. But I guess I just wanted to highlight the development needs for metallic fuels, the first being, incorporate material properties for transient analysis, the second being, for redefined fission gas release model, and the third being, incorporate a zirconium redistribution model, fourth being to expand allowable geometries -- this would be specifically to address non-cylindrical geometries, such as the heat pipe reactor -- and lastly, just perform more assessment, because of the available data, such as EBR-II data.

MEMBER CORRADINI: I don't know enough about these designs. So, in the heat pipe-cooled reactor, the fuel is not cylindrical? I thought it was like a block of stuff with cylindrical pencils interspersed with heat pipes.

MR. KYRIAZIDIS: So, I don't know how much of this I can go into.

MEMBER CORRADINI: Well then fine. Never mind.

MR. KYRIAZIDIS: So, yeah. It's not necessarily --

MEMBER CORRADINI: If there's no more that you can say about it, that's fine. But the answer is --

MR. KYRIAZIDIS: Yeah. I don't want to --

MEMBER CORRADINI: -- it's complicated.

MR. KYRIAZIDIS: Yeah.

MEMBER CORRADINI: Okay, fine.

MR. KYRIAZIDIS: Yeah, I don't want to say more than that.

MEMBER CORRADINI: Okay, fine.

MEMBER PETTI: Could you guys model annular fuel?

MR. KYRIAZIDIS: With the new solvers, we will be able to.

MEMBER PETTI: Okay, great.

MR. GEELHOOD: We can currently model annular pellets. So, like VBR pellets, or pellets in the blanket region.

MEMBER PETTI: Good.

MR. KYRIAZIDIS: So, this slide highlights some of the metallic fuel data that we have identified that we require. This would really expand what we can model in FAST, but also give us the ability to model transients in FAST.

Some of the data needs here identified are H29 cladding, strain capability and fatigue data, and this really would give us an insight of how much strain the cladding can withstand before failure.

Another data need identified is rod internal pressure limits and end-of-life internal pressure. This would be used to assess FAST against. And the last being study state and transient data. And this includes transient fission gas release data, cladding strain and centerline fuel temperature.

And again, this would be used to validate fission swelling models in FAST, in addition to fission gas release. And the data would likely come from EBR-II, FFTF, and TREAT-M.

So, next point I want to talk about is the assessment data for metallic fuel. And this really -- so, in addition to thermal mechanical data, we need integral assessment data. And Argonne National Lab has been developing a database to house a large portion of the EBR-II data. And we believe that this should provide the essential data needed to validate FAST against.

So, recently, DOE hosted a DOE/NRC non-LWR data need meeting. This happened in September of this year. And during this meeting, an overview of what data was available was presented to us with respect to metallic fuels.

Examples included were EBR-II and FFTF transient testing data. So, there is ongoing work for us to get access to this database and begin reviewing what's in this database.

It is believe that there is enough data in there to be sufficient for initial licensing efforts. And then, similarly to the TRISO statement, NRC will coordinate with the BISON team to establish a common validation of verification test cases for metallic fuels. And this includes like a code-to-code comparison.

MEMBER CORRADINI: So, to get back to Joy's point, Dr. Rempe's point, this is all cast versus what some of the potential --

MR. KYRIAZIDIS: Correct.

MEMBER CORRADINI: -- designs would have as extruded. So, that has yet to be -- that difference has yet to be determined.

MR. KYRIAZIDIS: Correct.

MEMBER CORRADINI: Okay.

MEMBER REMPE: But my point's even a bit broader. I'm not sure the cast from EBR-II was always the same, because if you look at -- like look up a couple of the reports you cited in this document and they were explicit about what's changed over the years.

And I'm just curious what kind of differences one sees in the change over the years, because you may get -- since they haven't done it for a long time, some differences, just because somebody's coming in new with cast fuel. And you talked about manufacturing defects. I'm real curious on if it's the same.

MR. KYRIAZIDIS: I mean, that's just something that we'd handle with our sensitivity and uncertainty-type analysis. So, if the database does show differences in performance historically from EBR-II, at least we'll know -- we'll have some idea of what the range of differences are.

So, we could perhaps bound our calculations, or even maybe push them a little further in different directions, to explore any cliff edges that we might have.

So, yeah, that's certainly something that we'll need to do once we start digging into this database.

So, the next slide gets into the preliminary assessment that we've done. So, as I mentioned, in 2018 NRC staff and PNNL lead the efforts of doing a preliminary assessment on EBR-II fuel in FAST.

But we have copies of the report, or it's out there publicly on the top fuel website. But in this assessment, EBR-II fuel forms of U-Zr and U-Pu-Zr fuel bonded with liquid sodium clad in H29, were modeled. Coolant was liquid sodium.

And here, we just showed the outlet temperature and fission gas release. Just wanted to touch -- we do have like a simplified fission gas release model in FAST and that's just assumed to be a constant 70 percent independent of burn-up.

And I previously mentioned that we do want to have a more redefined fission gas release model, to really address the lower burn-up regions, outlet temperature for sodium, values agree fairly well, so it really showed that we incorporated our hue transfer correlations correctly in FAST.

MEMBER CORRADINI: So, help me. What's

16 percent burn-up atom percent to megawatt days per ton?

MR. GEELHOOD: So, one atom percent is close to ten gigawatt days per ton.

MEMBER CORRADINI: Okay, fine. Okay, thank you.

MR. KYRIAZIDIS: So, these results only highlight the X-425 case. And this was the U-Pu-Zr case. But we also looked at U-Zr and that report highlighted three cases. We'll go on to the next slide.

And this really just shows cladding strains as a function of axial height, but also burn-up. And this just shows that FAST is able to predict the trend and, I guess, the magnitude, fairly well. We're within .3 percent strain.

Ken was one of the leading authors of this paper, so if there's specific questions, we could have him speak to them. But this is all I really want to touch on, the preliminary assessment.

So, in Volume 2, we covered other fuel forms that weren't metallic, and charged those, such as oxide-based fuels, such as U02 and MOX, but also ceramic-based, such as carbides and nitrides.

So here, I just want to touch a little bit on what the methodology would be required to get these into FAST.

MEMBER REMPE: Could I slow you down for just a second?

MR. KYRIAZIDIS: Yeah. Yeah, yeah.

MEMBER REMPE: I'm thinking about this response about the correlation between atom percent and ten gigawatt-based for metric ton uranium. What data point? Was that like 170 gigawatt days from that --

MR. KYRIAZIDIS: Yes, that reactor fuel was burned to very high burn-ups.

MEMBER REMPE: Which reactor was that in?

MR. KYRIAZIDIS: This was EBR-II.

MEMBER REMPE: Really? Okay, thank you. I just was curious. That's a lot. Okay, thanks. Yeah, that's a lot. Thank you. Sorry to interrupt.

MR. KYRIAZIDIS: Oh, no problem. No problem. So, there are other non-LWR fuel forms being investigated. As I highlighted, there are U02, MOX, ceramic-based fuels, such as carbides and nitrides.

These fuel forms are of lower priority, based on our current understanding of industry plans. We've laid out the methodology in the TRISO section and metallic fuel sections of what we need to do to get these fuel forms into FAST.

And then historically speaking, we have seen U02 MOX fuel being used in the FFTF, but also nitrides and ceramics have been used in EBR-II. So, we believe that the data is out there, but we just -- there's no current near-term plans for it.

MEMBER KIRCHNER: Lucas, I've just -- seeing the UN there reminds me that at Los Alamos we made fuel for the SP-100. That was a space reactor. And it was now a FAST system.

I know the fuel was made. I don't know if there are any detailed irradiation data. But the pin size and such was very similar to the EBR-II.

MR. GEELHOOD: We do have a lot of the SP-100 data at PNNL. It's not publicly available and it's marked expert control right now. But we do have access to that if need be.

MR. KYRIAZIDIS: So, this last slide, at least the last slide in this section, just deals with the methodology that we would take to get these fuel forms into FAST.

So first, we would identify important phenomenon on UO2, the carbides and nitrides-based fuels. We did a little bit of that in Volume 2. The second step would be to gather material properties and determine whether or not we would have to model these important phenomena in FAST.

So, an example of this is, we identified zirconium redistribution from metallic fuels. So, now we're doing the valuation of whether or not we need to incorporate that into FAST. That's just one example for metallic fuels. And the last point is to perform assessment.

So, like I said before, we believe that there is data out there for uranium carbide and uranium nitrides, and UO2.

So, that covers my section. I'm going to pass it back to James to do the discussion between fuel performance and DBs, and beyond DBs.

MEMBER REMPE: Before you go there, I've been thinking from the very beginning of this meeting the discussion about where you crossed off the flowing metal fuel in your comment. And you're right. Section 3.8 says, hey, we're going to do that in Volumes 1 and 3 type of tools.

I'm just kind of thinking about, well, how would you do that? And I guess I can understand in MELCOR how you might be able to do it, although the devil will be in the details.

But I'm just kind of wondering what you

would do in Volume 1 with a flowing metal fuel? Would you have some sort of heat source in there? Because you won't be dealing with any sort of fission product release or transport, but it -- what would you do in Volume 1 type of.

DR. BAJOREK: The molten salts are very interesting and they kind of go into two areas. What we would be doing is we would be tracking the precursors through the system. So, you have to add those to the codes.

And you have to have feedback between your reactor kinetics -- the point kinetics, or something more advanced -- in order to get your power distribution within the system.

It also becomes a little bit of a chemistry problem, because in some of these molten salt reactors, the fuel salt in particular, the fission process will be building up with time.

That's going to be changing your thermal physics properties. It's going to change some of your cross-sections in there? And as we go along with the molten fuel salts, we're going to have to understand the chemistry at the time of the expected scenario, whatever those might be, and be able to have a feedback on the kinetics that keep track of where the precursors are.

Because if you have, let's say a loss of flow, okay? Now, instead of the precursor is dumping their neutron over by the heat transfer mechanism, it might be back in the core and that might be a reactivity increase.

In terms of fuel performance, okay, we can't really think of anything right now that fits into that realm of your traditional fuel performance. What changes with burn-up, apart from the chemistry as you use salt.

MEMBER REMPE: So, with the first example you cited, affirming data to validate this precursor tracking thing that you're talking about?

DR. BAJOREK: MSRE is probably -- well, it's the best and only information for the fuel salt reactor. That's something that, as we go on, we'll be pointing out as a data need, that we are going to need better information on that.

MEMBER REMPE: But MSRE didn't have some sort of test where you have data. So, there's no data in them. Folks are going to have to think about that.

DR. BAJOREK: That has to be developed.

MEMBER REMPE: Okay, thank you.

DR. CORSON: Okay, yeah. So, to wrap

things up, I'm going to talk about how FAST fuel performance interfaces with design-basis accidents and beyond-design basis accidents.

So, a lot of what FAST is used for for LWRs is normal operations and AOOs. So, it runs by itself, does its own thing with minimal inputs from other codes.

But for LWRs, we do use FAST for some design-basis accident calculations, in conjunction with TRACE and with some neutronics codes. So, the MELLLA+ calculations are really good examples of where we use FAST. And we feed initial conditions and take input from TRACE and from the PARCS. So, that's just one example of how we use it for design-based accidents.

For beyond-design basis accidents in LWRs, as I mentioned earlier, we really don't use FAST to support that. So, next slide.

Now, going forward, how do we do this for a design basis event and beyond design basis events for non-LWRs? For design-basis events, I think it would be a similar sort of approach to what we currently do now, where we pass some information back and forth between codes.

We've touched on this already. Whether

it's a tight coupling or something more manual is to be determined. But it's certainly a very similar approach we would use.

Now, for beyond-design basis events, we do think FAST would have some role. And Dr. Corradini asking about this. But it's especially important I think for TRISO fuel. MELCOR does a lot of the fission product tracking and it does have some models. But it doesn't know what the fuel failure criteria is.

Right now, it would take fuel failure as a function of temperature burn-up and so on. And it doesn't know what that table looks like. So, FAST could be a code that could provide that.

Again, we could also use experiments or something else, or we could use FAST to try to extend the experimental database as much as we can. But that's where FAST could have a role for beyond-design basis events.

MEMBER CORRADINI: But if there's -- I mean, just to use Dr. Petti's analogy, if there is a weak coupling, FAST could develop a table which then can be used within MELCOR. I mean --

DR. CORSON: Yeah.

MEMBER CORRADINI: Okay.

DR. CORSON: Yeah, exactly. So, MELCOR

needs a table, whether it's fast or experiment --

MEMBER CORRADINI: Okay, I got it.

DR. CORSON: Yeah.

MEMBER CORRADINI: I got it. Okay.

DR. CORSON: So, next slide. So, this goes --

MEMBER PETTI: Just a point. Back in the NGNP days, INL provided NRC -- Stu Ruben in particular -- of a spot surface analysis of exactly that. So, it's probably somewhere in the archives of the NRC, so you get a fact of what was done.

DR. CORSON: Yeah, we're aware of that. It's just with the new fuel, oxycarbide fuel, there would be some differences. So, MELCOR has something right now. But we would like to be able to update it with the latest information, if possible.

So, this is just a TRISO example that I just talked about. So, we can skip over this and just go to the summary.

MEMBER REMPE: Before you go to the summary --

DR. CORSON: Sure.

MEMBER REMPE: -- I brought this up when we had the Volume 1 and 3 discussion, and I guess its caused some consternation from folks. But instead of calling things design basis and beyond-design basis, to me, I guess in the SRP they talk about design basis accidents.

And when we think about fission product release, it covers AOOs, the whole spectrum. And what I really see is something about a more integrated evaluation in Volume 3 that could be used for the whole spectrum in a simpler way, and it does provide input to a source term.

And then I think Volume 1's more detailed evaluations, where you have to have this coupling, and there's a need for that because you have to be ready. But why don't we try and think of it that way, instead of design basis versus beyond-design basis.

Because AOOs aren't exclusively covered if you go with this division you have. And so, it's a simple terminology to it. And so, I was trying to point out and people got hung up on a different --

DR. BAJOREK: We're rethinking the terminology. It's the design basis, beyond-design basis, that's part of our dialect that we've gotten used to for the last 40 years.

As we start to use for some units LMP, okay, there's going to be a gray area between those two. And I think I'm going to go into it --

MS. WEBBER: Yeah, Steve's going to talk about that.

DR. BAJOREK: -- when I talk later on. It's addressing the same problem from two different angles of attack.

MEMBER REMPE: And historically, they're not going with the old way of -- and that's what I was trying to bring up at the beginning about this. We don't put conservatisms in this. No, we're going to do best-estimate and put uncertainties. And I think that's what you're going to do, from what I'm hearing.

DR. BAJOREK: Yeah. And I think Dr. Petti's point is very well taken. Our initial approaches are trying to be as simple as possible. In the last couple of slides we talked about the coupling of FAST and other codes, and using it for thermal hydraulics.

That's one of those things that we would likely use as more of a side calculation, as opposed to the everyday type of evaluation.

I like to think of it a little bit more as, do I need all of the detail in my reactor core when I -- the more I look with TRACE? Now, even though we can go through and model it like a model, every assembly in there, we don't really care about that most of the time.

We're after the hot assembly. Okay? And that might be the parallel over here, where the coupling is necessary now for me to take my more simple calculation, and now look at some of those details that might become of interest in the review.

MEMBER REMPE: So, I think we're approaching this -- a similar conclusion here, that I think, again, changing the volume names, and then your introduction document that you gave us a while back to talk about that approach would really make this hang together a lot better.

But I know you don't have a lot of time before you come back to us and all that. But boy, I sure would like to see that. Because I think it makes a much better story.

MS. WEBBER: Well, what I would like to do is, so Steve's going to touch on a lot of those comments. And so, we're just ending with this presentation. I don't know if you -- did you finish this slide.

MEMBER REMPE: I interrupted him before he did, because he was going the route design basis and beyond-design basis, so I thought it was a good time to interrupt him.

MS. WEBBER: So, it might be good to continue the dialogue when Steve's presentation --

MEMBER REMPE: Sure. Okay.

DR. CORSON: I mean, this is just a summary though, of what we talked about. We think FAST is the preferred path. We're working on developing it for non-LWRs for metallic and TRISO fuel. And we expect we'll have the data that we need to support licensing.

Again, we have a very different level of what we need than their's might need. We don't necessarily need quite as much detail.

So, I think, while we say we might be in really good shape, the vendors may have a slightly different perspective on what data they need. So, just to clarify that point and to conclude. So, I'd be happy to answer any other questions you have right now.

CHAIR BLEY: I think for the members, we're going to have a talk by Steve. We're just trying to address a number of things we've brought up in various meetings. So, questions of that general nature will wait until then.

At this time we're going to recess for 15 minutes. Be back here at quarter till.

(Whereupon the above-entitled matter went off the record at 10:30 a.m. and resumed at 10:48 a.m.)

MS. WEBBER: Yes, let's turn it over to Steve.

DR. BAJOREK: Thank you very much. Good morning, everyone. I am Steve Bajorek from the Office of Research. And what we wanted to follow-up this morning on is a more -- continuing discussion on Volumes I -- Volume 2 and Volume 3 and how they all fit together. We've had a number of questions over the last couple of months. Just to bring everybody -- -- everybody back, we had a subcommittee meeting on May the 1st. We went through Volumes 1 and 3. A couple of weeks ago, September 4, we had a -- I guess it was a ACRS review of research activities. We talked about what the work the we're doing in DSA. And there were some additional questions on non-LWR analysis because that falls -- the code development, that falls in the DSA scope.

Now, just to kind of go back and, you know, set the stage in where we're at with Volumes 1, 2 and 3 is the whole idea behind the IAPs. You know, and the strategy, too, that we've been talking about is readiness. Our mission has been to be ready. We started this work about two years ago. It's -- it's evolving as we go on. Now, and part of readiness means -- doesn't -- don't be prepared for a particular unit, or one or two particular units. Our goal here is to be ready for all plant designs. Okay, we're assuming that they are all equally likely to come in for a design certification.

Licensing approach has not been fully defined yet. Okay, now over the last couple --

CHAIR BLEY: I read that somewhere else. They're all equally likely -- well maybe they are eventually. But you know, of course -- you know, some are coming in sooner than others. And your -- in the last report, Volume 2, you have a big table that shows what you're doing next year and what you're doing the year after. And that -- you didn't tell us how you came up with what you're doing when. But I -- I assume it has mostly to do with what you expect to see first?

DR. BAJOREK: Well, up until now, most of our work has been generic. We have to do that, one, to avoid costs to any particular potential applicant. And we have been able to do that because there has been a number of different physical phenomena -- things that you need to do that is there regardless of, you know, the design. Putting different solvers in a code and that type of -- type of thing. Doesn't matter who it's for. We are getting to the point now where, and -- by working with NRO we are starting to see some of the applicants maybe taking a lead. And our expectation, there are going to be a couple of them that are going to be front-runners in this review process. So we are starting to shift gears and put a little bit more emphasis on those now.

CHAIR BLEY: So you're still expecting applications late this year? Maybe next year?

DR. BAJOREK: The NRO will correct me, but I believe that Oklo is still targeting a submittal in December of this year. We have been talking with another applicant, and they are regular visitors here to talk to us on their applications. I don't know the schedule, but I think a fluoride high-temperature reactor is -- is one of those. And -- and thank you very much, because that's what I wanted to do is, you know, talk just a little briefly about the advanced reactor landscape. It does continue to evolve and change. This is the -- the current schematic that we use of it. If you go back and look maybe a year ago, microreactors were not on there. They were sort of buried in here somewhere else. But you can see the --

the lay of the land here. And the green that we see -- that's supposed to be a kind of green on the -- on the -- the schematic here for the micro-reactors. It's pretty much apparent to the staff and maybe everybody that these are getting an awful lot of attention right now. We've been talking with Oklo. They look like they are very serious at coming in on the near term. There are others out there. Only two of them have given us a RIS. And, you know, to talk about when they are going to do submittals. But we attended a micro-reactor workshop back in, I think it was June. And it was surprising that there were -- there must have been about 10 or 12 different organizations which are all targeting micro-reactors and some -- some various flavor to come in. And they're talking about having these up and going within the next couple -- three years. I mean, very, very short -- short time scales.

And the complication for the staff is -- is both with the -- the technical analysis and with policy. The microreactors -- you can see, some are stationary. Some are mobile. And that's a brand new thing for -- for the staff to have to -- to really deal with. But the other point on this landscape is, if we look at some of the microreactors, we're looking at things which are down maybe a megawatt, two megawatts. That's almost more on a test reactors type of scale -- up to some of these which I think are at least several hundred. I think a couple of them are several thousand thermal megawatts. So as we are preparing for these, we are still a little bit leery about saying, hey, one size of review is going to fit all. And we think that is going to have to be addressed as we move on. So our bottom line is to be ready for all of these, and for the various types of reviews that might -- that might go on. The next one.

MEMBER KIRCHNER: Before you go on, how -- you've colored also the liquid salt fueled -- two of them in your green. Am I reading this chart correctly? Terrestrial and terra power?

DR. BAJOREK: Terrestrial and terra power -- I think the color is not coming -- coming through here. That's --

MEMBER KIRCHNER: Okay, so -- so that's not one of the leading --

DR. BAJOREK: That's not -- those aren't one of the leads. I would say it's --

(Simultaneous speaking.)

MEMBER KIRCHNER: That would complicate your life greatly.

PARTICIPANT: You're asking about the applicants?

DR. BAJOREK: Which applicants are most likely to come in --

(Simultaneous speaking.)

MS. CUBBAGE: Yes, so we're not going to speculate on that right now. The only thing I can say publicly is that Oklo is planning to submit a combined licensed application in December. And we are engaged with those other applicants, and they have varying plans. And as Steve mentioned, Kairos, we've had very extensive pre-application engagement over the last year, which is indicative of their progress.

MEMBER CORRADINI: So Amy, since you're there.

MS. CUBBAGE: Yes.

MEMBER CORRADINI: Help me -- remind me -- so, the first expectation is directly to a combined license application without a -- without a certification?

MS. CUBBAGE: That's right. So the combined licensed application would include all of the siting, environmental and design information in the combined license and not reference to certify design.

MEMBER CORRADINI: Under 10 CFR --

MS. CUBBAGE: Part 52.

MEMBER CORRADINI: Okay. Under 52.

MS. CUBBAGE: So there's an option for a combined license that they could reference and certify design, an ESP, neither or both. And they're opting to reference neither and add all the information in one application.

CHAIR BLEY: What makes that different from Part 50, then?

MS. CUBBAGE: It's -- it's -- Part 50 would be the construction permit and then operating license, whereas this would be a combined operating license.

CHAIR BLEY: All at once? Okay.

MS. CUBBAGE: All at once.

CHAIR BLEY: But it wouldn't then be a certified design?

MS. CUBBAGE: It would not be a certified design. Of course, with the one issue -- one review -- you know, we certainly could leverage this review to -- to provide a license for a future reactor.

MEMBER CORRADINI: So I know we don't care about this, but I -- in this committee -- but I guess I am kind of curious. This strikes me as a -- well, so maybe I am not understanding. So under Par 52 and

-- but they would be using the -- I will get it wrong. I want to call it the LMP. They'll be using the LMP approach? Or it's not clear?

MS. CUBBAGE: I can speak to that as well. We had some early engagement with them on a pilot for using an LMP approach. And they have not yet formally communicated how they're going to do their analysis. And it may involve a maximum credible, or a maximum hypothetical accident approach with some underpinnings at LMP. But we're waiting to see that in their application.

MEMBER CORRADINI: So -- so it could be a light water reactor-like approach where -- or, a non-power reactor approach.

MS. CUBBAGE: That's possible.

MEMBER CORRADINI: Because most research reactors essentially have an MCA. Okay.

MEMBER REMPE: So if they were to use an LMP, how does that -- or, excuse me, a -- if they were to use the maximum credible accident, why would we need a detailed code? I mean, aren't you just going to blow the core out?

MS. CUBBAGE: I think we would be looking more at a MELCOR/MACCS type of an approach if we were to do confirmatory calculations against something like that event.

MEMBER REMPE: Okay.

DR. BAJOREK: Can we move on?

MEMBER CORRADINI: So -- I am sorry. I -- I know we're talking about this, but -- where'd she go?

(Laughter.)

MEMBER CORRADINI: She's fast. She doesn't want to be --

(Laughter.)

PARTICIPANT: I am sorry, what?

MEMBER CORRADINI: What I guess -- I mean, Joy -- Joy asked a question about the tool. I want to ask a higher-level question. If I take an MCA approach like a non-power reactor, the licensing, if audited and analyzed appropriately, could be significantly simpler.

MS. CUBBAGE: There's a potential that we could have a -- a simpler review if you have a -- a scenario that we can all agree is credible, or -- is bounding of credible events and significant demonstrated margin. So those are things that we would consider in the review -- how much margin is there available --

MEMBER CORRADINI: Okay.

MS. CUBBAGE: -- and what other certainties exist?

MEMBER CORRADINI: Okay, thank you very much. Appreciate it.

DR. BAJOREK: The approach that we've taken in Volumes 1, 2 and 3 have been primarily to try to identify the gaps in the needed capabilities. It's not to try to tell how we're going to review any of these, or even say what scheme we're going to be using. But it's, what gaps are we going to need to satisfy in order to have the tools that will do this broad range -- okay -- of different -- different -- different types of designs. As we see it, we have two distinct but complimentary and coordinated sets of analysis tools that are going to look at this range of anticipated staff review questions. Volume 1 is more looking at -- I'm not even -- I'm not even word -- to use -- I'm no longer use design basis anymore.

MEMBER REMPE: That's why it's in red, right? That title has been put in red, and I wondered if that's why you're thinking of changing the title?

DR. BAJOREK: Actually, we forgot to change it in the first place.

MEMBER REMPE: Oh, okay.

(Laughter.)

DR. BAJOREK: Change it to black. Okay? But the goal behind the types of codes that we get in Volume 1 are to answer staff review questions -- are the safety functions and the systems acceptable? Okay. Basically like you would in a light water reactor world, is the ECCS system adequate? We expect to see those types of questions. When that plant, or that system is operated, is it operating within the operational limits that we feel are safe? And finally, I think one of the best things that you really get out of those types of tools is you -- is you get the -- that's where you develop your staff expertise. How does the machine work? Okay? By you exercising those tools, you start to understand what are the physics? What are the phenomena which are important to the operation of that design? What are the sensitivities to those phenomena? Okay? And what are the uncertainties that you should be considering as part of that review to make sure you don't head yourself over some type of a cliff?

On the opposite end of things, when you're looking at the -- the analyses from Volume 3, you'll start off, well what is that fission product inventory? Where's the -- what is the source term? And where do those fission products go? We can look at it from that opposite end. And even if you do get a -- a smaller-type of reactor -- more on a research end -- you could still have a fairly sizable fission product inventory. Remember lifting rods in a trigger reactor. You made sure there was nobody in the bay when you lifted one out of the water because you could get a very sizable dose very quickly. So even though it's a small power megawatt size, you may still have a fission product inventory that you want to make sure is contained.

So together, as we exercise both of these -- these types of tools, with Volume 2 feeding into either one of these, okay, this is where the staff is going to learn how these new machines operate. That is going to be important to us because in many cases -- or in some cases, we are dealing with systems that do not have a lot of operating experience. We have not operated or developed these in the past. And they're being developed by organizations that, I think, have been characterized as mom and pop shops where they do not have a lot of experience in licensing reactors, licensing fuel, or licensing evaluation models in order by which to -- to evaluate them.

A few questions on the role of NRC codes with respect to the LMP. In development of the tools, this remains to be defined. Okay, it's going to depend on what the applicant submits to it, which route they want to go. They may or may not use the LMP. They may decide to go to something -- something different. So our goal? Be ready because we don't know what that approach is going to be. And we don't know what the user office is going to need as part of that review at this point. They may need those details at some point, they may not. But we need to be ready on both ends of the spectrum.

Now we've gotten a few of the LMP pilot studies in. And -- and I think that they do provide a little bit of insight on where review questions might be generated. Can I just put the -- the LMP up there, with just a few stars up there on where things are -- what you see. I would characterize the ones that I've looked at -- most of the stars are on that y-axis. They're on that frequency curve. Essentially, they're saying there is no source term. There is not going to be release. The defense-in-depth barriers work, and there's lots of margin. That is where we would expect our reviewers to start having question. Do you have that safety margin? Do you have that defense-in-depth? If I fail that next barrier -- might be the fuel, it might be the vessel, okay? Top or bottom. I mean, we've got very thin-walled vessel. It might need a heat exchanger. Something along those. Does that point on that left axis and it's uncertainty with those phenomena pop you to the opposite side here?

Given that the vast -- almost the majority of points are lining up on there, we would expect some of those review questions to start focusing on those types of questions. And our belief right now is that is where you are going to need some detail in your -- in your analysis in order to justify that margin, or show it doesn't exist. You've got other cases out there where, yes, you're going to have a source term. There's going to be a non-zero dose. And I think that's very apparent in gas-cooled reactors where you have circulating activity, you have graphite dust, you have air ingress, you have water ingress. You have a high pressure system to begin with. And there's going to be some mobility of those -- those fission products. That is probably a case where I am hoping when it comes to the tools I am dealing with, go away. Okay?

CHAIR BLEY: That would be really nice. Can you tell us anything about what the pilot studies have been?

(No audible response.)

CHAIR BLEY: Are they -- the pilot study --

(Simultaneous speaking.)

CHAIR BLEY: -- the LMP pilot studies?

DR. BAJOREK: There's been, I think, four or five of them --

CHAIR BLEY: Are they public? Are they available?

DR. BAJOREK: I --

MEMBER KIRCHNER: Are these -- are these the desktop exercises?

(Simultaneous speaking.)

PARTICIPANT: I believe so.

DR. BAJOREK: Several companies --

PARTICIPANT: So they provided us several references.

MEMBER KIRCHNER: Oh, it's the same ones?

PARTICIPANT: Yes.

MEMBER KIRCHNER: That's good.

DR. BAJOREK: There's been four or five -- I'm not sure if they're public or not. That's why I kind of made up the --

(Simultaneous speaking.)

PARTICIPANT: Okay, yes.

MEMBER CORRADINI: I think staff last year provided -- I am trying to think which two.

PARTICIPANT: This one, I know -- one.

PARTICIPANT: There was PRISM, too.

DR. BAJOREK: PRISM -- PRISM was out early. There's -- there's a --

PARTICIPANT: PRISM and MHGTR.

MEMBER CORRADINI: That's right. That's the one.

DR. BAJOREK: We've also seen a couple recent ones from a molten salt and at least one of the -- the microreactors. At least conceptual. So we're -- we're starting to get more information out there. I am just not sure whether it's publicly available or distributable. But anyway, the bottom line is, we're starting to see a couple of ranges -- a couple of different types of situations in -- you know, our goal then is to be prepared for this range of questions, okay, that we just don't know because we don't have the application yet.

MS. WEBBER: I think John Segala is at the microphone.

MR. SEGALA: Yes, hello, this is John Segala, Chief of the Advanced Reactor Policy Branch in the Office of New Reactors. We have six pilot reports. They're all on our public website under advanced reactors. You can click on all of them and take a look through them.

PARTICIPANT: Thank you.

MR. SEGALA: They're all limited scope. They don't do the entire LMP process.

MEMBER CORRADINI: Thank you, John.

DR. BAJOREK: Okay. In one of the emails we received there were a number of questions. So I tried to organized --

CHAIR BLEY: Yes, I -- I kind of picked those out of the transcript and from note people fed me. So those are individual people's questions or comments.

DR. BAJOREK: Thank you --

MEMBER CORRADINI: These aren't the same questions that Mike asked of us

CHAIR BLEY: That Mike asked of us?

MEMBER CORRADINI: Mike Case asked us some questions as we had --

(Simultaneous speaking.)

CHAIR BLEY: No. Well, unless he parroted them back.

MEMBER CORRADINI: Okay.

CHAIR BLEY: They came from us first.

MEMBER CORRADINI: Oh, okay.

DR. BAJOREK: These are the ones that came from -- from your email. And I wanted to cover some of these and I don't think we have time to give to each and every one. So certainly ask if you have questions. One of those, you know, what are the most significant modeling and simulation gaps for non-LWRs in the reports submitted? And, you know, we -- you know, an ethic and prioritize. You know, we -- we feel that the Volumes 1, 2 and 3 do point out the gaps that are needed both in what you need to do to the codes, okay, and where some of the experimental data is needed and lacking and what the validation you're going to need. We do agree that, yes, there needs to be some prioritization. As we move forward it's certainly in our best interest to start to focus on one or two of these designs and try to make more progress in those rather than spreading the wealth among everybody at this point. And that's going to be especially the case as we start to do more validation work -- which is fairly time intensive.

Right now I would say that microreactors and the Kairos design look like they're maybe a little ahead of the pact. But that's -- that can change quickly. Data needs something that's very important. And now that we're starting to identify the gaps and what validation is, kind of one of our next steps is to continue with that validation and identify data needs. We had a recent meeting with Department of Energy and the labs a couple of weeks ago. And we're characterizing the data as data that preexists. Okay, maybe like EBR -- EBR-II. We need to get it. We need to understand it. We have to bring it in-house. We have to be assured of the quality of that data. And I think the question is on completeness. You know, they -- extruding versus the casting. Those types of questions. But first we have to get those data.

There's a lot of other data out there. We don't have ready access to it, so we're trying to identify where it's at. Is it in a format that we can still use? Because a lot of these data are quite old. Analysts now want to have this in electronic format so they can go ahead and use and start to get this in -- in the case where there are gaps in the experimental data, nobody has it. We're trying to point that out and at least identify to Department of Energy in the labs that for us to be convinced of the safety case, there are uncertainties that are going to have be addressed in the data. We've started that process.

And I think this is the -- the next step in understanding where we need to develop these codes, and what's important for some of these -- these reactor designs.

Does this strategy represent the best course of action with -- to develop sufficient expertise? What changes? We've hit on this a few times, and we think that the introduction report -- I called it the overview here -- we need to build on that one because that's -- it's too vague and confusing at this point -- is what the approach. You know, I think the -- the idea is that, hey, we have a set of tools that is going to be looking at adequacy of the safety functions. And I use that term as rather than an active system because everyone wants to go to passive systems, or a microreactor where it's natural forces that remove the energy from the system. Okay, they may not even want to say that they have a safety-significant component as part of all this. But -- you know, it's -- so we needed to get the adequacy of those safety functions and also be able to make sure we understand the source term and its distribution for both internal and external events, if that's what results in an MHA.

We think that both capabilities are going to be needed as the NRC moves ahead. If we're going to be doing our independent analysis, and we're going to do it in an efficient, effective manner, okay, we expect that the reviews to be much more expedited than they have been in the past. I think that the applicants need that, and that might be justified because of the margins which are out there. But that means for us, we have to get those capabilities developed before those applications come in the door. I am sorry, Mike?

MEMBER CORRADINI: No, no, no. I'm just listening. I'm trying to understand the third bullet. So are you saying the staff has a -- a consensus view on how to re -- I will use the rewrite, or re-describe the overview of the attack of this?

MS. WEBBER: Well the -- I think the reference to the overview report is really a reference to the introduction, which we presented on May 1st. Is that right, Steve?

DR. BAJOREK: Yes, that's the introduction.

CHAIR BLEY: Are you in the process of revising that? Might we see a revision before you come back in a few weeks?

MS. WEBBER: We hadn't start revising it

yet, but --

CHAIR BLEY: Well, then you aren't going to give us any --

(Simultaneous speaking.)

MEMBER CORRADINI: Okay, that's fine. But -- so let me a little bit about it. The -- the first thing in quotes tells me that you would need a set of tools to make sure that I'm within operational limits for AOOs? I'm still -- I'm struggling to understand -- I understand you need a tool for the source term. That I get. I don't understand the first thing in quotes -- what are -- your meaning there?

(Off-mic comments.)

MEMBER CORRADINI: Yes, I know that, but I --

(Simultaneous speaking.)

MEMBER CORRADINI: Can I show that without a tool? That's what -- what's going through my mind is --

DR. BAJOREK: Some systems will look at a decay heat removal system. Okay? And they may be dependent on a shutdown to remove the energy, okay? Is the staff convinced that that system works adequately, which -- within the -- the operating limits of the reactor? Some of the -- some of these designs say we're so safe, we can do a unanticipated loss of heat sink, or loss of flow -- multiple failures. And we don't need an SSCs to do that. Okay, well if you don't take credit for that and you have to remove the energy by either natural forces or your remaining systems, we expect those types of things to be -- come up as questions in the review.

Now those -- now those are the types of things that you don't have a source term.

MEMBER CORRADINI: No, I understand.

DR. BAJOREK: -- everything within the system. But the staff -- we would expect that as we look at -- you know, maybe an example -- and, you know, this is -- there is a large break LOCA. Okay, where you have a tool that basic function is to help define the power limit for the reactor --

(Simultaneous speaking.)

MEMBER CORRADINI: No, I mean -- I mean, let's just -- let's pick on something since I don't know even what this thing looks like. The Oklo design, it strikes me, if I have a heat pipe and I understand -- based on experiments, the performance of the heat pipe, now I have to understand how the heat pipe couples to the core, how it couples to the power conversion system, how it also couples to a -- some sort of redundant or a high, reliable decay heat removal system when it's shutdown. And then I have to ask myself, how many of these things don't work and I still am okay? So I could do that with a lot of relatively simple calculations once I have the data on the heat pipe performance. But without that data --

MEMBER KIRCHNER: Mike, since I worked in that area --

(Simultaneous speaking.)

MEMBER KIRCHNER: Well, I -- probably what they'll do is design it so whether the heat pipe functions or not, doesn't matter. They'll just have passive decay heat removal out of the -- by conduction -- out of the body of the reactor core. And I shouldn't pre-guess what they're design approach would be. But that would be one approach.

(Simultaneous speaking.)

MEMBER KIRCHNER: And then you can demonstrate with simple calculations that you could reject all of the decay heat.

MEMBER CORRADINI: Okay.

MEMBER REMPE: So I guess to -- there was an example brought up during the Volume 1 discussions where I could see what Steve's saying make sense. The gas reactor and the hot deck. Thermal stratification.

That might be something that needs a tool. Now, you could also just put a hole in MELCOR and blow it out and see what happens with sensitivity studies. But if a vendor were to come in and really need to reduce the margin for some reason, you might need it. But I guess -- and so I like what you're coming through here and saying.

Associated with it, I think, is the implied assumption that the resources devoted to it may not be as much at first until you -- you know, you're going to be ready, but you realize that these detailed tools may probably not be needed as often as the workhorse to get you source term. Is that a good extrapolation of what you're saying too?

DR. BAJOREK: I think it is, and you know, I mean, I'll throw out one example. You know, because we are interested in microreactors, we've already completed a -- a small reference model that looks and should operate much like one of the microreactors. And this is a way that we will be able to examine, you know, the performance -- the operation. What happens if you fail one heat pipe? The parts have said, hey, scenario you've got to look at is cascading effects. No, that's -- that -- you might get the -- with a simple calculation -- might need to be more detailed as you look at some of these structures, which are kind of complex. And some scenarios. So you -- you explore things on a simple basis. When we did this one, we don't want a all-inclusive model of a heat pipe and the sonic velocities inside the pipe. It's a super conductor. Dial-in a large thermal conductivity. See how it operates. Are you close to a limit? Are you less than a limit? If I increase the power, you know, a little bit higher, do I run into a eutectic temperature in the metallic fuel? Okay, when you go through some of those transients. Once we get our feet wet on that, we're going to be able to tell I think pretty quickly whether we actually have to go to a -- a lot more detail, or hey that's -- that's what you -- that's enough for the staff to ask intelligent questions of the applicant because it's their analysis that's going to be the -- the analysis of record.

CHAIR BLEY: I wanted to jump in. We -- I talked earlier and said, could you get us this report ahead of time? I don't think that's reasonable, even if Steve says it's not a big deal. But if you had some slides at the full committee meeting that outlined what you were going to include in that revision, I think that would make our letter writing much easier.

MS. WEBBER: Yes, I took that as a no earlier in the presentation.

CHAIR BLEY: Okay. I think that could be really important for us.

DR. BAJOREK: Final point on here, I think one of the comments is a pilot study. You know, I -- just in talking amongst -- yes, we think a pilot study on the staff's end is a good idea. Pick a design. Stay away from proprietary issues. Address it from both tools. How would we calculate something with the LMP? It will at least be informative as we move forward and we do get a real -- a real application in. So -- it's a matter of resources and what would be a design that we would be able to use in a -- more of a public format?

Should the NRC consider developer and applicant codes for confirmatory or sensitivity analyses? I think, you know, our view is that we want to -- we -- I think we agreed with one of the comments we got there. We really don't want to just pick up the applicant's tool and repeat some calculations. And I think the idea here is that you have to understand these codes. You just can't pick these things up and use them as a black box. You have to learn how to use them. You have to understand what's inside them. You've got to look under the hood before you really understand how they really are. And many applicants -- you know, the applicants are all over the place in what they've talked about as potential codes they're going to use. So we'd rather, you know, focus on maybe a smaller set, learn those and use those rather than try to address anything that those 50 or 60 designs might come in with.

We have found -- you know, our -- looking at this from the safety function analysis point of view is that using the -- the NIM tools in combination with some of the NRC tools gives us something that allows us to use the details if we want to go there. But it also represents a very large cost savings to the NRC. In working with DOE, we're expecting them to do the code development -- the verification of those -- of those codes. We -- yes?

CHAIR BLEY: What do you have to do to have confidence in the codes once the DOE says, V&V is done, these are great?

DR. BAJOREK: Well first of all, we work with them to do V&V. And we say, hey, if you look --

(Simultaneous speaking.)

CHAIR BLEY: Okay, so it's not just --

DR. BAJOREK: It's not just what -- now, we're pointing out -- and that was part of the data in the NIM, hey we're going to point out what validation that we think is important for us to have the confidence in the codes. And one way that's not real difficult -- because as you look at the non-LWR -- there's not a whole lot of data out there. So you're -- we're all kind of -- we all want to know which life preserver we're going after. So that -- I don't think that's a -- that's really -- that's not a -- a point of contention. I think the developers realize, yes, they have to validate those types of tools. Well, they're doing that. And that's -- that's a big expense. And I am not even sure we have the total number of staff to go ahead and do that.

But, as part of the learning process, we are doing some of that -- that validation ourselves. We're engaged in an IAEA -- or we think we are going to be able to do this one using a Chinese fast reactor data. That's a separate issue. You know, that will help us benchmark some of the fast reactor analysis tools. We have a staff member that's setting up a model for FFTF. We're going to do this. We're doing this in-house. I am hoping to actually maybe talk with Dr. Corradini. I am looking for the Wisconsin

RCCS data, and the NSTF RCCS data. We will be taking some of these things and we'll be doing our own validation because that's how we're going to learn and we're going to train ourselves to make sure we understand those tools, look under the hood to make sure they're doing the right things for the right reasons. And if they aren't working properly, we're going to get on the phone to the developers and have that corrected.

CHAIR BLEY: Let me -- you made the -- kind of a big point in Volume 2 that in some cases the costs work out kind of equally no matter which way you go. But also that, you know, you have a computer base here that's pretty limited. Someone mentioned earlier, I think it was James, that there's a way to go --

DR. BAJOREK: Using the --

CHAIR BLEY: In the cloud and run --

DR. BAJOREK: We -- we've -- we think we've mastered that. We've been doing that with TRACE and --

CHAIR BLEY: So you don't think you'd be computer limited should you need to use these more than you expect you'll have to?

DR. BAJOREK: No, we're looking at it in

three different ways. One, we think most of these things will run on desktop-type systems with multiple processors. Those are our -- those aren't very expensive anymore. Using the cloud gives us access to a lot. But we've also been talking and working with the Department of Energy, and they've given us access to their high performance computing system. So, you know, some of us have accounts on those. We're starting to use those. So we've got three different areas. But we think, for the most part, running on desktop-type systems of 16 or 32 CPUs is going to handle -- handle these types of things. And that's -- we're pretty confident that the high performance system is not going to -- not going to come bite us.

CHAIR BLEY: And issue? Okay.

MEMBER REMPE: So could you go to slide 12 where you have BlueCRAB. And I'd like to understand this last bullet a little bit more. You've got -- yes because I think sometimes it's good to look at the actual slides here -- or, the -- the codes.

PARTICIPANT: Got it?

(Simultaneous speaking.)

MEMBER REMPE: Yes, that one.

DR. BAJOREK: Let's -- let's --

MEMBER REMPE: So you're saying -- you

said the DOE codes is going to save us money. Which of those codes that are now white -- because you -- you did listen to a prior suggestion of putting all the NRC ones on the left. Which of the codes is going to save you money there?

DR. BAJOREK: I think it's ultimately MOOSE and SAM that will do most -- do a lot of this.

MEMBER REMPE: And help NRC in saving money?

DR. BAJOREK: As I mentioned, MOOSE allows you to do data transfers. Okay? And I think I said on one of the other slides, you know, you see all the stuff in coupling. For the Fortran lovers out there, think of these as sub-routines. Okay? It's much easier than it had been 20 or 30 years ago. Okay, so -- but, you know, something like MOOSE allows you to do these data transfers. It also allows you to do tensor mechanics. So if I am looking at a -- let's say a microreactor that is heating up, the big feedback there is as it grows radially and axially, that's your -- that's your source of negative reactivity. That's what shuts it down. And that's what you've got to predict. We don't have that in our NRC codes, okay?

You have the same problems in a sodium

fast reactor, VTR. Now they -- they get a little bit easier because the core plate is all in a constant temperature bath and you can kind of do a side calculation. But this allows you to attack those types of things. SAM has some attribute in there that allows you to get at thermal striping stratification where systems codes don't do a very good job. And just to point out, a couple of things that we've tried to clean up on this is, you know, the solid arrows -- those are things which are done. We've completed those. It's operating And we're ready to move ahead on those. The dashed are things that we're working on. And that's coupling fast either to trace directly or through MOOSE. MOOSE might actually be the easiest way. And just to kind of pick up on, you know, this -- this coupling And why sometimes it's good -- right now, if you go to FAST to TRACE, you've got that solid line over there on the left. What that basically means -- I go run FAST And FRAPCON. I take the input. I give it to the analysts. Now, for those 30-some heat structures, you type in the arrays. It may take you a couple of weeks, but you'll have something to do for those couple of weeks.

So doing that type of a coupling is actually a big cost and time saver, okay? But anyway, let's assert a point here. Now, if you go to the next one --

MEMBER REMPE: No, before you leave here. You said MOOSE and I got the data transfer and there might be even some numerics that you didn't -- or numerical solutions that you might like -- and all that, the SAM -- that's with the sodium reactor? Or what does it do? Help me remember.

DR. BAJOREK: That -- oh, I am sorry. That does all liquid metal reactors -- lead-bismuth, sodium, also does molten salts.

MEMBER REMPE: Okay, why can't you put -- I thought you'd already put some liquid metal properties in TRACE? And what does SAM do you don't have the capability with your current --

(Simultaneous speaking.)

DR. BAJOREK: We could put them in the TRACE, but SAM is where the validation is going on.

MEMBER REMPE: So --

DR. BAJOREK: I can --

MEMBER REMPE: It can -- because --

DR. BAJOREK: You know, I can go and validate TRACE against all the liquid metal type of tests out there, but I will be asking for my colleague at the end of the table for quite a pot of money in order to go ahead and do that.

MEMBER CORRADINI: But I think what Joy is asking -- I am not -- I am not sure where she is going, but I think at least on this question what she is asking is SAM just simply a liquid metal RELAP?

(No audible response.)

MEMBER CORRADINI: Isn't it?

DR. BAJOREK: Yes, it's basically -- you know, in one way it's RELAP that you can do a sodium -- you know, you can do the liquid metals, the sodium, molten salts.

MEMBER CORRADINI: I mean, it was developed in a -- in a different group, but in -- for all intents and purposes, a tube and tank model.

(Simultaneous speaking.)

MEMBER CORRADINI: It's essentially orifice --

DR. BAJOREK: Yes, it's a systems code.

MEMBER CORRADINI: Okay, fine.

DR. BAJOREK: There are -- there is -- there is -- there are some models in there that kind of gives you a -- a CFD light that you -- if you choose to turn it on. So it has some of those capabilities.

MEMBER CORRADINI: Okay.

(Simultaneous speaking.)

DR. BAJOREK: But, anyway --

MEMBER REMPE: So -- okay, so then I would be careful with that bullet that was earlier in this presentation. It's not all the DOE codes, it's some codes. And it may save you money is where you -- I wouldn't be over-stating it. But there's selected ones. It's not the -- everything in your --

(Simultaneous speaking.)

DR. BAJOREK: We've done an evaluation. It will save us money.

MEMBER REMPE: Okay, but for all of these codes? PRONGHORN and MAMMOTH, too?

DR. BAJOREK: I do it by application.

MEMBER REMPE: So all of these codes that are in white and green?

DR. BAJOREK: Applying -- yes, yes.

MEMBER REMPE: Are going to save you money if you use them? And you do want to do all of them because the DOE is going to validate them to your standards?

DR. BAJOREK: Let me -- let me just also explain on this. This -- this figure, which we call -- all that stuff on there BlueCRAB -- is sort of the -- the artists' pallet. Okay? These are all the tools that we're interested in. But when it comes to an application, okay -- modeling a sodium fast, a microreactor -- you don't use all of these. Let's go to the next one.

In our microreactor model, these are the only ones that get turned on. Okay, you get cross-sections from SERPENT, okay? And you have your kinetics passing information as the model expands. And getting its heat-pipe information from SAM through a very simplified component. So when it comes to validating, you know, something for a microreactor, you're looking at a very -- a small population out of all of those tools.

MEMBER CORRADINI: I guess -- I guess -- I understand how you're explaining to Joy. I -- where I am personally -- I have a hard time is, since I don't know it, is if you have invested all of this time and effort in SCALE and Parks, to switch to SERPENT and MAMMOTH strikes me as a big training exercise. I understand SAM because you either got to put it there, or you got to put it in TRACE. But the reactor physics part of this strikes me as an odd sort of choice. Just me alone. I'm -- knowing -- because I then drag your reactor physics people in and ask them quite --

DR. BAJOREK: This might be the blind leading the blind, then, but one of the things that we kind of have to keep in mind when we're dealing with fast reactors -- and for that matter, you know, some of the gas-cooled reactors -- the mean free path of the neutrons are much, much larger than they are --

MEMBER CORRADINI: Sure.

DR. BAJOREK: -- in a light water reactor. PARCS is diffusion-based, okay? MAMMOTH can do diffusion, but it also has transport capabilities. And it has a mesh that I can put the detail where I want it, or I can ignore it. Okay? So I can -- I can make it run much like a PARCS or a diffusion-based code, but where I have to look at a situation where my control rod over here is -- is affecting my assembly over here, I can do that. I can't really do that with PARCS. Joe can probably explain this much better.

MR. KELLY: This is Joe Kelly from Office of Research. In this particular example for the microreactor --

PARTICIPANT: Turn the mic on.

MR. KELLY: Okay, Joe Kelly from the Office of Research. This particular microreactor example is a good one to show why you would choose the advanced tools. As Steve stated earlier, the two primary negative activity feedbacks have to do with radio expansion of the core support plate, and then axio-thermal expansion of the fuel slugs. So we do that, you know, with the thermal analysis in SAM and then the tensor mechanics module in MOOSE. That gives us the displacements. But how do you factor those displacements into the reactivity feedbacks? In the case of MAMMOTH, because this is all an unstructured finite element mesh, we actually distort the mesh and let the reactivity feedbacks calculate themselves. And I verified that for uniform dilations by checking with Monte Carlo solution versus the MAMMOTH solution for the microreactor model and it worked very, very well. And there's no way we can do that with our legacy tools.

DR. BAJOREK: Thank you, Joe. The other -- the other point that, you know, I might want to make -- and if Dr. Petti is still there -- is this is also a bit of an example on how we can take some simplifications. And SAM, for example, we have a very simple model in there to represent the heat pipe. And we're not convinced we need all the detail. That's one place. But if you notice FAST and BISON are shut off on this. Okay? The initial approach is just to use models for thermal conductivity, specific heat --

you know, those material properties -- those go in either through SAM or for MOOSE. And just use it like that. Okay? We can get most of the information out.

If we have to go to the detail, then we can go back and start turning on something like FAST or BISON if you need more information for the fuel. Or if there's a reactor cavity cooling system that's associated with this, a water-cooled system -- now that we already have the link over to TRACE and we can model helical coil tubes and all sorts of geometries where we have boiling and sub-cooled boiling and stuff that we really like to spend our time on -- okay, because that's fun too -- we can go ahead and use TRACE for that or any of the secondary systems.

So we do make it a little bit simpler for the analyst that if he has to do something like model the secondary system in RCCS, there are things that we have some familiarity with. And we think that for looking at boiling in tubes or boiling anywhere in a -- in a bundle, we think TRACE is extremely well validated for that type of thing. So it is taking advantage of things that we've already validated for. Taking advantage of tools that have largely been developed for these types of tasks -- and taking advantage of working together with Department of

Energy where they are responsible for validation and development of these tools. We take on the -- the need to understand them, learn them effectively, and use these to help address the questions that we get from our friends at NRR or NRO. And I don't know where we're at in terms of slides.

MEMBER PETTI: Steve, I had a question. What's the strategy in the event DOE changes its direction and decides not to support these at the level that they decided to, you know, a year ago. This is not uncommon in the DOE space.

(Simultaneous speaking.)

DR. BAJOREK: How would you know that?

(Laughter.)

DR. BAJOREK: That's -- that's certainly an -- is a question mark. The funding for these types of tools in advanced modeling simulations has been consistent over the last ten years. I think in the most recent bill, actually the number has gone up. I am -- I am sorry, I can't predict the future, especially with our funding. But --

(Simultaneous speaking.)

MEMBER CORRADINI: But, I --

DR. BAJOREK: -- we have the same problem with our -- our funding is for those types of things.

MEMBER CORRADINI: I guess what -- what -- there are still kind of underlying assumption, which I am not sure you're the right one to answer this, but I am going to put Kim on the hot seat. The assumption is that what you get delivered from DOE is validated. I am real concerned that you're going to actually have enough data to take -- for these complicated calculations and actually have the data you need. That's the one thing I thought we started with that Joy asked.

DR. BAJOREK: That's -- that's a bit of a -- that's a separate question.

MEMBER CORRADINI: Right.

DR. BAJOREK: It's one, taking the data you have and validating those tools. The other question -- and that's one of the reasons we had this data need meeting -- do we have all the data that we need out there to validate it? And one of the things, I mean, since we had microreactors up here -- we can model these things. There's some information for heat pipes. I don't think there's a whole lot of information when it comes to taking one of these monolith structures and ensuring that you can get convection, radiation and conduction through a -- a system where you may have a lot of contact resistance.

Physically, you can do it.

PARTICIPANT: Right.

DR. BAJOREK: But the way you have something that the whole system of codes can handle -- that's a shortcoming. And --

MS. WEBBER: But I also think that, you know, with the notion of developing these reference plant models ahead of the application, you know, the purpose for that is to sort of evaluate where the safety issues are, and then focus data needs in that regard.

DR. BAJOREK: Oh, yes, and it was brought up earlier -- the idea of uncertainties, that's key. I mean, when we get these reference models, one of the things we want to do are sensitivity studies to explore and understand the uncertainties. Now you kind of -- it's kind of code, telling you that. But what are the phenomena which tend to be more problematic in your -- your evaluation? At least tells you where you can sharpen the pencil, or where you might want to ask and push for more data. And the other thing with uncertainties -- we don't want to put any more codes on top of this. But the goal is to use our SNAP tool. Symbolic Nuclear Analysis Programs. It's a graphical -- a graphical process, say --

processors that guys of this age like to use. You know, I -- I kind of like card decks. But, you know, that's a way of processing the input and output. But we have -- we have linked that. We have merged that with the DAKOTA statistical package so that when we run something from SNAP, we can take a model, run it in times -- whatever you need to get the -- the statistics -- bring that stuff back and then you get a statistical evaluation of your figure of merit and some of the coefficients that you get you out of it that tell you which ones were more dominant.

So you know, our goal as we go along is certainly to integrate uncertainty in the uncertain capabilities that we would use with light water reactors. So that's -- you know, not talked -- talked up much in the report, but that is part of the -- part of the goal.

MEMBER REMPE: So this story hangs better. A couple of questions. One, you are using these codes to identify data needs, and the codes aren't validated, so you might have a pitfall there. The other thing is, I think I asked this a long time ago, and I think the last time I asked it, I was told yes, DOE said they would give you the source coding. Is that still true?

DR. BAJOREK: Yes. We have access to that.

MEMBER REMPE: Okay. And you'll be able to archive it? I mean, if you invest any time on it, that way you better make sure because, like Dave mentioned, DOE does change its mind sometimes.

DR. BAJOREK: If somebody comes along and disbands Department of Energy, yes we would be able to get the source code and move on. But you know, I don't think that's going to happen.

CHAIR BLEY: Steve, just to give you an anchor, you had just finished slide 8. So if Kim types number 9 and return, she'll jump right to slide 9.

DR. BAJOREK: Go back one more please. Yes, I think we covered that one.

MEMBER CORRADINI: I think -- I think -- but if -- but since you did it -- I think Dr. Rempe's point about significant cost savings is -- without -- without putting words in her mouth, strikes me as a stretch. I can see where there's cost savings in very specific instances, but it's almost a case-by-case sort of discussion.

DR. BAJOREK: Well, put together a model for EBR-II, okay, FFTF, MSRE -- DOE is off doing those. Now I -- I've kind of gone under the rule of thumb that if you set up a plant model or a very large integral tests, it can take you a good six months to put those -- that model together with any kind of -- any kind of, simple -- you know -- you start adding up things which are going to take, you know, a dozen or so of these tests -- and separate effects tests -- you start adding those up, you get to a large number. Okay, we're talking about things that's already on Department of Energy's plan, okay? We're going to reinforce the need for those. They're going to do them. They're going to try to push the -- but the schedule --

MEMBER CORRADINI: But where I am pushing back, though Steve, is where you pointed to SAM versus TRACE in installing a liquid metal, I can see it. But I would have to almost look at each one of these individually to decide if I make the decision. That's where the -- where I think Joy and I kind of reacted to the bold and the underlying.

DR. BAJOREK: Yes, I think it's on an application basis --

MEMBER CORRADINI: Okay, fine.

DR. BAJOREK: You know, you're closer in one place to the other. Microreactors -- we aren't going to get there with our -- our tools.

MEMBER REMPE: But you may not need such a sophisticated tool for the microreactors. They may not be pushing the margin. You might be able to do something a lot simpler with MELCOR MACCS as mentioned earlier by NRR.

DR. BAJOREK: Well like you said, we're -- we're becoming ready. I -- if we can approach it with MELCOR and MACCS, okay that's good. In other reviews that, you know, I've been involved with, the staff wants to get into the details. Okay? We're --

(Simultaneous speaking.)

MEMBER KIRCHNER: It's not like that. I mean, you're always going to have a safety function. I was going to save this comment, but maybe this is a good time to make it. There always will be a safety function, even with the microreactors. Whether it's passive or active, there's going to be -- for example, advanced reactor design criteria in 26 is going to have to be satisfied.

DR. BAJOREK: Sure.

MEMBER KIRCHNER: So you are going to have to verify that. So you always have a safety function like evaluation to complete. That's what sets a microreactor apart from a spent nuclear fuel cap. You have to ensure that it shuts down. So I don't think you do that in MELCOR.

MEMBER REMPE: You have to make sure that you don't go critical in a spent fuel path too.

(Laughter.)

(Simultaneous speaking.)

DR. BAJOREK: You know, kind of follow on that, if -- if they say that the reactor will shut down passively, we're going to want to be convinced and do our calc and show, yes, it will shut down. And if it shuts down, will it go re-critical under some situation? And I -- you know, I'd like to -- you know, I love to do hand calculations. They're more fun. But it's -- you know, there are going to be situations where we're going to have to delve in to some of those details. And that's what we're -- where we're getting ready for those.

CHAIR BLEY: To the comments from my colleagues here. You've demonstrated -- at least to my satisfaction -- that there are situations in which there will be substantial cost savings. If we get no applications, you know, it's -- there's no cost savings anywhere. But you are prepared to take any application and use the tools that -- or you're becoming prepared to use the tools that will address whatever the application is. And that to me is the -- makes sense.

(Simultaneous speaking.)

DR. BAJOREK: Ready and -- the one thing about, you know, using some of the legacy tools -- we saw that landscape of dozens of different reactor types. I don't know what that landscape will evolve to in five years. Are we going to have ten gas-cooled reactors? Thirty microreactors? A couple of lead-bismuth and some molten salt? I don't think anyone things we're going to see that. It's probably going to wind up to a design or two. Okay? So at this point, okay, we aren't taking all of this new infrastructure and putting it in my TRACE or my NRC codes, which I am going to have to hang on to. The more I put into those codes, the more complex I make those and their maintenance as I make any -- any other change.

So at this point, it's not a bad -- we don't think it's a bad idea to go ahead and use separate set of tools, okay, and if the day comes that we're building 50 microreactors, okay, and then we can start doing some more consolidation and refining them where we're at. We're not there yet. Where are we at?

Oh, last question -- we talked about it earlier on the -- you know, the licensing modernization and, you know, some of the -- the various cases and sort of in conclusion, the -- you know, the scope and type of independent calculations -- they'll likely depend on what that design is, what the margin is, what the perceived margin is. It may or may not use the LMP. But because of the -- you know, the lack of experimental and operational data for non-LWRs, we feel there are going to be -- we would expect there's going to be some technical issues that are going to have high analytical uncertainty and we may need to use the -- the details of these codes, or we may be able to get around it. Time will tell. And that's -- we have -- we've kind of covered, I think the -- those parts there. So -- that's -- yes, that was just a -- that's just extra. Anyway, I wanted -- I do want to thank everyone's questions. It's -- it's very engaging. And we appreciate it. Thank you.

CHAIR BLEY: Thank you. Anything else from the members? We'll be going around the table in a few minutes. We're going to get the phone line opened up. But while we wait for that, is there anybody in the room who would like to make a comment?

If so, please come to the microphone and identify yourself.

MEMBER CORRADINI: They look happy back there. They look happy.

CHAIR BLEY: It's open. It's magically quiet. Anyone on the phone line who would like to make a comment, please identify yourself and make your comment. There's only one on the phone line. Say yes or no. I guess that's it.

Well, at this point, I would like to go around the table and I'd like to ask people to think of all three volumes and the introduction when you make your comments and thinking about things that we need to flag in the letter and things we'd like to see the staff focus on at the full committee meeting. Why don't we start on the phone. Who's on the phone? Matt Sunseri. Matt, do you have anything?

MEMBER SUNSERI: Yes. Thanks, Dennis. I thought as far as the staff has gone to meeting their obligation to Congress to develop codes and be ready for the next generation of this work is a big step, I guess, in that direction. And a lot of effort is being put in.

As far as things for us to think about, I agree with the comments that other committee members have made regarding, and I'll characterize, the framing the application of this suite of information. So there's the various sections, if you will, that apply to different functional areas and then some to come and then the introduction.

But as it was mentioned, I think putting something together like a framework of how applicants will tie this thing, the beginning to end, would be useful, I think. We can talk about that.

CHAIR BLEY: Thanks, Matt.

MEMBER SUNSERI: Thank you for all the thorough presentations.

CHAIR BLEY: Pete Riccardella, are you on the phone still?

MEMBER RICCARDELLA: I am. I am. I have to say I found the presentations very education, worth getting up early for. I don't have any comments.

CHAIR BLEY: Well, you can go back to bed now. Dave Petti?

MEMBER PETTI: Yeah. I appreciated the presentations. I just think that it's going to be really important in that introduction to set the context a little bit better. I think a lot of what we've heard wasn't adequately reflected yet in that introduction, the need for flexibility and different approaches depending on when you need the sharpest pencil, you get the sharpest pencil. But sometimes you don't need that. Some of that, I think, in the introduction would help it a lot going forward.

CHAIR BLEY: Thank you, Dave.

MEMBER PETTI: No problem.

MEMBER REMPE: Oh, yeah. I want to thank everyone for their presentations and their work. I agree that the intro but also the volumes will need to have some tweaking to get -- it's not just the intro. I really am glad the decision or discussion of saying maybe we won't talk about design basis anymore and we'll talk about more detailed tools or safety function tools.

But I think writing the letter would be simplified, as you've said, if you commit to all the plan changes in the intro. As you do that, I'd recall the opening statement or a question Mike had about what's not still covered. If you have a transportable reactor, that's going to be a big thing that the NRC has still got to deal with in high enrichment and things like that.

So it would make the story even hang better if you identify what you have done and haven't done. And again, I appreciate you considering our comments and trying to address them because it helps to better understand what you really had in mind. Because I think many members have said it wasn't communicated in the reports. And so a lot of the questions came because we were concerned.

MS. WEBER: I think on just your latter point, there is a paragraph in the introduction that describes Volume 1, 2, and 3 and alludes to Volume 4 and 5. It's just not clearly identified as Volume -- Volume 4 is identified. Volume 5 is a little less clear. But we can enhance that.

MEMBER REMPE: Okay. Thank you.

CHAIR BLEY: Mike Corradini?

MEMBER CORRADINI: Oh, you're going in some different order.

CHAIR BLEY: Just random order.

MEMBER CORRADINI: Okay. All right. So thanks to the staff. I appreciate that. I think we've been doing this now for at least the third or fourth meeting. I can't remember how long we've been doing this. I think it all started because one of the Commissioners asked a question and I won't put the context other than that.

I guess I'm looking -- I think the way the discussion has evolved since the last May 1st meeting to this one, I think -- I sense that there's a coming together of the staff in how you want to explain this. But I think there's four attributes that have got to be there.

Dave already said one which was the need for flexibility. I think Walt and Joy mentioned it a couple times, a need for simplicity. I think Steve's point about -- I think -- I can't remember what slide. It was Slide 7 where he pointed out the need for -- show the adequacy of safety function operational limits.

There's a need for completeness. You don't necessarily stay on one tool for everything. But on the other hand, you want to make sure you're complete. And then the one that I guess I thought I said in May but I'll just repeat it here is you've got to work the problem backwards.

The only reason -- for all intents and purposes, the only reason we care about this is the source term. So I'd work it backwards from there and ask, what do I need to verify? I know what the source term is. I essentially feel confident that the safety functions per the advanced reactor design criteria are met and then I stop.

I will say something that maybe we

shouldn't talk about here but I worry about is if the cost of licensing is the same cost and the size of the machine decreases, all of a sudden, the cost of licensing becomes predominant. That's a bad thing. And if I were the reactor vendors, I'd sure make that apparent to some audience and it may not be you guys.

So it seems to me I've got to make sure this kind of fits together in some sort of overall package. But those four attributes I think are important. And I assume, as Ken was saying and Dennis suggested, if you guys -- you can't rewrite it. But if you can at least enunciate the key points of it come the October full committee, I think that'd be very beneficial. That's it.

CHAIR BLEY: Harold Ray is next.

MEMBER RAY: I agree with the comments that have been made, Dennis. And I have nothing to add.

CHAIR BLEY: Ron?

MEMBER BALLINGER: Yeah, I can't add -- I was going to say pretty much the same thing about the introduction and things like that but can't add much.

MEMBER DIMITRIJEVIC: I'm late to the party, so I have nothing to add to a lot of writing or anything. I just want to say that in general this principle of simplicity and flexibility will be the ones which will help most on expedite the review process.

You said that you are training expertise to expedite that process. But actually what would expedite that process is finishing and developing licensing approach which will allow for the lowest facility to have a streamlined process which may not require very complex calculations or uncertainties.

CHAIR BLEY: Thank you, Vesna. Charlie?

MEMBER BROWN: Not being a code person, an electrical I&C guy, I actually understood some of what James and Steve were talking about as well as Lucas on the generalities. And I guess I appreciated that presentation in terms of your interactions with the codes and stuff like that.

On Steve's presentation on one of the slides, I did not ask this because everybody else was on a roll and it would've interrupted the flow on the technical side. But on your Slide 5, you had a heading, a role of NRC codes with LMP and then stated in the first bullet that that remains to be --

CHAIR BLEY: Whoever is on the phone, put yourself on mute, please.

MEMBER BROWN: The first bullet said,

remains to be defined and will be based on applicant submittals and user needs. And so I didn't ask it because it was kind of a, what's the overall context? I thought codes were codes and you needed codes. And it made it -- it sounded like you didn't need any codes based on somebody's submittal.

And so didn't quite understand the context of the bullet relative to all the rest of the presentation. I don't think that adds anything to the letter. But I, quite frankly, did not understand the idea that LMP is just thrown out the window based on what the applicants may submit. So that was -- if you have an answer to that, that would --

MS. CUBBAGE: I'd like to answer --

MEMBER BROWN: -- be appreciated.

MS. CUBBAGE: -- that. This is Amy Cubbage, general staff. I actually reacted to that bullet as well with the same thoughts you had. And I think regardless of whether it's an LMP approach or a more traditional approach, there will be events. There'll be events. They'll need to be analyzed, and you'll have to have codes to do it that are validated. So the LMP are not -- it's a little bit of a red herring in this context.

MEMBER BROWN: Okay. Codes are codes.

You will be using codes. That's --

MS. CUBBAGE: Yes.

MEMBER BROWN: -- the way I read your answer.

MS. CUBBAGE: Yes.

(Simultaneous speaking.)

DR. BAJOREK: Yeah. My point was to the extent we have to apply. You have to use --

MEMBER BROWN: Whether simple or complex.

DR. BAJOREK: Simple or complex.

(Simultaneous speaking.)

MEMBER BROWN: I got it. Then I understand. Okay. Thank you very much. Sorry to throw that little --

CHAIR BLEY: Thanks, Charlie.

MEMBER BROWN: -- fish in the water here.

CHAIR BLEY: Walt?

MEMBER KIRCHNER: Thank you for the presentations. I will be repeating myself, I guess. But I see that the staff has a lot of flexibility and choices. Their analyses are confirmatory, so they can pick the tool they think they need to match the requirements to make their assessment on safety functions or whatever. It's different for the applicant because the applicant has to make proof.

I think FRAPTRAN which was most of the presentation this morning. That is, I think, a good choice, a prudent choice for the NRC. So that's one member's opinion.

What I still remain unclear about, and this is more for NRO, not for you and NRR. It's just not clear to me what the expectations are for the applicants. If the applicants pick up your document and think that applies to them, I think that would be very misleading.

So I think in the introduction strengthening what this is about and who it's for, it's not for the applicants. It's for the staff --

MS. WEBER: I think that's part of the --

MEMBER KIRCHNER: -- to be ready.

MS. WEBER: -- intro.

MEMBER KIRCHNER: It's part of the intro, but I think it could stand out and make it clear that if they pick the same thing you pick, that doesn't mean that they have verified qualified codes for their application. And so I remain a little bit -- again, it's a question more for a different time. But it's not clear to me what the expectations of the applicants are going to be for these non-LWRs.

I would expect that their codes would be

NQA-1 and DNV. And the burden is on the applicant through a topical report or some other mechanism to make that case.

DR. BAJOREK: In meetings --

MEMBER KIRCHNER: And that's much different than what is required of the staff.

DR. BAJOREK: In meetings with them, we've tried to point out that, hey, this is a path the NRC is doing. And it's because of the flexibility of the number of types out there.

MEMBER KIRCHNER: Yeah.

DR. BAJOREK: If an applicant wants to go a separate way, that's certainly their choice. And if you only have one design to have to design and license, it's going to look a lot different than what we're --

MEMBER KIRCHNER: Yeah.

DR. BAJOREK: -- presenting here.

MEMBER KIRCHNER: So with that, thank you, Dennis.

CHAIR BLEY: Yeah, thanks. I do want to compliment all of you on really good presentations and discussions and open discussions. I appreciate that. I appreciate also what feels to me like a coming together of thoughts since our first meeting. Well, it was kind of we got all these options and we've evaluated some. Here, we're starting to think about here's how we'll actually try to use them when things come up.

And again, you won't have the document. But if you can give us some slides on what that revised overview is going to look like and the things it's covering, I think that's great. I like Mike's principles and I especially like Walt's mention. Yeah, I was looking at these and I wrote a note to myself.

These are probably going to be NUREGs, although they don't say so on the cover. I'm not sure what they're going to be, but they're going to be looked at. And I think that first document has got to make clear what you've said here today, that this is for your to decide how to be prepared to review things. And applicants are free to come up with their own approaches.

And you haven't -- I don't think you've put out guidance that tells them anything about what codes are okay to use, if you use these, you're okay. And that we're expecting -- and you've said it twice today -- that these are going to be QA'ed and come in with a -- I think the document itself, at least Volume

2 talked about having topical reports come in to get approved on the codes people use. So making all that stuff clear I think is important.

MS. WEBER: I think that --

CHAIR BLEY: I'm sorry. Go ahead.

MS. WEBER: -- to that last point, I mean, I don't think in the history of NRC we've ever said that applicant has to use Code XYZ.

CHAIR BLEY: No, but you've often said if you use Code X, your life is going to be a whole lot easier. And we're going to be looking for that at some point. I was just hanging up I didn't talk to Derek and I forget how much time we have on the agenda. So talk with Weidong and Derek in between times to see how much time. I'm not quite sure how you --

MS. WEBER: It's two hours as I understand it.

CHAIR BLEY: You squished this up to cover all the volumes. So you got to think on that. Kind of emphasize --

MS. WEBER: Yeah, the intro.

CHAIR BLEY: -- the intro and the kind of things we were talking about that everybody has talked about in our meetings and give a summary of the possible codes in each of the three areas and how you're addressing that. So lots less than we had in the two meetings, three if you count the research meeting. But a real focus in on how they're going to be used and what you're going to be expecting.

So thanks very much. At this point, we are adjourned.

(Whereupon, the above-entitled matter went off the record at 12:03 p.m.)

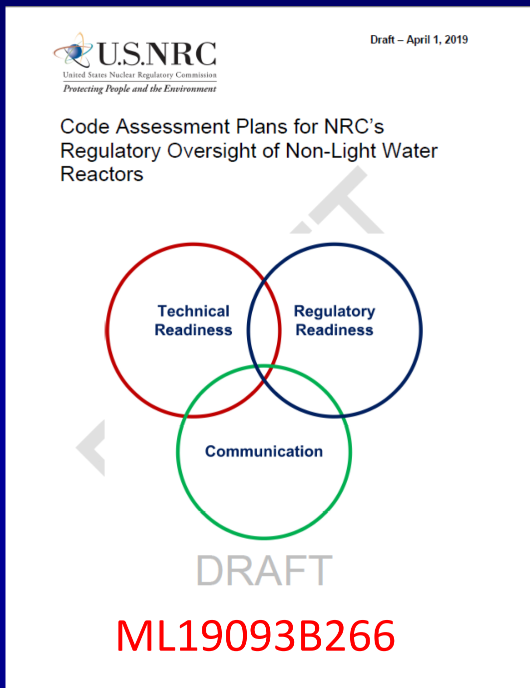
Advanced Reactor Code Development Status

Fuel Performance Analysis for Non-Light Water Reactors

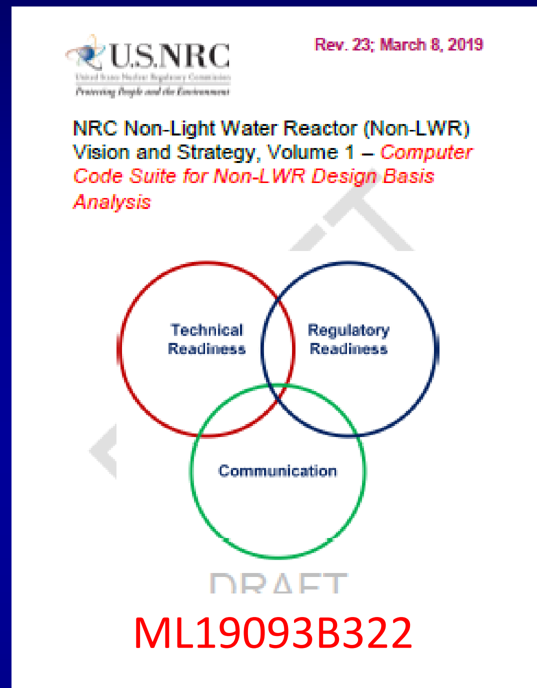
Kimberly A. Webber
Office of Nuclear Regulatory Research

Presented to:
ACRS Future Plant Design Subcommittee Meeting
September 17, 2019

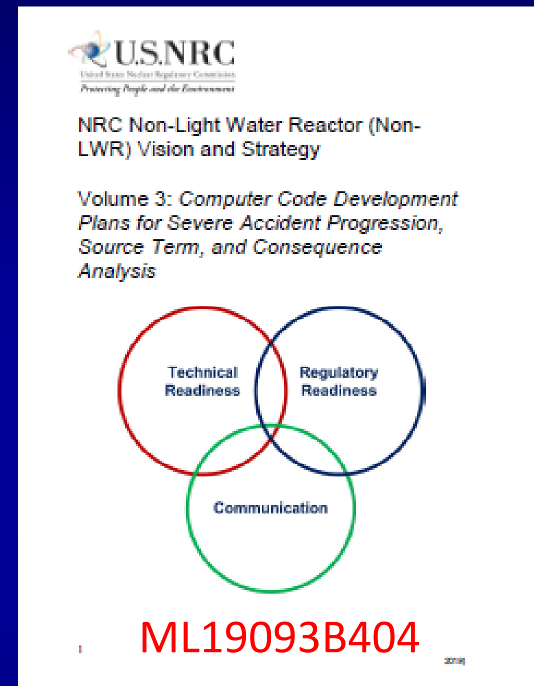
NRC's Implementation Action Plan, Strategy 2 – Computer Codes



Introduction



Volume 1



Volume 3

Volume 2 = Fuel Performance – Subject of September 17th meeting

Volume 4 = Radiation Protection – Work in Progress

Agenda

- Overview – Kim Webber
- Volume 2 – Fuel Performance Analysis for Non-LWRs – James Corson, Lucas Kyriazidis
- Response to May 1st and September 4th Questions on IAP "Strategy 2" Codes – Steve Bajorek